Appendix B – Technical Constraints

Contents

Introduction

The best way to ensure the safety of a major rail project is to put in place reliable and proven concepts and criteria for the fixed installations, rolling stock, risk and hazard detection devices and rules for monitoring, maintenance and operations. This appendix provides an overview of legal and technical constraints that must be taken into consideration when designing a new high speed line. Each point must be studied in more detail at a more advanced stage of study.

1 Regulation and legislation on high speed components

The main principles for designing, building and operating a High Speed Line are derived from directives coming from the UIC and from the European Union.

1.1 UIC standards

Directives are taken from the International Union of Railways (2001 report for the "state of the art"), and from reports by the International Working Group linked to the High Speed Department of the UIC, including representatives of DB AG, GIF, FS, RENFE, SNCB and SNCF.

1.2 Interoperability European Directive

A new Interoperability Directive, 2008/57/EC, was published in the Official Journal of the European Union on 18 July 2008. It set out a number of essential requirements to be met for interoperability, which include safety, reliability and availability, health, environmental protection and technical compatibility along with other requirements specific to certain sub-systems. The new Interoperability Directive replaces both of the existing Interoperability Directives; High Speed (96/48/EC) and Conventional (2001/16/EC) as well as the two amendments (2004/50/EC and 2007/32/EC).

The European Railway Agency (ERA) has developed Technical Specifications for Interoperability (TSI) for the following sub-systems:

- Infrastructure subsystem – TSI 2002/732 & 2008/217 (track points, engineering structures, station infrastructure, protective equipment, etc.)
- Energy subsystem – TSI 2002/733 & 2008/234 (OHLE and on board parts)
- Control command and signalling sub-system to ensure safety – TSI 2006/860 – altered 2007/153 & 2008/386
- Rolling stock subsystem – TSI 2002/735 & 2008/232
- Maintenance subsystem – TSI 2002/730
- Traffic operation and management subsystem – TSI 2002/734 & 2008/231 (procedures and related equipment to enable a coherent operation)
- Telematics applications for passenger and freight services (PIS, PA, booking systems, luggage management, etc., for passengers and real time monitoring of trains and wagons for freight) – TSI 2006/62
- Tunnel – TSI 2008/163
- Persons with reduced mobility – TSI 2008/164

Each TSI defines the technical standards required to satisfy those essential requirements.

In each case, the UK has two years from the above date to transpose the requirements into domestic legislation. This will be done by a revision of the Railways (Interoperability) Regulations, which will establish how these changes are to be applied in the UK.

1.3 Particular features on the British network

The physical dimensions of a railway vehicle and its load are governed by gauge capabilities (height and width profiles) and ensure the vehicle will not come into contact with a line side or overline structure. UIC (Union internationale des chemins de fer) defined four main international types of gauge that were adopted by most of European countries, but UK kept its reduced gauge on existing lines. As a consequence, the "Official Journal of the European Communities" referenced L 245/196 EN and issued on 12 September 2002 allows the following particular features on the existing lines of the British network:

Platform height

Platforms used on upgraded lines in Great Britain have a standard height of 915 mm with a tolerance of +0/-50 mm. The platform horizontal distance (L) shall be chosen so as to make optimal use of the step positions on trains built to the UK1 loading gauge.

Minimum platform length

The minimum platform length is reduced to 300 m on the upgraded lines of the British network, so as to cope for the limitation of trains' length to 320 m on the upgraded lines of the network.

Stabling tracks: minimum length

On the upgraded lines of the British network, the length of stabling tracks may be limited so as to accommodate for a maximum train length of 320 m.

Structure gauge

The minimum structure gauge on upgraded lines in Great Britain shall allow passage of trains to the UK1 loading gauge.

Pantograph gauge

On existing lines upgraded for high speed and their connecting lines, the normal height of the contact wire is 4,720 mm (minimum 4,170 mm, maximum 5,940 mm).

Distance between track centres

The minimum nominal distance between track centres on upgraded lines in Great Britain shall be 3,165 mm.

2 Operations and constraints

2.1 Dedicated passenger high speed traffic

Building railway lines that are able to operate both passenger high speed trains and slow freight trains may appear to be a valuable option as it gives two sources of revenue and it was also the original intention for HS1.

Allowing for mixed passenger-freight traffic on a high speed line, however, poses problems including additional safety constraints, operating challenges of timetabling, extra cost of cab-based signalling systems for freight trains, reduced allowances on cants and gradients, larger curve radii, etc. Therefore, the conclusion was drawn in Workstream 2 that if operating high speed passenger trains is the main target; freight access to high-speed infrastructure needs to be carefully managed so that it does not disproportionately reduce the capacity, increase the cost, or the value of the HSR infrastructure.

2.2 Integrated or segregated network

When compared with operating mixed traffic with mixed speeds, segregating high speed trains on a dedicated network increases operating capacity and leads to dramatic increases in punctuality of trains and reliability of the timetabled services. The all-new infrastructure can be built to the UIC C gauge, thus allowing higher capacity trains to be operated, and train delays are not spread from the classic network to the new network.

Nevertheless, the following main advantages of designing for operation of high speed services on conventional as well as high speed lines can be highlighted:

- ability to use historical stations located close to city centres with connections to urban transport systems,
- ability to extend high speed services to beyond the high speed rail lines,
- ability to improve other services by partial use of the high speed network.

Both options have been studied and the preferred option is to provide integration between these two modes and facilitate connections between high speed trains (HST) and local/regional trains. This could allow HST to serve the city centres of the biggest towns. It shall be noted that this adds a constraint as the British reduced aerial gauge (W6a) will need to be integrated in the design of the future rolling stock, and future operators will have to choose either a single (UK gauged fleet or two sub-fleets; one UK gauged (ORR - Railway Standards publication and Guidance) and the other one UIC C gauged providing more seats per unit.

2.3 Double track or single track

Today, high speed networks are almost always double track. Nevertheless some short sections of single tracks exist, especially on connecting line sections. Recent studies carried out by Systra at a pre-feasibility stage have designed sections of single track high speed lines in Argentina (Buenos-Aires –Rosario-Cordoba, Buenos-Aires-Mar del Plata) and in France (Poitiers-Limoges). The main concern with this option remains the frequency and capacity constraints related to train crossings. (A minimum 60 km double track section is needed for two 300 km/h HS trains to cross with the assurance that the track preceding them will be unoccupied).

According to the expected level of traffic in Britain, double tracks are required on the whole HS network. Most of the junctions between HSL and classic lines are also expected to be double track and flyovers are recommended. Another advantage of double track is the ability to draw independent timetables for the two directions.

2.4 Links between speed, signalling and headway

2.4.1 Speed and signalling

Since high speed trains are expected to run at more than 250 km/h, the drivers cannot possibly see a sign on the side of the tracks. Thus a computerized cab-signalling system such as ERTMS – level 2 - is needed on tracks and in train cabs.

Signal information travels through the tracks and the information is centralized in a RBC (Radio Block Centre) which supervises a part of the line and supplies track allocations to the trains. A permanent communication train-ground is realized by GSM-Radio and the track allocations are transmitted to the train by radio from the RBC.

2.4.2 Speed and headways

Maximum commercial speed and braking sequences will define the minimum headway distance and time between two trains. Figure 1 shows the 7 block sections that are required to meet the braking sequence and consequently to follow the previous train.

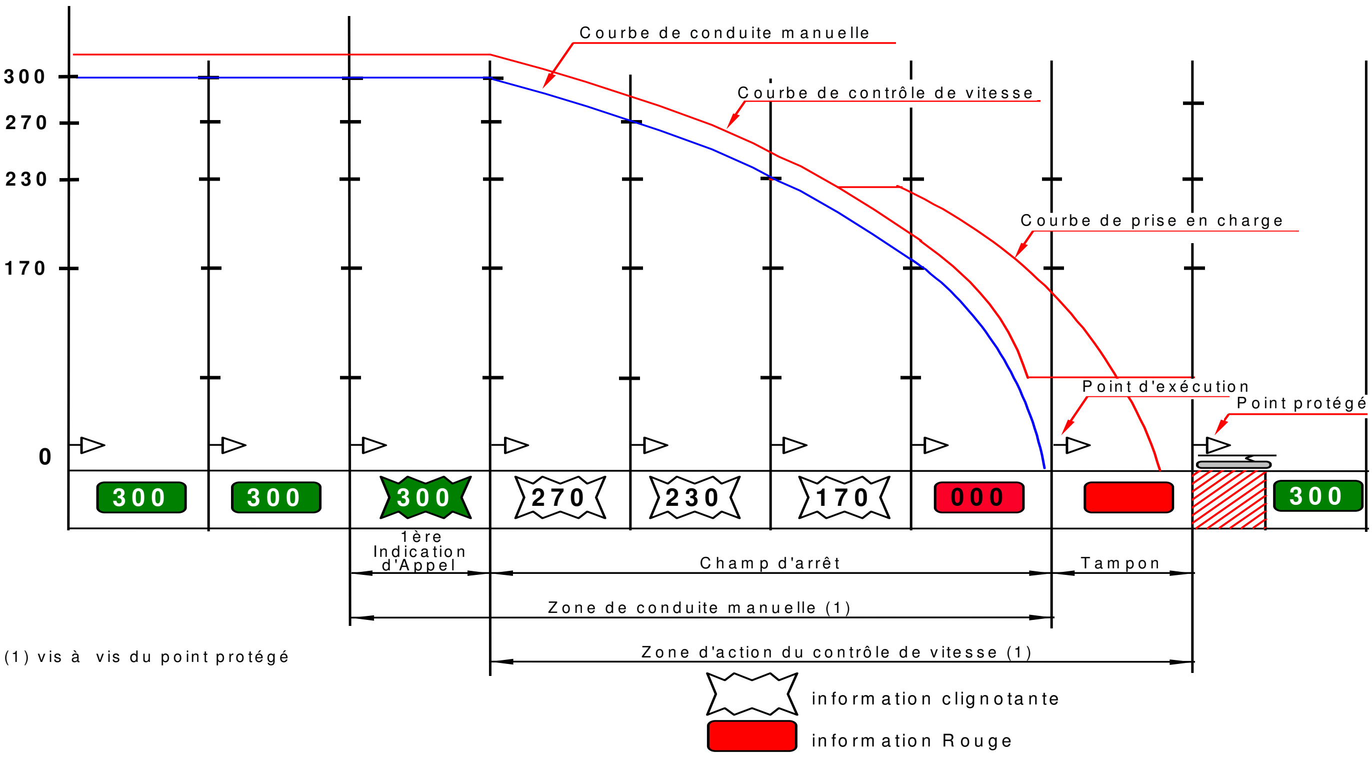

Figure 1 : Headway between two 300 km/h trains

A major threshold shall be considered as seven blocks are needed when running at 300 km/h (sequence is 300, (300), (270), (230), (170), (000), 000) including the buffer block) but eight blocks are required when running at 320 km/h.

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Depending on the expected traffic, 320 km/h block length can vary from 1500 up to 2000 fictional metres as the gradient information is averaged over the length of the block for the computing system to account for in its calculation.

The UIC recommends using no more than 75% of design capacity during peak hours and 60% over an entire day.

Figure 2 provides capacity figures (trains per hour at 75% of design capacity) based on 1600 and 2000 fictional metre blocks with different operating speed.

Maximum speed limit (km/h)	Speed with 5% punctuality margin (km/h)	Number of blocks	Block lengths (m)	Headway (m)	Speed (m/minute)	Technical headway (min)	Trains/hr, design capacity	Trains/hr 75% of design capacity
300	285	7	1600	11600	4750	2.78	21.6	16.2
300	285	7	2000	14400	4750	3.36	17.8	13.4
320	304	8	1600	13200	5067	2.94	20.4	15.3
320	304	8	2000	16400	5067	3.57	16.8	12.6
350	332.5	8	1600	13200	5542	2.72	22.1	16.6
350	332.5	8	2000	16400	5542	3.29	18.2	13.7

Figure 2 : Speed limit and capacity. A 20 second driving margin is added to headway.

2.5 Bi-directional signalling and consequent equipment

All high speed lines (HSL) are double track with the ability to run in both directions, allowing trains to operate at full speed, in either direction, on either track. It is mandatory to be able to operate high speed services even during a blockade on one track and to quickly recover service patterns after incidents. This arrangement also facilitates possessions and works on tracks.

Crossovers between the Down and Up tracks shall be designed to provide the ability to divert trains from one track to another at reduced speed (170 km/h on the pointwork). These crossovers shall be spaced about 25 km apart (standard interval of 4 minutes between two trains running at 320 km/h means 22 kilometres). Two types of “change of track” areas are planned with alternate one providing only the ability for trains to divert from one main track to another and the next one providing the same plus the ability to park a train on a dedicated track. So these areas will provide means of coping with any possible traffic incidents and rolling stock failures.

The locations of the crossover shall take into consideration the planned stations and junctions in order to integrate the ability to exit or to enter the HSL from/to the wrong side.

2.6 Journey times and capacity of a high speed line

2.6.1 Journey times

Journey times on HSL are based on the minimum journey time linking two points and including acceleration and deceleration plus a 5% to 7% recovery time for punctuality (recommended practice, depending on an exclusively HS path or on a path running on both HS and classic lines).

Acceleration and deceleration have been based on 320 km/h TGV-R rolling stock. Dwell times are then added.

2.6.2 Capacity

The line capacity is closely linked with both running times, headways and stopping patterns. The most critical point is the difference between running times of different stopping patterns. Globally the highest possible capacity would be attained with only one stopping pattern per service and evenly distributed departures.

Existing headway times and ERTMS

High speed lines are divided into fixed block sections about 1500-2000 metres long and, as shown in section 2.4.2, several blocks are needed to brake a high speed train. Headway times are calculated on the longest headway block (gradient information is integrated over the length of the block to give a fictional distance) and on a stopping sequence depending on the maximum speed limit. The existing stopping sequence between two trains provides the following aspects: 320, (320W), (300W), (270W), (230W), (170W), (000W), 000. The following schemes in France have been set:

- 3min45 technical headway on the South East LGV (*ligne à grande vitesse,* High Speed Line) – TVM 300 – 75% of design capacity = 12 paths per hour – interval between 4 and 6' when leaving Paris (to cope with 3' headway needed on classic lines where classic trains run up to the triangle de Pompadour)

- 3min45 technical headway on the Atlantic LGV – TVM 300 – 75% of design capacity = 12 paths per hour – regular interval of 5'

- 2min45 technical headway on the Northern LGV – TVM 430 – 75% of design capacity = 16 paths per hour – regular interval of 3' when leaving

- 2min20 technical headway on HS-CT

- 3min20 headway on the Eastern TGV due to a higher speed of 320 km/h, resulting in the addition of a supplementary headway block and to longer headway blocks (up to 2500m)

Limited speed at junctions and impact on capacity

Reducing the speed at junction and stations has a direct impact on the line capacity. The impact is dependent on the maximum speed allowed (80, 170 or 230 km/h) at the respective junctions or station with lower speeds resulting in a greater impact on capacity. Distances to reduce the speed of trains from 230 to 160 km/h (allowing access to the classic network) needed to be sufficient so as not to reduce capacity on the HSL.

Intermediate stops at stations and impact on capacity

Single stop at station

Providing stops on a HSL leads to reduce capacity as shown in the figures below. The braking sequence is provided in Figure 3 with two kinds of signal aspect at a station: the first one with a "proceed" departing signal and the second one with a "at danger" departing signal.

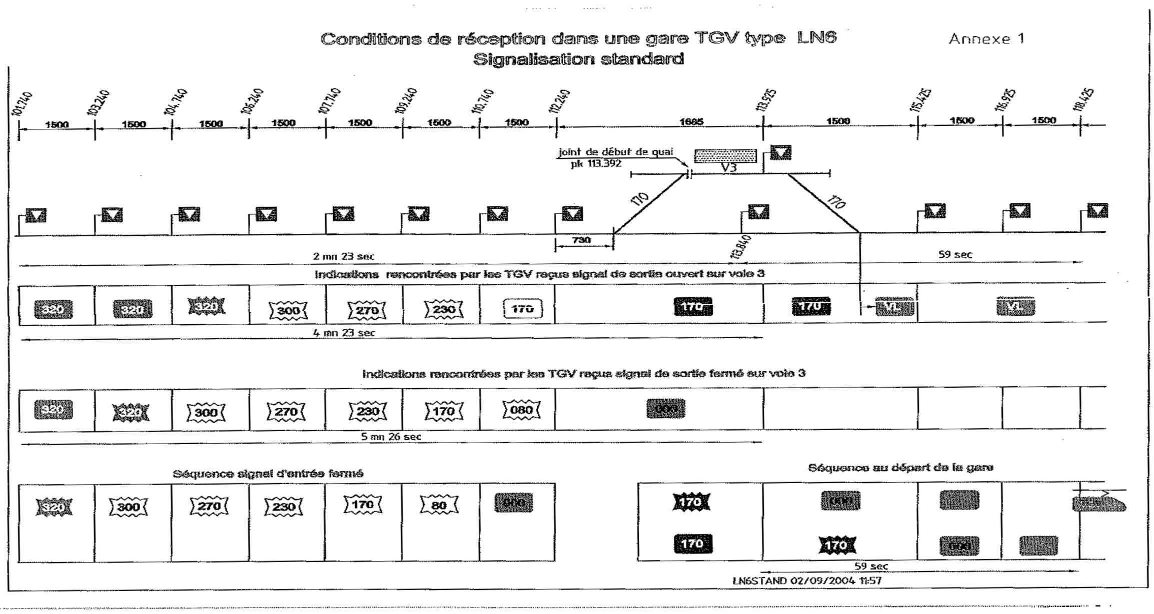

Figure 3 : Stopping sequence at station (loop)

Based on a standard sequence with outer signal giving a proceed indication, a space-time graph example is provided for a 3 minute call at a through station. The following sequence has been set 320, (320W), (270W), (230W), (170W), (170E), 000 and leads to a loss of 9 min when compared to a non stopping train. The case of a train at 300 km/h is shown in the space-time graph below.

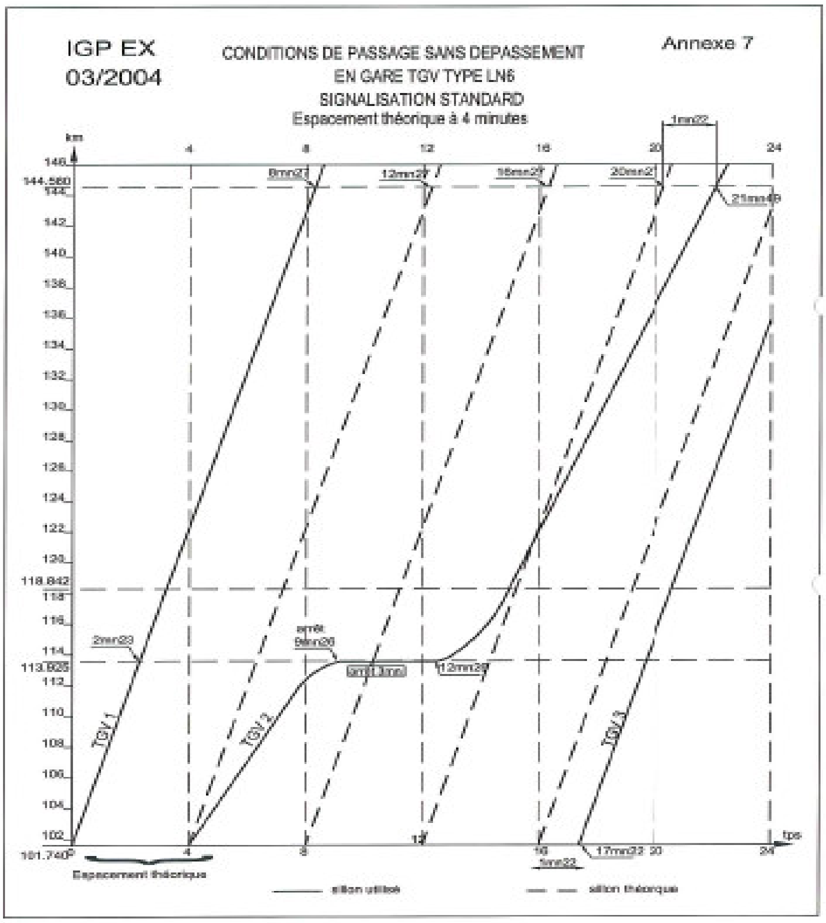

Figure 4: Stop on a 320 km/h HSL

Time is shown on the X axis and distance is shown on the Y axis. Every oblique line is a potential non-stop path. Interval of time between trains is set at 4 minutes and distance between mobiles is about 20 km.

More than two paths have been lost for this stop.

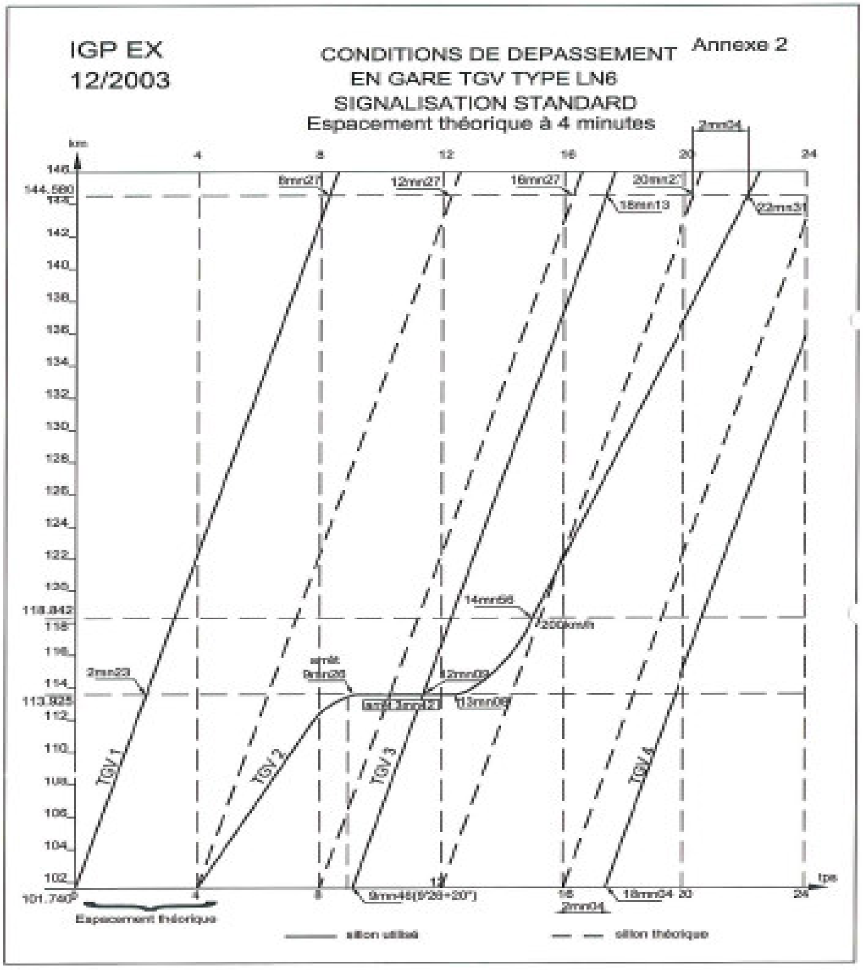

Figure 5: Stop with overtaking

The above figure shows the advantage of making in the same time the overtaking of the first train during its dwell time. Global time lost will be 10 min 04 secs but only one and a half paths will be lost. Three minute dwell time is the French standard but according to passenger behaviour, this can be reduced or extended. Five minute dwell time is a standard for airport stations as passengers often carry heavy luggage.

2.7 Timetabling

For timetabling purposes, interfaces with the existing network will become a major concern, and there is a need to work closely with the Infrastructure Manager and the other operators to provide paths to the HS trains that allow for efficient operation of both the high speed and the classic network. This includes also the stops at stations. The presence of a full double segregated track on the line and at junctions will help to provide efficient travel times.

2.8 Stations and operations

2.8.1 On the classic network

Station platforms located in city centres need a sufficient length to cope with the length of the rolling stock. Demand studies indicate that in some stations it will be necessary to provide several 320- or 400-metre platforms to cope with double unit trains, while in others it will be sufficient to provide 160- or 200-metre platforms with the capability of berthing only one-unit trains.

To reduce the risk of excessive gaps between the train doors and platform the use of curved platforms should be minimised as TGV doors are located close to the bogie.

As said previously, TSI states that: "Platforms used on upgraded lines in Great Britain shall have a standard height of 915 mm with a tolerance of + 0/-50 mm. The platform horizontal distance (L) shall be chosen so as to make optimal use of the step positions on trains built to the UK1 loading gauge".

The number of platforms will depend upon the expected traffic with a layout coping with commercial needs and with operations. Approximately 30 minutes are generally set between the arrival of a loaded TGV and its start with passengers. At the Gare du Nord in Paris, a turnaround time of 26 minutes is achieved, and at the Gare de l'Est, also in Paris, the turnaround time is 27 minutes.

For trains starting from the termini, a minimum waiting time period at platform should be determined (SNCF's passenger charter requests a minimum of 20 minutes).

However, British practice in this area is for shorter turnrounds, with many Intercity services turning round in 20 minutes. There is no strong reason to require longer turnrounds for high speed rail than other Intercity rail services.

2.8.2 Through stations on high speed lines

Even if the station layout depends on the operating speeds on direct and diverted tracks, on platform length, and on civil engineering design and space constraints (urbanised areas), the same requirements exist: 400 metre long platforms, 550 or 760 mm platform height and a minimum width of 8 metres. Several types of stations can be designed in order to meet operation requirements.

No gradient is normally permitted at HSL stations.

Elementary station

No platforms are located on the high speed lines for safety reasons and for capacity matters. TSI prohibits such platforms when speed is above 250 km/h. Usually, they are built on external loops with 170 km/h speed limited tracks and crossovers. The timetable cannot therefore accommodate either terminating or reversing of trains at such stations. This scheme requires limited land acquisition.

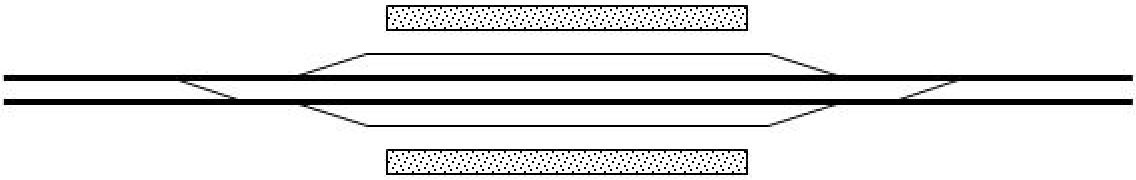

Figure 6 : Elementary station

High speed tracks must be efficiently isolated from the rest of the station by a sufficient distance (more than 6.5 metres to the stopping tracks) or with a protection wall to limit sound, ballast stone projections and derailment impact. Crossovers are located in close proximity before and after the station to allow two-way working of tracks in case of maintenance or an incident on one track. They usually allow crossings at 170 km/h. Two or four crossovers can be installed depending on the expected flexibility requested by operations.

Stations with few daily trains terminating at or starting from

When the level of traffic is higher, it could be necessary to keep or stable units during some periods. In this case there is a need to build sidings in order not to add constraints to the occupancy diagram of the station. Refuge sidings, dead end sidings and crossovers (for reversing trains) are added for operational and safety reasons.

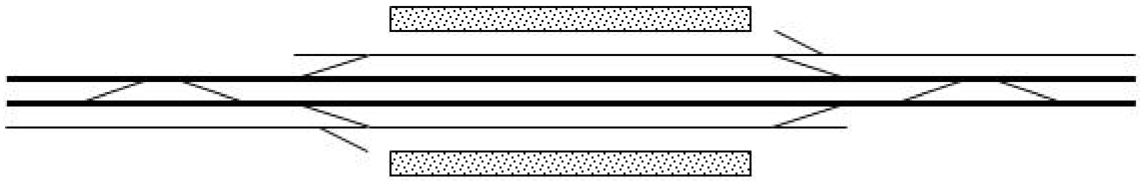

Figure 7 : (Saint-Exupéry, Valence, Avignon, Aix-en-Provence)

Station with many daily trains terminating at or starting from

The frequent terminating of trains requires reversing and therefore the placement of loops between the two high speed tracks in order to facilitate operations.

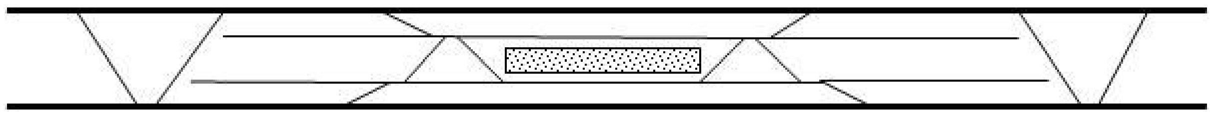

Figure 8 : Marne La Vallée type station (2 or 3 platform tracks)

Station allowing extra capacity with numerous stops

Long deceleration tracks have been added in Korea and Formosa (Taipeh-Kaohsiung) to allow stops without impact on the following train and therefore with no loss of capacity. Due to the extra costs such stations should only be considered where frequent overtakings is required.

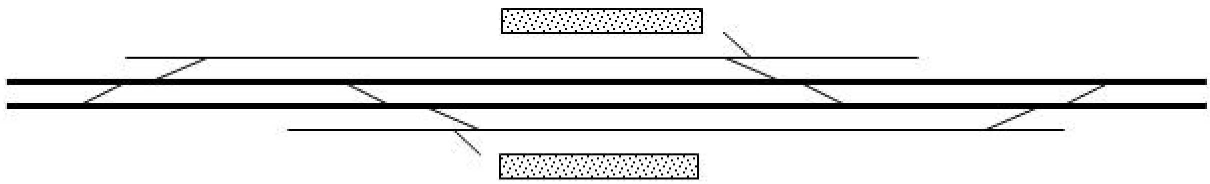

Figure 9 : Full station with distant crossovers (Taichung, Formosa ; Taegu,Korea)

Emergency sidings

Emergency siding tracks should be planned along the line every 30 kilometres to allow a train to stop, alight its passengers, park the train, and bring another train to board passengers with minimum traffic disruption.

3 Design of a new line

The track design should ensure perfect stability of the rolling stock and passenger comfort while ensuring a minimum wear on the rolling stock and track infrastructure at any speed.

Topography of the areas where HSL is supposed to run has a large impact on costs, and there is a need to fully meet the technical constraints in order to provide reliable operation of the line.

3.1 Topographic constraints

The topographic constraints are expected to be reduced as the new high speed tracks will be passenger only and will not have to take account of freight traffic. It should however be noted that the high speed tracks will be able to accommodate HS freight trains such as those operated in France (TGV postal running at 270 km/h). This choice allows for higher gradients and reduces constraints for curves, cant and cant deficiency.

3.1.1 Profile of the line

The maximum gradient allowed for 300 km/h train speeds is set by the latest STI to 35 mm per metre. No gradient is normally admitted at stations.

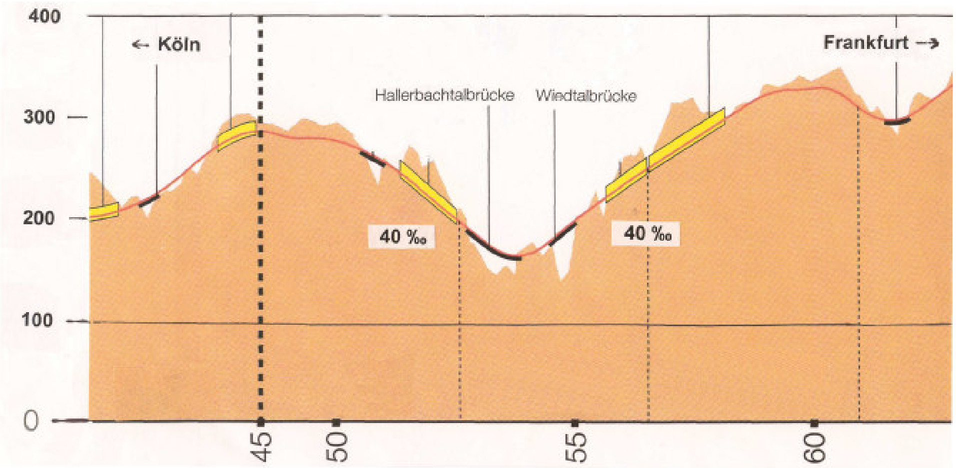

Figure 10 : Profile of the Köln-Frankfurt section of line

3.1.2 Horizontal curve radius

Design characteristics will allow trains to run at their maximum speeds. Minimum radius, associated with cant and cant deficiency, defines the maximum commercial speed, providing a good level of comfort to passengers. According to TSI, the minimum radius of curvature needs to ensure that the curve cant set does not exceed the minimum values. The table below provides French examples of the minimum radius at different speeds.

Commercial speed	220 km/h	300 km/h	350 km/h
Minimum radius	2000 m	4000 m	5556 m (*)

(*) is the minimum exceptionally admitted but the recommended value is 7143 m and the standard one is 6250 m.

3.1.3 Vertical curve radius

Progressive transitions between uphill and downhill must be provided. Minimum radii are provided in the table below.

Commercial speed	**220 km/h**	**300 km/h**	**350 km/h**
Minimum radius	10,000 m	25,000 m	32,000 m

3.2 Track standards

These standards are summarized in the following paragraphs below. Ranges of speed taken into account for all the other components are set between 250 km/h and 350 km/h.

3.2.1 Track gauge and loading gauge

Taking into account the connectivity of the future HS network with the existing conventional rail network, 1,435 mm standard European track gauge is mandatory as well as the loading gauge (maximum axle load) that should be set between 17 and 18 tons for the passenger dedicated lines.

3.2.2 Track pitch

A minimum width shall be considered between the two tracks to allow an acceptable wind effect during the crossing of trains. Current standards are set at 4.80 metres for 350 km/h and 4.50 metres for a speed of 300 km/h. TSI "infrastructure" allows for some smaller values.

The minimum distance of 2.30 m is required to ensure the safety of maintenance staff at an operating speed of 300 km/h; a larger distance is required for higher speeds. The actual distance on the Atlantic LGV is 2.8 m, and 3.1 m on the Mediterranean LGV.

Entering the dangerous area is forbidden without possessions or 160 km/h speed restrictions. Safety of staff working on a track with trains running on the parallel tracks is ensured by switching devices reducing the maximum allowed speed to 160 km/h.

3.2.3 Radius and associated standards

Tracks in a curve are built with a cant allowing the trains to maintain their existing speed. The radius when associated with cant and cant deficiency defines the maximum commercial speed limit that provides a good level of comfort to passengers via the formula below.

Minimum R $= 11.8V^2/(I+d)$

Where R = radius (m)

V = speed (km/h)

I = cant insufficiency (mm)

d = cant (mm)

Cant

Cant is defined as the maximum height between the inner and the external rail. It allows trains to maintain their speed when running on curves without decreasing passenger comfort. 180 mm maximum cant is set for speeds between 230 and 350 km/h.

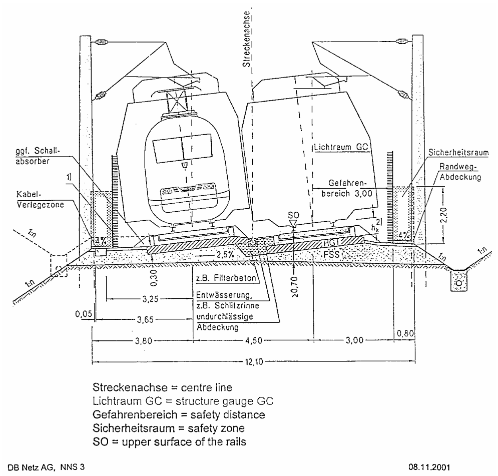

Figure 11: Cant and cant deficiency

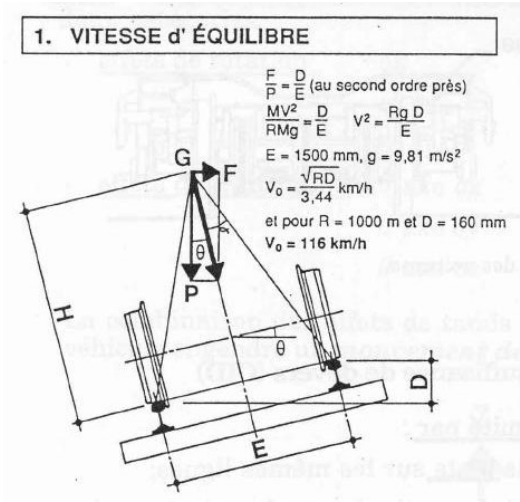

Figure 12: Balance between speed and cant deficiency

Cant deficiency is the difference between the theoretical cant needed to remove lateral acceleration and the practical cant applied on site. The maximum cant deficiency is set between 100 and 130 mm for 300 km/h and above and 80 mm for 350 km/h. Cant deficiency variations are allowed from 30 mm up to 50 mm per second

3.2.4 Structure gauge

Aerial gauge

The figures below show the Static vehicle gauge and GC kinematic reference contours.

