High Speed Two Phase 2b
Crewe to Manchester
West Midlands to Leeds
Economic Case

November 2016

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Department for Transport

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Preface

This document presents our advice to Government on the Economic Case for building the Phase 2b part of the high speed route from Crewe to Manchester and the West Midlands to Leeds. It is part of a suite of documents that set out the case for building Phase 2b, with the overall plan to build the whole High Speed Two (HS2) network by 2033. It should be read in conjunction with the Phase 2b Strategic Case and the Phase 2b Command Paper, which summarise the vision for HS2 and provide an update on our plans.

In 2013, HS2 Ltd published the Economic Case for the whole HS2 network. In 2016, HS2 Ltd published a further Economic Case setting out the proposal to accelerate the building of the Phase Two route from the West Midlands to Crewe six years earlier than planned, in 2027.

The aim of this document is to set out the costs and benefits of building Phase 2b in order to complete the full HS2 network. It provides:

- an update on the costs and benefits of the full HS2 network;
- the costs and benefits of the Phase 2b part of the route, as an additional investment decision to Phase One and Phase 2a; and
- the costs and benefits associated with different potential route options – in particular, potential route options through South Yorkshire.

Our economic case analysis has been carried out in accordance with HM Treasury's Green Book and the Department for Transport (DfT)'s Web Based Transport Analysis Guidance (WebTAG). In line with that guidance, our analytical framework continues to be based on a 'social cost–benefit analysis', which attempts to place a monetary value on as many impacts as possible.

HS2 is a unique proposal in that its scale and complexity pushes at the boundaries of standard appraisal practice. Working with government and other transport appraisal specialists, we continue to develop our appraisal methodologies and modelling capabilities, and this Economic Case sets out how and where we have developed our approach since the last published Case.

1 Executive summary

1.1 Overview

1.1.1 Phase One of HS2, due to open in 2026, will see a new high speed line constructed from London to the West Midlands where it will join the existing West Coast Main Line (WCML) at Handsacre. Current plans are for a second phase delivered in two parts. Phase 2a will extend the line from the West Midlands to Crewe in 2027, bringing benefits to the North West six years earlier than first planned. Phase 2b will extend the line north from Crewe to Manchester and join the WCML south of Wigan. It will also deliver a new eastern leg which will stop in the East Midlands, South Yorkshire and Leeds, and connect to the East Coast Main Line (ECML) near York.

1.1.2 This document presents the HS2 Ltd Economic Case both for this western leg extension, and the creation of a new eastern leg, alongside a presentation of the Economic Case for the full HS2 network. It is a significant update to the appraisal of HS2, including a number of key assumption updates, and brings the Economic Case up to date with recent developments in rail travel behaviour.

1.1.3 HS2 is a large undertaking, with significant upfront capital investment, but with benefits that will accrue for generations to come. The sheer size of the project, and longevity of its impacts, magnify the opportunities for transformational impacts, while also being a source of risk for the investment. It is not possible to forecast far into the future without a degree of uncertainty, and we therefore continue to focus our economic analysis on understanding the range of possible outcomes, rather than simply providing a single benefit–cost ratio (BCR).

1.2 Economic appraisal

1.2.1 We continue to fully apply standard guidance on how to assess the costs and benefits of transport infrastructure projects, as set out in the DfT's WebTAG.[1] As part of this analysis, we compare the costs and benefits against each other to generate the BCR, i.e. the value of benefits – including WebTAG-compliant wider economic benefits – that would result from every £1 that the scheme costs.

1.2.2 This assessment captures the costs, benefits and changes in revenues for the whole of the rail network – not just those directly associated with the HS2 infrastructure. It includes the costs of both constructing and operating the railway. The benefits include lower levels of crowding on both HS2 and standard rail services, and the impact of quicker, more frequent and reliable journeys for passengers.

1.2.3 We capture all of these benefits and changes in revenue using a highly complex and detailed model of rail passenger flows, the product of over six years of development (the PLANET Framework Model). The model forecasts the likely behaviour of rail passengers, taking into account real-world information on how people make choices, such as what trains to get and

[1] WebTAG – the Department for Transport's Web Based Transport Analysis Guidance.

which train station is best to use for particular journeys. It forecasts the anticipated levels of demand we expect to see using the HS2 and classic rail networks.

1.2.4 Since the last Economic Case, we have undertaken a number of updates to our model. Previous cases were based on independent forecasts of growth in rail demand from 2010/11 and have consistently understated growth in rail patronage since then. This Case has now brought the passenger demand assumptions up to date. We do, however, await updated forecasts of gross domestic product (GDP) from the Office for Budget Responsibility (OBR) that take into account possible impacts of Brexit, though we believe these will likely be within the bounds of our sensitivity analysis.

1.2.5 We have also made significant updates to the value of travel time assumptions in line with groundbreaking research commissioned by the DfT, which has provided up-to-date information on the value of time for all passengers. We have also incorporated changes to WebTAG, and have updated the price base so that all figures are presented in 2015/16 prices.

1.2.6 Cost assumptions have been revised and now assume that construction costs will rise with a higher project-specific inflation rate until 2020.[2] Taken overall, the project inflation rate is higher and has increased our costs in line with the envelope agreed for the 2015 Spending Review.

1.2.7 The modelling makes a number of assumptions around how we assess the impact of upgrades to parts of the existing rail network and how HS2 will change the use of land near HS2 stations and within cities that HS2 serves. The combined effect of these extensions to our appraisal suggest that our assessment of the case for HS2 is likely to be conservative.

1.3 Case for Phase 2b

1.3.1 Since the consultation on Phase Two, there have been a number of changes made to the route. HS2 Ltd has commenced work to bring forward delivery of the route section from the West Midlands to Crewe, and has also proposed a new way of serving South Yorkshire via a spur to the existing network, with HS2 serving the existing Sheffield Midland station. This has enabled a new alignment through South Yorkshire (the 'M18 Route') which provides for faster journey times to key markets in Leeds and the North East. HS2 Ltd is also giving further consideration to a northern connection back onto the main HS2 route to provide a loop through South Yorkshire.

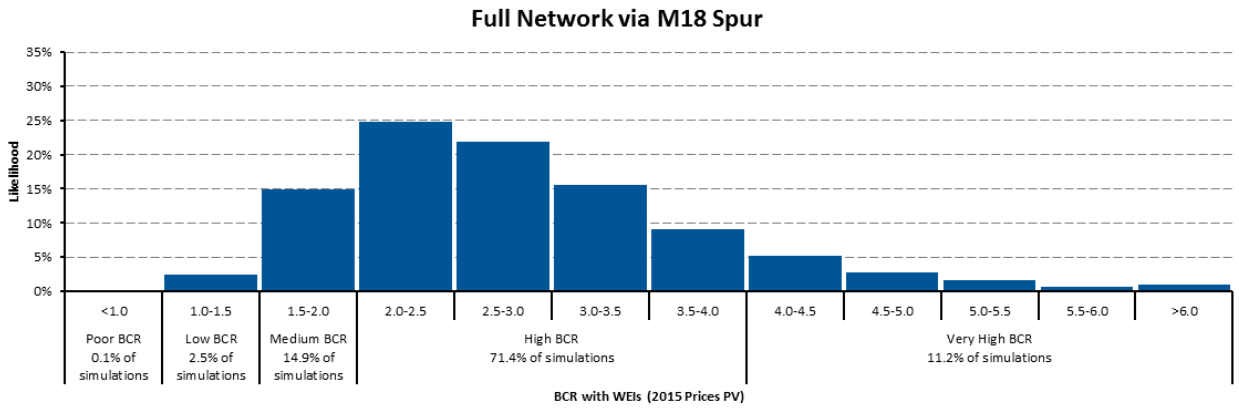
Full Network

1.3.2 Taken together, the M18 Route combined with a spur to Sheffield Midland generate a BCR for the Full Network with a point estimate of 2.7 (to one decimal place), as does the option of an additional loop connection back to the main HS2 route. The BCR spread (see Figure 1) suggests the scheme will provide an 82% chance of returning a high value for money rating, given variations in the core variables of GDP growth, values of time, rolling stock costs and

[2] These costs were presented as a scenario in section 4.6 of the HS2 West Midlands to Crewe Economic Case.

Phase One construction costs. Risk assessments given throughout this Economic Case are all based on variations in these core variables.[3]

Figure 1: Risk analysis – Full Network incorporating a Phase 2b eastern leg via M18/Spur (2tph)

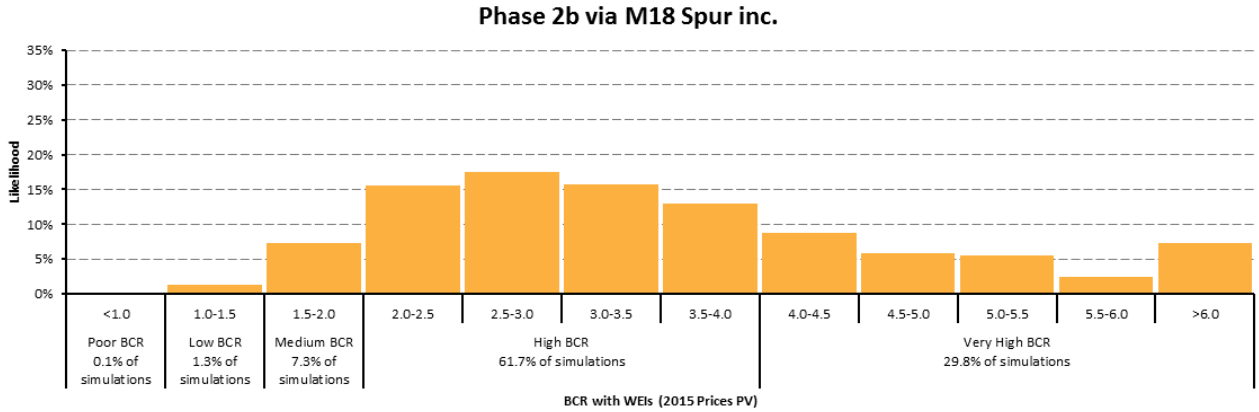


1.3.3 In fact, regardless of the route option or service pattern assumption used for serving the South Yorkshire region, the case is very similar and equally robust. The Meadowhall Route produces a slightly lower BCR point estimate of 2.6 and a very similar spread of BCRs to the M18 Route with the scheme providing a 79% chance of returning high value for money against variations in core criteria.

Phase 2b Increment

1.3.4 Looking at the incremental case for Phase 2b, the M18 Route combined with a spur to Sheffield Midland generates a BCR for the Phase 2b Increment of 3.2. The BCR spread for this option provides a 91% chance of producing high or very high value for money against variations in core criteria.

Figure 2: Risk analysis – Phase 2b Increment incorporating a Phase 2b eastern leg via M18/Spur (2tph)



[3] Chapter 4 provides more detail on the variables explored as part of our risk analysis.

1.3.5 The incremental case for the Phase 2b network provides very high benefits and revenue, as it both opens up benefits to the eastern side of the country and enhances them for the western side, pivoting off the by-then already constructed Euston to Birmingham and Crewe sections of the route.

1.3.6 As with the Full Network, the case for the Phase 2b Increment remains robust to the different route options assessed in this Economic Case. The Meadowhall Route produces a slightly lower BCR point estimate of 3.0 and a very similar spread of BCRs to the M18 Route with the scheme providing an 88% chance of producing high or very high value for money.

1.4 Robustness of the case

1.4.1 Although we have sought to understand and quantify a proportion of the risks and uncertainties by generating a range of BCRs, there are some that cannot be easily understood in this way. For these areas, we look at specific scenarios to understand the potential impact on the case for the scheme. We group the analysis in this chapter into three categories, namely: the impact of long-term demand assumptions, the impact of different cost assumptions, and the impact of different appraisal assumptions.

1.4.2 The majority of the scenarios we examine to assess the robustness of the case are based on the Meadowhall Route, as it represents the line closest to the currently consulted route. However, as discussed above, the alternative route options do not have a significant impact on the BCR. We therefore consider that our primary conclusions on the robustness of the case apply equally to the Meadowhall and M18 South Yorkshire route options.

Impact of long-term demand assumptions

1.4.3 One of the key assumptions that drives the BCR we calculate is the amount of rail demand that is forecast to occur, using industry-agreed approaches for rail travel in future years. We have investigated the impact of both higher and lower levels of demand that might occur if yearly GDP growth rates were 10% higher or lower than our central assumption. For the more challenging lower growth scenario, the Full Network would still provide high or very high value for money in just under 63% of cases.

1.4.4 In the modelling undertaken, the growth in demand for rail is assumed to stop in 2036 in line with DfT guidance. If we were to assume, however, that growth were to continue in line with population growth after this date, then the economic case improves significantly, with over a 90% chance of HS2 returning high or very high value for money.

1.4.5 We flag that the rail demand forecasts which underpin our analysis are predicated on the latest available OBR outlook for the economy, which does not yet take into account any impact of Brexit. Independent forecasters have typically lowered their growth forecasts post-Brexit. We do, however, cap rail demand at 2036 which is a conservative assumption. Moreover, we believe any effect of Brexit on the UK's long-term growth potential will likely be captured within the sensitivity analysis covered above.

Impact of alternative cost assumptions

1.4.6 The cost of the scheme is clearly a key part of assessing its value for money. The Phase Two costs have been calculated applying optimism bias of around 40%, in line with standard appraisal guidance from HM Treasury. To understand how robust the case is we have looked

at what the impact would be if we were to assume a higher level of Phase Two construction costs based on a 50% optimism bias assumption. This scenario continues to provide a high value for money case with over 74% of modelled scenarios providing high or very high value for money.

Impact of alternative appraisal assumptions

1.4.7 We have also assessed how robust the scheme is to other factors such as changing fares policy, and the impact of our assumptions around the reliability of HS2 when compared with the existing rail network.

1.4.8 Making an assumption that fares growth continues at the current level of Retail Prices Index (RPI) +0% beyond 2020, means that rail is relatively more attractive and increases the level of rail demand. This increased demand has a corresponding impact on HS2 giving a 96% chance of producing high or very high value for money. Increasing fares has the opposite effect, and would reduce the demand for rail travel, and also lower the case for HS2.

1.4.9 Turning to benefits from increased reliability, we examine the extreme case where HS2 delivers no reliability improvements when compared with the existing rail network. Our analysis suggests that, even under this extreme assumption, the Full Network likely provides over a 50% chance of delivering high value for money.

1.5 Conclusion

1.5.1 Overall, the case for the full HS2 network remains robust in the face of a variety of changes and developments in both the scheme and cost assumptions. It provides a spot point BCR estimate between 2.6 and 2.7, subject to the route and train service assumptions through South Yorkshire. In all the scenarios examined, it continues to provide a spread of BCRs with the majority of scenarios providing over an 80% chance of the scheme providing high or very high value for money.

2 Introduction

2.1 Scope and purpose of this document

2.1.1 This document sets out HS2 Ltd's advice to Government on the Economic Case for Phase 2b of HS2. It is published as part of the Strategic Outline Business Case (SOBC) for Phase 2b, which includes the five cases for the scheme (Economic, Strategic, Commercial, Management and Financial). Taken together, these cases set out the complete rationale for building the HS2 routes from Crewe to Manchester and the West Midlands to Leeds, and the connections to the classic network. This document sets out HS2 Ltd's Economic Case for Phase 2b as an increment to Phase One and Phase 2a and as the final phase of the full HS2 network.

2.1.2 The SOBC stage for a major project gives a high-level indicative view on what the project is intended to deliver, along with estimates of its benefits and delivery costs. The project will move through the business case development stages until a Full Business Case is produced to support a final investment decision. The scope, costs and schedule of the scheme will be refined during the development process to provide greater confidence in the scheme's value for money. At this SOBC stage, assumptions and modelling inputs including the scheme design and train service specification (TSS) are indicative. These indicative assumptions reflect our current best assessment of the Phase 2b scheme and are designed to provide Government with sufficient confidence of the intentions and outputs of the project to proceed beyond the SOBC stage.

2.1.3 The value for money of alternatives is not covered in this Economic Case. Analysis of rail alternatives has been commissioned and managed through the DfT and is presented in the DfT's Economic Case.

2.2 Document structure

2.2.1 This document is structured as follows:

- Chapter 3 provides an overview of the HS2 scheme and the route we are appraising in this Economic Case.
- Chapter 4 gives an overview of our approach to the economic appraisal of the HS2 scheme, and summarises what has been updated in the modelling framework since the Phase 2a Economic Case was published in January 2016.[4]
- Chapter 5 summarises the economic appraisal for the HS2 scheme, setting out the analysis for the Full Network and Phase 2b as an increment using the standard set of appraisal assumptions.
- Chapter 6 assesses the robustness of the case by evaluating the impact of changing key assumptions on the case for HS2.
- Chapter 7 outlines some of the costs and benefits, which may be important to the

[4] *HS2 Phase Two West Midlands to Crewe: Economic Case*, January 2016 . Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/490312/Economic_Case_report_2016.pdf.

scheme but are not currently included in the primary BCR.

- Appendix 1 sets out the modelling approach using the PLANET Framework Model (PFM).
- Appendix 2 sets out the scheme service patterns that have been assumed for modelling purposes.
- Appendix 3 has more detail on the cost assumptions that have been incorporated into the appraisal.
- Appendix 4 sets out more detail on benefits and how we calculate the BCR.
- Appendix 5 reports transport impacts for the Full Network and Phase 2b Increment.
- Appendix 6 reports the point estimate BCRs for the scenarios covered in Chapter 5.
- Appendix 7 sets out examples of the journey times used in this Economic Case.

2.3 Supporting documentation

2.3.1 For more information on certain aspects of the analysis, this Economic Case should be read in conjunction with other reports. These include:

- *PLANET Framework Model (PFM V6.1c) – Model Description*;
- *Assumptions Report: PLANET Framework Model Version 6.1c*;
- *Risk Analysis for the HS2 Economic Case – Technical Documentation*;
- *Model Development Report: PLANET Framework Model Version 6.1c*;
- *Model Development Report, PFMv5.2 to PFMv6.1c Updating the Exogenous Forecast*;
- *Audit of Development of the PLANET Framework Model Versions 5.2 to 6.0 and use for the HS2 Phase 2b SOBC*;
- *Summary of Key Changes to the Economic Case 2015 to 2016.*

3 The HS2 network

3.1 Full Network

3.1.1 HS2 is a new high speed rail network for the UK, connecting London with major cities in the Midlands and the North of England. It is a Y-shaped network that will be delivered in several phases. Trains will also run beyond the 'Y' network to serve places such as Liverpool, Preston, Newcastle and Scotland.

