Broad options for upgraded and high speed railways to the North of England and Scotland

March 2016

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Department for Transport

High Speed Two (HS2) Limited has been tasked by the Department for Transport (DfT) with managing the delivery of a new national high speed rail network. It is a non-departmental public body wholly owned by the DfT.

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This work has been jointly commissioned by DfT and Transport Scotland.

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Contents

List of figures

List of tables

Executive Summary

Background

In November 2013, the Department for Transport (DfT) commissioned High Speed Two (HS2) Ltd to undertake a feasibility study to explore broad options for improving rail capacity and journey times to the North of England and Scotland.

Currently the typical journey time between London and Glasgow is 4 hours 31 minutes, and between London and Edinburgh 4 hours 23 minutes.

The study investigated the feasibility of delivering journey times of 3 hours or less between London and Scotland, by looking into upgrade options to the existing West Coast Main Line (WCML) and East Coast Main Line (ECML), and options for high speed routes extending from HS2 Phase Two.

The range of options developed would improve rail travel to the North of England and Scotland in terms of increased capacity and reduced journey times. HS2 Ltd has not set out a preferred option or route, as options developed are only at an early stage of design for feasibility assessment. The work presented in this report has been overseen by a steering group comprising HS2 Ltd, the Department for Transport, Transport Scotland, Network Rail and the Scotland Office.

HS2 Phase One and Two serving the North of England and Scotland

HS2 Ltd's work to develop Phase One and Phase Two continues to demonstrate that the high speed rail project will deliver a range of benefits for the UK as a whole, improving connectivity and driving regional growth. As the project develops, it will deliver progressive improvements as follows.

Scotland

HS2 will significantly improve connections with Edinburgh and Glasgow. Following the completion of Phase One in 2026, Glasgow will benefit from a reduction in journey times to London to 3 hours 56 minutes.

In November 2015, the Secretary of State announced that delivery of the route between the West Midlands and Crewe would be accelerated by six years, to 2027. This will spread the expected benefits to the North West of England and Scotland sooner. Delivery of this section of the route will deliver a London-Glasgow journey time of 3 hours 43 minutes.

Services on the full Phase Two route will commence by the end of 2033. With the completion of Phase Two, the journey time between London and Edinburgh reduces to 3 hours 39 minutes, and to 3 hours 38 minutes between London and Glasgow.

North of England

Connectivity will be improved to cities in the North of England, both by services to HS2 stations in Leeds, South Yorkshire and Manchester, and by classic-compatible services continuing to destinations such as Newcastle, York, Preston and Carlisle. Following the completion of Phase One in 2026, journey times to the North West of England will be reduced. Preston will have a journey time from London of 1 hour 41 minutes, compared to the current time of 2 hours 8 minutes, and this would be further reduced to 1 hour 17 minutes on the completion of the full Phase Two route.

Following the completion of the full Phase Two route in 2033, journey times between London and the North East of England will also be significantly improved. The journey time from London to Newcastle would be reduced from 2 hours 49 minutes to 2 hours 17 minutes.

In addition to HS2, further opportunities are being developed by Transport for the North through the Northern Powerhouse Rail programme to address existing rail constraints, which would benefit cities in the North East. The Transport for the North aspiration is to reduce the Leeds-Newcastle journey time from 1 hour 21 minutes to 1 hour, and this could be achieved through localised interventions, such as bypasses between Northallerton and Durham, which may be relevant to future considerations.

Route corridors and markets

There are a number of infrastructure constraints on the West Coast Main Line and East Coast Main Line which restrict capacity and journey times. These constraints include steep inclines, tight curvature and geometry which limit speed. In addition, conflicting rail movements, sections of two-track railway and the mix of passenger and freight traffic all cause congestion and further reduce capacity.

This feasibility study has identified that the most promising options for upgrades and high speed lines are towards the east and west coasts as a consequence of the markets that could be served, as well as the challenging terrain in the North of England and Scotland. This landscape includes the protected areas of the Lake District, Yorkshire Dales and Northumberland National Parks and Areas of Outstanding Natural Beauty.

For both high speed and upgraded options, there is no single route that could equally serve major cities and markets in the North of England and Scotland. Route options to the west could serve Preston, Lancaster and Carlisle, as well as equally serving Glasgow and Edinburgh. Route options to the east could serve York, Darlington, Durham and Newcastle. Eastern routes could serve Edinburgh well, but would give a longer journey time to Glasgow. Serving Scotland via the North East would connect more centres of demand, but would result in longer journey times to Glasgow at a higher cost when compared to routes to the west.

Benefits

A 3-hour journey time between London and Edinburgh and Glasgow is expected to generate around £3 billion of present value (PV) in benefits and £3 billion (PV) in revenue in addition to Phase Two. Wider economic impacts could add around a further £1 billion (PV). Delivering a 2 hour 30 minute journey time could generate around £5 billion (PV) in benefits and £5 billion (PV) in revenues, in addition to those that would already be delivered by HS2 Phase Two. Greater wider economic impacts could add over £1 billion (PV) to these benefits. It should be noted that there are limitations in producing benefit analysis for such a high-level piece of work.

Upgrades to the existing routes

Consideration of options for upgrades to both the East and West Coast Main Lines identified that solving all capacity issues is very challenging. Upgrades within the footprint of the existing network would deliver limited journey time savings, short of the 3-hour journey time aspiration.

Achieving a 3-hour journey time to Glasgow and Edinburgh through upgrades to existing lines would require around 137 miles (220km) of new high speed bypasses on the West Coast Main Line. These would cost £17 billion - £19 billion[1] and would present sustainability and engineering challenges, similar to those for a new line. Furthermore, on the unimproved sections of the railway, existing challenges regarding capacity, traffic mix, disruption and resilience would remain.

Upgrades on the East Coast Main Line, with 150-220km of bypasses, could deliver a 3-hour journey time to Edinburgh, but not Glasgow. This would cost £11 billion - £13 billion without addressing the capacity issues; a solution addressing the capacity issues would cost up to £20 billion.

These lengths of upgrades represent approximately two-thirds of the West Coast Main Line and East Coast Main Line routes between Phase Two and Scotland.

High speed options

A new high speed route from the northern end of Phase Two to Scotland would involve more than 190 miles (300 km) of new railway, and the potential to serve other city centres. A new high speed route would increase capacity, which is constrained on the existing rail network, and reduce journey times. However, a high speed route would have associated sustainability impacts which would need further consideration.

Using a route to the west, a high speed option has been developed which closely follows the topography and existing transport infrastructure corridors whilst delivering a journey time of 3 hours. This option would serve both Glasgow and Edinburgh equally. This high speed alignment was designed to include localised reductions in speed in challenging locations, reviewing sustainability features, whilst delivering capacity and journey time benefits. The option would run north of Phase Two on the western leg, and deliver a journey time from London to Glasgow and Edinburgh of 3 hours. This option assumes that it would connect to the mid-point of an Edinburgh to Glasgow high speed line. This work identified that a 3-hour high speed route would cost £22 billion - £25 billion (excluding the cost of an Edinburgh to Glasgow high speed line).

Continuous, full high speed routes with Phase Two as a starting point could provide a journey time between London and Scotland of 2 hours and 30 minutes, an improvement of 1 hour and 8 minutes on the Phase Two journey time, and nearly 2 hours on the current journey time. In addition, journey times to cities in the North East or the North West of England could be significantly improved.

A full high speed route to the west could have a potential journey time between London and both Glasgow and Edinburgh of 2 hours 30 minutes, costing £32 billion - £34 billion.

A full high speed route to the east could serve markets in the North East and Edinburgh in between 2 hours and 30 minutes and 3 hours. However, serving both Edinburgh and Glasgow within 3 hours would require significantly more infrastructure, with the associated cost and sustainability impacts. Eastern high speed options would cost £27 billion - £43 billion.

Staging

Staging the delivery of any of the options would provide the benefits of a full implementation incrementally. Working with Network Rail, the study has identified a number of priority areas for intervention, such as congested areas or steep gradients with large speed differentials. However, further

[1] Costs are Q2 2011 and exclude rolling stock. See Appendix A for methodology.

consideration would be required as to how a staged approach could be delivered in a way that complements Network Rail requirements and investment plans.

Conclusion

In this study, HS2 Ltd has developed broad options for reducing journey times and improving rail capacity to the North of England and Scotland.

Upgrading the existing network on the west, either through an extensive package of interventions using new high speed sections or a new route, could deliver comparable journey time improvements to both Edinburgh and Glasgow, including 3-hour journeys between both cities and London. Upgrades would cost less than a new line and would allow benefits to be delivered in stages, but would not bring the same capacity benefits nor provide the resilience of a new line.

On the east, only a full high speed route could deliver such a journey time saving to both Edinburgh and Glasgow. As part of the work, HS2 Ltd has also identified opportunities to address existing capacity constraints which would benefit cities in the North East. These could align with the developing aspirations of Transport for the North, such as for improved services between Leeds and Newcastle.

Staging the delivery of any of the options would provide incremental improvements in journey times and benefits. Network Rail, Transport for the North and Transport Scotland would have a significant role in exploring how staging would be delivered. Further design work would need to consider a detailed assessment of potential routes (both from an engineering and environmental perspective) as well as cost, risk, services and benefits.

1 Setting the context

1.1 Remit

1.1.1 HS2 Ltd was remitted by the Department for Transport to carry out a feasibility study to investigate a broad range of options for delivering improved rail travel between the North of England and Scotland (NES). This feasibility study would:

- develop options that could deliver improvement to journey times between the North of England and Scotland, including journeys from London to Edinburgh and Glasgow of 3 hours or less;
- develop options that could improve capacity for passengers and freight;
- develop options for upgraded and high speed railways;
- develop options for both the east and west coast rail corridors; and
- be developed in partnership with Transport Scotland and Network Rail.

1.1.2 The study was overseen by a steering group with representatives from DfT, Transport Scotland, Scotland Office, Network Rail, and HS2 Ltd.

1.1.3 The study considered the broader advantages that interventions to the existing network could achieve in terms of connectivity, capacity and congestion relief for passengers and freight. A sequence of interventions that would deliver incremental improvement was also to be considered.

1.2 Overview of the study area

1.2.1 This section describes the main characteristics of the study area, including terrain, existing transport corridors and key environmental features, which form the context for much of the work that has been undertaken. It also describes the current rail network to the North of England and Scotland, including constraints and congestion points.

1.2.2 The geographical extent of the study area is from the northern end of the HS2 Phase Two route on the western and eastern legs, to Glasgow and Edinburgh. This is a distance of some 200 miles (322km).

Terrain

1.2.3 The study area (see Figure 1) is dominated by the undulating terrain of the Pennines, running more than 100 miles (160km) from the south end of the area to the 'Tyne Gap'. Immediately north of this, the Cheviot Hills and then the Southern Uplands in Scotland continue the undulating nature of the area.

1.2.4 This terrain would be challenging and costly to construct a route through, as it would likely require extensive lengths of deep cutting, high embankment and tunnels to create the straighter alignments required for a high speed route. This means feasible routes are more likely to be found on lower ground towards the coast, i.e. along the lower ground between the hills and the east coast through the Vale of York, or to the west of the Pennines in Lancashire.

Figure 1: Terrain and transport corridors

1.2.5 In the north of the study area, the undulating terrain in places stretches from east to west across the country towards the coast. This can be seen in Cumbria and in southern Scotland, where the undulating terrain of the Southern Uplands forms a near-continuous line of hills from coast to coast. Any route between England and Scotland would have to negotiate a route through this terrain, as is evident in the existing transport corridors that run north-south through the UK.

Existing transport corridors

1.2.6 The primary transport corridors in the west are the West Coast Main Line and the M6, which run to the west of the Pennines and through the undulating terrain between the Lake District and the Yorkshire Dales. North of Carlisle, the West Coast Main Line and the A74(M) continue to run parallel until Abington, following a winding route through the undulating terrain of the Southern Uplands. From here, the M74 runs north west towards Glasgow. The West Coast Main Line takes a more easterly route towards the Carstairs area, where it splits before continuing to Glasgow and Edinburgh.

1.2.7 On the east side, the A1(M) and East Coast Main Line are the established north-south transport routes. From Leeds and York, the A1(M) takes a more westerly line through the flat terrain of the Vale of York, with the East Coast Main Line running about 5 miles (8km) to the east. North of Darlington, the motorway and the rail line run closer together, and cross each other several times before the A1(M) passes to the west of Newcastle. The East Coast Main Line serves Newcastle station, in the centre of the city, via the High Level and King Edward bridges. The A19, another major north-south route, runs generally to the east of the East Coast Main Line, closer to Middlesbrough and Sunderland, and through the east side of Tyneside. North of Newcastle, the A1 and the East Coast Main Line cover the 120 miles (193km) to Edinburgh. These routes follow the flatter ground nearer the coast, past Alnwick and Berwick, and then turn west, parallel to the coast, to reach Edinburgh. The A696/A68 route from Newcastle to Edinburgh takes a more direct inland line, which is 15 miles (24km) shorter, and passes though Northumberland National Park and the Lammermuir Hills on the east side of the Southern Uplands.

Sustainability considerations

1.2.8 The study area covers a large area. In terms of sustainability, the natural and historic environment, as well as the geography of settlements, provide further important context.

1.2.9 The extent of environmental sites and features is wide ranging and, in places, covers extensive areas. In particular, the north of England and Scotland is rich in natural and historic environmental features. Figure 2 illustrates some of the key communities, environmental sites and features, and the nature and geographical extent of protection (including internationally and nationally designated features).

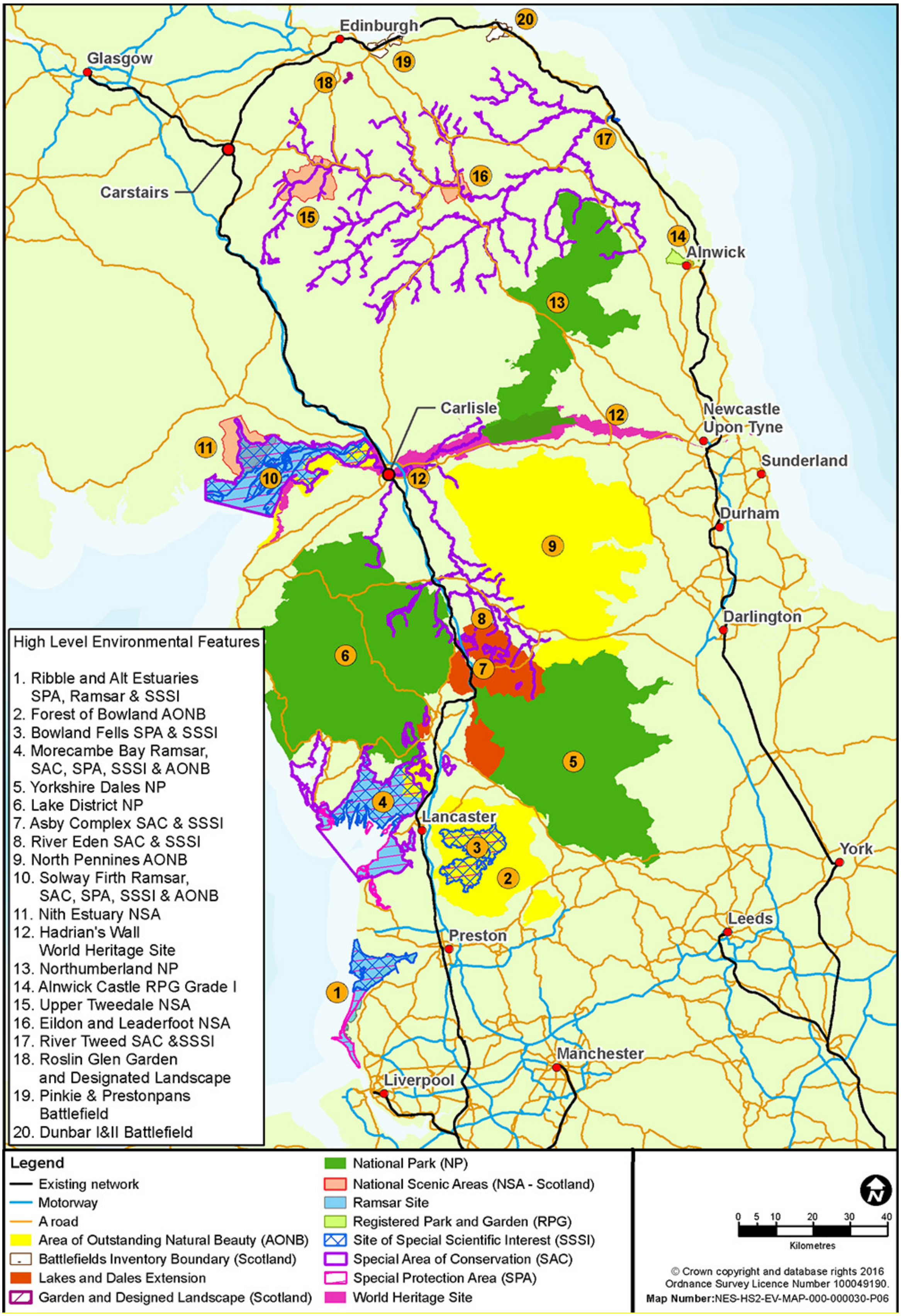


Figure 2: Overview of environmental features

Note: Appendix B provides more explanation on the terms and abbreviations

1.2.10 Appendix A describes these important sites and features and provides a brief explanation of their importance. It also discusses the methodology adopted in appraising key environmental features and communities as part of this feasibility work.

1.2.11 From south to north, some of the key sustainability features identified are described as follows:

The western corridor

1.2.12 From a community perspective, the corridor encompasses both Wigan and Preston and their associated urban areas, which represent the most built-up part of this corridor outside Glasgow and Edinburgh. Other settlements along the corridor include Lancaster, Penrith and Carlisle. North of Carlisle to Carstairs is a rural landscape; whereas, in contrast, the corridor north of Carstairs on approach to the urban areas south of Greater Glasgow is densely populated.

1.2.13 The broad corridor in the west is characterised by a series of areas between Preston and Carlisle protected for ecological, heritage and landscape reasons. To the west of Preston are the Ribble and Alt Estuaries, which are designated as Ramsar sites, Special Protection Areas (SPAs), and Sites of Special Scientific Interest (SSSIs). Travelling north from Preston to the east is the Forest of Bowland Area of Outstanding Natural Beauty (AONB) and, within it, the Bowland Fell SPA and SSSI. Further north west is Morecambe Bay, designated as an AONB, Ramsar site, Special Area of Conservation (SAC), SPA and SSSI. North of Morecambe Bay is the Lake District National Park, and to the east of that, the Yorkshire Dales National Park. From August 2016, the Lakes and Yorkshire Dales National Parks will be coalesced to form the Lakes and Dales corridor[2]. The northern area between the two national parks is designated as the Asby Complex SAC and SSSI, and north of that, the River Eden SAC and SSSI. North west of this area is the North Pennines AONB. Further north is the Hadrian's Wall World Heritage Site, which runs east-west across the country, including near Carlisle. West of Carlisle is the Solway Firth, which is designated as an AONB, Ramsar site, SAC, SPA and SSSI.

The eastern corridor

1.2.14 From a community perspective, Garforth to Northallerton is a rural landscape with a number of small settlements. In contrast, towns and cities such as Darlington, Middlesbrough and Stockton-on-Tees, Durham and Newcastle conurbation form a densely populated area. From the edge of Newcastle and past Blyth, the landscape along the east coast is once again largely rural, with a number of smaller towns such as Alnwick, Berwick-upon-Tweed and Dunbar, and other small settlements.

1.2.15 North of Leeds, the broad corridor in the east is densely populated and therefore there might be a higher risk of encountering heritage features. In the east, there are a number of features such as Alnwick Castle Grade I Registered Park and Garden, Hadrian's Wall World Heritage Site, and Northumberland National Park.

1.2.16 North of Northumberland National Park, onwards from the Scottish Borders and south of Edinburgh, the landscape is largely rural and undulating, with Lammermuir Hills, Moorfoot

[2] https://www.gov.uk/government/publications/national-parks-extensions-to-the-lake-district-and-yorkshire-dales-parks

and Pentland Hills. At the border between England and Scotland, the River Tweed is designated as an SAC and SSSI. West (and upstream) of the Tweed is the Eildon and Leaderfoot National Scenic Area. Further west and upstream is the Upper Tweedale National Scenic Area. North towards Edinburgh there are a number of battlefields including Pinkie, Prestonpans and Dunbar Battlefields which are all noted on the Historic Scotland Inventory of Battlefields. South of Edinburgh are Roslin Glen and Hawthornden Castle. The Glen is a Category A Garden and Designed Landscape. Roslin Castle and Roslin Chapel are Scheduled Monuments and Category A Listed Buildings within this suite of features.

Ground risk and mining activity

1.2.17 Within the study area there are extensive areas of both active and historical mining activity, principally for coal and carried out by both surface and underground means. These areas have associated industrial legacy and widespread brownfield ground conditions, including land contamination and landfilling. Figure 3 shows the coalfield elements of this mining activity, as defined by the Coal Authority in its Coal Mining Reporting Areas. These areas are defined as "the known extent of coal mining activity and are used to determine whether a coal mining report is required for property transactions and the conveyance process". This requirement confirms the ground movement hazard.

1.2.18 The hazards presented in these areas are a significant risk to any routes passing through them, both to above-ground and below-ground construction, because of the association of voids, flooded works, trapped methane, weak collapsible ground and general irresistible ongoing ground movements across wide areas. These movements can arise as groundwater levels recover to pre-mining levels, for example, and can be concentrated at the location of geological faults. The shallow mined areas, landfills and backfilled opencast sites also present a risk of ongoing localised ground settlement.

1.2.19 Naturally poor ground conditions include, for example, peat or soft ground in flood zones, and are applicable to most route options.

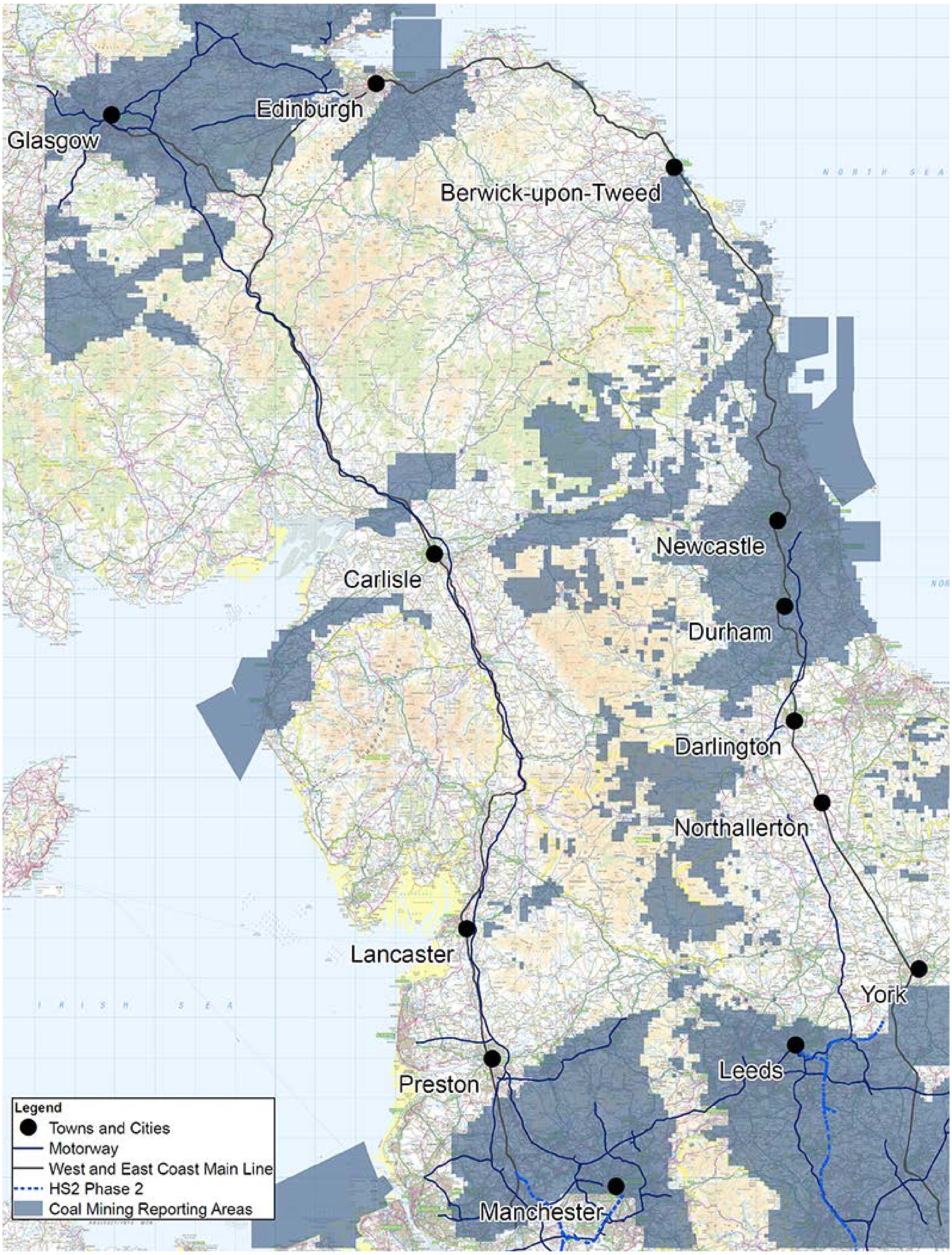


Figure 3: Existing transport corridors, HS2 Phase Two and areas of historic coal mining

1.3 Existing rail network

1.3.1 The two primary railway routes serving Scotland and cities in the North of England are the West Coast Main Line and East Coast Main Line. Both of these routes are heavily used by passenger and freight services.