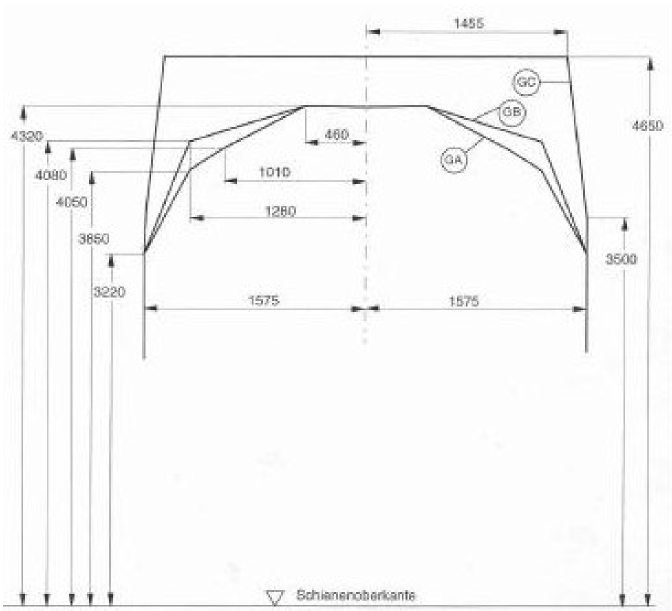

Figure 13: GC static vehicle gauge

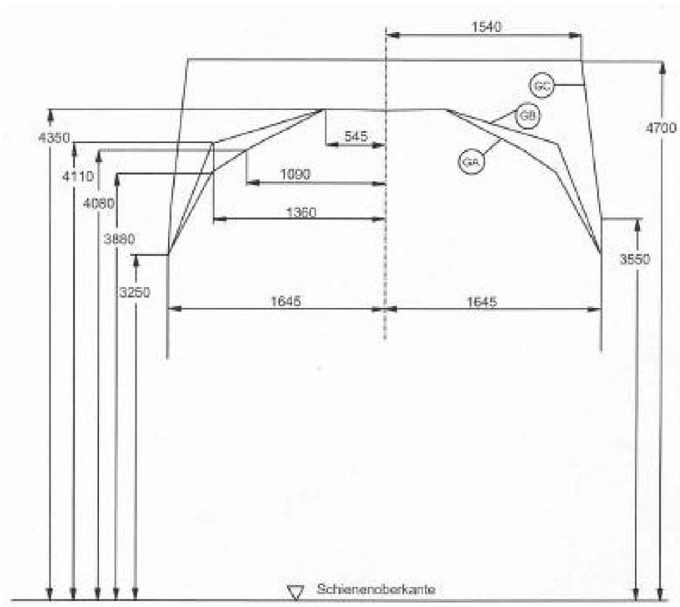

Figure 14: European GC kinematic reference

All new lines shall be built to UIC C gauge as this permits both international high speed rolling stock and double deck domestic rolling stock. TSI allows specific features for the UK network (see section 1.3).

Moreover, aerial gauge shall take into consideration the OHLE gauge needed to install the catenary, and bridges and tunnels should allow a height between 6.00 and 6.35 metres depending on the length of the structure.

Issues on aerial gauge

Adopting the standard Continental gauge (UIC leaflets 505-1 & 506 and TSIL245)) for high speed trains would lead to major issues when these trains run on the existing UK network, which has been built with standards belonging to the British aerial gauge (GE/RT8073): height problems (in the case of duplex trains; height would not pose a problem for single-level trains) and width problems on line and at stations (British gauge obtruding platforms).

A report on re-gauging the UK for European freight agreed that it would be very costly to correct.

Issues on platform gauge

To cope with TSI, it is mandatory to design high speed stations for UIC C gauged trains (most European trains). As the choice has been made to operate an integrated railway, HS trains shall be able to serve both types of platforms (UIC C and BR). The complicated steps that have been built onto the Eurostar (Classes 373/3 and 373/2) trains are the only solution that does not involve separate platforms for BR gauged trains and UIC C gauged trains. Thus UK gauged (ORR - Railway Standards publication and Guidance) trains will have moveable steps to board and alight trains, and will require mechanisms to move wheelchairs and the mobility impaired passengers into and out of trains. UK gauged trains will be able to operate without the moveable steps on UK gauge platforms.

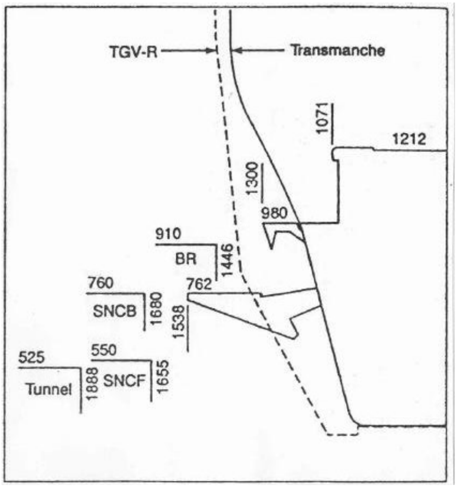

Figure 15: Steps on Eurostar trains

4 Superstructure

4.1 Track bed

The track bed width for a double track section of line is estimated at 25 m between fences and a 14-17 m wide embankment. Overall width obviously depends upon the size of the embankment. Drainage of the track bed and of the approaches is necessary to provide safe operation even during difficult meteorological conditions and to limit erosion following water discharge.

4.2 Resistance of track to lateral forces (cross wind)

Some high level viaducts could be located in windy areas. Impacts of cross winds on such viaducts should be calculated so that adequate track resistance can be provided. It is sometimes necessary to install either crosswind protections diverting wind outside the rolling stock gauge (as shown below) or anemometers with direct control of signalling to force trains to reduce speeds during windy times.

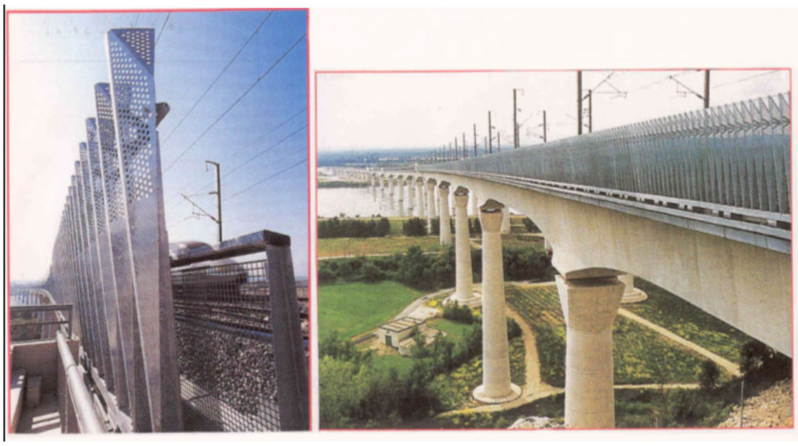

Figure 16 Cross wind protection, Viaduc des Angles, TGV Méditerranée

4.3 Tunnels

Based on the design speed, train gauge and track axis to axis distance, the tunnel diameter is calculated to limit pressure variations on the tunnel lining and rolling stock body. The sizing of the safety niches is taken into consideration in this calculation. Standard double track HSR tunnels do not usually require mechanical ventilation, but the safety performance of the evacuation of a non ventilated tunnel should be carefully studied. In addition, designers need to consider connecting points on the tunnel walls to be able to fix jacks and winches to lift and re-rail trains.

On new high speed lines, tunnels could be designed with a single or double bore depending on the geological conditions. Safety instructions and access are provided by both TSI and national legislation.

Some tunnels are limited to a maximum speed of 230 km/h to reduce the size of the tunnel's cross section. No ballast is laid in tunnels to allow easy access to emergency services.

Special attention shall be taken for tunnels including underground stations (wind effect on platforms, etc…). For example, trains are limited to 200 km/h when going through the Lille-Europe HS station.

4.4 Environmental impacts

4.4.1 Grade separation from roads

High speed operations cannot be considered without providing full grade separation from roads and the removal of all level crossings. This leads to land acquisition costs, earthworks and additional drainage facilities. Every bridge will be equipped with safety systems both to prevent falls and stop trains in case of a road vehicle falling on the tracks.

Figure 17: Added fences on road bridge

4.4.2 Fences, emergency egresses, walkways, cross passages

A definition of criteria for the provision for emergency egress/walkways shall be developed and applied accordingly with the specific characteristics of each site. Provision for emergency egress shall also be consistent with the inspection and maintenance requirements

Fencing

Fences at least two metres high shall be set along the track with emergency access and intrusion detectors. These detectors shall control signalling in order for signals to be put at danger in case of intrusion. This also leads to the construction of tunnels under the HS infrastructure in order to allow animal movements.

Road access to equipment facilities

As heavy components shall be carried up to substations, parallel stations etc…, road access is mandatory.

Cross passages for maintenance

Cross passages for maintenance must be built to ensure timely inspection by minimizing the walking distance of the inspection and maintenance staff. When the need is proved, HS train announcement systems or speed restriction switches will be set.

Safety walkways

The closest side of the safety walkway should be no less than 0.70 metre from the "danger area" line)

4.4.3 Noise reduction

The noise caused by high speed trains shall not exceed normative maxima, and walls against noise will be installed when the line passes close to urban areas. Cut and cover design facilitates the integration of the line within an urban area and is often considered as the best solution by inhabitants although it is more expensive.

4.4.4 Environmental constraints

Environmental constraints and impacts should be considered from design through to construction phases and will require Environmental Impact Assessments (EIA) to be carried out in parallel with the design studies. Traversing Areas of Outstanding Natural Beauty or other environmentally-designated areas will lead to extra costs.

The line lay out shall, as far as possible, avoid zones where special local hazards exist:

- nuclear power plants
- chemical product reservoirs
- seismic fault crossings
- windy areas

5 Track laying

5.1 Type of track support

Slab track or ballast track can be set.

5.1.1 Ballast size and thickness

Ballast is a major component of the quality of the railway infrastructure and its quality shall maintain the track in a good state. Elasticity of the ballast layer (more than 35 cm) dampens vibrations and reduces (lessens) dynamic movements produced by the train.

PARAMETER	France	Germany	Italy	Spain		Belgium	STIs
Speed	300/350	300	300	300	350	320	≥ 300
Size distribution of the ballast (minimum/maximum size in mm)	25 / 50	22.4 / 63	30 / 60	32 / 63	32 / 63	25 / 50	National standards
Minimum thickness of ballast (cm)	30 / 40 (1)	35 / 40 (2)	35	30	35	35	35
Minimum thickness of sub-ballast (cm)	Shape 30 / 70 Sub layer 20	Shape 30 Anti-cold 30	12 + 30 (3)	25	30	Shape 50 / 70 Sub layer 20	Shape 30 / 70 Sub layer 20

(1): 40 in/on civil structure
(2): 40 is usually recommended
(3): 12 cm with bitumen sub ballast and 30 cm compacted sub layer

Figure 18: Ballast size

5.2 Rail equipment

5.2.1 Rail

The 60 E1 rail type is recommended ("UIC 60", 60.3 kg/m). The inclination of the rail is usually 1:20, except in Germany where it is 1:40. European STIs recommends 1:20 for all speeds above 280 km/h.

5.2.2 Sleepers

Except for in France, where two-block and mono-block sleepers are both accepted on open tracks, all other European countries use only mono-block sleepers. In France, short mono-block sleepers are required on platform tracks. Their weight is set between 245 kg in France and 400 kg in Italy (TSI >220 kg). There are usually 1666 sleepers/km (one every 60 cm). This value is recommended by TSI and used by all countries. The height of concrete sleepers varies between 180 mm to 242 mm (no STIs recommendation) and their length varies between 2.415 m and 2.60 m (STIs recommendations is more than 2.25m)

Figures 19: Laying of the track

5.2.3 Fasteners

In general elastic rail fasteners are used, with rail pads in elastomer elements of 9 mm thickness, and steel springs.

5.2.4 Points and crossings

For track stability and maintenance purposes, the positioning of switches follows some very strict rules, especially when on structures (elevated stations, for example).

Switch positioning shall be agreed by the signalling engineers due to obvious interfaces with the signalling system.

All switches laid on HSL are installed on mono-block sleepers.

- Switches with moveable frogs (tg 0.0154 - length 209.440m) are installed at junctions to provide 230 km/h maximum speeds on the diverted route. Swing nose crossings are laid down in order to remove the gap between the nose and the wing rail as high speed requires permanent guiding of the wheels. Due to heavy investment and heavy maintenance, this type of switch is limited to junctions.

- At track change points and at the entries and exits of platform lateral tracks, 170 km/h (on the diverted route) maximum speed switches are laid down. These switches have a 0.0218 tangent and are 148.275 meters long.

- Depending on the access speed, other types of switches are provided to set routes to refuges, sidings etc.

5.2.5 Permanent monitoring of the track

Regular track inspections made at ground level and with dedicated engines (ultrasonic testing) shall be planned.

6 Depots and maintenance workshops

Depot and maintenance workshops shall be planned to ensure a rolling stock fleet is provided at an optimum cost combining service compliance with safety, reliability, availability and comfort to passengers.

6.1 Five types of maintenance

The following types of maintenance are now global standards and the methods similar, if not identical, across the world

6.1.1 At station and depot

Level 0 includes cleaning and monitoring in service before, during or after commercial usage. These procedures are undertaken by the operating staff and automatic recording devices

6.1.2 At depot or at the maintenance workshop

Level 1 - examination in service: includes checks, tests, simple preventive maintenance and breakdown service on a limited period on special tracks without any disruption to commercial service.

Level 2 - periodical inspections: comprises periodical preventive inspections and replacement of some components of the train set, which generally must be removed from commercial service.

6.1.3 At the main workshop

Level 3 - **standard replacement of components:** focus on the repair and overhaul of train bodies or components. It requires specific skills, special technologies, processes, documentation and appropriate fittings.

Level 4 - **actions on bodies and structural parts:** focus on alterations, transformations or very major repairs. This level of maintenance requires special techniques and equipment.

The figure below summarizes all types of works that shall be carried out for the various levels of maintenance and their present frequencies.

Level/Action	Frequency every:	Time out of service	Major categories of work
1/ Examination in service (ES)	5,000 km	1 hour	refill water, sand and oil; empty toilets, check wheels, running gear, bogies, brake blocks, pantograph
2/Comfort examination (CE)	9 days or 20,000 km (± 20%)	4 hours	repair, refurbish items in passenger compartments, toilets, other interior
2/Running gear inspection	18 days or 40,000 km (± 20%)	4 hours	Inspection of bogies, wheels and all rotating parts and bearings, brakes and suspensions, including pantographs and pneumatic systems
2/Normal cleaning (NC)	with CE	30 mins. during CE	Dusting, sweeping, and spot washing to keep good cleanliness
2/Limited inspection (LI)	7 months or 170,000 km (± 20%)	24 hours	Complete check of functioning of all control systems, change and clean motor components.
2/General inspection (GI)	Every other LI	40 hours	As above, plus more in-depth electrical and pneumatic component checks
2/Profound cleaning (PC)	with GI	8 hours, during GI	Restore passenger areas to excellent cleanliness
2/Full general inspection (FGI)	Every other GI	56 hours	As above, plus even more in-depth work including battery replacement, ultrasonic wheel checks
2/Major cleaning (MC)	with GI	40 hours during GI	Annual very extensive disassembly, cleaning, washing of trainset interior
3/Overhaul (OH)	10 years or 4/5,000,000 km	600 hours	Rebuilding of trainset components

Figure 20 : Maintenance and cleaning activities

6.2 Depots and Workshop

The workshops in charge of maintenance are specialized by class of equipment and by the level of the operation (as described above) in order to optimize the use of technical means and staff abilities. An average availability of 95% is expected for these equipments.

6.3 Stabling facilities

The stabling facilities are located as close as possible to the terminal stations, in order to avoid costly empty train movement. Routes to the major stations are not expected to use the high speed lines.

During reversal times, units can either stay at station where a quick cleaning will be done or they can be sent to the stabling area for toilet sewage and/or heavy cleaning. These areas are also used as sidings at night to park trains.

7 Maintenance equipment

For a complete network, one or more depots shall be equipped to carry out the maintenance of the fleet.

For a depot servicing approximately 100 units, an area of 40 hectares will be required for all the tracks, buildings, with 2/3 of the area for stabling and 4 ha for shelter. This will of course depend on the type of rolling stock, the exact size of the fleet, the type and number of motors, etc., but the bulk of the necessary equipment will not dramatically change and typically includes:

- A dedicated substation, providing around 20 MW of power.
- A short maintenance operation (less than a day) centre (see Figure 21) with a signal control room, two washing units ①, 5 pit tracks ②, a workshop ③, sheltering 8 tracks, 220 m long, 60 m wide, overhead cranes (2 t), switchable electric power and movable catenary, 5 servicing tracks ④ equipped for interior cleaning and servicing, a wheel lathe ⑤ including an overhead crane to handle bogies and motors.
- A long maintenance operation (more than a day) with a bogie drop facility, a 40 t jack to hold the train, an overhead crane for 12 t (motor bogie), a whole trainset lifting equipment. appropriate jacks able to lift simultaneously a whole trainset, 7 inspection tracks for all categories of long lasting inspections, an electrical workshop, a deep cleaning shop, a mechanical shop,

They typically include 10 km of maintenance and workshop tracks. About 50 % of that length can be counted as a part of the required stabling tracks. As far as possible, a sequential layout is preferable, in particular for the short time maintenance and the stabling. It allows train unit movements in one direction, with few shunting and turn-arounds, thus saving time and money and reducing the risk of incidents.

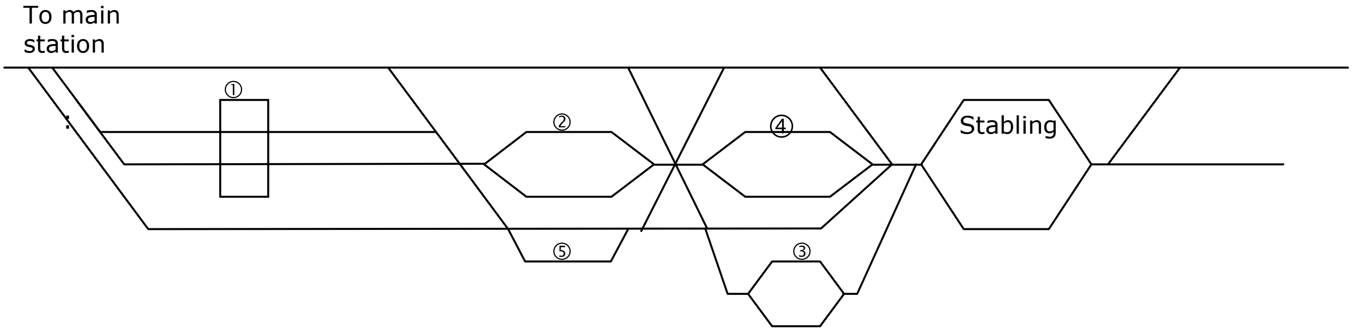

Figure 21 : Schematic plan of stabling and short time maintenance facilities (the long time maintenance facilities must be close and linked, but with little layout constraints).

8 Power supply and OHLE

Electrification is a mandatory component of any high speed train as no diesel engine can cope with speeds over 220 km/h.

8.1 Feeding voltage

All existing high speed lines (except those in Germany, with 15 kVAC at $16^2/_3$ Hz) are equipped with 25 kVAC-50 Hz, and especially the 2 x 25 kV type. The choice on CTRL1 and French high speed lines is 2x25kV and is recommended even if leads to 30% additional cost when compared to 1x25 kV because it provides 60 km intervals between sub-stations due to a 50 kV feeder with autotransformer located every 15 km.

Moreover, this voltage copes with existing 25kV AC that is used in the majority of the UK on classic lines.

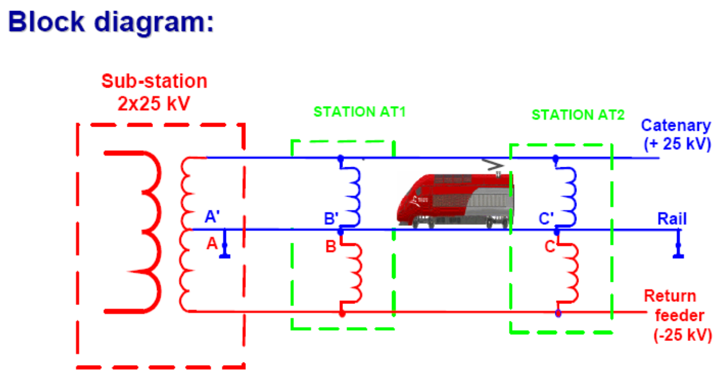

Figure 22: Block diagram

8.2 Catenary and sectioning

The catenary used on the high speed lines copies the one used on classic networks with some additional technical constraints such as a copper contact wire with a 150 mm^2 cross section and a bronze carrier with a 65 mm^2 cross section. Overhead contact lines are between 5.08 and 5.30 metres high (TSI).

Sectioning to isolate catenary sections that are not fed by the same sub-stations shall neither be located on gradients nor close to stations, though exceptions exist.

8.3 Power control remote control

A power supply room that remotely controls all devices permanently monitors electrical power supply and distribution. This power supply room is usually located close to the Operation Control Centre room as they have to work closely for maintenance and emergency purposes.

8.4 Safety issues

Two major safety risks are related to the power supply. First of all, equipment may fall on platforms and on the line. This risk is avoided via design and construction rules and standards, and via monitoring and maintenance. Secondly, there is some risk of electrocution or short circuits. This risk is dealt with via the automatic interruption of the power supply.

9 Signalling and telecoms

In an emergency it takes three kilometres to stop a HS train running at 300 km/h. In normal (non-emergency) operations, stopping sequences shall be set in accordance with the braking rates recommended by rolling stock manufacturers. Moreover the system shall be "fail safe", so a failure may not result in an increased safety risk, and the probability of failure shall stay around 10^{-9} per hour and per equipment.

9.1 Signalling

On European high speed lines, only a cab-signal system is allowed when running above 220 km/h. Three systems exist on the different networks:

- French "TVM" 430 that equips all the French high speed lines (signalling boxes and automatic headways), South Korean line, Benelux lines, and Eurostar service.
- German "LZB" that equips the German high speed lines and the Madrid-Sevilla Spanish line.
- "ERTMS" ("European Railway Traffic Management System") is the only "normalized system" for European Interoperability that is recommended. ERTMS level 2 now equips the Milan – Bologna Italian line, the Madrid – Barcelona Spanish line, and the new Eastern European Line in France and Germany, but it currently duplicates another system. It will equip the Barcelona – Perpignan international line, as well as other lines currently under study in Argentina and Morocco.

ERTMS

ERTMS level 2 is a digital radio-based signalling and train protection system that can be superposed on an existing system or implemented autonomously. The sectioning is fixed, and an on-board computer continuously monitors and calculates the maximum speed. The braking curve is determined in function of the relative position of the train preceding the current train, the route and the occupation of track circuits. Track release signalling and monitoring of the integrity of the train are realized by the existing systems (track circuits, axle counters).

The heart of the system is the RBC (Radio Block Centre), which interfaces with the interlocking, the control centre, the adjacent RBCs and the track-side subsystems, as well as other systems such as the maintenance & infrastructure database. It centralizes all information and supervises a part of the line, supplying track allocations to the trains (movement authorities). The beacons are used only for odometry calibration and repositioning.

The train-ground communication is continuous and realized by GSM-Radio, and the track allocation are transmitted to the train by radio from an RBC.

The following functions concerning the safe operation of trains are integrated into the system:

- ATP – Automatic Train Protection establishing the movement authorities issued to the on-board equipment.
- IXL – Interlocking controlling the function of wayside elements.
- ARS – Automatic Route Setting for scheduled train operations.
- AVI – Automatic Vehicle Identification provides rolling stock location and operation information.
- TMS – Train Management System.
- LTC – Local Traffic Control manages the signalling installations locally at stations.

- TDD – Train Detection Devices (overheated wheel bearings, dragging equipment, and wheel impact loads).
- LX - Level crossing protection of vehicles and pedestrians.

9.2 Cab-system

The driver receives the speed limit indications on his cab-signal display. These are fed in as coded frequencies or digital messages carried by the current flowing in the rail. An automatic monitoring of driver's actions is realised by the system through an emergency computed braking curve able to take the lead when a gap of more than 10 km/h above the limit is reached.

9.3 Integrated interlocking and signalling system

An interlocking system is used to safely route trains through a railway network. It ensures that a given route is reserved for a given train and prohibits conflicting train movements. It also prevents the switch from being thrown under a train. Because interlockings are critical to train operations, they must be extremely reliable. Interlockings are proprietary systems and are nowadays computer-based systems. Two architectures are possible: centralized interlocking (wherein all the logic for route setting and block spacing is located in centralized equipment anywhere on the network) or distributed interlocking, located at route stations. Stations along the lines will not be manned in normal circumstances by operational staff.

9.4 Telecommunications

All the high speed lines are equipped with radio systems linking trains, stations, and centralized traffic control and dispatching centres. So even if telecommunications are not primary safety equipment, they supplement the signalling system. As a consequence, telecommunications systems shall be designed to resist a pre-determined level of earthquake or fire in a tunnel and shall be compatible with smoke emission regulations.

On the lines equipped with ERTMS level 2, a special equipment of ground-train radio link, with data exchange, called "GSM-R", ("Global system for mobiles – Railways », which is a sub-system of the ERTMS) is necessary to transport the signalling ground information to the cab-equipment on board of trains.

9.5 Traffic management and signalling

Management of the traffic and signalling is carried out remotely from a single control room that allows signalmen and the traffic manager to supervise all rail traffic from the same location. This control room is normally close to the power supply room. The Central Traffic Control room should encompass some or all of the following activities and will include others.

1. Control and monitoring of
   - the signalling system (including hot box detectors, overflood, intrusion sensors…)
   - The planned maintenance work and unforeseen incidents including any infrastructure failure, rolling stock failure….
   - The train plan (via control panel,…) and the contingency plan
2. Radio communication
3. The Public Information System and Public Address
4. the voice recording system

It will also provide the required interfaces between and among these activities in order to ensure the safe operation of the system.

10 Rolling stock

TSI provides the main rolling stock standards that shall be met. 320 km/h is currently the standard (even though the Chinese railway has started 350 km/h operations and future AGV speed are expected to be 360 km/h).

Spare diesel locomotives shall be parked at close distance in order to haul HS trains in case of malfunction (OHLE or rolling stock) up to emergency siding tracks.

10.1 Trainsets and capacity

Major manufacturers offer various designs and capacity, but all are constrained by the length and width of the infrastructure and equipment. UK standard gauge (ORR - Railway Standards publication and Guidance) adds another constraint. There are two main options with 200 m trains:

- Single deck trainsets provide up to 420 seats depending on the first/second class ratio, the size of the catering facilities and the seat pitch.

- Double deck trainsets provide 500 to 550 seats. To cope with the high traffic forecast of this project, double deck trains seem more appropriate.

Therefore the possible trainset configurations are the following:

- 2nd generation Eurostar based on a 2+8 configuration capable of being coupled together, offering about 400 seats (800 if coupled together). This would be within both gauge and length constraints on the classic network. A longer version could be considered (up to 320m within most British main stations), but would not then able to be coupled together, or to the UIC C gauge rolling stock below; we only consider 200m long BR gauge trains in the study.

- TGV Duplex or equivalent that are based today on power cars push-pulling 8 to 10 trailers for a total length of 200 m, with around 500 seats. This ratio can be modified to accommodate marketing decisions or local habits, thus providing more or less total seating accommodation. Coupling the above trainset and providing a 2-unit train doubles the number of seats and leads to halving the number of paths used as a double unit train has the same performance as a single unit train.

- AGV is the fourth generation of TGV. It will employ new technology using distributed power. The original concept of a modular and articulated trainset is retained to offer an economic solution (modular consist) providing high levels of performance, comfort and safety with motorization that is distributed along the entire length of the train. This architecture also allows for the reduction of operating and maintenance costs.

10.2 Gauges

Adopting the standard Continental gauge C (TSI) for high speed trains would lead to a major issue as these trains will be too high and wide (at platform level) to run on the classic network (W6a gauge). In order not to increase the existing gauge clearances on the national network, TSI admit that "trains designed for interoperable running on upgraded lines in Britain shall comply with BR gauge" but it also states that all new lines shall be built to UIC C gauge to allow international rolling stock running only on HSL and possibly double deck services dedicated to the new line.

The major consequence is the need for manufacturers to review their rolling stock characteristics in order to provide a high speed train that is compatible with British loading gauge, in particular platforms – a second generation Eurostar. For services dedicated to high speed lines, existing designs such as the TGV operating in France can be used, as they are compliant with the UIC C loading gauge.

It seems wise to plan two sub-fleets to offer direct services on both HSL stations and classic stations.

10.3 Electrical power

HS domestic services shall run with 2 X 25 kV on HSL. This fits with the existing 25 kV that is in the north of UK.

Electrification in the South of UK has been installed through a 750 V DC third rail and Eurostar trains were able to be fed by this system through a sleeper.

A European approach leads to consideration of the 3000 kV used in the Netherlands and Belgium as well as well as the 16 $^{2}/_{3}$ Hz single-phase railway power supply in Germany and Switzerland. The 1.5 kV DC used in the south of France could also be considered. It would be a decision for any operator who wished to go to such destinations to acquire appropriate rolling stock.

10.4 Tilting trains

Tilting trains can be seen as an alternative to the construction of a new high speed line from London to Scotland, or as an interim measure prior to full completion of the high speed network. The first part of the journey would be provided with new high speed track and the second part can offer better journey times than classic trains as tilting trains have a mechanism that enables increased speed on regular railway tracks. Tilting trains may be constructed such that inertial forces cause the tilting (Talgo 350 with passive tilt), or they may have a computer-controlled power mechanism (Fastech 360 Shinkansen N700 with active tilt). These two trains are experimental and currently undergoing tests.

It is highlighted than the time saved depends directly on the cant deficiency that is allowed. In France, where restrictive values have been chosen, the time saved does not exceed 14% when compared to classic trains. On the contrary, Germany and Sweden obtain a 25% reduced travel time. Moreover, on the West Coast Main Line where tilting 200 kph trains already operate, a tilting high speed train will be necessary both to match journey times and for capacity reasons when operating the same route as classic tilting trains.

11 Maintenance of way sites

Several maintenance bases will be necessary to cover the whole network. Maintenance sites are expensive, and thus their number and location must be optimized, but too few maintenance bases lead to long access trips for maintenance equipment and staff and therefore low productivity.

A maintenance base would easily control the maintenance requirements for a 200 km section of line. This means that 3 to 4 maintenance bases would be needed along the line to Scotland. The location can also not be too far from important cities and it requires shunting tracks for work trains and space for maintenance cars.

In addition, sidings will have to be installed along the line, so that some heavy equipment (tamping machine, ballast plough…) can be stored overnight during maintenance works when they last several nights.

In general, it is recommended that the line be equipped with cross-overs every 25 km, and that one out of every three cross-overs includes a 400 metre long siding, to store a disabled train and transfer passengers when necessary. It will also be used to store maintenance equipment as mentioned above. A maintenance base will be available at one out of every three such sidings.

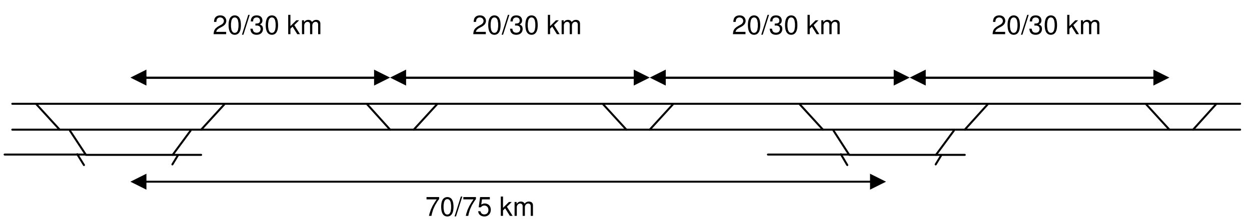

Figure 23 : Crossovers and sidings

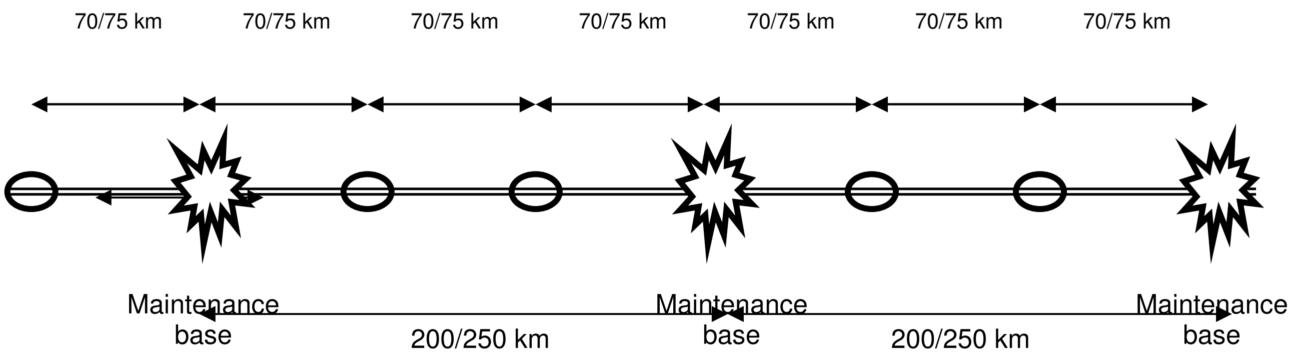

Figure 24 : Sidings and maintenance bases

Appendix C – Cost of 4-track High Speed Lines

Contents

1 Investment Costs for a Four-Track High Speed Line

1.1 Introduction

Over the long term, demand on the British high speed network travelling north out of London will likely exceed the capacity of a single high-speed line. Two solutions present themselves: (1) either two different north-south corridors out of London can be used, or (2) a single four-track high speed line could be built along one corridor.

Though no four-track high speed line (HSL) has been built to date, it would seem probable that such an endeavour would cost less than building two completely independent double-track high-speed lines. The first section of this document describes the approach used to provide an estimate of costs generated by the construction of a four-track HSL, based on experience related to the construction of double-track high-speed lines.

Two possible approaches present themselves for the construction of a 4-track HSL:

- Construction of all four tracks at one time.
- In two phases: construction of the first pair of tracks initially, followed by the second pair of tracks at a later date when demand requires them.

The cost assessment carried out in section 1.2 assumes the first case (all construction in one phase), whereas section 1.3 discusses the second case (construction in two phases).

The analysis in this Appendix covers the route of a HSL but does not quantify the implications for terminals (specifically that in London), or for the complex junctions that would be implied by a 4-track route; they are both briefly discussed, but not fully evaluated.

1.2 Cost Assessment

1.2.1 At-Grade Alignment

Figure 1.1 below depicts the configuration based on average values of (a) two double-track lines and (b) one four-track line.