3.1.2 Phase One of HS2 will see a new high speed line constructed from Euston to just north of Birmingham, where it will join the existing WCML, allowing fast, direct services to destinations including Manchester, Liverpool, Crewe, Preston and Glasgow. New high speed trains will also serve Birmingham city centre via a dedicated high speed line and a new station at Curzon Street, with an interchange station designed to serve the wider West Midlands and Birmingham Airport. At Old Oak Common in West London, a new interchange will be built connecting HS2 with Crossrail and the Great Western Main Line. Phase One will be built and operational by 2026, subject to parliamentary approval of the High Speed Rail (London - West Midlands) Bill.

3.1.3 The full Phase Two proposal is to extend the line to the North West to Manchester with connections onto the WCML, and to the North East to Leeds with a connection onto the ECML. There will be stations in Manchester and Leeds, with intermediate stations in the East Midlands and South Yorkshire, as well as at Manchester Airport subject to funding. Phase Two is planned to be delivered in two phases. The first element, Phase 2a, will deliver the section of route from the West Midlands to Crewe in 2027 in line with the announcement in November 2015. The second element, Phase 2b, the subject of this Economic Case, will deliver the remaining route to Manchester and the WCML connection along with the entire eastern leg six years later in 2033.

3.2 South Yorkshire

3.2.1 The Phase 2b route has to date been focused on a consulted eastern route that incorporates a station at Meadowhall. As set out in our *Sheffield and South Yorkshire Report 2016*,[5] there are different options for HS2 services in South Yorkshire which deliver different benefits. The aforementioned report makes a recommendation that the best way to serve South Yorkshire is by an alternative route. This route would incorporate a new alignment for a section of the main line which will run to the east of the consulted route. In addition to this new alignment, there are two options for serving Sheffield which this Economic Case considers.

3.2.2 One option is a spur to Sheffield Midland which would join the classic rail network on the Erewash Valley Line just south of Chesterfield. This spur, along with some electrification of the classic line, would allow classic compatible services to run via the Midland Main Line to Sheffield city centre, with the potential to call at Chesterfield and run on beyond Sheffield. A

[5] *HS2: Sheffield and South Yorkshire Report 2016*, July 2016. Available at: www.gov.uk/government/organisations/high-speed-two-limited.

second option is a loop via Sheffield Midland which would follow the same route to the south of that station but would provide a junction to the north of Sheffield Midland to connect the classic network to the main HS2 route alignment. Under this option there is an assumption that the the classic line to the North of Sheffield Midland station is electrified under our 'do minimum' scenario to facilitate HS2 use.

3.2.3 The majority of the Phase Two route is the same under all scenarios, for example, the entire western leg from Crewe to Manchester and to Golborne where the junction with the WCML is proposed. The recommended change in South Yorkshire is, however, the most significant change to the Phase Two route, and we have therefore labelled the scenarios in this Economic Case by the different South Yorkshire alignments that are being considered, while holding the remainder of the Phase Two route constant.

3.2.4 We have therefore undertaken appraisal of the following routes for this Economic Case:

- The Phase 2b route with the eastern leg via Meadowhall ('Meadowhall Route') – which assesses the original consulted eastern route that incorporates a station at Meadowhall.
- The Phase 2b route with the eastern leg via M18/Spur ('M18 Spur Route') – which assesses the same Phase 2b scheme as the Meadowhall Route but with a new alignment in South Yorkshire for a spur via the Erewash Valley to Sheffield city centre.
- The Phase 2b route with the eastern leg via M18/Loop ('M18 Loop Route') – which assesses the same Phase 2b scheme as the M18 Spur Route but gives an *indicative* appraisal of the potential impact of also building a northern connection back to the main HS2 route.

It should be noted that the M18 Loop Route is only indicative at this time, as the key use for this infrastructure would be to facilitate Northern Powerhouse Rail services between Leeds and Sheffield, an option that is currently being considered by Transport for the North.

3.3 Assessing the benefits of the Hs2 network

3.3.1 The HS2 scheme brings a number of key benefits to the UK. This includes increased capacity between key city destinations, faster and more reliable journey times bringing cities closer together, and the release of capacity on the classic network, allowing the classic network to refocus on serving shorter-distance markets. Importantly, released capacity on the classic network also creates options for the future to respond to changes in passenger demand and freight travel.

Journey times

3.3.2 The full HS2 network provides a number of significantly reduced journey times. For example:

- London to Manchester will reduce from 2 hours 7 minutes to 1 hour 8 minutes; and
- London to Leeds will reduce from 2 hours 10 minutes to 1 hour 22 minutes.

3.3.3 Appendix 7 provides more detail on the journey times that we have used to model the benefits of the HS2 network and, more importantly, shows the impact of changes to the route in South Yorkshire.

3.3.4 The Phase 2b scheme itself provides journey time improvements over those provided by Phase One and Phase 2a. For example London to Manchester journey times reduce by a further 20 minutes over the times from Phase 2a, to 1 hour 8 minutes once Phase 2b is built.

3.3.5 The proposed change to route in South Yorkshire – the M18 Spur Route – also generates a few changes to journey times which affect key journeys on the eastern leg. The modelled journey time for services that use the proposed M18 alignment for the main line through South Yorkshire reduces the journey time for all services by a small amount compared with the Meadowhall Route, due to an overall faster alignment.

Increased capacity between key city destinations and on the classic network

3.3.6 The HS2 network will provide trains that are much longer than possible on the current rail network (except HS1), with 400m trains serving the key city stations providing significantly more capacity on a single train than available today.

3.3.7 Alongside the increase in capacity, the potential to revise services on the classic network will allow both a mix of additional capacity to intermediate stations from the transfer of long-distance passengers to HS2, and services of new markets. For example, once HS2 arrives, it would be possible to revise the type and makeup of services on the WCML into and out of Euston to provide significantly more commuter seats.

4 Our approach to economic appraisal of the HS2 scheme

4.1 Overview

4.1.1 In January 2016, the Economic Case for HS2 Phase 2a and the full HS2 network was published, setting out the case for accelerating the section of route between the West Midlands and Crewe.

4.1.2 Since then we have continued to review and update our appraisal methodology in line with updated guidance from the DfT, and develop our modelling framework, so as to further enhance our ability to assess the impact of HS2. We have also conducted work to reflect proposed changes in the proposed line of route for the Phase 2b scheme, alongside other associated changes with the early scheme elements (Phase One and Phase 2a).

4.1.3 There have also been a number of recent proposed changes, both to WebTAG and the DfT's recommended approach to undertaking the appraisal of the HS2 network, which we have incorporated into our modelling.

4.1.4 This chapter gives brief details of our approach to economic appraisal of the scheme, and the key enhancements we have made to our data and appraisal methods since the Phase 2a Economic Case. Further details on the changes made – notably the impacts and implications around demand – can be found in the supporting documentation listed in section 2.3.

4.2 Appraisal of the HS2 scheme

4.2.1 As with previous economic cases, we appraise the value for money of the HS2 scheme using a highly complex and detailed model of long-distance travel in Great Britain called the PLANET Framework Model (PFM).

4.2.2 PFM looks to understand and provide forecasts for the level of travel and the changes in travel behaviour across rail, air and road that would result from building HS2. PFM is a strategic-level model and provides a strategic view of the rail, road and air markets and networks, while also drawing on detailed information on passenger travel from ticket sales and other data.

4.2.3 PFM is a framework of a number of models, each highly complex and aiming to understand different dimensions of passenger behaviour. Key components are as follows:

- PLANET Long Distance (PLD): the long-distance component that models the behaviour of over 650,000 rail passengers, and how and where they want to travel on the rail network, both with and without HS2. The data for this component comes from latest ticket sales data, and we then apply standard forecasting methods drawn from the Passenger Demand Forecasting Handbook (PDFH). Alongside this analysis is a representation of how many people travel long distances on the road network, and how many use air travel.

- PLD works in conjunction with the Station Choice Model (SCM): the SCM looks at how passengers choose which station to use to catch a train from, and allows passengers to consider and change their access station once a new scheme is built, based on an analysis of journey times. Hence, the model allows passengers to decide that sometimes it might be better to drive slightly further to catch a quicker train from a different rail station. Such choices have been calibrated against surveys of passenger behaviour.
- Regional models: there are also three regional models which are designed to look at the local changes that can be facilitated by HS2 and the released capacity generated. These specifically look at rail passengers and include the millions of commuting passengers into London, Birmingham, Manchester and Leeds, and the benefits that can be accrued to those travelling into these cities from changes to the commuter service.

4.2.4 The model then provides a monetised estimate of the benefits and revenue of these forecast travel changes from the HS2 scheme which can be compared against the costs involved, and lead to estimates of the value for money of the scheme.[6] These changes include not only the impact of the HS2 network but also an estimate of the value created through the HS2 scheme releasing capacity on the existing rail network.

Benefits

4.2.5 PFM produces an assessment of the scale of likely benefits from building the HS2 network. These benefits are initially assessed in units of time before being converted to monetary values. They include an assessment of the following, all using standard DfT compliant procedures:

- quicker journeys;
- improved reliability associated with high speed rail;
- reductions in crowding;
- reductions in congestion on the road network; and
- other impacts such as changes in the costs of accessing the rail network, time spent waiting for a train or the number of times a passenger has to change train on their journey.

4.2.6 The model we use is designed to capture all these impacts, whether positive or negative and, importantly, whether they are directly related to HS2 or represent other knock-on impacts. The model looks at the change in overall journeys, not simply the experience on HS2. Therefore, if someone chooses a longer journey to access an HS2 station in order to gain a faster journey time once on board the HS2 train, we would count the negative cost of the increase in access time together with the benefit of the reduction in journey time. Similarly, if

[6] Full details of the PFM can be found in *PLANET Framework Model (PFM v6.1c) – Model Description*.

there are any trips disadvantaged, for example, due to changes on the classic network, this would be captured in the model.[7]

4.2.7 The benefits assessed also include the standard wider economic impacts as outlined in the DfT's WebTAG (Unit A2.1). There are three types of wider economic impacts we calculate in our modelling:

- *agglomeration* arising from increased connectivity between cities and towns. This is about reducing the costs of travel between areas, creating opportunities for more intense and productive interactions between businesses and workers;
- *imperfect competition* as reduced costs facilitate an increase in output. Companies operating in imperfectly competitive industries will be able to increase their production as a result of lower transport costs; and
- *increased labour force participation*: transport changes can affect the individual incentives to work and therefore affect the overall level of labour supply.

Risks and uncertainties

4.2.8 For a large and complex scheme like HS2, a single forecast value alone does not provide enough information for decision-makers. This is because, when projecting costs and benefits into the future, assumptions have to be made about a number of unknowns. Key unknowns concern future levels of demand, people's future willingness to pay for high speed rail travel, and revenues and revenue growth. There are also unknowns in the estimation of costs. In the Economic Case we classify these unknowns into two categories: risks and uncertainties.

4.2.9 The term 'risk' is used for unknowns for which it is possible to derive a statistically robust understanding of the likelihood of different values occurring. For example, the OBR produces a short-run central estimate of growth and a range of longer-term scenarios.

4.2.10 Where the likelihood of different values can be quantified in this way, we have used established statistical techniques to analyse the impact of many of these factors, and hence determine the likelihood of different benefits, costs, revenue and therefore BCR.

4.2.11 This approach relies on the definition of probability distributions of possible values for key factors, and the repeated simulation of the impact of different combinations of those factors on the outcomes in question. A key advantage of such an approach is that it guards against placing excessive weight on extreme outcomes that require the coincidence of a set of unlikely events. Hence, our risk analysis provides a distribution of results rather than a single spot point BCR.

4.2.12 The second type of unknown in the appraisal of the HS2 scheme are termed 'uncertainties', and refer to areas for which there is not a statistically based understanding. In some instances this may be because there is no statistically robust evidence or competing theories in existence, in other cases the variables of interest are subject to policy decisions or are a known policy lever.

[7] For full details see the model description and other modelling documents as detailed in section 2.3.

4.2.13 For this Economic Case, such uncertainties have been analysed as discrete scenarios, and for each of these scenarios, a risk analysis is conducted to give a distribution of outcomes. Table 1 sets out the key factors that have been analysed with a) risk analysis and b) scenario tests.

Table 1: Variables examined through risk analysis and scenario tests

Variables explored as part of risk analysis	**Variables explored through alternative scenarios**
Short- and long-term economic growth (GDP) which feeds into: • projections of demand and revenue; and • valuation of time savings and other impacts.	When the growth in long-distance rail demand is capped.
Statistical variation in the value placed on time savings by leisure, commuting and business travellers.	Rail fare assumptions for the network.
Sensitivity of demand projections to economic growth.	Construction costs with alternative optimism bias or value engineering assumptions.
Sensitivity of business, leisure and commuter travellers' valuation of time to growth in GDP.	
Rolling stock costs for Phases One and Two using the quantified risk assessment work undertaken by HS2 Ltd.	

4.2.14 Assessing risks and uncertainties is key to understanding how robust the value for money assessment of the HS2 scheme is, and whether it will continue to provide good value for money under different circumstances.[8] This Economic Case therefore sets out the case for HS2, and assesses its robustness, through exploring the implications of both types of unknowns.

4.3 Updates to our appraisal framework

4.3.1 As mentioned previously, we have updated our modelling and appraisal framework to reflect the latest changes in journey travel and other information, and the latest guidance from the DfT in how best to appraise rail schemes. In the process our model has evolved to a new version termed PFMv6.1c. This section details the key changes implemented.

Demand forecasts

4.3.2 Our forecast of passenger numbers expected to travel on HS2 remains a central element of the Economic Case. It incorporates a well-developed, industry-agreed approach set out in the PDFH, which is endorsed by the DfT. Since 2015, we have updated our rail passenger demand forecasts, which have consistently proved conservative, to incorporate the following:

[8] We undertake our risk analysis using a tool which builds on the outputs of the PFM. For more details of this tool please see *Risk Analysis for the HS2 Economic Case – Technical Documentation*.

- An update in the base year matrices: updating the demand forecasts to take account of the differences between the previous forecasts and actual outturn demand. All previous economic cases have used a base year of 2011. Each has shown how the recent trends for growth in journeys on long-distance operators have been higher than forecast.[9] Indeed, the 2014/15 demand outturn was some 12% higher than the previous forecast for 2014/15. The change in base year matrices updates brings our modelling up to date with the most recently available data.
- An update to the way the model deals with demand growth: in previous economic cases, HS2 used a bespoke method of 'capping' the demand in the model that was different to other rail schemes. For this Economic Case, we have aligned our approach with the standard rail forecasting method and fixed our forecast at 20 years in the future, i.e. 2036.
- An updated price base for assessment: this Economic Case provides all costs and benefits in 2015/16 prices. This will show as an increase for all elements over the previous economic cases, which have been presented in 2011/12 prices. This change has no impact on the BCR, as costs and benefits are both uprated by the same factor, but does mean that numbers in this Economic Case cannot be compared with previous economic cases without adjusting for this price base change.
- Changing external factors, such as revised assumptions on economic growth which have been incorporated into the latest WebTAG Databook (December 2015) on appraisal guidance.
- The latest evidence on how rail demand changes in response to economic growth, as set out in WebTAG: this has updated our modelling to reflect the latest changes in the DfT's WebTAG since the last Economic Case.

4.3.3 The latest rail demand forecasts which underpin our analysis of Phase 2b are predicated on the OBR outlook for the economy, and its latest published figures do not currently take into account any impact Brexit may have on the economy. Independent forecasters have typically lowered their growth forecasts following the EU referendum. We would, however, note that we cap rail demand at 2036, which is a conservative assumption. Moreover, we provide a sensitivity analysis of rail demand to GDP growth and we believe any effects of Brexit on the UK's long-term growth potential will likely be captured within the range provided by the GDP scenarios assessed (see Chapter 6).

Updates to the modelling approach

4.3.4 The transport impacts in this Economic Case continue to be forecast using a complex computer model (PFM). HS2 Ltd continues to make updates and enhancements to the model

[9] *The Economic Case for HS2*, October 2013 – section 5.2, page 33 (available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/365065/S_A_1_Economic_case_0.pdf); *HS2 Phase Two West Midlands to Crewe: Economic Case*, January 2016 – section 5.2, page 22 (available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/490312/Economic_Case_report_2016.pdf).

in line with guidance from the DfT. This includes a number of significant changes over the previous model version, most notably:

- Numerical integration. In previous economic cases, we have presented the impacts of applying a specific technical approach – known as numerical integration – in calculating passenger benefits as a sensitivity test. The approach provided lower benefits than the standard approach applied across conventional DfT rail programmes (a single application of the 'rule of a half'). Following advice from the DfT's transport appraisal team, we have now adopted numerical integration, which is recommended for consideration for schemes such as HS2 where there are large changes in demand or travel time.[10]

- Changes in the values of time. We have taken on board the implications of the recently published and updated guidance on the value of travel time savings as issued by the DfT. This value of travel time saving work from the DfT follows on from a comprehensive research project looking to understand the willingness to pay for travel time savings for business, commuting and leisure passengers. It enables us to assess the value of travel time savings for users of HS2 on a far more rigorous basis than previously. The results of the change to the latest guidance is similar to the assessment presented in the last Economic Case and leads to a small increase in the BCR.[11]

- The risk analysis approach has been updated and re-estimated in line with the changes in all other assumptions detailed here. For further details of this see *Risk Analysis for the HS2 Economic Case – Technical Documentation*.

Updates to the 'without HS2' baseline

4.3.5 The 'without HS2' baseline, or 'do minimum', against which HS2 is compared, has been updated to reflect recent changes in franchise commitments and updates to the high-level output specification for the period 2014–2019, and some changes beyond this point. In particular, the following aspects of the 'do minimum' have been updated:

- the WCML timetable to incorporate the recent granting of rights to the open access operator Great North Western Railway, to provide off-peak services to Blackpool;

- the capacity, journey times and stopping patterns of trains on Crossrail, Heathrow Express and the Great Western Main Line;

- CrossCountry journey times and capacity assumptions; and

[10] For further details see section 6.3 of HS2 Phase Two West Midlands to Crewe: Economic Case, January 2016. Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/490312/Economic_Case_report_2016.pdf.

[11] Details of the travel time research can be found at: www.gov.uk/government/publications/transport-appraisal-in-investment-decisions-understanding-and-valuing-the-impacts-of-transport-investment.
Details of forthcoming changes to WebTAG can be found at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/541455/webtag-tag-unit-a1-3-user-and-provider-impacts-forthcoming-change-november-2016.pdf.

- the Northern and Trans Pennine Express franchises, to reflect the recent set of commitments made as part of the franchising process.

HS2 service patterns

4.3.6 There have been a number of changes in the journey times modelled for services, which have come about both from changes to the route and from more up-to-date modelling. The majority of changes are fairly minor.

4.3.7 The Phase 2a TSS now assumes that all the Manchester services route via Crewe, which represents a slight change to the assumptions in the previously published Phase 2a Economic Case.

4.3.8 Chapter 5 sets out the impact on the value for money of the scheme of proposed changes to the route in the South Yorkshire area – and the associated changes to journey times and stopping patterns those proposals make to the scheme.

