High-Speed Rail Development Programme 2008/9

Principal Consultant

Evaluation Methodology

Final Report for Workstream 3

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mvaconsultancy

Contents

1 Introduction

1.1 The Study

The Principal Consultant is required to develop a strategy for a UK high-speed rail network in five stages, with a formal report to be issued after each.

- Workstream 1 – Determine the starting point for the study by evaluating relevant work already completed elsewhere, including an open call for further relevant material;
- Workstream 2 – Determine the strategic choices to be made in defining the high-speed network using the principal categories such as national and local policy, target markets and technical considerations, in consultation with various stakeholders;
- Workstream 3 – Create and document assessment and appraisal methodologies through development of a strategic business case model, incorporating a ridership forecast model which can later be applied to route and network options; identify, at strategic level, the full economic benefits, assess capital costs, evaluate environmental impact, evaluate CO_2 emissions; use these models to generate performance indicators for options;
- Workstream 4 – Evaluate corridor options by application of tools developed in Workstream 3, building on previous studies and identifying key constraints, to produce status reports and route development reports;
- Workstream 5 – Using output from all other Workstreams, define an overall network development strategy, including a preferred long-term network specification; phasing; the overall case for the national network based on benefits delivered; and the level of investment.

This report describes the work undertaken in Workstream 3.

1.2 The objective of Workstream 3: Business Case methodology

The objective of Workstream 3 is to develop a methodology to prepare a Business Case for a high speed rail network in accordance with government guidelines. It must enable selection of preferred options both at the corridor level and for an overall network in a consistent evidence based manner. It must also demonstrate the value of the proposed solution in terms of both quantified metrics such as benefit:cost ratios and unquantified elements that might include meeting stakeholder aspirations or environmental concerns.

This report describes the framework for assessing the different options developed as part of a high speed line strategy in a consistent way. This framework consists of a number of different models (which work mainly in Excel) that together meet the objectives of the Workstream. For a limited number of areas, some judgement is also used to provide a better estimate of behaviour than is possible using models; this is particularly in the context of the response of classic rail and air operators to the introduction of HSR services.

The component models and processes are described in the following chapters.

1.3 The Report Structure

Following this introduction, the remainder of this report is set out as follows:

- Chapter 2: Assessment framework
- Chapter 3: Demand forecasting
- Chapter 4: Cost model
- Chapter 5: Social and economic appraisal
- Chapter 6: Wider economic benefits
- Chapter 7: Model outputs.

There is one appendix covering:

- Appendix A: Demand Model Zoning System
- Appendix B: Technical Note on Cost of Four Track HSL

2 Assessment Framework

2.1 Introduction

The Greengauge study seeks to identify a vision for high speed railway for the UK. The objective of Workstream 3 is to develop a methodology to prepare a Business Case for a high speed rail network. As part of Workstream 4 of this study we will be undertaking analysis of a range of options for a potential high speed network. As part of this process it is important to have in place an assessment framework which allows a consistent evaluation of options.

The Assessment Framework has therefore been developed using industry best practice and the collective expertise and experience of MVA and Systra. The framework's design also takes into account the outputs which would be of value to stakeholders for interpreting the impacts of the HSL scenarios.

There are a number of factors which should be taken into account as standard when assessing any transport scheme. Developing a long term strategy for high speed rail requires additional elements to be taken into account and the Assessment Framework includes an allowance for these.

This chapter provides an overview of the methods which will be used to assess the range of high speed rail corridor and network options.

2.2 The Assessment Framework

The Assessment Framework will take into account a wide range of impacts that would result from a high speed network in the UK. It includes all costs, revenues and economic benefits applicable to high speed lines and their associated impacts. We identify capital and on-going costs and revenues separately, as this will be an important input to the funding workstream; it is possible that some capital costs might be transferred to lease costs through the funding arrangements, or in principle on-going costs could in some cases be capitalised.

The framework includes an assessment of:

- capital costs of infrastructure and rolling-stock
- operating costs of high-speed lines and train services
- revenue from high-speed train services
- economic impacts to users (time savings and crowding benefits, less any additional fares paid)
- economic impacts to non users (impacts on highway etc)
- safety, security, accessibility, integration and environmental impacts
- wider economic benefits (impact on local regions' economic performance)
- cost, revenue and crowding impacts on the 'classic' network – where HSL will significantly abstract from classic services (e.g. current Intercity) we will calculate loss of revenue and demand, and hypothesise an appropriate level of service to meet residual demand
- the value of paths released for local and inter-regional passenger, and freight services; this will vary by broad location

The Assessment Framework consists of a number of 'Models' and 'offline assessments' as follows:

- Demand Forecasting Model
- Cost Model
- Land-Use Model
- Wider Economic Benefits Model
- Business Case Model
- Qualitative Environmental Assessment
- Value of Capacity Released Assessment

The structure of our approach and the way in which the various models interact is demonstrated in the following diagram:

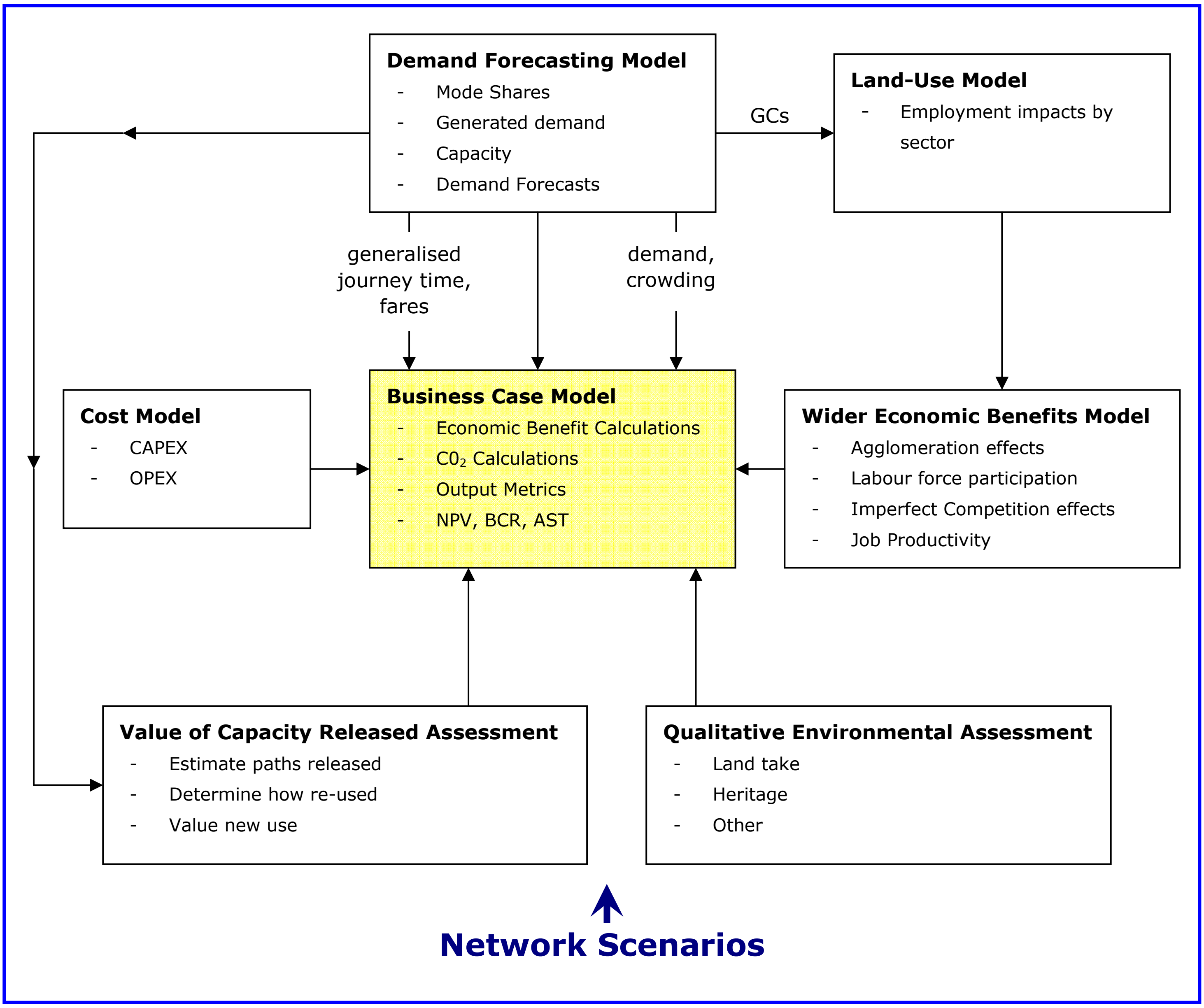

Figure 2.1 Assessment Framework

The demand forecasting model is the most complex of the components. It starts from a representation of current travel patterns by rail, air and car for business and leisure travel. This is grown into the future, and then assessment is made of the impact of high speed rail. At its heart is a mode choice model that incorporates the very different accessibility characteristics of rail, air and car, but it also recognises that some travellers are captive to specific modes and that new demand is stimulated by a new mode such as high speed rail. The model also takes into account the impact of crowding on both the high speed rail network and classic rail.

The cost models are based on unit cost rates found in Britain and elsewhere for construction and operation of high speed and other rail. They reflect the extent of construction that is expected to be in open country, in tunnel, special structures (eg viaducts) and also for particular large elements such as new stations. Where necessary, they include the cost of augmenting the existing railway.

The land use model is based on David Simmonds Consultancy's DELTA model that is recognised as one of the leading transport land use interaction models. This estimates the impact of high speed rail on land use and hence employment in different sectors of the economy.

The wider economic benefits model utilises outputs from both the demand forecasting model and the land use model to estimate the impact of high speed rail on the overall economy of the UK and its regional impacts.

An assessment of value of capacity released on the classic rail network is also an important benefit from high speed rail. The principal uses of such capacity will be for:

- local services, particularly commuting where many local networks are currently effectively full and future growth can be expected to lead to considerable crowding
- inter-regional services to increase frequency of trains
- freight services on the main lines which compete for paths with passenger services.

This module makes a high level assessment of the likely take up of any capacity released and of its value.

A separate environmental assessment is undertaken to cover impacts other than $C0_2$ (which is calculated in the business case model based on the analysis undertaken by ATOC). As the study is not undertaking detailed route alignment, the environmental assessment is of necessity high level. Much of this will be qualitative, but we will seek to estimate the extent of mitigation measures that will be put in place so as to be able to put an outline cost on these.

Each of these elements is brought together in the Business Case model. This undertakes the appropriate calculations to appraise each scenario in a consistent way in accordance with DfT guidelines as expressed in WebTAG (Scottish and Welsh guidelines are very similar), covering costs, revenues, economic benefits, and carbon emissions. The results are presented in an Appraisal Summary Table, including benefit:cost ratios and similar metrics. Additionally, some elements will be quantified at the regional level.

2.3 Policy Testing

As part of Workstream 4, a range of corridor and network options will be tested through the assessment framework. The Business Case model will act as the 'master model' drawing together each of the elements of the assessment from other models. As such it is the natural point to compare the relative impacts of the different scenarios, and to develop improved variants on them. It will also present the overall case for the eventual selected high speed rail network scenario.

It must demonstrate the value of the proposed solution in terms of both quantified metrics such as benefit:cost ratios and unquantified elements that might include meeting stakeholder aspirations or environmental concerns. Chapter 7 provides further detail on the types of outputs which will be used to test the different scenarios.

For each scenario (corridor or network option) the study team will develop a specification of the proposed solution. The scenarios will be defined in terms of the high level infrastructure required, including which cities to be served and broad corridor/routing. It will also give an outline train service pattern, in terms of journey time, cities served, frequency and capacity; this will be at level of typical off-peak, with commentary on additional peak capacity available.

Where appropriate this information will be used and interpreted within each of the separate models and offline assessments.

3 Forecasting Demand

3.1 Introduction

This section sets out the theories and methodologies used to forecast demand and revenue for the new HSL. This model forms direct inputs into the Business Case Model where the outputs are used to calculate economic benefits and assess the overall business case. The outputs from the demand and revenue model are:

- high speed demand and revenue
- change in classic rail, car and air demand
- impact on rail crowding of introducing high speed rail
- generalised costs by mode

Potential demand for HSL is likely to come from two sources:

- passengers switching from other modes including Classic Rail
- totally new trips made due to the step change in service provided by HSL

The model allows different high speed scenarios to be tested against a base case without high speed rail. The difference between the base and scenario is therefore the impact of HSL.

3.2 Understanding the Market – Demand Today

The base demand matrix structure

An assessment of the current demand for travel was made between 39 zones which cover England, Wales, Scotland and Europe. The zoning reflects the intercity nature of the market for high speed rail and split between city centres and annuli allows differential access to be reflected. The Europe zone is used to model travel between the UK and European destinations which are likely to become more attractive once high speed rail is introduced. Demand has been split into business and leisure travel. For the purposes of modelling, commuting trips have been grouped with business trips. A further discussion of this is located in Section 3.6.

The model zones form a 39 by 39 matrix of movements between zones (1,521 origin destination pairs). Flows have been assumed to be one way which results in the Manchester to London flow having an equivalent London to Manchester flow.

The base year in the model is 2007. Data for each mode of travel has been sourced and processed so that it fits into our 39 by 39 matrix of movements. In addition to the demand data generalised costs of travelling by each current mode have been built up for each OD pair.

Selecting the model zones

The model zones used in the model have been selected to ensure that a variety of HSL scenarios can be tested. UK cities likely to be served by HSL in one or more scenarios have been allocated a model zone. In addition Heathrow and Stansted have been given their own model zones. Each city has then been given at least one annulus which covers the area immediately surrounding the city. The purpose of the annulus is to account for differences in travel behaviour and mode share between trips from the city centre and those from its hinterland. For example, trips beginning in the city centre may be more likely to use rail for a trip due to easier access to the city centre station. A list and map of the model zones has been included in Appendix A.

Car demand has been sourced from the DfT National Travel Model

The number of car trips between each of the 39 model zones has been sourced from the DfT National Travel Model (NTM). This data is split by business, leisure and commuting. For inclusion in the model business and commuting demand has been combined. In addition to demand data, the NTM has been used to source cost and journey time data. The cost data includes the cost of petrol. The journey time data is the journey time between each GG21 model zone and includes an allowance for congestion on the network (at its current level). Due to the aggregated nature of the GG21 zones the costs and journey times have been weighted by the number of trips from each smaller NTM zone. This avoids the need to pick a point in each zone where journey times are measured from.

Classic rail demand has been sourced from the demand forecasting tool MOIRA

Base classic rail demand has been sourced from the demand forecasting tool MOIRA. MOIRA contains a database of national rail trips and revenue between each principal station on the network. Smaller stations are allocated to nearby principal station. Journeys and revenue were extracted for each station to station pair. Demand at each station was then aggregated up into the GG21 model zones to give a 39 by 39 matrix of rail journeys and revenue. Where people access principal stations by modes other than rail, MOIRA will allocate them all to the city centre station zones, whereas some should be allocated to the annulus. NRTS data on true origin/destination was used to correct for this.

MOIRA provides journeys and revenue by ticket type (Full, Reduced and Seasons). To be able to use this data in our model it was necessary to convert this into Business, Leisure and Commuting. To do this a mapping was obtained from National Rail Travel Survey data (NRTS). This was applied at different distance bands. Before the data was entered into the model business and commuting were combined.

MOIRA was also able to supply Generalised Journey Times (GJT) between each GG21 model zone. Generalised Journey Time is the measure of the quality of a rail service between stations. It combines journey time, frequency of service and any interchanges the passenger would need to make. GJTs at each station have been grouped into one value for each GG21 pair by weighting by the number of journeys from each station. MOIRA uses very large interchange penalty penalties (up to 85 mins) for long journeys; this results in exceptionally large GJTs for some journeys, especially to annuli and cross-London where three or more interchanges can be involved. This resulted in the model not accurately forecasting mode shares for such flows, and interchange penalties have therefore been restricted to maximum of 40 mins.

MOIRA includes all rail demand to and from Heathrow in the London zone. To be able to model the impact of HS on access to Heathrow it was necessary to model the Heathrow demand separately from London. Using survey data from the CAA survey supplied by BAA, we have been able to extract the origin/destination of air trips through Heathrow. This gives a demand value to Heathrow from each of our GG21 zones. This demand was then removed from the London zone; note that this process excludes trips to/from Heathrow which are not for the purpose of catching a flight, which is a small number for long distance travel.

Eurostar have supplied data showing the demand from Europe to destinations across the UK. This has enabled the Europe zone data to be populated.

Although long distance coach demand has not been considered in our model (see Section 3.3), access to Heathrow by coach has been considered. On routes such as Birmingham to Heathrow coach competes favourably with classic rail which requires the passenger to interchange in London. This coach market will be in direct competition with HSR and so the mode shift from coach to HSR needs to be assessed. Using the Heathrow access survey data total number of passengers accessing Heathrow by coach has been included in the model and considered to behave in a similar way to classic rail.

Air demand data has been sourced from the Civil Aviation Authority (CAA)

CAA data has been used to provide demand data for domestic flights between airport pairs. The following flows were included for UK airport pairs (Europe to UK flows have been treated separately):

- Flows entirely within mainland UK therefore excluding all flows to/from Channel Islands, Northern Ireland and Scottish Islands
- Flows greater than 30,000 passengers per year

Using the above criteria there are 29 airports that are included within the base demand. Two types of passenger have been included in the air demand data:

- Domestic passengers travelling between UK airports
- Passengers arriving/departing from outside the UK who then use air to travel within the UK (interliners).

This gives demand data for the airport to airport pairs. The GG21 model needs to know the GG21 model zone that the trip originated in. Using CAA annual surveys the demand at each airport has been mapped to GG21 model zones.

The Europe model zone is treated separately as we are only concerned with splitting UK to Europe aviation demand by model zones in the UK. For the purposes of this study Europe was assumed to be Paris, Brussels and the area in-between therefore incorporating the following airports:

- Paris (Charles De Gaulle, Beauvais, Le Bourget and Orly)
- Brussels
- Charleroi
- Lille

Total demand from UK mainland airports to the above Europe airports was calculated from CAA 2007 data and then mapped onto GG21 model zones using the same methodology as the UK domestic air demand.

Summary of current demand

A summary of existing demand on key HSR corridors is shown in Table 3.1 below. Note the cities refer to the city centre and some annuli zones rather than just City centre to City centre flows.[1] London consists of Greater London, but excluding any traffic to Heathrow that is interlining to other (international) airports; however, London in this table excludes the rest of the south east.

[1] Zones: London= 6, 26, 33, Manchester= 12, 13, 21, 23, Birmingham=1, 2, Leeds= 16, 17, 18, Glasgow= 10, 11, Edinburgh= 8, 9.

Table 3.1 2007 Demand between zones on key HSR corridors by mode (millions)

Corridor	Rail	Car	Air	Rail Share
London - Birmingham	7.38	4.40	-	63%
London - Bristol	4.51	2.06	-	69%
London - Cardiff	1.49	0.98	-	60%
London - Edinburgh	0.74	0.20	1.41	32%
London - Glasgow	0.39	0.19	1.30	21%
London - Leeds	3.44	1.48	0.12	68%
London - Liverpool	1.17	0.42	0.07	71%
London - Manchester	3.89	1.31	0.44	69%
London - Newcastle	1.88	1.26	0.39	53%
London - Sheffield	0.70	0.34	-	67%
Manchester - Birmingham	2.11	55.89	-	4%
Manchester - Edinburgh	0.18	0.23	0.12	34%
Manchester - Glasgow	0.18	0.22	0.10	35%
Manchester - Leeds	3.16	43.06	-	7%
Manchester - Newcastle	0.40	1.40	-	22%
Manchester - Sheffield	0.76	2.79	-	21%
Birmingham - Leeds	0.54	3.83	-	12%
Birmingham - Newcastle	0.27	1.64	-	14%
Birmingham - Edinburgh	0.08	0.32	0.31	11%
Birmingham - Glasgow	0.08	0.31	0.30	11%
Leeds - Edinburgh	0.39	0.32	0.05	51%
Leeds - Newcastle	1.73	35.99	-	5%
Leeds - Glasgow	0.15	0.31	0.04	30%
Newcastle - Edinburgh	0.86	6.83	-	11%
Newcastle - Glasgow	0.31	0.73	-	30%
Edinburgh - Glasgow	7.99	72.43	-	10%

The large car flows are between zones where the annuli touch (Manchester – Birmingham, Manchester – Leeds, Leeds – Newcastle, Newcastle – Edinburgh, Edinburgh – Glasgow) and hence represent very local journeys; in these cases, the rail flows also overstate that which is of interest to high speed rail.