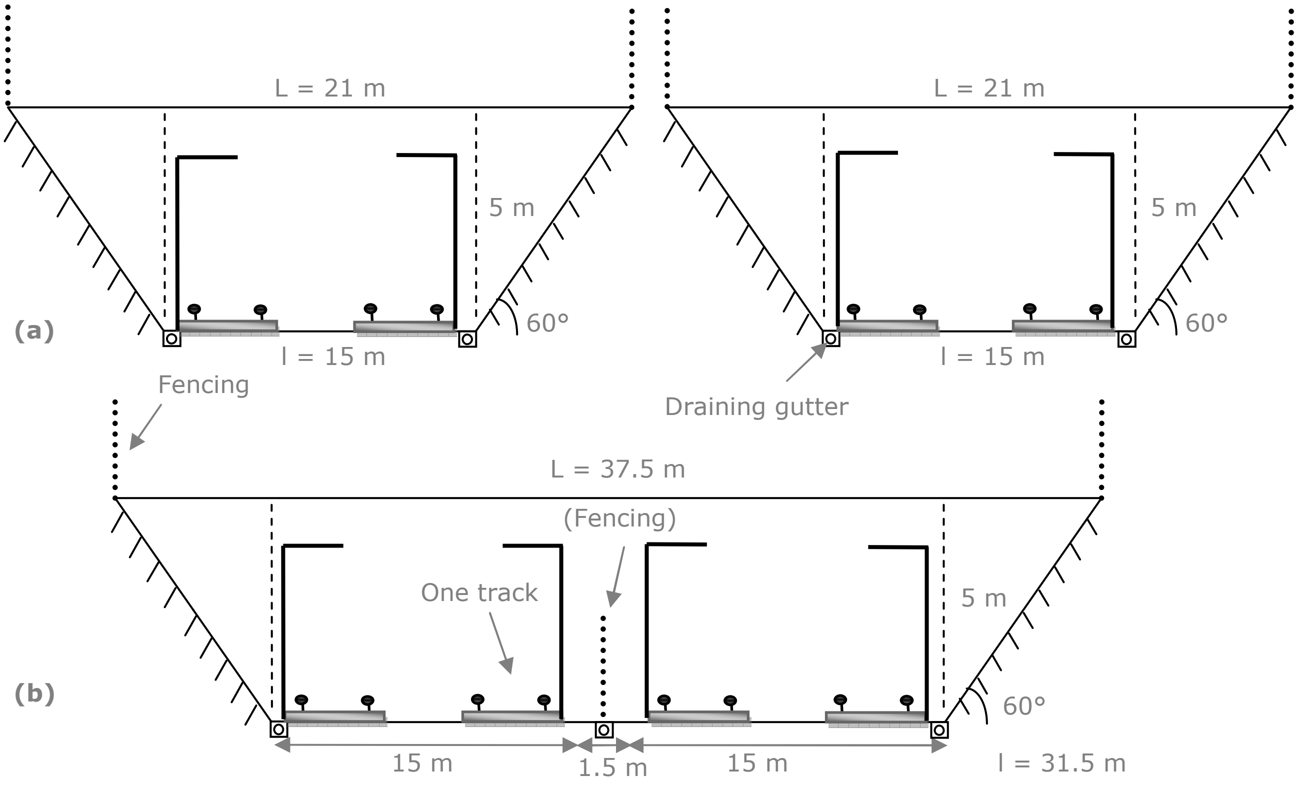

Figure 1.1 Configurations of (a) 2 double-track lines and (b) one 4-track line

For maintenance purposes, a minimum space of 1.5 m between overhead line pylons, combined with fencing, is needed in order to ensure the safety of personnel during maintenance operations (and therefore avoid stopping traffic).

The characteristics of these two configurations are listed in Table 1.1.

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Table 1.1 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
Trench	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:

- Trench 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 the following table.

Table 1.2 Possible savings due to 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). All costs are given in 2008 economic conditions, and do not include optimism bias, land acquisition costs, professional fees, or provisions.

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**, compared to 2 x £14.1 million per km for two segregated lines (9% overall saving).

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,** compared to 2 x £11.3 million for two segregated lines (15% overall saving).

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,** compared to 2 x £10.8 million for two segregated lines (10% overall saving)**.**

1.2.2 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.[1]

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

- 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[2]. A more precise estimation requires 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 unlikely to be room to build the necessary number of 400-metre platform tracks in a single station.

In order to reduce headway conflicts on line, route conflicts at stations between departures and arrivals and to provide some flexibility, the 4-track high speed line should split into two lines that lead up to two operationally independent London stations, even if these are contained within a single location. Some platform tracks may be useable by both lines. The number of platforms depends on how many trains per hour can be expected and the necessary turnround time. The station capacity should be consistent with that of the track rather than a specific timetable, but it is anticipated that some trains will serve Heathrow or Europe rather than .central London. Based on a single station operating 4 sequences of 3 trains arriving and departing with 4-minute headways (ie 12 trains per hour to/from London), and with a standard reversing time of 30 minutes, 8 platforms are considered to be the theoretical minimum. This would allow each platform to remain free for 10 minutes between a departure and an arrival.

However, this theoretical minimum is unrealistic because:

- It would make it necessary to establish the timetable only as a function of the London termini.
- A minimum of 6 minutes must be added for routing the train to and from the platform track. With these 6 additional minutes taken into consideration, the platform tracks are only free for 4 minutes between a departure and an arrival.
- Some trains will not reverse, but rather will shunt to/from the depot, thus creating additional movements.

To cope with a flight of delayed trains and more generally to provide reliable service, a minimum of two additional platforms is necessary per elementary station, implying a total of 20 platforms.

The unit costs of major structures for a four-track high-speed line are presented in Table 1.3.

Table 1.3 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*

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

1.3 Cost of Phased Construction of a 4-track HSL

The costs established above assume that all four tracks are built in their entirety in a single phase. However, it is quite possible that, in the initial years of operations, the demand will be such that 2 useable tracks will be sufficient. Only later, as the nationwide high speed network grows, will the use of all four tracks become necessary.

It is thus logical to wonder to what extent capital expenditures can be delayed in order to make the overall business case more attractive.[3]

The following sections address the following questions:

- Which works must be carried out in the first phase, and which can wait until the second?
- Given that there is some excess cost associated with the decomposition of the works into two phases, how many years must separate the two in order for the two-phase option to become more economically attractive than the single-phase option?

1.3.1 Scheme of the two double-track lines

Two different layouts can be envisaged for a four-track line, depending on the choices made in terms of operation.

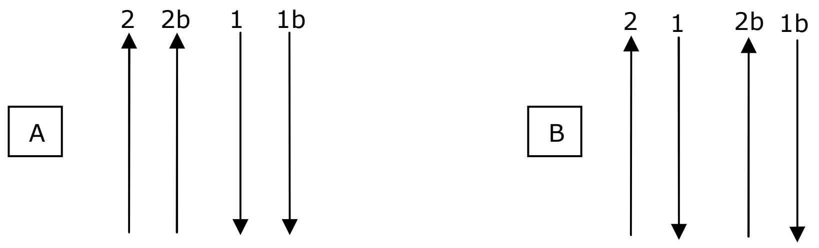

Figure 1.2 Two schemes for four-track lines

Scheme (A) is probably less expensive to build, in particular with regards to the construction of junctions. Scheme (A) also provides for easier operations in the case of an incident, as it would be possible to transfer traffic directly to the adjacent track with the same direction. Scheme (B) offers the possibility to independently operate both lines. At this stage, the scheme is not chosen, but it is worth pointing out that the economic attractiveness of the two-phase option depends on this choice.

If scheme A is chosen, there are again two phasing possibilities:

- (A-a): the left-hand pair of tracks is first built as an independent two-track line, then, when necessary, the right-hand pair is built (n°1/1b), and finally the direction of track initially n°1 is reversed to become n°2b (see Figure 1.3).
- (A-b): the two central tracks built first (n°2b/1) and then, when necessary, the two external tracks are built (n°2/1b).

[3] The use of a discount rate in the business case expresses the assumption that a pound spent today has more value than a pound spent tomorrow. For example, if an expense of £100 can be delayed by a year, at a discount rate of 3.5%, it will appear as an expense of only £96.50.

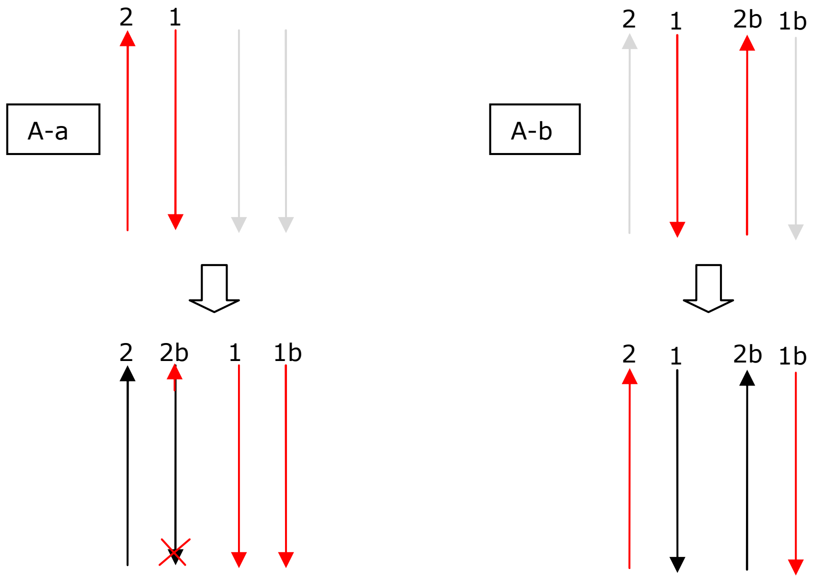

Figure 1.3 Phasing possibilities for scheme A

Thought it is difficult and risky at this stage to make declarations on the economic wins of each option, it should nevertheless be noted that:

- (A-a) will lead to the construction of cross-overs every 30km that will lose their usefulness as soon as the second phase is built.These are mandatory in a (2/1) configuration, but will not procure operating advantages in a (2/2b) configuration. The cost of reversing the direction of a track is very low for tracks with TVM430 or ERTMS[4].
- (A-b) will also lead to the construction of cross-overs that will no longer be used once phase two is built. However, the most problematic issue is that construction of phase two will interfere with two live railways (construction of a track in the vicinity of an operated track and junctions to this track), which could lead to expensive indemnities for operators.

Scheme (B) is considered at this stage as the most relevant choice in terms of ordinary operating constraints and possibility of phasing. The economic attractiveness of doing so will be assessed in the next paragraphs.

1.3.2 Land acquisition

Two-stage construction requires total land acquisition in the first phase. If not, constructions in the vicinity of the first pair of operated tracks would lead to the technical or financial impossibility of building the second pair of tracks.

1.3.3 Embankments

There are always risks when building a new embankment adjacent to an existing one. The second embankment is not totally pressed down, whereas the old one has reached its equilibrium. The settling of the new embankment may destabilize the old one, and thus costly special measures must be taken to prevent this destabilization. We therefore do not recommend this option.

[4] Limited to a reconfiguration of sections

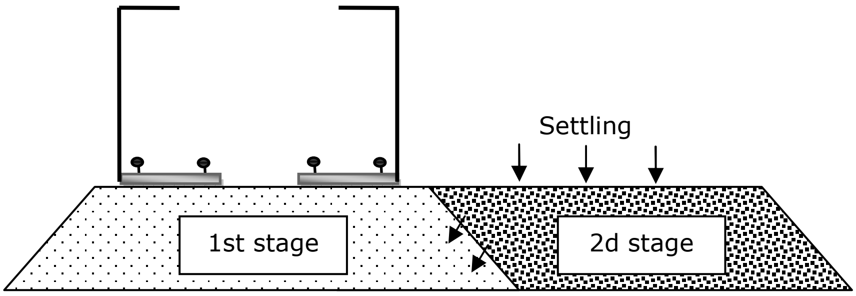

Figure 1.4 Interaction between embankments

1.4 Comparison of options for two-phase construction

When two-stage construction is chosen, two different options are possible:

- First option: total construction of civil works, equipment of the first line (in red in Figure 1.5), then, 5, 10 or 15 years later, equipment of the second line and linking to existing networks (in black).
- Second option: total construction of the first line (in red), then, when needed, construction of the second line, on the reserved land (in black).

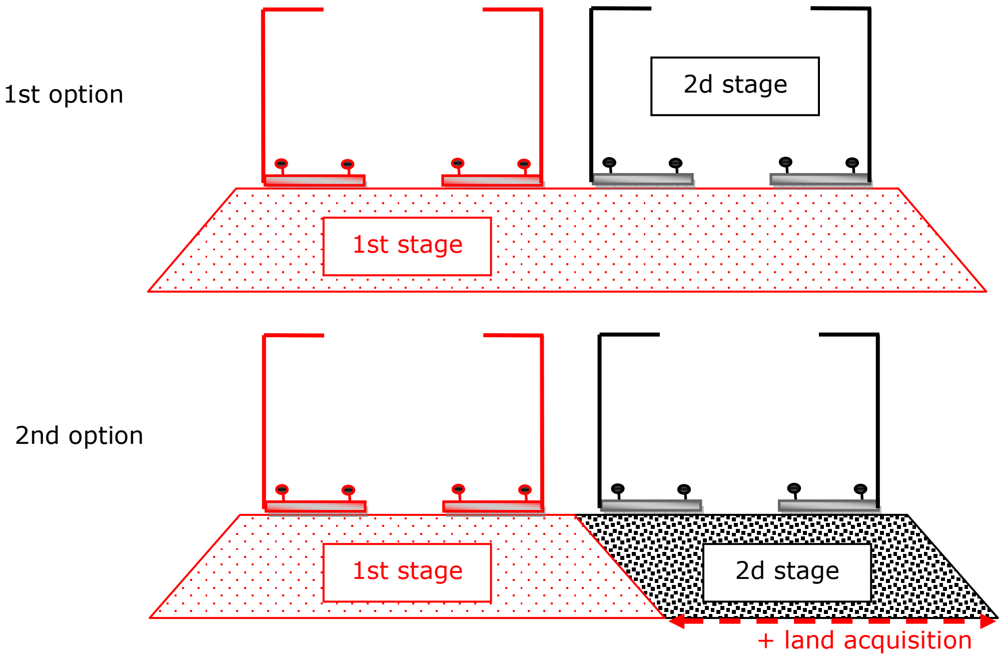

Figure 1.5 Phasing options

The following tables summarise the advantages and drawbacks of each option.

Table 1.4: Assessment of phasing option 1, in which all earthworks are carried out in phase 1

Advantages	Drawbacks
Savings of the system costs of the second line between the two construction periods	Construction of civil works without immediate use
Permanent land acquisition	Necessity to recreate work bases for equipment of line 2 (loss of synergy)
Protection measures and equipment on rail shoulder are in their final configuration	Works in immediate proximity of a high speed operated line and possible need to allot space for engine circulation
	Linking and homogenization of the signalling system on operated lines (early reservations to be made in signalling boxes for control equipment and control of future routes) Laying down of points on live railway Early reservations to be made in sub-stations (space, initiation of junctions...)

Table 1.5: Assessment of phasing option 2, in which earthworks associated with tracks 3 and 4 are carried out in phase 2

Advantages	Drawbacks
Saving of the total costs of the second line between the two construction periods	Necessity to recreate work bases for civil works (including tunnels and viaducts, due to the assumption of segregated constructions) and equipment of line 2 (loss of synergy)
	Works in immediate proximity of a high speed operated line
	Protection measures and equipment to be destroyed and rebuilt: fencing, anti-noise barriers, landscaping, etc.
	Linking and homogenization of the signalling system on operated lines (early reservations to be made in signalling boxes for control equipment and control of future routes) Laying down of points on live railway Early reservations to be made in sub-stations (space, initiation of junctions...)
	Total land acquisition mandatory at the first stage
	Grade-separated junctions between the two lines have to be built at first stage
	New earthworks and excavations adjacent to those built in first phase particularly expensive and dangerous, not recommended

1.5 Effect of discount rate on cost

1.5.1 Cost with discount rate of a 4-track HSL

Building a 4-track high-speed line is anticipating the future. As the current traffic does not require an immediate use of these 4 tracks, it could be advantageous to build them in two stages. Nevertheless, we have seen that:

- Only one scheme of tracks is applicable if built in two stages: scheme B (see Figure 1.2) in which the two lines are operated separately (except for some possible junctions). Thereby, scheme A, which could have been theoretically applicable in terms of operation, is automatically rejected.
- Only one option of building is recommended: option 1 (see Figure 1.5) in which all civil works are constructed in the first phase. Option 2 would be more risky and insecure and therefore generate additional costs.

Thus, the question to be answered is: **after how many years is it economic to build the second phase of the line (equipment of line 2), considering the discount rate of the project?**

A first assessment would be to calculate the minimum time interval of relevance as described succinctly below.

Calculations show that:

- The cost per km of a 4-track line on easy terrain built in one phase would be £18.4 million or **£19.0 million** including land acquisition.
- The cost of the first stage would be the cost of the whole civil works (£10.1m) plus the cost of equipment of line 1 (£4.2m) plus the total land acquisition cost (£0.6m[5]), that means **£14.8 million.**
- **The second stage** would cost the price of equipment of line 1 (£4.2m) plus a 25% increase due to the difficulties generated by this type of building (twinning, live railways…). In the end, the cost would be **£5.3 million per km.**

Considering a discount rate of 3.5% per year during the first 30 years and 3% beyond, a simplified approach would therefore be to calculate the year n such that:

$$Cost_{stage1} + Cost_{stage2}\frac{1}{(1+3.5\%)^n} < Cost_{4-track}$$

i.e. $$14.8 + 5.3.\frac{1}{(1+3.5\%)^n} < 19$$

The result is **n>7 years.**

This means that if the interval between construction of the two phases is greater than seven years, it is cheaper to construct two independent 2-track routes than a single 4-track route.

It is of course a very simplified approach, and it would be necessary to complete these approximations by:

- Characteristics of the infrastructure and the necessity (or not) of building major constructions (such as grade-separated junctions) in the first phase;
- Spreading of investments;

[5] Calculated on the assumption that the needed area for a 4-track line is 33% more than the area needed for a 2-track line.

- Traffic forecasts: a greater offer could bring more traffic and make the early 4-track building more relevant.

1.5.2 Cost with discount rate of a 4-track HSL versus that of two double-track HSL

When discount rate is taken into consideration, the construction of a 4-track HSL in two phases is likely to come out to be more expensive than the construction of two double-track HSL in two phases.

This point is illustrated in Figure 1.6, which illustrated costs in 1 phase of construction and Figure 1.7, in which we have considered that the two phases are 15 years apart.

The 4-track line may appear to be slightly less expensive than two double-track lines in constant currency (or if all construction occurs in one phase, as illustrated in Figure 1.6).

However, imagine that construction will be undertaken in 2 phases, 15 years apart, with a 3.5% annual discount rate.

In the case of two double-track lines, a full 50% of the investment cost can be postponed until the 2nd phase. Thanks to the discount rate the "cost" of the second phase has dropped by 40% from about £10.5m to about £6.3m per km. This means that the total cost of construction of the two lines is only 80% of the cost in constant currency. That is, for at-grade infrastructure that would cost £21.1 million in constant currency, as far as the business case is concerned, only about £17 million have been spent per 4 km of tracks.

As described above, in the case of a 4-track line, only about 26% of construction cost can be postponed until phase 2 (£5.3 million out of £20.1). With a 15-year wait the perceived cost of phase 2 is £3.1m instead of £5.3m, and thus, as far as the business case is concerned, £18 million have been spent per 4 km of tracks.

In this particular case (at-grade infrastructure on easy terrain) overall costs of building a single 4-track line exceed those of building two 2-track lines if the two construction phases are 7 years apart or more. The more the second phase is delayed, the wider the gap between the cost of the two options. For example, if 10 years separate the two phases, a km of 4-track line is only about £600,000 more expensive, but if 30 years separate the two phases, a km of 4-track line is £2.4 million more expensive than a km each of two 2-track lines.

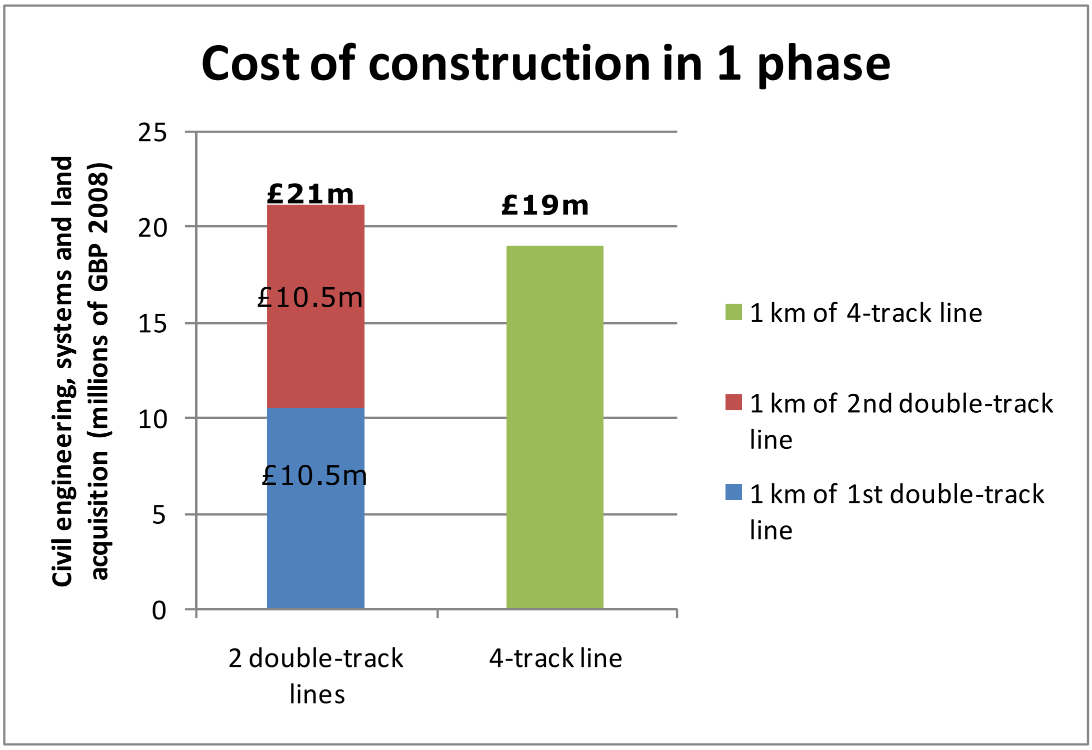

Figure 1.6: Cost of construction in 1 phase: 1 km of 4-track line or 1 km each of two 2-track lines. Cost includes civil engineering, systems and land acquisition for at-grade construction on average terrain.

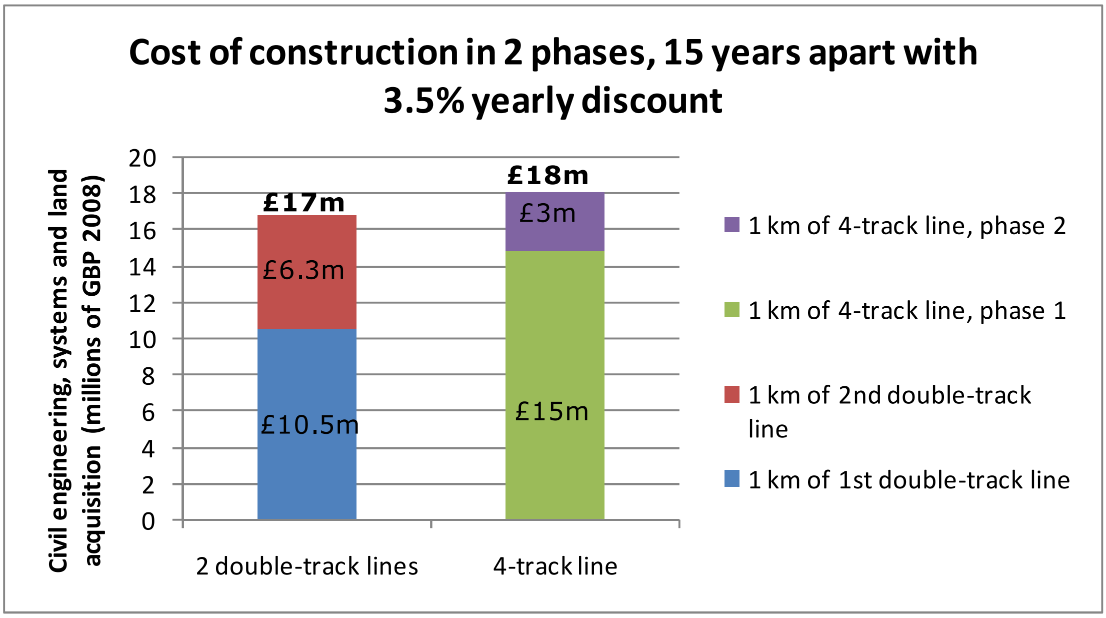

Figure 1.7: Cost of construction in 2 phases, 15 years apart, with 3.5% discount rate: 1 km of 4-track line or 1 km each of two 2-track lines. Cost includes civil engineering, systems and land acquisition for at-grade construction on average terrain.

Appendix D – Tunnelling Costs

Contents

1 Introduction

The purpose of this document is to examine the relationship that may exist between the cost of tunnel construction and, ultimately, the speed at which trains may pass through the tunnels.

Because of aerodynamic and pressure effects, it may be necessary to build tunnels with larger cross-sections in order to allow trains to pass through the tunnels at greater speeds. (Though in the case of underground stations, safety concerns, rather than tunnel cross section, may limit train speeds.) Furthermore, if all other factors are identical, a tunnel with a larger cross-section is likely to cost more to build than a tunnel with a smaller cross-section.

This document seeks to determine whether it is possible to define separate *preliminary and generalised* unit costs for the construction of a tunnel in function of desired train speed through the tunnel.

2 Calculation of free and excavated tunnel sections in function of max train speed

Though aerodynamic considerations are only one of the various aspects that determine tunnel cross section dimensions, in the design of high speed lines aerodynamic considerations are often the most important. For a design speed of 250 km/h or less, however, it is not demonstrated that aerodynamic criteria are the most suitable for cross section area design. Attention should be paid to other criteria, such as train gauge, space for walkways, clearance for any fixed equipment in the tunnel (jet fans, ...), etc.

The determination of the size of the free cross section on the basis of aerodynamic considerations is conducted according to UIC Code 779-11.

It is based on the following assumptions:

- Case 1
  - Regular lining of the tunnel (no hewn rock)
  - Single tunnel with two tracks
  - Two identical trains can circulate in the tunnel, on opposite tracks
  - Tunnel length: 2000 m
  - Train length: 200 m
  - **Non-sealed train**
  - Base-line comfort criteria: The pressure experienced by a passenger on board a train should not exceed a change of 4.5 kPa within a period of 4 seconds
- Case 2
  - Regular lining of the tunnel (no hewn rock)
  - Single tunnel with two tracks
  - Two identical trains can circulate in the tunnel, on the opposite tracks
  - Tunnel length: 2000 m
  - Train length: 200 m
  - **Sealed train**[1]

---

[1] Sealed trains are normally insulated against rapid pressure changes occurring in the interior of the train. Tunnel cross-sections are nonetheless determined such that, in the case of a rupture in the train's seal, passengers would experience no negative medical effects.

– Medical health criterion

The following tables presents the preliminary results of the calculation of the free cross sectional area for cases 1 and 2 and for different train speeds at the entry to the tunnel.

It must be pointed out that accurate sizing of a tunnel's cross section and optimisation require the use of numerical simulation tools. For a preliminary approach many curves have been derived (in particular by the International Union of Railways) to give preliminary values for tunnel cross sections considering the key parameters above.

The free cross sections calculated are based on aerodynamic effects only. It is possible that free tunnel sections may need to be larger (particularly for 250 km/h) in order to accommodate equipment, passageways,...

		Case 1	
Train speed entering the tunnel	[km/h]	250[2]	300
Blockage ratio (B)		0.12	0.10
Train cross-sectional area	[m²]	11	11
Tunnel free section	[m²]	91	110
Equivalent diameter (d_{eq})	[m]	10.8	11.8

Figure 1: Calculation of the free cross sectional area for case 1

		Case 2	
Train speed entering the tunnel	[km/h]	250	300
Blockage ratio (B)		0.245	0.17
Train cross-sectional area	[m²]	11	11
Tunnel free section	[m²]	45	64
Equivalent diameter (d_{eq})	[m]	7.5	9.1

Figure 2: Calculation of the free cross sectional area for case 2

Figure 3 presents a database of ratios between the excavated cross section and the free cross section on high speed line (HSL) single bore tunnels. This ratio has an average value of 1.49:1, a minimum value of 1.41:1 for the LVG Atlantique (France) Vouvray tunnel and a maximum value of 1.59:1 for the HSL Bruxelles – Germany tunnel.

[2] It should be noted that the free cross sections are calculated based on aerodynamic effects.The necessary cross section for trains travelling at 250 km/h, *calculated only on the basis of aerodynamic effects*, is thus larger than the cross-section that would be required for trains travelling at 230 km/h. **At these speeds, however, it is likely that free cross section must be greater than that determined solely on aerodynamic effects**, in order to take account of factors such as train gauge, evacuation passages, etc.

High Speed Rail Line	Tunnel name	Excavation	Length (m)	Free tunnel section (m²)	Excavated section (m²)	Speed design (km/h)	Ratio Excavated section / Free section
Atlantique (France)	Vouvray	Traditional method.	1,496	71	100	270	1.41
Paris-Marseille (France)	Pennes-Mirabeau	Traditional method, use of partial-mechanised blasting techniques, full section excavation.	1,530	63	90	230	1.43
Taiwan High Speed Rail (Taiwan)		Traditional method.	2,000	90	130	350	1.44
Paris-Marseille (France)	Tartaiguille	Traditional method according to Lunardi, full section excavation.	2,430	100	150	320	1.50
Paris-Marseille (France)	La Galaure	Traditional method with pre-cut.	2,759	100	150	320	1.50
High Speed Rail Line Cologne - Rhine / Main (Germany)	Schulwald Tunnel	Constructed in mining technique, headed with excavators and drilling and blasting.	4,460	92	140	300	1.52
Paris-Marseille (France)	Marseille	Traditional method, use of partial-mechanised blasting techniques, full section excavation.	5,414	63	90	230	1.43
HSR - Thalis Paris / Amsterdam	Groene Hart tunnel	Driven with a slurry shield TBM using a hydraulic mucking out system.	8,636 m, of which 7,155 is bored tunnel	109	174	300	1.59
Seoul - Busan (Korea)		Traditional method (TBM to get past the rivers).	10,200	107		350	
Seoul - Busan (Korea)		Traditional method (TBM to get past rivers).	18,000	107		350	

High speed passenger railroad Tohoku Shinkansen (Japan)	Iwate-Ichinohe Tunnel	Depending on the geology, drill and blast or mechanical excavation and full face or bench cut methods.	25,810	61.9	70 to 85	256 (Operating speed)	
HSL Brussels-German border	Tunnel de Soumagne	First mechanical excavation, then drill and blast.	6,405	69	110	200	1.59

Figure 3: Ratio between excavated section and free cross section in constructed HSL single bore tunnel

On the basis of those ratios Figure 4 and Figure 5 present the range of excavation area that could be expected for case 1 and case 2 depending on the speed of the train entering the tunnel.

		Case 1		
Train speed entering the tunnel	[km/h]		250	300
Tunnel excavation section	[m²]	Min	129	154
		Max	145	175
		Average	136	163
Equivalent diameter (deq)	[m]	Min	12.8	14.0
		Max	13.6	14.9
		Average	13.2	14.4

Figure 4: Calculation of the excavation sectional area for case 1

		Case 2		
Train speed entering the tunnel	[km/h]		250	300
Tunnel excavation section	[m²]	Min	63	91
		Max	71	103
		Average	67	96
Equivalent diameter (deq)	[m]	Min	9.0	10.7
		Max	9.5	11.4
		Average	9.2	11.1

Figure 5: Calculation of the excavation sectional area for case 2

It should be noted that tunnel free cross section is not the only factor that determines the top speed of a train through a tunnel. In the case of an underground station in a tunnel, speed may be limited in order to limit pressure effect risks for underground platforms (TSI infrastructure point 4.3.3.27).

3 Calculation of cost in function of excavated tunnel section

3.1 Observed costs

An analysis of real and estimated excavation costs in function of cross-section area shows that there seems to be no clear general relationship between these two data. Indeed a tunnel with a smaller cross-section excavated in difficult geological conditions may be much more expensive than a tunnel with a higher excavation section bored in favourable geological conditions.

Figure 6 below shows a sample of tunnels, with their cost per km and excavated cross-section. Figure 7 presents a graph of these costs per km of tunnel in function of excavated cross-section.

	Year	State	Length (m)	Excavated Section (m²)	Excavation	Ground Conditions	Design Speed (km/h)	Cost / km (millions of EUR, 2008 ec)
La Encrucijada-Puerto Cabello	2001-2010	Under Construction		73	Drill and blast	Gneiss-granite (RMR IV)		48
Marhar (Morocco)	2009	Under study	970	169	Traditional	Class RMR IV and III	350	42
TGV Atlantique - Sceaux	1984	In Operation	827	100	Presplitting			36
TGV Atlantique - Fontaney	1984	In Operation	474	95	Presplitting			35
TGV Sud Tunnel of Bonpass	1998	In Operation	303	145	Traditional / divided section	Caumont shale, without water		31
LGV Brussells - German border Tunnel TGV de Soumagne	2005	In Operation	6405	110	Partial face machine, then explosives	Schist and limestone	200	25
LGV Est - Tunnel of Saverne		Under study	4019	160	Traditional	Sandstone, limestone and shale	350	23
LGV Madrid - Sud Tunnel of Cartama	2006	In Operation	3019	128		Rock		20
TGV Atlantique - Vouvray	1985	In Operation	1498	100	Traditional			13
La Encrucijada-Puerto Cabello	2001-2010	Under Construction		73	Drill and blast	Gneiss-granite (RMR II)		13

Figure 6: Data base on tunnel excavation costs for railway tunnels (mainly HSL)

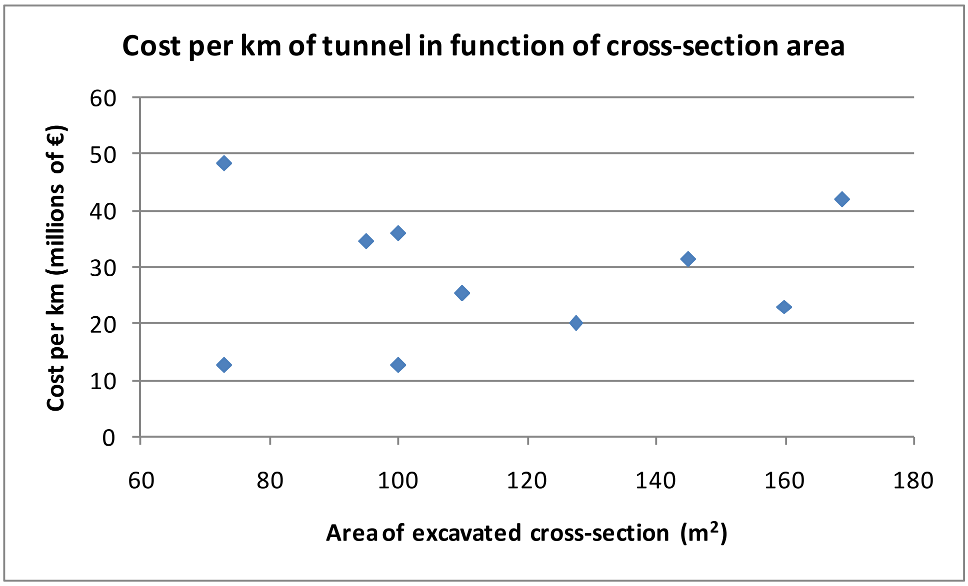

Figure 7: Graph of cost per km of tunnel in function of area of excavated cross-section

Geological conditions appear to be a much more decisive criterion than tunnel section when an initial evaluation is to be made of the excavation cost of a tunnel. Indeed, Figure 7, which is a mapping of the data in Figure 6, indicates that no strict correlation can be found between cost per km of tunnel and the cross-section area excavated for tunnels built in varying geological conditions.

Data from "La Encrucijada – Puerto Cabello" tunnels corroborates this observation. Indeed the foreseen excavation price is almost four times higher for excavation in poor geological conditions (48,300 €/m for excavation in rocks of RMR class IV) than for excavation in favourable geological conditions (12,575 €/m for excavation in rocks of RMR class II).

Finally it should be pointed out that the excavation cost of a tunnel with a large cross section will be higher for the same geological conditions than the excavation cost for a tunnel with a small cross section. However we cannot identify a clear relationship between cost and cross section dimension.

3.2 Case study

The High Speed Rail Development Programme remains an extremely preliminary study. The constraints of this study make it impossible to evaluate the cost of each individual tunnel (including an assessment of the specific geological conditions in each case).

Thus, costs of different types of HSL infrastructure (at-grade track on different types of terrain, viaducts, tunnels) are evaluated on the basis of generalised unit costs (cost per km of the given infrastructure), as discussed in the Workstream 3 report.