West Coast Main Line

1.3.2 The West Coast Main Line runs up the west side of the UK, connecting Scotland and the North West with London, the South East and the Midlands. The route accommodates intercity trains and a significant number of regional trains, and is also the primary freight route. Some of the markets served directly by intercity trains to Scotland are London, Milton Keynes, Birmingham, Crewe, Manchester, Warrington, Wigan, Preston, Lancaster, the Lake District and Carlisle. The West Coast Main Line splits at Carstairs, with trains going to either Glasgow or Edinburgh.

1.3.3 Between London and Preston, the West Coast Main Line is predominantly four-track, which aligns with where the route is at its busiest. North of Preston there is very little four-track – only in the Carlisle and inner Glasgow area. Four-track sections have the advantage of segregating the slower regional and freight services from the faster intercity trains.

1.3.4 Between Preston and Lancaster, the West Coast Main Line is relatively flat. Continuing north there are significant areas of undulating terrain with steep inclines (as indicated in Figure 4), showing the change in height along the length of the line. The steep inclines at Shap and Beattock summits have significant influence on the overall end-to-end capacity of the line; this is discussed further below.

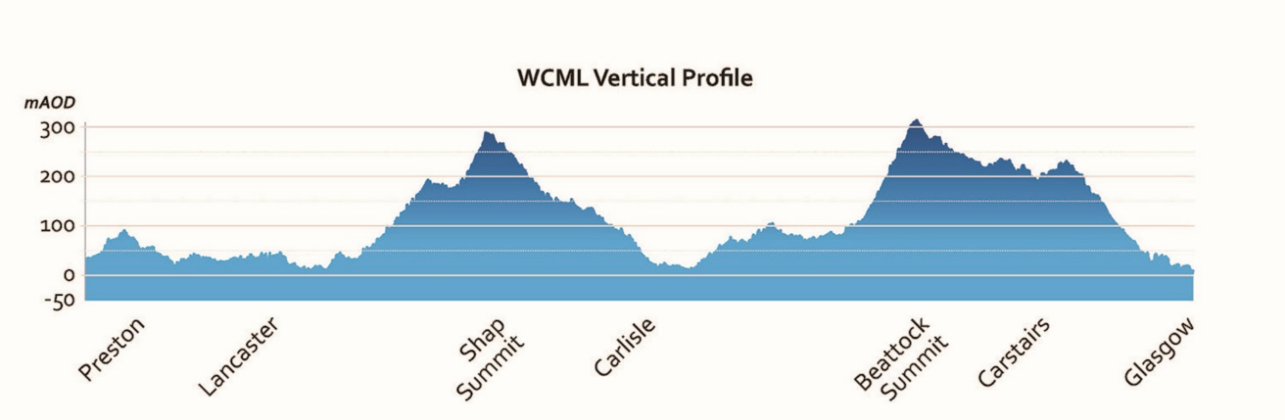


Figure 4: Vertical profile of the West Coast Main Line

Note: Vertical scale is exaggerated for clarity. mAOD = metres above Ordnance Datum.

1.3.5 On the West Coast Main Line north of the planned Phase Two route, the main areas that constrain speed and capacity are:

- Wigan to Preston: This section is 16 miles (26km) long. Just north of Wigan, the line goes from four-track to two-track for approximately 8 miles (13km), then reverts to four-track for the remaining distance to Preston. This stretch of track handles a high concentration of intercity, regional services and freight trains, making the two-track stretch of the line a major bottleneck on capacity and a significant risk to timetable resilience. At Euxton Junction, between Wigan and Preston, trains from Manchester join the West Coast Main Line. This is a flat junction, and so the conflicting movements at the junction compound the issues on this busy stretch of line.

- Preston station: Plans for the station, being developed by Network Rail, would address capacity constraints and provide the opportunity to include 400m long platforms required for HS2 trains. These works are being investigated separately under the scope of Phase One and Phase Two.
- Lancaster to Tebay: This section of track twists to follow the winding terrain, and the resulting curvature requires speeds to be restricted to 80mph - 90mph (130kph - 145kph) in several places. The line passes between the Lake District and the Yorkshire Dales National Parks.
- Shap Summit and Beattock Summit: This is followed by a steep incline to Shap Summit between Oxenholme and Penrith. North of Lockerbie, there is an equally steep climb leading to Beattock Summit. On the south side in particular, both of these inclines are significant constraints to the West Coast Main Line. Diesel-hauled freight trains climbing the hill can take about 30 minutes to make the climb, compared to 15 minutes for more highly powered electric freight trains and 6 minutes for passenger trains. The 30-minute climbs represent a significant occupation of the line, as no other trains can use this section of line for half an hour at a time. While diesel freight trains do not currently run every hour, there are aspirations to increase the number of freight trains, which would further constrain the capacity of the line.
- Carlisle station: The 20mph (30kph) speed limit through Carlisle station has a significant impact on journey times for any non-stopping trains. There may be an opportunity to improve this during Control Period 6 and 7 (2019 - 2029) when Network Rail expects to carry out renewal works at the station. This is discussed further in Section 3.
- Carlisle to Carstairs: The line climbs to the summit at Beattock, in a similar fashion to Shap, with the steeper gradients being on the southern approaches.
- Carstairs towards Glasgow: The West Coast Main Line route runs through an urban area and suffers from significant congestion, with the highest density of traffic outside of Greater London. This stretch of line has eight flat junctions, as well as a mix of suburban trains serving the Glasgow area, intercity trains and freight trains.

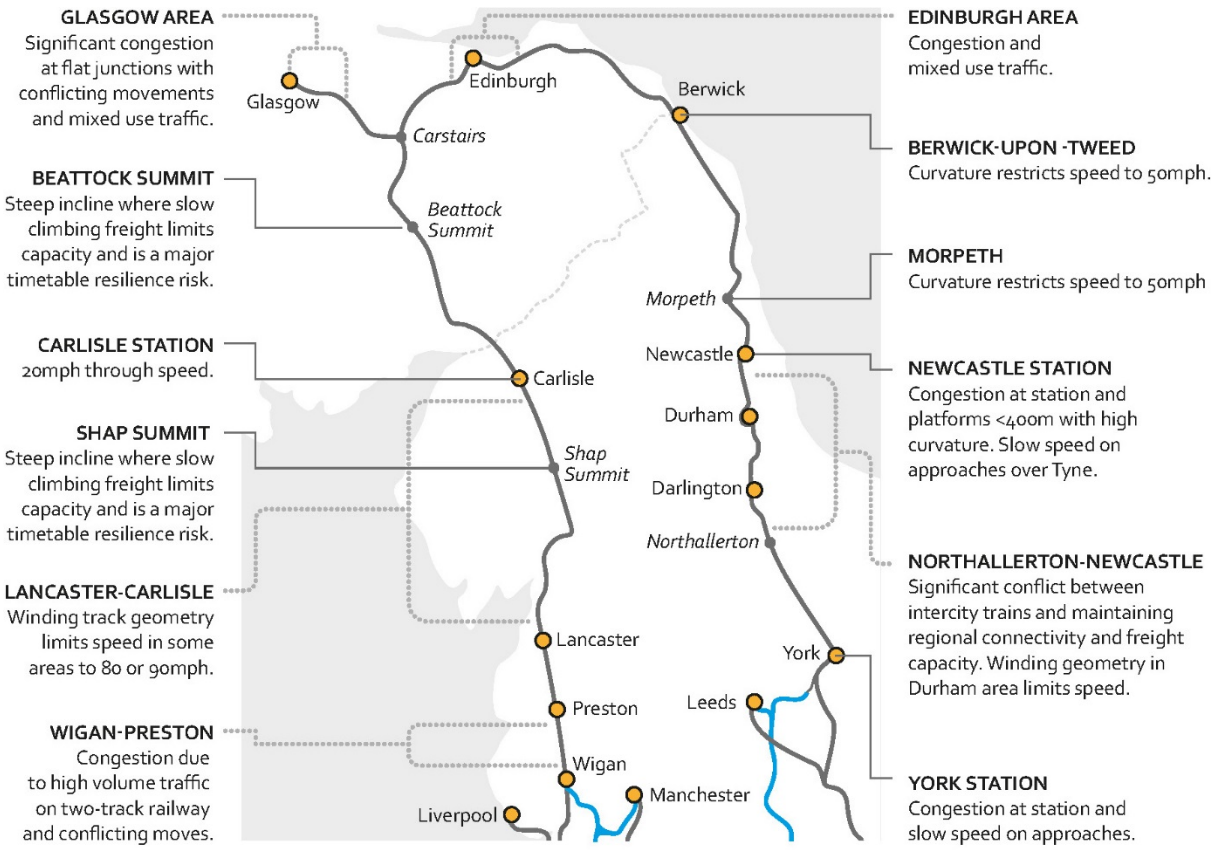


Figure 5: Constraint points on West Coast Main Line and East Coast Main Line

East Coast Main Line

1.3.6 The East Coast Main Line runs up the east side of the country, connecting Scotland and the North East to London, the South East, East Anglia and the East Midlands. CrossCountry services between the North West and South West and Scotland and the North East also use the East Coast Main Line north of Doncaster and York. TransPennine services from Manchester operate between York and Newcastle. Like the West Coast Main Line, the route accommodates a mixture of intercity, regional and freight trains. The main stops served directly by intercity trains from London to Scotland include Peterborough, Doncaster, a branch to Leeds and Wakefield, York, Darlington, Durham, Newcastle and Berwick-upon-Tweed.

1.3.7 The East Coast Main Line is a four-track railway from the Phase Two connection to York and from York to Northallerton, a total distance of 33.5 miles (54km). North of Northallerton, the line is essentially a two-track railway, apart from approaches to main stations. There are a few overtaking loops along the route.

1.3.8 On the East Coast Main Line north of Phase Two, the main areas that constrain speed and capacity are:

- York station: Due to the curvature of the line through York station, trains running through the station are limited to a speed of 30mph (50kph). The station is also tight on platform capacity and is already busy with a number of terminating trains.
- Northallerton to Darlington: There is a fast, two-track section of the route. However,

the speed differential between fast and slow trains limits capacity.

- Durham area: Track curvature in the Durham area restricts speed to 75mph (120kph) in places. The line is also congested.
- Newcastle station: The speed is limited to 30mph (50kph) on the tightly curved approach to the west and through the platforms, which are also tightly curved. There are no platforms long enough for 400m trains.
- North of Newcastle: There are a number of slow curves through Northumberland and southern Scotland, such as Morpeth and Berwick, where speeds are limited to 50mph (80kph) and 55mph (90kph) respectively. There are also a number of level crossings on this stretch of line.
- Berwick: Curvature restricts speed to 50mph (80kph). In addition, Network Rail is monitoring coastal erosion adjacent to a stretch of line close to the cliff top north of Berwick.
- Edinburgh: The route becomes increasingly congested due to local suburban trains serving East Lothian, Midlothian and the Borders.

1.4 HS2 proposition

1.4.1 Passenger journeys on the rail network have doubled over the past two decades. The demand for intercity journeys, commuting and freight rail transport is increasing and will continue to do so in the future. This means that the UK's existing railway network will be over-stretched and will get more overcrowded over the next 10 to 20 years.

1.4.2 High Speed Two (HS2) will be a new high speed railway, providing increased capacity and connectivity between 8 of the 10 largest cities in the UK. HS2 services will also be able to run on to the existing rail network, continuing on the existing West Coast Main Line and East Coast Main Line.

1.4.3 The Strategic Case for HS2[3], published in October 2013, demonstrated the clear and robust case for HS2. The Strategic Case showed how HS2 will free up space on our crowded rail network, promote regeneration, boost local skills, generate tens of thousands of jobs and will help support economic growth. HS2 will have a transformational effect, supporting growth and increasing productivity across the country, including the North of England and Scotland.

1.4.4 On completion of Phase One in 2026, Glasgow will benefit from high speed services. The journey time between London and Glasgow will reduce from 4 hours 31 minutes to 3 hours 56 minutes.

1.4.5 The route section between the West Midlands and Crewe, due for completion in 2027, will further reduce the London to Glasgow journey time to 3 hours 43 minutes.

1.4.6 Under the full Phase Two proposal, 400m trains from London would connect to the West Coast Main Line near Golborne and continue on to Preston and Carstairs, where the trains

[3] https://www.gov.uk/government/publications/hs2-strategic-case

would split[4], before continuing to Glasgow and Edinburgh. The journey time from London to Glasgow will be 3 hours 38 minutes and 3 hours 39 minutes to Edinburgh.

1.4.7 High speed services from Birmingham to Scotland would also use the connection near Golborne and continue north on the West Coast Main Line.

1.4.8 The Phase Two route also includes a connection to the existing network at Church Fenton, south west of York. From here, trains would continue on the Leeds to York line for a few miles before joining the East Coast Main Line, calling at York and Darlington, and terminating at Newcastle. The journey time from London to Newcastle would be 2 hours 17 minutes, a saving of over 30 minutes on the current journey time. In HS2 Ltd's current modelling, high speed services from Birmingham would also call at York and stations to Newcastle.

[4] The journey times to Glasgow and Edinburgh for the full Phase Two route assume a 5 minute stop at Carstairs for the train to split. This reduces the journey time savings provided by the full Phase Two network.

2 Appraisal of demand and benefits

2.1 Introduction

2.1.1 This section describes the demand for cross-border trips that is expected with the currently proposed HS2 network and the key markets for high speed services to Scotland. It goes on to consider the demand implications of various illustrative service patterns for a high speed option, the benefit and revenue impacts of improved journey times and the factors affecting the benefits of classic line enhancements.

2.1.2 Further explanation of the assumptions used to undertake the high-level demand and benefit analysis can be found in the Methodology in Appendix A.

2.2 Cross-border demand and key markets

2.2.1 With the currently proposed HS2 network, the Planet Framework Model (PFM) estimates that by 2036 there will be around 163,000 trips per day between stations in Scotland and stations in England and Wales (including trips in both directions). Figure 6 depicts this, showing how demand for cross-border trips using all modes (rail, air and highway) varies across regions. The regions creating the greatest demand for cross-border trips to and from Scotland are London, the North East and the North West, which together make up more than half of the total demand.

2.2.2 London is the largest source of forecast demand for travel to and from Scotland from England and Wales, and London stations are estimated to be responsible for around 30% of cross-border rail trips once the proposed HS2 network is in place. Newcastle is the second key market, with more than 3,000 daily cross-border rail trips forecast. Carlisle, Manchester, York, Birmingham and Preston also have relatively high numbers of forecast cross-border rail trips.

2.2.3 Within Scotland, Edinburgh is estimated to account for 46% of cross border rail trips and Glasgow 27%. Of the cities listed above, Carlisle is an exception in having greater demand for cross-border trips to and from Lockerbie, than to and from Edinburgh or Glasgow; this reflects its close proximity to the border and more local/regional travel.

2.2.4 More than 60% of forecast cross-border rail trips are for leisure purposes, with most of the rest being for business and a small share for commuting.

2.2.5 In terms of extending the HS2 proposed network in the west or considering enhancements to the West Coast Main Line, Preston would be a key market to factor into the design, as it provides interchange potential in the North West for London-Scotland rail traffic. Indeed, analysis using PFM suggests that missing the Preston stop on HS2 London-Scotland services would lose more than one-third of the additional benefits of speeding up London-Scotland services to 3 hours.

2.2.6 For a high speed option on the east or enhancements to the East Coast Main Line, Newcastle and York are key markets to serve. If an east coast high speed option to Scotland were considered, more than one-third of the benefits of speeding up the journey between London and Edinburgh to 3 hours would be lost if a Newcastle stop on the HS2 services to Scotland were omitted.

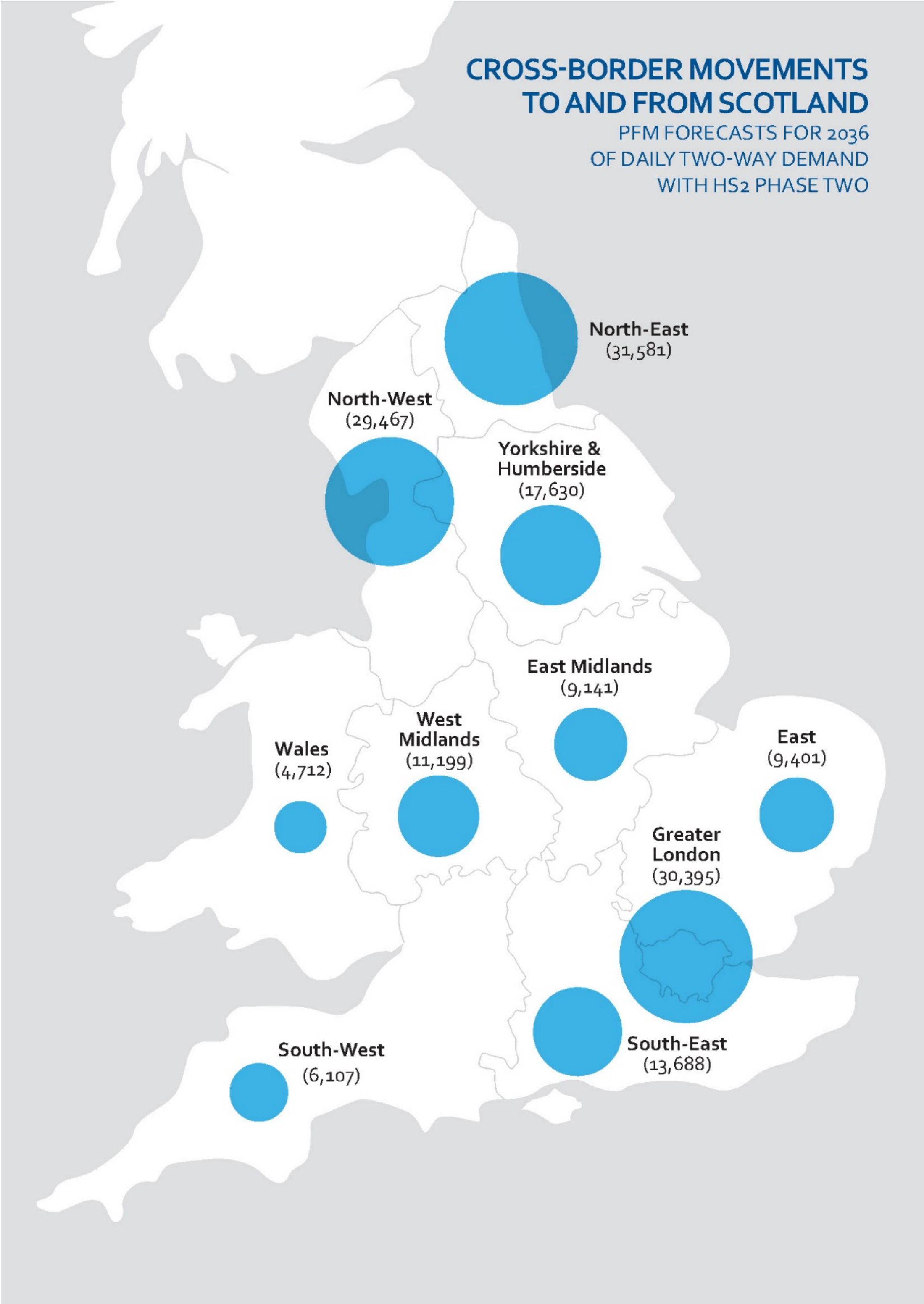


Figure 6: Cross-border movements to and from Scotland

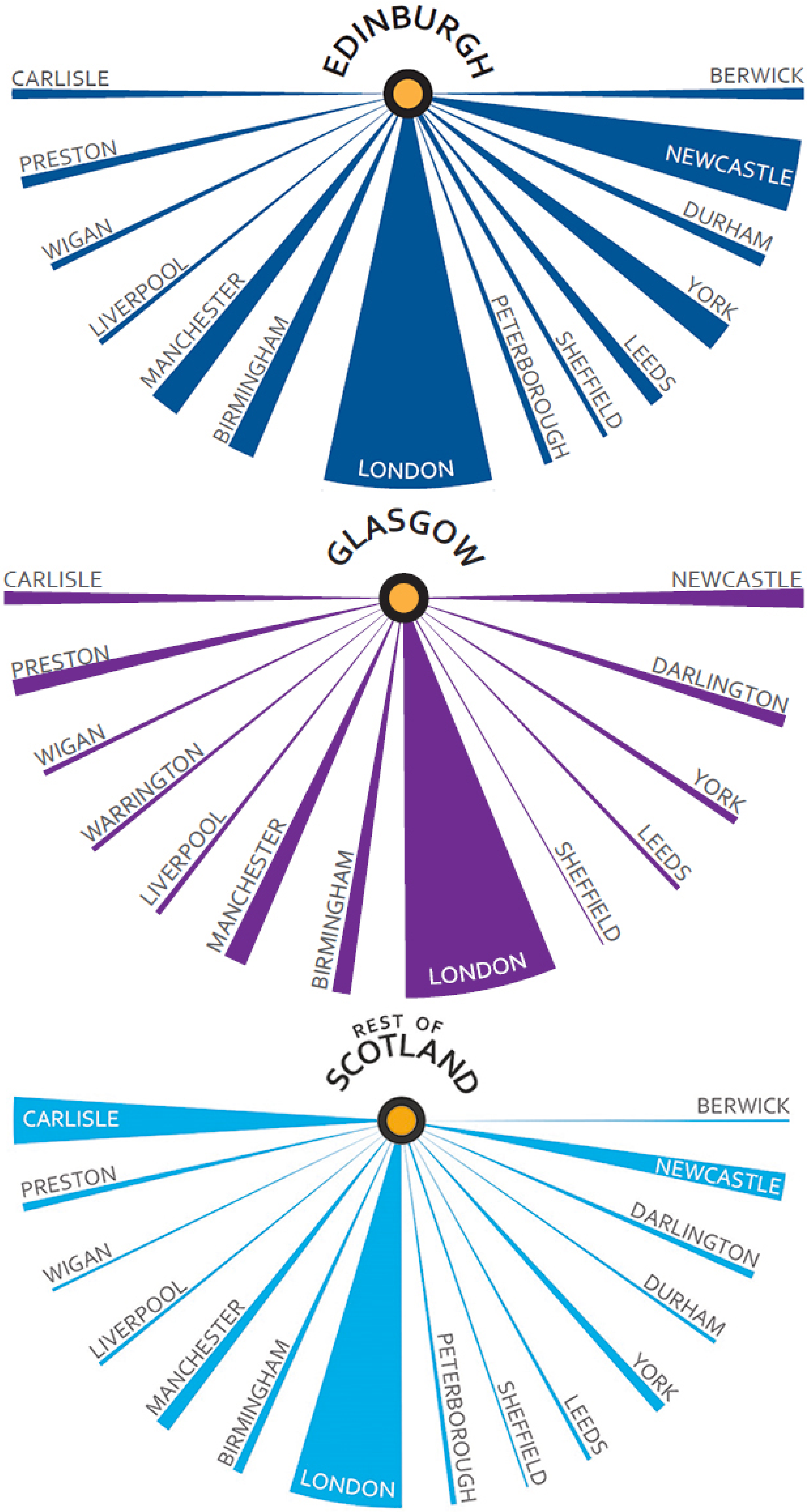


Figure 7: Relative demand for cross-border rail trips

Note: Based on forecast volumes of passengers for 2036 with Phase Two

2.3 Enhancements to the existing line

2.3.1 Enhancements to the West Coast Main Line or East Coast Main Line north of Phase Two's connection points could provide many advantages, although they may not be able to deliver as much in journey time improvements on HS2 services to Scotland compared with a full high speed option. Both high speed services and long-distance classic passenger services could derive journey time improvements from the enhancements. Investment could be targeted to sections of the classic line where there is a high utilisation of the route, and a relatively high benefit and revenue gain could be made by reducing journey times compared with other sections of the line.