4.4 Cost estimation

4.4.1 Cost estimates for HS2 are being continually refined and we have sought to ensure that the most up-to-date estimates are used in the Economic Case. The cost estimates used for this analysis are consistent with the Spending Review 2015 allocation.

4.4.2 As detailed in the High Speed Two (HS2) Ltd Annual Report and Accounts 2015/16, overall funding of £55.7 billion at 2015 prices is allocated as follows:

- Phase One London–West Midlands £24.3 billion;
- Phase 2a West Midlands–Crewe £3.7 billion;
- Phase 2b West Midlands–Manchester/Leeds £20.6 billion; and
- railway operations and rolling stock £7.1 billion.

4.4.3 In undertaking the appraisal within this Economic Case, a number of adjustments are made to the above cost estimates to adhere to HM Treasury Green Book and DfT WebTAG for undertaking appraisal of transport schemes. Significant adjustments include:

- discounting to present value – in order to provide estimates of costs and benefits in a BCR in consistent values; and
- adding an estimate for higher construction cost/project specific inflation between 2015 and 2020.

4.4.4 It should be noted that the addition of higher construction cost/project-specific inflation means the appraisal incorporated within this Economic Case is undertaken on a higher overall cost estimate than the Financial Case. This provides a further conservative assumption for the appraisal of the scheme.

4.4.5 It should also be noted that, in line with HM Treasury appraisal guidance, we have removed sunk costs from the calculation of the BCRs. If we were to include sunk costs, we estimate that this would reduce the BCR for the Full Network by 0.1.

5 The case for Phase 2b

5.1 Introduction

5.1.1 Here we present the case for HS2, providing assessments of the full HS2 network and Phase 2b as an increment on the previous two phases (Phase One and Phase 2a). As discussed earlier, Phase 2b refers to the northern part of the Y-shaped rail network, notably the route from Crewe to Manchester in the west, and the eastern leg from Birmingham to Leeds. We also capture wider benefits as HS2 trains run beyond the Phase 2b track to serve places such as Liverpool, Preston, Newcastle, York and Scotland.

5.1.2 As set out in Chapter 3 we have undertaken appraisal of the following routes for this Economic Case:

- the Phase 2b route with the eastern leg via Meadowhall ('Meadowhall Route') – which assesses the original consulted eastern route that incorporates a station at Meadowhall;
- the Phase 2b route with the eastern leg via M18/ Spur ('M18 Spur Route') – which assesses the same Phase 2b scheme as the Meadowhall Route but with a new alignment in South Yorkshire for a spur via the Erewash Valley to Sheffield city centre;[12] and
- the Phase 2b route with the eastern leg via M18/Loop ('M18 Loop Route') – which assesses the same Phase 2b scheme as the M18 Spur Route but gives an *indicative* appraisal of the potential impact of also building a northern connection back to the main HS2 route.

5.2 Appraisal

5.2.1 The benefits presented in this chapter are derived from the PFM. This is a highly complex model used by HS2 for the assessment of passenger benefits and is the result of many years of development. It looks at the behaviour of rail, road and air passengers, as they are likely to respond to the changes brought about by the HS2 scheme. It calculates how passengers are likely to change their behaviour and the benefits that will occur, taking account of the improvements in capacity, journey time, connectivity and reliability that HS2 brings to the rail network.

5.2.2 Building on PFM model outputs, this chapter then assesses the case for the scheme using our risk analysis modelling approach. This work presents the BCR for a range of values, and allows us to better understand the resilience of the case. The risk analysis is undertaken using an additional model which applies statistical and probabilistic information to large numbers of outputs from the PFM.

5.2.3 All the benefits and accompanying BCRs in this section include WebTAG-compliant wider economic impacts, such as agglomeration effects arising from better connectivity between cities and towns. However, they do not fully capture wider transformational benefits, such as

[12] Details of the South Yorkshire routes can be found on gov.uk at: www.gov.uk/government/publications/hs2-sheffield-and-south-yorkshire-report-2016.

those that may follow from changes in land use, and as such provide a conservative estimate of benefits.

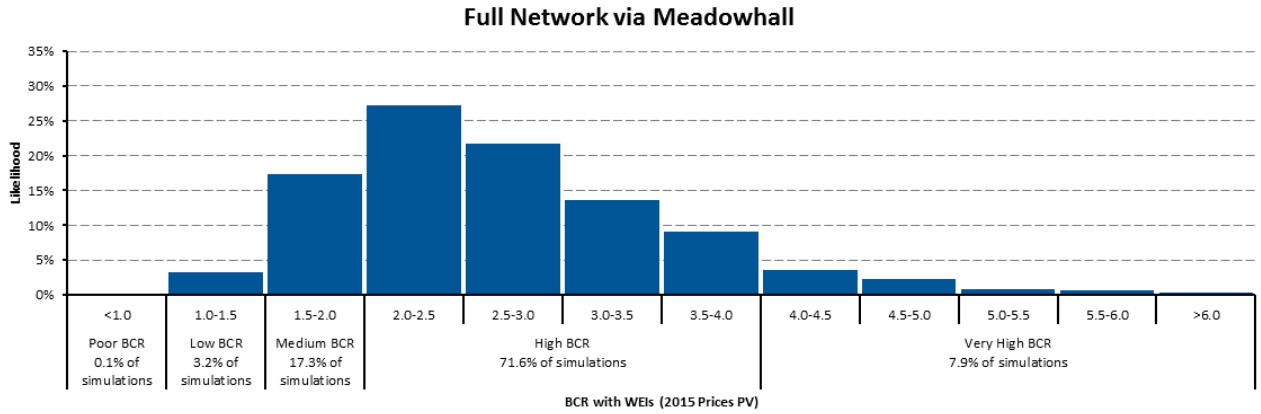
5.3 Phase 2b route with the eastern leg via Meadowhall

5.3.1 In this section, we look at the case for the original HS2 route for Phase 2b with the eastern leg routed via Meadowhall (the Meadowhall Route). Following the 2013 consultation, HS2 Ltd undertook further design development work to refine the route. This included considering alternative alignments through Meadowhall station and locations to the north of Meadowhall alongside revisions to the south of the East Midlands Hub and locations on the western leg. This revised route made small changes to journey times and costs in various locations, which are reflected in our analysis.

Full Network

5.3.2 Figure 3 presents the results for the Meadowhall Route risk analysis for the Full Network. With this option we are assessing the overall case for the whole network comprising Phase One and Phases 2a and 2b. The chart shows the relative probability of different levels of BCR, mapped against the DfT's value for money categories. For the factors included in the risk analysis, which include economic growth and variations in the value of time for commuting and leisure passengers, the value for money of the Full Network incorporating the Meadowhall Route continues to be strongly weighted towards the higher value for money categories.

Figure 3: Risk analysis – Full Network incorporating a Phase 2b eastern leg via Meadowhall



5.3.3 The central BCR value for the Full Network Meadowhall Route is 2.6. We can see from Figure 3 that the Full Network using the Meadowhall Route continues to have at least a high value for money in around 80% of modelled scenarios. The chart also shows that there is a low risk, for the factors analysed, of the scheme yielding low value for money – of around 3%.

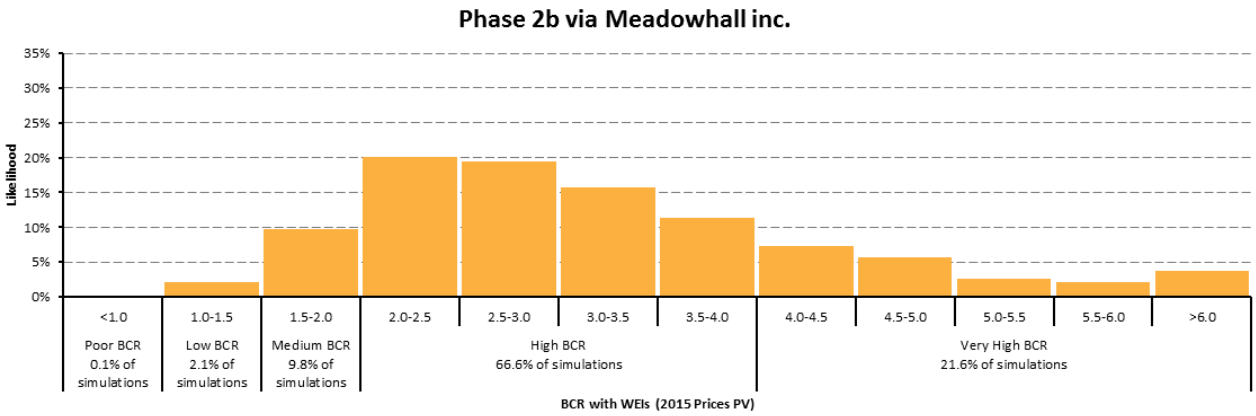
5.3.4 Wider WebTAG-compliant economic impacts are included in the above figures and provide 21% of total scheme benefits. More than half of the wider economic benefits (some £21 billion) arise from agglomeration economies of improved connectivity.

Phase 2b Increment

5.3.5 Here we consider the benefits, costs and revenue of the Phase 2b scheme only, effectively just considering those benefits for the Phase 2b element given that the Phase 2a and Phase One elements are already built. This will therefore give a sense of the benefits from the addition of

the eastern leg and the faster services to Manchester, the wider North West and Scotland. Figure 4 shows the results for the Phase 2b incremental risk analysis. It shows the relative probability of different levels of BCR against the value for money categories.

Figure 4: Risk analysis – Phase 2b Increment incorporating a Phase 2b eastern leg via Meadowhall



5.3.6 Figure 4 indicates that the incremental case for Phase 2b likely represents high value for money and suggests a strong case for extending the high speed network to Leeds and Manchester. The central BCR value of the incremental case is 3.0, 0.4 points higher than the Full Network BCR, also with a low risk of the scheme yielding low value for money. Hence, it appears there are significant benefits in extending the reach of HS2 to previously underserved areas of the country, while also benefiting from elements of Phase One and Phase 2a, such as the station development at Euston. We therefore conclude that the case for the Phase 2b extension to the HS2 network is a worthwhile development of the scheme.

5.4 Phase 2b route with the eastern leg via M18/ Spur

5.4.1 Following on from the presentation of the original Meadowhall Route, this section presents the results for the Phase 2b route with the eastern leg routed via the M18, the new HS2 Ltd preferred route through South Yorkshire. All the remaining areas of the route on the western leg, and both north and south of the M18 alignment on the eastern leg, remain as for the Meadowhall Route. The key element to understanding the M18 Route is how this provides a service for Sheffield and South Yorkshire. Sheffield and South Yorkshire are served by classic compatible services running off the HS2 network via a new spur constructed to the south of Chesterfield. This spur can be used for a number of different possible train services which could serve Sheffield Midland from London.

5.4.2 The effect of adopting the M18 Route, when compared with the Meadowhall Route, is that all eastern leg services that did not stop at Meadowhall would gain 1 minute of journey time due to the faster route to the north. There are also changes in journey time related to those services which called at Meadowhall, and whether there are split/join services considered. For

Sheffield and South Yorkshire, the new direct services from London into Sheffield Midland are assumed to take between 85 and 87 minutes.[13]

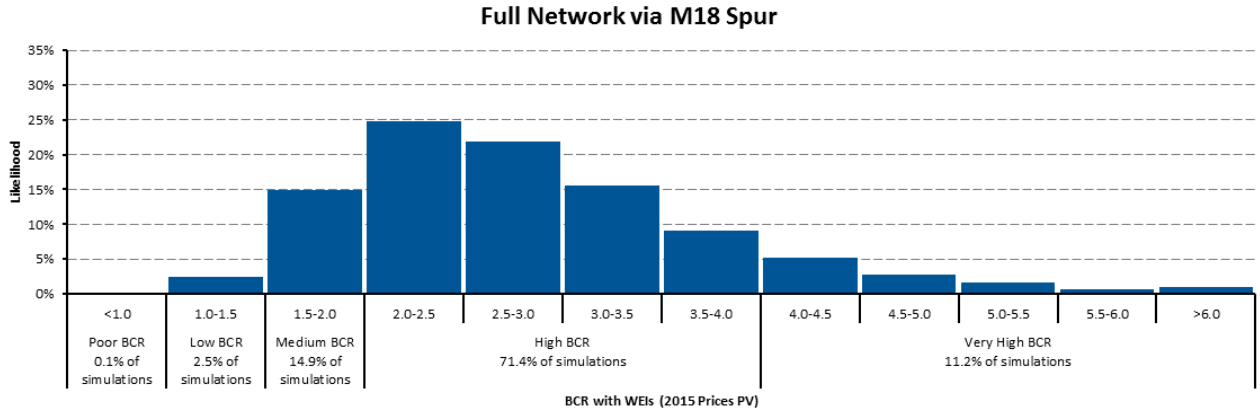
Full Network

5.4.3 We now turn our attention to the impact of serving Sheffield Midland with two classic compatible services per hour via the spur. There are a number of potential TSSs which would deliver a service of 2tph, and here we discuss the option which would return the highest level of benefits. The particular TSS we model is detailed in Appendix 2 and comprises the following changes to the TSS assumed for modelling HS2:

- changing the York portion from the third Leeds/York splitting and joining service into a portion travelling to Sheffield Midland splitting at the East Midlands Hub; and
- adding a new service using one of the paths previously reserved for a Heathrow service, which is a split/join service which would serve Sheffield Midland, Chesterfield and York.

5.4.4 Our analysis suggests this service would produce additional benefits over the Meadowhall Route of £2.1 billion including wider economic benefits, and an increase in revenue of £1.2 billion. At the same time, a reduction in capital costs (£1.2 billion) and an increase in operating costs (£1.5 billion) combine to increase the overall total costs for this option by just under £0.4 billion compared with the Meadowhall Route. If we look at the BCR range for the M18 Full Network as shown in Figure 5 with 2tph, we can see that the spot point BCR increases by 0.1 over the Meadowhall Route to 2.7.

Figure 5: Risk analysis – Full Network incorporating a Phase 2b eastern leg via M18/Spur (2tph)



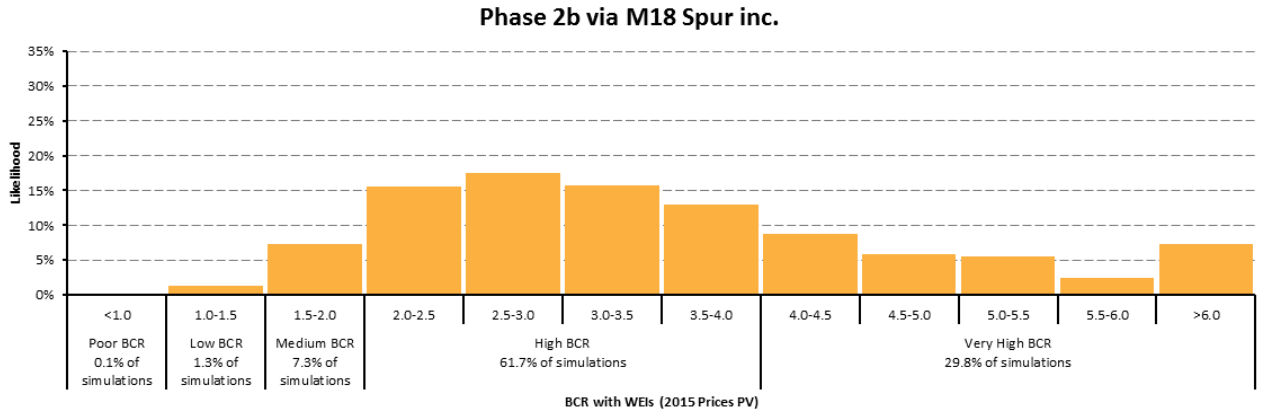
Phase 2b Increment

5.4.5 The impact at an incremental level is very similar to that seen for the Full Network with the incremental spot point BCR increasing slightly to 3.2. The BCR spread, for the Phase 2b M18

[13] These journey times are subject to change following a consideration of railway operations which may need to introduce additional time due to any splitting and joining of services.

Spur Route Increment with 2tph serving Sheffield, is shown in Figure 6 below. This again shows that the impact of the M18 Spur Route, when compared with the original Meadowhall Route, provides a marginal increase in value for money with a slight reduction in the probability of low value for money.

Figure 6: Risk analysis – Phase 2b Increment incorporating a Phase 2b eastern leg via M18/Spur (2tph)



5.4.6 The high level of benefits accruing from the M18 Spur Route comes, however, at the cost of increased operating and rolling stock costs, the opportunity cost of committing to using one of the spare paths now, and enhanced risks that it might be difficult to timetable or run the service reliably.

Alternative train service frequency (one train per hour)

5.4.7 The sections above consider the impact of serving Sheffield Midland with 2tph. We also estimated the costs and benefits of serving Sheffield Midland with only 1tph via the M18 Spur. This type of service offering matches the capacity for an HS2 train against the estimated demand from the South Yorkshire region. It provides enhanced services to Leeds due to the faster line of route and loss of Meadowhall stops, and retains 3tph to York in the modelled service pattern.

5.4.8 The spot point BCR for the Full Network was the same to one decimal place for 1tph or 2tph – at 2.7. The spot point BCR for the Phase 2b Increment was slightly higher for 1tph (3.3 to one decimal place) than for 2tph (3.2). While the option of 2tph generated higher benefits (£0.5 billion) and higher revenues (£0.2 billion), these additional benefits were partly offset by higher costs of £0.5 billion.

5.5 Phase 2b route with eastern leg via M18/ loop

5.5.1 The analysis above presents the use of the spur to Sheffield Midland. One of the key issues around this spur is the lack of northbound connectivity. We have undertaken an *indicative* assessment of the impact a northern connection would have on the HS2 scheme. It should be noted that the northern connection is based on an estimate of the operational requirements and journey times. We have also excluded any further rolling stock costs that may be required

– which may lead to an underestimation of the rolling stock needed to run any TSS via this route.[14]

5.5.2 One of the main strategic benefits of a loop arrangement is allowing connections between the city centres of Sheffield and Leeds – a key aspiration of Transport for the North. This aim can be accomplished through the addition of a junction between the classic network and the HS2 infrastructure around the Clayton area, and would form effectively a classic compatible loop off the main HS2 network infrastructure. HS2 Ltd is undertaking consultation on this proposal following the announcement of the Phase 2b route.

5.5.3 This loop could support a number of service options, and one obvious service offering would provide connections between Birmingham and Sheffield, and between Sheffield and Leeds. These services do, however, only cover HS2 services and as such would not provide the conditional outputs specified as part of Northern Powerhouse Rail, which could be added as additional services to the HS2 offer, should Transport for the North select this option.