As indicated above, though (in otherwise identical conditions) in general the cost per km of tunnel increases as the size of the excavated cross-section increases, the size of the cross-section is not necessarily the primary factor in the estimation of tunnel cost.

Nonetheless, as interest in the relationship between train speed through tunnels and tunnel cost is very high, we have carried out the exercise of, *for a specific case study,* determining the ratio between the cost of a 250 km/h tunnel[3] and the cost of a 300 km/h tunnel.

It is extremely important to remember that this ratio does not necessarily apply to conditions differing from those in the case study.

This exercise has been carried out based on a more-detailed version of case 2 (described in section 2):

- Regular lining of the tunnel (no hewn rock)
- Single tunnel with two tracks
- Two identical trains can circulate in the tunnel, on the opposite tracks
- Tunnel length 2000m
- Train 200m long
- Sealed train
- Medical health criterion
- Tunnel excavated in non weathered and low-fracture granite
- Based on the calculations presented in Figure 5, costs are estimated for a tunnel with an excavated cross-section of 70 m^2 (allowing trains to pass at 250 km/h) and an excavated cross-section of 100 m^2 (allowing trains to pass through the tunnel at 300 km/h).

The ratio of the excavation costs of a 70 m^2 free cross-section tunnel (250 km/h) as compared to those of a 100 m^2 tunnel (300 km/h) *in the conditions described above* is around *1:1.33*.

Appendix E – Anglo-Scottish Links

Contents

1 Introduction

The purpose of this document is to evaluate and compare the overall costs and journey times related to different possible high speed routes linking Scotland and England. A route is considered to be a rail connection between two points that follows an identified corridor and/or passes via well-identified points.

The following Anglo-Scottish routes are evaluated:

- West Coast route from Manchester to Glasgow via Carlisle, with a connection at Carstairs leading to Edinburgh
- East Coast route from Newcastle to Edinburgh (passing near Morpeth, Berwick on Tweed and Dunbar) and through to Glasgow via Carstairs
- Direct Newcastle-Glasgow route via Carstairs, with a connection at Carstairs leading to Edinburgh

The assumption is made that ultimately any high speed Anglo-Scottish connection will not be standalone, but rather will be linked to a complete route to London. Therefore, though the work concentrates on the Anglo-Scottish routes and their variants, some consideration is of necessity granted to the routes used to link London and Northern England.

Indeed, the consideration of each Anglo-Scottish route in the context of a complete Scotland-London connection makes a comparative analysis possible. The routes and their variants are not only compared with each other, but are also examined in terms of a key criterion: whether the routes can provide Edinburgh/Glasgow-London journey times of 3 hours or less.

2 Approach

2.1 Regarding upgrades of classic lines

Workstream 3 provides generalised unit costs for the upgrade of a classic line. It is common practice to apply these costs to each km of upgraded classic line in a preliminary study. Here, however, we have been asked to take a closer look at the potential for using existing lines to link England and Scotland.

A more detailed costing of upgrading existing classic lines, along with a more detailed analysis of attainable journey times, would mean examining:

- Current gauge in tunnels, under bridges, at station platforms, etc.
- Specific curve radii of existing lines, both in plan and in profile
- Existing cant in curves
- Progression of passenger traffic
- ...

Once the existing conditions are identified, it would be necessary to carry out a detailed analysis in order to define and cost the work to be done for each curve, for each bridge, for each tunnel, etc.

As such a task is beyond the scope of the High Speed Rail Development Programme, a detailed analysis of the costs and speeds associated with an upgrade of existing classic lines has not been carried out.

2.2 Classic line assumptions

In light of the fact that it is not possible to carry out a detailed analysis of infrastructure upgrades at this stage, we propose an alternative approach to evaluating the way in which certain sections of classic line may be utilised in the absence of any upgrading of the future high-speed Anglo-Scottish connection.

We assume that there are two major types of infrastructure:

- New high speed lines (HSL), for which the cost per km depends on the civil engineering required (tunnel, viaduct, at-grade on average terrain, etc.)
- Reutilised classic lines (CL), for which absolutely no cost per km is assessed

All options evaluated are composed of different combinations of new HSL and reused CL, in order to determine which tradeoffs may be made in terms of cost and journey time.

The following assumptions are applied to the classic lines:

- Speeds will not exceed existing speeds.
- For any classic lines that are not currently electrified, they will be by the time the HS services begin, and the cost of electrification will not be attributed to the HSL project.
- Only British gauge trains may use these lines.

Depending on the line, these reused sections of classic line may or may not retain non high-speed passenger or freight services, in addition to high-speed services. The impact that this sharing of infrastructure may have on line capacity and journey times is outside the scope of the current document.

All routes and variants are evaluated only according to journey time and construction cost.

It is nonetheless important to keep in mind that the construction of all-new high-speed infrastructure, as opposed to the reuse of classic lines, offers two important advantages (that are not quantified in this document):

- Extra rail capacity is provided.
- New infrastructure allows for the use of UIC gauge duplex trains up to 400m long, and thus a maximum number of seats per train.

2.3 Costs

2.3.1 Approach

Only the capital costs of new high speed lines (infrastructure, systems, land acquisition, professional fees and provisions) are included in this evaluation. All prices are in constant 2008 GBP, and optimism bias (OB) is not included. As mentioned above, no cost is assessed for reused classic lines.

Cost assessments are produced in two steps:

1. Hypothetical HSL alignments are defined. The approach used to define these alignments is described in the following section.
2. Unit costs are applied to these alignments. These costs are described in Workstream 3.

The objective of the current document is to offer a comparative analysis of the cost and journey times of potential high speed routes. As the cost of remodelling or building stations could vary enormously in function of factors unrelated to the choice of routes, station costs are excluded from this analysis.

2.3.2 Alignments

Alignments consist of two elements:

- Horizontal alignment, that is where the high speed line goes.
- Infrastructure. All sections of line are assigned a type of infrastructure in order to estimate cost: at-grade on easy terrain, at-grade on difficult terrain, viaduct, tunnel, etc.

In general alignments follow an existing motorway or rail corridor, though they may diverge from the existing corridor if a less expensive path seems possible elsewhere.

With the exception of Newcastle and London, the access to city centre stations is assumed to be accomplished at least partially via existing classic lines in order to reduce cost. Both Newcastle Station and London are accessed via newly-built tunnels; London because of lack of capacity for additional services; Newcastle because the route north is very curvaceous as far as Morpeth (17 miles). The cost of these tunnels, but not of the stations, is included in the overall costs.

Where possible, curve radii are large enough to allow a theoretical maximum speed of 350 km/h. Though the gradients of the natural terrain are taken into consideration when designing alignments and when choosing infrastructure, the detailed profile (exact gradients of the line, extent of earthworks, etc.) of the alignments has not been determined.

At this preliminary stage, these alignments should be considered reasonable hypotheses that are necessary in order to estimate infrastructure cost.

2.4 Complete London-Scotland connection

Each of the Anglo-Scottish HSL scenarios must be evaluated in the context of a complete London-Scotland connection in order to determine overall costs and London-Scotland journey times.

Therefore each of the Anglo-Scottish scenarios is evaluated as if it were part of a complete London-Scotland high speed line, with one or two possible London-Northern England routes.

Only the costs of the high speed lines leading from London to Northern England that are part of the London-Scotland connection are included. Costs of spurs to city centres or branches in other directions are not included. As mentioned above, the cost of building or remodelling stations is not included.

The following English routes are used:

- London to Manchester via the M40 corridor. The HSL by-passes both Birmingham and Manchester, which are served by spurs. (As mentioned above, the costs of these spurs are not included.)
- London to Newcastle via the M1 corridor. The HSL by-passes Leeds and city centres in the East Midlands, which are served by spurs. (The costs of these spurs are not included.)
- London to Newcastle via the M11 corridor and then past Cambridge and Peterborough. The HSL by-passes Leeds and city centres in the East Midlands, which are served by spurs. (The costs of these spurs are not included.)

2.5 Journey times

Journey times are estimated based on the performance of the TGV-R and on deceleration patterns imposed by the TVM 430 signalling system. At this level of study both gradients and weather conditions (wind, etc.) are ignored. A 7% punctuality margin is added to all journey times.

The maximum speed on new high speed infrastructure is assumed to be 320 km/h.

For a given route scenario, two variables in particular can affect overall journey times:

- Speed through tunnels. As discussed in the technical note on tunnel costs, maximum speed through tunnels (assuming that there are no platforms in the tunnel) may depend on the tunnel's free section. **The default maximum tunnel speed is considered to be 230 km/h**, but journeys time with a maximum tunnel speed of 300 km/h are also assessed.[1]
- Tilting or non-tilting rolling stock on classic lines. On the West Coast Main Line maximum speeds may be greater with tilting rolling stock (enhanced permitted speed). **By default the journey times on classic lines *in the Anglo-Scottish links* are based on standard, non-tilting maximum speeds.** Nonetheless, the journey times with tilt are mentioned when they differ from the journey times without tilt.

Variations in maximum speeds in tunnels are tested only for the Anglo-Scottish routes, not for the English routes.

The journey times assessed are minimum values, assuming that there are no intermediate stops between London and Scotland, and that the trains are not slowed by the presence of other services.

As mentioned above, in this part of the study we consider that, in general, access to city centres is via existing lines. It is important to keep in mind, though, that overall journey times could be improved if access to city centre stations were made via all-new (expensive) infrastructure.

It is important to note that journey times on high speed lines are indicative, and are based on the hypothetical alignments designed for this study (those on classic lines are based on

[1] Please see Appendix D for a discussion of the impact that tunnel design speeds may have on tunnel cost. No attempt is made here to differentiate between the cost of a 230 km/h and a 300 km/h tunnel. All things being equal, a 300 km/h tunnel would undoubtably have a larger cross section than, and thus be more expensive than a 230 km/h tunnel. Nonetheless, other factors (gelogical conditions in particular) are likely to have a much greater impact on tunnel cost than the tunnel's section.

actual line speeds). Factors that are impossible to determine at this stage (exact horizontal alignment of newly built infrastructure, profile, exact tunnel dimensions, curve radii, operating constraints, etc.) could cause these journey times to vary. Furthermore, as noted above, the hypothetical alignments used in this study are not the only possible alignments along these routes, and alternative alignments would naturally not produce exactly the same journey times.

In the same way, impacts that different maximum speeds (in tunnels in particular) may have on overall journey time are indicative, not exact.

3 Evaluation of costs and journey times

3.1 Overview of options

The following Anglo-Scottish routes are evaluated:

- West Coast route from Manchester to Glasgow via Carlisle, with a connection at Carstairs leading to Edinburgh
- East Coast route from Newcastle to Edinburgh (passing near Morpeth, Berwick on Tweed and Dunbar) and through to Glasgow via Carstairs
- Direct Newcastle-Glasgow route via Carstairs, with a connection at Carstairs leading to Edinburgh

These potential routes are presented schematically in Figure 3.1.

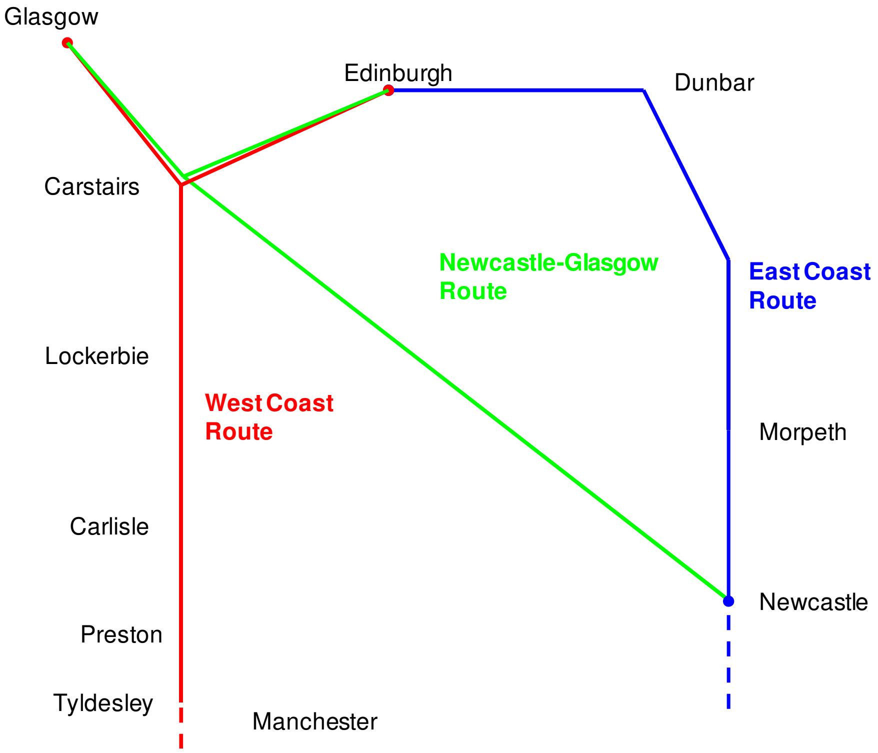

Figure 3.1: Possible Anglo-Scottish routes

Certain sections of the West Coast and the East Coast route may be made up of reused classic line either in all variants or in some variants. Figure 3.2 presents those sections that may be composed of reused classic line.

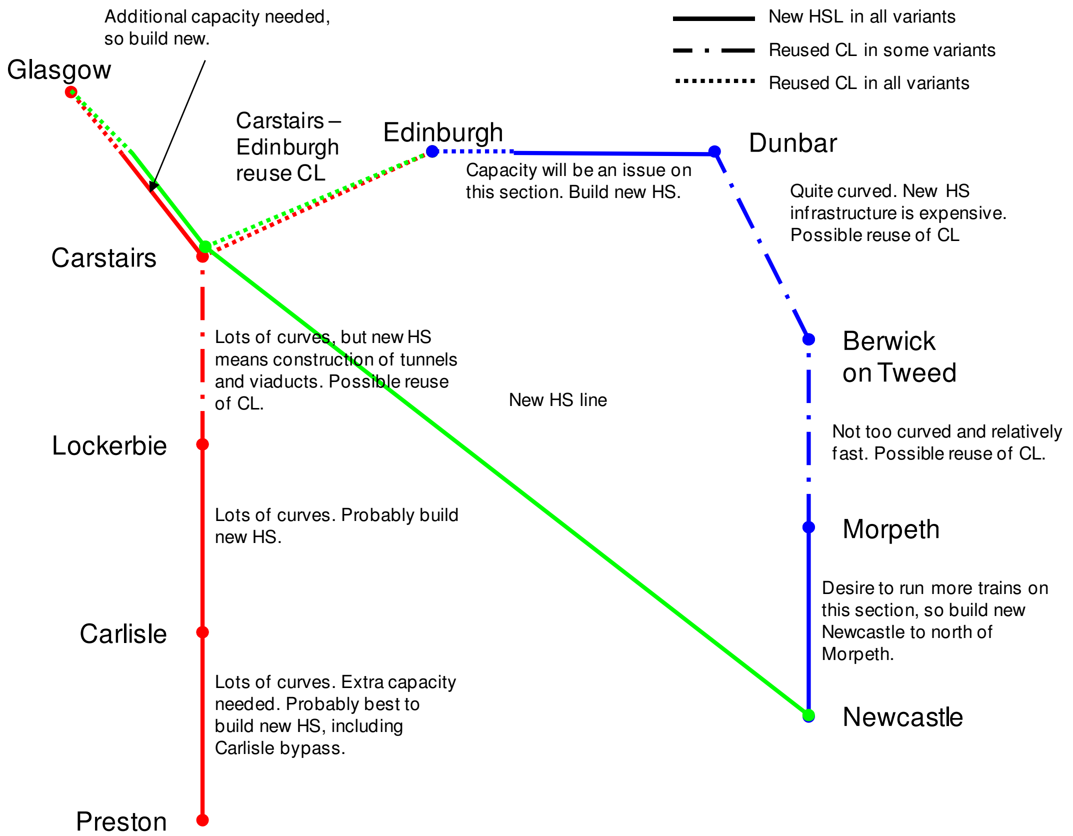

Figure 3.2: Route sections that may potentially be composed of reused classic line

3.2 West Coast route

For the purpose of this study, the West Coast Anglo-Scottish route is considered to stretch from outside Manchester, to Carstairs, and then branch to Glasgow and to Edinburgh.

In all cases the existing classic line is reused in order to run from Carstairs to Edinburgh and in order to access Glasgow.

The variants of the West Coast route are the following:

- All new high speed line (HSL) from West of Manchester to Carstairs
- Reuse of classic line between Lockerbie and Carstairs

These variants are presented in Figure 3.3.

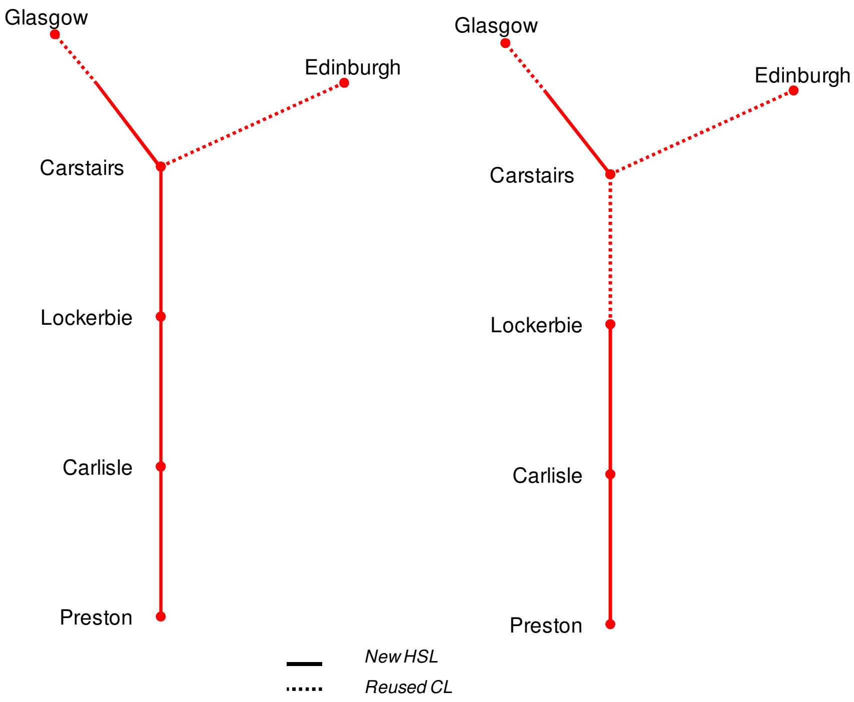

Figure 3.3: Variants of the West Coast Anglo-Scottish route

In order to assess total costs and journey times for the West Coast London-Scotland HSL, the HSL from London to outside Manchester is the route following the M40 corridor described in section 2.4.

Figure 3.4 summarises the characteristics of the high speed West Coast Anglo-Scottish route.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
W of Manchester to outside Preston	39	1	5	**44**	0	**44**	**950**	**22**
North of Preston to Carlisle	82	40	7	**129**	0	**129**	**3,730**	**29**
Carlisle to Lockerbie	37	4	0	**42**	0	**42**	**820**	**20**
Lockerbie to Carstairs (**all HSL**)	37	18	11	**67**	0	**67**	**2,120**	**32**
Carstairs to Glasgow, join CL approach Glasgow	33	0	0	**33**	19	**52**	**630**	**12**
Carstairs to Edinburgh	4	1	0	**5**	43	**48**	**140**	**3**
Total near Manchester to Edinburgh	**199**	**65**	**23**	**287**	**43**	**331**	**7,770**	**24**
West Coast Route from Manchester to Scotland	*232*	*65*	*23*	***320***	*63*	***383***	***8,400***	***22***
London to Manchester, M40 corridor						***307***	***6,280***	***20***
Total West Coast Route London Scotland, HSL						***689***	***14,680***	***21***

Figure 3.4: Characteristics of the high speed West Coast route to Scotland

Though there is a significant amount of expensive infrastructure to be built between Preston and Carlisle, this section must be composed of a new HSL line in order to provide more capacity.

The Lockerbie to Carstairs section likewise necessitates expensive infrastructure and indeed has the highest infrastructure cost per km of the entire route. It may be possible to reuse a section of existing classic line between Lockerbie and Carstairs in order to avoid the construction of this expensive new infrastructure, as the number of trains that currently run on this section is rather low.

The characteristics of the West Coast route, with some reuse of classic infrastructure between Lockerbie and Carstairs, are summarised in Figure 3.5.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
W of Manchester to outside Preston	39	1	5	**44**	0	**44**	**950**	**22**
North of Preston to Carlisle	82	40	7	**129**	0	**129**	**3,730**	**29**
Carlisle to Lockerbie	37	4	0	**42**	0	**42**	**820**	**20**
Lockerbie to Carstairs (**some CL**)	27	2	0	**28**	42	**70**	**550**	**8**
Carstairs to Glasgow, join CL approach Glasgow	33	0	0	**33**	19	**52**	**630**	**12**
Carstairs to Edinburgh	4	1	0	**5**	43	**48**	**140**	**3**
West Coast Route from Manchester to Scotland	*221*	*48*	*12*	***281***	*105*	***386***	***6,830***	***18***
London to Manchester, M40 corridor						***307***	***6,280***	***20***
Total West Coast Route London -Scotland, some CL between Lockerbie and Carstairs						***693***	***13,110***	***19***

Figure 3.5: Characteristics of the West Coast route to Scotland, with reuse of classic line between Lockerbie and Carstairs

About £1.5 billion is saved (without optimism bias), or about 10% of all HSR infrastructure cost (excluding stations) for the London-Scotland link, by using 40 km of classic line between Lockerbie and Carstairs.

So how do these variants perform in terms of journey time? As show in Figure 3.6, both variants of the West Coast route provide a journey time of under 3 hours to both Glasgow and Edinburgh.

English route	Anglo-Scottish route	Max speed tunnels (km/h)	London-Glasgow Len. (km)	London-Glasgow Journey time (min)	London-Glasgow Average speed (km/h)	London-Edinburgh Len. (km)	London-Edinburgh Journey time (min)	London-Edinburgh Average speed (km/h)
London-Manchester, M40 corridor	West Coast, HSL	230	641	**153**	251	637	**156**	244
London-Manchester, M40 corridor	West Coast, some CL between Lockerbie and Carstairs	230	644	**162**	239	641	**164**	234

Figure 3.6: London-Scotland journey times for the West Coast Anglo-Scottish HSL

Nonetheless, the variant with some classic line between Lockerbie and Carstairs loses about 10 minutes in overall journey time to both Glasgow and Edinburgh. The use of tilting rolling stock would provide journey time savings of 2 or 3 minutes for the option in which some classic infrastructure is reused between Lockerbie and Carstairs, thus reducing the journey time disadvantage to 7-8 minutes.

One way to determine the advantage of one variant over another is to identify the capital expenditure that would be necessary in order to save a single minute. The smaller the investment necessary in order to save a minute of journey time, the more likely it is that the investment is worthwhile.

Building an all-new HSL from Lockerbie to Carstairs would cost over £1.5 billion more than building a line that reuses some classic infrastructure on this section. Figure 3.7 shows that the more expensive infrastructure would save 9 minutes in journey time for a cost of £175 million per minute saved.

Proposed infrastructure	Instead of	Extra cost (m£)	Time saved (min)	Cost/min saved (m£)
All new HSL from Lockerbie to Carstairs on the West Coast route	Some reuse of existing CL	1,570	9	**175**

Figure 3.7: Cost per minute saved (London-Glasgow journey time) of building all-new HS infrastructure between Lockerbie and Carstairs (as opposed to reusing some existing classic infrastructure).

Figure 3.8 presents the effect on journey time if tunnels in Scotland allow for a top speed of 300 km/h. This hypothesis shaves around 5 minutes off overall London-Scotland journey times, as compared to a scenario in which trains are limited to 230 km/h in tunnels (which were shown in Figure 3.6).

			London-Glasgow			London-Edinburgh		
English route	Anglo-Scottish route	Max speed tunnels (km/h)	Len. (km)	Journey time (min)	Average speed (km/h)	Len. (km)	Journey time (min)	Average speed (km/h)
London-Manchester, M40 corridor	West Coast, HSL	300	641	**148**	260	637	**151**	253
London-Manchester, M40 corridor	West Coast, some CL between Lockerbie and Carstairs	300	644	**158**	244	641	**161**	239

Figure 3.8: London-Scotland journey times for the West Coast Anglo-Scottish HSL: Effect of increased tunnel speed

3.3 East Coast route

The East Coast Anglo-Scottish route connects Glasgow, Edinburgh and Newcastle in one line. The Glasgow-Edinburgh connection is made via Carstairs.

In all cases the existing classic line is reused in order to run from Edinburgh to Carstairs, though some new infrastructure is used to travel from Carstairs to Glasgow. Access to Edinburgh from the East is also via the existing classic line[2]. The access to Newcastle from the North is in all cases via a newly built tunnel.

The variants of the East Coast Corridor are the following:

- Variant HH: All new high speed line (HSL) from outside of Edinburgh to Newcastle
- Variant CH: Reuse of classic line between Dunbar and Berwick on Tweed
- Variant CC: Reuse of classic line from Dunbar all the way to the north of Morpeth

[2] It may be necessary to build new high speed infrastructure to access Edinburgh city centre from the East because of capacity constraints on the existing line.

These variants are presented in Figure 3.9.

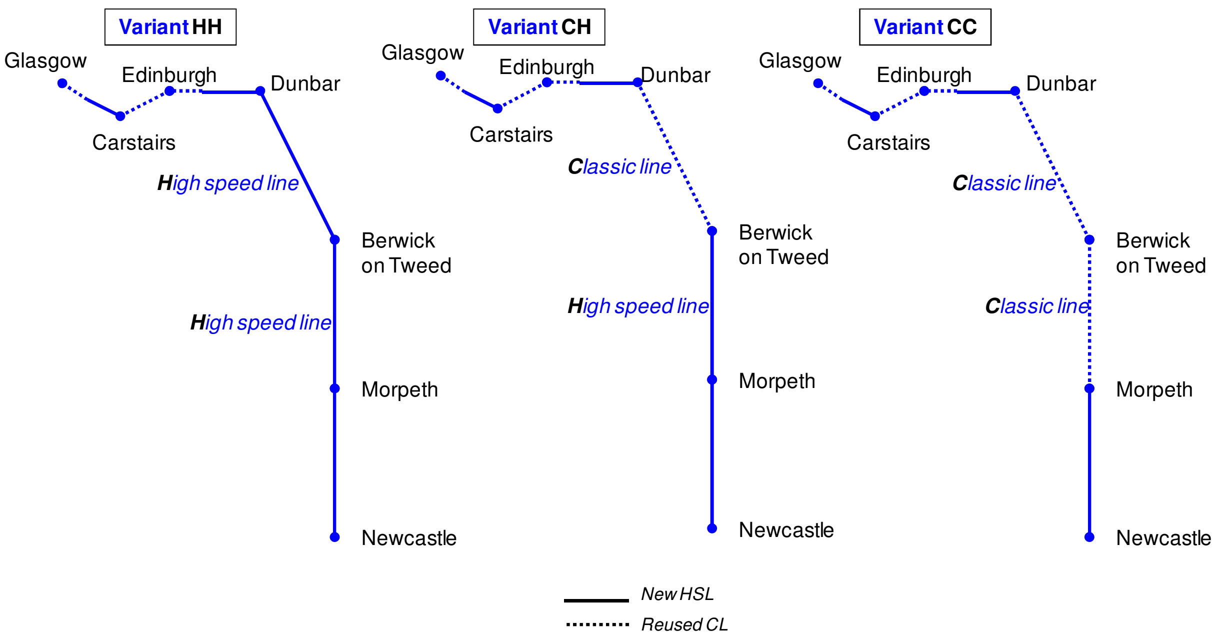

Figure 3.9: Variants of the East Coast Anglo-Scottish route

In order to assess total costs and journey times for the East Coast London-Scotland HSL, the HSL from London to Newcastle may follow either the M1 or the M11 corridors described in section 2.4.

Figure 3.10 summarises the characteristics of the high speed East Coast Anglo-Scottish route.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
Newcastle UG station to outside Morpeth (all HSL)	16	1	7	**24**	0	**24**	**650**	**27**
Near Morthpeth to near Berwick on Tweed (all HSL)	68	8	0	**76**	0	**76**	**1,350**	**18**
Near Berwick on Tweed to outside Dunbar (all HSL)	26	8	7	**42**	0	**42**	**1,210**	**29**
Outside Dunbar to Edinburgh (HSL, then reuse CL into Edinburgh)	29	1	0	**30**	11	**41**	**530**	**13**
Edinburgh-Glasgow link via Carstairs	30	0	0	**30**	59	**89**	**560**	**6**
East Coast Route Glasgow-Edinburgh-Newcastle	***169***	***18***	***14***	***201***	***70***	***271***	***4,300***	***16***
London-Newcastle, M1 corridor						***452***	***10,030***	***22***
Total East Coast Route, HSL, M1 corridor						***723***	***14,330***	***20***
East Coast Route Glasgow-Edinburgh-Newcastle	***169***	***18***	***14***	***201***	***70***	***271***	***4,300***	***16***
London-Newcastle, M11 corridor						***477***	***11,020***	***23***
Total East Coast Route, HSL, M11 corridor						***748***	***15,320***	***20***

Figure 3.10: Characteristics of the high-speed East Coast route to Scotland, variant HH

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When connected to the M1 corridor, the cost of the East Coast HS route from London to Scotland (variant HH) is slightly less than that of the West Coast route, whereas it is slightly more when connected to the M11 corridor.

The segment from Newcastle to Morpeth is expensive because of the tunnel coming out of Newcastle. Nonetheless, there is a desire to run more trains on this section, and therefore the new high speed infrastructure here is maintained in all East Coast variants.

The section between Berwick on Tweed and Dunbar is also particularly expensive per kilometre of new HSL, in this case because of the terrain. Here it may be possible to reuse the existing classic infrastructure. Figure 3.11 presents this alternative, variant CH.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
Newcastle UG station to outside Morpeth (all HSL)	16	1	7	**24**	0	**24**	**650**	**27**
Near Morpeth to near Berwick on Tweed (HSL)	68	8	0	**76**	0	**76**	**1,350**	**18**
Near Berwick on Tweed to outside Dunbar (mainly CL)	16	1	2	**19**	25	**44**	**420**	**10**
Outside Dunbar to Edinburgh (HSL, then reuse CL into Edinburgh)	29	1	0	**30**	11	**41**	**530**	**13**
Edinburgh-Glasgow link via Carstairs	30	0	0	**30**	59	**89**	**560**	**6**
East Coast Route Glasgow-Edinburgh-Newcastl, CL btw Berwick and Dunbar	***159***	***11***	***9***	***179***	***95***	***273***	***3,510***	***13***
London-Newcastle, M1 corridor						***452***	***10,030***	***22***
Total East Coast Route, CL from Berwick to Dunbar, M1 corridor						***725***	***13,540***	***19***
East Coast Route Glasgow-Edinburgh-Newcastl, CL btw Berwick and Dunbar	***159***	***11***	***9***	***179***	***95***	***273***	***3,510***	***13***
London-Newcastle, M11 corridor						***477***	***11,020***	***23***
Total East Coast Route, CL from Berwick to Dunbar, M11 corridor						***750***	***14,540***	***19***

Figure 3.11: Characteristics of the East Coast route to Scotland, variant CH: reuse of classic line between Berwick on Tweed and Dunbar

In variant CH about £800 million is saved (without optimism bias), or about 5% of all HSR infrastructure cost (excluding stations) for the London-Scotland link, as compared to variant HH, by reusing 25 km of classic line between Berwick and Dunbar.

It may be possible reuse a great deal more of the existing classic line on this route: the third variant of the East Coast Anglo-Scottish route, variant CC, is thus made up primarily of classic line between Morpeth and Dunbar. The characteristics and cost of variant CC are presented in Figure 3.12.

Variant CC saves about £2 billion as compared to variant HH, or nearly 15% of all infrastructure costs (excluding stations) for the London-Scotland link.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
Newcastle UG station to outside Morpeth (all HSL)	16	1	7	**24**	0	**24**	**650**	**27**
Near Morthpeth to near Berwick on Tweed (CL)	14	1	0	**15**	62	**77**	**360**	**5**
Near Berwick on Tweed to outside Dunbar (CL)	8	0	0	**8**	39	**48**	**160**	**3**
Outside Dunbar to Edinburgh (HSL, then reuse CL into Edinburgh)	29	1	0	**30**	11	**41**	**530**	**13**
Edinburgh-Glasgow link via Carstairs	30	0	0	**30**	59	**89**	**560**	**6**
East Coast Route Glasgow-Edinburgh-Newcastle, CL btw Morpeth and Dunbar	***97***	***4***	***7***	***107***	***172***	***279***	***2,260***	***8***
London-Newcastle, M1 corridor						***452***	***10,030***	***22***
Total East Coast Route, CL from Morpeth to Dunbar, M1 corridor						***731***	***12,290***	***17***
East Coast Route Glasgow-Edinburgh-Newcastle, CL btw Morpeth and Dunbar	***97***	***4***	***7***	***107***	***172***	***279***	***2,260***	***8***
London-Newcastle, M11 corridor						***477***	***11,020***	***23***
Total East Coast Route, CL from Morpeth to Dunbar, M11 corridor						***756***	***13,290***	***18***

Figure 3.12: Characteristics of the East Coast route to Scotland, variant CC: reuse of classic line between Morpeth and Dunbar

Journey times of under 3 hours are obtained between London and Edinburgh for all variants. As shown in Figure 3.13, variant CH, which uses the existing classic line between Berwick and Dunbar, adds about 5 minutes to overall journey time as compared to variant HH. The use of classic line between Morpeth and Dunbar, variant CC, adds about 20 minutes to overall journey time, as compared to the journey time achieved with variant HH, in which an all-new high speed line from Morpeth to Dunbar is built.

The London-Glasgow journey time is around 3 hours only if the M1 corridor is combined with variant HH, the completely high speed line from Newcastle to just east of Edinburgh. Otherwise, London-Glasgow journey times all exceed 3 hours.

English route	Anglo-Scottish route	Max speed tunnels (km/h)	London-Glasgow			London-Edinburgh		
			Len. (km)	Journey time (min)	Average speed (km/h)	Len. (km)	Journey time (min)	Average speed (km/h)
London-Newcastle, M1 corridor	East Coast, Variant HH: HSL	230	723	**182**	238	634	**142**	268
London-Newcastle, M1 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	230	725	**188**	231	636	**148**	258
London-Newcastle, M1 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	230	731	**203**	216	641	**163**	237
London-Newcastle, M11 corridor	East Coast, Variant HH: HSL	230	748	**187**	240	659	**147**	269
London-Newcastle, M11 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	230	750	**193**	233	661	**153**	259
London-Newcastle, M11 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	230	756	**208**	218	667	**168**	239

Figure 3.13: London-Scotland journey times for the East Coast route

Building an all-new HSL between Berwick on Tweed and Dunbar would cost nearly £800 million more than building a line that reuses some classic infrastructure on this section. Figure 3.14 shows that the more expensive infrastructure would save 6 minutes in journey time for a cost of about £130 million per minute saved. The construction of all-new HS infrastructure between Morpeth and Berwick on Tweed is significantly less expensive per minute of journey time saved: 15 minutes would be saved for an extra cost of about £1.2 billion, for an overall cost of "only" about £90 million per minute saved.

Proposed infrastructure	Instead of	Extra cost (m£)	Time saved (min)	Cost/min saved (m£)
All new HSL from Berwick on Tweed to Dunbar (Variant HH)	Some reuse of existing CL on this section (Variant CH)	790	6	**127**
All new HSL from Morpeth to Berwick on Tweed (Variant CH)	Reuse of existing CL on this section (Variant CC)	1,250	15	**86**

Figure 3.14: Cost per minute saved (London-Glasgow journey time) of building all-new HS infrastructure on two sections of the East Coast route

An increase in tunnel speed has virtually no impact on overall journey times for the East Coast Anglo-Scottish route.