The air flows, and to a lesser extent rail to/from London, are less than that through London airports and terminals, as demand to other counties in the south east (eg Kent, Surrey, Sussex, Hants, Essex, Herts, Beds, Bucks, Berks) is excluded, as is interlining traffic at Heathrow. This south east demand may be of a similar size to the London demand and is included elsewhere in our model.

3.3 Who will use the HSR (mode choice)

A proportion of the journeys likely to be made on HSR will be made by passengers who would have made the trip previously by another mode. To be able to estimate the passengers likely to switch from air, car or classic rail it is necessary to understand what is driving people to make their mode choice decisions. This section sets out how we have assessed the decision making process and the modelling methodology used to predict the likely switch to HSR services in the future.

How to model the decisions passengers make?

For the purposes of modelling HSR the modes considered as likely competition with HSR are car, air and classic rail. Short distance trips that could be done by walking, cycling or by bus are not considered in our approach. Long distance coach travel has also not been considered in our modelling. Passengers choosing long distance coach have already chosen this mode instead of classic rail, thus demonstrating (in most cases) they are not sensitive to journey time and have chosen coach because it is cheaper or because it does not require an interchange. This group of passengers are unlikely to consider using HSR. However, travel to Heathrow by coach has been included as its journey time competes favourably with rail from many places.

When we make a medium or long distance trip we have to make a decision about which mode we will use. We make that decision based on many factors including fare, journey time, service frequency (e.g. how many trains per hour), service reliability, access to stations or airports, availability of a car and also personal preference. Car travel also has the added benefits for passengers who need to transport heavy luggage or need the car once they arrive at their destination.

Taking London to Manchester as an example, passengers currently have the choice of using classic rail from Euston, air from one of the city's airports or using their car (if they have access to one). The choice they make depends on many factors. The GG21 demand model is designed to model the choice passengers make. By assessing each of the options a value can be given to each mode that is available for a particular trip. This value is called a generalised cost and is made up of the sum of each aspect affecting the choice a passenger makes.

The generalised cost is then used as an input into our mode choice model. The mode choice model takes the generalised cost for each mode in the decision (in the case of London to Manchester there is a choice of three modes before HS is introduced) and applies a LOGIT choice formula that predicts what the mode share, based on the generalised costs of all three modes, of each mode on that route would be.

What happens when HSR is introduced?

Taking the London to Manchester example again we need to ask the question "what will happen to mode shares on the route when HSR is introduced?". Introducing the new mode means the mode choice model has four generalised costs to process. The mode shares of each of the three original modes will reduce with the new HSR service gaining model share. Sensitivity tests can be carried out by adjusting the service provision of existing modes and testing the impact. This will allow the impact of reducing the provision of classic rail services on routes where HSR is introduced.

How are the generalised costs estimated for each existing mode?

The generalised costs of each mode are in units of minutes. Generalised cost can be in either minutes or as a monetary value. Each of the tables below shows the elements of generalised cost for each mode. Where an element is in a monetary value (e.g. fares) a value of time has been used to convert it into a value in minutes. Once all the attributes are converted into minutes they are added together to give the generalised cost value for that mode to be used in the mode choice model.

Table 3.2 Classic Rail Generalised Cost

Generalised Cost Attribute	Source	Notes
Generalised Journey Time	MOIRA	This includes in vehicle time, frequency and interchange penalties
Fare	MOIRA	The average revenue per journey has been used (this differs depending on whether the trip is for leisure or business). This assumes that business passengers are more likely to travel on higher priced full tickets.
Reliability	Network Rail	This uses the Passenger Performance Measure which is the percentage of trains arriving more than 10 minutes late. This is converted into average minutes lateness and received a weighting of 3 (based on PDFH) so that it is in equivalent in vehicle time.

Table 3.3 Car Generalised Cost

Generalised Cost Attribute	Source	Notes
Car Journey Time	National Travel Model	This has an allowance for road congestion
Car Cost	National Travel Model	Includes petrol costs
Car Park Costs		Parking costs of £20 for London and £10 for other city centres; for all other zones parking costs have assumed to be zero.

Table 3.4 Air Generalised Cost

Generalised Cost Attribute	Source	Notes
In-air time	Operator websites	
Wait time		60 minutes for business and 90 minutes for leisure have been added to account for wait time at the airport (includes departure and arrival time at the airport).
Access and egress time	Route Planner Websites	The nearest airport to each GG21 model zone has been identified and the drive time to the airport extracted from an online route planner. An access time weighting from the PDFH has been applied to account for passengers valuing access time roughly twice that of in vehicle time.
Air Fare	Operator websites	Extracted for flexible and non-flexible tickets. Leisure was assumed to buy non-flexible ticket with Business buying 50% flexible and 50% non-flexible.
Air Reliability	CAA	Measured in average minutes lateness weighted by a factor of 3.
Air Frequency	Operator websites	Number of flights per week was converted into the time between each flight departing

Structuring the choice between modes

Our model uses a hierarchical decision tree to assist with forecasting the choice between modes. Figure 3.1 shows the hierarchy we have used in the GG21 Demand model.

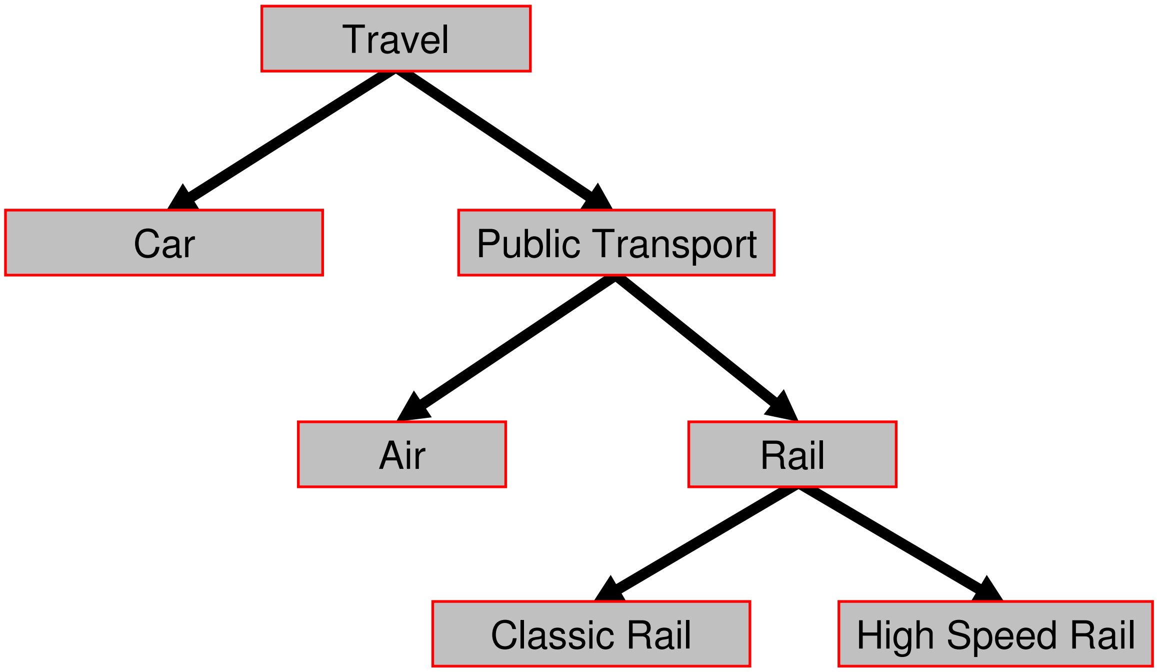

Figure 3.1 Mode Choice Hierarchy

In this hierarchical model structure passengers first choose to make their journey by car or public transport and then whether to go by air or rail. Once HSR has been introduced this becomes a choice between classic rail and HSR. It is possible for people to move between car and HSR but in this structure it is more likely that people move from classic rail to HSR. If people have already chosen to use their car the HSR service is going to have to be significantly better to persuade them to leave their car at home.

3.4 Captive and Induced Demand

Some passengers will never give up their car and some passengers will always use rail

The previous discussion has been in the context of people who have decided to make a specific journey and then are deciding which mode to use. However, we know that this is not the case for many people:

- Some people are captive to car due to large amounts of luggage, children or infirm people to transport, or the need for a car at the destination; however good the rail service is, these people will not be attracted to it.
- Other people may be attracted to make a particular journey because of a particular offer, which will typically be by a specific mode; in our case, there will be people who because of the presence of high speed rail make a journey that they would not otherwise have made. This phenomenon is perhaps best known with Low Cost airlines which have clearly stimulated substantial demand to the destinations they serve; but evidence from market research on long distance rail services is that approximately a half of passengers generated by an improvement (eg time saving or fare offer) would not have travelled at all if the service had not been unavailable.

We have therefore assumed in our model that a proportion of the current car demand is captive to car, and similarly a proportion of current rail demand is captive to rail. These proportions were estimated as part of the calibration process.

Hence, in addition to passengers switching between modes, improved journey opportunities provided by HSR will encourage completely new trips to be made. This is referred to in this report as induced demand. By forecasting the change in generalised cost of overall rail (a combination of classic rail and HS rail) with and without HS rail a forecast of the induced demand has been made. This uses an elasticity based formula. For example, if the generalised cost for rail decreases by 10% with an elasticity of -1 the induced demand would be +10%. This 10% is only applied to the proportion of rail trips that are captive to rail. We have again estimated this elasticity as part of the calibration process.

3.5 Model calibration

Model calibration is the process by which we ensure that our model will make reasonable forecasts of what will happen in different future scenarios. The traditional way of doing this is by adjusting the parameters in the model to ensure that the current situation (in particular mode share for the relevant zone pairs) is accurately represented. This is certainly necessary, but it is not sufficient.

Typically there are different combinations of parameters that will reproduce the current mode shares with similar levels of accuracy. As well as reproducing the current mode shares, we need our model to accurately represent the sensitivity of demand to various factors, notably journey time and fare or cost. These sensitivities are normally called elasticities, and typical values are presented in the PDFH, although as these are for small changes in journey time, we might modify these from domestic and international experience where large changes have been made.

The parameters we have adjusted to finalise our model are:

- spread parameters in the mode choice model (this gives the overall sensitivity to journey time of the mode choice element of the model)
- parameter on cost (the inverse of the value of time), which gives the overall sensitivity of mode choice to fare level
- proportion of the car demand that is captive to car
- proportion of the rail demand that is captive to rail
- elasticity of the rail captive demand to generalised cost of rail (which combined with the previous item gives the induced demand)
- the alternative specific constants (ASC) that are used to reflect inherent advantages or disadvantages of each alternative (or mode) that have not otherwise been modelled.

The process we adopted for calibration consisted of trying different parameter values so as to obtain approximately the desired sensitivity to changes in journey time and fare, and then using a macro to get the best fit to the mode share data. This macro also produces a goodness of fit measure (sum of square of the errors) so that different solutions can be compared.

Alternative parameter values were tried until a model having a good fit to the base mode share data and appropriate sensitivities was created.

Note that only the zone to zone flows we are interested in were included in the model calibration; we are not interested in whether the model predicts local short distance flows. Separate models were constructed for business and leisure.

3.6 The Future

Commuting on HSL

As previously indicated, we have included in our model only two journey purposes: business and leisure. Typically when forecasting rail demand, commuting is considered as a separate purpose.

Currently there is very little commuting on flows likely to be served by HSR. However, there is substantial commuting to London on flows of 45 mins which may be what HSR will achieve to/from Birmingham, for example. Can we expect commuting to increase substantially from such places, and if so how should we model it? We cannot extrapolate from the current level of commuting demand.

To determine the likelihood of substantial commuting on HSR, we need to consider what the HSR offer would look like, in particular fares. Current season ticket fares for long distance commuting are very low in comparison with daily return (full 'anytime' fares); typically a weekly season is about 1.5 to 2 times a day return – this is because of the regulation of weekly seasons which does not apply to 'anytime' fares. We would expect that a HSR would be attractive to business travellers and hence very busy at peak times which coincide with commuting peaks generally. If we were to offer as cheap fares to commuters as now, then there might be a large demand that could not be satisfied at peak times without a large investment in additional rolling stock, increased station size and potentially even additional high speed tracks; it would be difficult to make a n economic case for this. Eurostar does not offer season tickets, even though there was interest in commuting from northern France to London, and the timetable has not been designed to be attractive to this market. Some discount to reflect loyalty would be appropriate, perhaps 3.5 times a daily ticket for a weekly season (even this is a greater discount than many short distance seasons attract). The following table gives some indication of potential fares, assuming a 20% premium for the anytime fare for HSR.

Table 3.5 Possible weekly season ticket fare

	Peterborough	Birmingham
Distance	76 miles	115 miles
Journey time mins	55 (classic)	45 (HSR)
Current Anytime return fare	£87	£132
Current weekly season	£147.30	£216.20
Possible future anytime return fare (HSR)	n/a	£158.40
Possible future weekly season (HSR)	n/a	£554.40

The annual season for Peterborough is under £6,000; that for Birmingham might increase from about £8,600 to £22,000. Such a level would significantly deter commuting.

Considering now the reasons people choose to commute long distance; these include:

- trade off between travel costs and mortgage (as house prices increased rapidly, this led to longer distance commutes)
- lifestyle choices (prefer living in certain location)
- Two worker households means someone may have to make long distance commute
- Reluctance to change home after change of job, as new job may be only for relatively short period.

In the context of Birmingham (in contrast to say Peterborough), there is a larger choice of local jobs, and some of the lifestyle issues may not apply (desire for rural location). Even at the same fare level, we would expect lower commuting from Birmingham (relative to size) than from somewhere like Peterborough.

The conclusion is therefore that long distance commuting by HSR is unlikely to be extensive, assuming that current fares regulation does not apply to HSR. We have therefore not modelled commuting separately, but included it within business travel.

If it is decided that HSR would be subject to a form of fares regulation such that weekly seasons are more comparable to current long distance commuting fares, then there will be a need to make an assessment of the level of commuting outside the forecasting model. It will be important to consider the impact that such a policy would have on the capacity available on the HSR for other travellers, particularly business travellers.

Forecasting demand for HSL into the future

Although 2007 is the base year for the demand forecasting model, HSL is unlikely to be running until beyond 2020. To account for this the model takes the base data for 2007 and grows the data forward to future dates specified. The model is able to forecast HSL demand for 2021, 2025, 2040 and 2055.

The base car, classic rail and air demand are grown forward using growth factors obtained from various sources as shown in Table 3.6.

Table 3.6 Applying growth assumptions to the base data

Mode	Source of Growth data	Notes
Classic Rail	TEMPRO	Demand has been grown by multiplying by the forecast growth in population and then by GDP per capita growth. GDP elasticities from PDFH have been applied.
Air	TEMPRO	Classic rail demand growth has been applied to air demand.
Car	NTS	Based on DfT Car Traffic Forecasts.

An alternative would be to use the DfT Air Passenger Demand Forecasts (January 2009). These give slightly higher growth rates for both unconstrained and constrained (by airport capacity) domestic air travel by about 0.5% pa than the rail forecasts. However, recent growth in domestic travel at Heathrow has been lower than this due to constraints, and we prefer to be prudent; rail and domestic air are essentially competing in the same market, so it is reasonable to use the same growth rate for non-interlining air travel. We have used a growth in interlining air based on the expected throughput of Heathrow airport (with different scenarios dependent on the number of runways).

We also need to consider the demand for international air travel as this determines the potential extent of interlining at Heathrow or rail access to Heathrow. We will test both growth in line with the capacity of a two and a three runway Heathrow airport.

The forecasts of exogenous growth by mode are shown in Table 3.7 below. The growth figures are the weighted average across all zone pairs, excluding within zone. Both cumulative and compound annual growth rates are given. The rail air growth rates are unconstrained and therefore subject to an additional constraint depending on future capacity of services in places. The forecast car growth has been constrained in based on the road networks assumptions in the DfT's NTM.

Table 3.7 Exogenous Demand Growth Forecasts from 2007

	Unconstrained Rail/Air Growth		**Constrained Car Growth**	
Year	Cumulative	CAGR	Cumulative	CAGR
2025	64%	2.8%	18%[2]	0.9%
2040	150%	2.8%	tbc	tbc
2055	285%	2.8%	tbc	tbc

For future years it is necessary to make two modifications to the model. The value of time is increased in line with the recommendations in the WebTAG recommendations. The base mode shares are then adjusted to match those results from the growth rates in Table 3.6. This is done by adjusting the mode specific constants.

For each model year a base without HSR is set up, against which a variety of HSR scenarios can be tested.

Defining the base case

We will confirm the base case after discussion with Network Rail. It is likely to include all committed schemes (in HLOS), plus a few additional proposals. This includes:

- more seats in Intercity trains (IEP project)
- the new high frequency timetable on WCML
- electrification of MML, GWML and (parts of) Cross-Country
- a six standard Intercity paths per hour timetable on ECML, based on that presented by Network rail in context of the East Coast Track Applications, but with somewhat faster journeys
- increased capacity at Reading and Birmingham based on the plans in HLOS
- Crossrail
- Thameslink project

[2] Provisional, subject to review

Note that the latter two have relevance for HSR in terms of option development, rather than additional HSR services.

Modelling the impact on rail crowding and the potential for capacity to be released on the Classic network

In future years, without HSR, classic rail is likely to become increasingly crowded resulting in large numbers of passengers being crowded off the network. These people will either switch modes or decide not to travel at all. The introduction of HSL will provide relief to the classic rail network by abstracting passengers from rail. The load remaining on classic will depend on the service level maintained once HSR has become operational.

The additional capacity provided by HSR will mean the crowding suppression seen in the base run will not be as high and will result in a benefit to passengers. This benefit has been quantified and forms an input to the GG21 Business Case Model.

We model crowding separately for HSR and Classic rail, in a consistent way. The objective of the modelling is twofold:

- to determine the effect on demand and revenue of constraints on capacity
- to establish the economic disbenefits associated with crowding.

PDFH[3] provides evidence on the valuation passengers place on overcrowding; MVA has also just completed a study for the DfT which provides further evidence. In the Intercity market, there is little disbenefit provided there are seats available on the train, but once people have to stand there is significant disbenefit, not just for those who stand, but also for those who get a seat. The exception to this is the limited number of services with significant levels of commuting where standing is more accepted; the most marked example of this is Reading to London.

Hence, with the exception of a few commuter flows, we assume that passengers are not prepared to stand on Intercity or HSR services, except on a very occasional basis. Indeed, on many HSR services (eg French TGV) it is compulsory to have reserved a seat on the train (this can be booked just before departure, if available).

We do not model demand on a train by train basis; this would be far too detailed. Instead we assume that demand is distributed across trains according to a probability distribution. This distribution is based on observed demand on typical Intercity services in Britain and on TGVs for the new HSR services, on the basis that we will operate a similar compulsory reservation system – this allows a more even spread of demand. For both HSR and Classic Intercity trains, we assume that any demand in excess of capacity is lost. We do not consider crowding on local trains.

We consider crowding on the busiest sections of the principal routes which are approaching London, plus between Manchester and Leeds on Transpennine services. Suppression of demand on these sections will also result in reduced demand on other sections of route, as we reduce all flows to/from London on a given route by the same proportion; hence this works as a good proxy for the overall impact of crowding.

As the ratio of demand to supply of seats increases, the number of trains over capacity increases, as does the demand on each of these trains. This is the lost demand. However, both current Intercity services and future HSR will operate revenue management systems which have higher fares on busy trains. This means that some of the loss of demand will be compensated by an increase in average yield.

[3] Passenger Demand Forecasting Handbook v 4.1 (ATOC)

We have assumed that 30% of classic loss of demand is replaced by improved yield (ie for each 1% loss of demand, average yield increases by 0.3%); we assume that HSR will have compulsory reservation and no regulation of off-peak fares, it therefore has greater ability to manage demand and we have assumed that 60% of demand is replaced by improved yield.