2.3.2 Analysis using illustrative train service specifications for serving London-Scotland indicates that there is a higher value associated with improvement in journey times on the southernmost sections leading on from Phase Two connection points, where there are higher volumes of passengers. In particular, reducing journey times on the section from York to Newcastle looks to yield the most positive benefit and revenue impacts.

2.3.3 A route which follows the existing West Coast Main Line or East Coast Main Line relatively closely could allow high speed London-Scotland services to easily access existing central stations, where this is considered more advantageous than a new parkway station. For example, there are expected to be demand advantages to using Preston central station and making compensatory time savings elsewhere on the Western route.

2.3.4 Consideration would need to be given as to where bypasses are introduced so that key markets could still be served. The train service specification would also need to be carefully considered, especially if an East Coast Main Line upgrade was undertaken, to balance provision of high speed services across routes.

2.3.5 If enhancements provide a bypass on the classic line at a point of likely congestion or delay, this could provide further benefits by allowing improved sequencing of services and reducing issues associated with trains of different speeds operating on the same line. Benefits from reduced delay due to a more resilient network have not yet been captured.

2.4 High speed options

West Coast options

2.4.1 A high speed route on the West Coast would allow similar services as proposed for Phase Two, but with quicker journey times for the two splitting services from London to Edinburgh/Glasgow. A high speed West Coast route could therefore provide a similar journey time improvement to both Edinburgh and Glasgow, allowing passengers to and from both cities to benefit from journey time savings.

2.4.2 As well as improving times between London and Scotland, a high speed West Coast option would provide improved journey times between Preston and Scotland. Preston is a hub that facilitates interchange between London-Scotland services and services within the North West, including to Manchester, Blackpool, Lancaster and Oxenholme, meaning benefits would spread across the North West.

2.4.3 New infrastructure could also enable services to split at another location than Carstairs. If that splitting point were a station with a greater demand centre, like Preston or Carlisle, this could provide additional time savings and/or access to a new market.

2.4.4 This option would provide benefits for trips between Scotland and London, the South East, the North West and the West Midlands. A large proportion of additional passengers on high speed trains would be from newly generated trips, along with some movement from air trips from London and the South East and road trips from the North West.

2.4.5 The question of how to serve intermediate markets from a full high speed route between the North of England and Scotland would need to be considered further. Initial analysis suggests that serving Preston with a parkway station would have lower benefits and revenue than a high speed route using the central station. A parkway station in Preston would not have the potential for interchange between high speed London-Scotland services and classic line services, as serving the central station in Preston would.

East Coast services

2.4.6 A high speed route in the East could allow the proposed Phase Two London to Newcastle services to be extended to Edinburgh. This would improve journey times between London and Edinburgh, provide better connections from Yorkshire and the North East to Scotland, and improve journey times on the London to Newcastle section. Newcastle and York are significant markets for travel to Scotland, for which this option could provide. This option could also deliver benefits to those making trips on the well-used London to Newcastle route.

2.4.7 High speed services to Edinburgh on the East Coast could be extended to Glasgow with a high speed link or continue on the classic network to Glasgow. A high speed route from the eastern leg of Phase Two to Edinburgh could reduce journey times for London - Glasgow trips compared with Phase Two services on the West, although it would not be possible to provide relatively even times to Edinburgh and Glasgow from London. However, a high speed route from the eastern leg of Phase Two to Glasgow via Edinburgh would provide benefits for internal Scotland trips on the Edinburgh - Glasgow section, and additional shuttle services between Edinburgh and Glasgow could yield further benefits. An alternative or complementary way of serving Glasgow with a high speed line to Edinburgh would be to run a classic-compatible service to Glasgow via Preston on the West Coast Main Line at similar times to those proposed for Phase Two, which would maintain journey times between the North West and Glasgow.

2.4.8 Consideration would be required of how to balance the use of high speed train paths on the western and eastern legs. It would likely be necessary to switch an HS2 train path to the east to provide sufficient capacity between London and Newcastle if London-Scotland demand were using services on the East Coast Main Line. The potential for high loadings along the East Coast Main Line means that serving Scotland would be likely to require 400m trains through Newcastle, or a Newcastle parkway station. A balance would need to be maintained to provide sufficient capacity on the east, while ensuring sufficient provision to Preston to allow onward interchange.

2.4.9 The issue of how to serve intermediate markets via a high speed line would also need further consideration. Newcastle and York are key markets on the east route, and omitting either without providing major time savings would adversely affect benefits and revenues. Bypassing York could provide significant time savings on through journeys, for example London-Newcastle and London-Scotland. If sufficient time were to be made up by bypassing York, then a parkway on the bypass might provide more overall benefits and revenue than a slower route through the central station. In this scenario, journey time savings on through trips would outweigh the loss in benefits within Yorkshire from reduced ease of access. Stopping for a parkway station is expected to be more advantageous in terms of benefits and revenue than not taking the time to stop along a bypass route.

East Coast splitting service

2.4.10 A high speed East Coast alignment that served Newcastle before splitting in southern Scotland could allow a relatively even service to Edinburgh and Glasgow. This would have the benefit of speeding up journeys from London to both Edinburgh and Glasgow, although journey time improvements to Edinburgh would be more limited than a direct East Coast high speed option. This option would provide a better rail link between Newcastle and Glasgow.

2.4.11 As with a direct East Coast option, an East Coast splitting service would also allow access to the Newcastle-Scotland market and create benefits for London-Newcastle trips. There would need to be consideration of rebalancing the currently planned train service specification to provide sufficient capacity on the east to serve Yorkshire and the North East as well as Scotland.

Overall benefit and revenue impacts of high speed options

2.4.12 Based on testing a range of the service patterns discussed above, the incremental benefits of delivering a 3-hour London to Scotland service compared with the proposed HS2 network are expected to be around £3 billion in present value (PV) over the 60-year appraisal period. The incremental increase in revenue is also estimated to be around £3 billion (PV). Wider economic impacts are estimated to add around a further £1 billion (PV) to benefits.

2.4.13 A full high speed route would be able to deliver a faster journey time than 3 hours. As an indication of the impact, London to Scotland services via a western route of 2 hours 30 minutes calling at Preston central station would generate an estimated £5 billion (PV) in benefits and £5 billion (PV) in revenue. Wider economic impacts would add to these benefits.

2.4.14 The above appraisal is based on journey time improvements to Phase Two services and potential reconfiguration of service patterns. The extension of a high speed line would also increase rail capacity, which could create released capacity benefits and possibly generate benefits from improved local and regional passenger services on the classic line. These impacts have not been assessed at this stage.

2.4.15 The addition to capacity could also provide more freight paths, subject to compatibility with classic passenger services. The additional paths which are taken up by freight, which would otherwise have been transported by road, could provide environmental and decongestion benefits. To give a sense of scale, preliminary analysis (using DfT's marginal external cost approach and a series of assumptions[5]) shows that an additional freight path between Preston

[5] Articulated vehicle MECs applied, rural motorway category used as the alternative road route is expected to be the M6, based on 300 haulage days per year and a range in number of containers per freight train.

and Carstairs (every haulage day in one direction) could generate approximately £20 million (PV) in benefits over the appraisal.

2.4.16 Further analysis would be needed to understand all potential benefits.

3 Options for upgrading the existing line

3.1 Introduction

3.1.1 This section outlines the findings of HS2 Ltd's assessment of upgrades to the existing West Coast Main Line and East Coast Main Line as a means of improving journey times and overall capacity of the network. It begins with an overview of the potential for upgrades within the current railway footprint. It then describes the current performance of the railway by area, and sets out the potential interventions that could address particular issues in the area, and contribute to improvement in overall journey time. Options for packages of interventions will be described to illustrate how the individual options could be combined into packages to achieve overall targets. This will include a 3-hour journey time between London and Scotland, and how a package could be delivered in stages.

3.2 Overview of upgrades considered

3.2.1 Details of the methodology used are outlined in Appendix A of this report.

3.2.2 Potential interventions to the existing network were assessed, and more than 250 options were considered across the two routes. The options considered ranged from upgrades within the footprint of the existing line, such as minor realignment of a curve to improve speed, to varying lengths of high speed bypass of single or multiple constraints. The work was carried out in conjunction with Network Rail through a series of workshops and the steering group.

Interventions within the boundary of the existing railway

3.2.3 Packages of interventions were developed, limited to interventions within the boundary of the existing railway. It was found that they would achieve no more than 15 minutes of journey time saving on West Coast Main Line, and less on East Coast Main Line. The conclusion was that interventions wholly within the boundary of the existing railway would not achieve the remit of a journey between London and Scotland of 3 hours or under. This is because only a relatively small speed increase of circa 15 mph (24 kph) was considered feasible in many places, and for much of the route it is not possible to achieve any increase in speed within the confines of the existing boundary.

3.2.4 These packages of interventions would involve modification to more than half the line length north of Phase Two and would cost around £15 billion. It would also:

- cause major disruption to rail traffic during construction, since all work would be on or adjacent to the operational railway;
- worsen capacity by increasing speed differential between fast trains, slower stopping services and freight traffic; and
- represent high cost per minute of journey time saved, compared with bypasses.

General findings on high speed bypasses of the existing railway

3.2.5 Long bypasses have a lower cost per minute of journey time saved than short bypasses due to the potential to achieve and sustain a higher running speed, and because the extra costs of leaving and joining the existing railway are mitigated by a greater length of bypass. Bypasses in difficult terrain have a higher cost, but as the existing line in these areas is often slower, the potential benefits are greater. Other advantages of high speed bypasses include:

- bypass construction can be off-line, with much of the work undertaken away from the existing line, with disruption limited to high speed connection points only. This would therefore be less disruptive to the operation of the railway than upgrades to the existing line;
- improvement in capacity as well as speed, as they would enable dynamic overtaking of slower trains, such as freight; and
- being designed to high speed standards, allowing operation at up to 250mph (400kph) where practicable, and so could ultimately be joined together to form a continuous end-to-end high speed route.

3.2.6 Even if bypasses were only used by a few fast trains, the capacity of the existing line would be improved, as they would remove the speed differential between fast trains and local services, which could continue to use the existing line.

3.2.7 A typical package of bypasses required to achieve a 3-hour journey between London and Glasgow/Edinburgh would require 124 miles (200km) of the route north of HS2 to be on a new high speed line, or approximately two-thirds.

Splitting trains

3.2.8 The Phase Two proposition assumes that trains from London would split at Carstairs, with one part each continuing onto Glasgow and Edinburgh. This adds an extra stop and journey time penalty, as the train stops to split at a location where there is no significant market to serve.

3.2.9 The West Coast Main Line upgrades developed in this study have assumed that the trains between London and Scotland would split and join at Preston, with the two portions running in quick succession from Preston to near Carstairs, where they would diverge for Glasgow and Edinburgh. An alternative would be splitting and joining at Carlisle. However, although Carlisle would attract more passengers than Carstairs, the numbers would still be considerably less than at Preston. This would need to be investigated in more detail in any further work.

3.3 Options for upgrading the West Coast Main Line

Phase Two to Preston

Existing railway

3.3.1 The Phase Two Consultation Route runs to the east of Warrington and joins the West Coast Main Line near Golborne. From that point, the West Coast Main Line has four tracks as far as Wigan, then reduces to two tracks for about 8 miles (13km) to Balshaw Lane, where four tracks resume for the remaining 7.5 miles (12km) to Preston station, before becoming six tracks on the final approach. About 2 miles (3km) north of Balshaw Lane is Euxton Junction, where the route between Manchester and Preston joins at a flat junction.

3.3.2 About half of the two-track section immediately north of Wigan station has only ever been a two-track railway. The remaining section was a four-track railway in the past, and the disused track bed still lies within the railway boundary.

3.3.3 Network Rail considers this section to be a significant constraint on capacity, as it carries a range of regional passenger services and freight as well as long-distance services. Conflicting movement of railway traffic at the flat junction at Euxton compounds the issues.

Possible interventions

3.3.4 Widening the 8 miles (13km) of two-track railway to four-track railway would reduce the congestion in this area and add additional capacity. However, reinstating the section further north that was formerly four-track would be less complicated and have far less impact on surrounding property. Reinstating just the former four-track section would reduce the length of the constraint by about half, but offer limited overall benefit. The land available within the current boundary is unlikely to be wide enough for the extra clearances and track spacing required for a full high speed specification, so the trains passing through this area would be limited to conventional speeds. However, this would not be a major disadvantage, as all trains would be likely to be stopping at Preston.

3.3.5 An alternative approach would be to bypass the two-track section altogether. The bypass could connect directly to Phase Two, and effectively extend the high speed line further north. Potential connection points to the West Coast Main Line are constrained by the built-up area around Wigan. This high speed bypass would save about 2.5 minutes on journey time.

3.3.6 This West Coast Main Line connection point would be on the formerly four-track section. Reinstating the four-track railway from this new junction would be relatively straightforward. As mentioned above, several built-up areas are next to the line, so the width of land within the boundary would not be suitable for high speed running.

3.3.7 This and previous studies have also concluded that the flat junction at Euxton would require grade separation because of the number of regional trains that cross the main line here, affecting the capacity and operation of through trains.

Sustainability

3.3.8 In the Wigan area, a bypass option is likely to encounter a number of natural features including landfill, ancient woodland and groundwater Source Protection Zones (SPZ). Further work would be required to understand the potential impacts on these features through route selection and design.

3.3.9 One SSSI was identified within the potential upgrade proposed to make the existing line four-track. Further work would be required to avoid any potential impact on the SSSI, which is a nationally important designated site.

3.3.10 From a community perspective, the following is noted in relation to a bypass option:

- Property type – properties are predominantly residential;
- Urban/rural – properties are mainly within rural areas; and
- Index of Multiple Deprivation distribution – properties are within the two highest (least deprived) quintiles of the index.

Preston to Lancaster

Existing railway

3.3.11 Preston station has train services from East Lancashire, the Fylde, Liverpool, Manchester, Lancaster and the Lake District, making it an important station in the North West for interchange between routes.

3.3.12 About 1 mile (1.6km) south of Preston, the four-track stretch becomes six tracks on the approaches to the station. Immediately north of the station, the Blackpool route diverges westwards, with the West Coast Main Line continuing as a two-track railway with loops at intervals allowing freight trains to stop and passenger trains to overtake.

3.3.13 North of the station, the line continues as two-track for the 20.5 miles (33km) to Lancaster. There are two static overtaking loops on the northbound line, and two on the southbound line.

Possible interventions

3.3.14 This study assumes all trains will call at the existing Preston station, requiring use of the existing alignment within the built-up area.

3.3.15 The train service proposed for Phase Two requires some work at Preston station to provide platforms long enough for the 400m coupled pairs of 200m HS2 trains which will serve Glasgow and Edinburgh. The classic services from London and Birmingham that serve intermediate stations on the existing West Coast Main Line are also proposed to terminate at Preston, requiring some changes to the track layout to allow the existing platforms to be used more flexibly. The scope of this work is still being investigated, but is expected to happen in Control Period 6 and 7 (2019 - 2029), and so it is assumed no further work would be required in the station area for the purposes of this study.

3.3.16 Network Rail advises that these works will mean that there will no longer be capacity for freight trains to stand at Preston, as they do at present, waiting for an opportunity to continue north or south without delaying passenger trains. As a solution to this, Network Rail proposes some extra and longer loop tracks alongside the main line between Preston and Lancaster. An alternative would be to build a high speed bypass section that would diverge from the West Coast Main Line at the northern fringe of the Preston built-up area, run close to the existing alignment, and re-join south of Lancaster. This would save approximately 3 minutes on journey time, and enable passenger trains to overtake freight trains that could continue running on the existing route. Although likely to be more expensive than the loops, the bypass does offer a journey time saving as well as capacity benefits.

3.3.17 This bypass line could be extended past Lancaster, as discussed below. In this case, a connection to the existing line would be retained so that trains calling at Lancaster could still use the new line to the south.

Sustainability

3.3.18 An upgrade at Preston station could affect the immediate surrounding area. A bypass north of Preston could affect the historic and environmental features in the area. Further work would be required to consider the potential impact on these local and nationally important features and communities through route selection and design.

3.3.19 From a community perspective, the following is noted in relation to a bypass option north of Preston to south of Lancaster:

- Property type – there is a low density of properties along this bypass, which are predominantly residential;
- Urban/rural – properties situated along the option are mainly within rural areas; and
- Index of Multiple Deprivation distribution – properties along this bypass option are within the two lowest (most deprived) quintiles of the index.

Lancaster to Carlisle

Existing railway

3.3.20 From easy terrain around Lancaster, the West Coast Main Line ascends into undulating territory as it passes between the Lake District and the Yorkshire Dales, before descending towards Carlisle. The major capacity constraint on this section is the final climb to the summit at Shap, which is particularly severe for northbound trains. The gradient slows passenger trains a little and freight trains much more so, particularly those hauled by diesel locomotives, which have less power available than electrics. The journey time difference between diesel freight and passenger trains is more than 30 minutes. There is also poor rail adhesion in adverse weather conditions which can result in freight trains losing traction and coming to a stop, causing severe delays to following passenger trains.

3.3.21 The route throughout this area is a two-track line with freight loops at intervals. Line speed is limited to 80mph (130kph) to 110mph (180kph) due to track curvature. Tilting trains have higher permitted speeds up to 125mph (200kph).

3.3.22 Some passenger trains terminate at Lancaster, where the platforms are on loop tracks to allow them to do so without blocking the main lines. North of Lancaster, branches diverge to a number of destinations:

- towards Morecambe;
- towards Barrow and Leeds at Carnforth; and
- towards Windermere at Oxenholme.

3.3.23 All of these have some through services to and from the south, meaning the southern end of this section is generally busier than the northern end. However, most freight runs through between Preston and Carlisle, as do intercity trains.

Possible interventions

3.3.24 Resolving the Shap area is a priority if capacity and timetable resilience on West Coast Main Line for end-to-end journeys is to be improved. Several options could address the constraints posed by the incline, including:

- static freight loops on the ascent, allowing slow trains to move off the line into a loop and wait there while faster trains overtake;
- long overtaking loops at the top and bottom of the incline, allowing slow trains to be overtaken just before or after the climb, managed with the timetable to optimise

occupancy of the incline;

- a 'crawler lane' – effectively a third track on the northbound side to allow freight trains to be overtaken as they move slowly up the gradient;
- a bypass of the climb, building a new stretch of line near the existing line. This would allow faster trains to overtake slow climbing trains, and also run at higher speeds; and
- restricting use of the line by slow freight diesel trains during passenger operating times, limiting use to electric hauled freight.

3.3.25 A static freight loop on the ascent is not considered to be worthwhile. Freight trains would come to a stop in the loop and would be able to attain only a slow speed as they re-start climbing against the gradient, so the impact on passenger trains would arguably be greater than if the freight trains had run through without stopping. Static loops at either end of the climb, which could be built in flatter terrain where construction costs would be lower than on the climb itself, could be combined with higher speed bypasses further north or south. However, the constraint and associated risks would still remain, though perhaps be slightly reduced.

3.3.26 A crawler lane and the bypass option would enable both freight and passenger trains to travel up the incline at the same time and so resolve the current issues. Both would involve construction in difficult undulating terrain, requiring substantial earthworks with the added complexity of the significant environmental sensitivities in the vicinity, as outlined below. A crawler lane would be constructed next to the operational railway and would inevitably cause significant disruption during construction, while a bypass would be constructed off line. The minimum length of bypass that would be required is estimated to be about 4 miles (6km). Over this length the journey time saving would be a modest 15 seconds, but it could be linked to bypasses at either end and so contribute to longer-term speed increases for passenger trains.

3.3.27 This is a complex and challenging area to resolve, and a detailed analysis would have to be carried out to find the right balance between all the issues involved. This would require detailed assessment of the risks and cost of construction, balanced against the commercial issues of using electric versus diesel freight and their expected usage in the future.

3.3.28 North of Shap there would be opportunities to make significant journey time savings by constructing a series of bypasses as far as Carlisle, while retaining the connection to the existing route north of Shap, allowing northbound passenger trains to overtake freight and re-join the existing line to call at Penrith. As the route approaches Carlisle, the flatter terrain makes it a relatively cost-effective area to construct a new faster line. Various lengths of bypasses have been considered in this area; for example, if the entire length were bypassed, there could be a journey time saving of over 9 minutes.

3.3.29 Immediately south of the climb to Shap is the Lune Gorge, a deep and steep-sided valley. The existing railway curves through the valley, as the western slope is shared with the M6 corridor and the eastern side is in proximity to the Yorkshire Dales National Park. Any bypass of this area could require extensive tunnelling, and would only be considered worthwhile if attempting to reduce London-Scotland journey times well below 3 hours.

3.3.30 Between Lancaster and south of the Lune Gorge, a bypass option of 30 miles (48km) could reduce journey times by 10 minutes 45 seconds. This bypass could not be used by trains calling at Lancaster or Oxenholme.

Sustainability

3.3.31 Bypasses around Shap Summit could affect a number of features, including the Asby Complex SAC, which includes the Crosby Ravensworth Fell SSSI, a scheduled monument, and the potential to encounter peat in this area. Bypasses north of Shap, in the Penrith area, could affect the River Eden SAC and SSSI. Both bypasses could affect a number of ancient woodlands.

3.3.32 Due to the level of protection afforded to SACs, any route option which directly or indirectly adversely affects a SAC creates a need for additional appraisals as required under the Habitat Regulations Assessment process. Further work would need to be undertaken, ensuring alternatives are considered as part of route selection and design as per the requirements under the Habitat Regulations Assessment process.

3.3.33 From a community perspective, the following is noted in relation to bypass options from Lancaster to Carlisle:

- Property type – there is a low density of properties along these bypass options, which are predominantly residential;
- Urban/rural – properties situated along the option are mainly within rural areas; and
- Index of Multiple Deprivation distribution – properties along this bypass option are within the mid to higher (less deprived) quintiles of the index.

Carlisle station

3.3.34 Trains are currently limited to 20mph (30kph) through Carlisle station, due to the track layout at the south end of the station. As mentioned previously, the track and signalling is due for renewal before completion of Phase Two. There is an opportunity for the renewal to include simplifying the layout around the station to increase approach speeds, possibly up to about 45mph (70kph), according to Network Rail. The limiting factor on train speed through the station would then be a curve just outside the south end of the train shed, which cannot be realigned without taking the railway outside its boundary, affecting adjacent parts of the town. The station improvements could also include provision for extending platforms to take 400m HS2 trains, which would improve operational flexibility, as it would enable 400m trains to stop and split at Carlisle. (This study assumes all high speed trains running north of Preston are 200m single sets, having split there.)

3.3.35 Even at the improved 45mph (70kph) speed, this would be the most significant speed restriction encountered by a high speed service between London and Glasgow. (Preston would remain more restricted, but this imposes less time penalty because all trains would stop there.) This study therefore considered options for bypassing Carlisle. The terrain on either side of Carlisle is fairly flat, which would normally be favourable for a high speed surface. However, there are extensive high-level environmental constraints on such route options. Much of this area is within the Hadrian's Wall World Heritage Site, and there are also a number of other environmental designations associated with the estuary and other habitats.

On the west, there is Solway Firth AONB, Ramsar, SAC and SPA, and the Nith Estuary NSA. On the east, there is Hadrian's Wall World Heritage Site and River Eden SAC, SSSI and floodplain.

3.3.36 To mitigate impacts on these areas, it is highly probable that a long tunnel would be necessary, at least 4 miles (6km) long. The study identified that infrastructure interventions elsewhere would allow a 3-hour journey time between London and Glasgow or Edinburgh to be achieved at lower cost. A tunnel bypass would therefore be a longer-term option if an end-to-end high speed route is required.

Sustainability

3.3.37 Carlisle station is a Grade II* listed building. Any upgrades to the station as part of further work would need to consider the impact on listed structures and features, and the impact on properties and communities situated in the vicinity of the station.

Carlisle to Carstairs

Existing railway

3.3.38 Northwards from Carlisle, the West Coast Main Line continues as two-track with a number of freight loops. The terrain is fairly flat between Gretna and Lockerbie. North of Lockerbie, the assent through the Southern Uplands is dominated by the steep incline on the northbound climb to Beattock Summit. Train performance and the capacity issues on the incline here are very similar to those outlined above for the incline at Shap.

Possible interventions

3.3.39 The range of options to be considered to address the incline at Beattock would be the same as those outlined above at Shap, and the analysis of the relative merits would be similar, though perhaps without the complication of being in close proximity to an SAC.

3.3.40 There is potential for a bypass from near Gretna Junction to Beattock village. The existing line allows maximum conventional speeds over some of this section, so potential journey time savings are less than elsewhere. However, the terrain is also easier, so construction costs could be relatively low, and a bypass in this area has a reasonable journey time to cost ratio. The connection to the existing route near Beattock could be retained, so that trains calling at Lockerbie could take advantage of the new route further north. A bypass from Gretna to Beattock village would save almost 10 minutes in journey time.