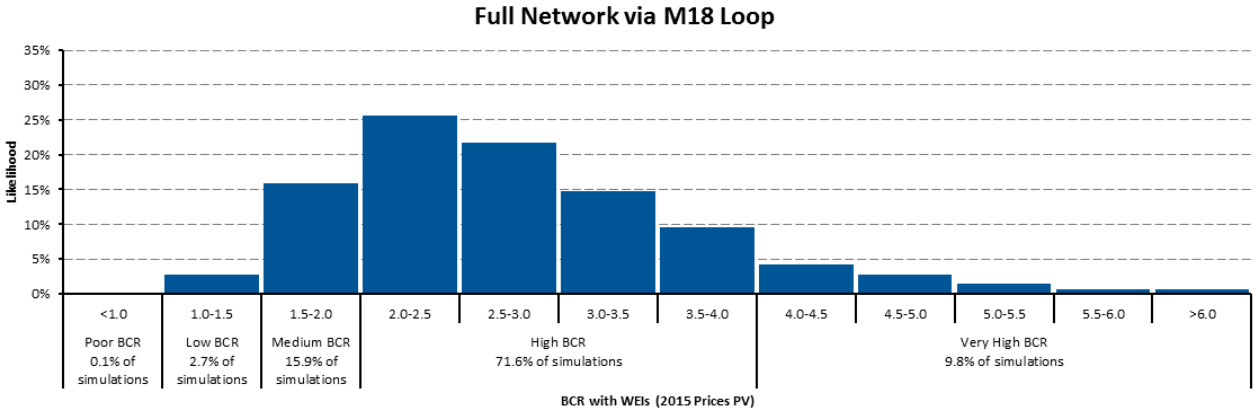
Full Network

5.5.4 We have undertaken an indicative assessment of serving Sheffield Midland with 2tph using the M18 Spur Route while also building a northern junction to allow services back onto the main HS2 route. Figure 7 shows that the spot point BCR for the loop option is similar to the M18 Spur Route at 2.7. We find that the M18 loop service would produce additional net transport benefits over the Meadowhall Route of £2.0 billion including wider economic benefits, and an increase in revenue of £1.1 billion. In comparison with the Meadowhall Route, the M18 Loop would likely give an incremental reduction in capital costs of around £0.9 billion and an increase in operating costs of £1.7 billion.

5.5.5 The option of a northern loop connection will incur additional cost over the M18 Spur and our indicative assessment puts the additional capital costs at just under £0.3 billion and operating costs at just under an extra £0.2 billion. The loop would provide several service options and, as an indicative assessment, we have estimated the benefits that could be provided by diverting the HS2 Birmingham to Leeds services via such a loop. That analysis suggests net transport benefits are slightly lower (-£5 million) compared with the M18 Spur, although clearly there could be a wider strategic impact of improved connectivity between Sheffield Midland and cities to the north.

[14] These issues could mean that the journey time assumptions require revision once the full design and train service timetabling work has been completed.

Figure 7: Risk analysis – Full Network incorporating a Phase 2b eastern leg via M18/Loop (2tph serving Sheffield Midland and 2tph serving Birmingham and Leeds)

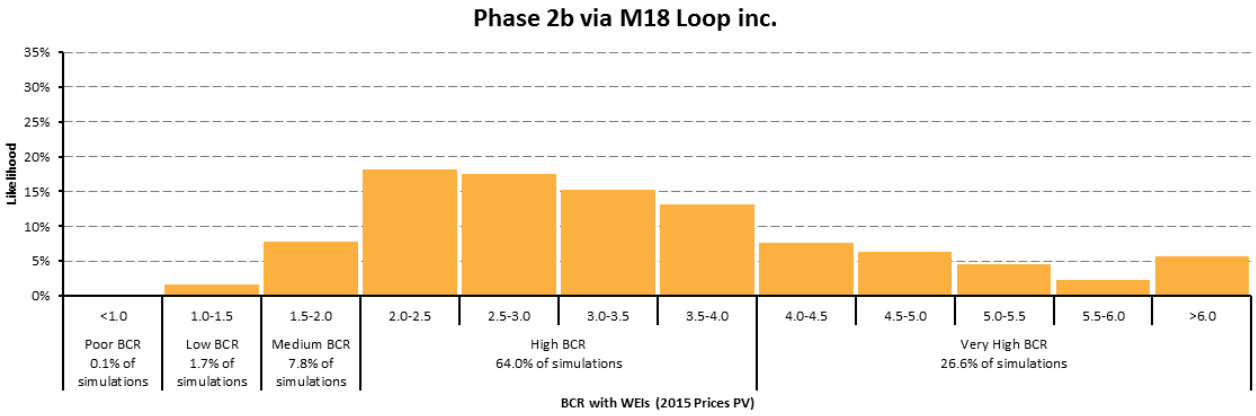


5.5.6 The BCR spread for this is shown in Figure 7 above. We can see from the analysis that the BCR spread is very similar to that produced for the Full Network M18 Spur Route 2tph test.

Phase 2b Increment

5.5.7 The impact of the M18 Loop Route at an incremental level is very similar to that seen for the Full Network, with the incremental spot point BCR increasing slightly to 3.1 compared with 3.0 for the Meadowhall Route. The BCR spread for the Phase 2b M18 Loop Route increment is shown in Figure 8 below. This again shows that the M18 Route, when compared with the original Meadowhall Route, provides a marginal increase in value for money with a slight reduction in the probability of low value for money.

Figure 8: Risk analysis – Phase 2b Increment incorporating a Phase 2b eastern leg via M18/Loop (2tph serving Sheffield Midland and 2tph serving Birmingham and Leeds)



5.6 Conclusions

5.6.1 Our analysis suggests that the M18 Spur Route provides high value for money whether or not Sheffield is served with 1tph or 2tph. Our assessment has compared the preferred M18 Spur Route with the original Meadowhall Route, and found that it provides slightly higher BCRs, with a similar BCR spread, and a slightly lower likelihood of supplying low value for money.

5.6.2 Our indicative assessment of adding a northern loop connection shows that, while there are additional costs, the overall BCR is similar to the M18 Spur Route. Further development is expected by Transport for the North to examine the benefits of providing additional services between Leeds and Sheffield as part of the Northern Powerhouse Rail business case.

5.6.3 The rest of this document looks at how robust our conclusions on Phase 2b are, notably by assessing their sensitivity to changes in key assumptions such as the forecasts of GDP, population growth and variations in fares. We have used the Meadowhall Route for the majority of this sensitivity analysis as it is closest to the currently consulted route. However, the M18 route options provide similar value for money to Meadowhall, while the vast majority of the route and journey times for Phase 2b as a whole are the same. Hence, the implications of the sensitivity analysis in the following chapter apply equally to the M18 routes.

6 Robustness of the case

6.1 Introduction

6.1.1 The appraisal of HS2 draws on a number of data sources and appraisal assumptions that seek to forecast the costs and benefits of the scheme over a 60-year timeframe, i.e. 60 years from the opening of Phase Two in 2033. A number of these variables are subject to some uncertainty and could theoretically have a significant impact on the Economic Case for HS2. For example, the rate of growth of demand, the level of demand, fares, cost and optimism bias assumptions. This chapter examines the impact that changes to these key variables could have on the value for money of the scheme.

6.2 Structure of this chapter

6.2.1 The analysis in this Economic Case covers a wide range of data sources and appraisal assumptions. In order to help explain our assessment, we have grouped the analysis in this chapter into three categories, assessing:

- the impact of different long-term demand assumptions;
- the impact of different cost assumptions; and
- the impact of different appraisal assumptions.

6.2.2 We have undertaken the majority of our assessment of the robustness of the case on the Meadowhall Route, as it represents the line closest to the currently consulted route. As explained in Chapter 5, however, the alternative route options do not have a significant impact on the BCR. We therefore consider that our primary conclusions from this chapter would apply equally to all route options considered in this Economic Case.

6.2.3 The results of this chapter are compared with the results shown in section 5.3 that showed:

- a central BCR for the Full Network of 2.6 with around 80% of modelled scenarios being within the high or very high value for money categories; and
- a central BCR for the Phase 2b Increment of 3.0 with around 88% of modelled scenarios being within the high or very high value for money categories.

6.3 Assessing the impact of different long-term demand assumptions

6.3.1 Our forecast of the number of passengers expected to travel on HS2 remains a central element of the Economic Case. Our standard approach to forecasting demand growth remains unchanged from previous economic cases. A number of factors – including the cost of travel, population growth, employment rates and economic (GDP) growth over time – drive transport demand.

6.3.2 Guidance on the relationships between rail demand growth and other economic factors is set out in WebTAG and is, in large part, based on the rail industry's PDFH. Our analysis also draws

on data included within the WebTAG Databook. Our analysis is based on the most recent version of the Handbook[15] and the December 2015 version of the WebTAG Databook.[16]

6.3.3 As set out in Chapter 3, our demand forecasts have also been updated for this Economic Case to:

- incorporate an update in the base year matrices; and
- fix our forecast at 20 years in the future – with a final forecast year of 2036 in this Economic Case – with passenger demand held constant thereafter.

6.3.4 The update to our demand forecasts has had a significant impact on improving the case for HS2. The following sections assess the impact of changing these demand forecasts on the value for money of the scheme.

i) Higher levels of demand

6.3.5 In this section, we test the impact on the value for money of the scheme if we assume that GDP growth rates are 10% *higher* than the GDP deflator referenced in the WebTAG Databook,[17] GDP growth being one key factor determining rail demand. This increase in GDP growth would lead to an increase in rail demand of around 6% by 2036. As can be seen in Figure 9 and Figure 10, the increase in forecast GDP growth rates shifts the risk analysis results slightly to the right when compared with the Meadowhall Route, indicating that higher levels of demand would increase the likelihood that the HS2 scheme will deliver high value for money:

- For the Full Network 90% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment 94% of modelled scenarios are within the high or very high value for money categories.

[15] PDFH Version 5.1. – more details can be found at http://www.raildeliverygroup.com/pdfc/about-the-pdfh.html

[16] *WebTAG: TAG Databook*, December 2015. Available at: www.gov.uk/government/publications/webtag-tag-data-book-december-2015.

[17] See the Annual Parameters worksheet in the December 2015 WebTAG Databook. By 10% higher we take the yearly growth rate and increase the forecast for each year by 10%. For example, an annual growth rate of 2.5% is increased to 2.75%.

Figure 9: Risk analysis results for the Full Network Meadowhall Route: higher GDP

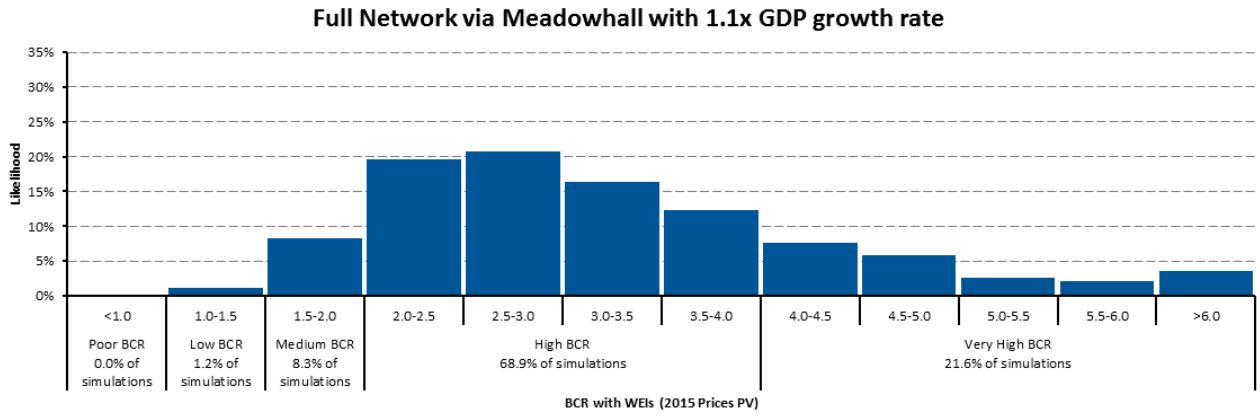
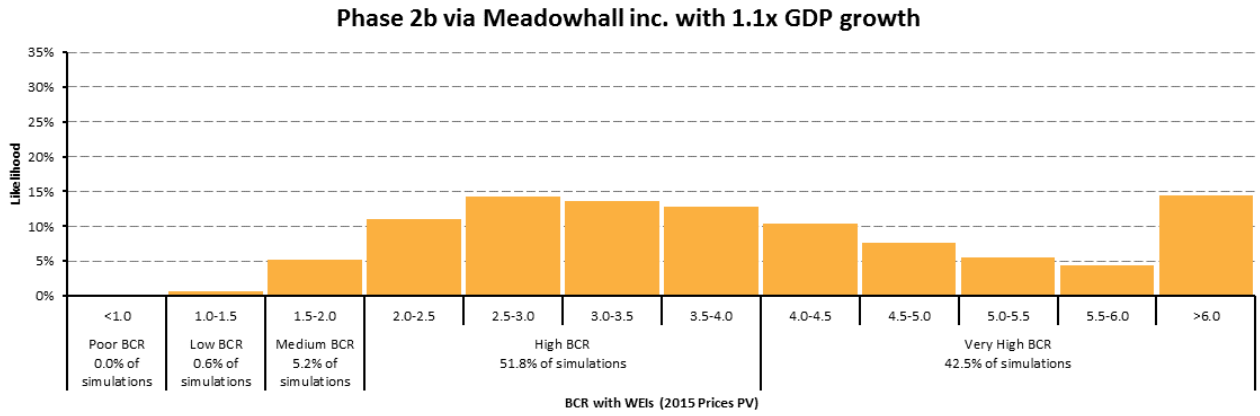


Figure 10: Risk analysis results for the Phase 2b Increment Meadowhall Route: higher GDP



ii) Lower levels of demand

6.3.6 In this section, we test the impact on the value for money of the scheme if we assume yearly GDP growth rates are 10% *lower* than the GDP deflator referenced in the WebTAG Databook. As can be seen in Figure 11 and Figure 12, the decrease in forecast GDP growth rates reduces demand for HS2 services. This shifts the risk analysis results slightly to the left when compared with the Meadowhall Route:

- For the Full Network 62% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment 72% of modelled scenarios are within the high or very high value for money categories.

Figure 11: Risk analysis results for the Full Network Meadowhall Route: lower GDP

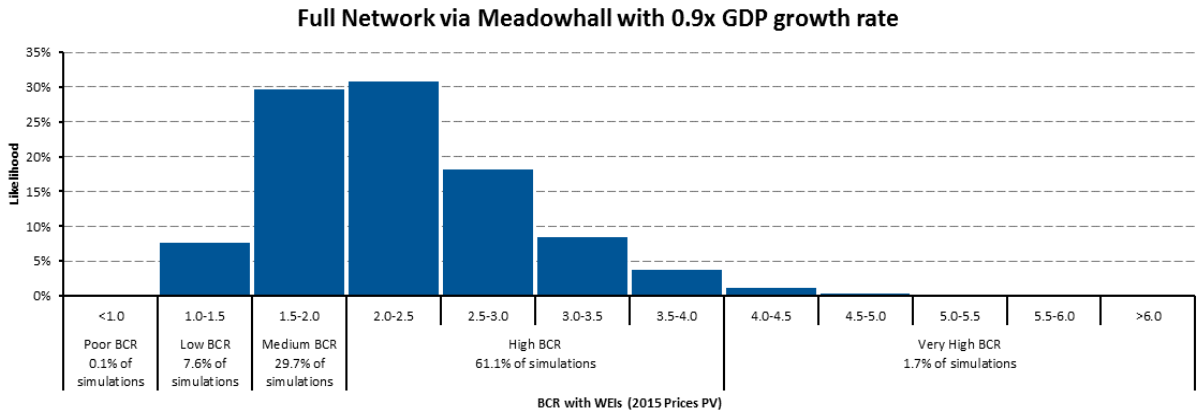
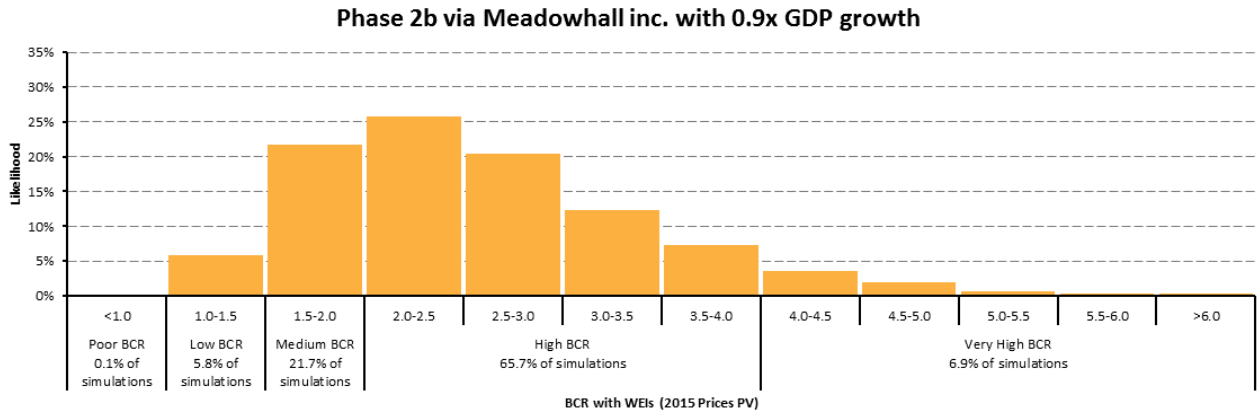


Figure 12: Risk analysis results for the Phase 2b Increment Meadowhall Route: lower GDP



iii) Alternatives to the final forecast year – increasing benefits in line with population growth

6.3.7 As summarised in Chapter 5, we have held benefits constant after the final forecast year (2036 for this Economic Case). This approach leads to potentially conservative estimates of the return on investment for HS2. Holding benefits constant after 2036 implicitly assumes the number of trips per person falls after the final forecast year, as population is forecast to continue growing. We have therefore looked at the impact of assuming that demand continues to grow in line with Office for National Statistics (ONS) population forecasts.

6.3.8 In changing this assumption, we are implicitly assuming that the number of trips per person is held constant after 2036. As can be seen in Figure 13 and Figure 14, this assumption generates an increase in the demand for HS2 services and once again shifts the risk analysis results slightly to the right when compared with the Meadowhall Route:

- For the Full Network 90% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment 93% of modelled scenarios are within the high or very high value for money categories.