English route	Anglo-Scottish route	Max speed tunnels (km/h)	London-Glasgow Len. (km)	London-Glasgow Journey time (min)	London-Glasgow Average speed (km/h)	London-Edinburgh Len. (km)	London-Edinburgh Journey time (min)	London-Edinburgh Average speed (km/h)
London-Newcastle, M1 corridor	East Coast, Variant HH: HSL	300	723	**180**	242	634	**140**	273
London-Newcastle, M1 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	300	725	**187**	233	636	**147**	260
London-Newcastle, M1 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	300	731	**202**	217	641	**162**	238
London-Newcastle, M11 corridor	East Coast, Variant HH: HSL	300	748	**185**	243	659	**145**	274
London-Newcastle, M11 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	300	750	**192**	235	661	**152**	262
London-Newcastle, M11 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	300	756	**207**	219	667	**167**	240

Figure 3.15: London-Scotland journey times for the East Coast Anglo-Scottish HSL: Effect of increased tunnel speed

3.4 Newcastle-Glasgow route

The Newcastle-Glasgow Anglo-Scottish HSL connects Glasgow to Newcastle via Carstairs. A spur onto the classic line at Carstairs provides a connection to Edinburgh. The configuration studied is presented in Figure 3.16.

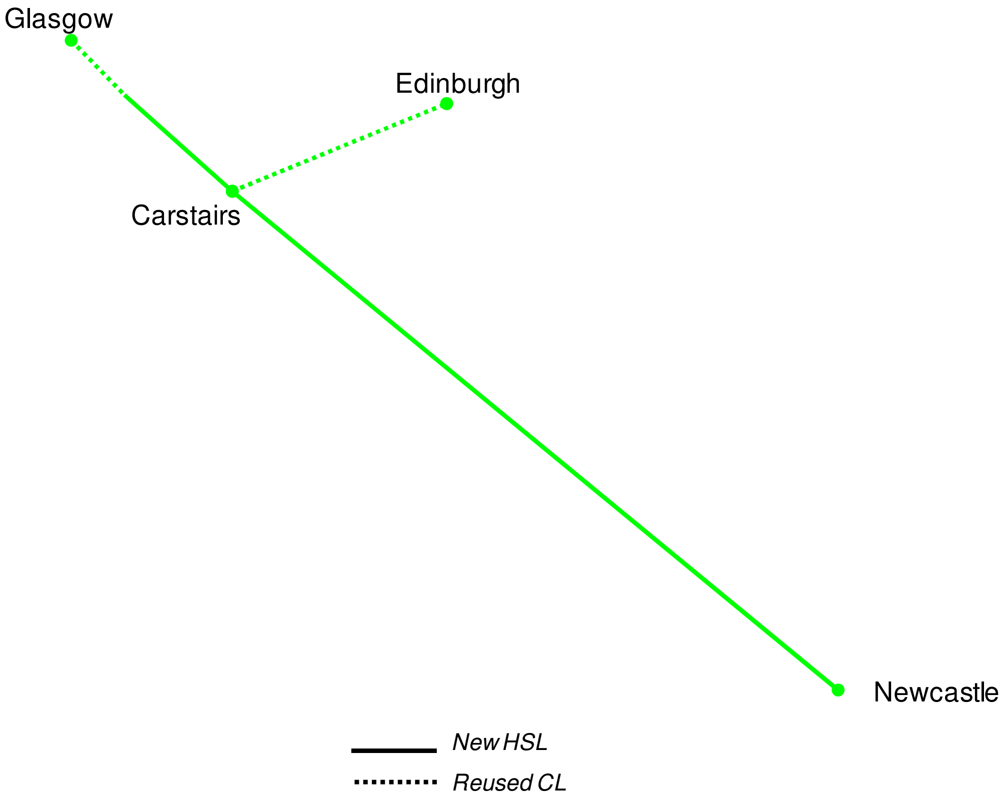


Figure 3.16: The Newcastle-Glasgow route

In order to assess total costs and journey times for the Newcastle-Glasgow HSL, the HSL from London to Newcastle may follow either the M1 or the M11 corridors described in section 2.4.

Figure 3.17 summarises the characteristics of the high speed Newcastle-Glasgow route.

	Lengths						Cost (m£ 2008, without OB, without stations)	
	New High Speed Line (km)				Classic Line (km)	HSL + CL (km)		
	At Grade	Viaduct	Tunnel	Total HSL			New Build	Average cost/km
Newcastle UG station to Carstairs	33	35	90	**158**	0	**158**	**7,050**	**45**
Carstairs to Glasgow	31	1	0	**32**	19	**51**	**590**	**12**
Carstairs to Edinburgh	5	0	0	**5**	40	**45**	**90**	**2**
HS Route Newcastle to Glasgow via Carstairs	***68***	***36***	***90***	***194***	***59***	***254***	***7,740***	***30***
London-Newcastle, M1 corridor						***452***	***10,030***	***22***
Total Newcastle-Glasgow route, HSL, M1 corridor						***705***	***17,760***	***25***
HS Route Newcastle to Glasgow via Carstairs	***68***	***36***	***90***	***194***	***59***	***254***	***7,740***	***30***
London-Newcastle, M11 corridor						***477***	***11,020***	***23***
Total Newcastle-Glasgow Route, HSL, M11 corridor						***731***	***18,760***	***26***

Figure 3.17: Characteristics of the high speed Anglo-Scottish route from Newcastle to Glasgow via Carstairs

The cost of the direct Newcastle-Glasgow route is particularly high because it traverses a mountainous zone and thus necessitates expensive infrastructure. The cost to link Newcastle to Edinburgh and

Glasgow in this case is around £7.7 billion (without stations and without optimism bias), whereas it is "only" £4.3 billion to build all-new infrastructure along the East Coast route.

English route	Anglo-Scottish route	Max speed tunnels (km/h)	London-Glasgow			London-Edinburgh		
			Len. (km)	Journey time (min)	Average speed (km/h)	Len. (km)	Journey time (min)	Average speed (km/h)
London-Newcastle, M1 corridor	Newcastle-Glasgow Route, HSL	230	661	**158**	252	654	**160**	246
London-Newcastle, M11 corridor	Newcastle-Glasgow Route, HSL	230	686	**163**	253	679	**165**	248

Figure 3.18: London-Scotland journey times for the East Coast route

London-Scotland journey times on the direct Newcastle-Glasgow route are around 2'40" to both Edinburgh and Glasgow. The M11 corridor in England adds 5 minutes as compared to the M1 corridor.

Error! Reference source not found. Figure 3.19 presents the journey times if the maximum speed in tunnels as 300 km/h. (As mentioned above, this modification in speed is applied only to the line from Newcastle to Scotland, and not to the line from London to Newcastle.)

An increase in tunnel speed to 300 km/h decreases overall journey times by over 8 minutes.

English route	Anglo-Scottish route	Max speed tunnels (km/h)	London-Glasgow			London-Edinburgh		
			Len. (km)	Journey time (min)	Average speed (km/h)	Len. (km)	Journey time (min)	Average speed (km/h)
London-Newcastle, M1 corridor	Newcastle-Glasgow Route, HSL	300	661	**149**	266	654	**152**	259
London-Newcastle, M11 corridor	Newcastle-Glasgow Route, HSL	300	686	**154**	267	679	**157**	260

Figure 3.19: London-Scotland journey times for the Newcastle-Glasgow HSL: Effect of increased tunnel speed

4 Conclusions

Though the current document makes it possible to compare the characteristics of different scenarios for an Anglo-Scottish high speed connection, any identification of the "best" scenarios can only be made in conjunction with an analysis of service patterns, demand forecasts and a complete business case.

Furthermore, as mentioned above, the High Speed Rail Development Programme is a preliminary study, and as such can only offer indicative answers and indeed must leave some questions unanswered.

For example, journey times have been assessed based on two different possible maximum speeds in tunnels. The effect of speed on tunnelling costs has not been estimated, as doing so would necessitate detailed studies of the terrain for each potential tunnel. For this reason a generalised cost has been applied to all tunnel segments.

The reader should thus keep in mind that, though some conclusions are drawn here, they can generally only be confirmed with a complete business case.

The costs, lengths and journey times of the Anglo-Scottish scenarios are summarised in Figure 4.1 and presented graphically on the following pages.

English route	Anglo-Scottish Route	Cost (m£)	London-Glas. Len. (km)	London-Ed. Len. (km)	Vtun = 230 km/h		Vtun = 300 km/h	
					London-Glas. Journey time	London-Ed. Journey time	London-Glas. Journey time	London-Ed. Journey time (min)
London-Manchester, M40 corridor	West Coast, HSL	14,680	641	637	153	156	148	151
London-Manchester, M40 corridor	West Coast, some CL between Lockerbie and Carstairs	13,110	644	641	162	164	158	161
London-Newcastle, M1 corridor	East Coast, Variant HH: HSL	14,330	723	634	182	142	180	140
London-Newcastle, M1 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	13,540	725	636	188	148	187	147
London-Newcastle, M1 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	12,290	731	641	203	163	202	162
London-Newcastle, M1 corridor	Newcastle-Glasgow Route, HSL	17,760	661	654	158	160	149	152
London-Newcastle, M11 corridor	East Coast, Variant HH: HSL	15,320	748	659	187	147	185	145
London-Newcastle, M11 corridor	East Coast, Variant CH: CL between Berwick and Dunbar	14,540	750	661	193	153	192	152
London-Newcastle, M11 corridor	East Coast, Variant CC: CL between Morpeth and Dunbar	13,290	756	667	208	168	207	167
London-Newcastle, M11 corridor	Newcastle-Glasgow Route, HSL	18,760	686	679	163	165	154	157

Figure 4.1: Summary of costs, lengths and journey times

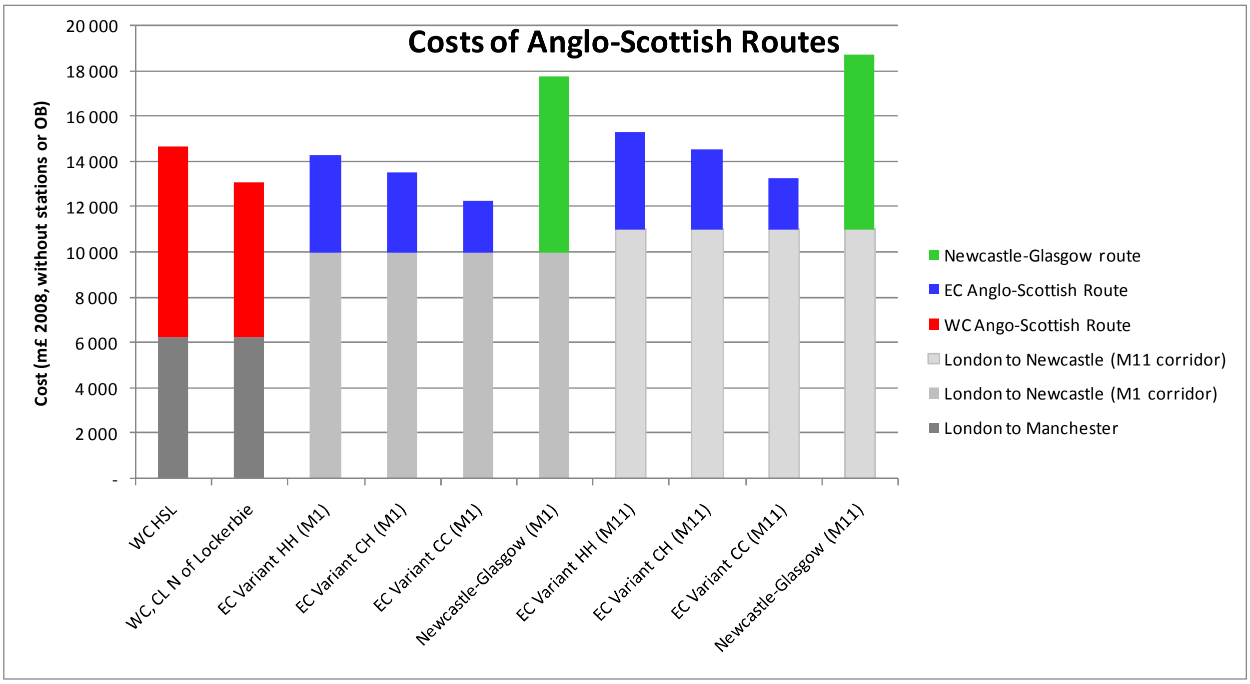


Figure 4.2: Overall costs of routes from London to Scotland. Costs include links to both Edinburgh and Glasgow, without stations or OB.

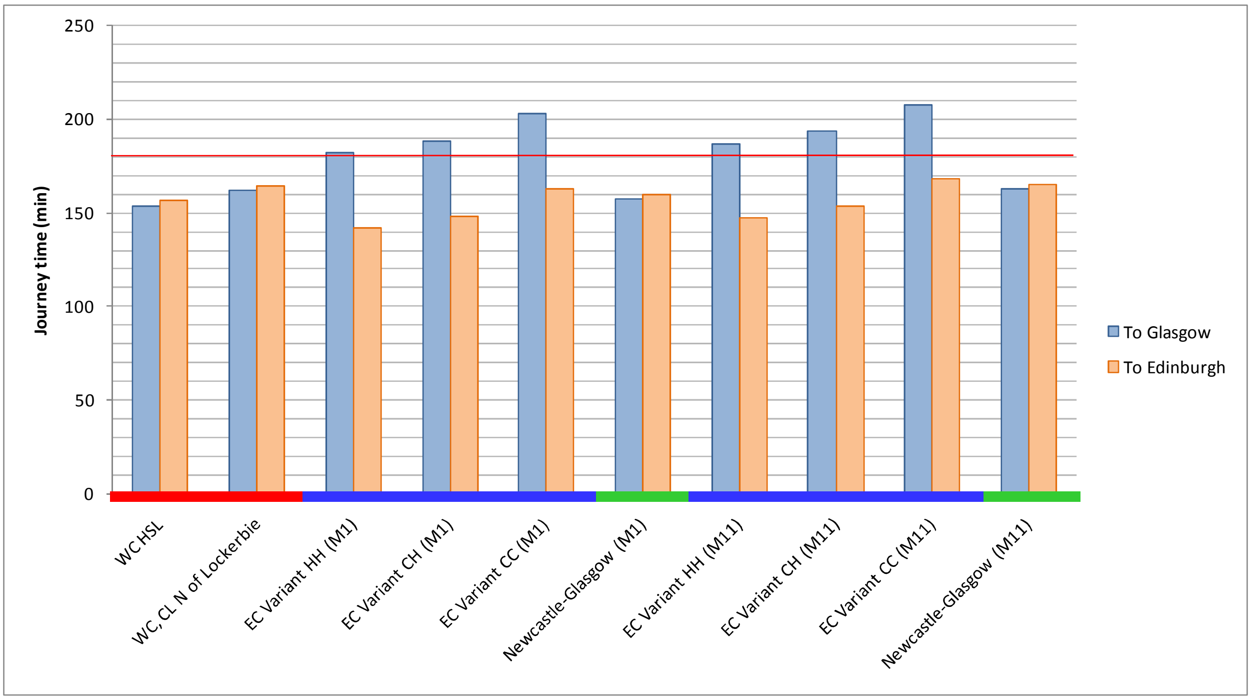
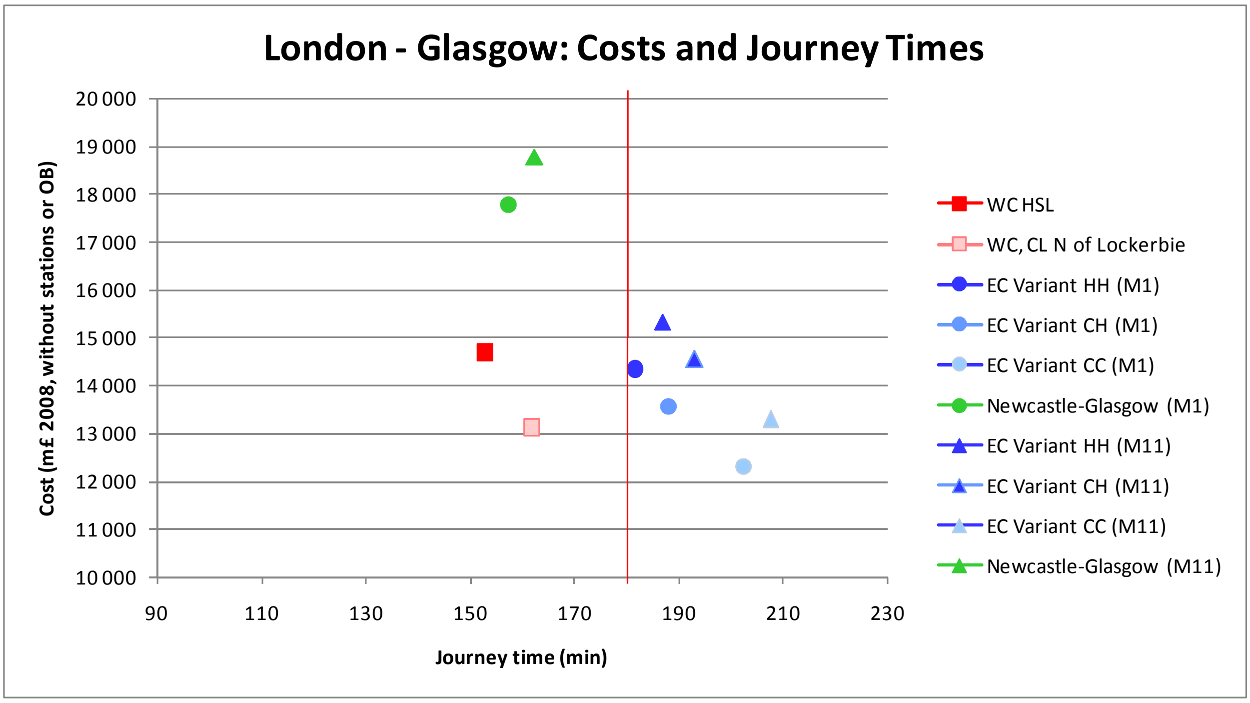


Figure 4.3: Overall journey times of routes from London to Glasgow and Edinburgh. The red line indicates a journey time of 3 hours. Max speed in tunnels = 230 km/h.



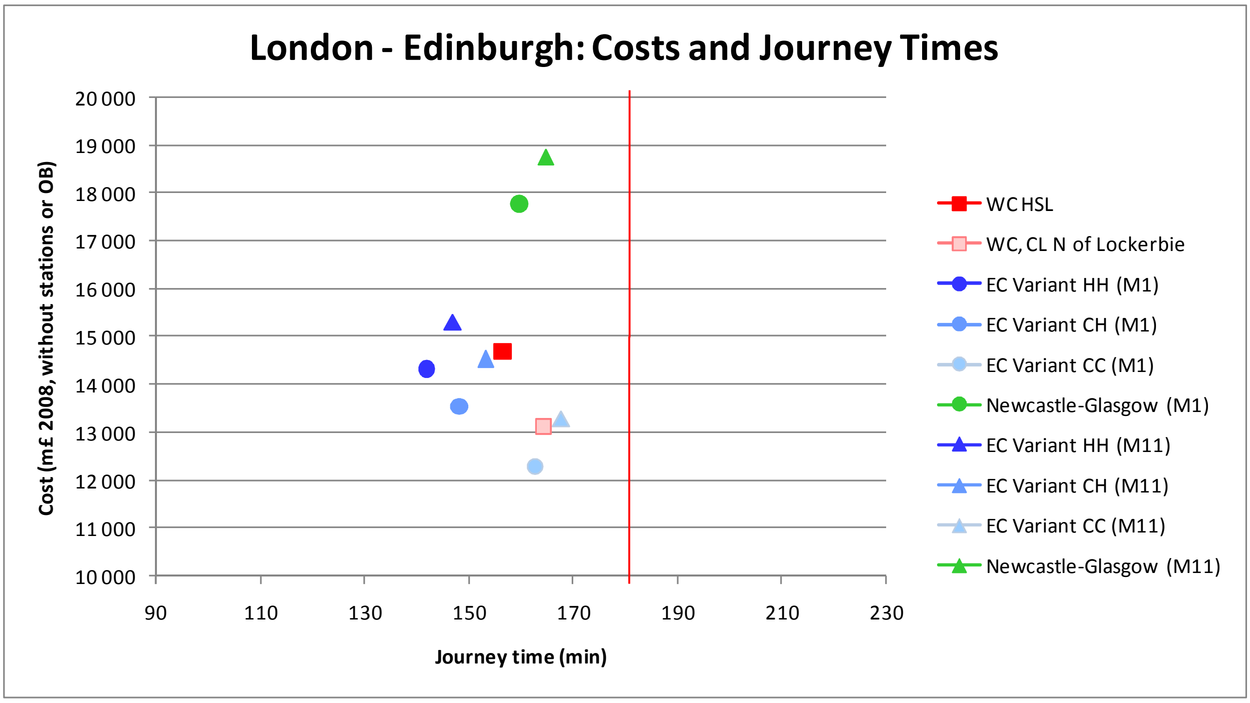


Figure 4.4: Costs and journey times of high speed lines from London to Glasgow and from London to Edinburgh. The red lines indicates a 3-hour London-Scotland journey time. Max speed in tunnels = 230 km/h.

East Coast Route vs. West Coast Route

For an approximately equivalent overall cost (from London to Scotland), the East Coast HSL route provides slightly better journey times to Edinburgh (under 2’25”) than the HSL West Coast route (a savings of about 10 min, depending on the London-Newcastle route).

The advantage of the West Coast route, however, is that it provides equivalent journey times to both Edinburgh and Glasgow (under 2’35”), whereas in the case of the East Coast Route all London-Glasgow journey times are 3 hours or more.

If the only concern in designing a high-speed network were the speed of the London-Scotland connection, a decision would need to be made between the fastest possible London-Edinburgh connection and equitable connections to both Glasgow and Edinburgh. In reality, however, it is likely that the choice between the East and West Coast Routes will be conditioned by the shape of the network in England.

The Newcastle-Glasgow route

The Newcastle-Glasgow route provides roughly equivalent London-Scotland journey times (depending on tunnel speed) as the West Coast route for a significantly higher cost. If the only concern in designing a high-speed network were the speed of the London-Scotland connection, the West Coast route would thus clearly be preferable to the Newcastle-Glasgow route.

The Newcastle-Glasgow option could only be envisaged if the business case or other circumstances lead to a preference for a Newcastle-Scotland rather than a Manchester Scotland link. In this case the Newcastle-Glasgow direct route, as opposed to the East Coast route, offers the distinct advantage of offering fast connections to both Edinburgh and Glasgow.

Though the cost of this route may appear exorbitant, it is interesting to note that its cost per minute of time saved to reach Glasgow (as compared to the journey time of the East Coast route) is “only” about £140 million (Figure 4.5).

Reuse of existing classic lines

Proposed infrastructure	Instead of	Extra cost (m£)	Time saved (min)	Cost/min saved (m£)
All new HSL from Lockerbie to Carstairs on the West Coast route	Some reuse of existing CL	1,570	9	**175**
All new HSL from Berwick on Tweed to Dunbar (Variant HH)	Some reuse of existing CL on this section (Variant CH)	790	6	**127**
All new HSL from Morpeth to Berwick on Tweed (Variant CH)	Reuse of existing CL on this section (Variant CC)	1,250	15	**86**
Direct Newcastle-Glasgow route	East Coast HS route, Newcastle to Glasgow	3,440	24	**141**

Figure 4.5: Cost per minute of journey time saved (London-Glasgow) for specific sections of new HSL

West Coast route

The reuse of 40 km of classic line between Lockerbie and Carstairs adds under 10 minutes to overall journey time. With the use of tilt, only about 7 minutes would be added to overall journey time. If, on the other hand, all new high speed infrastructure is built between Lockerbie and Carstairs, assuming that the rolling stock is does not tilt, the cost per minute saved is £175 million.

As shown in Figure 4.5, the cost of each minute saved by building a completely new HSL on this section is higher than that of any other "optional" section of HSL. Therefore, of all the sections studied in which the existing classic infrastructure may be reused, this is the section in which it would make the most sense to do so.

East Coast Route

The high speed line from Morpeth to Berwick on Tweed is relatively inexpensive to build (average of 18 m£/km without OB). Of all the sections studied in which the construction of a new high speed line is optional, this is the section in which it makes the most sense to build new high speed infrastructure. That is, the cost per minute of journey time saved (under £90 million/minute) is lower than for any other section.

The journey time impact of using the existing classic line between Berwick and Dunbar in order to reduce costs is around 5 minutes, and thus the cost of each minute saved is under £130 million.

In this study it is assumed that the existing classic line is used in the approach to Edinburgh city centre from the East. However, because of limited capacity on the existing line, it may be necessary to build all new high speed infrastructure to access Edinburgh centre from the East. This would add about £500 million (without optimism bias, and without taking into consideration renovations to Edinburgh Waverley) to construction costs, and would save about 2 minutes in overall journey time. The cost per minute saved would thus be at least around £200 million. At such a high price per minute saved, it is clear that a new line to access Edinburgh city centre from the East cannot be justified on journey time grounds alone.

Non-quantified advantages to the construction of new high speed infrastructure

Only journey times and costs are evaluated in this document.

It is nonetheless important to keep in mind that the construction of all-new high-speed infrastructure, as opposed to the reuse of classic lines, offers two important advantages (that are not quantified in this document):

- Extra rail capacity is provided on the classic network
- New infrastructure allows for the use of UIC gauge duplex trains up to 400m long, and thus a maximum number of seats per train.

Appendix F – Comparison of M1 and M11 East Coast Corridors

Contents

1 Introduction

In the future British high speed network, the East Coast London-Newcastle high speed line (HSL), if built, will serve London, the East Midlands, Leeds and Newcastle. This corresponds to Corridor 2 in the High Speed Rail Development Programme. It can be either an alternative or a complementary line to the West Coast Corridor 1 line, which would provide a London-Birmingham-Manchester link.

Two major route alternatives exist for the East Coast London-Newcastle HSL:

- M1 corridor: North out of London following the M1 to East Midlands Parkway and on to Leeds and Newcastle
- M11 corridor: North East out of London following the M11 (possibly using Lea Valley initially) to Cambridge, Nottingham and then north to Nottingham, Leeds and Newcastle

This document offers an initial comparative analysis of these two routes.

2 Approach to cost evaluation

Only the capital costs of new high speed lines (infrastructure, systems, land acquisition, professional fees and provisions) are detailed below. All prices are in constant 2008 GBP, and optimism bias (OB) is not included. As mentioned above, no cost is assessed for reused classic lines.

Cost assessments are produced in two steps:

1. Hypothetical HSL alignments are defined. The approach used to define these alignments is described in the following section.
2. Unit costs are applied to these alignments. These costs are described in Workstream 3.

The objective of the current document is to offer a comparative analysis of the cost and journey times of potential high speed routes. As the cost of remodelling or building stations could vary enormously in function of factors unrelated to the choice of routes, station costs are excluded from this analysis.

Furthermore, the cost of spurs to the existing classic line are also excluded. That is, costs only include the straight line from London to Newcastle.

Alignments consist of two elements:

- Horizontal alignment, that is where the high speed line goes.
- Infrastructure. All sections of line are assigned a type of infrastructure in order to estimate cost: at-grade on easy terrain, at-grade on difficult terrain, viaduct, tunnel, etc.

In general alignments follow an existing motorway or rail corridor, though they may diverge from the existing corridor if a less expensive path seems possible elsewhere.

Where possible, curve radii are large enough to allow a theoretical maximum speed of 350 km/h. Though the gradients of the natural terrain are taken into consideration when designing alignments and when choosing infrastructure, the detailed profile (exact gradients of the line, extent of earthworks, etc.) of the alignments has not been determined.

At this preliminary stage, these alignments should be considered reasonable hypotheses that are at the appropriate accuracy necessary to estimate infrastructure cost.

3 Description of the alternate routes

3.1 M1 corridor

For the purpose of this study, the London terminus of the HSL that follows the M1 corridor is not defined, but would be close to central London with good access to a range of LUL and other onward modes for distribution of passengers. There is also an option which consists of some trains (GB gauge) using existing East Midlands Trains platforms in St Pancras, and others into an expanded or new station (probably via tunnel).

As mentioned above, costs related to construction and renovation of stations are excluded here. Nonetheless, as any infrastructure inside Greater London is likely to be expensive, the choice of the nature and location of the London terminus is critical to an HS alignment option.

The HSL following the M1 corridor serves East Midlands Parkway, passes to the East of Sheffield (the cost of a spur to Sheffield is not included here), to the East of Leeds and on to Newcastle.

3.2 M11 corridor

Gaining access from this corridor to a central London terminus is likely to involve extensive tunnelling and new build of stations. Hence, for the purpose of this study, we have assumed that a station just outside central London (but still with good LUL, etc access) is provided for the M11 corridor HSL. The line passes near Stansted, Cambridge and Nottingham. Spurs may lead into these city centres, (though their costs are not included here), or new parkway station may built to serve these cities. The M11 corridor converges with the M1 corridor line north of Nottingham, to pass east of Sheffield and east of Leeds, then Newcastle.

4 Cost and journey time comparison

The table below summarises the characteristics of the high speed lines following the two potential East Coast corridors from London to Newcastle.

Table 4.1 Characteristics of the alternative East Coast corridor high speed lines (core sections excluding stations, spurs and London termini)

	Length (km)	Cost (£m 2008 without OB or stations)	Average cost/km (£m 2008 without OB or stations)	Journey time London to Newcastle (min)
M1 Corridor (London – Newcastle)	452	10,300	22	100
M11 Corridor (London – Newcastle)	477	11,020	23	105

The high speed line following the M1 corridor is about 25 km shorter, and is slightly less expensive per km than the M11 corridor.

However, it is likely that a station at St Pancras/Euston would be more expensive than at Stratford. In the final evaluation it was estimated that when including stations and optimism bias, the M1 corridor was more than £3bn more expensive than the M11 alternative.

Due to the shorter length, the London-Newcastle journey time of the M1 corridor line is about 5 minutes shorter than that of the M11 corridor line.

5 Demand, revenue and economic benefits

There is no clear preference between the routes in terms of their benefits:

- the M11 route has 5% greater demand (passenger journeys) on HSR
- the M1 route has 3% greater revenue (and similar on user benefits)
- the M11 route allows for more classic services to be substituted, particularly on the crowded West Anglia route; it thus gives greater benefits in terms of opportunities to reuse the classic network
- the cost of the M1 route is greater once stations are taken into account
- overall the NPV and BCR of the M1 route are better.

The reason for these differences is that the M1 route being faster gives greater long distance demand and revenue between London and Nottingham, Leeds and Newcastle, whereas the M11 route has considerably more demand on shorter distance such as London to Stansted and Cambridge. The following Table provides the forecasts for the two routes. The scenarios evaluated include HSR and services as far as Scotland via the East Coast; the relativity between the two routes is unlikely to be affected by this.

The table also includes the BCRs incorporating indicative costs of stations, rolling stock and all other relevant costs.

It can be seen that, in terms of overall economic benefits and the BCR, the M1 route appears slightly preferable. However, the evaluation of the scenarios is not simply being done using the BCRs and economic benefits; there are wider issues as reflected in the Guiding Principles to be taken into account.

In terms of abstraction from car and air, the M1 corridor performs better, but in terms of providing additional transport capacity and country-wide benefits the M11 corridor is preferable; in particular it is the only route that can effectively bring the benefits of HSR to East Anglia, although the M1 corridor is capable of releasing capacity for extra services to Cambridge. The M11 corridor also provides easier access to HS-CT and potentially Heathrow. It also allows a connection to the East Coast Main Line (ECML) so that services over the Peterborough – Doncaster – York section could access the HSR into London; and likewise, it would be possible for services from the southern section of the ECML to access the HSR going northwards.

The model seems to allocate greater economic benefits, including Wider Economic Benefits, to the M1 corridor, but we are not wholly convinced it fully reflects the benefits related to the M11 corridor.

Table 5.1 Forecasts of demand, revenue and economic benefits

	M11	M1	% difference
Demand Analysis			
Total HS demand (million) (2055)	160.4	151.6	-5%
Abstracted from classic rail (million) (2055)	93.7	84.4	-10%
Abstracted from air (million) (2055)	27.0	27.1	0%
Abstracted from car (million) (2055)	10.8	11.6	7%
Generated HS users (million) (2055)	28.9	28.6	-1%

Revenue Analysis			
HS Revenue £m (2055)	£7,980	£8,169	2%
Net Rail Revenue £m (2055)	£3,639	£4,030	11%
Costs Analysis			
Infrastructure Capital costs £m (2008 prices)	£64,419	£68,100	6%
HS operating costs £m (2008 prices) in 2055	£3,460	£3,346	-3%
Reduction in classic operating cost £m (2008 prices) in 2055	£1,175	£1,151	-2%
Number of 200m Rolling Stock units (required in 2055)	334	327	-2%
Other Impacts			
Car kms removed (millions) (2055)	2,477	2,692	9%
Air passenger kms removed (millions) (2055)	16,660	16,670	0%
CO2 reduction (million tonnes) (2055)	0.937	0.945	1%
User and non-user benefits			
NPV User benefits £m (2002 prices)	£86,934	£87,419	1%
NPV Non-user benefits £m (2002 prices)	£12,319	£12,149	-1%
NPV Benefits from HS and Intercity rail crowding reduction £m (2002 prices)	£9,491	£9,428	-1%
NPV Benefits from local classic rail crowding reduction £m (2002 prices)	£3,858	£3,603	-7%
NPV Other benefits of new classic services £m (2002 prices)	£2,524	£2,416	-4%
NPV Benefits to rail freight £m (2002 prices)	£2,037	£2,037	0%
NPV Wider regional economic benefits (£m 2002 prices)	£15,711	£15,817	1%
Financial Performance			
NPV Net Revenue (£m 2002 prices)	£24,326	£27,029	11%
NPV Costs (£m 2002 prices)	£63,690	£64,590	1%
NPV Benefits (£m 2002 prices)	£123,579	£126,597	2%
NPV Operating Surplus (£m 2002 prices)	£22,163	£24,554	11%
NPV Overall funding deficit (£m 2002 prices)	-£39,364	-£37,561	-5%
Total NPV (£m 2002 prices)	£59,889	£62,006	4%
BCR (excluding Wider Economic Benefits)	2.52	2.65	5%

6 Recommendation

The above analysis shows that the two routes are very close in terms of their performance.

For the purposes of this study and to develop an overall network, we have taken forward the M11 corridor.

However, the eventual decision needs to be based on a more thorough examination of the engineering issues for both routes, especially around the London terminals. These include:

- options for London terminals with each of the routes
- linkage to onward transport modes at the different station locations, including the spare capacity of these onward modes/routes
- ability (and cost) to cater for the major pedestrian flows at each of the station locations
- feasibility and journey time of links to Heathrow and HS-CT.