3.3.41 While a shorter bypass to avoid only the steepest section between Beattock village and Beattock summit is possible, the connection from this to the existing line at the north end would link directly to the slow section of line at the 'Crawford Curve'. This is likely to be a high priority for a bypass to improve overall end-to-end journey times. The cost of the connection would therefore represent abortive spend if the bypass were later extended, especially since there is no reason for a train to transfer between the high speed and classic infrastructure in this area. The combined longer bypass as far north as Abington would save 4.5 minutes. The undulating terrain means the cost per kilometre is relatively high, but it would resolve one of the major constraints on the West Coast Main Line, as well as providing some journey time saving on the relatively low-speed section through the hills. It would re-join the existing route near Abington, where higher speeds are possible.

3.3.42 Between Abington and Carstairs, higher speeds are possible and there is no significant capacity constraint, especially if the Beattock area immediately to the south is bypassed.

Sustainability

3.3.43 Any bypasses around the Beattock summit could affect several Category B listed buildings and scheduled monuments, as well as a number of ancient woodlands. Further work would be required to avoid any potential impact on the features through route selection and design.

3.3.44 From a community perspective, the following is noted in relation to bypasses around Beattock summit:

- Property type – there is a low density of properties along these bypass options, which are predominantly residential.
- Urban/rural – properties situated along the option are mainly within rural areas.
- Index of Multiple Deprivation distribution – the vast majority of properties along this bypass option are within the middle (third) quintile of the index.

Carstairs to Edinburgh and Glasgow

Existing railway

3.3.45 At Carstairs, trains split and run north east towards Edinburgh, or north west towards Glasgow. Edinburgh trains currently have to use a long 15mph (25kph) curve at Carstairs, but a proposed increase to 40mph (65kph) is under development by Network Rail. This study assumes that improvement will be already in place.

3.3.46 The Glasgow route has numerous flat junctions and intermediate stations, including Motherwell, and is consequently busy with suburban trains and most of the West Coast Main Line freight. The line therefore suffers from congestion and would require investment if improvement in capacity or speed is to be made. The Edinburgh route is less busy until Midcalder junction, and the ground conditions through Cobbinshaw are poor.

Possible interventions

3.3.47 This study assumes that work undertaken by Transport Scotland has comprehensively covered options north of Carstairs. Transport Scotland has shared the findings of their work for the purposes of this study and this study has used this to represent options in the area as part of overall methodology.

3.3.48 This assessment has considered a range of options for the area, including those developed by Transport Scotland that would form part of the route for a high speed link between Carstairs, Edinburgh and Glasgow. This would completely bypass the existing lines north of Carstairs except for the final approaches to Glasgow and Edinburgh.[6]

3.3.49 Baseline journey times to Glasgow and Edinburgh are virtually equal, at about 3 hours 38 minutes from London under Phase Two. The study objective of a 3-hour journey time between London and both cities means that any journey time saving towards one city has to be accompanied by a similar measure towards the other. Therefore, options north of Carstairs

[6]This study has only modelled and costed those parts of the route that could be used by north-south trains.

after the trains split do not represent the best way of meeting the north-south journey time objective. However, they could provide other potential benefits such as Glasgow-Edinburgh services, and decongestion and capacity release on the busy existing route into Glasgow in particular. At this stage, HS2 Ltd has not evaluated these broader aspects.

3.3.50 Platform lengthening at Glasgow Central and Edinburgh Waverley would not be necessary with a West Coast Main Line proposal, as although the trains to Scotland leave London as 400m coupled sets, they split at an intermediate location and so reach Glasgow and Edinburgh as 200m trains. Platform lengthening at Edinburgh Waverley would not be necessary with an East Coast Main Line proposal, since Edinburgh Waverley already has two platforms that are longer than 400m. However, further work would likely be required at both Glasgow Central and Edinburgh Waverley to increase the overall capacity of these stations.

Sustainability

3.3.51 The long bypass from Carstairs to the outskirts of Glasgow could affect nationally important scheduled monuments and a number of ancient woodlands. A bypass to Edinburgh could affect a number of historic and natural features, including scheduled monuments, an SSSI, a Category A listed building, and several ancient woodlands.

3.3.52 Further detailed study may be required to consider potential effects on the Clyde Woodlands SAC which extends over a large area in the vicinity of the West Coast Main Line, should any bypass interventions be considered within that area.

3.3.53 From a community perspective, the following is noted in relation to the bypass options from Carstairs to Glasgow and Carstairs to Edinburgh:

- Property type – the bypass option from Carstairs to Glasgow falls within a far more residentially populated area than the Edinburgh option.
- Urban/rural – the majority of the properties are in urban areas, as the Carstairs to Glasgow bypass option is within the densely populated Glasgow conurbation. In contrast, the properties situated along the bypass option from Carstairs to Edinburgh are mainly within rural areas.
- Index of Multiple Deprivation distribution – for the bypass option from Carstairs to Glasgow, the majority of the properties are within the lowest (most deprived) index of deprivation quintile. The bypass option from Carstairs to Edinburgh mainly affects properties within the mid to higher quintiles of the index.

Options for packaging of interventions on the West Coast Main Line

3.3.54 As outlined in Appendix A, there are a number of ways in which individual interventions could be combined with other interventions to form an overall set for the line. The final package to be delivered would represent a significant investment in the railway, and its make up would depend on the overall objective. This section outlines a representative example of how these could be done, and also how it could be phased in a number of stages.

West Coast Main Line Representative Package 1 – driven by cost/journey time and capacity enhancement

3.3.55 The priority for this package is to address Network Rail's three capacity concerns of Wigan-Preston, Shap Summit and Beattock Summit, so the intervention options that provided a bypass at these areas were included in the package first. Most of these interventions also deliver some journey time savings.

3.3.56 Following this, options were selected using a cost to journey time saving methodology – namely, selecting the options that provide the most cost-effective journey time reduction until a target of 3 hours between London and Glasgow or Edinburgh was achieved. The contents of the resulting package are outlined in Table 1, comprising a total of 137 miles (220km) of new line, and would cost an estimated £17 billion - £19 billion.

3.3.57 A number of sensitivity studies were undertaken on the package. For example, if the bypass of Wigan were omitted, it could be replaced with an option further north for a cheaper way to provide the time saving it brought. This would save around £300 million. However, this would have to be balanced by the fact that it is likely that major works would otherwise be needed to increase capacity at Wigan by other means, which would offset the additional cost.

Table 1: West Coast Main Line Representative Package 1

Intervention description	Journey time saving (minutes:seconds)	Length (km)
Bypass of Beattock Summit and Crawford Curve	04:37	26.0
Link from the Lockerbie bypass to Beattock bypass	01:14	4.8
Bypass from Gretna to Lockerbie	08:22	47.3
Bypass to the south of Carlisle	03:09	16.0
Bypass from north of Shap to Penrith	06:07	31.4
Bypass of Shap Summit	00:15	6.4
Bypass of Lancaster to the south of the Lune Gorge	10:44	48.0
Preston to South of Lancaster	03:12	18.4
Grade separate Euxton Junction and four-track upgrade from Balshaw Lane	-	3.5
HS2 Phase Two to Coppull	02:28	18.8
Total	40:37	220.6km

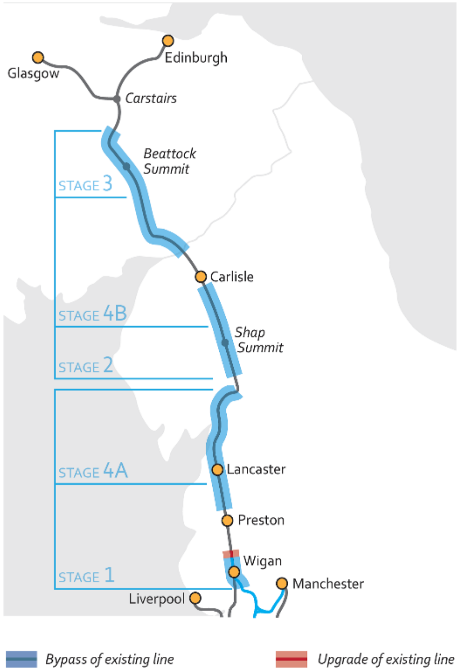
Phasing of options

3.3.58 For Representative Package 1, there would be many ways in which the construction sequence of the interventions could happen. Each stage of interventions would achieve incremental improvement to journey time and capacity, and the order in which they would be done would be investigated and agreed with stakeholders. The full series of stages would achieve a strategic target of a 3-hour journey, and could ultimately be combined to form an end-to-end high speed railway. The graph below illustrates one way which the package could be staged.

3.3.59 The first few stages are based around focusing work in each of the key congestion areas, along with some nearby interventions which would avoid abortive costs if built at the same time. In the final step, the remaining interventions provide effective journey time savings but do not address identified capacity constraints, and are therefore shown as being delivered at a later stage.

Table 2: Potential phasing of West Coast Main Line Representative Package 1

Priority	Description	Journey time saving (minutes:seconds)
Stage 1	Phase Two to south of Lancaster	5:40
Stage 2	Shap area and northwards to Carlisle	6:22
Stage 3	Beattock area and south to Lockerbie	5:50
Stage 4	South of Lancaster to Lune Gorge, Shap to Carlisle, and Gretna to Lockerbie	22:15



3.4 Options for upgrading the East Coast Main Line

Phase Two to Northallerton

Existing line

3.4.1 This section of route has four tracks throughout, and speeds of 125mph (200kph) are possible on the fast lines except in the vicinity of York station.

3.4.2 Located on a constrained site, and on a tight curve, the alignment through York station requires a 30mph (50kph) limit for trains travelling through the station. An avoiding route is available to the west of the station for freight trains, but some southbound freight trains pass through the station to avoid having to make a flat crossing over the fast lines north of the station.

3.4.3 South of York, the line carries a high volume of traffic and even though it is a four-track section, Network Rail advises that there is little capacity for growth in the area. As some trains from the south terminate at York or diverge to Scarborough, the route is less busy north of York.

Possible interventions

3.4.4 York lies well to the east of a straight line between Phase Two from the south and Darlington or Newcastle, so passing though York significantly increases the distance travelled by north-south high speed trains. Therefore, the largest time saving possible in this area would be achieved by a bypass that takes the more direct route following the A1 corridor and avoids the low-speed section through York, and re-joins the East Coast Main Line just north of Northallerton. This would provide a journey time saving of 14 minutes, including a parkway stop. With the surrounding area being very flat, construction of new alignments would be relatively straightforward, although there are significant areas of floodplain to be crossed requiring long lengths of viaduct, requiring appropriate consideration in the design process.

3.4.5 Shorter bypass options are also possible at a lower cost, avoiding only the low-speed section through York itself, although as noted above these give a longer overall journey. The speeds of up to 125mph (200kph) possible on the existing line's straight alignment limit the scope for journey time savings from new infrastructure in the same corridors. Nevertheless, options have been considered that could reduce journey time for trains serving York by building new high speed alignments adjacent to the existing rail corridors both north and south. These have performed reasonably well, particularly if they can be combined with options further north. The options north of York would have a journey time saving of 4 minutes.

3.4.6 Either a long or a short bypass of York could include a parkway station with access from the York-Harrogate railway line and the A59. This would be more attractive to some passengers, particularly those travelling to and from the Harrogate area, but less so for those accessing York or other destinations nearby.

3.4.7 A key question in determining the alignment on this part of the route is whether trains need to serve the existing York station, or a parkway west of York. The impacts of the York market would be considered in conjunction with the markets between the South and Newcastle or Edinburgh. Some illustrative packaging options are given below, but the final resolution would require more detailed assessment following engagement with stakeholders.

Sustainability

3.4.8 With regards to possible interventions between Phase Two and Northallerton, the following flood risk concerns were identified at this early stage.

3.4.9 The shorter bypass option in particular would need to consider a suitable design for crossing of the tidal River Wharfe and extensive floodplain, ensuring that there is a balance between cost of the structures (viaducts and embankments) and reducing the impacts on communities (due to an increase in vertical alignment), and ensuring that there are suitable mitigation options for flood risk. The existing railway line passes through the floodplain of the River Ouse in York and various 'ings' (water meadows/marshland) which have been subject to significant flooding in the past. Flood compensation or mitigation would be considered difficult in York city centre, and there is potential that using the network as currently engineered would not be resilient in the future. Therefore, further work would need to be undertaken ensuring alternatives are considered as part of route selection and design to ensure that any options taken forward in this location have addressed potential flood risk concerns, where possible.

3.4.10 The shorter bypass of York may also affect nationally important archaeological sites, monuments, buildings and structures. These would need to be avoided in the first instance through route selection and design if the proposed shorter bypass option is taken forward. This option could also affect a number of ancient woodlands.

3.4.11 From a community perspective, the following is noted in relation to bypass options in this area:

- Property type – options in this area have a low number of residential properties;
- Urban/rural – the properties within this area are mainly rural; and
- Index of Multiple Deprivation distribution – most properties within the section from Phase Two to Northallerton are within the higher (least deprived) quintiles.

Northallerton to Darlington

Existing railway

3.4.12 At Northallerton, two of the four tracks from York leave the East Coast Main Line as the slow lines diverge towards Eaglescliffe and Teesside by means of a grade-separated junction. The remaining two-track line from Northallerton to Darlington is reasonably straight, with permitted speeds up to 125mph (200kph), except for a curve in the Croft area where speeds are limited to 115mph (185kph).

3.4.13 Northallerton station has two platforms. These are located on the fast lines, meaning stopping trains have to use these platforms and thus stop on the fast lines. Stopping trains going towards Teesside must also make a flat crossing of the main line used by southbound trains from Darlington.

3.4.14 From Eaglescliffe, routes exist for trains to continue towards Tyneside without using the main line. The line towards Eaglescliffe (see Figure 8) is not electrified, and has several level crossings around Northallerton where road closure times are already disruptive to traffic and replacement by bridges would involve extensive works in residential areas. For these reasons, and because of the longer journey time, no passenger and few freight trains between York and Tyneside run via Eaglescliffe and there is limited scope for more to take this route in the future.

3.4.15 The double track between Northallerton and Darlington therefore carries a mix of traffic, ranging from 60mph (95kph) diesel freights through to 125mph (200kph) electric passenger trains. This mix of slow and fast trains is one of the most significant capacity constraints on the East Coast Main Line north of Phase Two. It is therefore a priority for capacity intervention, even though the existing high speed and undulating terrain give these interventions a lower journey time saving to cost ratio than some others on the route. Network Rail plans to install passing loops near the middle of this section, and although these proposals are not currently committed, they will improve capacity to some extent. Increasing the number of trains will worsen the current situation.

Potential interventions

3.4.16 The study assessed options for new high speed bypasses, that would include a deviation around Northallerton and closely follow the existing line to Darlington except to avoid the speed-restricted curve at Croft. This would have a journey time saving of 2.5 minutes. This intervention would avoid conflict with stopping trains at Northallerton and the capacity constraints posed on the busy line with mixed-use traffic and higher speed differential from Northallerton to Darlington.

Figure 8: East Coast Main Line from Northallerton to Newcastle

Sustainability

3.4.17 No nationally or internationally protected environmental features were identified near this option at the time of appraisal. However, further work would be required to understand the potential risk, including the likelihood for any indirect impact on protected features.

3.4.18 From a community perspective, the following is noted in relation to bypass option:

- Property type – the section from Northallerton to Darlington and Stockton-upon-Tees is in close proximity to built-up areas and has a high concentration of residential properties.
- Urban/rural – proportionally, there are very few properties within urban areas for the route option from Northallerton and Darlington.
- Index of Multiple Deprivation distribution – properties within the section from Northallerton to Darlington are mostly within the lower quintiles.

Darlington station

3.4.19 At Darlington, the main line passes immediately to the east of the station on a straight alignment and the line serving the station curves westwards into the station. All trains on the East Coast Main Line from the north must cross the main lines to make station calls, as do all trains to and from the branch to Teesside. This conflict is less severe today, as nearly all passenger trains stop, which means few actually use the through main line. However, the conflict would become worse if the number of trains increases, and particularly if more pass through without stopping.

3.4.20 Assuming trains continue northwards on a shared double track, the preferred solution would be to build one or (preferably) two through platforms for southbound main line trains and bay platforms for Teesside services to the east of the main lines. The existing platforms would be used only by northbound stopping trains and the Bishop Auckland service, and only through trains between Teesside and Bishop Auckland would cross the main lines.

3.4.21 In the longer term, an end-to-end high speed route could either bypass Darlington or run through the existing rail corridor. This is tightly bounded by built-up areas, so it might be necessary either to provide four tracks but design them for classic speeds, or to rebuild the existing double track to high speed standards and allow classic trains to use it for a short distance.

Darlington to Newcastle

Existing railway

3.4.22 A short distance north of Darlington, the East Coast Main Line becomes more curved, and maximum speeds drop from 125mph (200kph) to mainly 100mph (160kph) or less. Although this section remains double track, with loops at intervals and more loops planned, the reduced speed differential between fast and slow trains means capacity problems are less pressing than further south. However, some capacity intervention is desirable.

3.4.23 The northern part of this section of line was formerly duplicated by the Leamside Line to the east (see Figure 8), until the line was closed in the early 1990s. There are regional aspirations to re-open it for local passenger services and as an alternative route for East Coast Main Line freight. Although the infrastructure is somewhat degraded, the alignment has been protected and reopening would be significantly less difficult than building a new railway.

Potential interventions

3.4.24 Several options could reduce capacity problems on the route through Durham:

- Re-open the Leamside Line as a freight and regional bypass, and divert freight trains onto this route so the East Coast Main Line carries only high speed and other passenger trains through Durham. Because much of the freight needs to access Tyne Yard in Gateshead, and there is no other convenient freight facility in the area, it would also be necessary to restore a lifted curve in the Gateshead area so that freight could travel between Tyne Yard and the Leamside Line without crossing the main lines at a flat junction.
- Build a high speed bypass to either the west or east of Durham, avoiding slow sections of the line and Durham station. Passenger trains calling at Durham and all freight would still use the existing line. A high speed bypass of Durham would be about 12 miles (19km) long, with a journey time saving of 3 minutes, in addition to capacity relief through Durham. Some length of a high speed bypass east of Durham could follow part of the Leamside line, and neither of these options would preclude re-opening of Leamside for other traffic. However, some four-track may be necessary where the route is shared with a high speed bypass.

3.4.25 Either an eastern or a western bypass of Durham would re-join the East Coast Main Line in the Chester-le-Street area, from where reasonable speeds are possible towards Newcastle.

Sustainability

3.4.26 The following sustainability considerations have been identified for the bypass options described above.

3.4.27 A number of features, including an SSSI, battlefield and a number of ancient woodlands, were identified along the high speed bypass west of Durham. Potential direct or indirect effects would need to be considered further to understand the risks on these features and the potential to avoid or mitigate these in more detailed design.

3.4.28 No nationally or internationally protected environmental features were identified near the option that has been developed for new high speed infrastructure closely following the existing line around Northallerton and along the existing disused Leamside Line railway. Further work would be required to understand the risk more fully, including the potential for any indirect impact on protected features.

3.4.29 From a community perspective, the following is noted in relation to the bypass options:

- Property type – the section from Darlington to Newcastle passes in close proximity to a number of built-up areas, including the north of Darlington, south of Durham and Newcastle. The properties that are affected by these options are mainly residential.
- Urban/rural – About half the properties along the route are within urban areas.
- Index of Multiple Deprivation distribution – most of the properties within the section

from Phase Two to Northallerton are within the two higher (least deprived) quintiles (although it is a relatively small number of properties when compared to the rest of the route). In contrast, nearly two-thirds of the section from Northallerton to Newcastle are within the lowest (most deprived) quintile.

Newcastle station

3.4.30 Newcastle is the biggest market in the North East, and therefore all services are assumed to stop there. The Tyne and Wear Metro and other rail services provide good connectivity from most of the surrounding areas to Newcastle central station.

3.4.31 The level of predicted demand would require 400m long HS2 trains on many London to Edinburgh high speed services, requiring longer platforms at the station. However, under Phase Two the high speed trains do not continue north of Newcastle and platforms only need to be 200m long. Extra platform capacity is also necessary to handle more classic trains and because as services increase, many of the classic trains terminating at Newcastle will be too long for the short bay (terminating) platforms they use today.

3.4.32 Newcastle station is on a very constrained site. There are viaducts at either end of the station and a severely curved through alignment as the line effectively turns a 90 degree bend to cross the Tyne on historic bridges. Therefore, options for 400m long platforms are very restricted. The most likely solution is to create two new 400m through platforms by linking existing eastern and western bay platforms with new tracks through what is currently the main concourse (see Figure 9). This major rebuilding appears possible, but would have to be carried out in the context of the heritage train shed, and in the vicinity of the overhead historic footbridge. Significant areas of concourse space would be lost to the extended platforms and this would have to be replaced elsewhere in the station. This might be done by incorporating the station car park into the concourse and providing alternative parking nearby.

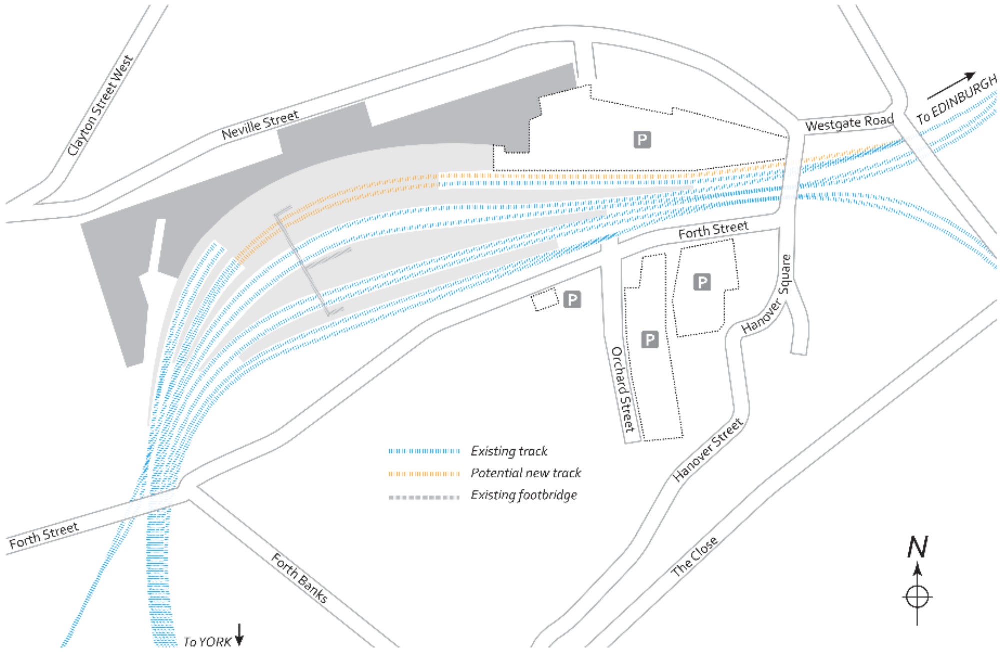


Figure 9: Option for a 400m platform at Newcastle station

Sustainability

3.4.33 Any upgrades or rebuilding of the Newcastle station would need to consider the impact on listed structures and features and the impact on property and community receptors in the vicinity of the station.

Newcastle to Edinburgh

Existing railway

3.4.34 Newcastle to Edinburgh is a double-track railway with freight loops. Capacity is a major issue between Musselburgh and Edinburgh. Capacity on the remainder of the route may also become a major issue in the medium to long term due to predicted growth in freight and passenger services. There are also aspirations for a regional service between Newcastle and Edinburgh serving two new stations at Reston and East Linton, which has been included in the new ScotRail franchise specification. These new stopping services would put additional capacity pressure on the line.

3.4.35 125mph (200kph) speeds are possible on sections in Northumberland and East Lothian where the terrain is fairly flat or undulating. There are some areas where speed is limited due to curvature of the line. At Morpeth, speed is limited to 50mph (80kph), and through Berwick and across the Border Bridge there is a 55mph (90kph) limit. North of the border, the section through the Lammermuir Hills is more curved and has a lower speed.

3.4.36 Network Rail has advised that they are monitoring the section of track that runs close to the cliff tops to the north of Berwick for coastal erosion.

Potential interventions

3.4.37 Through the slower sections in the Lammermuir Hills, the terrain makes new bypasses more difficult, and in parts of East Lothian historic battlefields and other constraints limit the scope to build new bypasses. Elsewhere, the terrain is more favourable for high speed alignment, as high speed bypasses north of Newcastle would allow large journey time savings at relatively low cost. However, fewer passengers would benefit than further south because trains are more lightly loaded north of Newcastle.