Released Capacity

We envisage capacity being reused by a combination of local commuting services (which might be long distance, especially in the case of London) and by freight services; there may also be some increase in inter-regional services (eg stopping services along the WCML). The proportional reduction in demand on classic Intercity services will indicate the proportional reduction in Intercity trains operated, although this will be tempered by the level of crowding suppression (which is calculated for Intercity as well as HSR services in the model). For each scenario we will thus make an assessment of the number of classic Intercity services per hour reduced.

Converting this to number of local commuting, freight and inter-regional paths will not necessarily be one for one. It could be higher where there is already commuting/ freight services on the tracks (as in this case Intercity paths may consume more than one commuting or freight path); on the other hand, where significant Intercity paths remain on the tracks, the released paths may result in a lower number of commuting and freight paths becoming available. We will use judgement of operational experts to estimate the number of commuting freight and inter-regional paths gained.

We then need to establish the value of these:

- Outside the peak, commuting paths probably have zero value.
- For the peak, we estimate the loading on current and future commuting flows
- We use crowding penalties (note this is very different from the way we treat crowding in the model) to estimate the economic value of crowding; providing additional paths should reduce or eliminate this
- We assume that the additional costs of providing the rolling stock and other operational costs are compensated for by the additional revenue
- We will use a freight expert to assess the likelihood (probability) of any available paths being taken up; the rate charged for such freight will be set by the marketplace and hence there will only be the 'normal' profit margin made on the flows, so we will not attempt to estimate revenues and costs; there are however economic benefits; the non-user benefits will be based on the number of lorry miles replaced, multiplied by the factor for 'sensitivity lorry miles'; the user benefits are probably smaller, consisting of companies being able to transport their goods cheaper; it is difficult to assess this in a reliable way, so to be conservative we will exclude this benefit
- Inter-regional services will reduce the generalised journey time for passengers through lower frequency penalties; these will be assessed as the equivalent journey time benefit in the economic benefit, with demand based on typical load factors for such trains.

Defining the scenario

To set up a model run it is necessary to have the following inputs for each zone to zone pair affected by HSR:

- HSR route and stations served
- HSR journey times
- HSR reliability
- HSR frequency
- HSR fare assumptions (should a premium be charged for HSR compared to classic rail?)
- Changes to classic rail provision (journey time, frequency and fare)
- HSR and Classic capacity – seats per route.

These inputs need to be provided for each model year. Once these inputs have been pasted into the GG21 Demand model the results are automatically produced ready for input into the GG21 Business Case model.

4 Estimating Cost

4.1 Introduction

This section presents the approach adopted for high speed rail cost modelling in the appraisal framework.

The business case model requires two primary components:

- Capital costs of infrastructure and rolling stock
- Operating and maintenance costs of high speed lines and train services

In addition to an initial capital cost, the business case also includes asset renewal costs (infrastructure and rolling-stock). These will be based on the life expectancy of each asset.

The accuracy of the cost estimation will reflect the preliminary level of the current study.

We will use our knowledge of high-speed systems worldwide in order to reduce the level of cost uncertainty. Costs are calculated based on comparable projects in the UK or abroad.

Finally, a survey of the cost of high speed rail (HSR) projects abroad will also be presented.

Capital costs will be calculated for each high-speed section in order to allow easy compilation while developing phasing proposals.

All costs are calculated based on 2008 economic conditions. Price levels are adjusted using the Tender Price Index for construction prices. For the purposes of the business case model cost adjustments will be made as described in Chapter 5.

It is to be noted that the conversion rate from EUR (€) to GBP (£) that has been adopted is the average conversion rate in 2008: £1 (2008) = 1.25€ (2008).

4.2 Capital Costs

4.2.1 Approach

Capital costs include all aspects of the initial investment made for the project, including:

- Costs of project development (client fees, professional fees and management costs)
- Construction costs (including stations and depots)
- Rolling stock purchase
- Land acquisition
- Possession fees

The alignment options developed during the corridor alignment studies are broken down into sections. Global network and phasing scenarios, assessed in Workstream 5, are defined in terms of the complete sections that are built at each phase of HSR construction.

In the business case, different global network and phasing scenarios are tested by plugging in and out the capital costs of the appropriate sections. Capital costs must thus be prepared for each section.

These capital costs per section are calculated by applying unit costs (per km of line, for example) to the alignment of the section. Some capital cost items are calculated as percentages of other costs. For example, design and professional fees may be considered to be a certain percentage of construction costs.

4.2.2 Items

Capital costs have been broken down into the following items:

Infrastructure and systems (high-speed sections)

This item includes the required civil works and rail systems equipment. In general, the high speed alignments are designed to allow for speeds of 350 kph. However, some sections (Transpennine, for example) may allow for lower speeds in order to avoid excessive costs.

Civil works encompass right of way preparation (earthworks) and construction of viaducts, tunnels and bridges; they include costs of work-sites.

System equipment broadly includes the permanent way, signalling, telecommunication, power supply, overhead line equipment, etc.

The cost has been differentiated according to infrastructure type as follows:

- At grade alignment, categorised according to topography:
  - Easy terrain: flat to slightly hilly terrain, little necessary earthworks
  - Difficult terrain: extensive earthworks necessary to compensate for uneven terrain

A specific cost for urban areas will also be considered when tunnelling can be avoided.

- Viaducts and exceptional structures
- Bridges
- Tunnels

Classic rail upgrade and interface with other lines

This item includes any necessary classic line-high speed line interfaces or upgrades to classic lines in order to permit high-speed trains to use them. HS trains may run on classical rail routes in order to access existing rail stations or offer onward service to regions that have not built a HS line.

Land acquisition and compensation

This item includes acquisition of land to secure property titles on the line corridor (for the right of way itself, but also for stations, depot, etc.).

It also takes into consideration the cost of acquiring and demolishing buildings.

Stations

The implementation of a high-speed line requires construction of new stations and renovation or extension of existing ones.

Rolling Stock

The cost of the purchase of rolling stock per trainset is determined based on current market rates.

The number of trains will depend on the implementation phase and on the service patterns determined in the operating study.

Depot

Design and construction costs of HS depots will depend on the size of the rolling stock fleet, and the number of locations required.

Professional fees and provisions

This item includes project management and design fees, as well as provisions for costs that are difficult to quantify at this level of detail: environmental mitigation measures, diversion of utility networks, fencing, possession costs (for interface with live railway), etc. Work sites costs are directly included in the other cost items (for information: they usually represent about 4 to 5% of project cost).

The cost of those items will be added as a percentage of total cost **excluding rolling stock.**

Because of the preliminary nature of this study, provisions for contingencies (geotechnical complications, archaeological excavations, etc.) are also added.

4.2.1 Optimism bias and risk

Optimism bias is defined by the Green Book as "a demonstrated systematic tendency for project appraisers to be overly optimistic." Therefore, the Department for Transport's Guidance on Rail Appraisal suggests percentages to be added to base case costs in order to correct for this bias. These percentages depend on project's development level as defined by the GRIP (Guide to Rail Investment Projects).

The current study is at Level 1, "Pre-feasibility". The recommendation for this level is that a **66% optimism bias adjustment be added to capital expenditure base prices**.

All prices provided in this document do not include optimism bias. The 66% optimism bias will be added to the prices when they are input to the business case model.

The Guidance on Rail Appraisal also discusses the need for a Quantitative Risk Analysis (QRA), that is the calculation of probability weighted costs related to risks. However, the QRA is not to be performed at this development level.

4.2.2 Key cost drivers

The cost of each of the items listed in section 4.2.2 will be defined by applying a unit cost (determination of unit costs described in section 4.2.3) to a key driver. These key drivers have to be simple enough to suit the level of detail (preliminary) of the present study.

The key drivers for each of cost items are the following:

- **Infrastructure and systems (high-speed sections):** at-grade route length by topographical difficulty, length of viaducts, number of bridges, length of tunnels.
- **Classic rail upgrade and interface with other lines:**
  - Upgrade of classic line (CL): length of single and double lines to electrify, and the length of single or double lines that need other improvements.
  - Interface with CL or HSL: length of single-track connections, number of grade-separated junctions, and number of turnouts.
- **Land acquisition and compensation:** length of at grade alignment by topographical difficulty, length of viaducts, length of tunnels, required surface for stations and depots.
- **Stations:** number of new parkway stations outside of city centres, number of new urban stations (e.g. underground), number of stations needing major or minor remodelling.
- **Rolling stock:** number of train cars required.
- **Depot:** cost of rolling stock.
- **Professional fees, provisions and contingencies:** total cost, total cost excluding rolling stock, classic line interface costs (including station remodelling).

4.2.3 Unit cost development

Unit costs are derived from different sources. The primary source is CTRL cost details as they concern the only high-speed line in the UK. These unit costs cannot simply be applied as they stand. HS1 is, per kilometre, the most expensive high speed railway that has been constructed anywhere in the world (financing costs excluded). And even if we take into account the high amount of tunnelling, it remains a very expensive line. We believe that costs for future HSR development could be less, particularly in the context of a large national HSR project that would have less overhead per km of line.

The high-speed rail study carried out by Atkins in 2003 adopted unit costs derived from contracts that have similar characteristics to the proposed line sections. For example, Contract 240, which is composed mostly of tunnels from Stratford to London West Portal, was used as a basis for urban tunnels.

This approach seems reasonable and will be adopted in the present study to reflect the order of magnitude of costs. However, we will widely rely on Systra's in-house database, and in particular on data in relation with construction of high-speed lines in France, in order to identify and adapt any costs that seem overestimated or underestimated. For example, the analysis performed by Steer Davies Gleave[4] points out that costs in London and Kent are higher than in most of the rest of the UK in terms of labour and land, and that the construction environment in these areas is likely to be excessively constrained compared to other areas in the UK. According to this report, overestimation of acquisition costs could be in the range of 5-15%.

[4] *High speed rail : international comparisons*, February 2004

Infrastructure and systems

- **At grade alignment**

At grade alignments are assumed to be built on ballast.

Two different unit costs were developed for at grade alignments: cost per km of line (double track) on easy terrain, and cost per km of line on difficult terrain.

Easy terrain is flat or slightly hilly, and requires little movement of earth to maintain an even right of way. Difficult terrain, though it does not require the construction of tunnels or viaducts, is uneven enough to require significant earthworks (creation of trenches and embankments) in order maintain gentle changes of gradient along the alignment.

The unit costs developed for the two types of terrain are as follows:

- **Easy terrain:** The cost per kilometre of line is based on CTRL open-country civil works contracts in relatively easy terrain (e.g. contracts 330 and 420) and on system procurement contracts (e.g. contracts 550 and 570) after having isolated at grade sections only. **Cost per km is thus £10.1 million.**
- **Difficult terrain:** According to our estimations and to our in-house costing method, a km of alignment built on difficult terrain would be 42% more expensive than a km of alignment built on easy terrain (civil works are 65% more expensive while system costs are equal). **Thus cost per km is £14.1 million.**

These unit costs include fencing and provisions for environmental mitigation works and archaeological surveys.

- **Viaducts and exceptional structures**

Viaducts are major structures that allow crossing of areas such as major motorways, railway lines or rivers, and to accommodate significant grade changes. They are multi-span structures.

In case an important exceptional structure is to be built in response to challenging terrain or specific aesthetic requirements, it will be taken into account separately.

The estimated costs of a viaduct could be based on the Medway Crossing contract (as in the 2003 Atkins study). System procurement costs are assumed to be equal to those of an at grade section. Cost per km would therefore be about £60 million in 2008.

In order to avoid basing viaduct cost on a single specific structure, however, Systra's in-house database was used. This data indicates that a kilometre of viaduct costs approximately 3.5 times a kilometre of line on easy terrain. **This leads to a cost per km of viaduct of about £35.6 million.** It is to be noted however that this cost does not include any required switches, environmental mitigation measures (supposed to be included in CTRL cost), etc.

We therefore adopt a cost per km of £35.6 million, as it seems to be a reasonable assumption for railway viaducts. We will then add the cost of required switches, environmental costs, etc.

- **Bridges**

Bridges are minor structures (compared to viaducts) that allow the new railway to cross over or under a small obstacle such as a road or other rail line.

It should be noted that pedestrian crossings, where the HSL bisects a footpath for example, are not included as bridges. A provision is made in this regard.

Given the level of detail of the alignment studies, it does not seem realistic to count the number of bridges. Furthermore, it is common practice when estimating prices for a preliminary study to include the cost of such small bridges as an average provision per kilometre of line.

Therefore, based on the work of the Atkins study, the average number of bridges per km will be identified. If possible a different number will be determined per corridor.

To give an example number, in Option 8 of Atkins study there is on average one bridge every 2.3 km, thus about 0.4 bridges per km.

After discussion with Network Rail, the unit cost would be around **£1.2 million per bridge.** This figure is to be adapted once we have more information about a typical crossing.

- **Tunnels**

Although it may be more somewhat more expensive to tunnel in city approaches than elsewhere (due to the risk of interactions with utility lines and higher land acquisition costs for surface access), no price differentiation is made between urban and rural tunnel.

The track is assumed to be installed on a slab platform in tunnels. System equipment costs in tunnels are higher, as they include provisions for additional mechanical and electrical systems.

In the Atkins study, tunnel cost was based on contract 240 - Stratford to Barrington Road. System equipment is estimated to be twice as expensive in a tunnel as in an at grade section. Cost per km would therefore be about £56 million in 2008 prices. Systra's in-house database indicates that a kilometre of tunnel costs approximately 5 times a kilometre of line on easy terrain. This leads to a cost of around £50 million.

Moreover, analysis of a representative group of European HS lines (about 20 lines, CTRL not included), shows that, on average, tunnelled sections cost about 14% more than viaduct sections leading to a cost of around **£40m per km.**

According to Network Rail, this cost would be around £36 millions. A kilometric tunnelled sections cost of £40 millions seems reasonable.

Classic line upgrade and interfaces

Construction of a new high speed line (max speed > 250 kph) very often requires interfaces with classic lines. For example, for a non-segregated HS network, which we assume to be the case here, HS trains may run on classical rail routes in order to access existing rail stations or offer onward service to regions that have not built a HS line.

These existing routes must be electrified in order to be compatible with the HS rolling stock, if they are not already. Or they may need to be renewed or enhanced in order to allow for higher operating speeds (straightening out, signalling, etc.). Higher operating speeds could also mean the necessity of suppressing level crossings.

Connection lines are single tracks with a maximum speed of around 220 kph, equipped with the required points and crossings.

High speed/classic line or high speed/high speed junctions could require grade separation (single track overpasses or underpasses) so as to avoid capacity-consuming line crossings. Of course, HS lines should not be unnecessarily charged for improvements that are not "essential" for HS services.

Interface between HS and classic lines

Connection between HS and (existing) and classic lines are considered to be single lines allowing a speed of 220 kph. This speed is to be confirmed in the context of the network and service studies.

Costs presented hereafter include civil works and systems.

- **Easy terrain:** According to our estimations and to our in-house costing method, a new 220 kph line would cost 10% less than a 350 kph line in easy terrain. **Cost per km for a double track would be around £9.1 million**, while it would be **£7.1 million for a single track.**
- **Difficult topography:** According to our estimations and to our in-house costing method, a new 220 kph line would be 4.5% less expensive than a 350 kph line in difficult topography. **Cost per km would therefore be around £13.5 million**, while it would be **£10.5 million for a single track.**

Upgrading existing lines

Existing classic lines used by high speed trains may require electrification, renewal, signalling works or rectification. The extent of works to be carried out depends on the characteristics of the existing lines.

- **Electrification:** according to our in-house database electrification would cost **£0.94 million per km for a double track and £0.60 million per km for a single track**. This cost is comparable to high level electrification cost estimations for UK.
- **Track and ballast renewal:** according to our in-house database, **for a double track, this would cost £1.1 million per km, while for a single track, it would cost £0.67 million per km**.
- **Signalling:** according to some works on the UK railway network, signalling would cost **£0.55 million per km for a double track and £0.39 million per km for a single track.**

– **Rectification:** works would aim to rehabilitate an existing line (curves, cants, etc.) to enable a speed of 220 kph. According to our in-house database, these improvements would cost about 79% of the cost of a new line capable of 220 kph in easy terrain. Therefore, **cost of double track rectification would be around £7.2 million per km, while it would be around £5.1 million per km for a single track.**

– **Level crossing suppression:** bridges would be required. The same bridge unit cost is adopted for the suppression of a level crossing as is identified for bridges built as part of HS infrastructure.

According to Network Rail, level crossing suppression would cost £4 million (for each).

Of course, the cost of improvements that will benefit classic lines, even in the absence of HSR, should not necessarily be attributed to the cost of a HSR project.

- **Grade separated junctions**

  The cost of a grade-separated junction between two double-track lines is composed of 3 elements:

  – The cost of the single track under- or overpass

  – The cost of the switches

  – The cost of the connecting lines (mentioned above)

We will consider the case of a Y-shaped junction connecting two double-track lines, with one track on an overpass or underpass, as show in Figure 4.1.

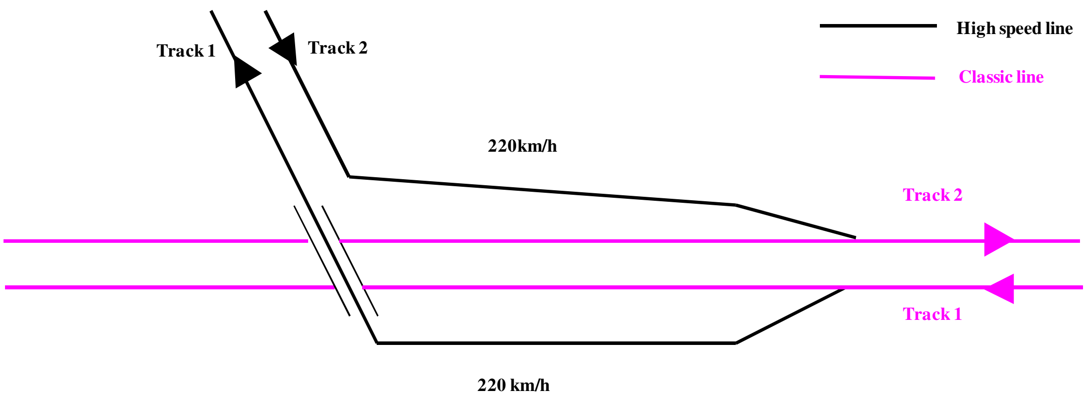

Figure 4.1: Configuration of a simple Y-shaped junction connecting two double-track lines

The unit cost of the underpass or overpass would be around £2.5 million. The cost of two 220 kph switches would be £1.1 million, and the linear cost of the approximately 1000 m of connecting line of the junction (assuming easy terrain) would be £7.1 million. **The total cost of a Y-shaped junction connecting two double-track lines (with one track on an overpass or underpass) is thus £10.7 million.**

According to Network Rail, the total cost of a bidirectional junction would rather be **£21 million**. The cost of more complicated junctions (involving more switches, more over/underpasses and more meters of connecting lines) would need to be calculated accordingly.

- **Points/turnouts**

Cost of points and turnouts largely depend on the allowed speed while crossing (60, 80, 160, 220 kph).

For the purpose of this study, and using Systra's in-house database, **the cost for a 220 kph point would be £550,000.**

The speed required will have to be confirmed in network and service studies, and cost will be adapted accordingly.

Land acquisition and compensation

This item includes acquisition of land to secure property titles on the line corridor (for the right of way itself, but also for stations, depot, etc.).

It also takes into consideration the cost of acquiring and demolishing buildings.

The strip of land to be obtained may be between 50 and 100 metres wide (Atkins said between 40m and 80m; Systra uses 50m and 100m to be on the safe side), depending on topography and infrastructure type. On easy terrain, 50 m would be sufficient, while 100 m would be required for difficult terrain and for special structures (viaducts, tunnel entrances, etc.).

As this study cannot examine in detail the costs associated with land acquisition and demolition of existing buildings, these costs are determined as a percentage allowance added to overall construction costs.

The Atkins study (based on a specialist analysis) showed that a maximum of 4.4 % of construction costs (not including rolling stock) would be attributed to land acquisition and compensation. An analysis of a number of representative European lines (20 lines, CTRL not included) showed that this item could represent up to 11% of total cost, the average being about 5.8% (not including rolling stock). It is nevertheless worth noting that these percentages are based on lower construction costs.