Figure 13: Risk analysis results for the Full Network Meadowhall Route: assuming benefits increase in line with population growth after final forecast year (2036)

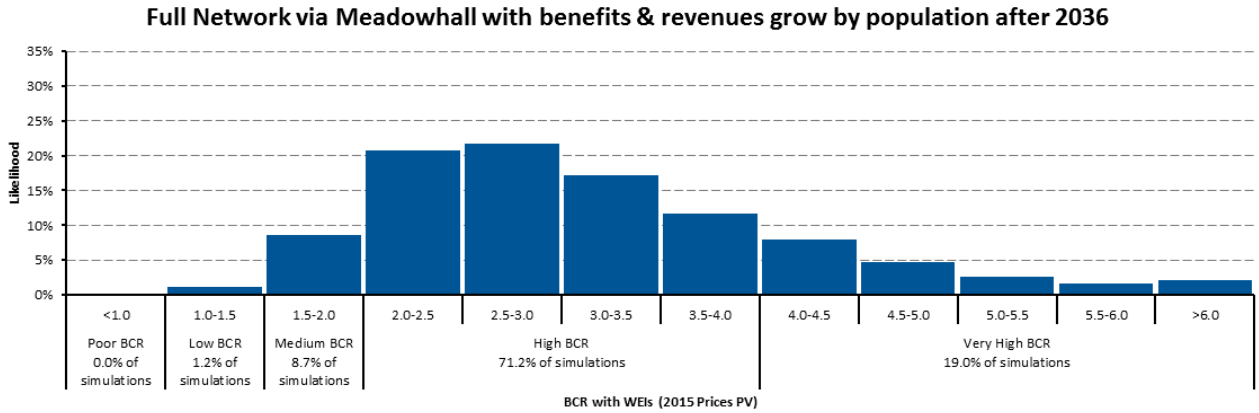
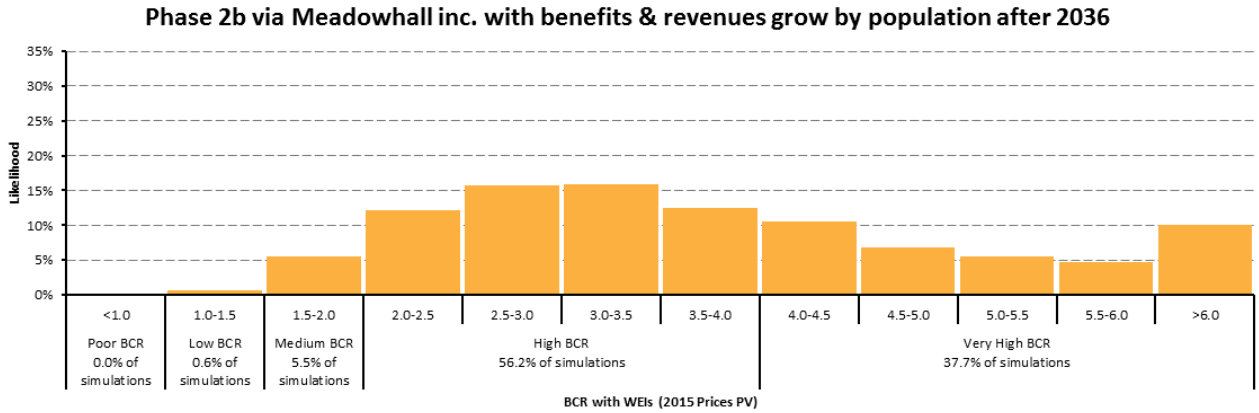


Figure 14: Risk analysis results for the Phase 2b Increment Meadowhall Route: assuming benefits increase in line with population growth after final forecast year (2036)



6.4 Assessing the impact of different cost assumptions

6.4.1 Our core appraisal assumptions incorporate two elements of contingency:

a) optimism bias at 40% for Phase Two construction costs following standard HM Treasury and DfT appraisal guidance; and

b) higher construction inflation for the years 2015 to 2020 – which adds an aggregate 8% to Phase Two construction costs.

Higher construction inflation (project-specific inflation) is an estimate of the higher construction inflation that the project may incur going forwards to 2020/21 and reflects the fact that construction inflation has been higher than general inflation in recent years, and there is a risk that this may continue over the next few years.

Construction costs – optimism bias

6.4.2 To test the impact on the value for money of higher Phase Two construction costs, we assess the impact on the BCR of increasing Phase Two optimism bias to 50%, i.e. an increase of 10 percentage points from our core assumption. An assumption of 50% optimism bias was

applied, in addition to higher construction inflation for the years 2015–2020, giving a total contingency for Phase Two of about 58%. The impact of this higher level of optimism bias will reduce the central BCR estimate for the scheme to 2.6, as it will increase the net costs to government of the scheme. Despite this, our risk analysis still forecasts that the likely outcome for the scheme is a BCR in the high or very high value for money categories.

- For the Full Network M18 Loop Route 74% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment M18 Loop Route 86% of modelled scenarios are within the high or very high value for money categories.

Figure 15: Risk analysis result for the Full Network M18 Route: assuming 50% optimism bias

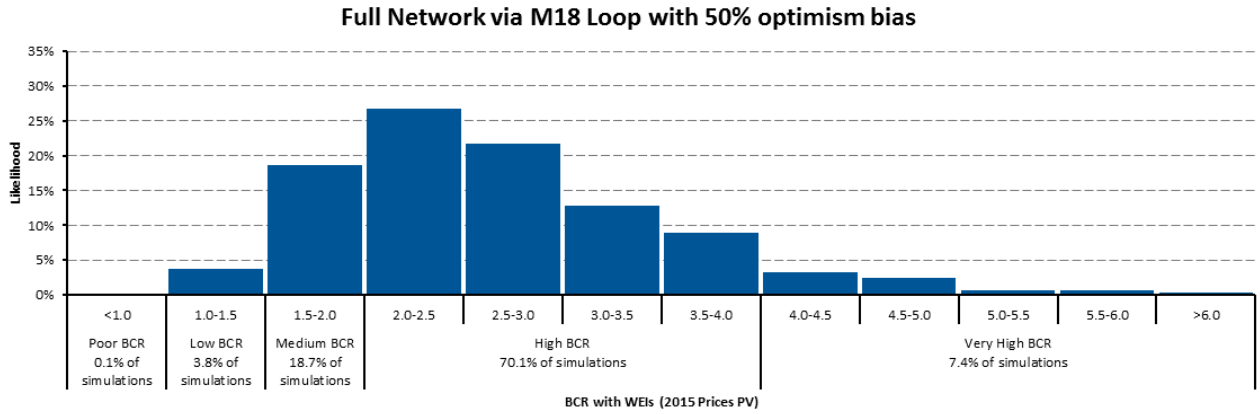
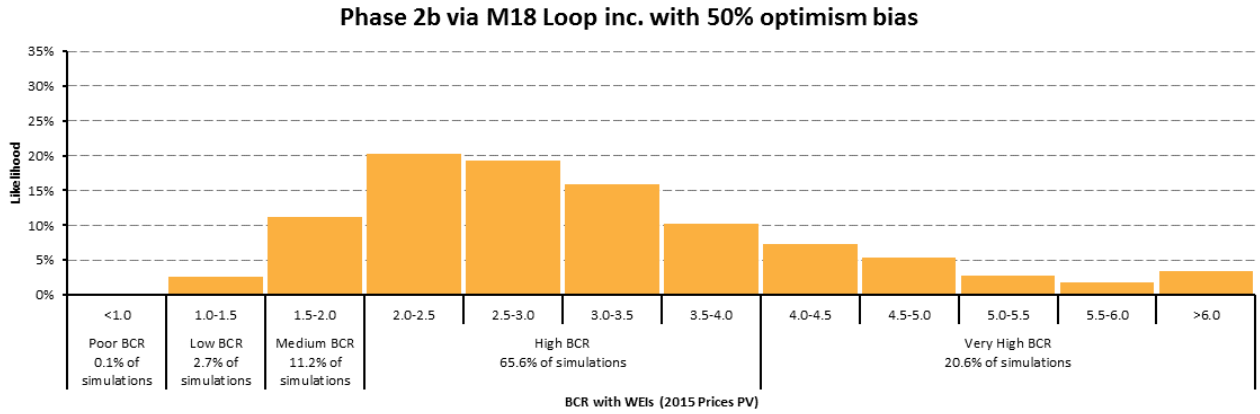


Figure 16: Risk analysis results for the Phase 2b Increment M18 Route: assuming 50% optimism bias



Delivering efficiency savings

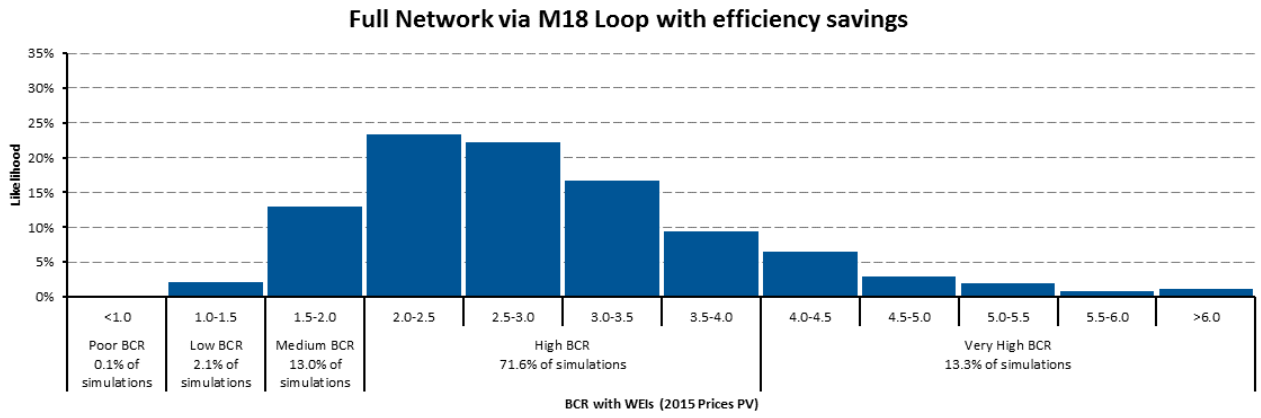
6.4.3 As set out in the Financial Case, a central assumption at this stage of the project is that Phase 2b will be delivered within the agreed Spending Review 2015 funding envelope. This is consistent with the cost for Phase 2b with the M18 Route option, including a loop to serve Sheffield Midland evaluated in this Economic Case.

6.4.4 As set out in the National Audit Office's report of July 2016,[18] at the time of Spending Review 2015 some £7 billion of savings was required to bring the costs of the whole of Phase Two within the agreed funding envelope. Owing to a rigorous programme of efficiency identification and management, HS2 Ltd did not seek additional funding from Spending Review 2015 beyond the funding envelope agreed at Spending Review 2013, uprated for inflation. The majority of these identified efficiencies are described in more detail in the Financial Case.

6.4.5 In this section we consider the impact on the BCR if HS2 were to successfully deliver the efficiency savings set out in the Financial Case while *holding all other appraisal assumptions constant*. As expected under this scenario the risk analysis shifts to the right when compared with the central scenarios, reflecting the fact that this scenario delivers the same economic benefits but for a lower cost:

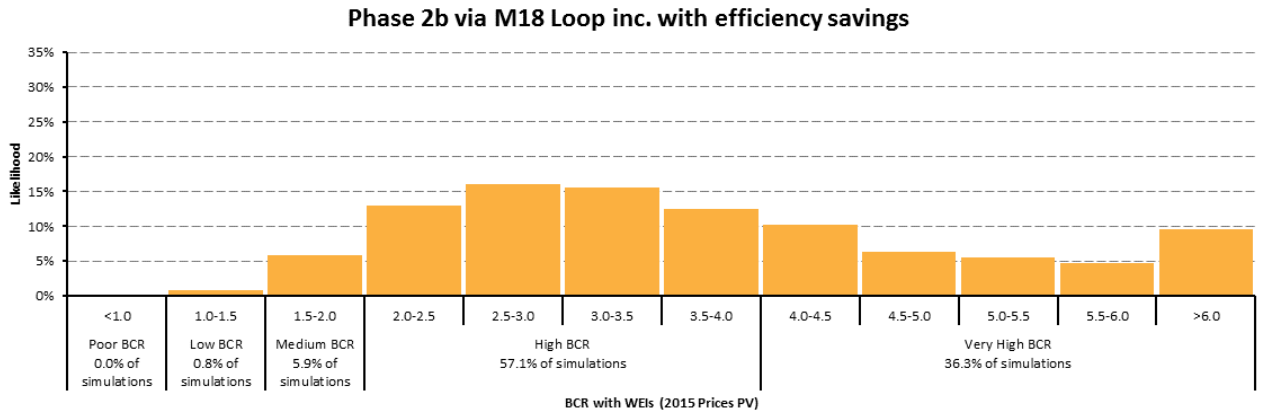
- For the Full Network the point estimate BCR (including wider WebTAG economic impacts) increases to 2.8 (compared with 2.6 for the Meadowhall Route). The risk analysis of this scenario shows just under 85% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment the point estimate BCR (including wider economic impacts) increases to 3.7 (compared with 3.0 for the Meadowhall Route). The risk analysis of this scenario shows 93% of modelled scenarios are within the high or very high value for money categories.

Figure 17: Risk analysis results for the Full Network: assuming delivery of potential efficiency savings



[18] *Progress with Preparations for High Speed 2*, June 2016. Available at: www.nao.org.uk/report/progress-with-preparations-for-high-speed-2/.

Figure 18: Risk analysis results for the Phase 2b Increment: assuming delivery of potential efficiency savings



6.5 Assessing the impact of different appraisal assumptions

6.5.1 This section outlines the impact changes to key appraisal assumptions have on the estimated value for money of the Meadowhall Route – namely fares policy and reliability.

Impact of fares policy assumptions

6.5.2 The fares policy assumption is a key component of the BCR for the scheme as future rail fares policy directly feeds through to our estimates of the likely revenue returned from the scheme. For this Economic Case, we have maintained this Government's policy on rail fares, reflecting the commitment to maintain rail fares at 0% above RPI for the duration of this Parliament. Rail fares are then assumed to increase at RPI+1% beyond 2020.

6.5.3 In this section we consider two alternative scenarios:

a) a lower fares scenario where we assume that fares increase at RPI+0% per year after 2020; and

b) a higher fares scenario where we assume that fares increase at RPI+2% per year after 2020.

6.5.4 These fares scenarios drive changes to two underlying relationships which affect the value for money of the scheme. The combination of these two relationships generates the overall impact on the value for money of the scheme.

a) Firstly, the real-terms change in rail fares will change the forecast of passenger numbers using HS2 – with the higher (lower) fares scenario reducing (increasing) the forecast of passenger numbers compared with our central forecast.

b) Secondly, the real-terms change in rail fares will change the forecast revenue – with the higher (lower) fares scenario increasing (decreasing) the forecast revenue per passenger compared with our central forecast.

i) Lower fares

6.5.5 As shown in Figure 19 and Figure 20, the lower fares assumption has a positive impact on the risk analysis:

- For the Full Network 96% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment 98% of modelled scenarios are within the high or very high value for money categories.

Figure 19: Risk analysis results for the Full Network Meadowhall Route: lower fares sensitivity test

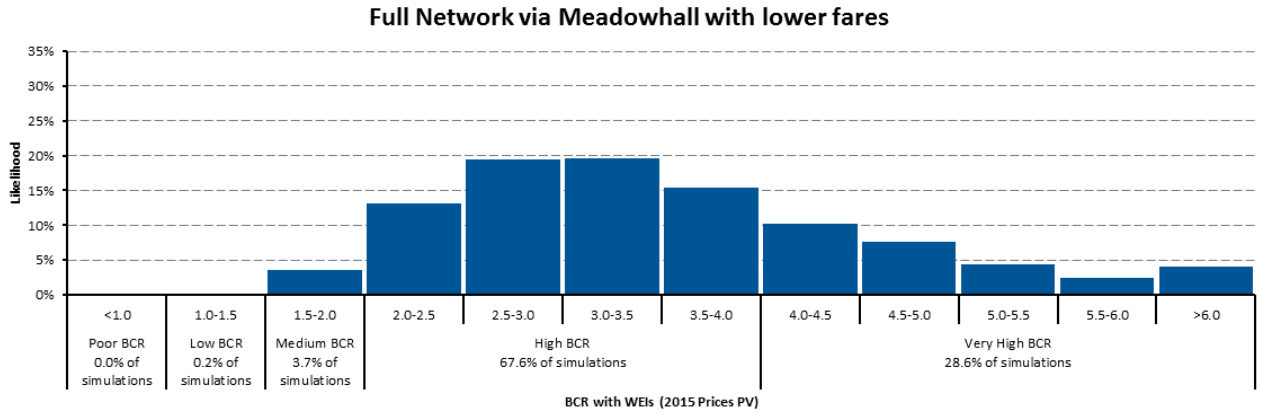
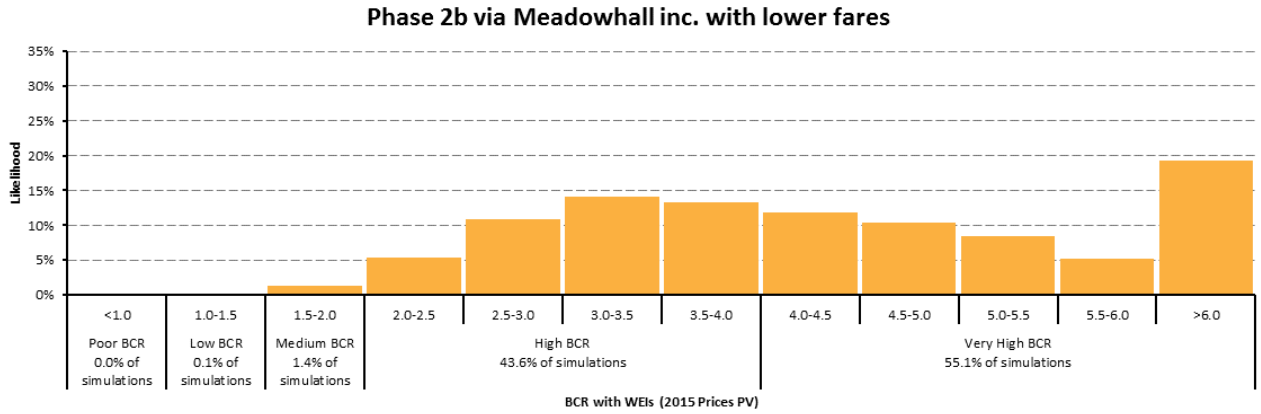


Figure 20: Risk analysis results for the Phase 2b Increment Meadowhall Route: lower fares sensitivity test



ii) Higher fares

6.5.6 As shown in Figure 21 and Figure 22, the higher fares assumption has a positive impact on the risk analysis:

- For the Full Network 45% of modelled scenarios are within the high or very high value for money categories.
- For the Phase 2b Increment 53% of modelled scenarios are within the high or very high value for money categories.