3.4.38 The existing railway broadly follows the A1 corridor close to the coast, and is significantly longer than the straight-line distance between Newcastle and Edinburgh. The straight line passes through some undulating areas and the Northumberland National Park, so is not considered a practical route for new railway alignment. However, the study has considered new infrastructure between Newcastle and Edinburgh in the A1 corridor, as well as on a more inland route closer to the straight line, some 12 miles (19km) shorter than the existing route. These are based on sections of high speed routes C and B respectively, described in Section 5. However, even avoiding the worst of the hills, the terrain means that the inland alignment has slightly higher costs and longer journey times than the A1 corridor alternative due to maximum speed not being possible in all places. It also has the disadvantage that the whole of the route would have to be built before it could be used, whereas the A1 corridor route could be built in part or in several stages with connections where it is close to the existing railway.

3.4.39 Any solution should preferably include diversion of the section of the existing line north of Berwick, which runs near the cliff tops and is susceptible to coastal erosion.

3.4.40 A full-length bypass in this area would potentially save 40 minutes. It would be possible to build it in short stages, for example three stages, with connectivity for Berwick and other points on the line.

Sustainability

3.4.41 The interventions along the A1 corridor route could affect a number of heritage features, including nationally important archaeological sites and monuments, nationally important buildings and structures, registered battlefields and nationally important gardens and designed landscapes within Scotland. Further work would be required to avoid any potential impact on these nationally important features through route selection and design.

3.4.42 In addition, any intervention is likely to have viaduct crossings of River Tweed SAC and the River Coquet. Therefore, the key consideration for any further work would be to seek to reduce the number of viaduct and embankment crossings to reduce the potential of flood risk and impact on biodiversity protected areas.

3.4.43 From a community perspective, the following is noted in relation to bypass option:

- Property type – This section from Newcastle to Edinburgh passes through the Newcastle and Edinburgh conurbations, and has a large concentration of residential properties in these areas.
- Urban/rural – About half of the properties are within urban area.
- Index of Multiple Deprivation distribution – properties within this section are widely distributed amongst all the quintiles.

Options of packaging of interventions on East Coast Main Line

3.4.44 A 3-hour journey time between London and Glasgow via the East Coast Main Line would require high speed infrastructure over virtually the whole distance between Phase Two and Edinburgh, and between Edinburgh and Glasgow. The 3-hour journey time representative packages below for East Coast Main Line are therefore to Edinburgh only.

East Coast Main Line Representative Package 1 – lowest-cost 3 hour package

3.4.45 This representative package was developed on the basis of finding the lowest-cost combination of interventions to achieve a 3-hour London to Edinburgh journey, calling only at Newcastle. The resulting package, illustrated in Table 3, comprises long sections of bypass north of Newcastle, plus fairly short bypasses of York and Durham. This package has 96 miles (154km) of bypass at a cost of an estimated £11 billion - £13 billion, but only addresses the objective of London-Edinburgh journey times while not considering connectivity to and within North East England. Capacity issues, including the most severe constraints between Northallerton and Darlington, are also not addressed.

Table 3: East Coast Main Line Representative Package 1

Intervention description	Journey time saving (minutes:seconds)	Length (km)
Bypass from north of Newcastle reconnecting with the ECML near Grantshouse	26:27	111.5
Bypass of Durham	03:17	18.8
Short bypass of York	05:00	16.6
Bypass extending the Phase Two alignment	03:40	7.2
Total	38:24	154.1

East Coast Main Line Package 2 – Package serving York and Darlington

3.4.46 The 3-hour target for this package includes a time allowance for stopping at Darlington and either York or a York parkway station, and therefore addresses the objectives of intermediate connectivity as well as end-to-end journey time. The most cost-effective solution is to serve the existing York station, with all journey time gains made north of Newcastle except for a short bypass south of York. The capacity constraints between Northallerton and Newcastle are not addressed, and this package might therefore require a Leamside re-opening for freight (not costed) and other measures south of Darlington to be viable. This package comprises 109 miles (175km) of bypass and costs an estimated £14 billion - £16 billion (if the long bypass north of Newcastle is built in one stage). If this northern section is built in three stages, the need for extra connections to the existing line increases costs by up to an estimated £500 million.

East Coast Main Line Package 3 – Package addressing capacity constraints

3.4.47 If the previous package is modified to include a bypass from Northallerton to south of Darlington and another avoiding Durham, then the 3-hour journey time target can be met with less new infrastructure north of Newcastle. However the cost would increase to an estimated £18 billion - £20 billion for 136 miles (219km) of new infrastructure.

Table 4: East Coast Main Line Representative Package 3

Intervention description	Journey time saving (minutes:seconds)	Length (km)
Bypass to the West of Dunbar	04:32	27.7
Bypass from Newcastle to North of Berwick	26:27	111.5
Bypass of Durham	03:45	17.9
Bypass between Darlington and Durham	02:27	14.7
Bypass North of Darlington	00:43	2.4
Bypass to the South of Darlington	01:33	17.5
Bypass to the West of Northallerton	01:03	14.4
Bypass extending the Phase Two alignment	03:58	12.5
Total	**44:30**	**218.6km**

Phasing of packages

3.4.49 If not built in a single phase, each package would most likely be built south to north to prioritise addressing the most severe capacity constraints and delivering benefit to the most passengers. As noted above, the long bypass north of Newcastle could be constructed in separate stages.

4 Delivering a high speed route to Scotland

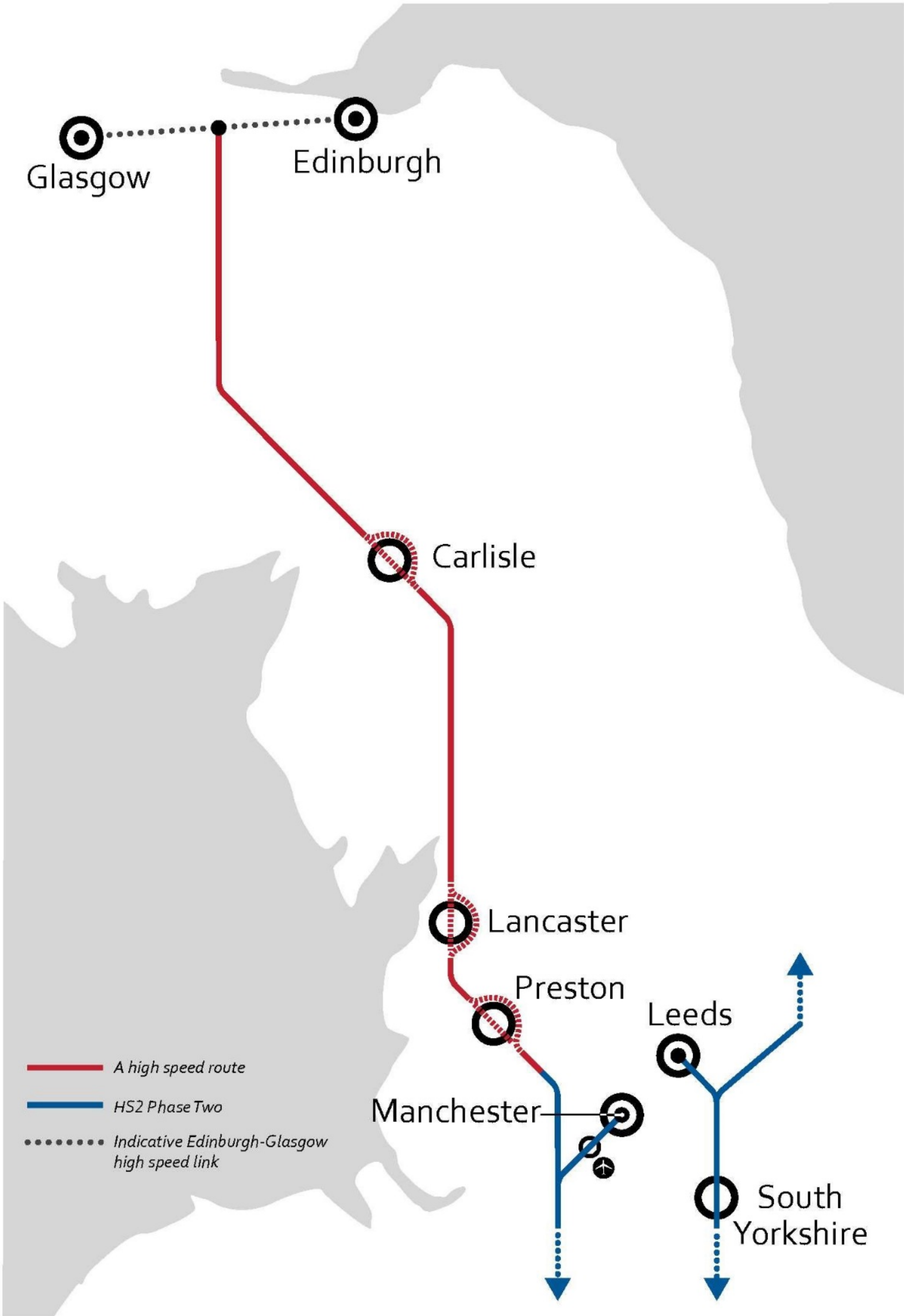


Figure 10: Potential high speed route

4.1 Introduction

4.1.1 This chapter outlines the work undertaken to develop a high speed route option that delivers a journey time between London and Edinburgh and Glasgow of less than 3 hours.

4.1.2 The initial study into high speed corridors explored the potential for extending a high speed route from the Phase Two network to the North of England and Scotland. These were designed as full high speed routes described in Section 5, and summarised below.

4.1.3 The study showed that the western Route A could equally serve Glasgow and Edinburgh, with a journey time of 2 hours 30 minutes from London to both cities.

4.1.4 Eastern high speed Routes B and C following the A697 or A1 corridors would be able to serve Edinburgh in 2 hours 30 minutes. However, the onward travel to Glasgow would result in a journey time between London and Glasgow of more than 3 hours.

4.1.5 The eastern Route D, which could serve Glasgow and Edinburgh equally within 3 hours, would perform less well than a western option due to the increased amount of infrastructure, cost and journey time.

4.2 Design approach

4.2.1 The next step in developing a 3-hour high speed route was to undertake further design development and refinement based on the findings above.

4.2.2 The western Route A showed the most potential for design refinement due to its ability to serve both Glasgow and Edinburgh, with comparable journey times and the lower cost compared to the eastern Route D.

4.2.3 The faster journey times of Route A compared to Route D also showed more potential for changes to the alignment to be introduced within the 3-hour target.

4.2.4 The route is therefore similar to western Route A described in Section 5, which would broadly follow the existing West Coast Main Line, M6 and A74(M) transport corridors which run in a north – south direction.

4.2.5 This alignment was reviewed with the aim of changing the design to reduce impacts including engineering complexity, environmental impacts and costs.

4.2.6 These changes sought to reduce the lengths of structures such as viaducts and tunnels, and the amount of earthworks required by considering a lower speed alignment in specific locations, which is able to incorporate tighter curves and follow the terrain more closely and reduce sustainability impacts.

4.2.7 Crossings of existing infrastructure were also reviewed to reduce their number and to simplify structures by minimising the skew angle at the crossing point.

4.2.8 The study assumed that a connection with an Edinburgh to Glasgow high speed line could be used to reach these cities and that it would be delivered separately from this route.

4.2.9 Finally, the study considered the locations where staging the delivery of the new route would be beneficial in terms of reducing congestion on the existing network.

4.3 Route description

Phase Two to Lancaster

4.3.1 The route would commence at the northern end of the Phase Two western leg in the Golborne area and head northwards, passing east of Wigan towards Preston.

4.3.2 The route would weave between settlements at speeds from 140mph to 220mph (230kph to 350kph), and make several road and motorway crossings.

4.3.3 From Preston, the route would follow the existing M6 and West Coast Main Line transport corridor to Lancaster.

Lancaster to Carlisle

4.3.4 The route would continue to follow the existing transport corridor, reaching more challenging terrain as it passes between the Lake District and Yorkshire Dales National Parks. Deep cuttings, viaducts and tunnelling would be required to negotiate the topography, and the design speed has been reduced in sections to 125mph (200kph) or 140 mph (230 kph) to follow the contours more closely.

4.3.5 Crossings over the M6 and West Coast Main Line would be required as the route follows the transport corridor north in the flatter section approaching Carlisle, where the route would pass to the east of the city.

Carlisle to Edinburgh and Glasgow

4.3.6 North of Carlisle, the route would follow the West Coast Main Line and A74(M) corridor past Lockerbie. Through the Southern Uplands, the design speed has been reduced to a minimum of 150kph to follow the contours of the topography and the existing transport corridor more closely. However, some sections of tunnelling would still be required.

4.3.7 The route would follow the West Coast Main Line towards Carstairs and join at the approximate mid-point of a high speed line between Edinburgh and Glasgow. At this location, a station facility would allow for trains from the south to split in order to serve both Glasgow and Edinburgh, and join in this location to head south.

4.3.8 The study did not include any work to design or appraise a potential high speed route between Glasgow and Edinburgh.

Sustainability considerations

4.3.9 North of Preston, the route would cross a significantly larger proportion of sparsely populated and quiet areas than options for the North East.

4.3.10 The route would pass the Forest of Bowland AONB and the Lake District and Yorkshire Dales National Parks, in all cases through difficult terrain. The Area of Outstanding Natural Beauty and National Parks are areas of protected landscape, with high cultural and recreational value and their designations mean that passing through or very close to them would create a requirement for careful consideration of potential impacts and mitigation.

4.3.11 The Secretary of State for Environment has confirmed that from August 2016, the Lakes and Yorkshire Dales National Parks will be coalesced. Further work would need to be undertaken to establish how to progress this option further without having an adverse impact on the national parks.

4.3.12 Any north-south routes around Carlisle would have to pass through the Hadrian's Wall World Heritage Site, which runs to the east and west of Carlisle. The terrain either side of Carlisle is fairly flat, which would normally be favourable for a high speed route. However, there are extensive high-level environmental constraints on such route options. In addition to the Hadrian's Wall World Heritage Site, there are a number of other environmental designations associated with the estuary and other habitats. These comprise the Solway Firth AONB, Ramsar, SPA and SAC as well as the Nith Estuary National Scenic Area on the west, and the River Eden SAC, SSSI and floodplain to the east. Any downstream impacts on International and European habitats (Ramsar sites, SPAs and SACs) would need to be considered at a more detailed level of assessment.

4.3.13 The route would pass two SACs which are valuable wildlife sites protected by European legislation. The River Eden SAC and SSSI is an area of tidal rivers, mudflats, bog, marshes and woodland; and the Asby Complex SAC is an area of bog, marshes and grassland.

4.3.14 Due to the level of protection afforded to SPAs and SACs, any route option which directly or indirectly adversely affects these sites creates a need for additional appraisal requirements and a thorough assessment of alternatives under the HRA process. Therefore, further work would need to be undertaken ensuring alternatives are considered as part of route selection and design as per the requirements under the HRA process.

4.3.15 In all cases, because of the level of protection the SPA and SAC designations carry, development which directly or indirectly affects an SAC or SPA creates a need for additional appraisal and mitigation requirements.

4.3.16 Between Carlisle and Lockerbie lies the Eskdalemuir Observatory. The site monitors ground vibration and seismological activity and may therefore be sensitive to any changes in the area with monitoring equipment spaced over an area of 4 square miles (10 sq km). Building a route past the site would require liaison with the Ministry of Defence and other potential stakeholders to ensure that there are no significant impacts on this facility or other unknown issues.

4.3.17 There are potential locations where there are likely to be long crossings of floodplains, or appear to be restricted by neighbouring development. These locations are likely to be crossings around Preston and Carlisle. These locations would have to be reviewed at the next stage as they are likely to increase cost due to the length of the viaduct, or potentially extensive floodplain mitigation to minimise flood risk increases elsewhere. Therefore, different potential design options would need to be considered at a later stage to address these risks.

4.3.18 From a community perspective, the following is noted in relation to the high speed route:

- Property type – the section from Phase Two to Lancaster has the highest concentration of residential properties along the route.
- Urban/rural – three-quarters of the route is in rural areas as the route joins the mid-point of the potential high speed route between Glasgow and Edinburgh developed

by Transport Scotland, thereby avoiding the urban conurbations of Glasgow and Edinburgh.

- Index of Multiple Deprivation distribution – across the route, around 3% of the properties are within the lowest (most deprived) quintile, with the majority of the properties (41%) within the higher (fourth) quintile.

Journey times

4.3.19 Journey times to Edinburgh and Glasgow would be in the order of the following times.

Table 5: Journey times for the high speed route option from London

	Today	Phase Two	High speed route option
To Edinburgh	4:23*	3:39	2:50**
To Glasgow	4:31***	3:38	2:50**

*Typical journey time; one train per day leaves Edinburgh at 05:40am and achieves 4 hours to London.
**From London Euston, on the basis of a stop at Preston and splitting the train.
***Typical journey time; one train per day leaves London at 16:30 and achieves 4 hours 8 minutes.

Route cost and length

4.3.20 The route would comprise 194 miles (312km) of new high speed railway between the end of Phase Two and the connection to a high speed line between Edinburgh and Glasgow. The cost is estimated at £22 billion - £25 billion, which reflects the reduced length compared with the high speed routes considered in Section 5, and reduced lengths of structures. This cost excludes a high speed line between Edinburgh and Glasgow.

4.3.21 Key risks would include the significant lengths of undulating terrain to be crossed and sustainability features such as the national parks, Hadrian's Wall World Heritage Site, and a number of wildlife sites protected by European and national designations.

4.4 Staging

4.4.1 In addition to a full high speed route, HS2 Ltd undertook initial work to review staging the delivery of the route to consider the areas of the existing network which would benefit most from sections of a new alignment, ahead of full implementation.

4.4.2 The locations on the existing network which cause the most capacity constraints have been identified in Section 3 as part of the study into upgrading the West Coast Main Line. These locations, where a bypass would ease congestion and which therefore would be candidates for early delivery, are Wigan, Carlisle, Shap Summit and Beattock Summit.

4.4.3 A bypass at Wigan or Carlisle would provide capacity relief around these congested station areas, whilst a bypass for the summits at Shap and Beattock would relieve the congestion caused by the speed differential between freight and passenger services.

4.4.4 Short bypasses of this nature would ease the issue of capacity but would have smaller benefits in journey times.

4.4.5 Additional connections to the existing network would be required to enable services to run off the existing network, and further work would be required to consider the longer-term use of such junctions once the route is fully implemented. These additional connections would also require additional investment above the cost of delivering an end-to-end route.

4.5 Benefits

4.5.1 As detailed in Section 5, a high speed route option would deliver significant benefits to the UK economy. It is expected that a 3-hour route option would provide benefits, but these would be lower than those delivered by a faster route, due to the longer journey time.

4.5.2 Another contributing factor to the level of benefits would be the impact of the expected benefits through the delivery of the route, whether in full or in a staged approach, and the operational assumptions made about the kinds of services using a new route. As with the full HS2 network, a proportion of the benefits delivered by this investment would arise due to the additional capacity provided on the classic network.

4.5.3 For this further route option, no specific demand modelling has been undertaken, but could be undertaken at a later date to consider potential operational impacts and benefits.

4.5.4 Indicative analysis suggests that the incremental benefits of a 3-hour journey time for high speed services are expected to be around £3 billion (PV) and incremental revenue around £3 billion (PV) as compared to Phase Two. Wider economic impacts could add around a further £1 billion (PV) to benefits.

4.6 Conclusion

4.6.1 This additional study has concluded that there is potential for a route which achieves a 3-hour journey time between London to Glasgow and Edinburgh, at a lower cost than a full high speed route.

4.6.2 By reducing the design speed in specific locations, the alignment is able to follow the topography and existing transport corridors more closely, thereby reducing costs associated with long structures and large volumes of earthworks.

4.6.3 A connection into the midpoint of the proposed high speed line between Edinburgh and Glasgow would allow trains to split and serve both destinations, and would require a shorter length of route compared to a route which splits further south.

4.6.4 Initial consideration of how the delivery of the route could be staged has highlighted how the same congested areas on the existing network would benefit from capacity relief, but that long sections would be required to achieve significant journey time savings.

4.6.5 Some of these interventions may deliver synergies with Network Rail's long-term investment plans. It may be appropriate to consider in collaboration with Network Rail whether this work could help to inform consideration of possible upgrades on this section of the West Coast Main Line.

5 Other options for continuous high speed routes

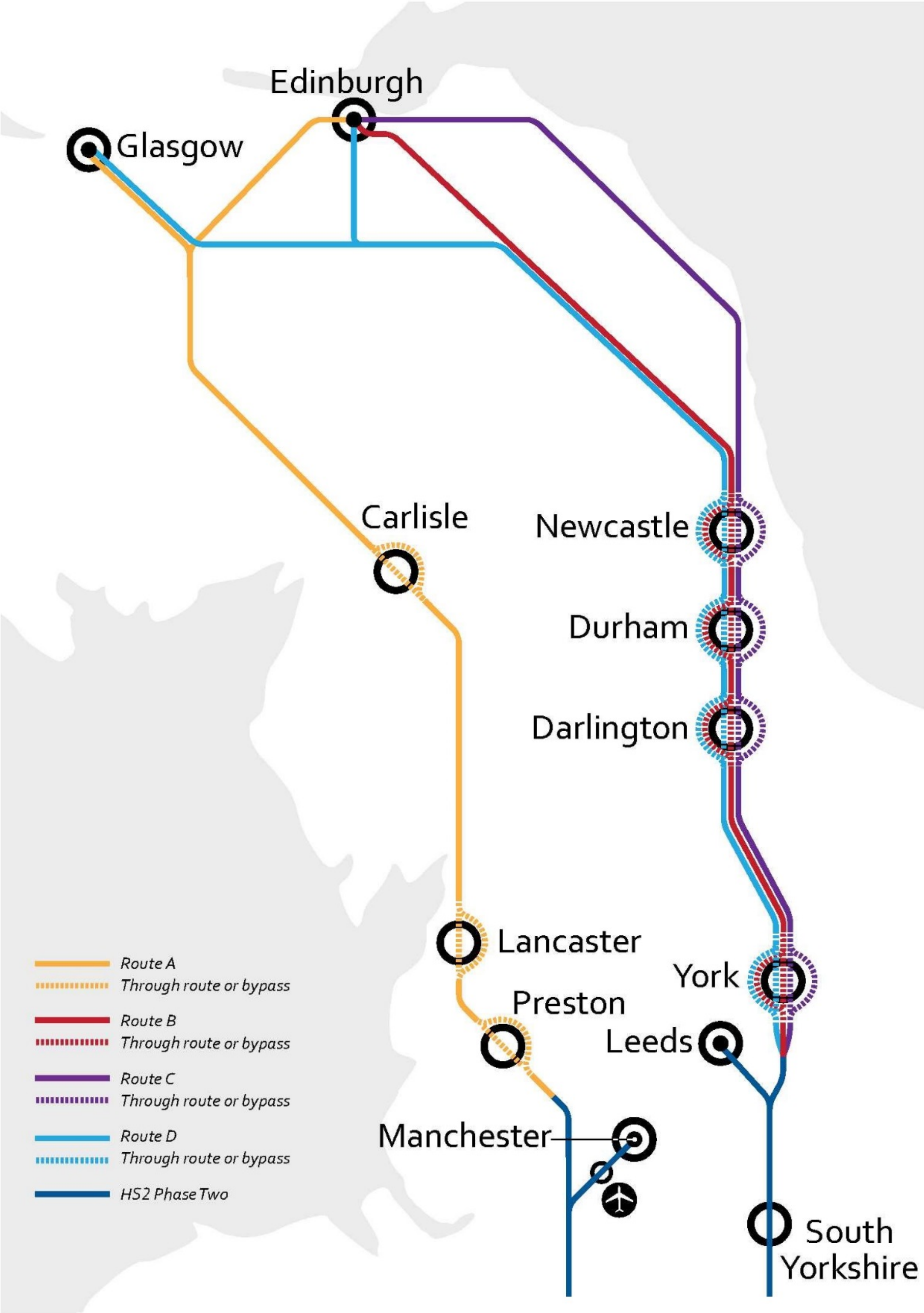


Figure 11: Broad options for high speed routes

5.1 Introduction

5.1.1 This chapter outlines four broad continuous high speed routes and how they perform against the assessment criteria outlined in Appendix A. These options should not be read as preferred options, but are intended to illustrate the pros and cons of providing an end-to-end high speed route as one of the broad options to be considered for serving the North of England and Scotland.

5.2 Serving markets in the North of England

5.2.1 High speed rail offers potential for significant improvement to rail travel for cities in the North West and the North East and Scotland. How best to serve these cities is a complex issue, requiring a balance of considerations. At a later stage of development, detailed study would assess all the options for serving these cities and towns, which would include input from local stakeholders.