During alignment studies, the consultant will be very careful about property expropriation and demolition, so as to keep this item at a reasonable cost level.

Land acquisition, demolition and compensation are taken to be 4.4% added to overall construction costs (not including rolling stock). Atkins figures according to corridors would be used in order to take into account differences between land costs in different UK areas.

Stations

New stations can be easy to design and relatively inexpensive to build outside of city centres (e.g. parkway stations), though they often entail a specific design and very high capital costs when built in densely-built urban areas (e.g. stations that must be built underground).

Existing stations may require major upgrade works to be able to cope with new HSR demand (extra and/or extended platforms, extra tracks) or minor refurbishment (for small stations).

In general, station renovation or construction must be assessed on a case by case basis. Station cost will include an allowance for land acquisition.

Using Systra's in-house database, the cost of new "typical" stations (ie 2 platforms, 4 tracks) would be around:

- £32 million (not including land acquisition) for parkway stations;
- £300 million for 4 platform track underground stations;
- £380 million for 4 platform track underground stations with acceleration/deceleration tracks;
- £480 million for 6 platform track underground stations with acceleration/deceleration tracks;
- £160 million for stations on a viaduct.

Rolling Stock

The only high-speed rolling stock used in the UK is the Eurostar TGV TMST (Trans Manche Super Train or Class 373) whose top speed is 300 kph. Trains are 394 m long and offer about 770 seats. The TGV TMST was developed on the basis of the TGV Réseau with some major adaptations (BR gauge, tri or quadri-current, new motorisation, specific Channel Tunnel safety requirements). As a result, the cost of TGV TMST was (at 2008 economic conditions) about £32 million, twice as high as the TGV Réseau.

Note that new trains - Hitachi British Class 395 – will be in operation on the line from December 2009, but their top speed is only 225 kph.

For the purpose of the present study, rolling stock procurement cost will be based on current market rates for typical high speed trains currently in operation. Trains considered are 200 m long, capable of 320 kph (minimum), so as to allow coupling if required. Capacity would be 400 to 500 seats.

Many rolling stock possibilities can be envisaged: TGV Duplex/AGV, ICE, Shinkansen, Talgo, etc. Note that specific characteristics and adaptations of the rolling stock have a significant effect on cost.

TGV Duplex type rolling stock, due to particular gauge specifications, could only be envisaged on new lines built with respect to UIC B+ gauge. Its maximum speed is currently 300 kph and its length 200 m, for a price of about £21.6 million (2008 EC). Its capacity of 510 seats could offer a significant advantage on particularly crowded sections. It is important to note that although conventional UK rolling stock and TGV Duplex can both operate on UIC gauge track, they can never use the same platforms due to the gauge constraints.

The only **ALSTOM AGV** contract for the moment has been signed between Alstom and the Italian company NTV, with a unit cost of £20.8 million (2008 EC, with a 30 year maintenance contract - not included in the cost) for 200 m, 460-seat trains. The relatively low cost is due to the fact that the rolling stock requested by NTV is only going to run at 300 kph (due to the characteristics of the Italian network), and not the 360 kph the AGV is capable of.

The cost of 200 m AGV trains, with a top speed of 360 kph, would be around £26 million (2008 EC).

The **SIEMENS ICE 3** is used (or will be shortly) for the:

- VELARO E (Spain 2004) - ten 200 m 400-seat trains for a unit price of about £24 million (2008 EC), all manufactured in Germany. Top speed is 350 kph.

- CRH 3 (China 2006-2008) - sixty 200 m 600-seat trains for a unit price of about £20 million (2008 EC), 3 manufactured in Germany and the rest in China, which explains the low cost. Wider than VELARO E with the same top speed of 350 kph.
- VELARO RUS (Russia): eight 250 m 600-seat trains for a unit price of about £28 million (2008 EC), all manufactured in Germany. Wider than VELARO E and different voltage with a top speed of 250 kph only.

SHINKANSEN trains are mainly used in Japan. Taiwan is the only other country that has chosen this type of rolling stock.

- 700T (Taiwan 2007), thirty 305 m 989-seat trains for a unit price of about £30 million (2008 EC). Top operating speed is 300 kph.
- N700 (Japan 2008): nineteen 255 m 546-seat trains for a unit price of about £35 million (2008 EC). Top operating speed is 300 kph.

TALGO HS trains are used by RENFE (Spain). In 2005, RENFE acquired thirty 200 m trains for a unit price of about £23 million (2008 EC). Top operating speed is 330 kph.

We can reasonably assume **a 200 m train unit cost of 26 m£ (2008 EC).** Specific research and development costs associated with the development of a new system (adaptation to British Gauge for example) are not included. A provision (percentage of RS cost) may have to be added if required by network and service studies.

Each train unit must be replaced after thirty years of operation.

Depot

The cost of the depot will be calculated as a percentage of the cost of rolling stock, following benchmarks of worldwide projects. Depot land acquisition will be included in the *"land acquisition and compensation"* item.

Depot cost will be a percentage of rolling stock cost. According to Systra's knowledge, this percentage is between 10% and 15%. However, we note that North Pole Depot for Eurostar (before HS1) and at Temple Mills (with HS1) were both more expensive, and that the percentage was quite high (around 26%).

We believe the cost of a new depot could be reduced to a maximum of 20% of the cost of rolling stock.

Professional fees, provisions and contingencies

According to CTRL data, professional fees have reached around 33% of total line cost. Analysis of several HS projects in Europe showed that this percentage is on average between 10% and 15%.

We believe that despite UK specificities, the existence of a large scale HS Scheme (which we assume to be the case here) would help to reduce design and management costs. As a result we believe **professional fees can be reduced to about 25% of total cost excluding rolling stock.**

Provisions concern:

- **Interfaces with live railway (possession costs):** usually a provision of **10%** of on the cost of classic line upgrades, station remodelling works and junction interfacing with existing lines. Possession costs could only be known in more detail at a much more advanced stage of project development, when the exact schedule of works is known.
- **Environment-specific measures:** general mitigation measures have been taken into account in the cost per km for infrastructure and systems. Nevertheless, specific measures may be necessary for unforeseen environmental constraints such as detection of protected species during civil works.
- **Archaeology, utility diversion:** also included in costs per km, but a provision can be made for risk.
- **Other**

Apart from the interface with live railway, the Consultant proposes to add a provision of 5% of total cost (excluding rolling stock) for items that are difficult to assess (and to forecast) at this level of studies.

4.2.4 Presentation of international HS line costs

Cost comparison

HS1, formerly CTRL, is the only high-speed line in operation in UK. This line, which cost more than £50 million to build per kilometre, is the most expensive high speed railway that has been constructed in the world. Many reasons may justify the high capital cost of the line: extensive tunnelling works on the approach to London, St Pancras improvements, etc. But even taking these factors into account, the line remains very expensive line in terms of unit costs.

In order to have an idea of the cost difference, the figure below gives the cost per km of some HS lines in the world as a percentage of HS1 cost.

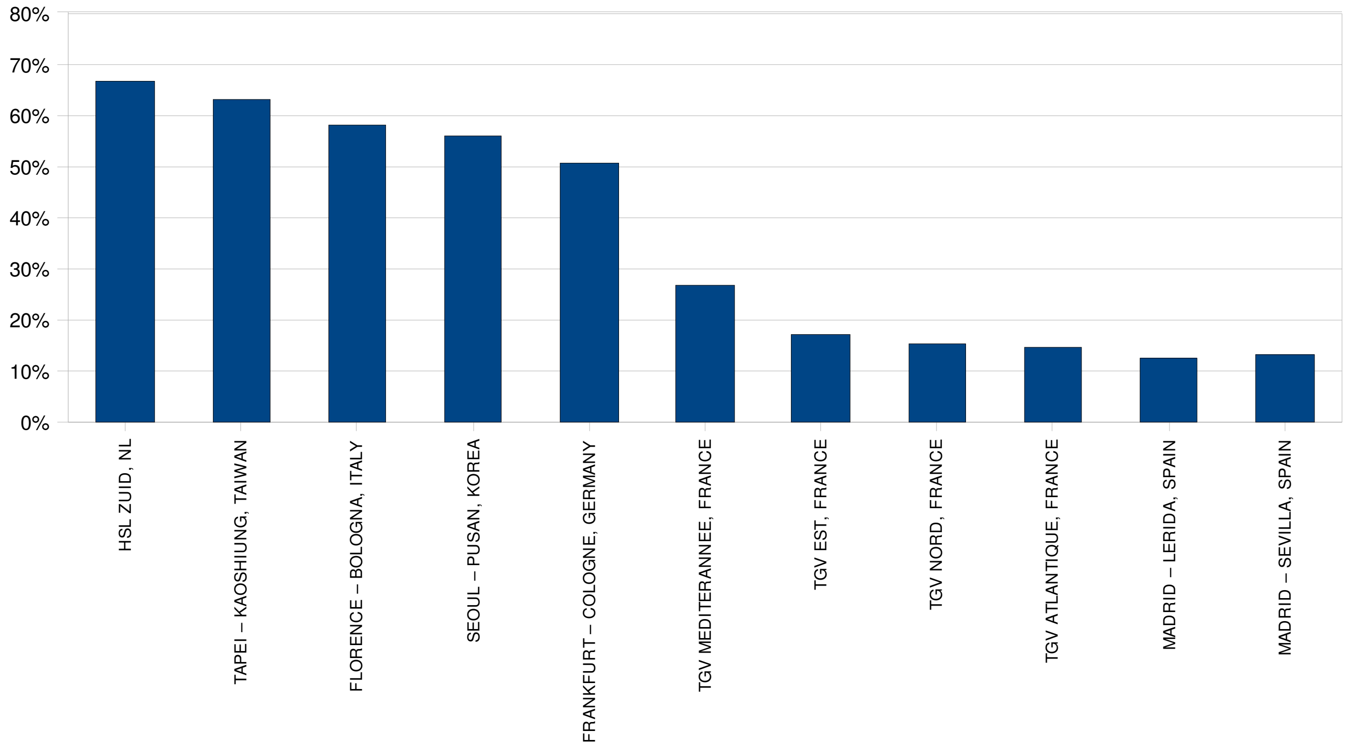

Figure 4.2: Costs per km of HS lines constructed worldwide as a percentage of HS1 cost

HS1 is, by far, the most expensive line, especially when compared to Spanish or French lines.

It must be kept in mind that this is to some degree a case of comparing apples and oranges, as the unique characteristics of the lines are different: the presence of special structures (viaducts, tunnels), passenger-only vs. passenger-freight lines with slope restrictions, etc.

The Commission for Integrated Transport report *High Speed Rail: International Comparison* prepared by Steer Davies Gleave draws some tentative conclusions regarding cost differences, with an interesting analysis of the high costs of HS1[5]. It also explains where significant cost savings could be achieved, while recognising that some cost probably cannot be reduced, such as higher land costs:

- Costs imputable to different regulations and long approval processes could be reduced in the medium term.
- By envisaging HS lines as part of a large scale programme, and not as "stand alone" projects, some professional costs could be reduced as personnel would gain experience. The 33% of total cost due to client and professional fees are seen to be too high compared to other countries.
- Design changes must be avoided once works have begun.
- At the design stage an effort must be made to avoid the addition of costly "extras" that provide small benefits.

[5] Note that there are some minor differences between costs of HS lines presented by Steer Davies Gleave and the present report, but the idea remains the same.

Moreover, using HS1 as a base for developing unit costs could exaggerate costs of new lines as costs in London area and Kent seem higher than in most of the rest of the UK.

As a result, the report claims that cost reduction could reach about 30%.

Typical cost breakdown

Analysis of **20 European HS lines** shows that, on average, typical cost breakdown is as follows:

- Land acquisition and compensation: 6%
- Civil works: 60%
- System: 20%
- Professional fees: 7%
- Other costs: 7%

However, we note that there are important differences in cost breakdown according to geography, regulatory processes, etc.

4.2.5 Line cost model

The cost of each scenario or phase will be determined following the structure presented in the figures below. The total cost will be given per section as an input to the business case.

Infrastructure & Systems

CORRIDOR	SECTION/OPTION	TOTAL SECTION LENGTH (km)	SECTION DESCRIPTION HS Sections* (e.g. V=350 km/h) At grade - Easy Terrain (km)	At grade - Difficult Terrain (km)	Viaducts (km)	Tunnels (km)	SECTION HS INFRASTRUCTURE & EQUIPMENT COST
UNIT COST (m£/UNIT) ->			10.00	14.20	50.00	56.00	
CORRIDOR 1	SECTION 1 - OPTION 1						
	SECTION 1 - OPTION 2						
	SECTION 1 - OPTION 3						
	SECTION 2- OPTION 1						
	SECTION 2 - OPTION 2						
	SECTION 2 - OPTION 3						
CORRIDOR 2	SECTION 1 - OPTION 1						
	SECTION 1 - OPTION 2						
	SECTION 1 - OPTION 3						
	SECTION 2- OPTION 1						
	SECTION 2 - OPTION 2						
	SECTION 2 - OPTION 3						

Figure 4.3: Approach to calculating infrastructure and system costs for HSR sections

Classic line upgrade & interfaces

CORRIDOR	SECTION/OPTION	SECTION DESCRIPTION – Non HS Sections (V < 250 km/h) – Upgrading existing lines: Single track - Electrification, renewal, signalling (km)	Single track - Rectification (km)	Double track - Electrification, renewal, signalling (km)	Double track - Rectification (km)	Interface btw classic/HS line: Single-track connection from/to HSL (km) Easy topography	Single-track connection from/to HSL (km) Difficult topography	Grade-separated junctions (nbr/length)	Switches/turnouts (nbr)	SECTION INFRASTRUCTURE & EQUIPMENT COST
UNIT COST (m£/unit) ->		0.70	5.35	1.05	7.20	7.10	10.60		0.50	
CORRIDOR 1	SECTION 1 - OPTION 1									
	SECTION 1 - OPTION 2									
	SECTION 1 - OPTION 3									
	SECTION 2- OPTION 1									
	SECTION 2 - OPTION 2									
	SECTION 2 - OPTION 3									
CORRIDOR 2	SECTION 1 - OPTION 1									
	SECTION 1 - OPTION 2									
	SECTION 1 - OPTION 3									
	SECTION 2- OPTION 1									
	SECTION 2 - OPTION 2									
	SECTION 2 - OPTION 3									

Figure 4.4: Approach to calculating cost of upgrades to and interfaces with existing classic rail lines

ROLLING STOCK

CORRIDOR	SECTION/OPTION	NUMBER OF TRAINS	ROLLING STOCK COST
UNIT COST (m£/200 m trainset) ->			
CORRIDOR 1	PHASE 1		
	PHASE 2		
	PHASE 3		
CORRIDOR 2	PHASE 1		
	PHASE 2		
	PHASE 3		

Figure 4.6: Approach to calculating rolling stock cost

DEPOT			
CORRIDOR	SECTION/OPTION	Total Rolling Stock Cost	DEPOT COST
	UNIT RATE (% of total rolling stock cost) ->	20%	
CORRIDOR 1	PHASE 1		
	PHASE 2		
	PHASE 3		
CORRIDOR 2	PHASE 1		
	PHASE 2		
	PHASE 3		

Figure 4.7: Approach to calculating depot cost

4.2.6 Cost of a 4-track line

It is possible that, in order to deal with very large passenger demand, one or more sections of HSL will need to be built using 4 tracks (instead of the 2 tracks assumed in general for a HSL). This section describes an appropriate method that will be applied to calculate the capital costs of such a 4-track line.

The cost of a 4-track line is calculated in comparison with the cost of building two completely independent 2-track lines.

The savings that can be had when building an at-grade section of 4-track line are as follows:

- Opening reduction: for earthworks, land acquisition, road-bridges.
- Reduction of length of: draining gutters, anti-noise barriers, fencing.
- Reduction of the number of working sites (that will nevertheless be bigger). This will not be taken into account here since working sites are assessed through a percentage of capital costs.
- Equipment that is not directly linked to the length of the infrastructure: electrical substations, telecommunication installations, maintenance equipment. In this field, savings could only come from civil engineering.

After calculation, the possible savings that will be taken into account when comparing scenarios are presented in Table 4.1.

Table 4.1 Possible savings of a four-track line compared to two separate double-track lines

	Possible savings compared to two double-track lines
Earthworks, land acquisition, road-bridges	11 %
Draining	25 %
Anti-noise barriers and fencing	50 %
Equipment	5 %

These assumptions lead to **a cost per km of a four-track line (on easy terrain) of £18.4 million**, to be compared to a cost of 2 x £10.1 million per km for two segregated lines (9% overall savings).

In general, the unit cost of major structures (viaducts, bridges and tunnels) for a 4-track line is generally the double the unit cost of the same structures for a 2-track line. Because of the necessary complexity of a grade-separated junction involving a 4-track line, the cost of this item is multiplied threefold.

The unit costs of major structures for a four-track high-speed line are presented in Table 4.2.

Table 4.2 Proposed costs of major structures for a four-track high-speed line

in millions of GBP	**Proposed costs of major structures (4-track line)**	*Costs considered for a 2-track line*
Viaducts	71.3 /km	*35.6 /km*
Rail bridges	2.4 /km	*1.2 /km*
Tunnels	80.0 /km	*40.0 /km*
"Simple" grade separated junction	32.1	*10.7*

4.3 Operating and maintenance costs

4.3.1 Description

Operating costs of a HS line can be divided into 2 distinct components: operating costs for the infrastructure manager and for train operating companies (TOC).

Infrastructure costs encompass line maintenance (including all fixed equipment – permanent way, catenaries, etc.), station maintenance and path allocation.

TOC operating costs include rolling stock maintenance, train operation staff costs, sales and ticketing costs and energy costs.

Operating costs depend on the level of service offered and maintenance strategy adopted.

Note that track access charges are a transfer payment between the TOC and the infrastructure manager and so do not need to be estimated.

4.3.2 Key cost drivers

The cost drivers for the operating and maintenance cost items are the following:

- **Infrastructure costs:** length of the new infrastructure and classic section HS trains run on.
- **Train operating company costs**: number of stations (station staff), number of train-km (for train maintenance and energy costs) and annual revenue.

4.3.3 Unit costs

Data for the operating and maintenance cost model are mainly derived from UK inter-city train operating company operating costs and on the existing infrastructure management costs, and adapted to the HS context according to practice on existing systems in other countries.

Infrastructure costs

- Infrastructure operating and maintenance cost

Track maintenance and operating costs are calculated in function of the estimated UIC line classification. Based on data on HS1 provided by Network Rail, the cost of maintenance and operation of a UIC class 3 high speed line is considered to be £180,000 per km and per year.

It is assumed that, in a first approach[6], the variable part of this cost is around 20%. Thus, the variable track maintenance and operating costs of the other classes of line are calculated based on ratios defined by the UIC.

Indeed, UIC Leaflet number 714 R – *Classification of lines for the purpose of track maintenance* aims at classifying the sections of a network according to traffic level (in fictive tonnes[7]), following the logic that the more tonnes travel on a section of line, the higher the maintenance costs for that section of line.

Classification goes from 1 to 9. High speed lines are generally considered to be from UIC 1 to 6.

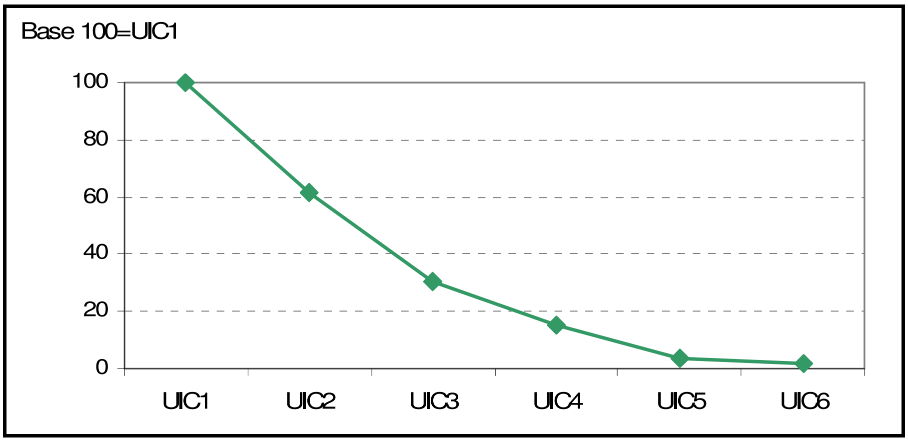

Figure 4.8: UIC line groups relative maintenance costs

The "fixed" part, assumed to be 80% of operating and maintenance costs, will be common to sections with high levels of traffic (UIC 1-3) but will be lower for sections with less traffic. The ratio used comes from our in-house database.