Appendix G – Infrastructure Assumptions

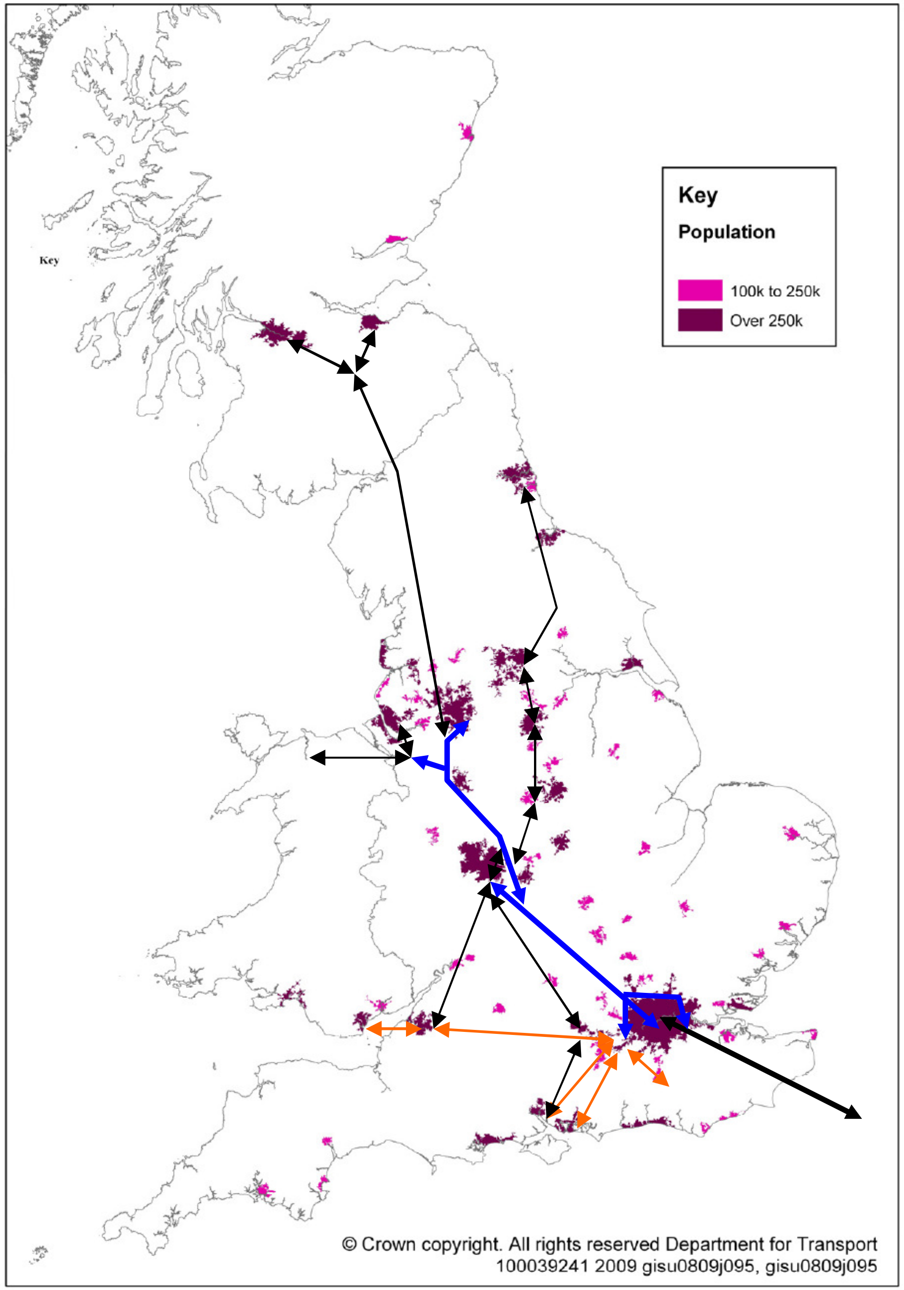
Scenario 1

Core HS routes

HS-CT

LHR links to South and West England

HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

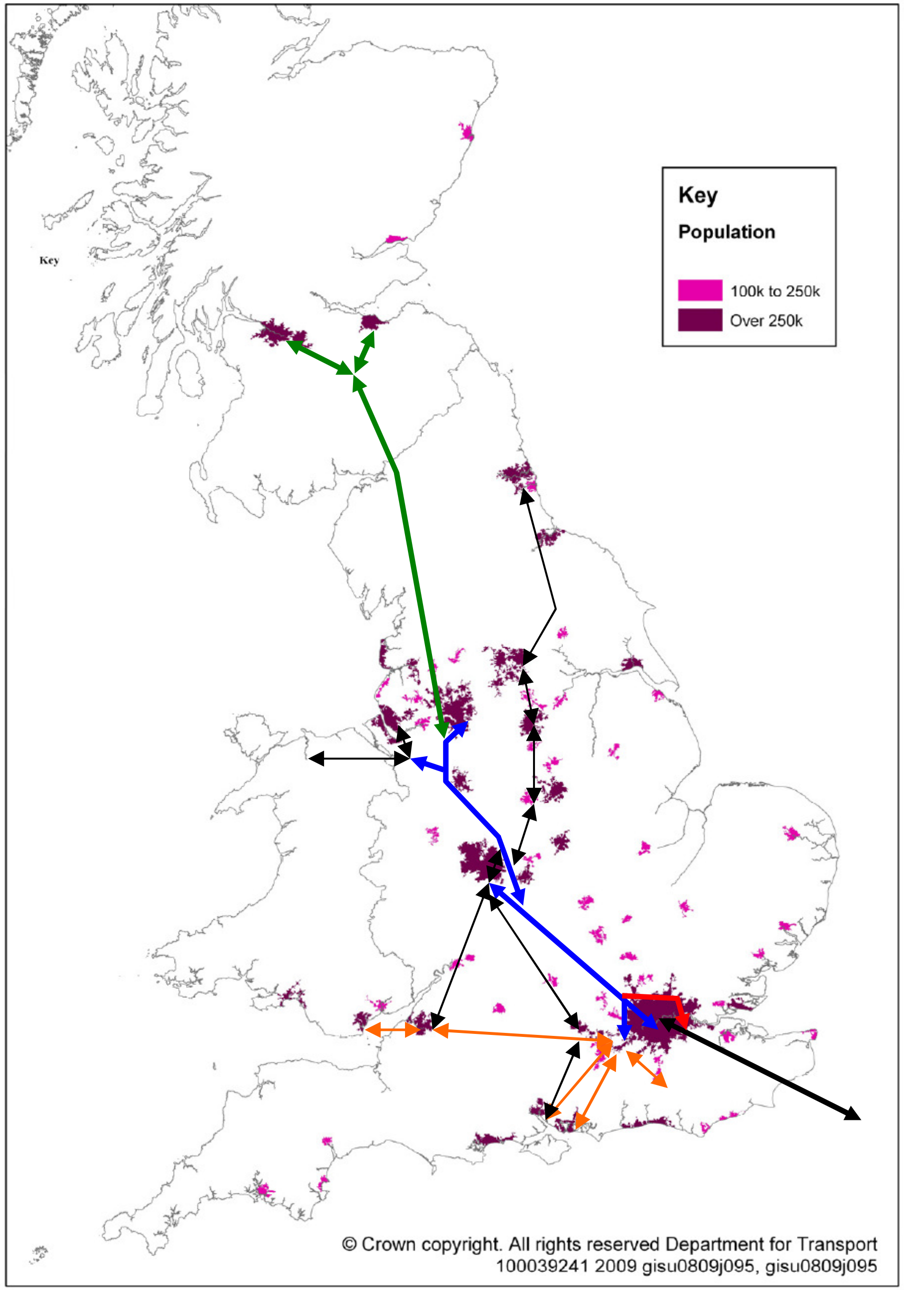
- HS-NW route via M40 and M6 to Birmingham, Crewe and Manchester
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Base Network
- HS service from Europe, London and Heathrow to Birmingham and Manchester
- Trains continue on classic tracks to Scotland, North Wales, Liverpool, Sheffield
- Cross-Country services to Manchester routed onto HS
- Heathrow service from Newcastle via Birmingham Int'l
- Connections from Heathrow to Cardiff, Bristol, Southampton, Portsmouth and Gatwick

Scenario 2

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

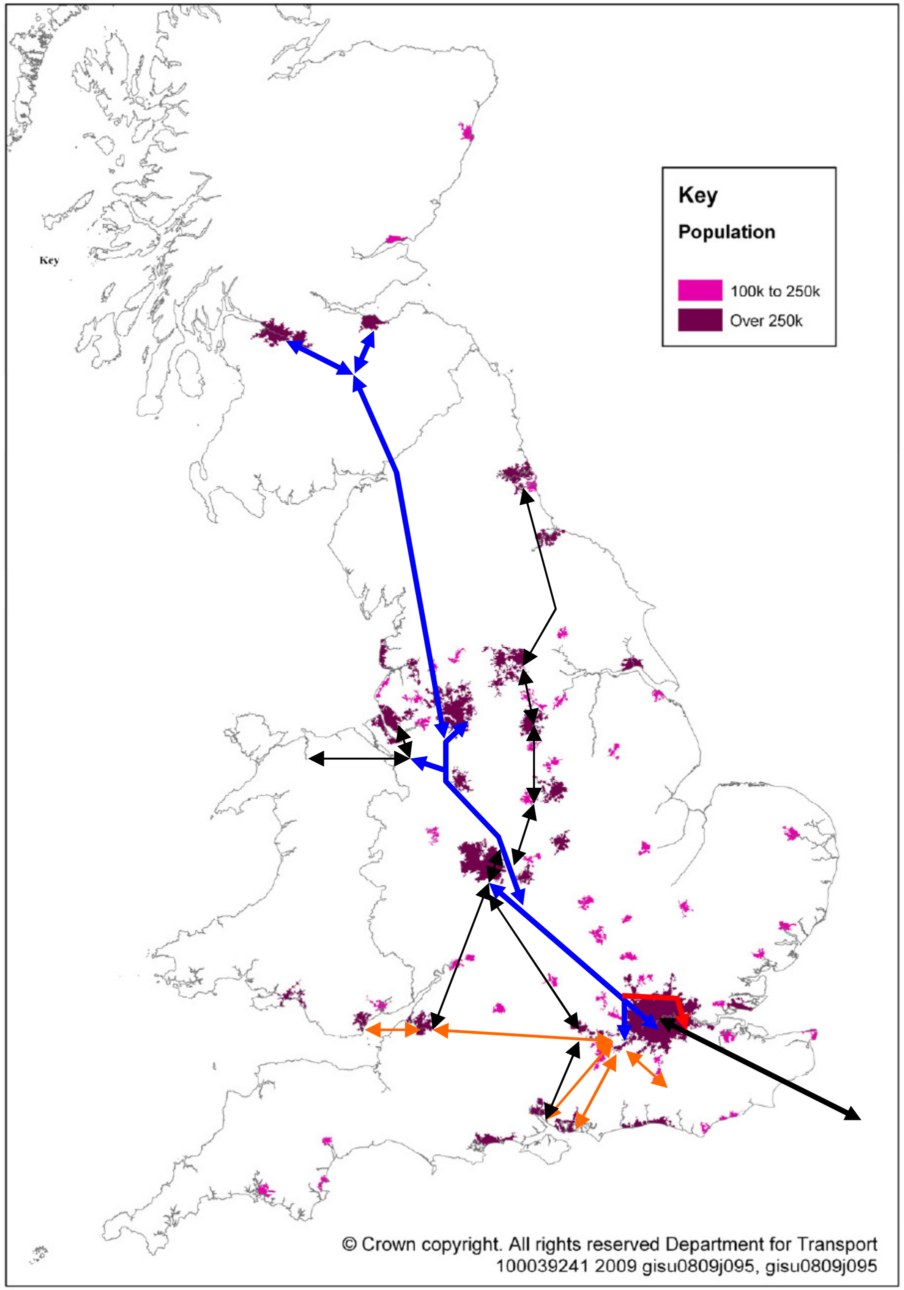
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Extension of HS from Manchester all the way to Scotland
- Addition of Scottish HS Shuttle Edinburgh - Glasgow

Scenario 3

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

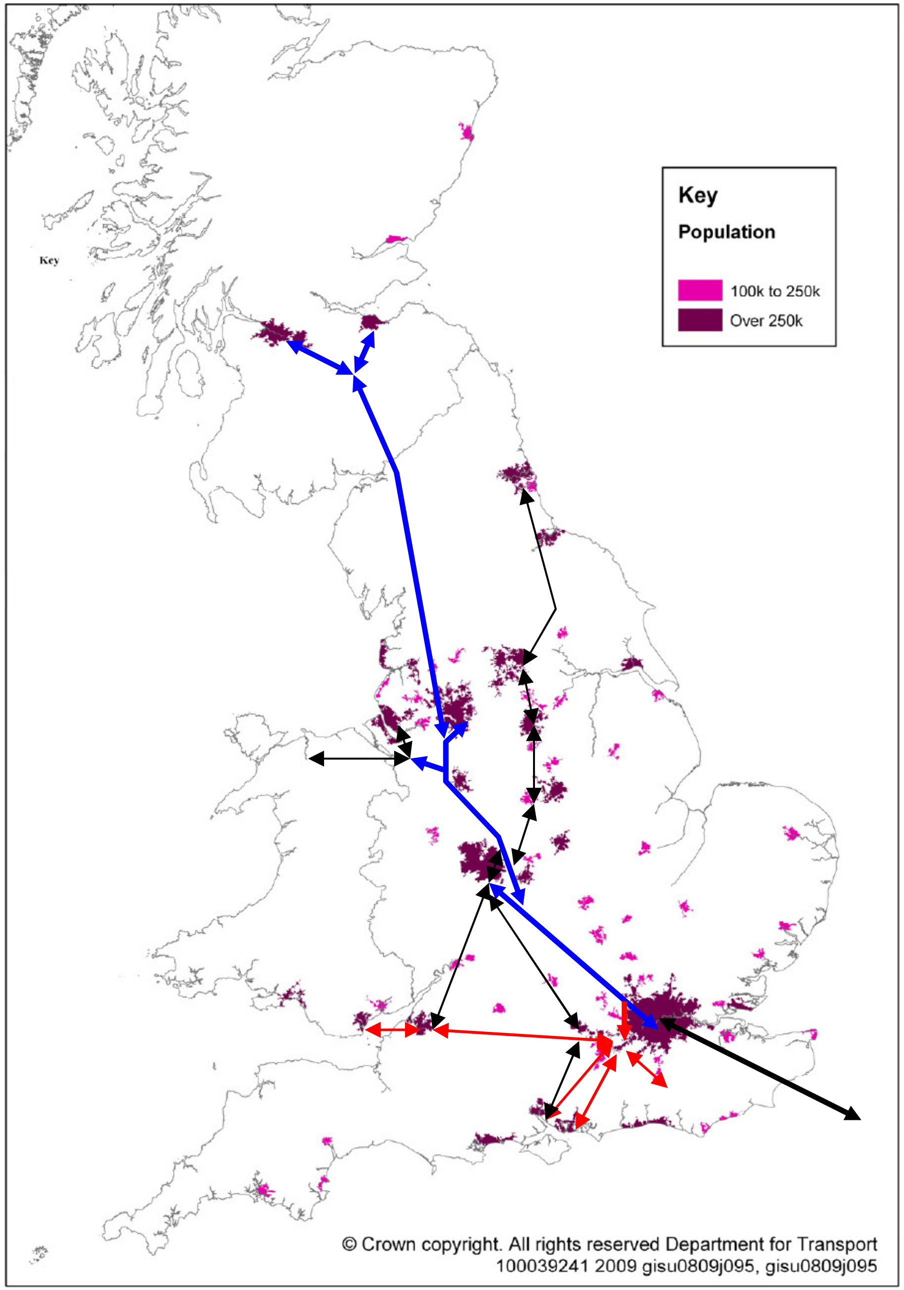
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- Connection to Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Value of connection to HS-CT

Scenario 4

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

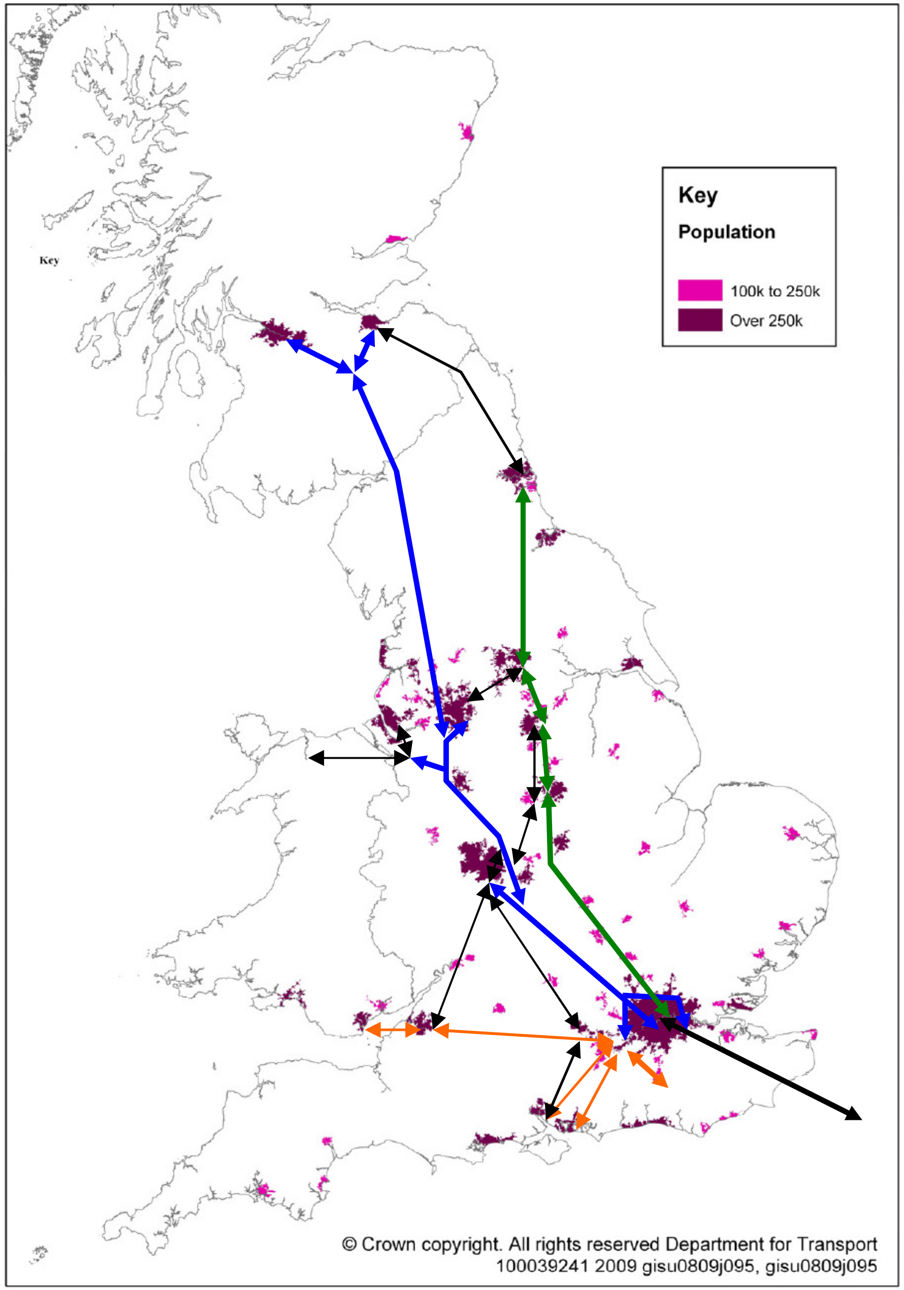
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh

Elements Tested

- Value of Heathrow branch and connections South and West of Heathrow

Scenario 5

- Core HS routes
- Added to Scenario 2
- Removed from Scenario 2
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

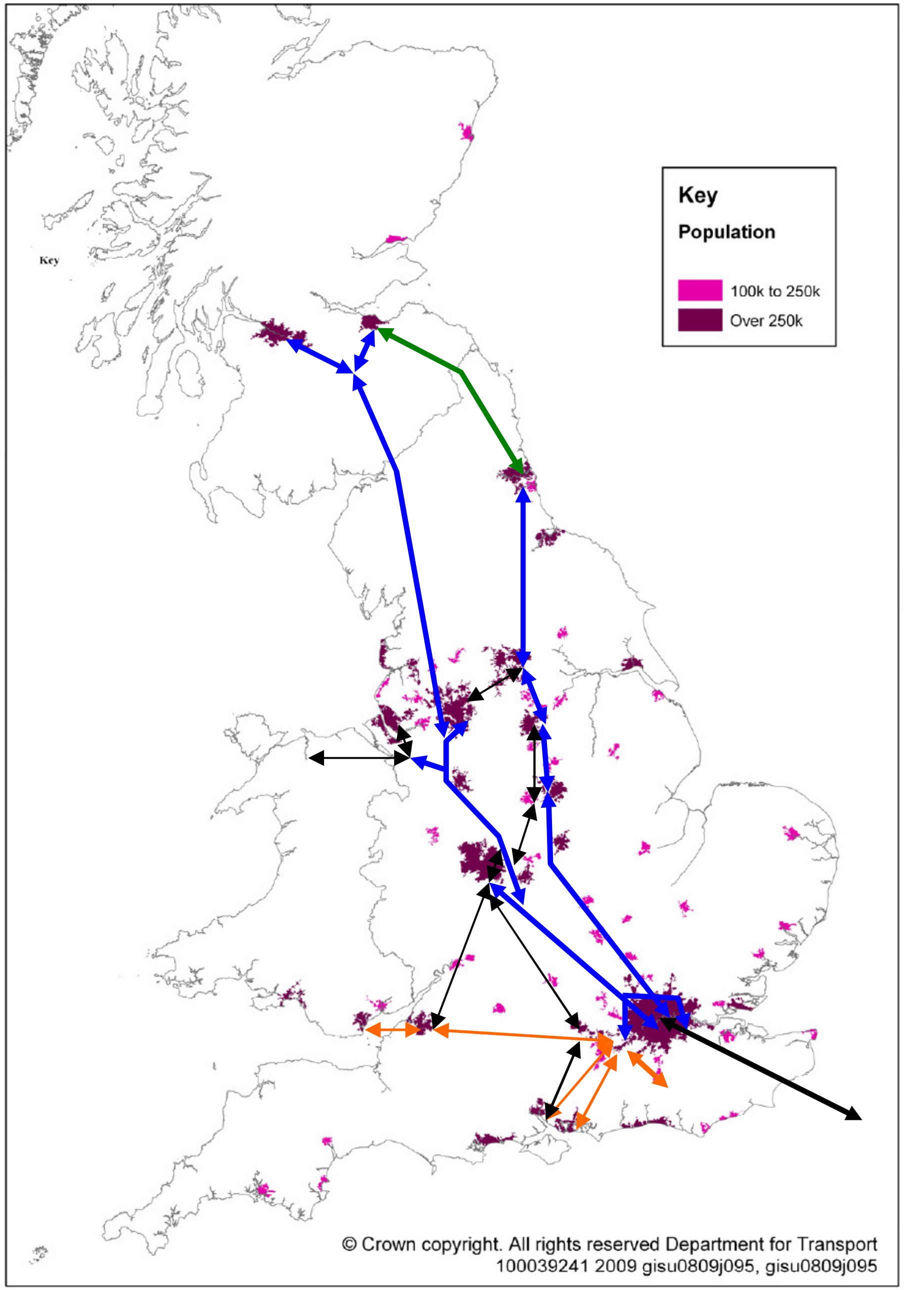
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- HS-NE route via M1 to East Midlands Parkway, Sheffield, Leeds and Newcastle
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- HS-NE till Newcastle, with all trains from London to Scotland remaining on HS-NW
- Shifting of Manchester – Newcastle services to HS-NE north of Leeds and Cross-Country / Heathrow services to HS-NE north of Sheffield

Scenario 6

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

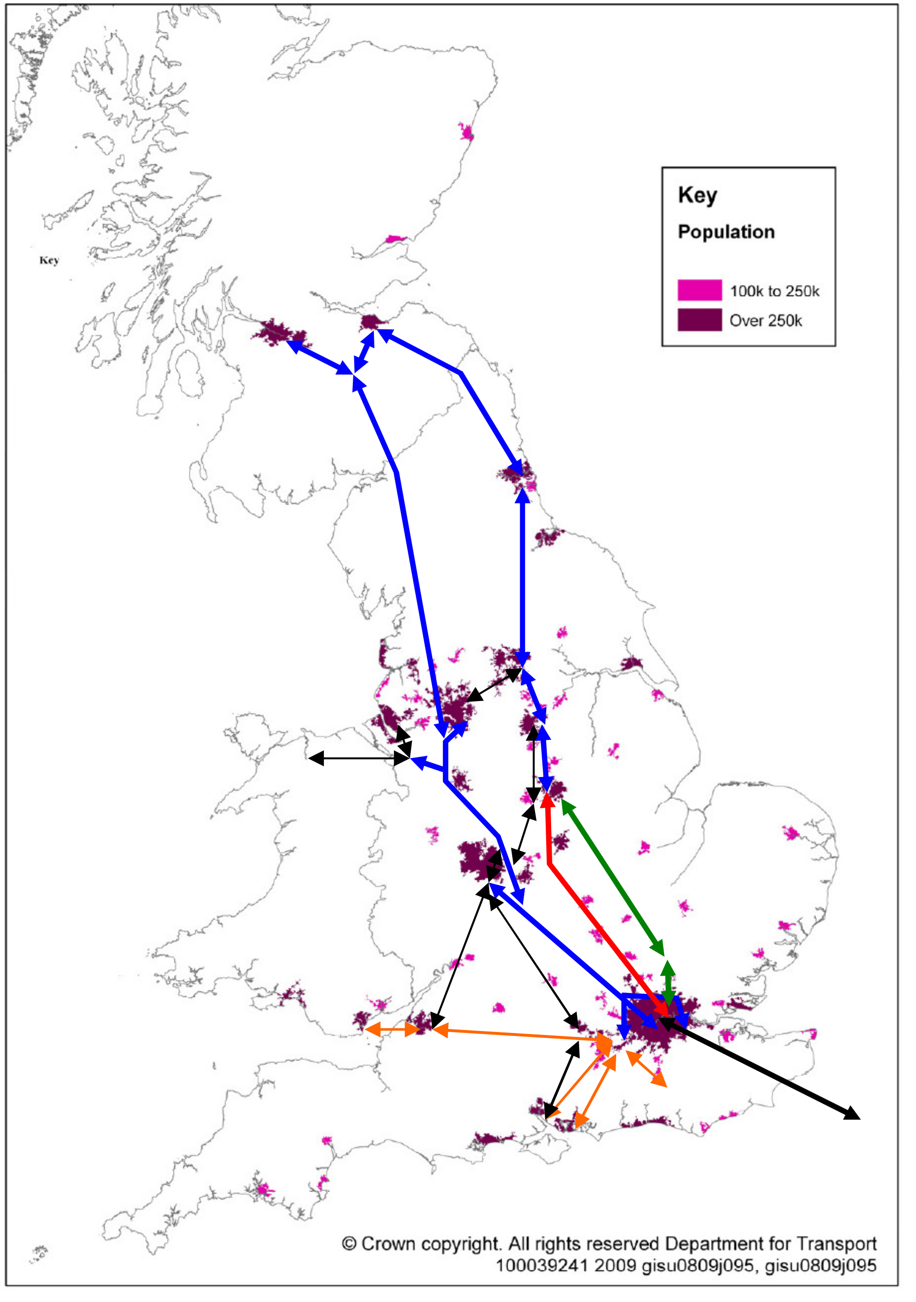
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- HS-NE route via M1 to East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Extension of HS-NE to Edinburgh, running London to Edinburgh trains via HS-NE and London to Glasgow via HS-NW
- Extension of Manchester – Newcastle trains to Edinburgh

Scenario A

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

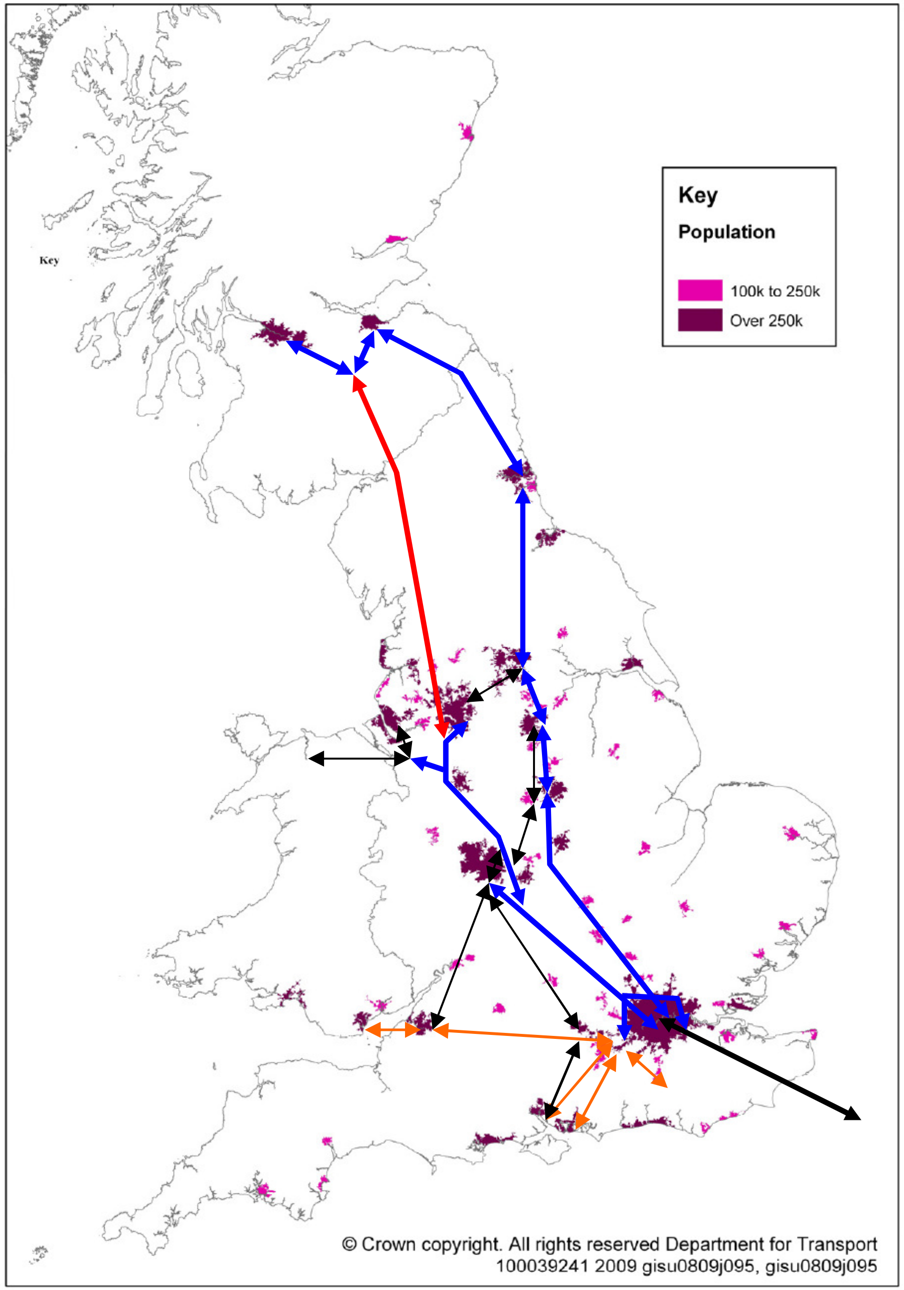
- HS-NW route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- HS-NE route via M11 to Stansted, East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Comparison of routing HS-NE via Stansted/M11 and starting at Stratford rather than St Pancras
- Direct connection from HS-NE to HS-CT

Scenario 7

- Core HS routes
- Added to previous scenario
- Removed from previous scenario
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

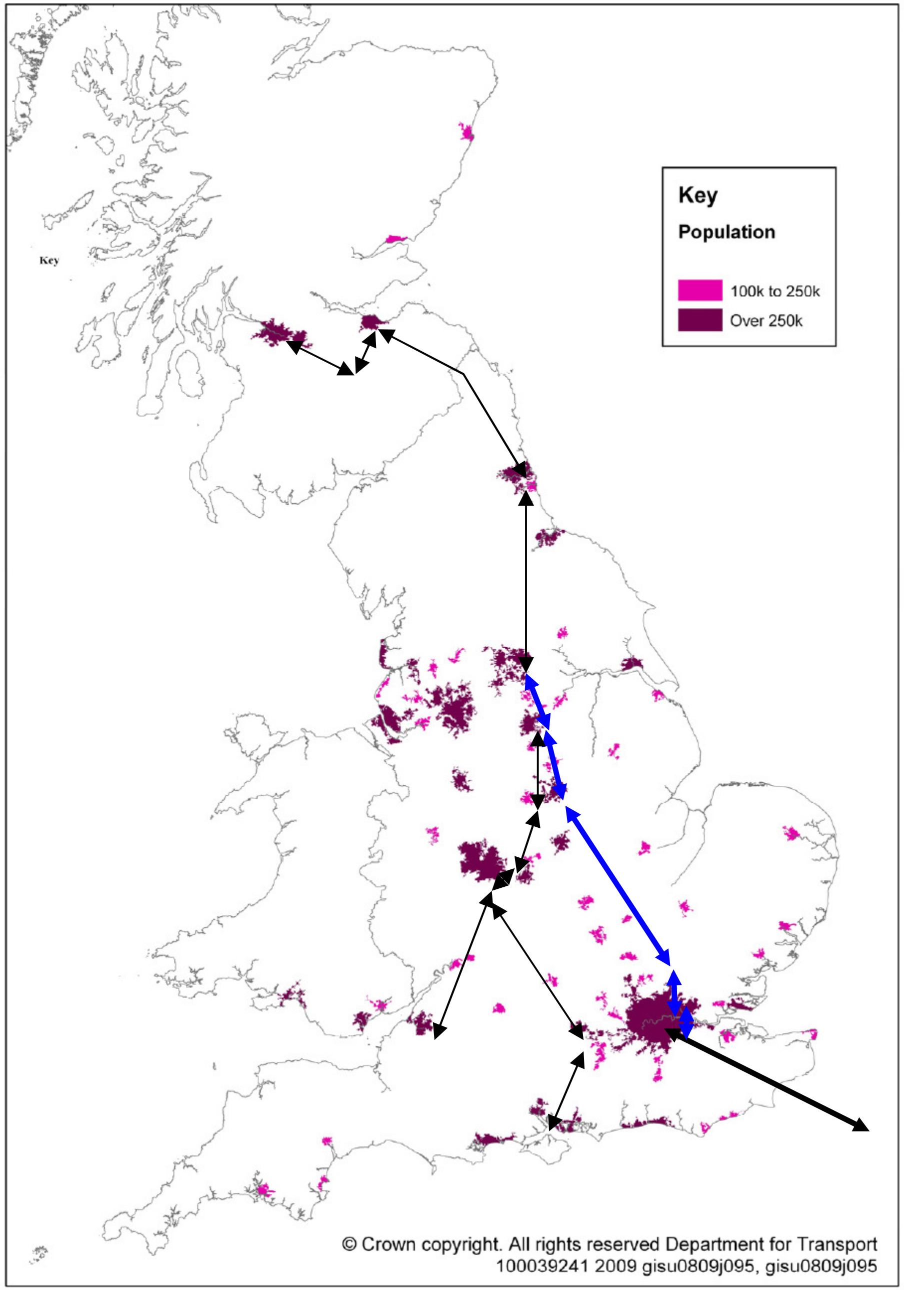
- HS-NW route via M40, M6 to Birmingham, Crewe, Manchester
- HS-NE route via M1 to East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Comparison of having all Scottish traffic run via HS-NE against having just a HS-NW or both routes to Scotland

Scenario B

(blue line)	Core HS routes
(thick black line)	HS-CT
(thin black line)	HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

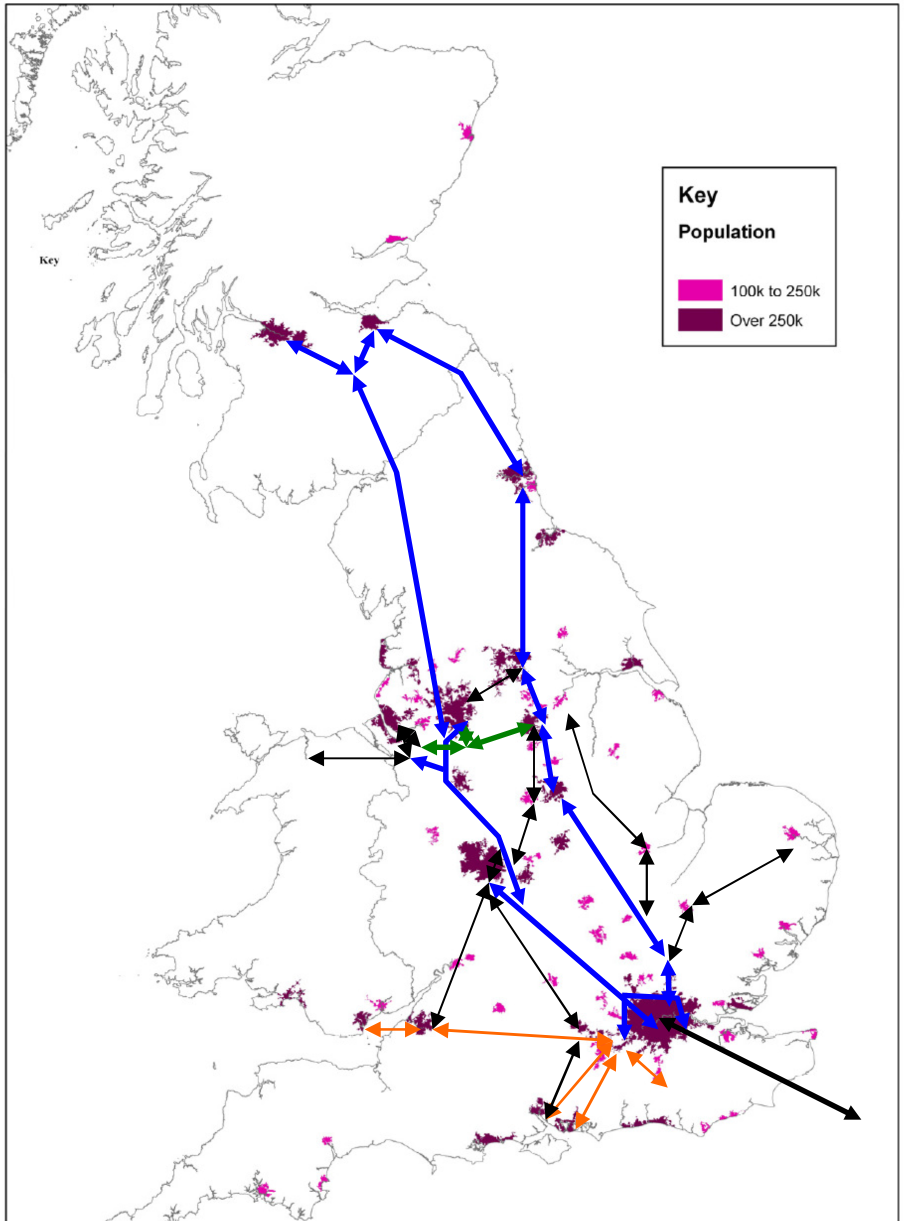
- HS-NE route via M11 to Stansted, East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- Connection to HS-CT