5.2.2 These destinations could be served in a number of ways:

- running the route on the existing railway via the existing city centre station (classic-compatible trains required);
- a fast bypassing route with a parkway station;
- a spur or loop from the high speed route into the city centre (classic-compatible trains required); and
- fitting a high speed (or near high speed) route through the city (GC gauge platforms or classic-compatible trains required).

5.2.3 City centres offer densely populated markets to which high-capacity, high speed lines are well suited, with ready access to business destinations. They also provide the hubs for local transport networks. High speed rail often works best when it focuses on serving those markets directly. As the established centres of business and commerce, city centre locations are also likely to offer the highest-value development opportunities. However, city centre stations are more likely to have a comparatively low-speed approach, causing extended journey times for all users, and have a higher potential impact on sustainability in terms of community and heritage from building the railway infrastructure into the city centre.

5.2.4 Parkway stations are out-of-town stations, typically near a motorway or major road. Station options tend to be less well located for city centre passengers, but better for those who drive to the station from the outskirts or outlying areas. They can potentially be accessed by public transport either by optimising existing links or through investment in new links. As they are less likely to be in well-developed locations, it is likely, at least initially, that there will be less development and established commerce and businesses. Parkway station options are likely to have a high speed approach, minimising journey time loss. By potentially being accessible to a wider region as opposed to a city centre, they can spread the benefits to a wider market.

5.2.5 Finding a solution would require detailed assessment of all the options to determine the best way of serving each location. This involves finding a balance between serving the location and the impact on through passengers.

5.3 Continuous high speed options

5.3.1 A number of continuous high speed routes were developed to assess the viability and performance of a high speed route, using the methodology set out in Appendix A. Unlike the route described in Section 4, these four routes were designed to run at a speed of 400kph.

5.3.2 The four options are:

- Route A – a route following the West Coast Main Line, M6, A74M corridor which splits near Carstairs to serve both Edinburgh and Glasgow.
- Route B – a route following the A1M to Newcastle and the A697 corridor to the border, where it runs through the Lammermuir Hill, to approach Edinburgh from the east.
- Route C – a route following the East Coast Main Line corridor east of Newcastle and along the coast to Edinburgh.
- Route D – a route following the A1M to Newcastle and through the Southern Uplands, where it splits to serve Glasgow and Edinburgh.

5.4 Options to the west

Route A

5.4.1 Options for routes on the west side are heavily influenced by the undulating terrain and extensive areas protected by environmental designations to the north of Preston. If the most difficult terrain and protected areas are to be avoided, route options are essentially limited to following the existing West Coast Main Line/M6/A74M corridor from Preston to the Glasgow and Edinburgh area. Any route within this corridor would have to negotiate significant lengths of undulating terrain in a number of areas; this represents one of the most challenging aspects of the route.

Phase Two to Lancaster

5.4.2 This section of the route would be about 50 miles (80km) long and connect to Phase Two. It would continue northwards passing to the east of Wigan before crossing the West Coast Main Line and running west of Preston. Even with a bypassing route such as this, Wigan could still benefit from high speed routes further north and south, with trains using connections between the West Coast Main Line and a high speed route.

5.4.3 Preston and Wigan and their associated urban areas represent the most built-up area of this route outside Glasgow and Edinburgh, requiring the route to weave in close proximity to a number of settlements. The route would also have to make several motorway and road crossings as it passes through the built-up area. A route to the west of Preston would cross the River Ribble on viaduct at sufficient height to maintain navigation clearance.

5.4.4 From Preston, the route would continue northwards, running parallel to the West Coast Main Line through largely flat terrain, avoiding the undulating area and ensuring that any impact to the Forest of Bowland is kept to a minimum. Significant lengths of viaduct would be required as it crosses over the Lancaster Canal, the River Wyre and extensive areas of floodplains.

Lancaster to Carlisle

67.5 miles (109km)

5.4.5 Running north from Lancashire, the Lake District National Park to the west and the Yorkshire Dales National Park and Pennines to the east constrain the route and limit alignment options to following the existing West Coast Main Line/M6 transport corridor to Carlisle. Initially flat, the terrain would become significantly more challenging as the route passes between the hills of the national parks and negotiates the narrow pass over the summit at Shap, having climbed to a total height of about 260m. The route would require a series of deep cuttings and embankments, as well as some lengths of tunnel. A number of crossings of the M6 and West Coast Main Line would be necessary as the route negotiates the terrain to achieve the straighter alignment required for high speed. As the route emerges from the hills, the terrain would be flatter towards Carlisle and the border.

Carlisle to Carstairs

75.5miles (122km)

5.4.6 North of Carlisle, the route would continue past Lockerbie following the A74(M) and would encounter an extensive line of undulating terrain in the Southern Uplands. The route would broadly follow the existing transport corridor through the narrow, winding valley between Beattock and Abington, requiring deep cutting, embankments and lengths of tunnel. From here, the route would continue northwards towards Carstairs.

Carstairs to Edinburgh and Glasgow

35 miles (56km) to Edinburgh and 29 miles (47km) to Glasgow

5.4.7 The route would split north of Carstairs, with separate legs running to Glasgow and Edinburgh. The eastern branch would re-join the classic network to the west of the A720 Edinburgh ring road, to serve Edinburgh Waverley, and the western branch would re-join the classic network near Rutherglen to serve Glasgow Central. This high speed alignment would share the same track as the high speed rail link between Glasgow and Edinburgh that was identified in an earlier study carried out by Transport Scotland, which also had a high speed link to the West Coast Main Line near Carstairs.

5.4.8 Since high speed trains would run along the existing rail network from the city outskirts to the existing city centre stations, classic-compatible rolling stock would be required. There is also an option to include one or more intermediate parkway stations in central Scotland to give better connectivity with the motorway network.

Sustainability considerations for Route A

5.4.9 As has been reported previously in Section 4, the sustainability considerations for Route A are broadly similar to the 3-hour high speed route and are listed below for clarity.

5.4.10 North of Preston, Route A would cross a significantly larger proportion of sparsely populated and quiet areas than options for the North East.

5.4.11 Route A would pass the Forest of Bowland AONB, Yorkshire Dales National Park, and the Lake District; in all cases through difficult terrain. The AONB and national parks are areas of protected landscape, with high cultural and recreational value, and their designations mean that passing through or close to them would create a requirement for careful consideration of potential impacts and mitigation.

5.4.12 The Lakes and Yorkshire Dales National Parks will be coalesced to form the Lakes and Dales corridor, and this will come into effect from August 2016[7]. Further work be needed to establish how to progress these options further without having an adverse impact on the national parks.

5.4.13 Any north-south routes around Carlisle would have to pass through the Hadrian's Wall World Heritage Site which runs to the east and west of Carlisle. The terrain either side of Carlisle is fairly flat, which would normally be favourable for a high speed surface. However, there are extensive high-level environmental constraints on such route options. Much of this area is within the Hadrian's Wall World Heritage Site, and there are also a number of other environmental designations associated with the estuary and other habitats. These are the Solway Firth AONB, Ramsar site, SPA, SAC and SSSI, as well as the Nith Estuary National Scenic Area to the west, and Hadrian's Wall World Heritage Site and River Eden SAC, SSSI and floodplain to the east. Any downstream impacts on International and European habitats (Ramsar sites, SPAs and SACs) would need to be considered at a more detailed level of assessment.

5.4.14 Route A would pass Bowland Fells SPA and SSSI. A Special Protection Area is a valuable wildlife site of particular importance to birds protected by European legislation – in this case, an area of upland heather moorland and blanket bog.

5.4.15 Route A would pass two SACs, which are valuable wildlife sites protected by European legislation. The River Eden SAC and SSSI is an area of tidal rivers, mudflats, bog, marshes and woodland, and the Asby Complex SAC is an area of bog, marshes and grassland.

5.4.16 Due to the level of protection afforded to SPAs and SACs, any route option which directly or indirectly adversely affects these sites requires additional appraisal and a thorough assessment of alternatives under the Habitat Regulations Assessment process. Therefore, further work would be needed to ensure alternatives are considered as part of route selection and design, under the requirements of the Habitat Regulations Assessment process.

5.4.17 Between Carlisle and Lockerbie lies the Eskdalemuir Observatory. The site monitors ground vibration and seismological activity and is therefore sensitive to any changes in the area with monitoring equipment spaced over 4 square miles (10 sq km). Building a route past the site would require liaison with the Ministry of Defence and other potential stakeholders to ensure that there are no significant impacts on this facility or other unknown issues.

5.4.18 On Route A, there are three potential locations that are either long crossings of the floodplain or appear to be restricted by neighbouring development. The first would be the long crossing of the River Ribble near Preston, which would be challenging due to the length of crossing required.

5.4.19 The second and third would be the long section crossings of the River Eden and River Esk north of Carlisle. Although they cross in rural locations, they are likely to increase cost due to

[7] https://www.gov.uk/government/publications/national-parks-extensions-to-the-lake-district-and-yorkshire-dales-parks

the length of the viaduct or potentially extensive floodplain mitigation to minimise flood risk increases elsewhere. Different design options and route alternatives would need to be considered as part of further design work to address these risks.

5.4.20 Some stretches of Route A would cross a groundwater Source Protection Zone. Further design work would need to consider in detail the potential impacts on potable groundwater through the route selection, and examine design options to address these risks.

5.4.21 From a community perspective, the following was noted for a high speed Route A:

- Property type – the section from Lancaster to Carlisle has the highest concentration of commercial and retail properties. The highest number of residential properties are between Carlisle and Carstairs.
- Urban/rural – Approximately one-fifth of the properties situated along the route are in rural areas.
- Index of Multiple Deprivation distribution – Although there is an equal distribution of properties within the five quintiles along the route, the section from Carlisle to Carstairs has the highest number of properties within the lowest (most deprived) quintile.

Route cost and journey times for Route A

5.4.22 The cost of Route A is an estimated £32 billion - £34 billion, which excludes the cost of a high speed route between Edinburgh and Glasgow. Potential journey times are as follows:

Table 6: Journey times for Route A from London

	Today	**Phase Two**	**Route A**
To Edinburgh	4:23*	3:39	2:30**
To Glasgow	4:31***	3:38	2:30**

*Typical journey time; one train per day leaves Edinburgh at 05:40am and achieves 4 hours to London.
**From London Euston, on the basis of a stop at Preston and splitting the train.
***Typical journey time; one train per day leaves London at 16:30 and achieves 4 hours 8 minutes.

5.4.23 There would also be potential to make time savings similar to those for the journey between London and Edinburgh and Glasgow from other destinations, such as Preston, though this would depend on whether it was a parkway or city centre station and on the calling patterns assumed for other stations on the route.

5.5 Options to the east

Route B

5.5.1 For routes to the east, the undulating ground of the Cheviot Hills and the Southern Uplands, as well as Northumberland National Park, force options towards the coast. The routes could also serve Newcastle and the main markets of the North East.

5.5.2 Route B would be an inland route running to the west of Newcastle, following the A697 to the east of the Northumberland National Park to the border where it would run through the Lammermuir Hills, approaching Edinburgh from the east.

Phase Two to Northallerton

42 miles (68km)

5.5.3 At its southern end, the route could join Phase Two in the Garforth area and continue north through the Vale of York as far as Northallerton. Alternatively, the route would join Phase Two and pass close to York, following the East Coast Main Line corridor northwards to Northallerton. The general terrain in this area is largely flat, with a large amount of open countryside and farmland, but a number of watercourses and floodplains would require considerable lengths of viaduct. Both route options would have to negotiate a number of settlements adjacent to the existing transport corridors.

5.5.4 On either of these routes, a parkway station could be provided to serve the region at the points where the routes cross the A59, the A64 and the York to Harrogate railway, or close to the York ring road.

Northallerton to Newcastle

54 miles (87km)

5.5.5 The route would continue north from Northallerton, passing to the east of Darlington and Durham along a similar line to the A1(M), and round to the west side of Newcastle. The terrain would be relatively flat to the south, becoming increasingly undulating towards Newcastle. At Newcastle, the route would cross the deep valley of the River Tyne on a high viaduct.

5.5.6 Where it passes east of Darlington, the route would cross the A66 and the Darlington to Middlesbrough railway, creating potential for a parkway station serving Darlington and Teesside. Use of the existing rail corridor through Darlington, with high speed trains stopping alongside the existing station, may be feasible but would require further investigation.

5.5.7 To the west of Newcastle, potential sites for a parkway station would be the Team Valley area, Metrocentre or by Newcastle Airport to the north west of the city. All of these sites would be near Tyneside highways and have connections to the metro or local rail network. A more detailed study would investigate the relative merits of these sites and the option of a city centre station.

Newcastle to Edinburgh

104 miles (167km)

5.5.8 Just north of the River Tyne, the steeply rising ground would require the route to enter a tunnel before continuing northwards following the A697 towards Wooler and Coldstream, keeping beyond the eastern edge of the Northumberland National Park. The terrain is increasing undulating north of Newcastle around the Cheviot Hills as far as Wooler. From Wooler, the route would head across country through relatively flat terrain, crossing the Tweed and a number of other watercourses, then the Lammermuir Hills. Fitting a high speed alignment along the valley would require deep cuttings, embankments and occasional tunnels.

5.5.9 Emerging from the Lammermuir Hills, the route would head west towards Edinburgh. In line with work carried out by Transport Scotland on the Edinburgh-Glasgow high speed link, it has been assumed at this stage that high speed routes would connect to the existing railway on the edge of Edinburgh and continue on existing line to serve Edinburgh Waverley. This would require trains on the route to be classic-compatible.

Sustainability considerations for Route B

5.5.10 From Phase Two to Northallerton and north towards Durham, Route B would pass through a largely rural landscape characterised by small settlements.

5.5.11 The route would enter the Newcastle conurbation and cross the River Tyne on a viaduct before passing in a tunnel under the Hadrian's Wall World Heritage Site.

5.5.12 North of Newcastle to the foothills of the Lammermuir Hills, the route would again pass through a largely rural landscape characterised by small settlements, making a number of viaduct crossings of the River Tweed SAC. The Tweed is an important river which forms part of the border between England and Scotland. The SAC is a species-rich watercourse providing a habitat for Atlantic salmon, otter and supporting aquatic vegetation. It is a very valuable salmon fishery and there is a significant commercial stakeholder interest in this habitat. Any route taken forward which could affect an SPA or SAC would be subject to a Habitat Regulations Assessment.

5.5.13 The higher ground of the Lammermuir Hills is a quiet and remote area characterised by an upland landscape and a sparse population. North of this area, Pinkie Battlefield (1547) is located on the eastern outskirts of Musselburgh. Historic Scotland has published an interim guidance note on Historic Battlefields (2011). This recognises the inevitability of a degree of change in designated battlefield areas that has to be accommodated through avoidance, mitigation and enhancement measures as a result of engagement and participation of key stakeholders and other interest groups.

5.5.14 On the section from Newcastle to Edinburgh, the proposed route option crosses the River Till floodplain. Although the crossing is predominantly in a rural location, it is likely to increase cost due to the length of the viaduct, or potentially extensive floodplain mitigation to minimise flood risk increases elsewhere. Different design options and route alternatives would need to be considered as part of further design work to address these risks.

5.5.15 Some stretches of Route B would cross a Source Protection Zone. The next stage would need to consider in detail the potential impacts on potable groundwater through route selection and design to address these risks. For example, there is likely to be minimal impact if the proposed route is on embankment in comparison to cuttings or viaducts.

5.5.16 From a community perspective, the following was noted for high speed route B:

- Property type – The section from Northallerton to Newcastle has the highest number of manufacturing and industrial, community and residential properties as it nears existing urban conurbations (Newcastle).

- Urban/rural – Approximately half of the properties along the route are within rural areas. There are very few properties within urban areas for the sections from Phase Two to Northallerton and Newcastle to Edinburgh.

- Index of Multiple Deprivation distribution – The majority of the properties within the section from Phase Two to Northallerton are in the highest (least deprived) quintiles (although this is a relatively small number of properties compared with the rest of the route). Along two-fifths of the length of this section, there are impacts on properties within the lowest (most deprived) quintile.

Route cost and journey times for Route B

5.5.17 The estimated cost of Route B is £27 billion - £29 billion, which excludes the cost of a high speed route between Edinburgh and Glasgow. Potential journey times are as follows:

Table 7: Journey times for Route B from London

	Today	Phase Two	Route B
To Edinburgh	4:23*	3:39	2:30
To Glasgow	4:31**	3:38	3:05 to 3:21***

*Typical journey time; one train per day leaves Edinburgh at 05:40am and achieves 4 hours to London.
**Typical journey time; one train per day leaves London at 16:30 and achieves 4 hours 8 minutes.
*** See 5.6 Journey Time Outcomes

5.5.18 There would also be potential to make time savings similar to those for the journey between London and Edinburgh and Glasgow from other destinations, such as cities in the North East, though this would depend on whether it was a parkway or city centre station and on the calling patterns assumed for other stations on the route.

Route C

5.5.19 Route C differs from Route B, as it passes east of Newcastle and follows the East Coast Main Line/A1 along the coast north from Newcastle.

Phase Two to Northallerton

42 miles (68km)

5.5.20 For the section of the route from Phase Two to Northallerton the options would be similar to those for Route B.

Northallerton to Newcastle

54 miles (87km)

5.5.21 The route would take a more easterly alignment, passing east of Northallerton and running west of Sunderland, and continuing to pass through the east side of the Tyneside area between Newcastle city centre and the coast. The terrain in this area is relatively flat at the south end, becoming increasingly undulating, and then flattening through Newcastle, with a shallow but wide valley at the River Tyne.

5.5.22 The southern and eastern suburbs of Newcastle are densely developed and significantly limit route options. The existing rail corridor in this area is tightly curved to avoid these areas. Developing an alignment for Route C with a bridge over the Tyne would therefore be very difficult, as demonstrated by the two existing crossings of the Tyne on the east side of Newcastle, both of which are already in tunnel. Therefore, a tunnelled crossing of the Tyne is very likely.

5.5.23 This route also crosses the A66 and the Darlington-Middlesbrough railway, so there is scope for a parkway station nearby.

5.5.24 In the Newcastle area, the station sites are constrained by the line being in tunnel beneath the Tyne for some distance either side of it. A surface station appears possible south of the tunnel with interchange to the Newcastle-Sunderland rail and Metro route, or north of the tunnel with interchange to the Metro line linking Newcastle with Whitley Bay. In both cases, access could be provided from nearby major highways.

Newcastle to Edinburgh

104 miles (167km)

5.5.25 The northern section of Route C would generally follow the existing East Coast Main Line and A189/A1 corridor past Alnmouth and Berwick. The terrain begins relatively flat, increasingly undulates towards Alnwick, and then becomes flatter again as it nears Berwick, where it would cross the River Tweed and a number of other watercourses and their floodplains on a viaduct.

5.5.26 North of Berwick, the route would pass through the edges of the Lammermuir Hills before heading westwards towards Edinburgh. Similarly to Route B, the route would connect to the East Coast Main Line and continue to Edinburgh Waverley on the existing line.

Sustainability considerations for Route C

5.5.27 This option runs closer to the coast than Route B. From Phase Two to Northallerton and north to Sunderland and Newcastle, the route passes through a largely rural landscape characterised by small settlements, but with some more built-up areas between Stockton-on-Tees and Darlington, and approaching the Newcastle conurbation.

5.5.28 Emerging from a tunnel under the Tyne, the route would cross built-up areas before continuing northwards to Dunbar and thereafter entering Edinburgh. En route to Dunbar and Berwick-upon-Tweed is Alnwick Castle Grade I Registered Park and Garden. Further work would be required to consider any indirect impact on this important feature.

5.5.29 From north of Newcastle to Edinburgh, the route would pass through a largely rural landscape characterised by small settlements.

5.5.30 Route C would make viaduct crossings of several rivers, including the Tweed SAC, the Coquet and the Whiteadder.

5.5.31 Further north are the Dunbar (I and II) and Pinkie battlefields. Historic Scotland has published an interim guidance note on Historic Battlefields (2011). This recognises the inevitability of a degree of change in designated battlefield areas that has to be accommodated through avoidance, mitigation and enhancement measures, which need to take place following engagement and the participation of key stakeholders and other interest groups as part of route selection and design.

5.5.32 Some stretches of Route C would cross groundwater Source Protection Zones. The next stage would need to consider in detail the potential impacts on potable groundwater through route selection and design to address these risks. For example, there is likely to be minimal impact if the proposed route is on embankment in comparison to cuttings or viaducts.

5.5.33 From a community perspective, the following was noted for a high speed route C:

- Property Type – Similar to Route B, the section from Northallerton to Newcastle has the highest numbers of residential properties given the close proximity to existing urban conurbations (Newcastle).
- Urban/Rural – More than half of the properties along the route are in rural areas. In particular, there are very few properties within urban areas for the section from Phase Two to Northallerton and from Newcastle to Edinburgh.
- Index of multiple deprivation distribution – The majority of the properties within the section from Phase Two to Northallerton are in the highest (least deprived) quintiles. Around half of this section affects properties within the lowest (most deprived) quintile.

Route cost and journey times for Route C

5.5.34 The cost of Route C is an estimated £28 billion - £30 billion, which excludes the cost of a high speed route between Edinburgh and Glasgow. Potential journey times to Edinburgh and Glasgow would be very similar to those for Route B as outlined above. Even though Route C is slightly longer, the flatter terrain means average speeds are higher, so journey times are similar.

Route D

5.5.35 Route D investigates a more direct route between Newcastle and Glasgow, rather than one with trains which would first have to pass through Edinburgh.

5.5.36 The most direct line from Newcastle to Glasgow would be in a north westerly direction; however, this route would have to cross through the Northumberland National Park. In order to avoid this, a route was developed which would follow Route B as far north as Wooler, then head west towards Glasgow with a branch heading north to Edinburgh.

5.5.37 From Wooler, the route would bear westwards and to the north of the Cheviot Hills, before crossing the Southern Uplands and splitting near Peebles. The western branch to Glasgow would follow a similar alignment as Route A from Carstairs and the eastern branch would head northwards towards Edinburgh

5.5.38 Despite aiming to follow valleys and run parallel to the lie of the hills, the route would require extensive lengths of deep cutting and deep embankment, and lengths of tunnel. It would also be longer than Routes B and C.

Sustainability considerations for Route D

5.5.39 Departing from Route B just north of Wooler, this route would pass through a largely rural landscape characterised by small settlements. The high ground of the Southern Uplands has a sparse population. Beyond the influence of the existing A72 corridor, it is a quiet and remote area.

5.5.40 A number of highly sensitive and nationally protected features would be encountered near Route D, such as Braehead Moss SCA and SSSI; Eildon and Leaderfoot NSA; and Upper Tweedale NSA.

5.5.41 Braehead Moss SAC is an area of raised peat bogs with marshes. The Eildon and Leaderfoot NSA, which is centred on the upper reaches of the River Tweed, is an area of landscape, historic and biological diversity. The Upper Tweedale NSA is characterised by diverse scenery with narrow and wooded valleys of the Upper Tweed and its tributaries passing through open hills. It is a quiet landscape with historical continuity of settlement. Any route options that are developed further would need to consider the impact on these features as part of route selection and design.

5.5.42 From a community perspective, for high speed Route D, focusing on sections from Newcastle to Edinburgh and Glasgow, the following is noted:

- Property type – the section from Newcastle to Glasgow has the highest concentration of residential properties, given the proximity to existing urban conurbations.
- Urban/rural – on the section from Newcastle to Glasgow, the majority of the properties along the route are within urban areas, whereas properties in sections from Newcastle to Edinburgh are mostly rural in character.
- Index of Multiple Deprivation distribution – There is a wider distribution of properties within the five quintiles along the route section from Newcastle to Glasgow. However, almost 70% of the properties are within the third quintile along the route section from Newcastle to Edinburgh.

Route cost and journey times for Route D

5.5.43 The cost of Route D is an estimated £41 billion - £43 billion, which excludes the cost of a high speed route between Edinburgh and Glasgow. Estimated journey times from London are as follows:

Table 8: Journey times for Route D from London

	Today	Phase Two	Route D
To Edinburgh	4:23*	3:39	2:50
To Glasgow	4:31**	3:38	2:45

*Typical journey time; one train per day leaves Edinburgh at 05:40am and achieves 4 hours to London.
**Typical journey time; one train per day leaves London at 16:30 and achieves 4 hours 8 minutes.

5.6 Journey time outcomes

5.6.1 High speed routes on the west would serve Glasgow and Edinburgh equally and could deliver a journey time in the order of 2 hours 30 minutes to both.

5.6.2 High speed routes on the east would approach Edinburgh from the east with a journey time of under 2 hours 30 minutes and could also serve Newcastle and other north-east markets. Trains could carry on to Glasgow from Edinburgh, the 45 mile (72km) journey would take a further 35 minutes if an Edinburgh to Glasgow high speed line were in place; otherwise, it would be 51 minutes assuming the Edinburgh-Glasgow Improvement Plan (EGIP) is in place. EGIP is due for completion in 2018.