Track renewal costs are calculated based on the following assumptions:

- Track equipment must be replaced every 30 years.
- Structures last 100 years.
- The renewal costs are the same for all types of infrastructure.

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[6] Econometric studies in Europe

[7] "Fictive tonnage" or "equivalent tonnage" is obtained by calculation. It considers the number, the average speed and the average tonnage of the trains running on a section, per type. More information on www.uic.asso.fr

- Costs:

  – The cost of renewing 1 kilometre of a two-track line is £4.21 million.

  – The cost of renewing 1 kilometre of a four-track line is £8.32 million.

- Station maintenance

Station staff costs have been determined for two very general cases:

- Staff costs for small stations: £570,000 pa
- Staff costs for main stations: £1,640,000 pa

These costs are estimated based on:

- Observed ratios of number of passengers to staff
- Typical pay rates in the UK
- Typical overhead per employee in the UK

The cost of station maintenance, based on Systra's database, is estimated to be about 0.4% pa of the cost of station construction.

TOC costs

- Train operation and rolling stock maintenance

Analysis of current TOC data included in the Rail Industry Monitor 2008, shows that InterCity operating costs per train-km are on average about £20, while those of West Coast and East Coast are about £28. The latter will be taken as a basis as they seem the most representative of the corridors HSR is very likely to serve. However, many of these costs are covered elsewhere in our analysis, notably track access (we include infrastructure capital and maintenance costs) and rolling stock lease costs; we also exclude energy and commercial costs. The remaining HSR operating costs are estimated as 35% higher than those for classic trains. **Overall train operation and rolling stock maintenance cost would be around £10 per train-km,** based on similar length trains (i.e. about 200m); a double length train costs close to double the amount to operate, the only saving being a driver.

Rolling stock undergoes major mid-life maintenance 15 years after purchase. This major maintenance costs 30% of initial acquisition cost.

- Sales and ticketing

Analysis of SNCF and Eurostar data shows that ticketing costs represent respectively 16% and 11% of annual revenue. However, domestic UK experience is much lower and reducing rapidly with internet technology. For the purpose of the present study, we will assume a percentage of **2.5% of annual revenue** as commercial costs.

- Energy Cost

Energy consumption of a HS train will be assumed to be about 22.2 kwh per km for a single unit and 40 kwh per km for a double unit for a maximum speed of 320 kph with Duplex stock (in-house database). SNCF experience is that the TGV Duplex consumes no more energy than a single deck train due to its superior aerodynamics and reduced weight materials. When running on classic lines at a reduced speed, energy consumption will be adapted according to the following figure:

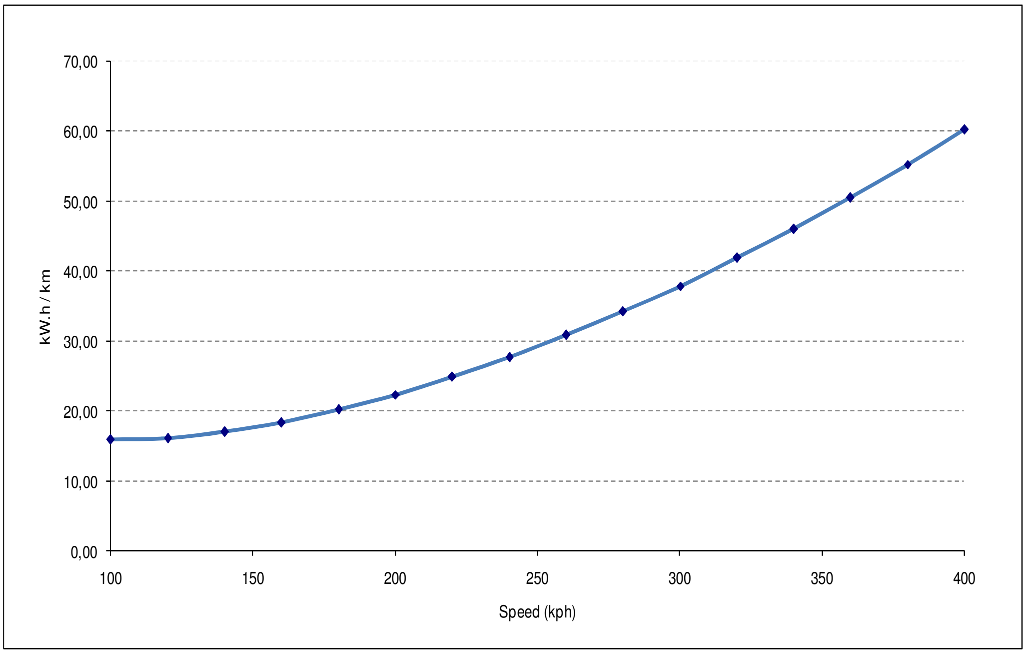

Figure 4.9 Power Consumption of TGV Duplex (Multiple Units)

Electrification asset usage costs published by the Office of Rail Regulation are different according to electricity traction type:

- DC (third rail) network: 0.267 pence per train-km
- OLE (AC) network: 0.702 pence per train-km

For example, assuming a consumption of 15 kwh/km for a conventional train, cost per kwh would be about 0.047 pence per kwh.

In practice, the cost of traction is negligible with regards to overall TOC costs.

4.3.4 Evolution of costs

Certain unit costs increase or decrease over time (inflation excluded) as they depend on: wear and tear of equipment, increase of energy costs, staff wages (which may vary in function of GDB, for example), productivity improvement, optimisation of ticketing costs, etc.

It can be considered that maintenance costs of infrastructure globally increase by 2% pa between two renewals.

TOC costs increase according to a weighted average between the evolution of ticketing costs (-1 to -1.5 % pa), energy costs (~+2% pa) and wages (~+1% pa)[8]. It is nevertheless worth pointing out that in recent years, TOC costs in the UK have been stagnating or for some decreasing, as TOC have gained in

[8] Source: in-house database

productivity[9]. Because the cost data available is rather approximate, we propose to use a global percentage of +0.5% pa that is commonly used in France in preliminary HSR studies. This rate can be revised at later stages of study, when an appropriate maintenance schedule is put into place.

4.3.5 Optimism bias

As mentioned above, optimism bias is defined by the Green Book as "a demonstrated systematic tendency for project appraisers to be overly optimistic." Therefore, the Department for Transport's Guidance on Rail Appraisal suggests percentages to be added to base case costs in order to correct for this bias. These percentages depend on project's development level as defined by the GRIP (Guide to Rail Investment Projects).

The current study is at Level 1, "Pre-feasibility". The recommendation for this level is that a **41% optimism bias adjustment be added to operating expenditure base prices**.

4.3.6 Operating and maintenance cost model

Once demand figures are known and a service level is defined, operating costs will be calculated per year and will be an input to the business case.

4.4 Phasing

Defining a HS network programme is the objective of workstreams 4 and 5. Phasing possibilities will be determined following affordability of schemes and the level of traffic on the HS lines.

The business case will therefore be an input and an output for/of the HS programme determination.

Capital costs will be given following an investment schedule taking into account construction schedule possibilities.

As an example, in preliminary stages of a project, Réseau Ferré de France (the owner of all rail infrastructures in France) uses a schedule based on the magnitude of capital investments:

Table 4.3 Example of investment schedule

Capital costs	Y-4	Y-3	Y-2	Y-1	Total
Costs <20 M€ (16 M£)			50%	50%	100%
20 M€ < Costs < 100 M€ (80 M£)		30%	40%	30%	100%
100 M€ (80 M£) < Costs	10%	30%	40%	20%	100%

[9] Source: Rail Industry Monitor 2008

5 Social Economic Appraisal

5.1 Introduction

This chapter aims to establish whether there is a transport, business and social case for a new High Speed Rail network in the UK. The case for HSR will be compared against the current Government key criteria for assessing transport schemes, which defines five key objective areas:

- Environment – an assessment of the impact of HSR on landscape, heritage, biodiversity, water, noise, air quality and climate change
- Safety – an assessment of the impact of HSR on accidents on both public and private transport, and security
- Economy – a cost-benefit analysis (CBA) of the user, non-user and wider economic benefits
- Accessibility – an assessment of the impacts on severance and access to the transport system
- Integration – an assessment of the impacts of the HSR integration with other modes and government policy particularly with regards to land use.

Each objective is split into a number of sub-objectives and the HSR proposals are assessed against each sub-objective. Where appropriate monetised benefits have been calculated. Where benefits cannot be monetised a ranking is given from a seven point scale ranging from 'significant beneficial' to 'significant adverse'.

The outputs of the appraisal are summarised in an Appraisal Summary Table (AST), and an AST is produced for each scenario.

This chapter will examine each of the above key criteria and explain how we have assessed HSR against the objectives and sub-objectives. WebTAG was used for guidance in appraisal techniques, assumptions and values. WebTAG[10] is the Department for Transport's (DfT) Website for Transport Analysis Guidance and is the industry standard for appraising transport schemes. For monetary valuations separate sections are completed for estimating the benefit to users and non-users.

5.2 Environment

The environmental appraisal aims to provide an initial assessment of the likely environmental impact of the different HSR network configurations.

There are 10 sub-objectives within the environment objective which fall into two main categories; land-use and traffic related. In addition several of the sub-objectives are monetised. Table 5.1 outlines the broad categories of the Environment objective.

[10] http://www.dft.gov.uk/webtag/index.htm

Table 5.1 Environmental Sub-Objectives

Sub-objective	Land-use Impact	Traffic Impact	Monetised Benefit	Non-Monetised
Noise		✓	✓	
Local Air Quality		✓	✓	
Greenhouse Gases		✓	✓	
Landscape	✓			✓
Townscape	✓			✓
Biodiversity	✓			✓
Heritage	✓			✓
Water Environment	✓			✓
Physical Fitness		✓		✓
Journey Ambience		✓		✓

Among the many considerations required to identify suitable, cost-effective high speed rail routes, environmental constraints could potentially be significant. Increasingly stringent European and UK environmental legislation, particularly related to designated sites and the need to maintain the integrity of sensitive landscapes, means that an appraisal of constraints and opportunities will be an important element of the current commission.

It is acknowledged that it is not the intention of this project to define specific rail routes as this could have implications for property blight and subsequent compensation claims, therefore, the aim will be to confirm the principle of potential routes and identify the major constraints that will need to be avoided, minimised or mitigated.

Given the potential length and width of the route corridors being considered, it would not be practicable at this stage to identify every environmental constraint and to then attempt to identify potential routes that fit around them down to the local level. We will therefore work with the route development team to appraise two route scenarios within each of the five high speed corridors. Where readily and freely available, environmental datasets with national coverage will be obtained and uploaded to a GIS database, which will then be interrogated to identify major constraints. Datasets are likely to include *inter alia*:

- sites of nature conservation importance (SSSI, SAC, SPA, National Parks etc);
- registered parks and gardens;
- registered battlefields
- sensitive land uses (urban/residential areas, high value agricultural land etc);

- major planning designations;
- hydrology and hydrogeology (floodplains, flood risk); and
- major woodland areas (ancient woodland);
- designated landscapes (AONB, AGLV).

A simplified sensitivity rating system will be applied based on the relative importance of each type of constraint eg. international designated sites with statutory protection will be given a higher sensitivity rating than local designations. Sensitivity will also be related to the potential difficulty of gaining the necessary consents for construction and/or the likelihood of significant opposition to a high speed rail link. These ratings will be used to determine the potential significance of the impact of the route passing through or adjacent to an identified environmental resource/constraint. Analysis of the data will be used to identify sections of the route that may require specific mitigation, such as the need for noise barriers near sensitive urban areas, or landscape mitigation where the route passes through an area of high landscape value. This can then be used by the team to develop the cost benefit model. For each indicative route a table of constraints will be generated with associated commentary on the potential impacts, opportunities for mitigation and enhancement and potential planning/consent implications.

The monetised impact from traffic related sub-objectives can be assessed using changes to passenger kilometres of different modes under the various scenarios. The changes to passenger kilometres are an output of the Demand and Revenue model. The traffic related monetised benefits are described in greater detail below and the subsequent valuation in sections 5.8 and 5.9.

Noise

Noise impacts have been monetised from the reduction in car kilometres following DfT guidelines for appraising rail schemes. The valuation of the noise benefits associated with a reduction in car kilometres is described in section 5.8. A monetary assessment has not been made of the direct impact of HSR, as the study will not define precise route alignments. It is assumed that sufficient mitigation measures will be put in place where HSR noise is a particular issue (such as new transport alignments).

Local Air Quality

As above with noise, the valuation of the local air quality benefits associated with a reduction in car kilometres is described in section 5.8.

Greenhouse Gases

CO2 is considered the most important greenhouse gas and is therefore used as the key indicator for assessing different HSR options impact on greenhouse gases and climate change.

Net carbon emissions are estimated in the base and scenario options for each year of the appraisal period. Interpolation and extrapolation are used to model years which have not directly been appraised. We will make a high level assessment of the carbon impact of construction.

The key inputs into calculating the impact on greenhouse gases are changes to passenger kilometres of the different modes and an estimate of CO2 emission per passenger kilometre for each mode over each year of the appraisal period. Passenger kilometres for each appraisal year and each mode are calculated within the Demand and Revenue model.

Guidance from ATOC on the energy consumption and CO2 impacts of High Speed Rail have been used to estimate emissions. The key findings and recommendations are outlined below.

The recommended CO2 impacts for each mode are shown in Table 5.2. The ATOC assessment will be used for car emissions but sensitivity tests will be completed using the King Review/CCC assumptions.

Table 5.2 Projected CO2 emissions by mode and loading for selected years from 2008 to 2055

		2008	2025	2040	2055
HSR	kgCO2 per train km	14.6	4.6	1.2	0.7
	gCO2 per seat km	22.4	7.1	1.8	1.0
	gCO2 per pass km (70% loading)	**32**	**10.2**	**2.6**	**1.5**
Classic (IEP[11])	kgCO2 per train km	N/A	3.48	0.89	0.58
	gCO2 per seat km	N/A	5.36	1.37	0.90
	gCO2 per pass km (70% loading)	N/A	**11.96**	**3.06**	**2.01**
Car (King Review/CCC)	kgCO2 per vehicle km	172	124	105	87.5
	gCO2 per seat km	34.4	25	21	17.5
	gCO2 per pass km (30% loading)	**114.8**	**82.6**	**70**	**58.3**
Car (Trend)	gCO2 per vehicle km	174	153	137	122
	gCO2 per seat km	35	30.6	27.3	24.4
	gCO2 per pass km (30% loading)	**116**	**102.1**	**91.2**	**81.4**
Aviation	kgCO2 per aircraft km	15.7	13.8	9.4	7.9
	gCO2 per seat km	100.7	88.1	60.4	50.4
	gCO2 per pass km (80% loading)	**125.9**	**110.2**	**75.5**	**63**

The demand model forecasts the impact on car and air passenger journeys, and these will be converted using the above CO2 performance by mode and each mode's passenger kilometres. This assumes that the average load factor of air remains unchanged (ie if demand is reduced, then the number of flights reduces pro rata); we consider this a reasonable assumption in the long term, as profit margins on domestic flights are not high. Average load factors for car will be reduced in line with government forecasts.

In some cases, we may find that the presence of HSR makes flights on a particular flow unviable as HSR is capturing almost all of the existing air market; in this case, we will remove the air service and obtain the full CO2 benefits. The monetary value of this assessment is described in the User and Non User Benefits section.

[11] From ATOC email; energy consumption based on DfT press release:
http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=392467&NewsAreaID=2&NavigatedFromDepartment=False

5.3 Safety

The safety objective is split into two sub-objectives:

- Accidents
- Security

Accidents

The impact of HSR on the accidents sub-objective will be assessed by examining the change in passenger kilometres (of rail, aviation and car) and hence the change in the number and cost of accidents. The change in accidents will be a result of:

- Reduction of accidents due to mode shift from car to rail
- Changes in the accident rate between classic and high speed rail
- Slight increase in accidents due to shift from aviation to rail

Changes in passenger kilometres of the different modes were taken from the Demand and Revenue Model.

Accident rate assumptions are set out in Table 5.3. Accidents on the road are split into fatal, serious, slight and damage-only. As the majority of abstraction from road to rail will be long distance journeys, it is assumed that the majority of the car kilometres removed will be from motorways. We are trying to acquire HSR casualty rates, these are currently shown the same as Classic Rail, although they may be lower due to lack of level crossings, etc.

Table 5.3 Casualties per million passenger km

	Fatal	Serious	Slight
High Speed Rail[12]	0.000014		0.01148
Classic Rail[13]	0.000014		0.01148
Aviation[14]	0.000014		0.01148
Car[15]	0.002244	0.015592	0.14377

The output of the Demand Model is car passenger kilometres but the appraisal required car vehicle kilometres. A factor of 0.7 is used to convert passenger to vehicle kilometres, in line with WebTAG recommendations. Using WebTAG recommendations it was assumed that 17.7 Damage Only accidents occurred per road casualty.

[12] Classic Rail rates shown, HSR rates under review

[13] based on Transport Statistics GB 2008 Table 9.8

[14] No domestic flights crashed since Kegworth 1989, but we have used same figure as for rail

[15] DMRB guidelines (Motorway)

Security

The impact of HSR on the security sub-objective is likely to be limited although there may be a perceived improvement in security due to the limited stops and seat reservation policy. However, the level of staffing and security at the main stations will be unchanged from the existing InterCity services and therefore as there will be no step change in security provision this sub-objective will be assessed as Neutral.

5.4 Economy

Within our assessment of High Speed Rail the following Economy sub-objectives will be appraised:

- Cost-Benefit Analysis
- Reliability
- Wider Economic Benefits

The Cost-Benefit Analysis within this assessment combines the three NATA sub-objectives of Public Accounts, Transport Economic Efficiency of Business Users and Transport Economic Efficiency of Consumers.

Cost Benefit Analysis

The Treasury definition of 'cost benefit analysis' is: "Analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value".[16]

The Government would like to value all the appraisal sub-objectives in monetary terms however for many of the sub-objectives this is unfeasible such as landscape or heritage. The cost benefit analysis does there not cover all the appraisal criteria. Impacts not included in the monetised cost benefit analysis must however be taken into account in the assessing overall value for money.

The appraisal of High Speed Rail within this report follows DfT recommendations including:

- use of Market Prices
- The scheme is appraised over a 60 year period from opening
- Values are discounted to Present Value with DfT standard discounting rates (3.5% for the first 30 years 3% for the next 30 years)
- The base year for discounting of all costs and benefits is 2008
- the price base year is 2002, all prices in the appraisal are adjusted for inflation back to 2002 prices

All monetary costs and benefits are calculated using the same method

Cost Assessment

The cost component of the cost-benefit analysis is a combination of scheme capital csots and scheme operating and maintenance costs. Further details of how the costs were derived are given in Chapter 4.

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[16] Appraisal and Evaluation in Central Government (HMT, 2003: p4)

The cost assessment provided spot costs (in 2008 prices) and phasing of the capital, operating and maintenance costs. From this appraisal costs are calculated using the method described in Figure 5.1.