Elements Tested

- An alternative base network to Scenario 1
- HS service from Stratford and Europe to Leeds and Sheffield
- Trains continue on classic tracks to Newcastle and Scotland
- Cross-Country services to the North East and Scotland routed onto HS between Sheffield and Leeds

Scenario 8

- Core HS routes
- Added to Scenario A
- Removed from Scenario A
- HS-CT
- LHR links to South and West England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

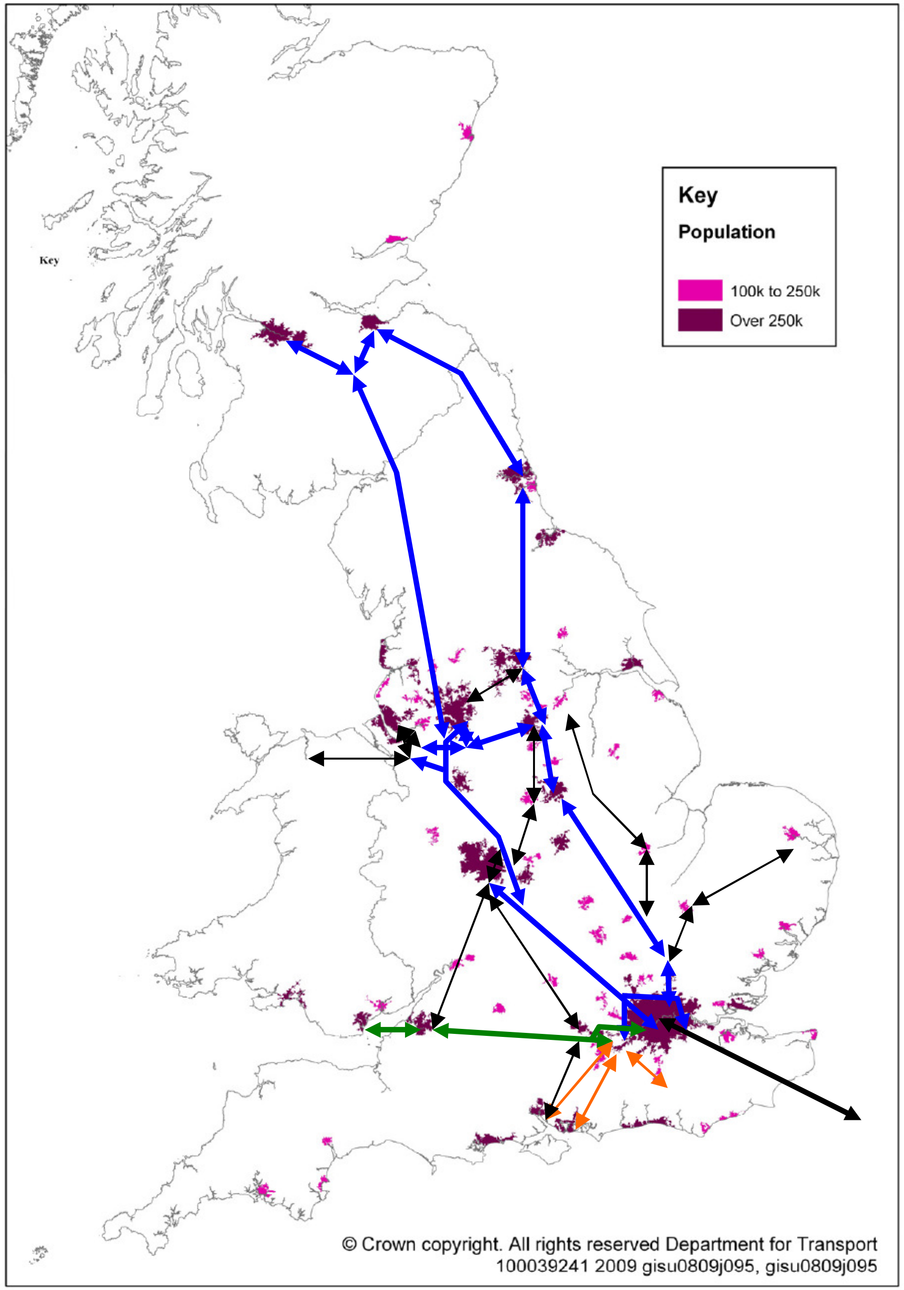
- WCHSL route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- ECHSL route via M11 to Stansted, East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- South Transpennine HS from Sheffield to Manchester and Liverpool via Manchester Airport
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South, South West and GWML

Elements Tested

- Transpennine Link with half-hourly service between Sheffield and Manchester
- Services from Liverpool to the North East via Sheffield
- Commuter services to East Anglia and Lincolnshire/ Doncaster via HS-NE

Scenario 9

- Core HS routes
- Added to Scenario A
- Removed from Scenario A
- HS-CT
- LHR links to South England
- HS services on classic tracks



Source of background map: Britain's High Speed Infrastructure – High Speed Two
http://www.dft.gov.uk/pgr/rail/pi/highspeedtwo/highspeedtwo.pdf

Key Features

- WCHSL route via M40, M6 and M74 to Birmingham, Crewe, Manchester and Carstairs, then on to Glasgow and Edinburgh
- ECHSL route via M11 to Stansted, East Midlands Parkway, Sheffield, Leeds, Newcastle, and Edinburgh
- South Transpennine HS from Sheffield to Manchester and Liverpool via Manchester Airport
- HS-SW from London to Cardiff via Bristol with connection to Heathrow and HS-CT
- Connections to HS-CT and Heathrow
- Connection from Heathrow to South & South West

Elements Tested

- Value of HS-SW services from London, Heathrow and Europe to Cardiff and Bristol

Table 1.1 Infrastructure Costs including depot costs and optimism bias in £m (2008 prices)

	1	2	3	4a	5	6	A	7	B	8	9
London - Birmingham Central & Birmingham Int'l	£9,013	£9,147	£9,073	£8,960	£9,176	£9,150	£9,211	£8,976		£9,211	£9,211
Birmingham - Manchester & Crewe	£7,467	£7,547	£7,524	£7,499	£7,607	£7,578	£7,571	£7,400		£7,574	£7,574
Heathrow - Northolt Jn	£2,191	£2,192	£2,191		£2,192	£2,192	£2,199	£2,191		£2,199	£2,199
Manchester - Edinburgh & Glasgow		£16,746	£16,695	£16,681	£16,702	£16,606	£16,491			£16,522	£16,522
London - Sheffield					£18,901	£19,202	£15,523	£19,269	£15,643	£16,036	£16,036
Sheffield - Leeds					£1,631	£1,627	£1,626	£1,647	£1,620	£1,636	£1,636
Leeds - Newcastle					£5,474	£5,654	£5,608	£5,677		£5,636	£5,636
Newcastle - Edinburgh						£5,851	£5,872	£5,851		£5,888	£5,888
Edinburgh - Glasgow								£2,728			
Transpennine										£2,592	£2,592
Great Western											£1,798
Classic Depot Infrastructure	£575	£202	£186	£142	£306	£239	£319	£239	£315	£319	£382
Total	£19,245	£35,835	£35,669	£33,283	£61,990	£68,099	£64,418	£53,977	£17,578	£67,612	£69,410

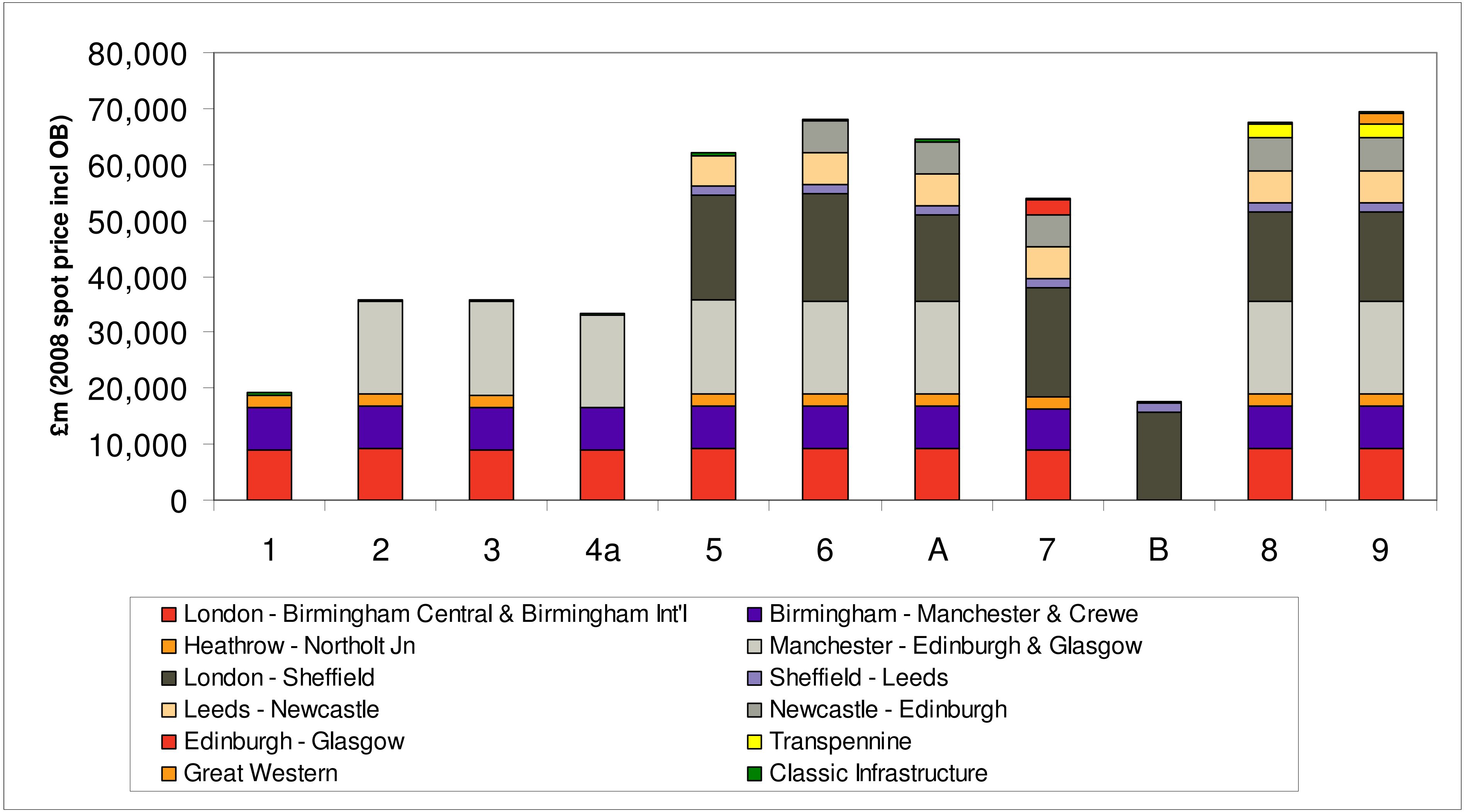


Figure 1.1 Infrastructure Capital Cost (£m) for each scenario

Table 1.2 CAPEX Costs including optimism bias in £m (2008 prices)

	1	2	3	4a	5	6	A	7	B	8	9
Infrastructure CAPEX (million £)	£19,245	£35,835	£35,669	£33,283	£61,990	£68,100	£64,419	£53,977	£17,578	£67,612	£69,410
RS acquisition (million £)	£5,749	£7,977	£7,537	£6,773	£12,285	£14,110	£14,421	£11,395	£4,250	£15,014	£15,386
RS major maintenance (million £)	£3,449	£4,786	£4,522	£4,064	£7,371	£8,466	£8,652	£6,837	£2,550	£9,009	£9,231
Infrastructure renewal (million £)	£2,692	£5,248	£5,234	£5,036	£8,500	£9,642	£9,930	£7,532	£2,536	£10,433	£10,831

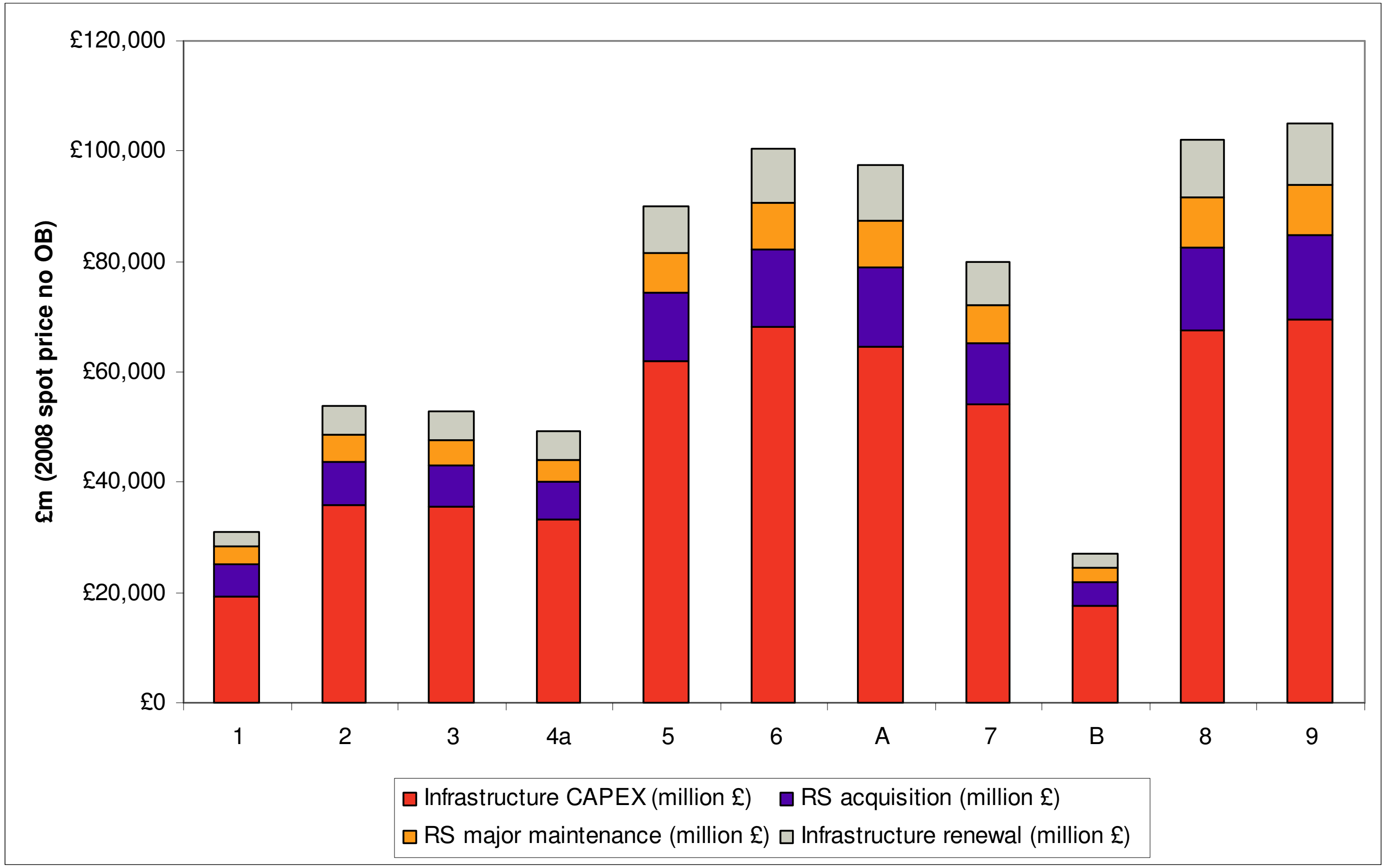


Figure 1.2 CAPEX cost (£m) of each scenario

Appendix H – Service Pattern Assumptions

Scenario 1

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	X1	X2	X3
Gatwick																			
Southampton																			
Portsmouth																			
Guildford																			
Woking																			
EUROPE																			
Ashford Int'l/Ebbsfleet Int'l																			
Stratford International																			
Heathrow Airport																			
London																			
Birmingham Central																			
Birmingham International							S												
South West																			
Bristol																			
Cardiff																			
Reading and South Coast																			
Birmingham New Street																			
Derby							1												
Crewe								S	S										
Chester + North Wales									1										
Sheffield							1												
Leeds																			
Newcastle																			
Manchester Airport																			
Manchester Central																			
Liverpool							1	1											
Edinburgh Central								1	1										
Glasgow																			

0

Scenario 2

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	C1	C2	A1	A2	A3	A4	A5	X1	X2	X3	H30	H31	H32	H33
Gatwick																								
Southampton																								
Portsmouth																								
Guildford																								
Woking																								
EUROPE																								
Ashford Int'l/Ebbsfleet Int'l																								
Stratford International																								
Heathrow Airport																								
London																								
Birmingham Central																								
Birmingham International											S													
Bristol																								
Cardiff																								
South West																								
Reading and South Coast																								
Birmingham New Street																								
Derby											1													
Crewe												S												
Chester + North Wales												1												
Sheffield											1													
Leeds																								
Newcastle																								
Manchester Airport							S																	
Manchester Central																								
Liverpool											1	1												
Edinburgh Airport Parkway																								
Edinburgh Central							1														1	1	1	1
Glasgow							1														1	1	1	1

Scenario 3

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
- 1tph
- 0.5 tph
- 0.25 tph

TRAIN TYPE
- **H1** UIC-Gauge, 2 x 200m units unless stated otherwise
- **C1** GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
- **S** Train splits at this station
- **1** Stop made by single unit
- **C2** 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	C1	C2	A1	A2	A3	A4	A5	X1	X2	X3	H30	H31	H32	H33
Gatwick																								
Southampton																								
Portsmouth																								
Guildford																								
Woking																								
EUROPE																								
Heathrow Airport																								
London																								
Birmingham Central																								
Birmingham International											S													
Bristol																								
Cardiff																								
South West																								
Reading and South Coast																								
Birmingham New Street																								
Derby											1													
Crewe												S												
Chester + North Wales												1												
Sheffield											1													
Leeds																								
Washington Parkway																								
Newcastle																								
Manchester Airport							S																	
Manchester Central																								
Liverpool											1	1												
Edinburgh Airport Parkway																								
Edinburgh Central							1														1	1	1	1
Glasgow							1														1	1	1	1

Scenario 4

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	C1	C2	H11	H12	C3	C4	X1	X2	X3	H30	H31	H32	H33
EUROPE																							
Heathrow Airport																							
London																							
Birmingham Central																							
Birmingham International															S								
South West																							
Reading and South Coast																							
Birmingham New Street																							
Derby															1								
Crewe												S			1								
Chester + North Wales												1											
Sheffield															1								
Manchester Airport																							
Manchester Central																							
Liverpool												1			1								
Edinburgh Airport Parkway																							
Edinburgh Central																				1	1	1	1
Glasgow																				1	1	1	1

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Scenario 5

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	C1	C2	C3	C4	C5	C6	A1	A2	A3	A4	A5	X1	X2	X3	X4	X5	X6	H30	H31	H32
	West Coast									East Coast																	GW									
Gatwick																																				
Southampton																																				
Portsmouth																																				
Guildford																																				
Woking																																				
EUROPE																																				
Ashford Int'l/Ebbsfleet Int'l																																				
Stratford International																																				
Heathrow Airport																																				
London East Coast																																				
London West Coast																																				
Birmingham Central																																				
Birmingham International																																				
Bristol																																				
Cardiff																																				
South West																																				
Reading and South Coast																																				
Birmingham New Street																																				
Derby																																				
Crewe																		S																		
Chester + North Wales																		1																		
East Midland Parkway																																				
Nottingham																																				
Sheffield																																				
Manchester Airport							S																													
Manchester Central																																				
Liverpool																		1																		
Leeds																																				
Tees Valley Parkway																																				
Washington Parkway																																				
Newcastle																																				
Edinburgh Airport Parkway																																				
Edinburgh Central							1																												1	1	1
Glasgow							1																												1	1	1

Scenario 6

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H8a	H9	H10	H11	H12	H13	H14	H15	H16	H17	H22	C1	C2	C3	C4	C5	C6	A1	A2	A3	A4	A5	X1	X2	X3	X4	X5	X6	H30	H31	H32
	West Coast									East Coast																				GW									
Gatwick																																							
Southampton																																							
Portsmouth																																							
Guildford																																							
Woking																																							
EUROPE																																							
Ashford Int'l/Ebbsfleet Int'l																																							
Stratford International																																							
Heathrow Airport																																							
London East Coast																																							
London West Coast																																							
Birmingham Central																																							
Birmingham International																																							
Bristol																																							
Cardiff																																							
South West																																							
Reading and South Coast																																							
Birmingham New Street																																							
Derby																																							
Crewe																					S																		
Chester + North Wales																					1																		
East Midland Parkway																																							
Nottingham																																							
Sheffield																																							
Manchester Airport																																							
Manchester Central																																							
Liverpool																					1																		
Leeds																																							
Tees Valley Parkway																																							
Washington Parkway																																							
Newcastle																																							
Edinburgh Airport Parkway																																							
Edinburgh Central																																					1	1	1
Glasgow																																					1	1	1

Scenario 7

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H22	C1	C2	C3	C4	C5	C6	A1	A2	A3	A4	A5	X1	X2	X3	X4	X5	X6
	West Coast						East Coast																					GW						
Gatwick																																		
Southampton																																		
Portsmouth																																		
Guildford																																		
Woking																																		
EUROPE																																		
Ashford Int'l/Ebbsfleet Int'l																																		
Stratford International																																		
Heathrow Airport																																		
London East Coast																																		
London West Coast																																		
Birmingham Central																																		
Birmingham International																																		
Bristol																																		
Cardiff																																		
South West																																		
Reading and South Coast																																		
Birmingham New Street																																		
Derby																																		
Crewe																			S															
Chester + North Wales																			1															
East Midland Parkway																																		
Nottingham																																		
Sheffield																																		
Manchester Airport																																		
Manchester Central																																		
Liverpool																			1															
Leeds																																		
Tees Valley Parkway																																		
Washington Parkway																																		
Newcastle																																		
Edinburgh Central																																		
Glasgow																																		

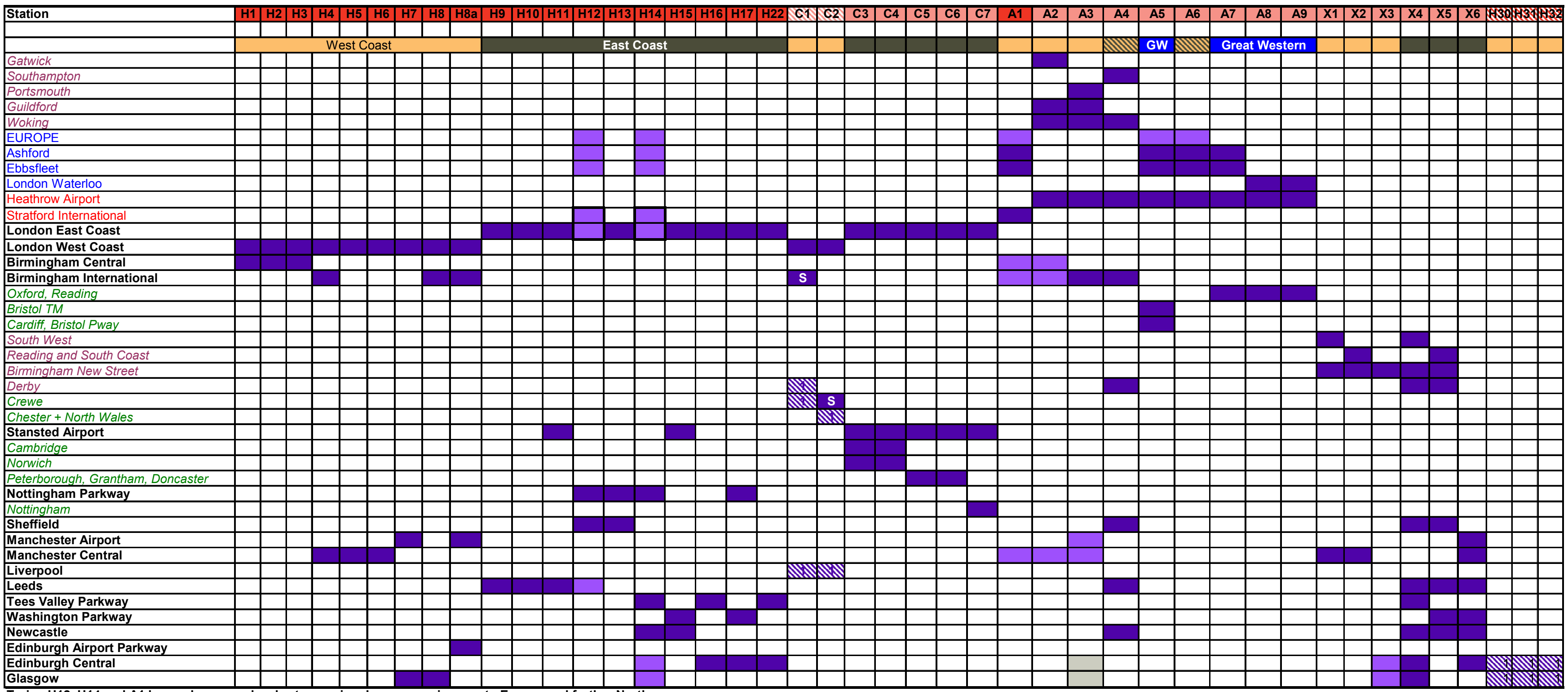
Scenario A

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
1 Stop made by single unit
C2 2 x GB-Gauge unit at start of journey



Trains H12, H14 and A1 have a longer and a shorter version. Longer versions go to Europe and further North.
Train A3 calls Manchester Airport when it goes to Scotland

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Scenario B

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
- 1tph
- 0.5 tph
- 0.25 tph

TRAIN TYPE
- H1 UIC-Gauge, 2 x 200m units unless stated otherwise
- C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
- S Train splits at this station
- Stop made by single unit
- C2 2 x GB-Gauge unit at start of journey

Station	H9	H10	H11	H12	H13	H14	H15	H16	C3	C4	C5	C6	C7	X4	X5
	East Coast														
Gatwick															
Southampton															
Portsmouth															
Guildford															
Woking															
EUROPE				0.5		0.5									
Ashford				0.5		0.5									
Ebbsfleet				0.5		0.5									
London Waterloo															
Heathrow Airport															
Stratford International				0.5		0.5									
London East Coast	1	1	1	0.5	1	0.5	1	1	1	1	1	1	1		
London West Coast															
Birmingham Central															
Birmingham International															
Oxford, Reading															
Bristol TM															
Cardiff, Bristol Pway															
South West														1	
Reading and South Coast															1
Birmingham New Street														1	1
Derby														1	1
Crewe															
Chester + North Wales															
Stansted Airport			1				1		1	1	1	1	1		
Cambridge									1	1					
Norwich									1	1					
Peterborough, Grantham, Doncaster											1	1			
Nottingham Parkway				1	1	1									
Nottingham													1		
Sheffield				1	1									1	1
Manchester Airport															
Manchester Central															
Liverpool															
Leeds	1	1	1	0.5										1	1
Tees Valley Parkway															
Washington Parkway															
Newcastle						1	1	1						1	1
Edinburgh Airport Parkway															
Edinburgh Central						1	1	1						1	
Glasgow						1	1	1						1	

Trains H12 and H14 have a longer and a shorter version. Longer versions go to Europe and further North.

Scenario 8

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
- 1tph
- 0.5 tph
- 0.25 tph

TRAIN TYPE
- H1 UIC-Gauge, 2 x 200m units unless stated otherwise
- C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
- S Train splits at this station
- 1 Stop made by single unit
- C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H8a	H9	H10	H11	H12	H13	H14	H15	H16	H17	H22	C1	C2	C3	C4	C5	C6	C7	A1	A2	A3	A4	A5	A6	A7	A8	A9	X1	X2	X3	X4	X5	X6	X7	X8	X9	H30	H31	X10
	West Coast									East Coast																					GW		Great Western														
Gatwick																																															
Southampton																																															
Portsmouth																																															
Guildford																																															
Woking																																															
EUROPE																																															
Ashford																																															
Ebbsfleet																																															
London Waterloo																																															
Heathrow Airport																																															
Stratford International																																															
London East Coast																																															
London West Coast																																															
Birmingham Central																																															
Birmingham International																				S																											
Oxford, Reading																																															
Bristol TM																																															
Cardiff, Bristol Pway																																															
South West																																															
Reading and South Coast																																															
Birmingham New Street																																															
Derby																																															
Crewe																					S																										
Chester + North Wales																																															
Ipswich/Norwich																																															
Stansted Airport																																															
Cambridge																																															
Norwich																																															
Peterborough, Grantham, Doncaster																																															
Nottingham Parkway																																															
Nottingham																																															
Liverpool																																															
Manchester Airport																																															
Sheffield														S																																	
Manchester Airport																																															
Manchester Central																																															
Liverpool																																															
Leeds																																															
Tees Valley Parkway																																															
Washington Parkway																																															
Newcastle																																															
Edinburgh Airport Parkway																																															
Edinburgh Central																																															
Glasgow																																															

Trains H12, H14 and A1 have a longer and a shorter version. Longer versions go to Europe and further North.
Train A3 calls Manchester Airport when it goes to Scotland

Scenario 9

H Trains Running HSL Only
C Trains Running Portion of Journey on HSL
A Heathrow Services
X Cross-Country (NOT London Services)

FREQUENCY
1tph
0.5 tph
0.25 tph

TRAIN TYPE
H1 UIC-Gauge, 2 x 200m units unless stated otherwise
C1 GB-Gauge, 1 x 200m unit unless stated otherwise

SPLIT/JOIN
S Train splits at this station
Stop made by single unit
C2 2 x GB-Gauge unit at start of journey

Station	H1	H2	H3	H4	H5	H6	H7	H8	H8a	H9	H10	H11	H12	H13	H14	H15	H16	H17	H22	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	A1	A2	A3	A4	A5	A6	A7	A8	A9	X1	X2	X3	X4	X5	X6	X7	X8	X9	H30	H31	X10
	West Coast									East Coast																									GW		Great Western														
Gatwick																																																			
Southampton																																																			
Portsmouth																																																			
Guildford																																																			
Woking																																																			
EUROPE																																																			
Ashford																																																			
Ebbsfleet																																																			
London Waterloo																																																			
Heathrow Airport																																																			
Stratford International																																																			
London East Coast																																																			
London West Coast																																																			
Birmingham Central																																																			
Birmingham International																				S																															
London Great Western																																																			
Oxford, Reading																																																			
Bristol TM																																																			
Cardiff, Bristol Pway																																																			
South West																																																			
Reading and South Coast																																																			
Birmingham New Street																																																			
Derby																																																			
Crewe																					S																														
Chester + North Wales																																																			
Ipswich/Norwich																																																			
Stansted Airport																																																			
Cambridge																																																			
Norwich																																																			
Peterborough, Grantham, Doncaster																																																			
Nottingham Parkway																																																			
Nottingham																																																			
Liverpool																																																			
Manchester Airport																																																			
Sheffield														S																																					
Manchester Airport																																																			
Manchester Central																																																			
Liverpool																																																			
Leeds																																																			
Tees Valley Parkway																																																			
Washington Parkway																																																			
Newcastle																																																			
Edinburgh Airport Parkway																																																			
Edinburgh Central																																																			
Glasgow																																																			

Trains H12, H14 and A1 have a longer and a shorter version. Longer versions go to Europe and further North.
Train A3 calls Manchester Airport when it goes to Scotland
Train H13 is a mixed train - 1xUIC + 1xGB gauge

Appendix I Freight Benefits

1 Introduction

The benefits to freight depend on the routing of HSR. This note sets out a methodology for estimating the benefits by each route. High level assumptions have been made on the effects of different HSR routings on available capacity released for freight services on the classic network.

2 Route corridors

2.1 West Coast Main Line (WCML) Corridor.

Most HSR options will provide a high speed service on a new alignment between London, Birmingham and Manchester, removing some of the Pendolino services from the WCML. (In this document reference to the WCML means the classic route from Euston and HSR is shorthand for any of the options for a new high speed alignment.) The WCML is the most important freight route, and furthermore is expected to grow most strongly (see section 6); it is therefore on this route that the majority of the freight benefits will occur.

2.2 East Coast Main Line (ECML) Corridor

In this document ECML is shorthand for London-Peterborough-Leeds/York-Newcastle-Edinburgh route. Whilst all of the HSR options provide a service for West Yorkshire and the North East conurbations, not all provide a comparable route to the classic ECML. In these circumstances, and given that the ECML conveys less freight traffic than the WCML, there is far less scope for increased freight capacity.

2.3 Midland Main Line (MML) Corridor.

There is some scope for increasing freight paths on the MML, but again expected demand growth on this route is less than on the WCML.

2.4 Great Western Main Line (GWML) Corridor.

This is the corridor between London-Reading-Bristol/South Wales. The HSR proposals provide for an upgrade to the existing GWML infrastructure for high speed services; the impact on capacity for freight depends on where capacity is released. This would be especially true on the Acton to Reading section which is an important freight artery for construction traffic, and where the current HSR proposals do not provide extra capacity.

3 Connections to classic stations.

We discuss below the most critical sections of route for freight in the vicinity of the principal stations. This enables consideration of the freight implications of alternative decisions regarding station location and approach.

3.1 Euston/North London.

The North London Line (NLL) is a major freight artery which connects the WCML to Stratford and the Haven Ports and North Thames side and joins the WCML at Camden Junction (Primrose Hill). Should HS2 use the WCML north of Camden Junction to access Euston or the NLL to access St. Pancras International then it would severely impair freight capacity on this important cross London link. (This could be partially alleviated by upgrading the Tottenham & Hampstead Line (T&H), although not all flows using the NLL could be diverted onto the T&H.)

3.2 Coventry to Birmingham.

Use of the "Coventry Corridor" (Coventry-Birmingham International-Birmingham New St.) by HSR to access Birmingham New St. would reduce freight capacity on the Coventry to Stechford section of line and would have a detrimental effect on freight capacity, especially Southampton to WCML intermodal traffic.

3.3 Stockport to Manchester Piccadilly.

The Stockport-Slade Lane Junction-Manchester Piccadilly-Deansgate route is the only rail access to the Trafford Park intermodal terminals – the most important freight terminal complex in North West England. Significant use of this route by HSR services would reduce freight capacity on an already heavily used section of line.

3.4 Conclusions.

The assumption for this study is that none of the above sections of route are used by HSR to any significant degree. If they were then any benefits gained from increased freight paths on the core WCML would be compromised by an inability to access terminal capacity

4 Assumptions on Network Rail (NR) upgrades to the existing network.

4.1 WCML.

By 2009/10 the PUG2 WCML Upgrade work will be completed. The only outstanding work package is the Bletchley area improvements to junction speeds and sidings.

4.2 Transport Innovation Fund Schemes.

Transport Innovation Fund (TIF) schemes are funded by the DfT to improve transport infrastructure. Several of these schemes are planned to improve freight capacity on the existing network and impact on HS2 freight benefits.

4.3 Felixstowe to Nuneaton via Peterborough.

TIF funding was announced in 2007 to enable both gauge and capacity enhancements on the route from Felixstowe to Nuneaton via Peterborough. This work will enable 9'6" ISO containers from the Haven Ports (Felixstowe/Parkeston Quay/Bathside Bay/Ipswich) to be conveyed on standard height wagons by increasing the gauge to W10, along with other works to increase capacity on the route. This will enable intermodal trains from the Haven Ports to reach the WCML and the West Midlands without having to run via Stratford, the NLL and the WCML between Camden and Nuneaton, thus freeing up capacity for intermodal and other freight growth on these routes. As at April 2009 this scheme is funded and at the implementation stage.