5.6.3 Route D would head west toward Glasgow north of the border with a branch to Edinburgh. This route would be slower to Glasgow than the western Route A, but would be faster than Routes B and C to Glasgow. It would be about 20 minutes slower to Edinburgh than Route A, B and C. It would also be longer, pass through more undulating terrain, and would be significantly more costly than a route on the west side. Time includes an allowance for trains to stop and split at Edinburgh Waverley, on the basis that only 200m trains could be accommodated at Glasgow Central.

6 Summary of findings

6.1 Upgrades to the existing network

6.1.1 There are different constraint issues to be addressed on West Coast Main Line and East Coast Main Line. On the West Coast Main Line, the steep inclines on the existing line at Shap and Beattock are major constraints, while on East Coast Main Line the high volume of mixed traffic between York and Newcastle creates a complex interface with very limited potential for growth. The Wigan to Preston area of the West Coast Main Line is a similarly congested area with mixed-use traffic.

6.1.2 Solving all capacity issues is challenging, but in many cases, interventions can be designed to both reduce overall journey times and address current network constraints.

6.1.3 Upgrades entirely within the boundary of the existing lines would deliver limited journey time saving (less than 15 minutes) have high cost, and potentially impact capacity due to increased differential between faster and slower trains. Therefore a journey time of 3 hours or less can be achieved only with lengths of high speed bypass of the existing line.

6.1.4 HS2 Ltd's assessment shows that about 125 miles (200km) of new line comprising a number of bypasses would be required to achieve a 3-hour journey time. Though shorter than an end-to-end high speed line, the bypasses approach would still encounter similar sustainability and engineering challenges, and would cost in the order of an estimated £17-19 billion.

6.1.5 Upgrades using high speed bypasses have the advantage of addressing operational constraints on the existing line while at the same time creating the first in a series of incremental steps that would ultimately lead to significant improvement in journey times and capacity, and could even provide an end-to-end high speed route, thus making staging of a build possible. They would also bring improvement earlier than a full high speed route.

6.1.6 Maximising the overall benefit to the network is likely to result in higher cost than a primarily congestion-relieving interventions package, or journey time saving package. The increased cost would be balanced by the potential for overall improvements to the route in terms of capacity, speed and reliability. Many of these issues would have to be addressed and some level of investment would therefore be required in any case. This approach would enable maximum overall return for that investment.

6.2 Delivering a high speed route to Scotland

6.2.1 The route development work set out in Section 4 has demonstrated that there may be scope to deliver a 3-hour journey time to the North of England and Scotland whilst reducing cost by taking a more flexible approach to the design speed, so that the route can follow the local topography more closely. This is achieved by reducing the 400kph design speed in specific locations.

6.2.2 A journey time from London to Glasgow and Edinburgh of 3 hours or less would deliver a substantial saving over current journey times and would deliver significant benefits.

6.2.3 This high speed route in Section 4 would follow a similar alignment to the high speed Route A in Section 5 and would therefore encounter similar sustainability features, including Hadrian's

Wall World Heritage Site and a number of Areas of Outstanding Natural Beauty, and wildlife sites protected by European and national designations.

6.2.4 Delivering some elements of this route early would deliver benefits by relieving points of capacity constraint on the classic network. However, to achieve significant journey time benefits it would be necessary to deliver longer sections of this route.

6.3 Continuous high speed routes

6.3.1 HS2 Ltd has developed options for high speed routes, including options for the east and west sides of the country, to improve on the journey time of 3 hours 38 minutes and 3 hours 39 minutes from London to Glasgow and Edinburgh respectively, that would be achieved with Phase Two in place. A continuous high speed route from the north end of Phase Two to the edges of Edinburgh and Glasgow would comprise over 190 miles (300km) of new railway and would cost more than £27 billion. HS2 Ltd has assumed that these high speed routes would be designed to the same requirements as the proposed HS2 route, to deliver a design speed of 250 mph (400kph).

6.3.2 This approach could achieve a journey time in the order of 2 hours 30 minutes from London Euston, saving over an hour on the substantial improvement already made with Phase Two. Depending on route and intermediate station provision, it could offer similarly significant savings to journeys between Scotland, the North of England and other cities in the UK.

6.3.3 Options for routes on the west are heavily constrained by undulating landscape and the environmentally protected areas of the Lake District and the Yorkshire Dales National Park and AONB. Over much of this distance, the only feasible corridor is that already occupied by the West Coast Main Line and the M6. All routes would have to cross the Hadrian's Wall World Heritage Site. The route would have to pass through areas of particularly undulating terrain in Cumbria and again in the Southern Uplands north of Lockerbie, requiring significant lengths of deep cutting, embankment and tunnels to fit a high speed alignment through the hills.

6.3.4 Options for routes on the east are pushed towards the coast to serve the main markets of the North East, and to avoid undulating ground in the foothills of the Pennines and the protected areas defined by Northumberland National Park. A route would still have to negotiate undulating ground as it passes through the Lammermuir Hills to the north of Berwick. Routes would also encounter extensive areas of former mining activity.

6.3.5 High speed routes would be feasible, but there are a number of challenges that would have to be addressed at a further stage of development in terms of environmental mitigation and management of cost and risk.

6.4 Sustainability

6.4.1 HS2 Ltd's Sustainability Policy describes HS2 Ltd's commitment to developing "an exemplar project", and to "limit negative impacts through design, mitigation and by challenging industry standards, [while looking] for environmental enhancements and benefits". The policy embeds sustainability within the HS2 Ltd business and during each phase of the project.

6.4.2 HS2 Ltd has carried out a high-level appraisal of potential sustainability impacts, building upon work completed on both Phase One and Phase Two proposals through the Appraisal of

Sustainability (AoS) process, although this study addresses an earlier stage of development. This desktop study has been designed to take account of sensitive and high-priority areas in Scotland as well as England.

6.4.3 The appraisal has looked at potential impacts on the natural and historic environment and communities of potential route options. Whilst no work has been done on mitigation, an allowance for mitigation on environmental features has been included within the cost baseline. The work also identified strategic development sites which may be of significance in route selection.

6.4.4 On both west and east the potential options (both high speed and interventions) must take account of extensive areas of highly protected natural and historic environmental designations, including national parks, AONBs, NSAs, Ramsar sites, SPAs, SACs, Hadrian's Wall World Heritage Site, and historic battlefields. Other extensive environmental constraints include SSSIs, floodplains, peat, and river crossings. Any future option(s) would also need to take account of localised features, including ancient woodlands, habitats of protected species, scheduled monuments and other features of cultural heritage importance such as registered parks and gardens, gardens and designed landscapes, and listed buildings.

6.4.5 In developing route options, the mitigation hierarchy would need to be carefully applied and balanced against all the other considerations faced in route development (e.g. engineering, cost and benefits). With further refinement it may be possible to avoid and mitigate the most significant impacts on these natural and historic environmental features, but the more extensive designations would provide the greatest challenge. Further design and appraisal would be required to understand the risks further, including HRA screening, and where necessary, appropriate assessment to comply with the Conservation of Habitats and Species Regulations.

6.4.6 The highest densities of population and most significant community effects of the high speed and upgrade options would be concentrated in the conurbations of Newcastle, Glasgow and Edinburgh. Other significant effects are likely in passing larger settlements, including Wigan, Preston, Carlisle, York, Darlington, Stockton-on-Tees and Sunderland. The countryside between the conurbations and other larger settlements is characterised by less populated open and quiet countryside. Some route options also pass through sparsely populated, remote and quiet upland areas in the Forest of Bowland, the Southern Uplands and the Lammermuir Hills.

6.4.7 From the sole perspective of protecting natural and historic environmental features and communities, the interventions to the existing network might afford more flexibility in avoiding impacts on extensive features, partly due to their shorter length and the ability to select more favourable alternatives.

6.5 Serving key markets

6.5.1 There is no single route that will equally serve all of the major destinations in Scotland and the north of England. Options on the west serve Edinburgh and Glasgow equally well, while options on the east serve Edinburgh and the North East well.

6.5.2 York and Newcastle are key markets for a route in the east. In the York area, there is a balance to be struck between serving York via a parkway station and the journey times savings that could be made by avoiding a slower route required to serve a city station.

6.5.3 Preston is a key market for a route in the west. The initial assessment suggests that it is better served by a central station, where passengers could interchange for connectivity to the wider region, than by a parkway station on a fast route around Preston.

6.5.4 Further assessment would be required to determine the best solution for serving each location.

6.6 Demand appraisal outcomes

6.6.1 The incremental benefits, beyond those of the proposed HS2 network, of delivering 3-hour London to Scotland high speed services are expected to be around £3 billion in present value (PV) over the appraisal period. The incremental increase in revenue is also estimated to be around £3 billion (PV). Wider economic impacts could add around a further £1 billion (PV) of benefits.

6.6.2 Delivering London to Scotland services in the west in 2 hours 30 minutes and calling at Preston central station is estimated to generate in the order of £5 billion (PV) in benefits and £5 billion (PV) in revenues. Wider economic impacts would add further to these benefits.

6.6.3 For enhancements to the East Coast Main Line or West Coast Main Line, there is generally a higher value associated with improvement in journey times on the southernmost sections leading on from Phase Two connection points. In particular, saving time on the section from York to Newcastle yields the most positive benefit and revenue impacts.

6.6.4 The results presented are based on journey time improvements using illustrative train service specifications. At this stage, service patterns have not been optimised. If options also increased capacity for classic line passenger services or freight trains, these could generate further benefits. Any benefits associated with improvements in service reliability or network resilience have not been captured at this early stage.

6.6.5 Benefits are presented in market prices and as a present value over a 60-year appraisal period. These are not directly comparable units to the construction costs presented, which are undiscounted costs. In considering value for money, it would also be necessary to consider other costs, including changes in operating costs, rolling stock costs and infrastructure renewal costs over the appraisal period.

Appendix A – Methodology

This appendix explains the approach adopted in the development and appraisal of the broad options, and the key assumptions made. These reflect the overall principle that this study follows similar assumptions and specifications to those used to date on Phase One and Phase Two.

Range of options considered

The broad options considered in this study included two distinct ways for delivering improved rail travel to and from the North of England and Scotland: high speed route options, and upgrades to the existing network. Options on the east and west of the country were considered.

Continuous high speed routes

Options were investigated for providing a continuous high speed route from the north of the Phase Two route to Edinburgh and Glasgow. This would be constructed as a single continuous route, with some potential connections to the existing network, and would comprise an alignment designed to HS2 Ltd's high speed railway standards.

Upgrade of the West Coast Main Line and the East Coast Main Line

This included:

- investigating what interventions could be made to the existing network to improve journey times to towns and cities on the route, including a 3-hour journey time from London to Edinburgh and London to Glasgow;
- considering options that looked at how interventions could address capacity constraints on the network and improve connectivity between towns and cities in the region served;
- considering a range of options including upgrades within the footprint of the existing line, and lengths of bypass of the existing line designed to high speed standards; and
- considering options for a sequence of interventions that would deliver incremental improvement and would ultimately achieve the target journey time of 3 hours.

High-level assumptions

A set of assumptions were required to define an agreed basis on which to progress the study. These were agreed from the outset with involvement from the steering group. The assumptions are intended for the purposes of this high-level broad options study only, and during subsequent stages they would be revisited and revised as appropriate. The key assumptions are the following:

1. The base case for this study assumes that Phase Two will be as outlined in the July 2013 consultation. Any potential changes to the scheme in response to consultation are not taken account of here, at this stage.
2. Improvement works on the existing lines that are currently being planned by Network Rail have been assumed to happen and have been incorporated into HS2 Ltd's base case.

3. The interface between the Edinburgh and Glasgow city areas was not examined in detail at this stage, on the basis that rail connections to the city centres had already been developed to a similar stage during the work carried out by Transport Scotland on a high speed link between Carstairs, Edinburgh and Glasgow. Transport Scotland has shared the current outcomes of this work with the working group and this has been taken into account as part of this study. The routes HS2 Ltd developed therefore aimed to connect to route options prepared by Transport Scotland for the Edinburgh and Glasgow area. In cost estimates, HS2 Ltd has included only the costs for the parts of the Carstairs, Edinburgh and Glasgow high speed link that would be used by north-south trains in the option to which the estimate relates.

4. High speed routes are designed to HS2 Ltd's design standards, similar to those developed for Phase One and Phase Two, insofar as is appropriate for this earlier stage of development.

5. Bypasses of the existing railway are also designed to HS2 high speed standards, where practicable. This could deliver a future-proof alignment that might ultimately be linked to other adjacent bypasses to form a continuous high speed line.

6. High speed options have been assessed for speeds up to 250mph (400kph), though in line with Phase One and Phase Two on opening, a maximum train speed of 225mph (360kph) would be assumed. It should be noted that achieving maximum speed requires relatively long distances of high speed track, so speeds on some of the shorter bypass sections would be lower.

7. HS2 trains operating on the route north of Phase Two would be classic-compatible. This is necessary even for continuous high speed routes, as they are developed on the basis of running on the existing conventional lines during the last few miles into Edinburgh and Glasgow stations, as per the Transport Scotland proposal. It would also avoid having to provide dedicated high speed platforms compatible with GC gauge standard at all existing stations served by the routes, which could not then be used by conventional trains. For all upgrade options, classic-compatible trains would also be necessary for running on the existing conventional infrastructure.

8. It is assumed that the train service specification used for this study would be essentially based on the Phase Two train service specification. For trains serving Scotland by the east coast (which is not part of the Phase Two proposition), a service specification has been developed that is comparable with the level of service provided via West Coast Main Line in the Phase Two proposition. Given that the train specification is similar, it is assumed that no new rolling stock costs would be incurred.

9. All trains from London to Scotland are assumed to be 400m long and will have up to 1,100 seats, comprising coupled pairs of 200m long trains with 550 seats each. Splitting of trains is assumed for services on the West Coast Main Line, with trains dividing to serve Glasgow and Edinburgh. For services on the East Coast Main Line, the issues for splitting are different and are covered in more detail in the relevant sections.

10. A number of detailed assumptions were also made which were specific to upgrades to the existing network – these are described in the section further below.

Appraisal criteria for route options

The appraisal criteria for assessing potential options included consideration of a range of factors, including:

- main markets – the ability of options to serve the main markets within the study area;
- engineering feasibility and complexity – the impact of terrain, floodplains, poor ground conditions and other factors on the options for high speed alignments. For example, undulating terrain could add cost and engineering complexity to an alignment design;
- impact on settlements – with the aim of avoiding impact on populations, while at the same time providing stations in locations that are easily accessible;
- sustainability considerations – with the aim of developing the route in a way that seeks to avoid potential impacts on communities and the natural and historic environment, as far as is practicable; and
- cost and risk – the development of a high-level cost for each option and an understanding of the main risks to that cost, e.g. areas of difficult ground or environmental sensitivity that are likely to require mitigation that could increase cost or construction time.

Identifying high speed alignments

Potential high speed routes were assessed in stages, with increasing levels of assessment and review at each stage. The approach to developing the routes progressively comprised:

Stage 1 – Inspection of terrain models and Ordnance Survey mapping to identify areas that would influence the broad options available for a high speed route, with the aim of avoiding areas of the most undulating terrain and areas of population. Extensive areas of sustainability features were also identified at this stage. These revealed a series of broad areas and pinch points.

Stage 2 – Approximate lines were then drawn to investigate if these individual areas could be connected to form potential high speed corridors.

Stage 3 – Following identification of potentially viable corridors, an initial horizontal alignment geometry was applied to demonstrate high-level feasibility for a high speed route. An initial appraisal of sustainability impacts was carried out at this stage.

Stage 4.1 – The next stage of the broad options study selected the more feasible routes in terms of the appraisal criteria mentioned above.

Stage 4.2 – A vertical alignment design was developed for the more viable routes, which enabled key features such as cuttings, embankment, tunnels and viaducts to be identified, and an estimate of lengths of each to be used in the cost model.

Stage 4.3 – A high-level sustainability appraisal of the potential alignments of the routes was carried out and adjustments made as appropriate.

Stage 4.4 – The vertical alignment also provided data that enabled indicative gradient profiles and length to be applied to the journey time model.

It became clear at each stage that a number of combinations of options and subsections of routes were possible. For example, a route to the west of Newcastle could be combined with a route that followed either a coastal or an inland route north of Newcastle, with similar choices for the section of route that would connect to it from the south. This range of options would equally apply to a route that ran to the east of Newcastle. If all combinations had been considered, this would have generated a high number of end-to-end options which would have led to a level of complexity that was unnecessary for a broad options study such as this. Therefore, a sample of combinations was selected at each stage, to be taken forward in order to illustrate the overall feasibility, cost, journey times and impacts of an end-to-end route.

Identifying options for upgrading the existing line

The methodology for identifying options for upgrading the existing network varied from that developed for high speed routes. The starting point was to assemble an understanding of how the existing network performed and identify those parts that are, or will be, constraints to capacity and journey time. Interventions were then developed to address these constraints and work towards achieving the overall strategic aims for serving Scotland and the North of England. Once potential interventions had been identified, they were then appraised using largely similar principles to those of high speed routes.

Over 250 separate interventions were considered, ranging in complexity from local interventions such as upgrade of pointwork, through realignment of an existing curve within the current footprint of the railway, to substantial lengths of new bypass line.

Process for identifying and assessing options

The main stages of the overall methodology to identify and assess upgrade options were as follows:

1. Sections were identified on the existing East Coast Main Line and West Coast Main Line that currently constrain speed and capacity. This desktop study examined existing permitted speed along the length of the line using published line speed profiles data. It then looked at line geometry along the line and plotted the maximum speed compatible with the curvature of the track. This enabled a comparison between possible and permitted speed (including enhanced permissible speed where appropriate);

2. Workshops were held with Network Rail to review constraint points, in order to confirm the reasons behind the constraint and identify potential solutions. The range of interventions considered both upgrades within the existing boundary and bypasses;

3. Each possible intervention was then assessed by carrying out a high-level design to establish feasibility, relative cost, potential journey time saving, key sustainability impacts, and the wider benefits to network capacity, passenger connectivity, potential for freight and potential to achieve a longer-term strategy;

4. Packages of options could then be assembled by combining a number of interventions until a target to achieve a particular objective was met, such as a 3-hour journey time;
5. A capacity assessment was undertaken by modelling the assumed train service specification against the particular package of interventions to identify the performance in terms of capacity to carry the assumed train service on each section of the route, and any adjustments made as necessary;
6. HS2 Ltd then reviewed the outcomes with Network Rail and refined the package content as necessary;
7. How the package could be built through a series of incremental stages was also investigated. There are several ways in which a package could be phased – for example, the initial phases could aim to address the main constraint points, with a lower priority given to packages that purely reduced journey time.

Assumptions specific to upgrade options

The main assumptions applied when developing options were as follows:

- Bypass sections were designed to high speed standards and a 250mph (400kph) alignment was applied where practicable. This would deliver a future-proof alignment that could be linked to adjacent bypasses, and ultimately to form a continuous high speed line.
- For upgrade options within the footprint of the existing line, 140mph (225kph) was used as the maximum potential speed. Railway Group Standards for the UK do not cover speeds faster than this for running on conventional railway alignments, and a considerable study would be necessary to assess the implications of higher speed on the current railway. European high speed standards do cover faster speeds, but this is for a set of circumstances different from those prevailing in the UK. There is a risk that running at speeds above 140mph (225kph) would require significant changes to the existing infrastructure, including increased separation between tracks, a need to widen the track formation and the consequent extensive civil engineering works to widen earthworks, bridges, etc. Therefore, it was deemed not to be economic at this stage. For these reasons, speeds have been limited to 140mph (225kph) for the purposes of this study.
- Where line speed was increased above the current maximum speed of 125mph (200kph), it was considered that some improvement would still be required due to the impacts of the higher speed, such as complete upgrade of the overhead line to ensure the wires and supports would be able to accommodate the forces arising from the higher speed.
- The cost of bypass options was estimated on the same basis as high speed routes, whereas the cost of on-line options was based on input from Network Rail to develop special rates built up by HS2 Ltd.

Packaging of options

Interventions could be combined in a number of ways to form an overall upgrade for a section of line. The final package would represent a significant investment in the railway, with its overall structure being agreed with stakeholders. For the purposes of this study, the range of options developed are based around the following scenarios:

- a package with all interventions within the boundary of the existing railway;
- a package to find the lowest-cost combination of options to achieve a 3-hour journey time, based on an assessment of the cost per minute of time saved;
- a package that gave priority to addressing particular congestion areas in combination with achieving a 3-hour journey time; and
- a package that included an option which was desirable for a particular reason (e.g. if it would form part of an Edinburgh-Glasgow high speed link).

A 3-hour journey time between London and Glasgow via the East Coast Main Line would be possible, but it would require high speed infrastructure over the whole distance between Phase Two and Edinburgh, and also between Edinburgh and Glasgow. It would provide a journey time of under 2 hours 30 minutes to Edinburgh and around 3 hours to Glasgow. A package of interventions similar to that outlined above for the West Coast could achieve the 3-hour journey time objective, but only between Edinburgh and London. Trains could carry on to Glasgow via Edinburgh with a 3 hours 35 minutes journey time if a high speed line between Edinburgh and Glasgow were in place, otherwise it would be 3 hours 51 minutes, assuming the current Edinburgh to Glasgow Improvement Plan (EGIP) is in place. This would be longer than the 3 hours 38 minute journey time between London and Glasgow as provided by HS2 Phase Two and the West Coast Main Line.

Freight traffic

Improvement to freight paths was specified in the remit for this study. It has been included as an integrated part of the study, rather than separating it out into a specific section. When improvements in capacity were being assessed, it included capacity for both freight and passengers services. In developing this work, Network Rail provided input on current paths and future growth to inform the development of improvements for freight. Freight has been included in the Train Service Specification model.

Usually travelling at lower speeds than passenger trains, it is likely that freight would benefit most from capacity created on the existing lines when passenger services move onto an adjacent high speed line, or bypass section. Bypasses would also enable passenger trains to overtake freight trains and reduce the need for trains to stop and wait in static loops to make way for passenger trains. This would improve journey time for freight in addition to the extra capacity created.

Estimating cost and approach to risk

This section outlines the approach and the methodology adopted for estimating the cost of both the continuous high speed routes and the upgrades of the existing network, including the related high speed bypasses.

The estimate for each route option has been developed using two methods:

- The cost estimates for the continuous high speed route options is based on a series of composite rates for each principal asset type, derived from the appropriate rates and allowances used on other similar schemes.

- The cost estimate for each of the options for upgrades of the existing network are broadly based on a series of principles that have been developed in collaboration with Network Rail. These were presented to an assurance panel comprising Network Rail and HS2 Ltd, and were subsequently reviewed and endorsed by Faithfull & Gould, for use in similar situations where there is a significant amount of intervention with the existing network.

The approach reflects the level of design information that has been produced for each of these routes and the available information, which comprises a series of large-scale route alignment drawings and a schedule of quantities of key asset types that make up each route to which the composite rates are applied. The key asset types considered at this stage were embankment, cutting, at-grade, viaduct, cut-and-cover tunnel and bored tunnel, distinguishing between urban or rural situations.

Within the estimate for each route option, allowances have been made for:

- contractors' preliminaries, other on-cost, overheads and profit and design;
- design, project management and other indirect costs;
- provision for environmental mitigation; and
- an allowance for land and property which is based on cost per kilometre, derived from the allowances calculated by CBRE for similar programmes.

The base date for the cost estimate has remained at Q2 2011, which is consistent with the approach used elsewhere on the HS2 programme during the development of this project.

Optimism bias

There is a demonstrated, systematic tendency for projects to be overly optimistic in the calculation of early estimates, particularly that they under-estimate timescales and costs of a project. The application of optimism bias ('OB') is used to counter this.

The existing supplementary Green Book guidance[8] on OB suggests that the "upper bound" on optimism represents a starting point, and the contributory factors that may affect the OB levels are assessed in terms of whether they can be mitigated.

As referred to above, these routes are at an early stage of development and accordingly the estimates contain an appropriate level of contingency, which represents the degree of uncertainty.

Exclusions

A number of areas are not within the scope of the current cost estimates, and are summarised below:

- inflation beyond Q2 2011;
- VAT and stamp duty land tax;

[8] https://www.gov.uk/government/publications/green-book-supplementary-guidance-transport

- costs of the proposed Edinburgh-Glasgow high speed link options, except where used by north-south trains on west side high speed routes or WCML upgrade options;
- costs may arise for the works at Edinburgh Waverley, Glasgow Central and the approaches to these stations;
- stabling in addition to that already provided for within Phase Two;
- work to major terminus stations;
- operating and renewals costs;
- rolling stock;
- costs that may be recovered from any third parties, including developers; and
- improvements to the existing network for which funding has been authorised, or is expected to be in the next control period, or would happen in the normal course of railway renewals.