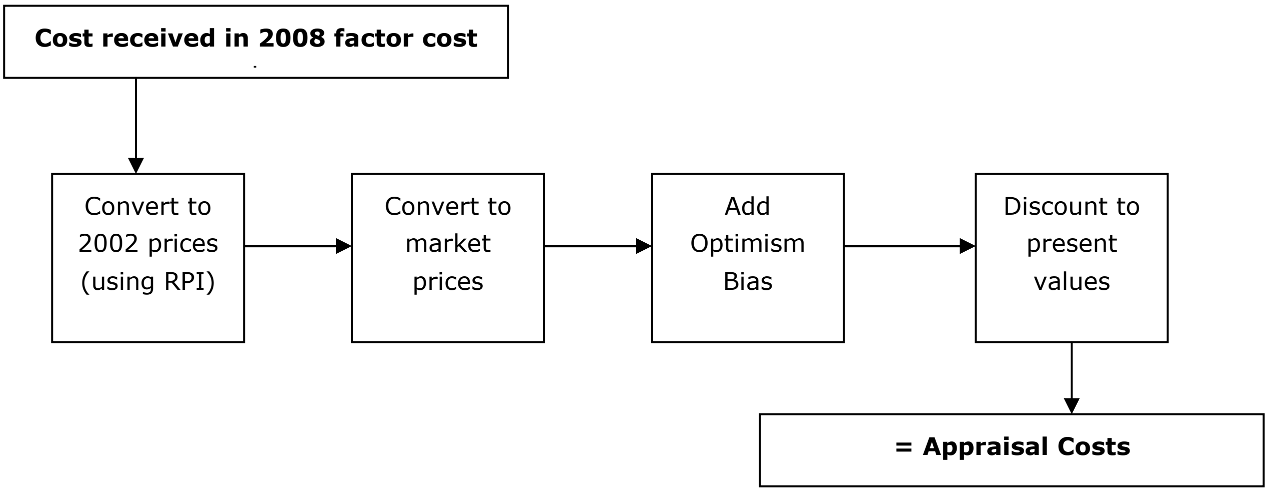


Figure 5.1 Appraisal Cost Calculation

The key steps in order to be compliant with DfT guidelines for the appraisal and ensure consistency in approach are:

- the cost including real inflation was converted into market prices using a factor of 1.209 as advised in DfT's WebTAG
- a discount rate of 3.5% for the first 30 years of the appraisal and 3% thereafter is used to discount the costs to present values (PV) following Treasury Green Book Guidance.

The above process is followed for capital, operating and maintenance costs.

Benefits Assessment

Scheme benefits are split into three categories:

- User benefits – rail users
- Non-user benefits – other transport users
- Wider Economic Benefits (recently these have been renamed as Wider Impacts)

In developing the benefits two additional issues need to be considered; demand/revenue build up in the early years after opening and the economic benefits obtained by new users.

A demand build-up period has been assumed in recognition that demand levels rarely achieve forecasts in the early years of operation because of imperfect knowledge of the new travel options on the part of passengers. A profile of build-up was taken from WebTAG recommendations and applied to all the demand and revenue inputs to the appraisal. The assumed profile is defined below:

- Year 1 (year of opening) 80% of forecast
- Year 2 90% of forecast
- Year 3 95% of forecast
- Year 4 100% of forecast

Section 5.7 covers the assessment of user benefits while Section 5.8 covers the assessment of non-user benefits. Wider Economic Benefits are described in greater detail below and in Chapter 6.

For each benefit the monetary value is converted into 2002 prices and discounted to present year (2008).

Outputs of Cost Benefit:

- Net Present Value (NPV) – PV benefits minus PV costs, this shows the absolute scheme benefits
- Benefit Cost Ratio – NPV (as above) plus Present Value of Costs to Public Accounts, all divided by Present Value of Costs to Public Accounts

The BCR is, therefore, a value for money measure, which indicates how much net benefit would be obtained in return for each unit of cost to public accounts. This is clearly relevant in the real world situation of limited funding available from public accounts.

Reliability

This sub-objective assesses the impact of a proposal on improving journey time reliability for transport users. It is expected that HSR will offer greater journey time reliability than either classic rail, car or air. Reliability was incorporated into the model using different methods for each mode:

- Classic rail – PPM was converted to minutes lateness for each OD pair
- Car – reliability within car cost assumptions
- Aviation – average delay per airport pair
- HSR – we use estimates from experiences elsewhere (particularly SNCF) of the reliability of HSR; when the route is essentially dedicated, the delays on HSR are approx 25% of those on classic rail; however where there is significant running on classic routes, delays are about 75% of classic rail.

Therefore the impacts of reliability on journey times, abstracted demand and generated demand are within the Demand and Revenue model and can not be simply disaggregated out. However, to distinguish between the different HSR route options, configurations and scenarios, the total length and % segregation of route are used to compare different options.

Wider Economic Benefits

The Wider Economic Benefit sub-objective is described in Chapter 6.

5.5 Accessibility

There are three sub-objectives within the Accessibility objective:

- Options value
- Severance
- Access to transport system

This sub-objective is of limited applicability to our HSR proposals. The Options Value refers to the willingness to pay to preserve the option of using a transport service for trips not yet anticipated or currently undertaken by other modes. A typical example is the re-opening of a previously closed railway line serving a series of rural towns and villages connecting to a larger city. Even if a rural resident does not intend to use the rail service, they may still value having the option to use the service if they choose so, such as for unplanned or unexpected trips.

There is significant guidance on valuation of the Options sub-objective but within our analysis a quantitative monetary assessment has not been calculated. This is because there will be few if any completely new opportunities to travel resulting from HSR; instead the HSR proposals will mainly provide major improvements to the existing transport options including a quicker service over existing rail modes, and in some cases the opportunity to make day trips where previously overnight stays would have been required. There may be some new Parkway type stations, but these can be considered as supplementing city centre stations rather than new opportunities. The most significant area where new opportunities are likely is at Heathrow, which in some scenarios may be offered rail services to new destinations.

The impact of HSR on this sub-objective will be assessed in a qualitative way.

Severance

The Accessibility sub-objective Severance refers to the impact of the proposal on non-motorised modes in terms of affecting journeys. For instance a new HS railway line may cross an existing footpath severing the route and increasing journey times; in most cases, this will be mitigated through the provision of bridges or underpasses.

Current proposals do not go into exact route detail so it is difficult to accurately assess severance. However, due to the large scale of proposals it is likely that there will be local severance issues for all options and although it may be possible to mitigate some, it is beyond the scope of this study to identify detailed local issues. We would expect that within the appraisal Severance will be assess as Negative for all options and scenarios, even though a cost provision will be included to mitigate the worst effects.

Access to Transport System

The most important determinant of access to the transport system is the availability of a vehicle for private use. For those without a car, access to the public transport system is crucial. Access to the transport system can be appraised through distance of population with no car from HSR.

WebTAG recommends examining how the transport scheme affects the number of people without access to a car and who do not live within 250m of a daytime public transport service. The inner city nature of most of the HSR stations will mean it will only directly affect a few people’s access to the transport system according to this definition.

However, the different options will be appraised by comparing the different populations who live within larger distance of HSR stations, for instance 10km, 25km and 50km. GIS will be used to estimate the number of residents and residents without access to a car in each of these distance bands.

5.6 Integration

The Integration assessment will assess whether the proposals fit with the Government's integrated transport policy. More specifically, this means: does high speed rail increase integration within and between different types of transport, so that each contributes its full potential and people can move easily between them and does it improve integration with land-use planning, at national, regional and local level, so that transport and planning work together to support more sustainable travel choices and reduce the need for travel.

There are three sub-objectives within the Integration objective:

- Interchange
- Land-Use Policy
- Other Government Policy

Interchange

Improving interchange is a key factor in achieving a truly integrated transport system. The transport interchange sub-objective aims to assess the impact proposals have on improving interchange between different transport modes. The sub-objective is broken down into whether proposals are likely to affect freight and/or passengers. Due to the nature of our proposals only passenger interchange is assessed.

Passenger interchange is recommended to be assessed using a qualitative approach by assessing how interchange indicators including waiting environment, information provision and staffing change at the interchange facilities. This level of detail is beyond the scope of this appraisal as detailed scheme design has not occurred.

However, the different route options can be compared using the following indicators:

- Number of existing stations served by HSR
- Number of new city centre stations
- Number of new parkway stations
- Number of stations which interchange with more than one other mode of public transport

Integration with Land use Policy

Land use policy varies by UK government region. Regional Spatial Strategies (formerly Regional Planning Guidance) are produced by each region and are the key policy documents relating to Land Use policy. Regional representatives from each government region have been fully involved in the Workstream 4 stakeholder workshops with the relevant Spatial Strategies and regional policy therefore informing decisions on routing strategies.

In addition, the Wider Economic Benefits are closely linked with this sub-objective and benefits will be split by region so it will be possible to assess the net number of regions that have economic benefit from the different scenarios.

The only assessment categories within this sub-objective are neutral, beneficial or adverse.

Integration with National and Regional Government Policy

This sub-objective will cover all Government Policy not covered in the Land-Use policy. This will include:

- Delivering a Sustainable Railway
- Future of Transport White Paper
- Towards a Sustainable Transport System
- Eddington Transport Study

The above Government policy documents were assessed as part of our Workstream 2 report. Our HSR proposals align with current policy and therefore HSR will be assessed as beneficial for the this sub-objective.

5.7 Estimating benefits to Users

HSR Rail Users are split into existing and new users. Existing users are defined as those that previously travelled on classic rail, car or air and have switched to HSR in the scenario. New users are generated users. This generated traffic needs special treatment in economic appraisal. The basic issue is that new public transport users (those that used a different mode, or did not travel before) do not have a time/cost with which to compare a benefit in the Base and Scenario, in effect there Base costs were zero. To account for this, the difference between the Base and Scenario public transport costs are taken, and half the benefit assumed to accrue to these new users (the rule of a half).

The user benefits evaluated were:

- net fare revenue
- journey time savings including reliability
- value of crowding
- accident savings

Net Fare Revenue

Fare revenues were determined from the Demand and Revenue model. HSR fares may have a premium on the existing classic fare. We will test different fares premium in the forecasting model, including the same fare as classic rail. The selected fare will involve discussion with Greengauge 21 and PwC (due to its impact on funding issues). We can expect there to be a trade off between maximising economic benefits and the revenue achieved. Experience elsewhere is that about 20% premium is typical.

The model provides the necessary information to calculate the revenue effect of a specific fare level on HSR by multiplying the demand by the average fare; the impact on classic rail revenue can also be estimated. The net impact on rail revenue, that is combination of HSR revenue and the change in classic revenue, is used within the economic appraisal. Different fares can be used in the model by year; our proposal is to increase all rail fares by RPI+1% in the central scenario, with air fares and car costs being adjusted to reflect the price of oil. The fares used in the economic evaluation will be consistent with those used in the demand forecasting.

Journey Time Savings

Journey time savings refer to two types of rail users:

- existing classic users who switch to HSR
- users of other modes (car or aviation) who switch the HSR

By using number of trips and Generalised Journey Time (GJT) from the Demand and Revenue model, and comparing with and without HSR, it is possible to estimate the total time savings.

Journey times are converted to a monetary value through the use of DfT Values of Time. The value of time varies by use and between resource/perceived and market cost. In this appraisal the perceived cost has been used. The following values of time have been used, given in 2002 prices:

- business: £30.57 per hour
- leisure: £4.46 per hour

The value of time has been grown through the appraisal period using DfT recommendations in WebTAG. The value of non-working time (leisure) is assumed to increase with income, with an elasticity of 0.8. Working values of time (business) are assumed to grow in line with income, with an elasticity of 1. The measure of income used is GDP per head.

Value of Crowding

The demand model has a crowding component that suppresses demand when trains are expected to be full (see section 3.6). It is not actually expected that passengers on long distance services (whether HSR or classic) will actually stand, rather they will be deterred from travelling by the unavailability of a seat on their desired train. We need to include the economic disbenefits of this suppression of demand.

While PDFH provides passenger valuations of travelling in crowded conditions, this is not the situation we are considering; rather people decide not to travel. We therefore use a different way to place an economic value on this, by converting the suppression of demand into an equivalent journey time; ie what increase in journey time would result in the same suppression of demand? Having calculated the equivalent journey time increase, this is multiplied by the number of passengers on the route and converted into economic disbenefit by applying the standard (WebTAG) value of time.

The same crowding methodology is applied in terms of both demand forecasting and economic benefits for HSR and classic rail services. If an HSR scenario increases capacity and hence reduces crowding, there will be a reduction in the disbenefits associated with crowding, which is equivalent to a crowding benefit. It is the benefit that we will report in our appraisal.

Accident Savings

User accident savings apply only to those who have transferred to HSR. To calculate the value of accident savings WebTAG was used for the value per casualty and accident, as well as the growth in accident value. Table 5.4 shows the average value for road casualties in 2002 prices. The majority of the cost of each casualty is due to lost output, human cost and medical costs. These will occur for casualties across all modes therefore the figures in Table 5.4 are applied to all modes. Damage only refer to car accidents, using WebTAG guidance it was assumed that 17.7 Damage Only accidents occur per slight, serious and fatal accident.

Table 5.4 Accident Cost (2002 prices)

	Fatal	Serious	Slight	Damage Only
Per casualty	£1,249,890	£140,450	£10,830	£1,986

5.8 Estimating benefits to non users

The non-user benefit assessment relates to benefits accrued by people not using the High Speed Rail. This covers people who continue using classic rail, continue using aviation and car, and people who were not travelling who accrue the wider benefits.

The non-user benefits that were evaluated were:

- environment benefits from changes in greenhouse gas emissions
- benefits from a reduction of car kilometres in the form of decongestion, maintenance of infrastructure, noise, local air quality and taking into account loss of tax from reduced car usage.
- vehicle operating costs
- passenger crowding benefits or freight benefits resulting from re-use of the freed capacity on the existing classic rail network

Greenhouse Gases

Section 5.2 describes how the impact of proposals on the production of CO2 and tonnes of carbon has been quantified.

Estimate of the value of the additional global damage arising from an additional tonne of carbon being emitted into the atmosphere are referred to as the Shadow Price of Carbon (SPC). The values used in this appraisal follow current DEFRA guidance[17] and originate from the Stern Review.

Table 5.5 shows the central, upper and lower recommended values for the shadow price per tonne of carbon released into the atmosphere for a variety of years.

Table 5.5 Shadow Price (£) per Tonne of Carbon in 2002 prices

	2000	2002	2006	2010	2020	2040	2060
Central	71.00	73.87	79.96	86.55	105.50	156.77	232.95
Upper	85.20	88.64	95.95	103.86	126.60	188.12	279.54
Lower	63.90	66.48	71.96	77.89	94.95	141.09	209.66

Within our Appraisal the Central estimate has been used. However, as the HSR proposals are very large in scale, and the impact on carbon emissions is likely to be high, the DfT recommends the upper and lower estimates to be tested for sensitivity.

[17] How to Use the Shadow Price of Carbon in Policy Appraisal DEFRA Dec 2007

External Car Cost

The HSR proposals will reduce the amount of car kilometres and therefore reduce the external cost of car use. External car costs are:

- decongestion
- infrastructure maintenance cost
- local air quality
- greenhouse gases
- noise
- accidents
- impact on indirect taxation

The monetary benefit of greenhouse gases and accidents have been calculated elsewhere so to avoid double counting are not included in this analysis.

The change in car kilometres is taken from the Demand and Revenue model and provided for each year of the appraisal period. Car kilometres are assumed to be 0.7 of passenger car kilometres, this is in line with assumed vehicle occupancy rates from WebTAG. Due to the national nature of the HSR proposals the congestion average uses national figures for motorway decongestion benefit.

The change in car kilometres is converted to a monetary value using the marginal external costs output from the NTM, which gives estimates per passenger car unit kilometre in pence. These values are shown in Table 5.6.

Table 5.6 External Car Costs (pence per vehicle kilometre)

	2025	2040	2055
Congestion Average	9.28	11.81	15.28
Infrastructure	0.01	0.007	0.01
Local Air Quality	0.28	0.15	0.15
Noise	0.04	0.05	0.05
Indirect Taxation	-3.01	-2.32	-1.78

Interpolation and extrapolation are used with the values from Table 5.2 to provide a pence saving per removed car passenger kilometre for each year of the appraisal period. Vehicle operating costs are incorporated into the congestion benefit in table 5.8.

Freed Capacity

The process for evaluating the benefits of additional capacity on the classic network is as follows:

- Convert the change in classic rail demand into a reduction in the classic rail service provision, measured in trains per hour by route; this will be a judgemental process, taking into account the level of crowding in the reference case
- Assess the opportunity for running additional freight and local and inter-regional passenger services on different parts of the route; this might be additional freight paths along the majority of the route, inter-regional services on certain sections, and local commuter services at each end; there might be more or less such paths than the number of Intercity paths removed, as there is not a one for one correspondence between different types of path – it depends on the mix of traffic on the route
- The benefits of the commuter services will only be relevant to the peaks; these will be reductions in actual crowding levels (unlike that for long distance services, where demand is suppressed); hence we will value them using an estimate of the change in average load factors and the crowding valuations from PDFH (as a sensitivity test we might use the valuations from MVA's recent study for DfT; this calculation is largely a high level manual calculation using load factors from published sources such as the RUSs)
- The benefits from inter-regional passenger services will consist mainly of frequency improvements, which will be converted into equivalent journey time following guidance in PDFH; these will then be valued using standard values of time
- The benefits from additional freight services will first consist of a market assessment of the demand for additional services on the route concerned; once a freight path is considered likely to be used (or a probability assigned to it), then the valuation assigned to it will consist of the estimate of lorry miles removed from the highways, multiplied by the 'sensitive lorry miles' benefit as in WebTAG
- In all these cases, we will assume that the actual revenue and cost of operation broadly cancel each other; for peak local commuter and inter-regional passenger services this is typically the case; for freight, the competitive market between rail operators prevents monopoly profits being made.

We will make explicit the assumptions made in this process. The treatment in the Business Case, is summarised in Table 5.7.

Table 5.7 Treatment of capacity released in Business Case

Element	In Business Case?	Comment
HSR revenue	YES	
HSR Operating costs	YES	
HSR economic benefits	YES	
Reduction in classic Intercity revenue	YES	
Saving in classic Intercity operating costs	YES	
Economic benefits of loss of classic Intercity traffic	YES	Included within the HSR economic benefits (we present the incremental benefits)
Revenue from additional local rail services	NO	Assume that revenue and costs broadly offset each other
Operating costs of additional local rail services	NO	
Economic benefits of additional local rail services	YES	Crowding benefits plus car decongestion where more passengers are carried
Revenue from additional inter-regional services	NO	Assume that revenue and costs broadly offset each other
Operating costs of additional inter-regional services	NO	
Economic benefits of additional inter-regional services	YES	Mainly frequency benefits plus car decongestion
Revenue from additional freight trains	NO	Assume that revenue and costs broadly offset each other
Operating costs of additional freight trains	NO	
Economic benefits of additional freight trains	YES	Measured as 'sensitive lorry miles'

6 Wider Economic Benefits

6.1 Introduction

In the economic appraisal of a transport scheme, it is important to incorporate all welfare impacts of the scheme. Conventionally, considerations have been mainly focused on the scheme's impact on transport users and operators. As the economic appraisals continue to evolve, further considerations have been included, on the impacts to the environment, landscape, accessibility and heritage.

The latest consideration incorporated into the Department for Transport's (DfT) appraisals is Wider Economic Benefits (WEB) – recently these have now been renamed as Wider Impacts, but they are essentially the same. In June 2006, the DfT published a discussion paper on the methodology and evidence to estimate WEB[18]. There are two types of WEB: those that affect GDP refereed to as GP effects; and those that affect wider welfare issues, referred to as WB. Overall, there are seven aspects of WEB to be considered:

- increase in labour force participation (GP1)
- people working longer (GP2)
- jobs moving to more productive areas (GP3)
- agglomeration benefits (WB1, GP4)
- increased competition (WB2)
- imperfect competition (WB3)
- exchequer consequences of increased GDP (WB4).

The benefits above are generated through the changes to the cost of travel, and related changes to where people live and work i.e. land-use. They are based on the rationale that the total benefit to society is different from the sum of the benefit to each individual, and that conventional appraisal methodology is inadequate in addressing such a difference.

This chapter discusses:

- land-use changes as a result of a transport scheme
- the quantification of WEB.

6.2 Land-use impact and Employment Impacts

Why the land-use model is required

Transport investments tend to reduce the transport costs for firms and individuals. Such reductions **have potential implications on where people live and work** – land-use. Therefore, it is important that such changes are captured and reflected in the forecast of demand, revenue and benefit of HSR.