Figure 21: Risk analysis results for the Full Network Meadowhall Route: higher fares sensitivity test

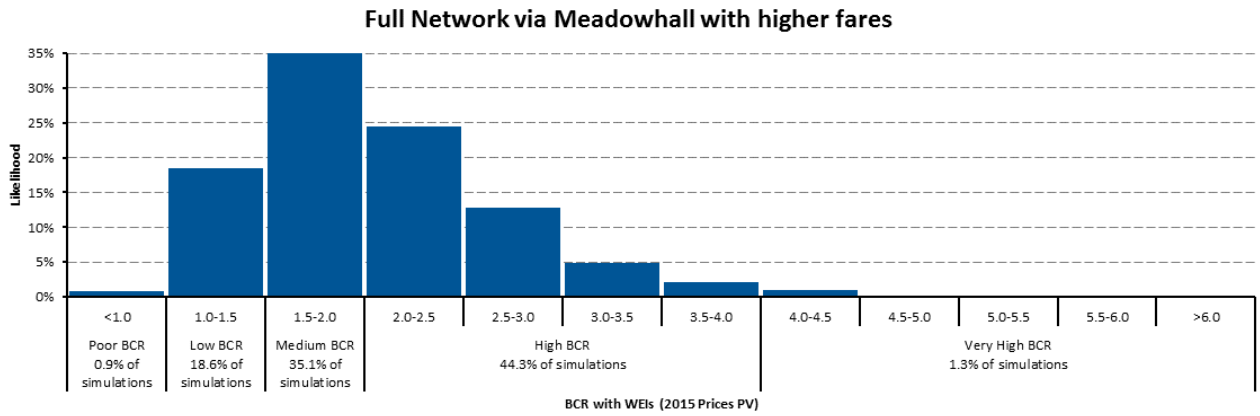
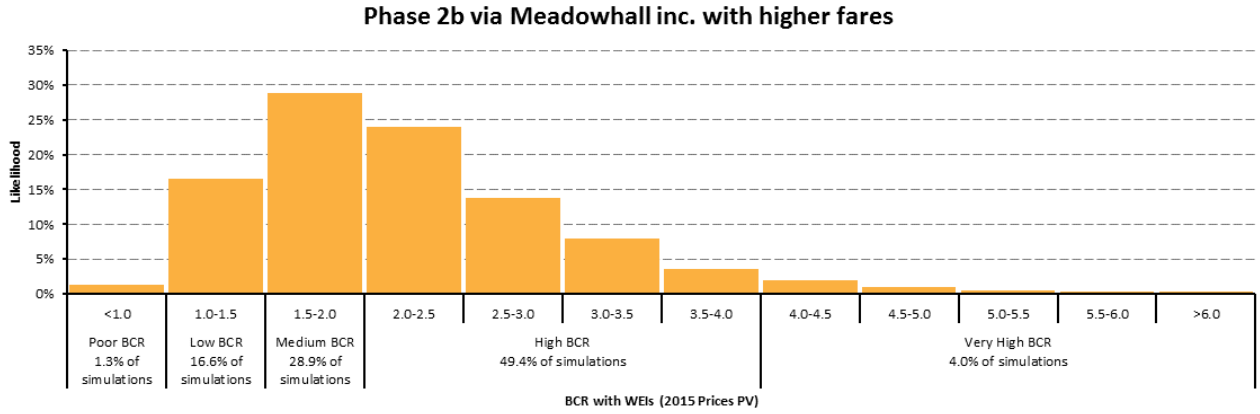


Figure 22: Risk analysis results for the Phase 2b Increment Meadowhall Route: higher fares sensitivity test



Reliability benefits

6.5.7 A key benefit of HS2 concerns the opportunity for improved reliability in the service, which feeds through to reduced journey times for HS2 passengers, and which is included within the monetised benefits for HS2. While we capture the higher reliability of high speed services on the HS2 network in the Economic Case, our modelling does not reflect the reductions in delays that could be achieved by relieving the pressure on the rest of network.

6.5.8 Appendix 5 provides a breakdown of the estimated benefits for the Meadowhall Route, which shows that reliability benefits account for just over 10% of overall scheme benefits. Reliability benefits are subject to some uncertainty as we seek to estimate the potential improvements that an operational high speed railway will bring. To reflect the potential impact of this uncertainty on the value for money of the scheme, we tested the impact of removing any reliability benefits from our estimated benefits for the HS2 scheme. This is an extreme test, in that it assumes the HS2 network, despite being built for purpose, is no more reliable than the existing classic network.

6.5.9 As expected, removing the benefits associated with reliability reduces the value for money of the HS2 scheme:

- Figure 23 shows that for the Full Network 50% of modelled scenarios are still within the high or very high value for money categories.
- Figure 24 shows that for the Phase 2b Increment 64% of modelled scenarios are still within the high or very high value for money categories.

Figure 23: Risk analysis results for the Full Network Meadowhall Route: assuming no reliability benefits

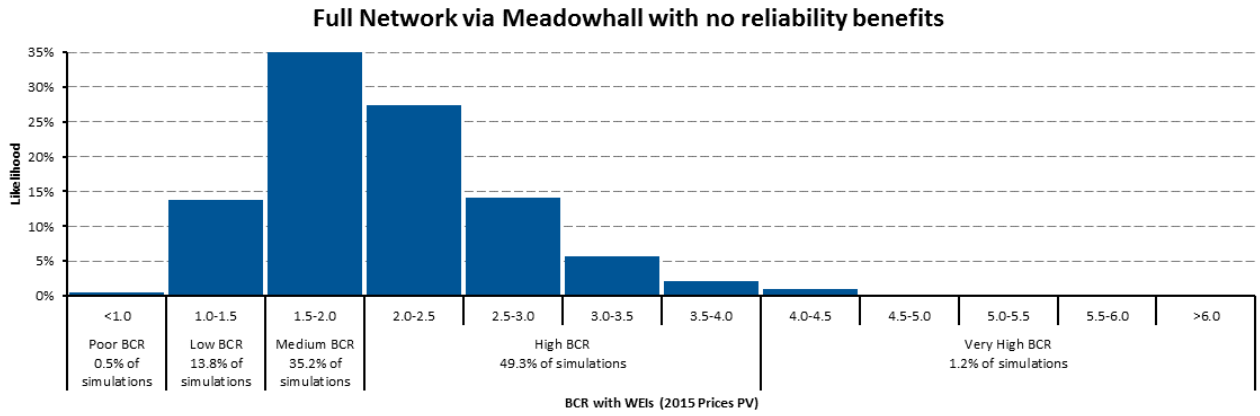
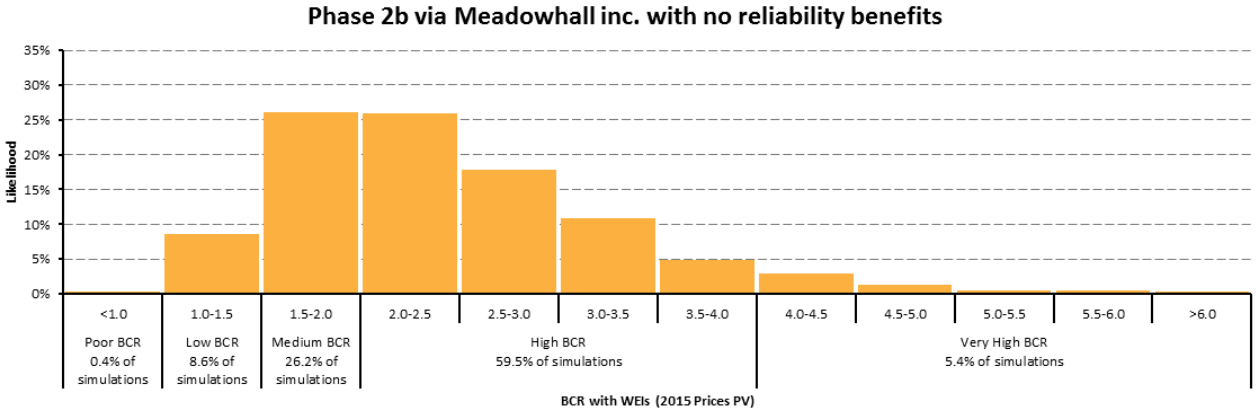


Figure 24: Risk analysis results for the Phase 2B Increment via Meadowhall Route: assuming no reliability benefits



6.6 Conclusions

6.6.1 This chapter has assessed the impact of various upside and downside risks on the value for money of the HS2 network. The analysis summarised above shows that, for almost all the risks, in the majority of risk analysis scenarios the Phase 2b scheme is still in the high or very high value for money categories.

7 Extending our appraisal

7.1 Introduction

7.1.1 This Economic Case so far has focused on the case for the HS2 network and HS2's standard approach to modelling and forecasting which follows the latest WebTAG on rail appraisal by the DfT. There are, however, a number of elements in the business case which are not currently assessed as part of the primary BCR measure. Some of these elements have the potential to add significant benefits to the scheme. We report these appraisal issues in this section.

Endogenous demand response

7.1.2 The PFM is a highly complex and detailed model looking at the performance of HS2 on the existing railway network. In particular, it takes in exogenous demand growth from an external source and uses this profile to forecast the future demand use for HS2. These elements follow standard transport modelling practice. However, there is one element of standard transport modelling which HS2 does not undertake, that of endogenous forecasting.

7.1.3 In essence, this means taking account of proposed and committed upgrades to sections of the existing rail network between now and the completion of HS2, and allowing passenger demand to respond to these schemes. This can have two effects. Where there are journey time reductions, additional services or market connections we would expect demand to grow. This demand is not currently modelled. The converse, however, is also true, in that where there are no committed schemes and demand is forecast to grow, increased levels of crowding would tend to reduce the level of demand on certain routes. Again this demand-dampening effect is not taken into account.

7.1.4 We have conducted some investigation to help us understand the impacts of the HS2 model by not undertaking this additional step in our modelling process. Our early investigations suggest that, for the rail network overall, the potential demand under-forecast is more significant than any impacts as a result of crowding, meaning we are likely under-forecasting overall demand. The scale of the underestimate is, however, unlikely to significantly change the BCR.

The impact of fixed land-use patterns

7.1.5 One outstanding limitation in the standard appraisal approach relates to the treatment of land-use change and the assessment of the impact of land-use change as a result of HS2. There are two issues at work here. The first is that the standard appraisal method is known to produce inaccurate results when used in circumstances where land-use has been allowed to change within the transport modelling framework.

7.1.6 Secondly, we expect that the scheme will trigger significant development in the areas immediately around HS2 stations, as they would become considerably more attractive places to locate for business. Any increase in the employment density around stations is likely to result in higher levels of HS2 and rail patronage, and higher levels of benefits and revenues as a result. These have not been captured in this analysis.

7.1.7 However, given the need to ensure comparability of results, we have not deviated from WebTAG, and we will conduct further analysis to better understand the balance of the two effects.

Impacts of disruption

7.1.8 HS2 will have an impact during the build phase in a number of areas across the country both on the existing railway network and on the local road network. Likely payments under existing legislation for these effects are already accounted for in the cost measures. However, there will likely also be a social welfare impact that is not currently assessed. In the majority of these cases, while there are important local effects, we would not expect the disruption to materially affect the overall value for money conclusion, given the relatively short timescales compared with the likely lifespan of the HS2 network, and numbers of people impacted when compared with the total number of passenger beneficiaries.

Station improvements

7.1.9 In a number of locations, HS2 will either require the building of new stations or have a considerable impact on existing stations. Both these impacts may have a combination of effects such as:

- improved passenger flow or connections in and around the stations;
- an enhanced retail offering;
- ambience impacts as a result of new station facilities and infrastructure.

7.1.10 The assessment of some of these elements, such as changes in station ambience, is allowed for in WebTAG (Unit A5.3) covering some values from the PDFH. HS2 Ltd currently does not put any value on these aspects of station improvements due to the uncertainty around monetising them though we do recognise them as important qualitative benefits.

Resilience and choice

7.1.11 The addition of the HS2 network alongside the existing rail network also improves the choice available to passengers. Widening the options available is an improvement, with passengers not only gaining the benefits of additional route options to get to their destination but also the ability to manage around any significant disruption on the rail network. For example, if there were disruption on the ECML, HS2 would provide an additional alternative route to get to some destinations.

7.1.12 While an assessment at this early stage of the value of these new choices and the resilience they may bring is speculative, in practice we believe that a wider choice for passengers, and increased resilience for the network, is a significant benefit for the network.

Appendix 1 – Modelling and appraisal approach

PLANET modelling, inputs and assumptions

Our modelling approach utilises the PFM, a detailed description of which is provided in *PLANET Framework Model (PFM V6.1c) – Model Description.* Its main aim is to provide forecasts of demand to drive the appraisal of HS2.

We have undertaken a series of model developments that build upon PFM V5.2 since September 2014 which have resulted in PFM V6.1c. This incremental approach has been fully documented and published in the report *Model Development Report: PLANET Framework Model Version 6.1c.* In order to understand the impacts of these incremental changes, HS2 Ltd has undertaken analysis on the changes to the benefits and revenues on each incremental version. We have documented this analysis and published it in the report *Summary of Key Changes to the Economic Case 2015 to 2016.*

HS2 Ltd has updated its demand forecasts and input assumptions to reflect industry guidance and recommendations at the time of model development. We describe these updates within the following three documents: *Model Development Report: PLANET Framework Model Version 6.1c*; *Model Development Report, PFMv5.2 to PFMv6.1c Updating the Exogenous Forecast*; and *Assumptions Report: PLANET Framework Model Version 6.1c,* which are published alongside this report.