4.4 Southampton to WCML.

This TIF scheme will provide both gauge and capacity enhancements on the Southampton-Reading-Leamington Spa-WCML route (along with diversionary capability via Laverstock) allowing increased capacity for intermodal trains from Southampton Docks. The gauge enhancement to W10 enables 9'6" ISO containers to be carried on standard height wagons, which improves productivity. This scheme was approved in 2007 and as at April 2009 is at the implementation stage.

Allied to the gauge enhancement is the NR Reading re-modelling which provides for a freight flyover at Reading West Junction, this removes the capacity bottleneck of the flat junction which all intermodal trains from Southampton have to negotiate. Most of the additional intermodal trains facilitated by these enhancements are destined for the WCML.

4.5 North London Line and Tottenham & Hampstead Line.

NR Business Plan has an upgrade to the NLL re-instating track between Camden Road and Dalston Junction to increase capacity. This is driven primarily by the need to path additional NLL passenger services in time for the 2012 Olympics but will also give additional capacity for freight traffic. This is critical since, at present, the NLL is the only cross London freight route cleared for W10 gauge connecting Stratford to the WCML.

DfT TIF funding has enabled work to start on gauge clearance to W10 on the Tottenham & Hampstead Line, which is the only other cross London freight route that can connect the WCML to Stratford and North Thames side. As of April 2009 this scheme is at the implementation stage.

4.6 Felixstowe to West Yorkshire Capacity and Gauge Enhancement.

As a condition of the planning permission for the latest phase of expansion of Felixstowe port, the owners, Hutchison Whampoa Ports are required to fund improvements on the Felixstowe to Ipswich branch to increase capacity and increase the gauge to W10 on the route from Ipswich to West Yorkshire via Peterborough. This requirement was made so that the percentage of containers leaving the port by rail would remain the same after the expansion of capacity. (See later section on port capacity for container traffic.)

5 Proposed Infrastructure Upgrades Not Assumed In Base Case.

The following infrastructure schemes that would increase traffic levels/capacity are NOT assumed in this base case.

5.1 East-West Rail Link.

This is the scheme to re-open/upgrade the rail line from Oxford to Cambridge/Ipswich via Milton Keynes and Bedford, currently being proposed by a consortium of local authorities.

Whilst primarily a through cross country route, if built it would increase the passenger traffic on the WCML around the Bletchley/Milton Keynes area.

5.2 Stafford Avoiding Line.

This scheme proposes a new alignment for the WCML avoiding Stafford, so as to increase line speeds and obviate the conflicts on the "at grade" junctions north and south of the town.

5.3 Hanslope/Roade Flying Junction.

This scheme replaces the present "flat" junction at Hanslope, where the Northampton Loop diverges from the WCML direct with a grade separated flying junction, increasing both line speeds and capacity.

5.4 Carlisle Station Avoiding Lines.

This scheme would re-instate the former goods lines that avoided Carlisle Citadel station. At present all freight traffic has to be routed through Carlisle station and there is a two track bottleneck at the north end of the station. The re-instatement of the goods line would remove that bottleneck and provide additional capacity for both freight and passenger traffic.

6 Assessment of demand for railfreight services.

Whilst the HS2 project may give extra capacity on classic rail routes (especially the WCML) the benefits from extra freight paths will only be realised if the demand for them is in excess of present capacity. This may be a statement of the self evident but without some estimate of the volume of freight wishing to use the classic routes it cannot be assumed that the demand is greater than present capacity. To test this case several sources of research have been used, the most important of which Rail Freight Group (RFG)/Freight Transport Association (FTA) demand forecasts. A short description of this model follows.

6.1 RFG/FTA Rail Freight Forecasts Methodology.

These are published on www.rfg.org.uk and show forecasts for 2015 and 2030. They are a combination of "bottom up" forecasts supplied by Freight Operating Companies (FOCs) built up sector by sector and flow by flow and "top down" forecasts derived from the GB Freight Model. The GB Freight Model was developed by the Strategic Rail Authority and has been adopted by the Department for Transport as a macro economic model of the demand for freight traffic. The forecasts published in Sept. 2008 provide the figures for the 2015 and 2030.

The RFG/FTA forecasts have found significant convergence between the "bottom up" and "top down" figures, giving confidence that they are a robust estimate of future demand. Their forecasts compare the volume of freight movements on sections of route in 2008 and the forecast level of demand in 2015 and 2030. Comparing these figures any shortfall in capacity is shown by route section.

It should be noted that the RFG/FTA forecasts have a base assumption that the level of passenger usage of a route section does not increase in the forecast period. Hence 2015 and 2030 levels of freight usage are overlaid on 2008 passenger use. Whether this is a robust assumption is open to discussion, especially as virtually every major route has some planned increase in passenger services to keep pace with forecast passenger growth. If there are increases in the level of passenger services then the only logical conclusion is that there will be even greater pressure on the available freight capacity.

6.2 RFG/FTA Freight Forecast Results.

On a base of 2006 by 2015 railfreight is expected to grow by 30% in terms of tonne-kilometres and by 2030 there is a doubling (100%) increase.

The report forecasts that growth in intermodal traffic is expected to be much higher given that international trade grows at a higher rate than national GDP. In a report dated 2001 "Developments and prospects for UK Container Ports" the DfT quoted an IMF study on world trade that stated that in the 1980s international trade grew at 1.2% per annum faster than national GDPs and that by the 1990s this had accelerated to 3.2%. The GB Freight Model predicts a growth of intermodal traffic on rail in this country of 100% by 2015 and a five fold increase by 2030. As previously noted, intermodal traffic has a disproportionate effect on the WCML as it links the major population centres of the UK by the only W10 gauge route. The majority of the flows of intermodal traffic from the ports of Felixstowe/ Tilbury/ Southampton use the WCML for some of their journeys.

The RFG/FTA model predicts that by 2030 a shortfall of freight capacity on the WCML will exist of approx. 100 trains per day in each direction between Willesden and Rugby, 60 trains per day between Rugby and Colwich and 100 trains per day between Colwich and Weaver Junction. Even the northern section of the WCML from Weaver Junction to Mossend (Motherwell) is forecast to be short of 50 freight train paths in each direction by 2030.

6.3 Possible flaws in the RFG/FTA forecasts.

Whilst the overall growth in freight traffic, especially intermodal, cannot be doubted, some of the routing assumptions are questionable.

Firstly, as outlined above, a model which assumes no increase in passenger use of the network is questionable to say the least. To take one example, on the WCML it might be expected that, over a 15 year period, some increase in frequency over the present Virgin Trains service from Euston to Liverpool (from 1 to 2 per hour) and the Euston to Birmingham service (from 3 to 4 per hour) will occur. This is without any new services that open access operators might want to introduce.

Secondly, being based on 2006 routings, the RFG/FTA model takes no account of network enhancements such as Felixstowe to Nuneaton via Peterborough gauge and capacity increases. All of the increase in intermodal traffic from the Haven Ports destined for the WCML is routed via the NLL in the RFG/FTA forecasts. No allowance is made for the use of the cross country route via Peterborough. This would relieve some, but not all, the pressure on the WCML south of Nuneaton.

Even with these caveats the RGF/FTA forecasts still make a robust case for an excess of demand over available pathways for freight.

6.4 Intermodal Market Specific Forecasts.

Network Rail Route Utilisation Strategy (RUS).

The NR Freight RUS has specific forecasts by market sector, which also used the RFG/FTA GB Freight Model for its "top down" forecasts. NR also gave "bottom up" forecasts of its own for the ten years 2004/5 to 2014/5 which predicted growth of 82% in Maritime (Deep Sea) containers. This is broadly in line with the GB Freight Model predictions.

In table 5.6 of the NR Freight RUS forecasts are given of the additional trains in each direction from both the Haven Ports and Shell Haven (east of Tilbury). By 2014/5 NR forecast the following additional trains:

- Haven Ports to West Midlands/N.W. England/Scotland = 11 trains per day.
- Shell Haven to West Midlands/N.W. England/Scotland = 8 trains per day.

At the time of publication (Sept. 2006) the Freight RUS foresaw a bottleneck at Stratford constraining growth, caused by the NLL being the only W10 gauge cleared route giving access to the WCML from the east of England. However, post publication both the Felixstowe to Nuneaton via Peterborough and Tottenham & Hampstead Line W10 gauge clearance schemes have been authorised, greatly increasing capacity.

High Cube (9'6") Container Volumes.

The NR Freight RUS gives projections for the proportions of the container fleet that will comprise of 9'6" high units (sometimes referred to as "high cube"). This is relevant to this study because 9'6" containers can only be moved on standard height wagons over W10 gauge cleared routes. 8'6" containers (the industry standard up to the mid 1990s) can be moved over W8 gauge cleared routes, which comprise of a much larger proportion of the network. Hence as the proportion of 9'6" containers increases so a greater volume of traffic has to be funnelled over the W10 gauge cleared routes.

While there are alternative wagons that have been designed as a solution for this, they have as yet not been widely adopted due either to capacity, cost or running speed. For the purposes of this study it means that more intermodal traffic has to run over the WCML.

The NR Freight RUS projections (based on evidence given to the Felixstowe South and Bathside Bay planning inquiries in 2004) show that from a base of 2007 when 40% of 40ft. containers were 9'6" high, by 2023 this figure is expected to be 60%. At this level, virtually all intermodal services will have to be routed over W10 gauge cleared routes.

6.5 Port Expansion.

The volume of intermodal traffic on the WCML is also influenced by a number of projects to expand the capacity of ports in the S.E. of England.

Felixstowe.

The Felixstowe South terminal expansion was approved in Feb. 2006 and is expected to open between 2009 and 2014. This will add a further 400k TEU (Twenty Foot Equivalents – the measure of ISO container volumes) to the Port of Felixstowe. Development beyond the

Felixstowe South and finding further land for the port to expand on the north bank of the River Orwell, gets increasingly difficult. (Any further expansion upstream takes the port into increasingly sensitive environmental areas.)

Bathside Bay (Approved March 2006).

Bathside Bay is between Harwich and Parkeston Quay on the south bank of the River Orwell. Hutchison Whampoa Ports (owners of the Port of Felixstowe) have gained planning permission for a port of 1.277m TEU per annum capacity (when the development is complete in 2020). Hutchison Whampoa predicted that a minimum of 22.5% of these containers would be transported by rail (with sensitivity tests for a rail market share of 25% and 30% thought to be possible). The Planning Application stated that at 22.5% rail modal share, Bathside Bay would generate an additional 33 train paths by 2023 of which 22 would be for WCML destinations.

Shell Haven (Approved 2007).

The Shell Haven development (sometimes known as London Gateway) is a development by Dubai Ports World (DPW) of the former Shell Haven oil refinery site for both a container port and industrial property. Shell Haven is approx. eight miles down river from Tilbury on the north bank of the Thames estuary. DPW are aiming to build a 1.6m TEU per annum capacity port. Being a former oil refinery it has a large "brown field" development area behind the water front and DPW are developing the site for large areas of warehousing and industrial property that could generate significant rail freight business, in addition to the port. MDS Transmodal's 2003 report "Forecast of Maritime Containers by Rail" stated that by 2020 Shell Haven could generate up to 28 trains per day.

The special problem with Shell Haven is that its rail connection comes off of the London, Tilbury & Southend (LTS) Line. Given the geography of the rail network the only way of routing freight traffic onto or off it is via either the NLL or, preferably, the upgraded T&H Line. (It makes no sense in terms of railway operations or miles travelled to attempt to route traffic off of the LTS Line onto the Ipswich-Peterborough-Nuneaton route.)

6.6 Conclusions.

From the above analysis it can be seen that the growth in ISO container traffic will continue in the long run, despite the down turn of the 2009/10 economic recession. (The assumption is that this does not turn into a 1930s style "Depression".) The main growth will come from the expansion at Felixstowe South and the developments approved at Bathside Bay and Shell Haven. The number of additional trains from these developments (assuming unconstrained rail growth) would be:

Year 2015/6 and beyond:

Felixstowe +10 trains

Bathside + 20 trains

Shell Haven +28 trains

Total + 58 trains.

In addition it is assumed that the other south eastern container ports, Southampton, Tilbury and Thamesport (Isle of Grain), keep their present level of throughput and rail forwarding. This is a reasonably conservative assumption as a case can be made for further growth at these ports.

6.7 Channel Tunnel.

The Channel Tunnel has underperformed as a railfreight carrier since opening in 1994. Original forecasts were predicting that by 2009 some 6m tonnes of freight should have been transiting the Channel Tunnel compared to less than a million tonnes in 2008, at best 2 or 3 trains per day.

The lack of the Channel Tunnel's success in attracting railfreight has been a combination of the high access charges levied by Eurotunnel and the poor quality of service, especially on the French side of the operation.

As things stand we do not believe that the Channel Tunnel will start to bring significant volumes of railfreight into the UK and volumes will continue at around the one million tonne per annum level. This is a conservative assessment of the situation and the NR Freight RUS and the RFG/FTA GB Freight model both predict significant growth with volumes increasing to 6m tonnes by 2014/5. This must be considered an "upside" risk, as much of this traffic would be routed over the WCML north of London.

7 Demand for freight paths.

This section will concentrate on the WCML as the major railfreight artery of Great Britain and the one where freight growth and the effects of HS2 will be felt most.

The NR Freight RUS estimates that the increases in freight capacity gained from the WCML upgrade (completed in 2009/10) and the Felixstowe to Nuneaton via Peterborough gauge and capacity work should enable forecast demand for intermodal trains from the Haven Ports to be satisfied up to 2015/6. From then on further growth will be constrained. In addition the opening of Shell Haven early in the next decade presents real capacity problems. Its traffic can only be moved via north London (either NLL or T&H) to access the WCML. So unless there is an investment in a gauge cleared route and extra capacity between north London and Peterborough (which this study has assumed there will not be) growth in rail traffic from Shell Haven will also be constrained.

Hence from 2015/6 there will be demand for intermodal traffic wanting to access the WCML that will not be able to be accommodated. Therefore the prime assumption of this report is that any freight pathways on the WCML freed up by HS2 development will be utilised for intermodal traffic.

7.1 Freight pathways available following HSR opening.

Firstly, all of the estimates in this report of paths available following the opening of HS2 are a judgement based on experience of railway operations and train planning, but without the benefit of "graphing" or computer simulation of a timetable.

The basis of this analysis is the outline passenger specification for the WCML post HSR:

Classic services withdrawn from WCML

- 3 trains per hour Euston – West Midlands
- 3 trains per hour Euston - Manchester
- 1 train per hour Euston - Liverpool
- 1 train per hour Euston – NW – Glasgow
- 1 train per hour Euston – North Wales

Alternative services introduced on WCML

- 2 trains per hour Euston – MK – West Midlands (125 mph)
- 2 trains per hour Euston – MK – Stoke - Manchester (with Trent Valley stops) (125 mph)
- 2 trains per hour Euston – MK – Northampton (100 mph)
- 1 train per hour Euston – Liverpool (with Trent Valley stops) (125 mph)
- 1 train per hour Gatwick – Clapham – Watford – MK – Birmingham (100 mph)

All trains are replicated in the up direction.

It is assumed that all the "Alternative Services" would be pathed on the Fast Lines. Additionally the two trains per hour Euston-MK-Northampton are the present Euston to Northampton fast services but pathed on the Fast Lines to Hanslope Junction, rather than being switched Fast Line to Slow Line at some part in their journey. Further it is assumed that the one train per hour Gatwick to Birmingham would be pathed on the Fast Lines and would replace the present hourly East Croydon to Milton Keynes service which is pathed on the Slow Lines.

Given the major caveat that no formal "timing" of these paths has been attempted, it is assumed that this pattern of off peak passenger service would create three additional freight paths on the Slow Lines from Willesden to Rugby during "daytime" hours. It is assumed that the above pattern of passenger operation would be:

0530–0700/0900-1630/1900-2100 = Total 11 hours.

Outside of these hours it is assumed that freight paths are not constrained by passenger services, although other factors, such as engineering work may well be a constraint.

From this analysis it is calculated that over 11 hours an additional 33 freight paths would become available on the WCML between Willesden and Weaver Junction post introduction of HS2.

8 Benefits accruing from additional freight paths.

8.1 Destination of additional paths.

Based on research by MDS Transmodal built into the GB Freight Model, the destination split for intermodal services on the WCML from Thames side and the Haven Ports would be:

- West Midlands = 34%
- North West = 50%
- Scotland = 16%

Applying this to the 33 paths in each direction gives:

- West Midlands = 11 return services
- North West = 17 return services
- Scotland = 5 return services

8.2 Sensitive Lorry Mile Calculations.

To calculate the environmental benefits from the Sensitive Lorry Miles (SLM) avoided by running these services, it is assumed that 50% originate from Shell Haven and 50% originate from Felixstowe.

The destination terminals for these trains are assumed to be:

- West Midlands – Hams Hall
- North West – Trafford Park
- Scotland – Mossend

The DfT's environmental benefit calculator was used to generate the SLMs for each destination, using their traffic routing navigator. In one case the traffic routing navigator was over ridden when it generated a route from Felixstowe to Trafford Park via the A14-A1-M18–M1-A616-A57 (Snake Pass), this was replaced with the more logical A14-Catcliffe Interchange-M6-A56-M56 route.

The SLM values for each flow of traffic were:

- Felixstowe to Hams Hall = £83-16 per single journey
- Felixstowe to Trafford Park = £137-50 per single journey
- Felixstowe to Mossend = £168-85 per single journey
- Shell Haven to Hams Hall = £50-18 per single journey
- Shell Haven to Trafford Park = £101-62 per single journey
- Shell Haven to Mossend = £144-35 per single journey

8.3 Split of train services:

	Hams Hall	Trafford Park	Mossend
Flexistowe	6	8	3
Shell Haven	5	9	2
Total	11	17	5

8.4 Number of wagons per train:

Numbers of wagons per train is assumed to remain at 24, with each train capable of conveying 72 TEU maximum. This is an extremely conservative assumption and it may well be that train lengths move towards 30 wagon trains capable of 90 TEU maximum; however this is not factored into the base case.

8.5 Load factor:

As quoted in the Planning Applications for Bathside Bay the average load factor of an intermodal train is 80%. This is governed not only by the volume of traffic on offer but also the mix of container lengths, either 20ft or 40 ft. Hence on a 60 ft platform wagon there may not be the ideal mix of 20 ft and 40 ft containers to maximise the loading of a train. The load factor in this study equates to:

- 24 wagons = multiplied by 80% = 19.5 wagons = 59 TEU per train.

8.6 Numbers of road equivalent journeys.

The 59 TEU per train equates to 39 individual containers comprising 20 x 40 ft and 19 x 20ft. Therefore each train conveys the equivalent to 39 road vehicle movements in each direction. (Note it is assumed that only one 20 ft container will be moved on a road vehicle because of gross vehicle weight restrictions, despite a 40 ft trailer being capable of conveying two 20 ft containers in length.)

8.7 Calculation of total environmental benefits.

For each flow of traffic the SLM valuation is:

- multiplied by 39 for the number of containers,
- then multiplied by 240 for the number of working days in a year (conservatively assumes no Saturday or Sunday working),
- multiplied by 2 for outward and return journeys
- multiplied by the number of paths available for each flow.

Environmental benefits per flow:

- Felixstowe to Hams Hall = £9,340,531
- Felixstowe to Trafford Park = £20,592,000
- Felixstowe to Mossend = £9,482,616
- Shell Haven to Hams Hall = £4,696,848
- Shell Haven to Trafford Park = £17,120,937
- Shell Haven to Mossend = £5,404,464

Total of environmental benefits per annum of additional freight paths = £66,637,396.

9 Additional freight benefits from HS2 not evaluated in this study.

There are two additional freight benefits that the opening of HSR might provide but which have not been evaluated in this report because the risk of them not being realised is too high.

9.1 High Speed Post or Parcels Services.

These would use a TGV Poste style vehicle and be of use if the route of HSR provided a connection to the Daventry area (the Royal Mail hub for its post operations). From Daventry services could be provided to Central Scotland, Heathrow, Charles de Gaulle airport, Schipol airport and Frankfurt airport. Costs and benefits have not been assessed.

9.2 Use of HSR for European Gauge freight trains.

HSR would provide a European Gauge (UIC) route into Central England. Again it would be provisional on HSR being routed via Daventry, which is the distribution hub for a number of large organisations. This would allow the movement of European Gauge freight wagons, during the night shift, to access Daventry Railfreight Terminal. Again no assessments of costs or benefits have been made.

Appendix J Regional and Wider Economic Benefits

1 Introduction

The economic benefits of a high speed rail network are of various types. They include:

- Journey time benefits to those who choose to use high speed rail, whether switching from another mode or newly generated
- Benefits for those who remain on the highways from reduced road congestion
- Benefits from reduced rail crowding
- Benefits from new local and inter-regional passenger services (including less crowding) and from freight
- Wider economic benefits from regional economic activity

The two largest are in most cases the first and the last, and these are the most easy to allocate to the UK regions. This Appendix describes these in more detail, particularly concentrating on the Wider Economic Benefits; it also allocates them to the regions of Britain. The other benefits are included in the cost benefit analysis in the main report, but are not allocated to the regions, nor are they included in this Appendix.

2 Journey time benefits

When an improved transport service is provided, individuals choose to use this service instead of their existing one. As a result they typically save time. This time is valued by the individual (or their employer in the case of travel for business purposes) at a certain monetary rate. This monetary value is the economic value of the improvement in time. Considerable research has been undertaken into values of time, and these are presented in WebTAG for use in appraisal. For a scheme such as a high speed rail network, the journey time savings are the principal element of the economic benefits.

The forecasting model calculates the journey time savings of those switching from classic rail; these form a significant part of the overall benefits. For those switching from other modes, one cannot simply take the journey time impact – in some cases, an individual might accept a slight deterioration in journey time, but with a cost or comfort benefit instead; it is the overall change in generalised cost that influences choice of mode, not simply journey time.

For people switching from other modes, or making new trips, we assume that they receive an average of half the journey time benefit of the change between classic and high speed rail. This 'rule of a half' is well established in transport economic theory and can be considered as either:

- that the demand curve is approximately linear across the change, or
- that a few people will switch with the first minute saved (thus benefitting from the whole saving), others will only switch with the last minute saved (receiving only a marginal benefit), and others somewhere in between; the average saving is a half of the total.

In reality these two explanations are the same.

Journey time benefits accrue to businesses for business travel, and individuals for leisure (and commuting) travel. We could argue that the region that benefits should be the place of residence or location of the business, however, some should also accrue to the destination, as it becomes a more attractive place to visit. Furthermore, we do not know which end of the trip is the origin (place of residence) and which the destination; hence in allocating to region we have allocated a half to each end.

3 Wider Economic Benefits

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 appraisal continues 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[1]. There are two types of WEB: those that affect GDP referred 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 hours (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. The DfT is in the process of modifying its guidance on how to forecast the impact of WEBs, and has issued a draft of new guidance; however, this is not finalised and certain parameter values are not yet defined. The previous definitive guidance has therefore been used in this evaluation.

The following section discusses how we have forecast changes in land use; this is then followed by an explanation of the process to estimate each of the Wider Economic Benefits.

3.1 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.

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"

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

(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 1:

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

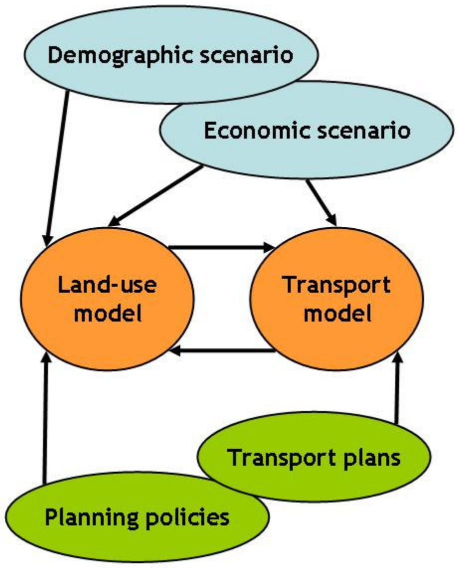

Figure 1 Greengauge 21 Land-Use model - scenarios and policy interventions

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 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 the 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.

3.2 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**.

However, we expect only a limited number of people to commute using HSR on a daily basis, and hence the value of this would be very small. There is a larger potential impact in this area which is that when the HSR releases capacity for additional local commuting services, this would result in a benefit under this heading; however, we do not calculate the journey time or generalised cost impact of the additional services, and hence cannot quantify this impact. Ignoring this benefit is hence a conservative assumption, although it should be noted that in most schemes such benefits have been relatively unimportant.

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**.

This benefit is related to that of GP1 (increased labour force participation), and for the same reason as given there, we are unable to quantify this benefit. We have therefore excluded this benefit which is a conservative assumption, although again, in most schemes such benefits have been relatively unimportant.

Agglomeration benefits (WB1, GP4)[2]

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 kilometres, 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 zone *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:

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

[2] It should be noted that the formula provided here for WB1 are 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**, the uplift in GDP of workers through the productivity gains resulting from 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)

Agglomeration benefits have almost always been the most important element of the WEBs, often making up 75% of total benefits.

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. These are included in our assessment of WEBs.

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[3], 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[4] and well as increased operating surplus.

As we have not quantified GP1, GP2 or GP3, we have not quantified this benefit either.

4 Allocation to Regions

In the table below we present these two benefits (in terms of NPV) to the different regions. Journey time benefits have been assumed to accrue a half to the origin and a half to the destination; this is reasonable as there is a benefit to a region whether more of its residents travel or whether more people travel to it. There are additional benefits (such as reduced CO2 emissions) that we have not been able to allocate to regions and hence are not included below. The benefits from increased classic services, including reduced crowding have also not been allocated to the regions.

The Wider Economic Benefits reflect the region in which they occur, which relate to the improvements in accessibility of each of the zones in our forecasting model (and hence employment and related changes), which are then summed to their relevant regions. These are shown in the following tables for the eventual complete scenario and then for each of the route corridors comprising this scenario.

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

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

Table 1 **Economic Benefits allocated to Regions Complete Network Scenario**

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£26,930	£3,739	£813	£31,482	30%
South East	£3,116	£371	£126	£3,612	3%
East	£5,273	£884	£172	£6,329	6%
South West	£1,145	-£436	£42	£751	1%
West Midlands	£5,370	£728	£165	£6,263	6%
East Midlands	£1,772	£302	£74	£2,147	2%
North West	£10,134	£2,370	£324	£12,829	12%
Yorkshire and the Humber	£7,077	£1,640	£259	£8,975	9%
North East	£2,672	£576	£73	£3,322	3%
Scotland	£19,537	£4,899	£586	£25,021	24%
Wales	£942	£36	£38	£1,016	1%
Europe	£2,882	£0	£91	£2,973	3%
TOTAL	£86,849	£15,109	£2,763	£104,721	100%

Table 2 **Economic Benefits allocated to Regions London – Birmingham – N West corridor**

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£8,958	£1,612	£296	£10,866	36%
South East	£887	£265	£40	£1,192	4%
East	£581	£333	£22	£936	3%
South West	£498	-£41	£23	£479	2%
West Midlands	£4,074	£688	£116	£4,878	16%
East Midlands	£246	-£14	£11	£242	1%
North West	£5,727	£1,244	£199	£7,170	24%
Yorkshire and the Humber	£720	£84	£29	£832	3%
North East	£44	-£30	£2	£16	0%
Scotland	£1,238	£165	£40	£1,443	5%
Wales	£512	£110	£23	£645	2%
Europe	£1,083	£0	£36	£1,119	4%
TOTAL	£24,566	£4,416	£836	£29,818	100%

Table 3 Economic Benefits allocated to Regions London – North East corridor

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£5,001	£816	£155	£5,972	28%
South East	£654	£81	£28	£763	4%
East	£671	£266	£23	£959	4%
South West	-£1	-£83	£3	-£81	0%
West Midlands	£710	£100	£22	£832	4%
East Midlands	£1,313	£256	£43	£1,611	7%
North West	£475	£69	£6	£549	3%
Yorkshire and the Humber	£4,418	£1,161	£161	£5,739	27%
North East	£1,773	£400	£42	£2,215	10%
Scotland	£1,698	£486	£38	£2,223	10%
Wales	-£4	-£27	£0	-£31	0%
Europe	£889	£0	-£5	£884	4%
TOTAL	£17,598	£3,524	£514	£21,636	100%

Table 4 Economic Benefits allocated to Regions London – S Wales and S West corridor

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£479	£51	£15	£546	38%
South East	£111	-£8	£4	£107	7%
East	£36	£1	£1	£39	3%
South West	£426	-£188	£18	£255	18%
West Midlands	£1	£0	£0	£1	0%
East Midlands	£0	£0	£0	£0	0%
North West	£0	£0	£0	£1	0%
Yorkshire and the Humber	£1	£0	£0	£1	0%
North East	£1	£0	£0	£1	0%
Scotland	£0	£0	£0	£0	0%
Wales	£391	£24	£15	£431	30%
Europe	£58	£0	£3	£61	4%
TOTAL	£1,505	-£118	£57	£1,443	100%

Table 5 **Economic Benefits allocated to Regions Transpennine corridor**

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£37	£4	£1	£42	1%
South East	-£5	£0	£0	-£4	0%
East	£179	£7	£6	£192	4%
South West	£0	£0	£0	£0	0%
West Midlands	-£42	£5	-£2	-£38	-1%
East Midlands	£174	£107	£10	£291	6%
North West	£1,506	£323	£59	£1,888	42%
Yorkshire and the Humber	£805	£301	£39	£1,146	25%
North East	£226	£66	£10	£303	7%
Scotland	£350	£187	£14	£551	12%
Wales	£0	£0	£0	£0	0%
Europe	£153	£0	£8	£160	4%
TOTAL	£3,383	£1,002	£146	£4,530	100%

Table 6 **Economic Benefits allocated to Regions Anglo-Scottish corridor (West Coast)**

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£8,924	£879	£234	£10,037	30%
South East	£1,260	£47	£46	£1,353	4%
East	£1,116	£170	£33	£1,319	4%
South West	-£10	-£148	£1	-£156	0%
West Midlands	£331	-£25	£16	£322	1%
East Midlands	£13	-£152	£0	-£139	0%
North West	£1,870	£630	£41	£2,542	8%
Yorkshire and the Humber	-£2	-£129	£0	-£131	0%
North East	£0	£11	£0	£10	0%
Scotland	£14,352	£3,390	£444	£18,186	54%
Wales	£1	-£71	£0	-£71	0%
Europe	£204	£0	£34	£238	1%
TOTAL	£28,057	£4,602	£851	£33,510	100%

London is the single largest winner in absolute terms, but this mainly reflects its higher population and GVA than other regions, and also that the HSR links it to almost all other regions. Scotland is the big winner in terms of Wider Economic Benefits when it is served by HSR.

An important point to note is that when the HSR is constructed it delivers benefits for the regions served, but that some of these benefits are at the expense of other regions; ie any region not served experiences a disbenefit as economic activity is sucked away to those regions which have improved accessibility. This can clearly be seen for the restricted network serving just London – Birmingham and the North West, where several regions experience negative agglomeration benefits. In the whole network scenario, there are some regions that receive little benefit from HSR, notably much of the South West; there is an agglomeration benefit for Bristol, but this is more than compensated by the loss in the rest of the South West.

Table 7 shows the specific WEBs for Wales and South West split by the model zones for the .

Table 7 WEBs by zone within Wales and South West NPV £ bn (2002 prices)

Zone	Agglomeration WB1	Imperfect competition WB3	Total WEBs
Bristol	£65	£21	£85
Bristol Annulus	-£126	£10	-£117
Cardiff	£108	£26	£134
rest of South Wales	-£37	£10	-£27
rest of South West	-£272	£0	-£272
rest of Wales	£20	£13	£33
TOTAL WALES	**£91**	**£49**	**£141**
TOTAL SOUTH WEST	**-£334**	**£30**	**-£304**

The benefits of each of the different elements are in most cases of the expected order of magnitude and accrue to appropriate regions. For example, the benefits of Transpennine corridor accrue principally to the North West and Yorkshire and Humber, with some benefits also to Scotland, the North East and East Midlands, as Transpennine trains are extended to Edinburgh via Newcastle and Nottingham.

The Anglo-Scottish benefits are based on the west coast corridor; ie they are the benefits related to extending north from Manchester to Glasgow and Edinburgh.

The corridor with the weakest benefits is the South Wales and South West corridor; here agglomeration benefits as calculated are actually negative. The reasons for this are:

- the journey time benefit is relatively modest and only applies to flows between London and Bristol, Cardiff and Swansea
- some other locations experience some lengthening of journey time in our modelling
- the agglomeration benefits that accrue to Bristol are offset by abstraction of economic activity from other parts of the South West

- the main component of economic benefit for this corridor is the crowding benefit; in the way we model this (and also in DfT guidance on economic benefits), it does not impact on generalised cost directly, hence neither does it feed through into the agglomeration benefits; thus, though this is consistent with DfT guidance, it is likely to underestimate economic benefits from agglomeration.

Overall, therefore, the Wider Impacts of this corridor will be lower than of others, but the estimate from our model as shown in Table 4 above, while consistent with DfT guidance, is likely to be particularly conservative.

Table 8 below shows the same economic benefits but just for 2055 in current (2008) price levels. In addition to the information provided in the previous tables, they are also calculated as a percentage of the estimated GVA of the region, which indicates the overall value of the economic benefits to each region.

Table 8 Economic Benefits allocated to Regions Complete Network Scenario in 2055

Region	Journey time benefits £m 2055 (2008 prices)	Agglomeration benefits £m 2055 (2008 prices)	Imperfect Competition benefits £m 2055 (2008 prices)	Total economic benefits £m 2055 (2008 prices)	Percentage of total regional GVA (2055 estimated)	Percentage of total benefits
London	£3,716	£430	£85	£4,232	0.6%	30%
South East	£433	£30	£13	£476	0.1%	3%
East	£767	£98	£18	£883	0.3%	6%
South West	£151	-£60	£4	£95	0.0%	1%
West Midlands	£727	£78	£17	£822	0.4%	6%
East Midlands	£254	£33	£8	£295	0.1%	2%
North West	£1,416	£277	£34	£1,727	0.6%	12%
Yorkshire and the Humber	£965	£190	£27	£1,181	0.6%	8%
North East	£370	£67	£8	£445	0.5%	3%
Scotland	£2,680	£579	£61	£3,319	1.4%	24%
Wales	£121	£2	£4	£127	0.1%	1%
Europe	£399	£0	£10	£409	n/a	3%
TOTAL	£11,999	£1,723	£288	£14,011	0.4%	100%

These show a similar message to the earlier figures for NPVs of benefits; slight differences are due to differential growth of the regions over time. It can be seen that as a percentage of economic activity, Scotland is the large winner, with London, North West, Yorkshire and the Humber, and the North East next.

The final table, below, shows the NPV of the benefits of the complete network when it is introduced in a phased way. All benefits are reduced due to the phased introduction by approximately 20%.

The links to the eastern side of the country are implemented after those to Birmingham and Manchester; this results in the proportion of the benefits that accrue to the east being slightly lower in the phased scenario than those shown in Table 1. Scotland is given a full high speed service as part of the second of four phases and its proportion is unchanged.

Table 7 Economic Benefits allocated to Regions Complete Phased Network Scenario

Region	Journey time benefits £m NPV (2002 prices)	Agglomeration benefits £m NPV (2002 prices)	Imperfect Competition benefits £m NPV (2002 prices)	Total economic benefits £m NPV (2002 prices)	Percentage
London	£21,640	£2,813	£582	£25,035	30%
South East	£2,495	£280	£98	£2,874	3%
East	£3,737	£642	£109	£4,488	5%
South West	£852	-£334	£30	£548	1%
West Midlands	£4,653	£578	£132	£5,362	7%
East Midlands	£1,300	£145	£48	£1,493	2%
North West	£8,375	£1,927	£267	£10,569	13%
Yorkshire and the Humber	£4,890	£1,027	£162	£6,079	7%
North East	£1,789	£386	£48	£2,223	3%
Scotland	£15,618	£3,731	£447	£19,795	24%
Wales	£721	£91	£49	£861	1%
Europe	£2,312	£523	£185	£3,020	4%
TOTAL	£68,380	£11,811	£2,157	£82,347	100%