[18] http://www.dft.gov.uk/pgr/economics/rdg/webia/webmethodology/

What the land-use model produces

The model forecasts the pattern of land-use and economic activity across Great Britain, taking account of the behaviour of households and firms under the given economic and demographic scenarios, which determine the total numbers of households, population and jobs across the modelled area.

How the model works

The land-use model developed for Greengauge 21 is a simplified application of the David Simmonds Consultancy DELTA package, which has been developed by David Simmonds Consultancy and widely used since 1995. The package is focused on the processes of change over time, working as far as reasonably possible in terms of decisions made by and outcomes affecting different categories of "actors" (residents, firms, developers, transport infrastructure and service suppliers) who interact through different markets, namely property, labour, product and transport markets.

There **are three sets of model inputs**, as illustrated in Figure 6.1:

- "top level" economic and demographic scenarios
- "parallel level" transport demand forecasting model
- "bottom level" more detailed policy and planning considerations

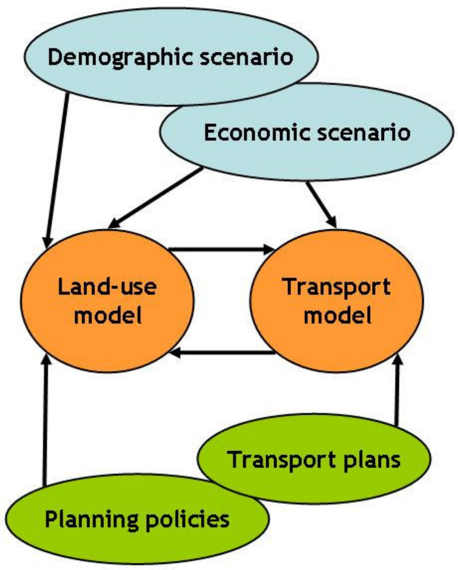


Figure 6.1 Greengauge Land-Use model - scenarios and policy interventions

Given the model seeks to establish the impact on land-use from a transport scheme, the land-use model uses generalised costs of travel from the transport demand forecasting model. This demand forecasting model, as discussed in Section 3, also supplies the land-use model with data on the characteristics of inter-regional passenger travel, as well as on intra-regional travel where there are multiple zones in one region.

In addition to the input from transport demand forecasting model, the land-use model considers changes to the demographic and economic scenarios as a set of "top down" inputs, as well as a set of "bottom up" inputs which captures the effects of more detailed planning considerations.

The model takes account of the changes in terms of:

- household and population
- businesses and the economy
- the development sector.

In terms of household and population, the model takes into account the changes to:

- demographics
- household moves driven by different factors including accessibility and households competing for housing (limited representation compared to full DELTA applications)
- household car ownership choices (exogenous changes based on TEMPRO forecasts)
- individual choices of whether and where to work, again affected by accessibility.

For businesses and the economy the model considers

- choices by consumers (household and business) of where to purchase goods and services (choices affected by transport)
- firms' choices of where to locate, first between the areas modelled and then between zones, with firms competing for commercial floorspace; both levels of choice are affected by different kinds of accessibility
- the demand for labour.

The development sector is treated separately: the model uses exogenous forecasts (estimated from TEMPRO) of the total quantity of development by type and zone.

The key outputs from the land-use model are the changes to:

- number of workers by zone
- number of jobs by zone.

6.3 Quantifying Wider Economic Benefits

The previous section has discussed the land-use model which forecasts the changes to the number of workers and jobs in affected areas. Such forecasts are inputs to the calculation of the seven aspects of WEB. This section discusses what each aspect of WEB measures and how they are estimated.

Increased labour force participation (GP1)

When deciding to go to a certain place for work, people are likely to weigh up their gains, from wages, and their costs, from items such as travel.

Travel takes time. Time is money. Longer commuting times are often perceived as higher costs to go to work. Such higher costs are weighed against the wage level. When it is the end-pay people seek, reductions to travel costs are perceived as increases to wages.

The DfT discussion paper suggests that there is a relationship between the supply of labour and the wage people receive. In general, the higher the wages offered, the more people put themselves forward for employment. **GP1 measures the change in GDP resulting from a change in the number of people working**. This benefit is applicable to the appraisal of HSR as HSR offers a step change to transport provision in the UK, reducing travel times, and therefore time-related costs, between key urban centres.

The following equation has been used to estimate GP1 for HSR:

$$GP1 = -\sum_i \left[\left(\sum_j C_{ij} \times \delta T_{ij} \right) \times \frac{\sum_j GDP_j \times C_{ij}}{\sum_j W_j \times C_{ij}} \right] \times El$$

where

C_{ij}	workers that live in area i and work in area j
δT_{ij}	change in generalised cost of commuting from i to j
GDP_j	GDP per worker entering the labour market in area j
W_j	average gross wage from working in j
El	elasticity of labour supply with respect to returns to work

People working longer (GP2)

The previous section has discussed the "volume" effect of travel time reduction – more people. Intuitively, there may be an "hours" effect in that less time travelling to and from work could lead to some people working longer – more hours. **GP2 is a measure of the GDP change resulting from people working longer.**

The DfT discussion paper suggests that there is little evidence supporting the above intuition – workers are unlikely to work longer. Therefore, in the absence of better evidence, the paper recommends that **GP2 should be assumed to be zero**.

Jobs moving to more productive areas (GP3)

The same job may have different levels of productivity depending on the area. Because transport improvements, such as HSR, have the potential to make some areas become more attractive and accessible to firms and workers, some jobs may be attracted to these areas and thereby increasing their productivity. **GP3 is the change in GDP resulting from the relocation of jobs**.

The following equation has been used to estimate GP3 for HSR:

$$GP3 = \sum_A \Delta E_A \times PI_A \times GDP$$

where

ΔE_A	change in employment in area A
PI_A	index of productivity per worker in area A, where the base is average national productivity per worker
GDP	national average GDP per worker

Agglomeration benefits (WB1, GP4)[19]

Close physical proximity facilitates the sharing of knowledge, greater access to more suppliers and larger labour markets. This means that some firms derive productivity benefits by being located close to other firms. Generally, larger clusters of employment are associated with higher productivities. However, when making its decision on where to locate, a firm would not consider the positive effects its location has on nearby firms – an aspect external to its decision-making. While conventional economic appraisals capture the direct cost savings to each firm, they do not capture this externality. **WB1 captures the effect of increasing employment density leading to increased productivity for existing workers**.

As discussed, proximity to other firms, workers and markets matter. The DfT discussion paper suggests that conventional distance measures, such as kilometre, do not necessarily suffice. Therefore an alternative measure of distance is required, in the form of **weighted generalised cost**. This is calculated as:

$$g_{ij} = \frac{\sum_{p,m}\left(g_{ij}^{p,m} T_{ij}^{p,m}\right)}{T_{ij}}$$

where

g_{ij}	generalised cost of travel from I to j
$T_{ij}^{p,m}$	number of trips from zone *i* to *j* by purpose p and mode m
T_{ij}	number of trips from zone *i* to *j*

Having established the measure of distance via weighted generalised cost, the next step is to establish a measure for proximity to other firms, workers and markets, in the form of **effective density**, calculated as:

$$d_i = \sum_j \left\{ \frac{E_j}{g_{ij}} \right\}$$

[19] It should be noted that the formula provided here for WB1are not exactly the same as those quoted in the DfT discussion paper. However, such formula are tried and tested and offer the same outputs as those in the DfT discussion paper.

where

E_j	number of jobs in zone *j*

The final step is to estimate **WB1**, uplifting GDP of workers through the effect of increased effective density, calculated as:

$$WB1 = \sum_{i,k}\left[\left[\left(\frac{d_i^{\mathrm{A}}}{d_i^{\mathrm{B}_0}}\right)^\wedge e(WB1) - \left(\frac{d_i^{\mathrm{B}}}{d_i^{\mathrm{B}_0}}\right)^\wedge e(WB1)\right] \times h_{i,k} \times E_{i,k}^{\mathrm{A}}\right]$$

where

k	an industry for which agglomeration benefits are being calculated;
d_i^A, d_i^B	employment densities of zone *i* in the alternative situation A and base situation B respectively;
$d_i^{B_0}$	effective density of zone *i* in the base year (2001);
$e(WB1)$	elasticity of productivity with respect to effective density (supplied by DfT);
$h_{i,k}$	GDP per worker in *zone i* and industry *k*; and
$E_{i,k}^A$	is employment (in the alternative [scenario] case)

Increased competition (WB2)

Transport cost is often a barrier to competition, as some firms may not be able to compete in certain geographic markets due to their lack of resources in getting their goods and services to those markets. Therefore, theoretically, it may be possible that a reduction in transport costs, as offered by HSR via time savings, may lead to an increase in competition. Increased competition benefits consumers, because it becomes more likely that any efficiency gains from the firms are passed to the consumers via price reductions – a dimension along which firms compete. Therefore, **WB2 measures the benefits from the market operating closer to perfect competition.**

However, the DfT discussion paper suggests that the evidence for transport making a difference to the level of competition is limited, and therefore WB2 benefits are not normally expected. Following this recommendation, we have **assumed WB2 to be zero**.

Imperfect competition (WB3)

In a perfectly competitive market, when a firm's cost is reduced, such as from lower transport costs, its efficiency is improved. This means it will reduce its price and out-sell all its competitors. However, our economy does not operate under such perfect competition, and firms do not necessarily have to pass on the lower costs to consumers as lower prices – there is a degree of market capture. **WB3 measures the**

value of efficiency benefits to firms from reduced transport costs, where these benefits are not passed on to consumers due to a lack of competition.

The DfT discussion paper recommends that **WB3 is measured as 10% of business time savings** and reliability gains. HSR will generate considerable time savings, plus some reliability benefits for business users.

Exchequer consequences of increased GDP (WB4)

People's decisions on joining the labour force (GP1), moving to more productive jobs (GP3) and working longer (GP2), are based on incomes after tax. If improved commuting generally gives people access to higher paid jobs, this would be recognised in appraisal by commuters' willingness to pay for time savings. However, as the benefits to the workers are based on post-tax income, there is an additional impact that is not captured by the individuals' willingness to pay: the extra tax revenues that accrue to the exchequer from that choice.

More people working (GP1), more people in more productive jobs (GP3) and more people working longer (GP2) means more revenue to the Exchequer. **WB4 estimates the effects of increased GDP to the Exchequer via increased tax revenues.**

The DfT discussion paper **recommends WB4 to be estimated as 40% of GP1 plus 30% of GP2 and GP3**. The 40% for GP1 relates to tax on average income effects[20], operating surplus and reductions in benefit claims, reflecting income tax, national insurance contribution and corporation tax. The 30% for GP2 and GP3 correspond to increased taxation from marginal income effects[21] and well as increased operating surplus.

[20] Average income effects: more people working, paying the average tax.

[21] Marginal income effects: existing workers being more productive and paying a marginal tax.

7 Framework Outputs

7.1 Introduction

To allow evaluation of the impacts of the high speed rail proposals the assessment framework has be designed to include a range of outputs which would be of value for this. The outputs are split into two broad categories:

- metrics and outputs to assist evaluation of the individual corridor and network scenarios; and
- outputs to allow comparison of the different corridor and network scenarios.

This section describes the types of outputs that will be produced. Most of these will be driven by the Business Case Model, which incorporates the results from each of the other framework components.

7.2 Individual Scenario Metrics

For each corridor/network option the following outputs will be produced:

- Service Summary
- Appraisal Summary Table
- Economic Impact
- Regional Wider Economic Impact
- Revenue on HSR and change in classic rail revenue
- HSR Capital Costs
- HSR Operating Costs
- Demand/load factor map
- Impact on domestic aviation routes
- Impact on GB car kms
- Value of capacity released
- Carbon impact
- Summary sheet

Service Summary

Within the outputs tables summarising the key service indicators and infrastructure requirements will be produced for each scenario. Examples of table are shown in Table 7.1 and 7.2 respectively. These will also act as key inputs for the other models.

Table 7.1 Example Service Level Summary

Origin	Destination	Classic journey time	Freq. (tph)	HSR journey time	Freq (tph)
London	Birmingham				
London	Manchester				
London	Leeds				
London	Glasgow				
Birmingham	Manchester				
Birmingham	Heathrow				
Manchester	Leeds				
Manchester	Glasgow				

Table 7.2 Example Infrastructure Provision Summary

Route Section	Destination	Length (km)	Max kph	Construction Start Date	Assumed Opening Date
London	Birmingham				
Birmingham	Manchester				
Manchester	Leeds				

Appraisal Summary Table

The Appraisal Summary Table (AST) displays the degree to which the fiver Central Government objectives for transport (environment, safety, economy, accessibility and integration) would be achieved. It is from the AST that a judgement should be made about the overall value for money of the option or options in achieving the Government's objectives.

An example AST is shown below in Table 7.3.

Table 7.3 Example Appraisal Summary Table

Objective	Sub-Objective	Qualitative	Quantitative
Environment	Noise	Score	PVB £m
	Local Air Quality	Score	PVB £m
	Greenhouse Gases	Score	PVB £m
	Landscape	Score	route length
	Townscape	Score	urban route length
	Heritage	Score	number of heritage sites in vicinity
	Biodiversity	Score	number of biodiversity sites in vicinity
	Water Environment	Score	length of line crossing flood plain
	Physical Fitness	Score	Score
	Journey Ambience	Score	Score
Safety	Accidents	Score	PVB £m
	Safety	Score	Score
Economy	Cost Benefit Analysis		BCR NPV £m
	Reliability	Score	% track segregated
	Wider Economic Impacts		PVB £m
Accessibility	Option Values	Score	Score
	Severance	Score	Score
	Access to Transport System	Score	Score
Integration	Transport Interchange	Score	Score
	Land-use Policy	Score	Score
	Other Government Policies	Score	Score

Economic Impact

For each scenario a table will be produced that outlines the economic impact in the form of a cost benefit analysis. The cost benefit analysis is broken down into three components of economic benefit; revenue, user benefits and non-user benefits (including wider economic benefit), whilst costs are broken down into capital costs, HSR operating costs and impact on classic operating costs. Finally, the table reports two economic indicators that can be used to compare different options; Benefit Cost Ratio (BCR) and Net Present Value (NPV). Figure 7.1 shows an example Economic Impact table.

Figure 7.1 Example Economic Impact

Corridor Number - London Birmingham Manchester	
Benefits	
Benefits - Revenue	NPV (£m) 2002
HSR Revenue	£
Classic Revenue	£
Net rail revenue	**£**
Benefits - Users	
Journey Time	£
Accidents	£
Crowding Benefits	£
Total User Benefits	**£**
Benefits - Non-users	
Decongestion Benefit	£
Greenhouse gases	£
Journey Time	£
Other benefits from reduced car kilometres	£
Value of freed capacity	£
Total Non-user benefits	**£**
Present Value Benefits	**£**
Costs	
Capital	£
HSR Operating	£
Classic Operating	£
Present Value Costs	£
Economic Indicators	
NPV	0
BCR	0:0
Wider Economic Benefits	£0.00
Economic Indicators	
NPV (with Wider Economic Benefits)	0
BCR (with Wider Economic Benefits	0:0

Wider Economic Benefits

The wider economic benefit will be summarised by Government Office Region and benefit type:

- agglomeration benefit
- more productive jobs
- increased participation
- imperfect competition
- exchequer consequences

Figure 7.2 gives an example graph showing the wider economic benefits.

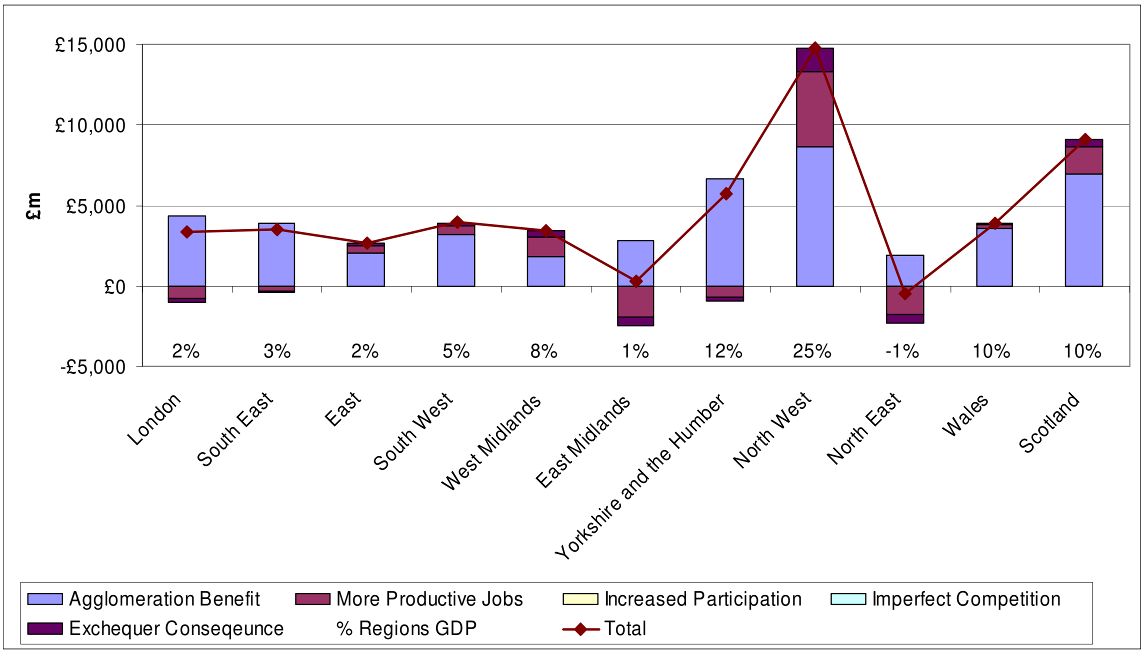


Figure 7.2 Regional Wider Economic Impact

Revenue/Demand

For each scenario and route option a summary table of trips, purpose, passenger kilometres and revenue will be produced for each model year. An example is shown in Table 7.4.

Table 7.4 Demand Forecast Summary

	2025	2040	2055
Passenger Trips (000s)	98.2	125.6	150.6
% business	50%	51%	55%
% leisure	50%	49%	45%
% from classic rail	83%	78%	71%
% from air	3%	4%	5%
% from car	8%	10%	14%
% generated	6%	8%	10%
Passenger-km (millions)	22.5	31.9	40.1
Passenger revenue HSR (£m)	894	1,236	1,405
Change in Classic revenue (£m)	-100	-120	-150

Demand and load factor will also be shown using maps of the route. Figure 7.3 provides an example for a theoretical scenario. The width of the line represents number of trips and colour the loading factor.

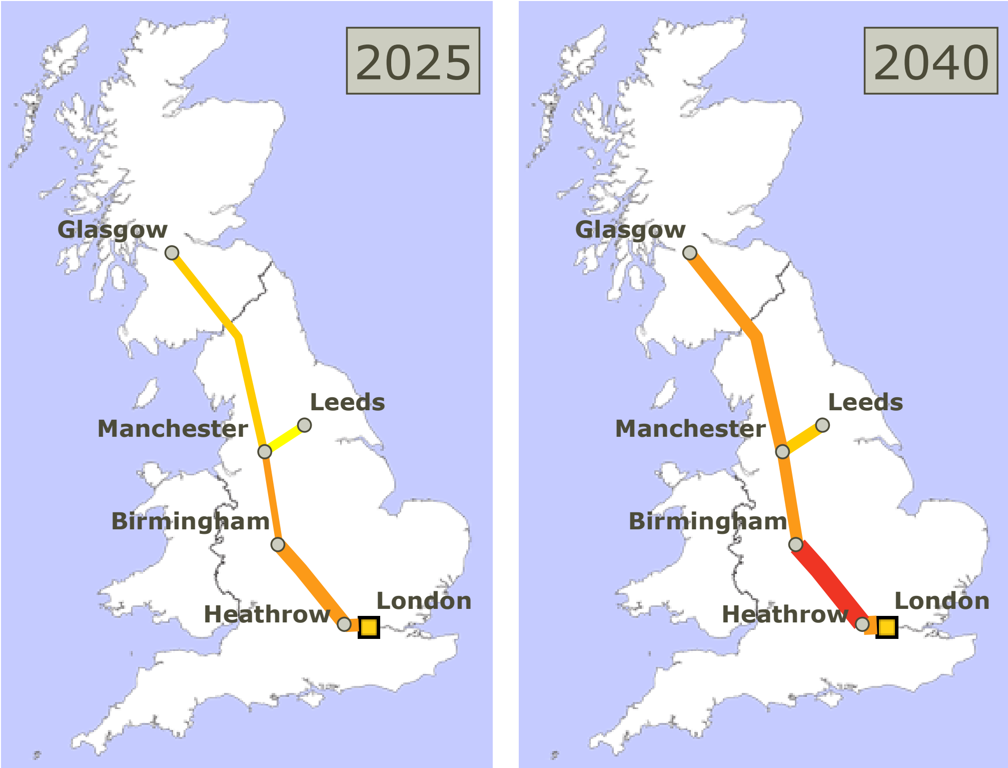


Figure 7.3 Scenario demand (line thickness) and loading factor (line colour)

Graphs will be produced which show HSR demand and changes in demand on other modes over time by city pair. Figure 7.4 provides and example.