Appendix 2 – Scheme service patterns

Western leg: Meadowhall Route

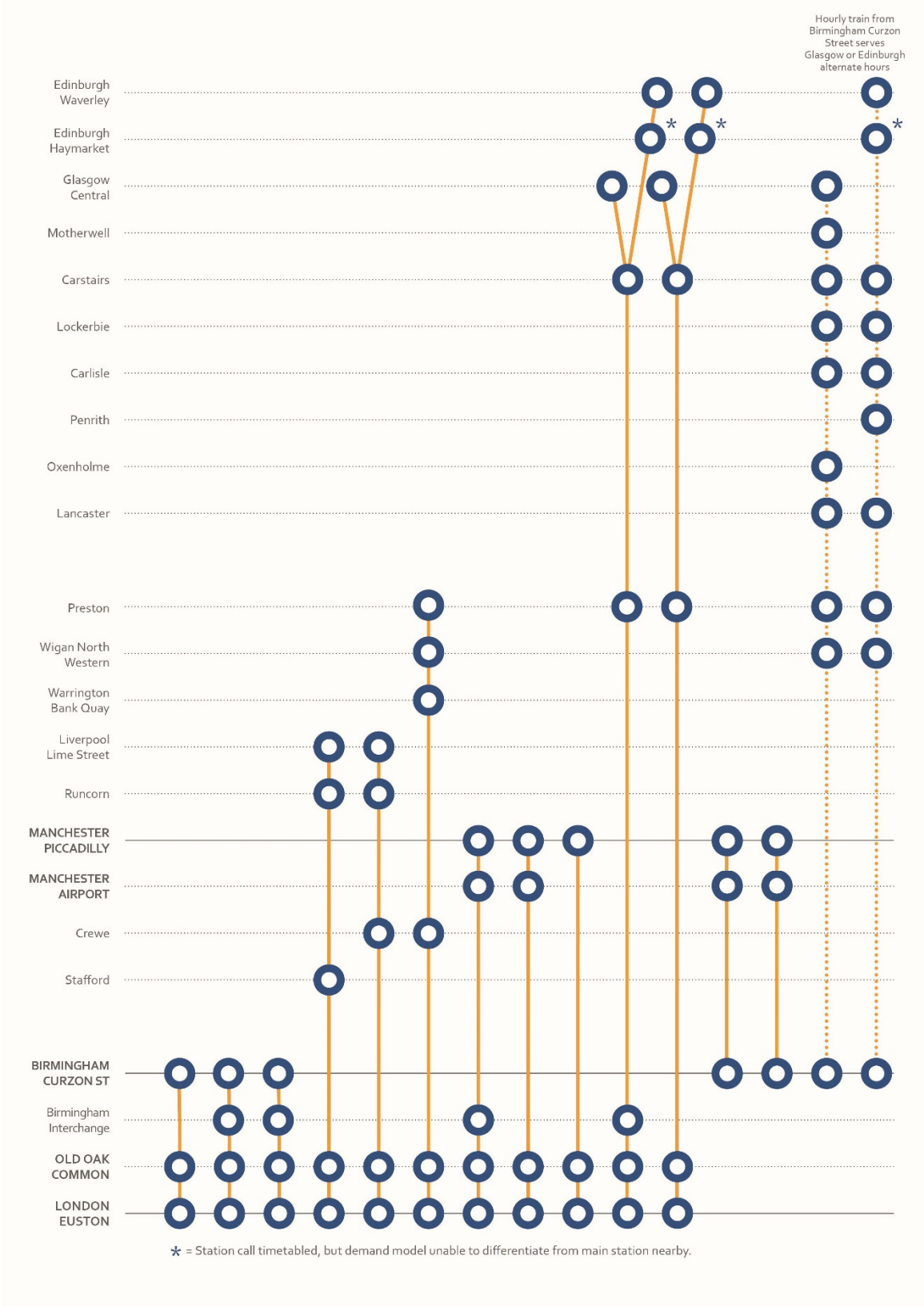


Figure 25: Scheme service pattern for the western leg: Meadowhall Route

Eastern leg: Meadowhall Route

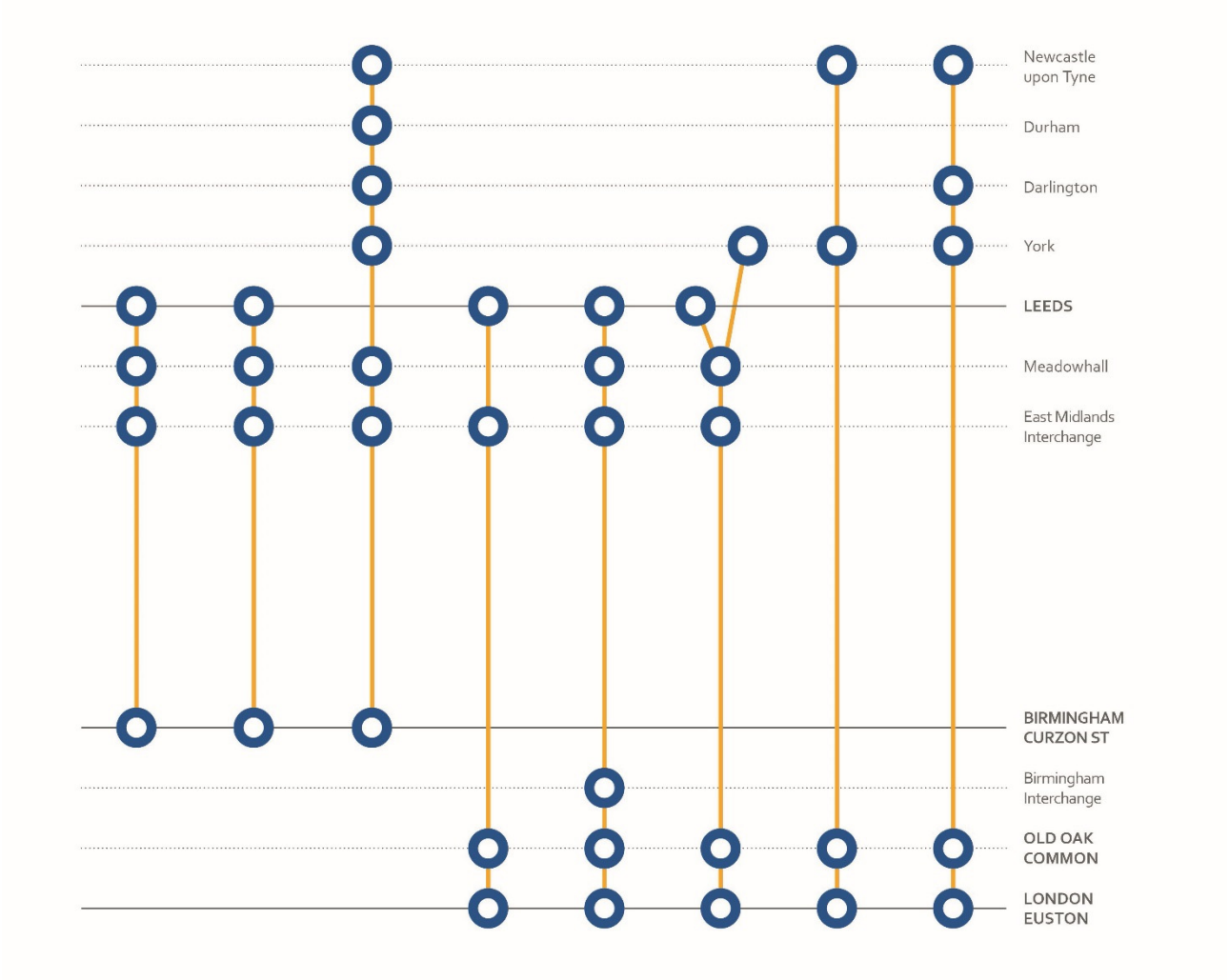


Figure 26: Scheme service pattern for the eastern leg: Meadowhall Route

Eastern leg: M18 Spur Route

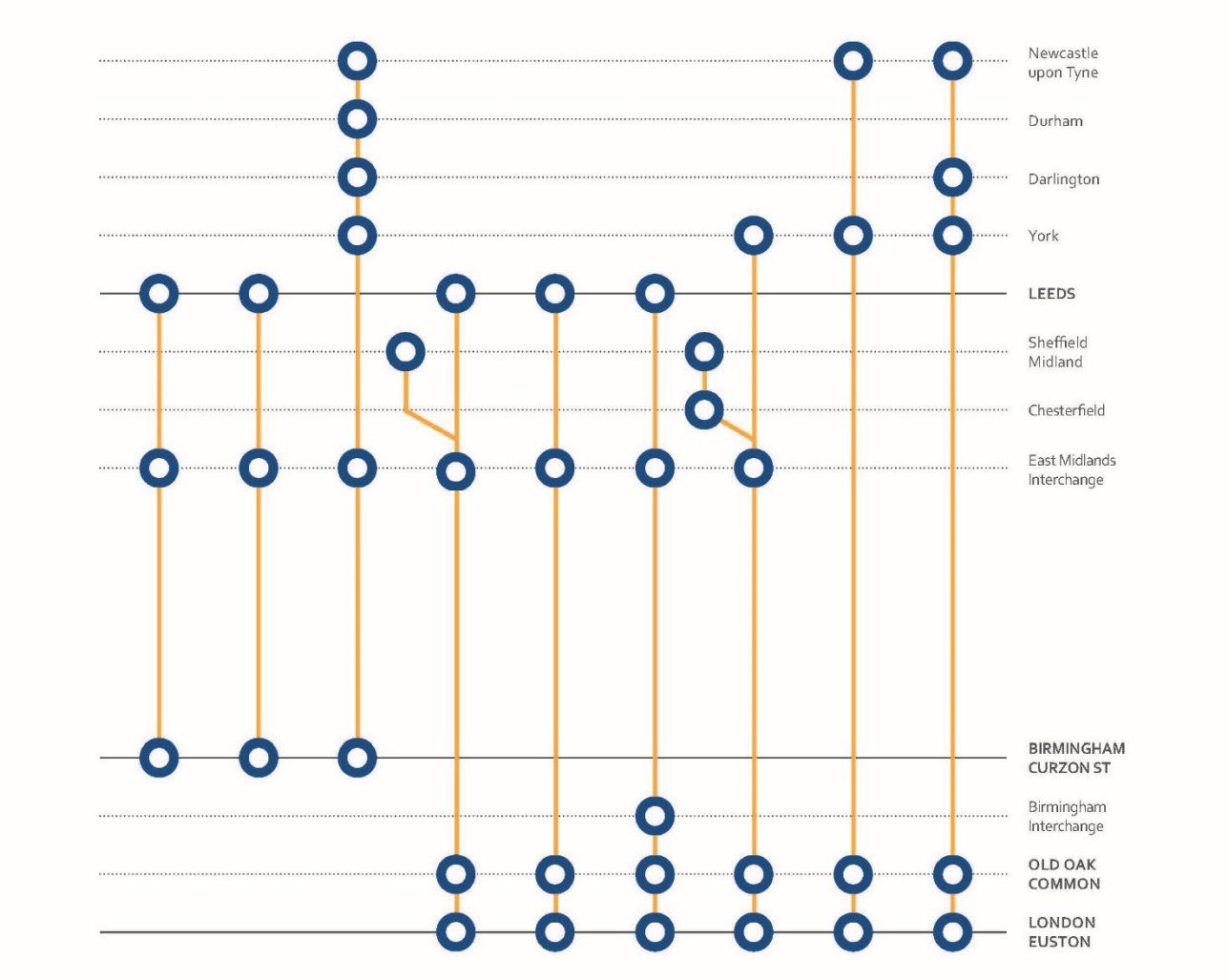


Figure 27: Scheme service pattern for the eastern leg: M18 Spur Route

Eastern leg: M18 Loop Route

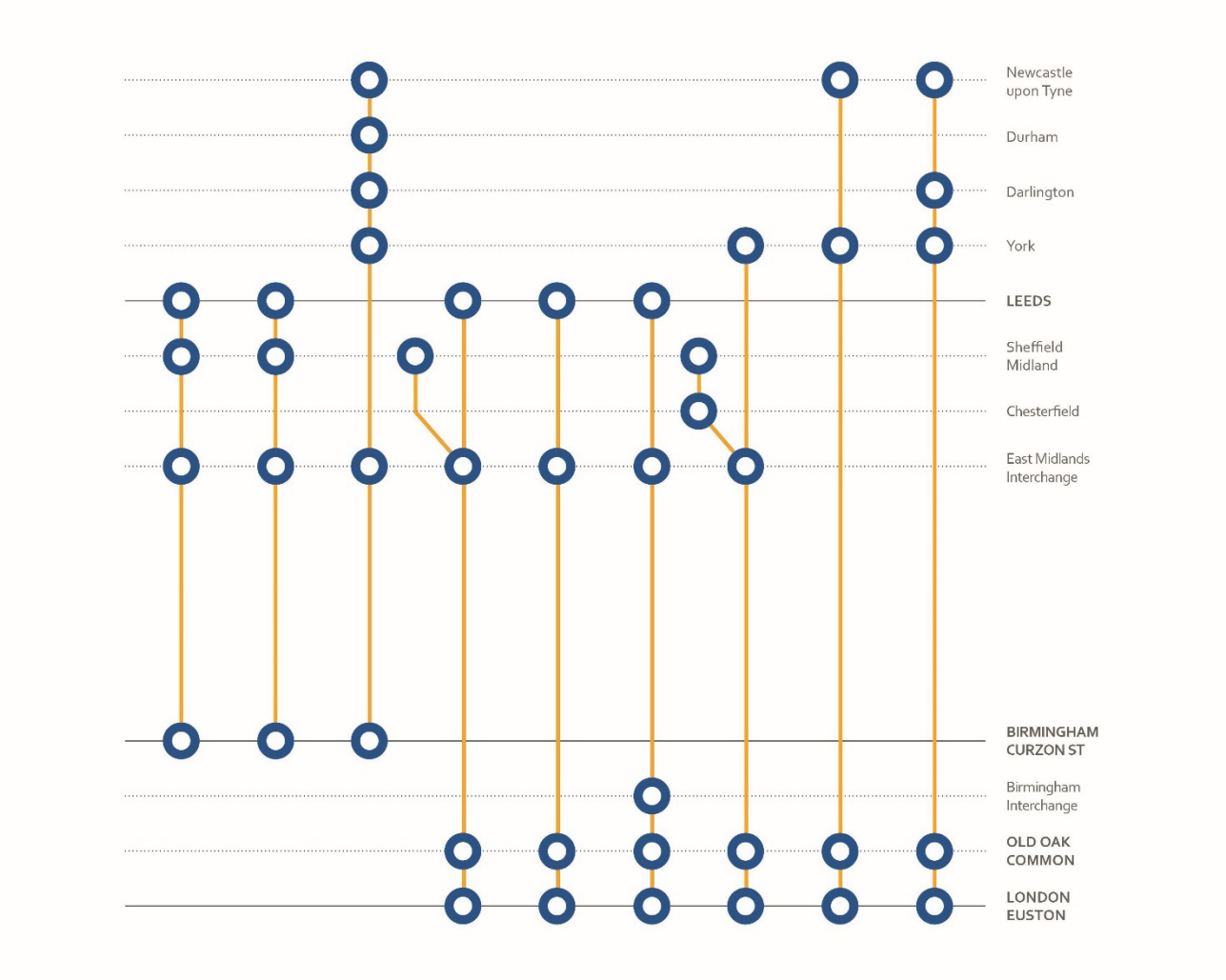


Figure 28: Scheme service pattern for the eastern leg: M18 Loop Route

Appendix 3 – Cost assumptions: Phase 2b

Overview

Costs are calculated in two primary groups outlined below, and then combined with revenue estimates to give the net cost to Government. Costs have been calculated in 2015/16 prices to remain consistent with the rest of the economic analysis. The two groups are:

- capital costs – including construction costs, rolling stock and depot costs, and infrastructure renewal costs; and
- operating costs – including operation and maintenance of trains and track, train crew and station staff for HS2, and any operating cost savings from changes to the classic network.

Spending Review 2015 funding allocation

The cost estimates used for this analysis are consistent with the Spending Review 2015 allocation.

As detailed in the High Speed Two (HS2) Ltd Annual Report and Accounts 2015/16, overall funding of £55.7 billion at 2015 prices is allocated as follows:

- Phase One London–West Midlands £24.3 billion;
- Phase 2a West Midlands–Crewe £3.7 billion;
- Phase 2b West Midlands–Manchester/Leeds £20.6 billion; and
- railway operations and rolling stock £7.1 billion.

Rolling stock and depot costs

It is currently assumed that two types of HS2 trains will be in operation: captive trains for use on HS2 track; and classic compatible trains, which are designed to be capable of using both high speed track and the classic rail network. All trains are assumed to be procured as 200m sets which can be used to form 200m or 400m services.

The number of 200m trainsets required under each phase and the base cost of purchase are outlined in the table below. The costs below are in 2015 prices. In addition to the per-trainset cost, non-recurring costs are added to cover design and other project costs, as well as an allocation to cover spares, maintenance tooling and simulators.

	Base cost per 200m trainset (£m)	Trainsets required for Phase One	Total trainsets required for full network
Captive fleet	22.05	16	70
Classic-compatible fleet	22.58	45	95

Rolling stock depot costs include the costs of one depot for Phase One and two depots for Phase Two. Efficiency Challenge Programme and Value Engineering reductions have been applied to these estimates.

It is assumed that rolling stock needs replacing after 35 years of operation and a portion of depot costs are incurred at that point to account for renewal. Costs are discounted to a present value and converted to market prices.

Infrastructure renewals

Since the Economic Case appraises schemes for 60 years from opening, estimates are included to reflect the need to repair and renew infrastructure over this time. Painting, cleaning and general maintenance of the infrastructure will be covered by operating costs, but larger expenditures such as repairs and replacements will require capital expenditure. Renewal estimates are based on assumptions of how frequently different types of assets would require capital spend, information on the cost of these assets in the base construction cost and adjustments to reflect how the cost may be different in an operational environment. The stream of renewal costs is discounted to a present value and converted to market prices.

Operating costs

The HS2 Operating Cost Model is used to appraise the operating costs of the railway infrastructure and trains required for the HS2 project (including savings to services on the existing National Rail network that will be replaced or amended following the introduction of HS2 passenger services). The main items of operating costs calculated are:

- rolling stock maintenance;
- infrastructure operations and maintenance;
- HS2 staff costs;
- traction electricity;
- Network Rail charges;
- HS2 train operator overheads and administration;
- HS2 station costs; and
- savings to existing National Rail operators.

Table 2 shows the breakdown of operating costs for Phase 2b and the Full Network (including Phase 2b).

Table 2: Breakdown of operating costs (2015 prices present value including optimism bias)

Item	**Full Network (£bn) Meadowhall Route**	**Phase 2b Increment (£bn) Meadowhall Route**	**Includes**
Rolling stock maintenance	9.7	6.0	Clearing, repairing and servicing the trains.
Infrastructure maintenance	3.6	1.5	Inspecting and repairing the infrastructure, and infrastructure manager head office.
Electrical consumption	7.1	4.4	Cost of electricity used by the trains and electrification asset usage charge.
Staff, offices and stations	12.9	6.2	Station staff, station maintenance and utilities, train crew, train operating company (TOC) overheads and administration, including head office staff.
Other	2.8	1.3	Fixed track access charge, variable usage charge, capacity charge, station access charge and rolling stock insurance.
Pre-operations	0.4	0.2	
Classic line savings	-11.2	-4.8	Staff, electricity, diesel, lease costs, maintenance and other.
Total	25.3	14.7	**All costs net of classic line savings.**

Appendix 4 – Calculation of the benefit–cost ratio

To generate a BCR for the scheme we need estimates of benefits, costs and revenues.

Description of benefits

As described in the introduction to the document, the estimation of the BCR is undertaken using a social cost–benefit analysis. The benefits that are estimated therefore include both direct effects for rail passengers and indirect effects on the wider population.

The benefits for HS2 that are used in the economic appraisal are calculated using different methods. The types of benefits that are assessed and their method of calculation are shown in the table below; the majority come from PFM. The benefits are then grouped into three primary groups as shown.

Table 3: Grouped and disaggregated benefits, what they are and where they are calculated

Grouped benefit	Disaggregated benefit	Description of benefit	Calculated using
Transport user benefits	Improved access/egress	The access/egress leg in the model is the part of a journey between the origin (house/work etc.) and the rail station initially used. Changes in the service patterns can mean that stations are more (or less) attractive, which can lead to changes in benefits.	PFM
	Reductions in crowding	There is a reduction in the level of crowding for journeys, which means passengers will experience a more pleasant journey.	PFM
	Improvements in interchange	The introduction of HS2 and associated released capacity will change how often people change trains across the network; in some cases more interchanges will be required, in some cases fewer.	PFM
	Reductions in waiting	The introduction of HS2 and associated released capacity will provide increases in frequency to a number of destinations, which means that passengers will spend less time waiting for trains.	PFM
	Reductions in walking	Some parts of the journeys made by passengers include walking between stations. This represents the benefits from whether passengers will need to make more or fewer of these walks.	PFM

Grouped benefit	Disaggregated benefit	Description of benefit	Calculated using
Transport user benefits (continued)	Reductions in train journey times	The journey times between a large number of destinations are reduced as a result of the introduction of HS2.	PFM
	Greater reliability on the HS2 network	HS2 will be a highly reliable service; passengers are therefore much more likely to be on time.	PFM
	Benefits to road users	The introduction of HS2 and associated released capacity takes vehicles off the road. There will be benefits for the remaining drivers who now encounter less traffic and enjoy faster journey times.	PFM
Wider economic impacts	Agglomeration benefits	The introduction of HS2 and associated released capacity will reduce the costs of travel between areas and businesses, which will lead to greater business interaction.	Wider Impacts in Transport Appraisal model
	Imperfect competition	Companies will be able to increase their production as a result of lower transport costs.	Wider Impacts in Transport Appraisal model
	Increased labour force participation	Transport changes can affect the individual incentives to work and therefore affect the overall level of labour supply.	Wider Impacts in Transport Appraisal model
Other impacts	Reduction of car noise	The introduction of HS2 and associated released capacity takes cars off the road, so there will be less noise caused by cars.	PFM
	Carbon	The introduction of HS2 and associated released capacity will reduce the total distance cars and diesel trains travel each year, which will reduce the carbon emissions they produce.	Spreadsheet model
	Reduction in car accidents	The introduction of HS2 and associated released capacity reduces the total number of cars on the road so there will be fewer car accidents.	PFM
	Noise from HS2 trains	HS2 trains will create noise and this will have a negative impact on areas close to the track.	Spreadsheet model
Tax impacts	Loss to government of indirect tax	As there will be fewer passengers travelling by car or other means, there will be a reduction in the level of tax generated as a result.	PFM

The estimates of benefits are then combined to provide an estimate of net benefits:

Net benefits = Transport user benefits + Wider economic impacts + Other impacts + Tax impacts

Costs and revenue

Costs are estimated for three primary groups: construction, rolling stock and operating costs. Operating costs include both the costs of operating HS2 trains and savings from changes to services on the classic network. The costs of renewals are also included.

Revenue is estimated using changes in passenger kilometres from the PFM, again incorporating changes from both HS2 and classic line passengers.

These estimates of cost and revenue are then combined to give a net cost to government:

Net cost to government = Construction cost + Rolling stock cost + Operating cost + Renewals - Revenue

Calculation of the benefit–cost ratio

All the estimates of the benefits and costs are then combined in the following equation to produce an estimate of the BCR.

BCR = Net benefits / Net cost to government

Appendix 5 – Transport impacts: Phase 2b

Benefits breakdown: Phase 2b eastern leg via Meadowhall

Table 4: Total net benefits including wider economic impacts for Phase 2b eastern leg via Meadowhall

		Phase 2b Increment (£m) Meadowhall Route		Full Network (£m) Meadowhall Route	
Grouped benefit	**Disaggregated benefit**	**Benefit value (£m)**	**Percentage of total***	**Benefit value (£m)**	**Percentage of total***
Transport user benefits	Improved access	-19	-<0.5%	1,170	1%
	Reduction in crowding	9,058	18%	14,270	14%
	Improvements in interchange	1,951	4%	1,696	2%
	Reductions in waiting	4,184	8%	10,003	10%
	Reductions in walking	23	<0.5%	73	<0.5%
	Reductions in train journey times	20,084	40%	44,116	44%
	Greater reliability on the HS2 network	5,237	10%	10,473	10%
	Benefits to road users	724	1%	1,586	2%
	Total	**41,242**	**82%**	**83,386**	**83%**
Wider economic impacts	Agglomeration (businesses closer together)	7,762	15%	14,343	14%
	Imperfect competition (increased output due to reduced costs)	3,051	6.%	6,198	6%
	Increased labour force participation	240	<0.5%	589	1%
	Total	**11,053**	**22%**	**21,130**	**21%**
Other impacts	Reduction of car noise	14	<0.5%	26	<0.5%
	Carbon	76	<0.5%	128	<0.5%
	Reduction in car accidents	179	<0.5%	329	<0.5%
	Noise from HS2 trains	-39	-<0.5%	-115	-<0.5%
	Infrastructure	14	<0.5%	26	<0.5%
	Total	**244**	**<0.5%**	**394**	**<0.5%**
	Loss to government of indirect tax	-2,162	-4%	-4,141	-4%
	Total benefits	**50,376**	**100.00%**	**100,770**	**100.00%**

* Rounded to nearest 1%. Total does not equal sum of figures in table as figures are summed before rounding.