Appraisal of costs

As this study is at an early stage and this report is not seeking to assess value for money, the cost estimation has been to inform the study on the magnitude of construction costs, which are the largest overall cost. The costs presented are not the full cost that would be used for appraisal purposes and the costs presented are un-discounted. While a construction profile has not been developed at this early stage, the value of construction costs would be lower if presented as a present value, given the investment would be taking place some years into the future. For appraisal of costs, it would also be necessary to consider other costs (such as those outlined in exclusions above) over the appraisal period – for example, including any incremental operational or rolling stock purchase costs.

Approach to sustainability (environment and community)

HS2 Ltd's Sustainability Policy describes HS2 Ltd's commitment to develop "an exemplar project", and to "limit negative impacts through design, mitigation and by challenging industry standards, [while looking] for environmental enhancements and benefits". The policy embeds sustainability within the HS2 business and during each phase of the project.

In line with the Sustainability Policy, both Phase One and Phase Two proposals reported on their sustainability performance through the Appraisal of Sustainability (AoS) process. While at an earlier stage, the high-level sustainability approach undertaken for this options study has been broadly based on the AoS principles and provides a systematic review of options being considered. It has been designed to take account of sensitive and high-priority areas in Scotland as well as England.

For these early options, a desktop appraisal has been undertaken using existing data and mapping information to form a baseline assessment. Information was obtained from appropriate data sources providing comprehensive coverage.

A number of different designations were drawn upon in carrying out the appraisal of the options as shown in Figure 2.

- Wildlife sites protected by International or European designations (Ramsar sites, Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)). Any routes taken forward would need to comply with the requirements of the Conservations of Habitats and Species Regulations 2010 (in England) and the Conservation (Natural Habitats, &c.) Regulations 1994 as amended (in Scotland). These regulations require a Habitats Regulations Assessment (HRA) screening and development proposals and, where necessary, appropriate assessment. The HRA is a step-by-step process that ensures that all feasible alternatives have been considered, or alternatively that the development can take place due to Imperative Reasons of Overriding Public Interest, provided that adequate mitigation and compensatory measures are in place.

- Wildlife sites protected by UK designation (Sites of Special Scientific Interest (SSSI)). Impacts on these sites would have to be avoided in the first instance. Where an adverse effect on one of these sites is unavoidable, there would be a requirement for adequate mitigation and/or compensation, provided it is in the overriding public interest.

- Heritage sites of international importance (World Heritage Sites). These are described as sites, places, monuments or buildings of "outstanding universal value" and their protection is the responsibility of national governments. This is reflected in UK Government legislation and planning policy which includes heritage assets of national importance – for example, listed buildings, scheduled monuments, registered parks and gardens, gardens and designed landscapes, and historic battlefields. Guidance states that planning permission for developments that are likely to have an adverse effect on heritage assets should be granted only once an assessment has shown that the significance of the site would not be adversely affected. Where an adverse effect is unavoidable, there would be a requirement for adequate mitigation, including investigation and recording.

- Areas protected by UK designations for landscape and countryside access are Areas of Outstanding Natural Beauty (AONBs) (England), National Scenic Areas (NSAs) (Scotland) and national parks. These areas are protected to preserve their landscape and heritage value and to conserve them as places where people can enjoy the countryside as outlined within NPPF and Scottish Planning Policy (SPP) (Scottish Government, 2014). Impacts on these aspects of the sites would have to be avoided. Alternatively, the development can take place only in the case of overriding public interest, and proposals must be made to mitigate any potential adverse effects.

Although not shown in Figure 2, other features (such as listed buildings and scheduled monuments) occur at locations which do not extend over large areas, and the further selection and refinement of route options would potentially provide an opportunity to avoid significant effects on these.

There are also a number of non-statutory, locally listed designations, information on which is held by a number of sources, notably the Wildlife Trusts and local data sources. This has not been considered as part of this study. Any potential impact on these locally designated sites will be addressed as part of further work.

Other environmental features

In addition to the high-level environmental features, which extend over large areas (refer to Figure 2), the sustainability analysis has also considered a wide range of other features (not shown on Figure 2) such as ancient woodlands, flood zones, Source Protection Zones and areas of peat and landfill. This responds to lessons learned from the work undertaken on Phases One and Two.

Floodplains

The route options have the potential to increase flood risk where they cross floodplains, by obstructing flood flows and reducing flood storage capacity. This potentially affects the severity and frequency of flooding on adjacent land and property.

Therefore, flood risk to, and as a result of, the high speed routes and interventions to the existing network is a key consideration where there are long crossings of floodplains, as mitigation of increased flood risks can be difficult due to the additional land take required for floodplain compensation mitigation, where properties are close to the route.

This is particularly the case in urban areas where there may be properties close to the route alignment which restrict mitigation options. Where routes would pass through coastal floodplain areas, further work would be required to understand the level of risk to the railway from the sea and to avoid potentially costly long-term maintenance. However, design of new alignments and bypasses has included provision of viaducts where coastal or river floodplains are crossed.

Flood risk to the existing network is a key consideration where upgrades are being considered. The existing rail infrastructure has generally been constructed to a lower standard of protection than that required for HS2. Therefore, existing rail infrastructure is likely to be more prone to flooding. Disruption to services could be expected in the event of floods that would otherwise not affect the planned HS2 network. This also means a higher maintenance cost for these more flood-prone sections of track. A combination of potential route options and upgrades would mean that although the bypass options would be resilient to flooding, the non-bypassed sections would not, and the overall risk of potential flooding in the future would still exist.

The design of these crossings and the construction methods used are therefore key design considerations in complying with national planning standards for England and Scotland with respect to flood risk.

Sections 4 and 5 outline areas of flood risk that would need consideration as part of future design and development because they are either within existing urban areas or require extensive mitigation measures.

National protection of water resources – Source Protection Zones

These are areas which have been designated to protect ground water, particularly aquifers, that support large abstractions for potable (drinkable) water supply. It should be noted that the Source Protection Zones are only defined for England, so no assessment could be made for Scotland. Further work on route selection and design would need to be undertaken with a view to reducing impacts to a practicable minimum. Chapters 4 and 5 outlines particular areas of Source Protection Zone where further work may be required to understand the impact of the routes on groundwater flows and quality.

Ancient woodland

Ancient woodlands are irreplaceable habitats and are important for their ecological and cultural significance. The need to avoid the loss of ancient woodland due to development is set out in government policy, including National Planning Policy Framework and Scottish Planning Policy. Many ancient woodlands are also protected as:

- Sites of Special Scientific Interest;
- sites listed on the Ancient Woodland Inventory as ancient woodland are also Habitats of Principal Importance (HPIs); and
- potential for ancient woodland as habitat for protected species.

The avoidance of effects on ancient woodland is therefore an important objective because of its ecological and cultural importance, especially because of the special nature of ancient woodland and the challenges in mitigating any impacts on them or providing suitable compensatory measures.

Chapters 4 and 5 reference when proposed route options would cross (or pass near) ancient woodlands. However, the quality and character of the ancient woodlands have not been considered as part of this early options study.

Therefore, the potential impact on ancient woodland would need to be addressed as part of further work, ensuring that any unavoidable loss is reduced as far as is reasonably practicable. It would also be necessary to ensure that any legislative requirements afforded to designated sites, such as Site of Special Scientific Interest status or protected species, can be met.

Peat

Areas of peat provide particular engineering and environmental challenges (e.g. in terms of construction in areas of deep peat) and the potential to cause damage to habitats and release of stored carbon. In addition to ground stability considerations, under the National Planning Policy Framework, there is an ecological requirement to consider whether displaced peat supports "irreplaceable habitats" such SACs and SSSIs. The Scottish Environment Protection Agency's concerns for peat are reflected in published guidance on the conservation of peat displaced by development[9] and in the SPP (Scottish Government, 2014). The implications of displaced peat for carbon dioxide emissions and climate change should also be considered as part of further design and development work.

Landfill

Areas of active or closed landfill are particularly challenging in terms of construction, and the associated risk of pollution from disturbing landfill material and the implications of having to relocate landfilled waste elsewhere.

Communities

In addition to the natural and historic environment, the protection of communities is a key consideration in route assessment. The route options have the potential to have a direct impact on rural and urban communities and to change their character and setting. The impact of change on communities may differ depending on their socio-economic classification.

This feasibility study has considered the potential impact on communities, including:

- the number of properties affected on either side of the potential route option,

[9] Developments on Peatland: Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste, 2012

including commercial and retail, residential, community and manufacturing and industrial[10];

- a rural/urban classification determining the nature of settlements affected[11]; and
- an index of multiple deprivation, focusing on the highest and lowest deprivation quintiles.

Potential effects of route options on communities have been determined for direct effects (e.g. land take) and for indirect effects (e.g. amenity impacts).

In England, each Lower Super Output Area (LSOA) is assigned one of five quintiles in the Index of Multiple Deprivation (IMD 2010)[12]; where the first quintile represents the most deprived 20% of areas in England. The quintile for each LSOA thereafter for each proposed route option has been identified, and the proportion of LSOAs which fall within each quintile calculated.

For Scotland, the Scottish Index of Multiple Deprivation (SIMD, 2012)[13] was employed, with data collected for data zones (based on Census Output Areas).

Currently, upgrade options are within the existing footprint, which is likely to have a range of potential impacts on community receptors, including noise. Should the footprint of the upgrade extend beyond the existing railway, then further details work would have to be carried out to assess impacts both within and outside the footprint of the existing railway.

Properties in proximity to the proposed route option have all been assigned to an LSOA or data zone and its associated index of deprivation quintile. This enabled the calculation of the number and proportion of properties (by type) falling within each SIMD/IMD quintile that may be directly or indirectly impacted by each route option.

The index of deprivation is used as a preliminary appraisal for an Equality Impact Assessment (EqIA), which is more appropriately carried out at a more detailed level. Severance and isolation effects would also have to be considered at a more detailed level of investigation.

This initial appraisal does not include any assumed mitigation and should be seen as indicative of the risk of community impact, rather than any measure of the likely final figures which would be derived at a later stage of design and appraisal.

Potential impacts on environmental features and communities have been used to appraise the sustainability performance of the route options, both in terms of potential legal and stakeholder issues. Whilst no work has been done on mitigation, an allowance for mitigation on environmental features has been included within the cost baseline.

[10] property types as set out within Phase One and Phase Two AoS
[11] Urban areas are defined as population centres with more than 10,000 people. In Scotland, these are described as large urban areas, and other urban areas; in England, they are described as major and minor conurbations, and cities and towns including fringe areas. Rural areas are defined as population centres with less than 10,000 people. In Scotland, they are described as small towns and rural areas; in England, they are described as towns and fringe areas, villages and hamlets and isolated dwellings.
[12] Department for Communities and Local Government, 2010
[13] Scottish Government, 2012

Bypass and upgrade sections

In relation to possible interventions on the existing network (i.e. bypass and upgrade sections) and improvements to the existing West Coast Main Line and East Coast Main Line, these have been appraised in a similar way to the high speed options as described above, where possible.

Conclusion

All of these potential impacts on communities, on natural sites and features, and on historic sites and features, would need to be appraised further through a continued process similar to HS2 Ltd's AoS process (i.e. through route selection and design to preferably avoid and otherwise reduce and mitigate any impacts). For proposed options where the route uses sections of the conventional network, it is suggested that further work would be needed to understand the resilience of that network to future weather taking into account climate change. It should identify how any new line could ensure any weaknesses are addressed, both to ensure the high speed network's reliability and potentially to improve the resilience of the conventional network.

Strategic development sites

A high-level desktop study was undertaken to understand the planning context for strategic growth in Scotland and the North of England, to begin to identify potential interactions with other proposed strategic development.

In Scotland, the National Planning Framework (NPF) sets out the Government's plans for development and infrastructure investment. Strategic Development Plans (SDPs) set out the long-term vision for the development of the four largest city regions. A review of the NPF and the SDPs for the Edinburgh and Glasgow City Regions was carried out to identify designated National Developments, Enterprise Area strategic sites and regional strategic development areas located within these corridors.

In England, Local Enterprise Partnerships (LEPs), comprised of local authorities and businesses, help to direct economic growth and decide priorities for investment in infrastructure, buildings and facilities at a strategic level. LEP Enterprise Zones (Government-backed sites established to promote growth across key industries and encourage local development) within North of England and Scotland corridors were identified and a high-level review was undertaken of LEP Growth Plans, Strategic Economic Plans and the Government Growth Deals and City Deals that have been agreed with the LEP areas to establish their identified growth priorities and strategic sites.

Both Preston and Newcastle are focal points for Growth Deals with the Government. The Lancashire LEP and North East LEP are each seeking to improve transport connectivity, support future development in strategic locations in and around the city centres, and maximise the local advantage of national infrastructure initiatives, including HS2.

The £1.2 billion Glasgow and Clyde Valley City Deal with the UK and Scottish Governments, the latest in a series of City Deal agreements, sets out to boost economic growth in the Glasgow region through initiatives including the flagship Infrastructure Fund to improve transport and redevelop sites. Further work would be required to ensure comparable sites are comprehensively captured and to understand any potential positive or negative impacts that the proposed routes could have on such areas.

Approach to estimating journey time

The approach adopted for estimating journey times for high speed routes and upgrades of the existing lines follows the same overall principles that were used for Phase One and Phase Two.

Journey times are estimated in a model that takes account of route length and changes in gradient, and also the capability of an assumed HS2 train set. For this study the 'ARTEM' model developed by HS2 Ltd's engineering consultants AECOM was used. This model has also been used on Phase Two and results have been verified against other models used to develop HS2 timetables and provide journey times for publication.

In common with Phase Two, journey times were developed assuming the maximum train performance. The calculated time was then adjusted to reflect uncertainties in timing, possible use of lower performance to reduce energy usage, and the need to allow extra time for recovery from minor delays. The uplifts adopted were 5% for running on continuous high speed infrastructure and 7.5% for running on Network Rail infrastructure or high speed bypasses. Network Rail mandatory allowances for recovery from engineering delays were additionally added according to the current planning rules for existing infrastructure.

Particular considerations for upgrade options

The methodology for assessing and packaging route upgrades required a working estimate to be made of the journey time saving achievable from each intervention. The journey time saving for each option was estimated taking into account speed before and after each intervention. Journey time was also reassessed and adjusted when options were being considered in combination with adjacent options to reflect the potential to achieve higher speeds over the longer distance.

After discussions with Network Rail it was assumed, at this stage, that both the East Coast Main Line and West Coast Main Line would require power supply upgrades to run more, or longer, trains before any significant investment in North of England to Scotland infrastructure. Journey time estimates therefore did not reduce performance to allow for the traction current limitations that were assumed on Network Rail when developing Phase Two timetables.

Approach to assessing demand and benefits

The initial demand, transport user benefit and revenue impacts of improvements in journey time have been estimated using the PLANET Framework Model (PFM)[14]. The version of PFM used for this analysis represents the same set of economic assumptions and forecasts as used for the Economic Case for HS2 (October 2013). However, the model has been refined to better reflect HS2's understanding of the rail network and improve the modelling process.

The demand analysis presented in this report is based on illustrative train service specifications that provide journey time improvements in the North of England or Scotland. The service specifications for improved services used have not been optimised, but rather reflect illustrative scenarios to inform the discussion of broad options for delivering journey time improvements.

[14] For background information on PFM please refer to the PLANET Framework Model Description Report published alongside the Economic Case for HS2, October 2013 http://hs2.org.uk/news-resources/economic-documents

The findings of these tests have been compared to a reference case that is based on the HS2 network as set out in the July 2013 Phase Two consultation and the train service specification used for Phase Two in the Economic Case for HS2 (October 2013)[15]. More detailed analysis of intermediate stations for a service via the East and enhancements on sections of the East Coast Main Line have also been compared to an illustrative alternative reference case where HS2 services to Scotland use the East Coast Main Line with classic line speeds beyond HS2's connection points.

The benefit and revenue appraisal has been carried out for 60 years following the introduction of the improved journey times in the North of England and Scotland. For modelling purposes only, the improvements are assumed to be introduced in 2037. The benefit and revenue findings reported are in 2011 prices and are present values over the full appraisal period.

Wider economic impacts have been estimated using DfT's Wider Impacts in Transport Appraisal software[16]. Initial investigations into freight benefits are based on the marginal external cost approach highlighted in TAG Unit A5-3[17].

PFM does not model intra-Scotland travel. Therefore, the benefits of any journey time improvements between Scottish markets are not captured in this analysis; nor are they captured in the wider economic impact analysis, since this depends upon results from PFM.

Given the early stage in options considerations, released capacity implications have not yet been analysed. Rather, the analysis is based on the same classic line train service specification as used for Phase Two in the Economic Case for HS2 (October 2013)[18]. Reliability assumptions also remain as in the Phase Two appraisal.

[15] For more details see page 72 of the Economic Case for HS2 (October 2013) http://www.hs2.org.uk/news-resources/economic-documents
[16] For more information on wider economic impacts see TAG Unit A2-1 https://www.gov.uk/transport-analysis-guidance-webtag
[17] Rail Appraisal TAG Unit A5-3 https://www.gov.uk/transport-analysis-guidance-webtag. Accessed in April 2014.
[18] Released capacity assumptions used in the Economic Case for HS2, October 2013 are set out in the PFMv4.3 Assumptions Report published at http://www.hs2.org.uk/news-resources/economic-documents

Appendix B – Glossary of terms

Ancient woodland – land that has been continually wooded since at least 1600 and which has never been cleared or replanted.

Appraisal of Sustainability (AoS) – the independent process used to support the development and appraisal of different high speed route options.

Area of Outstanding Natural Beauty (AONB) – statutory designation intended to conserve and enhance the ecology, natural heritage and landscape value of an area of countryside in England. AONBs have equivalent status to national parks as far as conservation is concerned and are designated under the national parks and Access to the Countryside Act 1949, amended in the Environment Act 1995. In Scotland, the National Scenic Areas are broadly equivalent to AONBs.

Category A listed building – Building of national or international importance in Scotland, either architectural or historic, or a fine, little-altered example of some particular period, style or building type.

Category B listed building – Building of regional or more than local importance in Scotland, or major examples of some particular period, style or building type which may have been altered.

Classic-compatible train – a European high speed standard train which can also run on existing UK rail lines, also known as the classic network.

Continuous high speed line – a railway line designed to high speed railway standards and capable of carrying trains at speeds up to 250mph (400kph). Use of the line would normally be limited to fast passenger trains only.

Flood Risk Zone – before considering development, land or property that lies within a Flood Risk Zone needs to be identified. The Environment Agency and Scottish Environmental Protection Agency produces indicative floodplain maps of areas at high, medium or low risk of flooding.

Garden and Designed Landscape – The Inventory of Gardens and Designed Landscapes is a list of sites that meet the criteria for defining national importance in Scotland identified by Scottish Natural Heritage and Historic Scotland. All sites included in the inventory are considered to be of national importance. Unlike listed buildings there is no category or grading system that distinguishes relative merit. Inclusion in the Inventory confers a measure of statutory planning control in relation to the sites concerned and their setting through the Town and Country Planning (General Development Procedure) (Scotland) Order 1992 (GDPO) and SDD Circular No 6/1992.

GC Gauge – gauge is the shape beyond which a vehicle is not to be built, or within which a structure is not to intrude. GC Gauge is an intermediate shape between a vehicle gauge and a structure gauge, defining limits that a vehicle should conform to in a limited range of operating conditions.

Grade I listed building – a listed building in England which is of exceptional interest, sometimes considered to be internationally important.

Grade II listed building – nationally important building in England that is of special interest.

Grade II* listed building – a listed building in England which is of particular importance, of more than special interest.

Habitats Regulation Assessment (HRA) – the Habitats Directive requires the competent authority to assess the effects of development on Natura 2000 sites – as enacted in the UK through the Conservations of Habitats and Species Regulations 2010 (in England) and the Conservation (Natural Habitats, &c.) Regulations 1994 as amended (in Scotland).

Historic Battlefields – the English Heritage Register of Historic Battlefields offers protection for English battlefields and promotes a better understanding of their significance. The Inventory of Historic Battlefields is a list of nationally important battlefields in Scotland that meet the criteria published in Scottish Historic Environment Policy. It provides information on the sites in it to raise awareness of their significance and assist in their protection and management for the future.

Index of Multiple Deprivation (IMD)/Scottish Index of Multiple of Deprivation (SIMD) – is a measure of the relative deprivation for areas within England and Scotland expressed in quintiles, where the highest quintile (5th) refers to the least deprived area and the lowest quintile (1st) refers to most deprived area.

Listed buildings – a building of special architectural and historic interest brought under the consideration of the planning system by Historic England. A listed building may not be demolished, extended or altered without special permission (listed building consent) from the local planning authority, which would typically consult Historic England.

Marginal external costs – impacts to wider society of a change in the use of heavy goods vehicles on the road network, including changes in congestion, air quality, greenhouse gases, noise, accidents, infrastructure and indirect taxation

National parks – areas of relatively undeveloped and scenic landscape designated under the National Parks and Access to the Countryside Act 1949. In Scotland, national parks are designated under the National Parks (Scotland) Act 2000.

National Scenic Area (NSA) – National Scenic Areas in Scotland were established in 1980 under planning legislation. They are defined as areas of "national scenic significance...of unsurpassed attractiveness which must be conserved as part of our national heritage". The strict development control regime which applies in NSAs is described in SDD Circulars 20/1980 and 9/1987. Planning authorities should take particular care to ensure that new development in or adjacent to an NSA does not detract from the quality or character of the landscape.

Optimism bias – a financial allocation in the cost estimate to compensate for the demonstrated, systematic tendency for appraisers to be over-optimistic about key project parameters, including capital cost, operating costs, works duration and benefits delivery[19].

Peat – Peat is a type of soil with a high organic matter content. In some places it forms an important part of the ecosystem in wildlife habitats which are protected by statutory designations (e.g. SSSIs and SACs). Outside of such habitats, however, the protection of peat is more generally covered in both England and Scotland by the planning guidance intended to maintain the natural functions of soils affected by proposed developments. The main requirement of this guidance is to conserve soils and peat displaced by development.

[19] HM Treasury, of The Green Book 2003 edition

Phase One/Phase One route – the Phase One route of HS2 between London to West Midlands, due to open in 2026, which will include a link to the West Coast Main Line. This route was announced by the Secretary of State for Transport in January 2012. Phase One will include new stations at Birmingham Interchange and Birmingham Curzon Street, as well as an upgrade of Euston station.

Phase Two/Phase Two route – proposed second phase of HS2 which would link the West Midlands to Manchester and Leeds, including stations in South Yorkshire and the East Midlands and connections to the West Coast Main Line and East Coast Main Line.

PLANET Framework Model (PFM) – The suite of models used by HS2 Ltd to analyse the impact of HS2 on rail travel in the UK.

Present value (PV) – the future value expressed in present terms by means of discounting.

Ramsar sites – are designated under the International Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention), agreed in Ramsar, Iran in 1971. The Convention covers all aspects of wetland conservation and wise use, recognising wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the wellbeing of human communities.

Registered Park and Garden – a landscape of note in England that must be treated with special care.

Scheduled Monument – important sites and monuments which have been given legal protection by being placed on a schedule by English Heritage.

Site of Special Scientific Interest (SSSI) – conservation designation denoting an area of particular ecological or geological importance. These areas require protection from damaging development on account of their flora, fauna, geological and/or physiological features. SSSIs are protected under the Wildlife and Countryside Act 1981 as amended.

Special Protection Area (SPA) – are protected sites classified in accordance with Article 4 of the EC Birds Directive. They are classified for rare and vulnerable birds, and for regularly occurring migratory species.

Special Area of Conservation (SAC) – are protected sites that conserve natural habitats of wild fauna and flora under Article 3 of the EU Habitats Directive. They are areas identified as best representing the range and variety of habitats and (non-bird) species.

Source Protection Zone (SPZ) – The Environment Agency has defined Source Protection Zones (SPZs) in England for groundwater sources such as wells, boreholes and springs used for public drinking water supply. These zones show the risk of contamination from any activities that might cause pollution in the area: the closer the activity, the greater the risk. The maps show three main zones (inner, outer and total catchment). The zones are used to set up pollution prevention measures in areas which are at a higher risk.

Spur – a railway line which branches off the main through route.

World Heritage Site – World Heritage Sites are cultural and/or natural sites considered to be of outstanding universal value – places or buildings which are considered to have special importance for everyone. They represent the most significant, unique or best examples of the world's cultural and/or natural heritage. Because of this they have been inscribed on the World Heritage List by the World Heritage Committee. World Heritage Sites are designated to meet the UK's commitments under the World Heritage Convention.

Web Based Transport Analysis Guidance (WebTAG) – the Department for Transport's guidance that provides guidelines on how to conduct transport studies.

Wider economic impacts – the agglomeration, imperfect competition and increased labour force participation benefits.