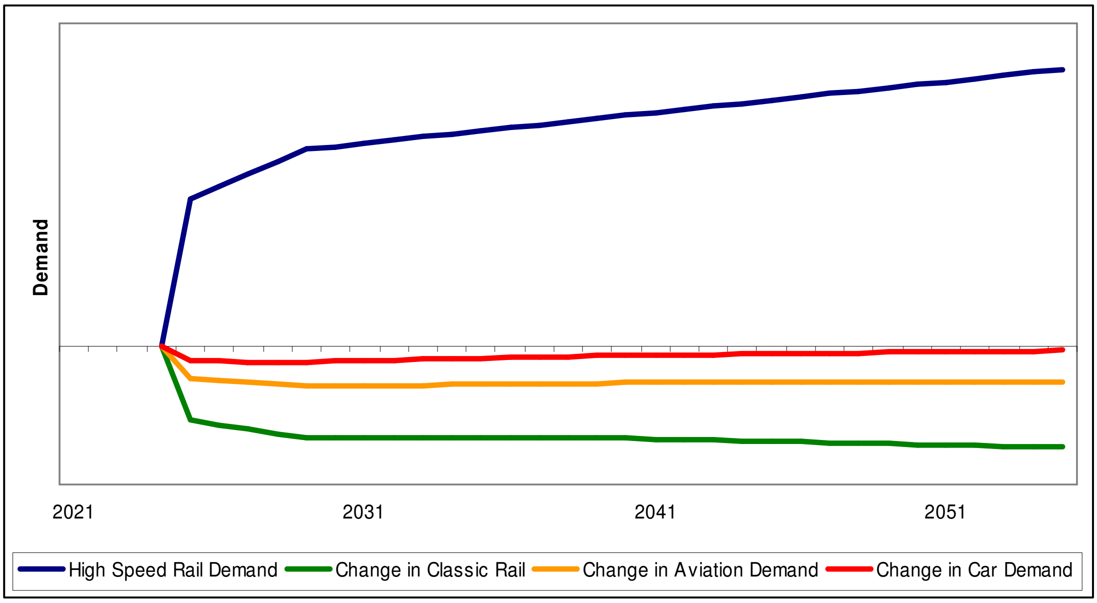


Figure 7.4 HSR demand and changes in other mode demand for London - Leeds

Specific attention will be paid to the impact on aviation demand which will gives details of the following:

- number of passengers abstracted from air
- number of reduced flights

In addition key air markets will be examined, an example Table 7.5 is shown below.

Table 7.5 Selected demand on key air markets

	2008	2025			2040		
	Base	**Reference**	**Scenario**	**% change**	**Reference**	**Scenario**	**% change**
London - Glasgow	7,700	12,000	11,000		15,000	12,000	
London - Manchester	2,500	3,000	1,500		3,500	1,800	

The final demand output will be the impact on total GB car kilometres. A comparison between reference and scenario will be made for each model year in a simply way as Table 7.5 shows.

Capacity Released

The key outputs of the capacity released assessment are shown in Table 7.6. The key outputs are:

- number of InterCity paths removed by broad route area
- total value of additional Intercity path
- number of additional local commuter services by key commuter destination
- total value of additional commuter services
- number of additional freight paths by route area
- lorry kilometres removed

Table 7.6 Capacity Released

	Number	2025 £m	2040 £m	2055 £m	Total £m
Intercity paths removed					
London - Rugby	xx	£	£	£	£
Birmingham - Manchester	xx	£	£	£	£
Total Value on Intercity		Total £	Total £	Total £	Total £
Additional Local Commuter services					
London	xx	£	£	£	£
Birmingham	xx	£	£	£	£
Manchester	xx	£	£	£	£
Total Value on Commuter Services		Total £	Total £	Total £	Total £
Additional Freight Paths					
West Coast Mainline	xx	£	£	£	£
East Coast Mainline	xx	£	£	£	£
Number of Lorry Kilometres removed		Total km	Total km	Total km	Total km
Total Value of additional freight paths		Total £	Total £	Total £	Total £
Value Capacity Released		£	£	£	£

Impact on Greenhouse Gases

The key output will be the net impact on carbon tonnes produced by the transport system within our model. This, together with carbon production by mode will be shown on a time series.

Summary

For each corridor a one page summary will be provided which will incorporate:

- key service and infrastructure characteristics including journey time improvements
- map of route including demand and load factors
- summary of economic impact including NPV and BCR
- graph showing demand (classic and aviation) and HSR revenue over time
- summary of key wider economic benefits
- net impact on carbon tonnes
- reduction in aviation demand
- summary of freed network capacity

An example is provided on the next page.

7.3 Comparison

In addition there will be outputs which will compare the different scenarios and route options. This will have route options across the top of the table and key indicators vertically. The key indicators are likely to be:

- Net Present Value
- Benefit Cost Ratio
- Total capital construction cost
- Total HSR demand
- Total HSR revenue
- Change in classic revenue
- Maximum load factor
- Total wider economic benefit
- Reduction in air flights
- Net impact on carbon tonnes

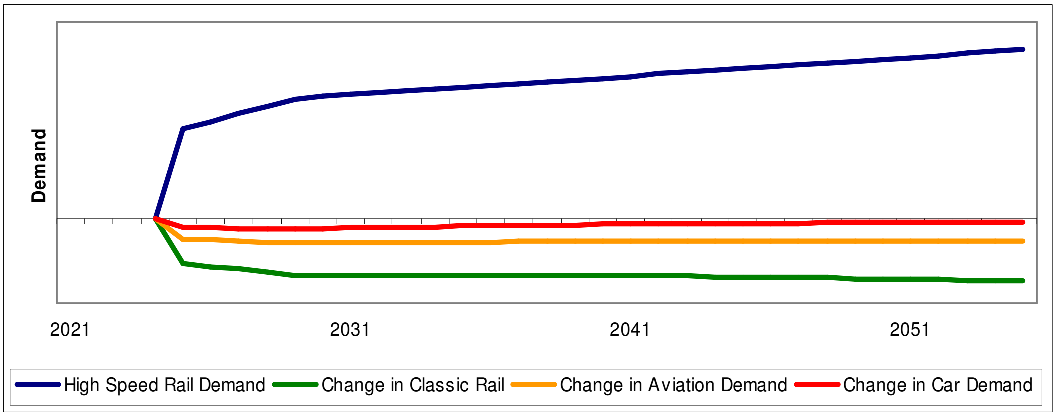
Option xx – London – Glasgow Opening Date: 2025

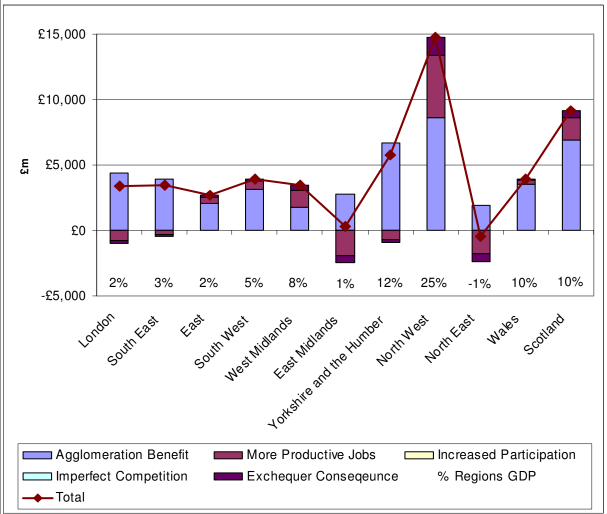
Stations Served: list stations served and key services
HS Infrastructure: describe HS infrastructure including track and new stations

	HS Journey Time	TPH
London – Birmingham	xx mins	x
London – Manchester	xx mins	x
London – Glasgow	xx mins	x

Total Capital Cost:	£xx bn
Annual Operating Cost	£xx bn
Total User Benefits:	£xx bn
Total Non User Benefits:	£xx bn
Wider Economic Benefits:	£xx bn
NPV: £xx bn	BCR: ratio

	2025	2040	2050
HSR Demand	xxm	xxm	xxm
HSR Revenue	£x.x bn	£x.x bn	£x.x bn





Net Carbon Impact	xx billion tonne
Reduction in domestic flights	xx per year
Removed car kilometres	xx million km
Reduction in AEFs	xx
Additional seats (2026)	xx

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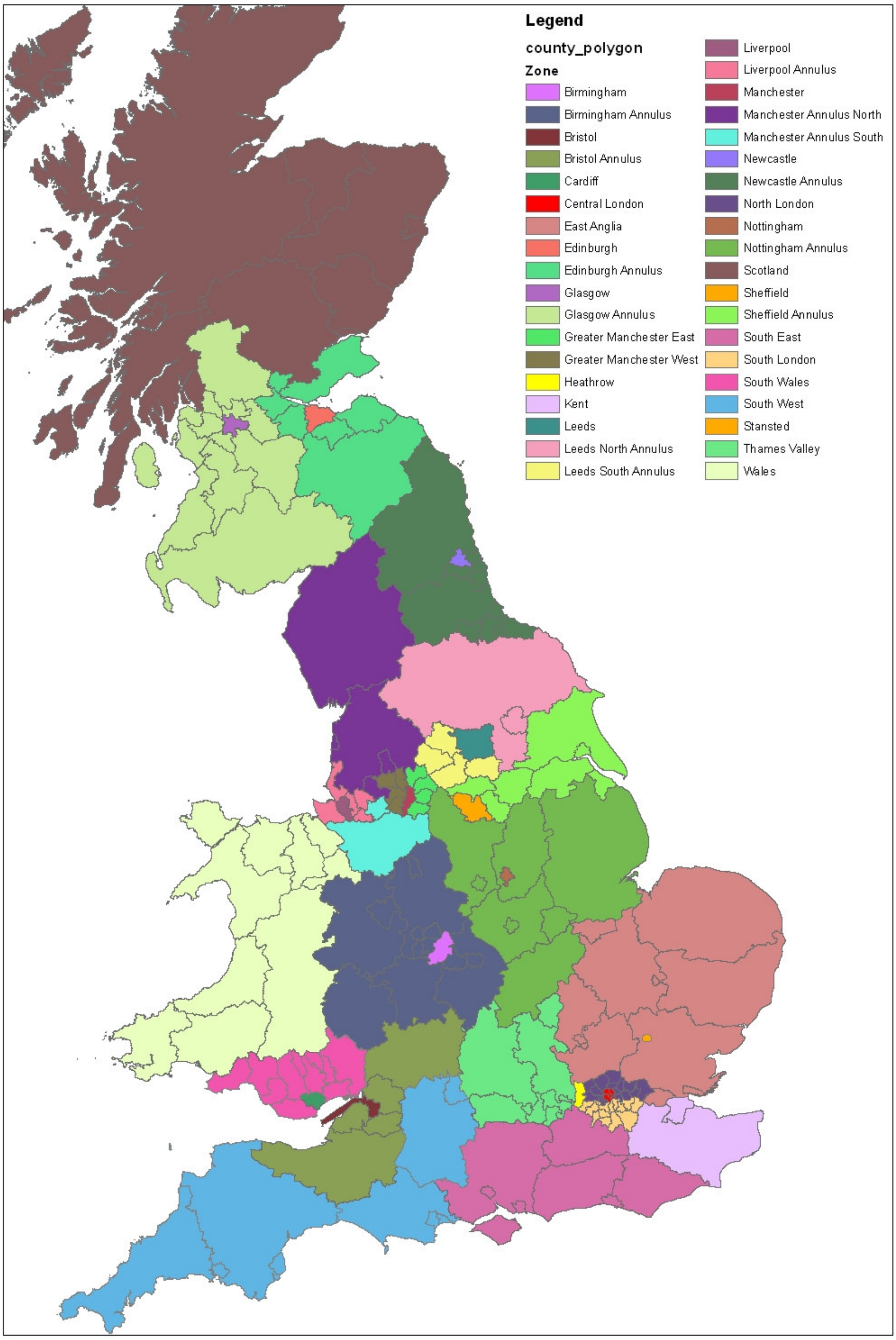
APPENDIX A : Zoning system for demand forecasting model



High-Speed Rail Development Programme 2008/9

Principal Consultant

Workstream 3 Report:
Appendix B:
Technical note on cost of four-track HSL

12 May 2009

Version 3.1

SYSTRA

mvaconsultancy

Cost of a Four-Track HSL

1 Assessment of the Costs Generated by a Four-Track Line

In the Y-shaped network scenario studied in Fast Track, a common trunk leads from London and Birmingham and splits at Birmingham International Airport (BIA) to go Manchester / Liverpool on one hand and to Sheffield / Leeds on the other. In order to handle the large amount of demand predicted between London and the two branches, it will be necessary to run over 15 HSR trains per hour and per direction on the stretch of line between London and Birmingham. As a two-track high-speed line (HSL) cannot handle more than 15 trains per direction and per hour, the line must be built using four tracks from London to Birmingham.

Though no four-track HSL has been built to date, it is probable that such an endeavour would cost less than building two completely independent double-track high-speed lines.

This section describes the approach used to estimate the cost of building a 4-track HSL, based on experience related to the construction of double-track high-speed lines.

2 Grade Alignment

Figure B below depicts the configuration based on average values of (a) two double-track lines and (b) one four-track line.

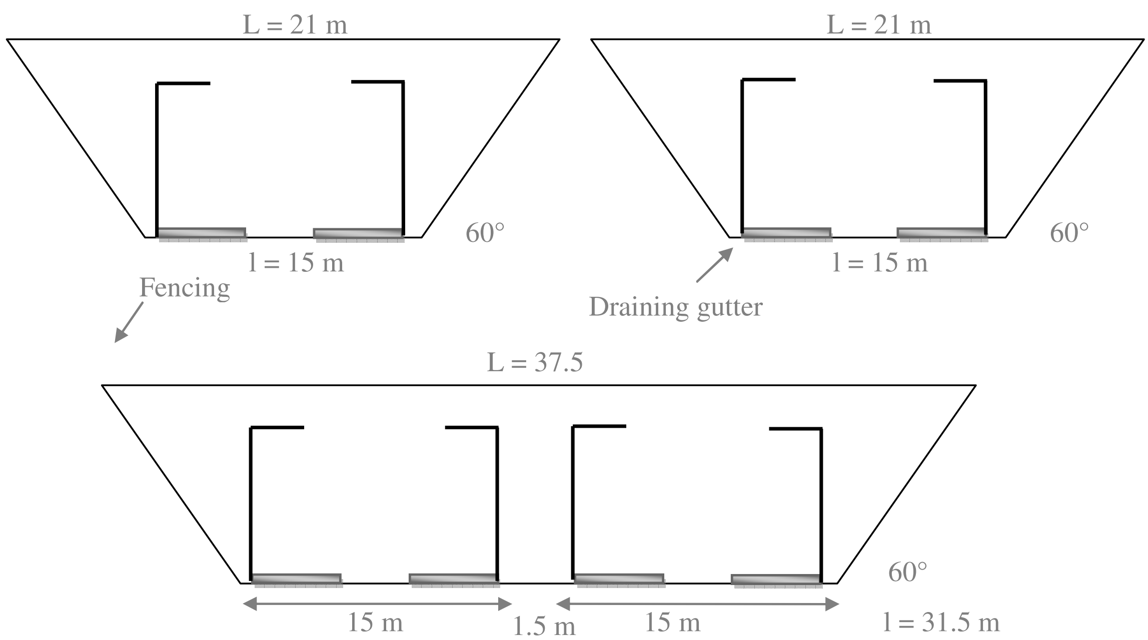


Figure B1 Configurations of (a) 2 double-track lines and (b) one 4-track line

For maintenance purposes, a minimum space of 1.5 m between catenary pylons combined with fencing is needed in order to secure people during maintenance slots (and therefore avoid stopping the traffic).

The characteristics of these two configurations are listed in B1

Table B1 Characteristics of the infrastructure configurations

	Two separate double-track lines	One four-track line
Width of the right of way	15 m * 2 = 30 m	30 m + 1.5 m = 31.5 m
Average height of cuttings	5 m	5 m
Opening	21 m * 2 = 42 m	37.5 m
Draining gutters	2 units * 2 = 4 units	3 units

Savings can be had when building one four-track line instead of two separate double-track lines. These savings are the result of the following:

- Opening reduction: for earthworks, land acquisition, road-bridges.
- Reduction of length of: draining gutters, anti-noise barriers, fencing.
- Reduction of the number of working sites (that will nevertheless be bigger). This will not be taken into account here since working sites are assessed through a percentage of capital costs.
- Equipment that is not directly linked to the length of the infrastructure: electrical substations, telecommunication installations, maintenance equipment. In this field, savings could only come from civil engineering.

After calculation, the possible savings that will be taken into account when comparing scenarios are presented in Table B2.

Table B2 Possible savings of a four-track line as opposed to two separate double-track lines

	Possible savings compared to two double-track lines
Earthworks, land acquisition, road-bridges	11 %
Draining	25 %
Anti-noise barriers and fencing	50 %
Equipment	5 %

These assumptions lead to **a cost per km of a four-track line (on easy terrain) of £18.4 million**, to be compared to a cost of 2 x £10.1 million per km for two segregated lines (9% overall savings).

It must be underlined that the obligation of building a track suitable for motor vehicles can also exist (as it is the case for double-track lines in Italy, to facilitate rescue services in case of accident) but this extreme case has not been considered here.

Following the approach described in the WS3 report, cost on **difficult terrain would be £25.6 million/km.**

In urban areas the cost per km of high-speed line is greater due to higher land acquisition costs that are taken into account later in the cost modelling process. Provisions must also be made for anti-noise barriers and special mitigation measures (our in-house database suggests to take twice the cost on easy terrain): at grade alignment in these areas could reach **£19.6 million/km for a 4-track line**.

If the curve radii allow it, the 4-track infrastructure (as well as 2-track infrastructure) may also be twinned with another infrastructure (such as a motorway or existing major railway line). Our in-house database suggests that it could lead to an increase of 15% of the costs of civil engineering, due to the geometrical constraints and the difficult restorations of crossings. One km of a twinned 4-track line would cost **£19.7 million on easy terrain.**

3 Major structures

- Viaducts and tunnels

The estimated cost of a viaduct (and rail bridges) with four tracks will be considered equal to twice the cost of a double-track viaduct as the solution will likely be to build two parallel viaducts. The same approach is used for tunnels.[22]

- Grade-separated junctions

Grade-separated junctions with a four-track line may be very complex to implement and will mostly depend on the orientations of the tracks. A first approach will be to consider that each junction involving the four-track line will cost three times as much as a "basic" grade separated junction[23]. A more precise estimation can be made in a more in-depth study.

- Stations

Major issues will be encountered if all four tracks reach the same railway station inside London as there is currently no room to build the necessary twenty 400-metre platform tracks in a single station.

The unit costs of major structures for a four-track high-speed line are presented in Table B3.

[22] The tunnels will need to be built far enough apart so that they do not cave in.

[23] The Y-shape grade-separated junction presented in WS3 report is considered as a "basic" one

Table B3 Proposed costs of major structures for a four-track high-speed line

in millions of GBP	**Proposed costs of major structures (4-track line)**	*Costs considered for a 2-track line*
Viaducts	71.3 /km	*35.6 /km*
Rail bridges	2.4 /km	*1.2 /km*
Tunnels	80.0 /km	*40.0 /km*
"Simple" grade separated junction	32.1	*10.7*