Benefits breakdown: Phase 2b eastern leg via M18/Spur

Table 5: Total net benefits including wider economic impacts for Phase 2b eastern leg via Meadowhall

		Phase 2b Increment (£m) Spur Route		Full Network (£m) Spur Route	
Grouped benefit	**Disaggregated benefit**	**Benefit value (£m)**	**Percentage of total***	**Benefit value (£m)**	**Percentage of total***
Transport user benefits	Improved access	-£18	-<0.5%	£986	1%
	Reduction in crowding	£9,559	18%	£13,325	13%
	Improvements in interchange	£1,912	4%	£1,302	1%
	Reductions in waiting	£4,637	9%	£10,176	10%
	Reductions in walking	£43	<0.5%	£65	<0.5%
	Reductions in train journey times	£20,899	40%	£46,200	45%
	Greater reliability on the HS2 network	£5,465	10%	£11,728	11%
	Benefits to road users	£722	1%	£1,583	2%
	Total	**£43,220**	**82%**	**£85,365**	**83%**
Wider economic impacts	Agglomeration (businesses closer together)	£7,778	15%	£14,359	14%
	Imperfect competition (increased output due to reduced costs)	£3,219	6%	£6,366	6%
	Increased labour force participation	£253	<0.5%	£601	1%
	Total	**£11,250**	**21%**	**£21,327**	**21%**
Other impacts	Reduction of car noise	£16	<0.5%	£28	<0.5%
	Carbon	£76	<0.5%	£128	<0.5%
	Reduction in car accidents	£194	<0.5%	£345	<0.5%
	Noise from HS2 trains	-£39	-<0.5%	-£117	-<0.5%
	Infrastructure	£15	<0.5%	£27	<0.5%
	Total	**£261**	**<0.5%**	**£411**	**<0.5%**
	Loss to government of indirect tax	-£2,270	-4%	-£4,249	-4%
	Total benefits	**£52,462**	**100.00%**	**£102,854**	**100.00%**

* Rounded to nearest 1%. Total does not equal sum of figures in table as figures are summed before rounding.

Benefits breakdown: Phase 2b eastern leg via M18/Loop

Table 6: Total net benefits including wider economic impacts for Phase 2b eastern leg via Meadowhall

		Phase 2b Increment (£m) Loop Route		Full Network (£m) Loop Route	
Grouped benefit	**Disaggregated benefit**	**Benefit value (£m)**	**Percentage of total***	**Benefit value (£m)**	**Percentage of total***
Transport user benefits	Improved access	-£16	-<0.5%	£987	1%
	Reduction in crowding	£9,554	18%	£13,320	13%
	Improvements in interchange	£1,889	4%	£1,279	1%
	Reductions in waiting	£4,611	9%	£10,150	10%
	Reductions in walking	£55	<0.5%	£76	<0.5%
	Reductions in train journey times	£20,936	40%	£46,237	45%
	Greater reliability on the HS2 network	£5,467	10%	£11,730	11%
	Benefits to road users	£715	1%	£1,576	2%
	Total	**£43,211**	**82%**	**£85,356**	**83%**
Wider economic impacts	Agglomeration (businesses closer together)	£7,747	15%	£14,328	14%
	Imperfect competition (increased output due to reduced costs)	£3,209	6%	£6,356	6%
	Increased labour force participation	£251	-<0.5%	£600	1%
	Total	**£11,208**	**21%**	**£21,284**	**21%**
Other impacts	Reduction of car noise	£16	-<0.5%	£28	-<0.5%
	Carbon	£76	-<0.5%	£128	-<0.5%
	Reduction in car accidents	£194	-<0.5%	£345	-<0.5%
	Noise from HS2 trains	-£39	-<0.5%	-£117	-<0.5%
	Infrastructure	£15	<0.5%	£27	<0.5%
	Total	**£262**	**<0.5%**	**£411**	**<0.5%**
	Loss to government of indirect tax	-£2,266	-4%	-£4,245	-4%
	Total benefits	**£52,415**	**100.00%**	**£102,807**	**100.00%**

* Rounded to nearest 1%. Total does not equal sum of figures in table as figures are summed before rounding.

Regional benefits: Phase 2b eastern leg via Meadowhall

Table 7 shows the distribution of benefits according to where a trip starts. The figures are the proportions from our modelled year of 2036.

Table 7: Regional distribution of transport user benefits

Region	Phase 2b Increment Meadowhall Route	Full Network Meadowhall Route
London	37%	41%
South East	3%	3%
West Midlands	5%	11%
North West	14%	19%
East Midlands	7%	4%
Yorkshire and the Humber	17%	10%
North East	6%	4%
Scotland	7%	5%
Other (East England, South West, Wales)	4%	3%
Total	**100%***	**100%***

* Total does not equal 100% due to rounding.

Regional benefits: Phase 2b eastern leg via M18 Spur/Loop

Table 8 shows the distribution of benefits according to where a trip starts. The figures are the proportions from our modelled year of 2036. It should be noted that the breakdown is the same for the Loop and Spur to one decimal place.

Table 8: Regional distribution of transport user benefits

Region	Full Network Meadowhall Route	Full Network Loop Route	Full Network Spur Route
London	41%	41%	41%
South East	3%	3%	3%
West Midlands	11%	11%	11%
North West	19%	19%	19%
East Midlands	4%	4%	4%
Yorkshire and the Humber	10%	10%	10%
North East	4%	4%	4%
Scotland	5%	5%	5%
Other (East England, South West, Wales)	3%	3%	3%
Total	**100%***	**100%***	**100%***

* Total does not equal 100% due to rounding.

Appendix 6 – Scenario results

This section reports detailed single point BCR estimates.

Meadowhall Route

Table 9: Economic analysis results for the Meadowhall Route reference case (2015 PV)

	BCR components		Phase 2b Increment (£bn 2015 PV) Meadowhall Route	Full Network (£bn 2015 PV) Meadowhall Route
1	Transport user benefits	Business	30.5	62.0
		Other	10.7	21.4
2	Other quantifiable benefits		0.2	0.4
3	Loss to government of indirect tax		-2.2	-4.1
4	Net transport benefits = (1) + (2) + (3)		39.3	79.6
5	Wider economic impacts (WEIs)		11.1	21.1
6	Net benefits including WEIs = (4) + (5)		50.4	100.8
7	Capital costs		24.4	57.1
8	Operating costs		14.7	25.3
9	Total costs = (7) + (8)		39.2	82.3
10	Revenues		22.2	43.4
11	Net costs to government = (9) - (10)		17.0	38.9
12	**BCR without WEIs (ratio) = (4)/(11)**		**2.3**	**2.0**
13	**BCR with WEIs (ratio) = (6)/(11)**		**3.0**	**2.6**

M18 Spur Route: 1 train per hour London to Sheffield Midland

Table 10: Economic analysis results for the M18 Spur Route scenario (1 train per hour – 2015 PV)

	BCR components		Phase 2b Increment (£bn 2015 PV) M18 Spur – 1tph	Full Network (£bn 2015 PV) M18 Spur – 1tph
1	Transport user benefits	Business	31.8	63.3
		Other	10.9	21.6
2	Other quantifiable benefits		0.3	0.4
3	Loss to government of indirect tax		-2.3	-4.2
4	Net transport benefits = (1) + (2) + (3)		40.8	81.1
5	Wider economic impacts (WEIs)		11.2	21.2
6	Net benefits including WEIs = (4) + (5)		51.9	102.3
7	Capital costs		23.2	55.8
8	Operating costs		15.9	26.4
9	Total costs = (7) + (8)		39.0	82.2
10	Revenues		23.2	44.3
11	Net costs to government = (9) - (10)		15.9	37.9
12	**BCR without WEIs (ratio) = (4)/(11)**		**2.6**	**2.1**
13	**BCR with WEIs (ratio) = (6)/(11)**		**3.3**	**2.7**

M18 Spur Route: 2 trains per hour London to Sheffield Midland

Table 11: Economic analysis results for the M18 Spur Route scenario (2 trains per hour – 2015 PV)

	BCR components		**Phase 2b Increment (£bn 2015 PV)** **M18 Spur – 2tph**	**Full Network (£bn 2015 PV)** **M18 Spur – 2tph**
1	Transport user benefits	Business	32.2	63.7
		Other	11.0	21.7
2	Other quantifiable benefits		0.3	0.4
3	Loss to government of indirect tax		-2.3	-4.2
4	Net transport benefits = (1) + (2) + (3)		41.2	81.5
5	Wider economic impacts (WEIs)		11.3	21.3
6	Net benefits including WEIs = (4) + (5)		52.5	102.9
7	Capital costs		23.3	55.9
8	Operating costs		16.3	26.8
9	Total costs = (7) + (8)		39.5	82.7
10	Revenues		23.4	44.6
11	Net costs to government = (9) - (10)		16.1	38.1
12	**BCR without WEIs (ratio) = (4)/(11)**		**2.6**	**2.1**
13	**BCR with WEIs (ratio) = (6)/(11)**		**3.2**	**2.7**

M18 Loop Route: 2 trains per hour London to Sheffield Midland

Table 12: Economic analysis results for the M18 Loop Route scenario (2 trains per hour – 2015 PV)

	BCR components		Phase 2b Increment (£bn 2015 PV) M18 Loop – 2tph	Full Network (£bn 2015 PV) M18 Loop – 2tph
1	Transport user benefits	Business	32.1	63.6
		Other	11.1	21.8
2	Other quantifiable benefits		0.3	0.4
3	Loss to government of indirect tax		-2.3	-4.2
4	Net transport benefits = (1) + (2) + (3)		41.2	81.5
5	Wider economic impacts (WEIs)		11.2	21.3
6	Net benefits including WEIs = (4) + (5)		52.4	102.8
7	Capital costs		23.5	56.2
8	Operating costs		16.4	27.0
9	Total costs = (7) + (8)		40.0	83.1
10	Revenues		23.3	44.5
11	Net costs to government = (9) - (10)		16.7	38.7
12	**BCR without WEIs (ratio) = (4)/(11)**		**2.5**	**2.1**
13	**BCR with WEIs (ratio) = (6)/(11)**		**3.1**	**2.7**

Appendix 7 – Estimated journey times

Table 13 and Table 14 set out some of the journey times used in the Economic Case modelling for the Full Network. It should be noted that these journey times evolve – as we align them with journey time modelling and our understanding of the route alignment and likely route times.

Since the last Economic Case published in January 2015, there have been the following changes:

- The majority of times on the eastern leg for the Meadowhall Route case have increased by 1 minute due to the route change around East Midlands Airport which leads to a longer journey time
- Times to Crewe and Liverpool have increased due to changes in the junction design to the south of Crewe, and times to Scotland have increased slightly due to route refinements around Culcheth.
- The times on the eastern leg for the M18 Spur Route reduce over the Meadowhall Route due to the faster route design.
- The times shown for the M18 Loop Route are an indicative estimate and may change once the full feasibility of any services via this route has been undertaken.

Phase Two journey times: western leg

Table 13: HS2 journey times for the western leg as used in the Economic Case modelling for Phase 2b and the Full Network

Origin	Destination	Full Network journey time
London	Crewe	57
London	Manchester Airport	63
London	Manchester Piccadilly	68
London	Preston	78
London	Liverpool	95
London	Glasgow	220
London	Edinburgh Waverley	226
Birmingham Curzon Street	Manchester Piccadilly	41
Birmingham Curzon Street	Edinburgh Waverley	197
Birmingham Curzon Street	Glasgow	200
Birmingham Interchange	Glasgow	186
Birmingham Interchange	Manchester Piccadilly	38

Phase Two journey times: eastern leg

Origin	Destination	Full Network journey time – Meadowhall Route	Full Network journey time – M18 Spur Route, 2tph	Full Network journey time – M18 Loop Route, 2tph
London	East Midlands Hub	52	52	52
London	Sheffield Meadowhall	69	N/A	N/A
London	Sheffield Midland	N/A	85	85
London	Leeds	82	81	81
London	York	85	84	84
London	Newcastle	139	138	138
Birmingham Curzon Street	East Midlands Hub	20	20	20
Birmingham Curzon Street	Sheffield Meadowhall	37	N/A	N/A
Birmingham Curzon Street	Sheffield Midland	N/A	N/A	(48*)
Birmingham Curzon Street	Leeds	54	49	(75*)
Birmingham Interchange	East Midlands Hub	17	17	17
East Midlands Hub	Sheffield Meadowhall	15	15	15
Sheffield Meadowhall	Leeds	15	N/A	N/A
Sheffield Midland	Leeds	N/A	N/A	(25*)
Sheffield Meadowhall	Newcastle	83	N/A	N/A
Sheffield Midland	Newcastle	N/A	N/A	N/A
Sheffield Meadowhall	York	23	N/A	N/A
Sheffield Midland	York	N/A	N/A	N/A
* In 'Loop' scenario only. Indicative estimate that may change significantly in subsequent analysis.				

Table 14: HS2 journey times for the eastern leg as used in the Economic Case modelling for the Full Network

Appendix 8 – Glossary

Definitions	Acronym	
Appraisal period	–	The assumed useful life of the assets for analysis. In this analysis it is 60 years from the opening of Phase 2b, i.e. 2093.
Benefit–cost ratio	BCR	The ratio of project benefits to project costs.
Capital costs/capital expenditure	CAPEX	The cost of acquiring the physical assets for HS2, including construction, land purchases and rolling stock.
Consumer price index	CPI	A measure of inflation, currently adopted as the Government's official measure of price increases.
Cost–benefit analysis	CBA	The process of calculating and comparing the benefits and costs of a project, usually to generate the BCR.
Demand cap level	–	The level of long-distance demand at which demand growth is assumed to halt.
Demand cap year	–	The year in which the demand cap is reached.
Department for Transport	DfT	The government department responsible for the English (and some of the Scottish) transport network.
'Do minimum'	DM	The set of train services and demand that are assumed to be in place if HS2 did not happen – the base case – against which the 'do something' is assessed.
'Do something'	DS	The transport intervention – HS2 scheme – being considered.
East Coast Main Line	ECML	The existing rail route connecting London King's Cross, Peterborough, Doncaster, Wakefield, Leeds, York, Darlington, Newcastle, Edinburgh and Aberdeen.
Elasticity	–	The responsiveness of a change in X as a result of a change in Y.
Full Network	–	The extent of the HS2 network currently being planned for construction.
Green Book	–	HM Treasury's guidance for public sector bodies on how to appraise proposals before committing funds to a policy, programme or project.
Gross domestic product	GDP	The market value of all officially recognised final goods and services produced in the UK within a given period.
Gross wage rate	–	The money you earn based on your hourly pay, before any taxes or other deductions have been taken out.
High speed rail	HSR	A railway that can operate at speeds of over 150mph.
Hybrid Bill	–	A proposal for new legislation that will provide the powers to build HS2.
National Air Passenger Allocation Model	NAPAM	A model used to forecast airport capacity constraints and the distribution of passengers between airports.
National Audit Office	NAO	The body responsible for auditing central government accounts and reporting on value for money issues.
National Passenger Survey	NPS	A network-wide survey of customer' satisfaction with rail travel.

Definitions	Acronym	
National Rail Travel Survey	NRTS	A survey of passenger trips on the National Rail system in Great Britain on weekdays outside school holidays.
National Transport Survey	NTS	The primary source of data on passenger travel patterns in Great Britain.
Office for Budget Responsibility	OBR	An independent body that analyses the UK's public finances.
Office for National Statistics	ONS	The UK's largest independent producer of official statistics.
Operating costs/operating expenditure	OPEX	The costs associated with running the railway including the maintenance of the track and trains, and staff costs.
Optimism bias	OB	A financial allocation to compensate for the systematic tendency for appraisers to be over-optimistic about key project parameters.
Passenger Demand Forecasting Handbook	PDFH	A summary of over 20 years of research on rail demand forecasting, service quality and fares.
Phase One	–	The section of HS2 between London and the West Midlands with a connection via the West Coast Main Line at conventional speeds to the North West and Scotland. Phase One includes stations at London Euston, Old Oak Common (West London), Birmingham Interchange (near the National Exhibition Centre and Birmingham Airport) and Curzon Street.
Phase Two	–	The section of HS2 that extends beyond the West Midlands to Manchester and Leeds with connections to conventional railway lines via the West Coast and East Coast Main Lines. Phase Two includes stations at Manchester Airport, Manchester Piccadilly, East Midlands Hub (between Nottingham and Derby), Sheffield Meadowhall and Leeds.
Phase 2a West Midlands to Crewe	–	The section of HS2 between the West Midlands (Fradley) and Crewe.
PLANET Framework Model	PFM	The suite of models used by HS2 Ltd to analyse the impact of HS2 on rail travel in the UK.
Quantified risk assessment	QRA	A formal method of calculating the quantity of individual risks.
Real terms	–	The financial value, after removing the effects of inflation.
Released capacity	–	The availability on the classic network created by the introduction of HS2.
Retail Prices Index	RPI	An alternative measure of inflation that was previously adopted by the Government as the official measure of price increases.
Service specification	–	The train service assumptions used in our modelling.
Standard case	–	Our scenario that most rigidly applies the assumptions in the DfT's WebTAG.
Strategic Outline Business Case	SOBC	This sets out the need for intervention (the case for change) and how this will further ministers' aims and objectives (the strategic fit). It provides suggested or preferred ways forward and presents the evidence for decision.
Sunk cost	–	A cost that has already been incurred and cannot be recovered.
Train operating company	TOC	A company that holds an operating contract for a rail franchise.
Value of time	VoT	The implicit value people place on time.

Definitions	Acronym	
Web Based Transport Analysis Guidance	WebTAG	The DfT's guidance that provides guidelines on how to conduct transport studies.
West Coast Main Line	WCML	The existing rail route connecting London Euston, Birmingham, Manchester, Liverpool, Glasgow and Edinburgh. It is the busiest mixed-traffic railway route in Europe.
Wider economic impacts	WEIs	The agglomeration, imperfect competition and increased labour force participation benefits.
Willingness to pay	WTP	The maximum value a consumer is willing to pay for a good or service.

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