SLC Rail

HS2 Midlands to Leeds and North East Options

Technical Advice for HS2 East Partnership

July 2023

SLC Rail

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Executive Summary

Introduction

HS2 East Partnership is a grouping of Combined Authorities and Local Authorities seeking to lobby for the maximum economic benefit from the Eastern Arm of HS2 and associated rail development. The Integrated Rail Plan (IRP) published by the Government in November 2021 included some major policy announcements directly affecting these aims. In particular, it cancelled the Eastern Arm of HS2 north of East Midlands Parkway, and refocussed this section of HS2 on providing benefits to Nottingham, Derby, Chesterfield and Sheffield.

This would have the effect of limiting the benefits of HS2 for journeys between the Midlands (both West and East) and Yorkshire and the North East. It would also not provide any benefits between Sheffield and Leeds or the North East which formed a key part of the Northern Powerhouse Rail (NPR) concept using parts of the (now cancelled) HS2 infrastructure.

Therefore, HS2 East Partnership have asked SLC Rail for technical advice on what would be an optimal solution to increase capacity and connectivity between Birmingham, East Midlands, Chesterfield and Sheffield, Leeds, York and the North East, together with a high level costs for the proposed solution.

Some of the key questions are:

- How to enhance journeys between Birmingham, Sheffield, Leeds, York and Newcastle
- How the Northern Powerhouse Rail ambitions for increased frequencies and transformative journey times between Sheffield and Leeds could be achieved
- The impact of HS2 services on existing services on the Midland Main Line

Overview of Impact of Integrated Rail Plan

The IRP proposals would deliver major benefits between Birmingham and Leeds and Birmingham and the North East through connecting up Birmingham – Manchester HS2 services with Manchester – Leeds/Newcastle NPR services. We recommend that this approach is endorsed rather than challenged, and then used as a "building block" for a wider set of benefits.

The IRP proposition delivers journey times of c. 1hr30 between London and Sheffield. However as can be seen in the circled area on the map below it does nothing for a range of key economic links:

- Birmingham - Sheffield
- East Midlands – Leeds/North East
- Sheffield - Leeds
- Sheffield – North East

Key issue is how can we take an incremental approach to fill these gaps and, in particular in a way which delivers the much needed benefits to all the regions along the line of route. Therefore, the following phased approach is based on IRP commitments being delivered in full **and the costings shown are those related to the additional phases only**.

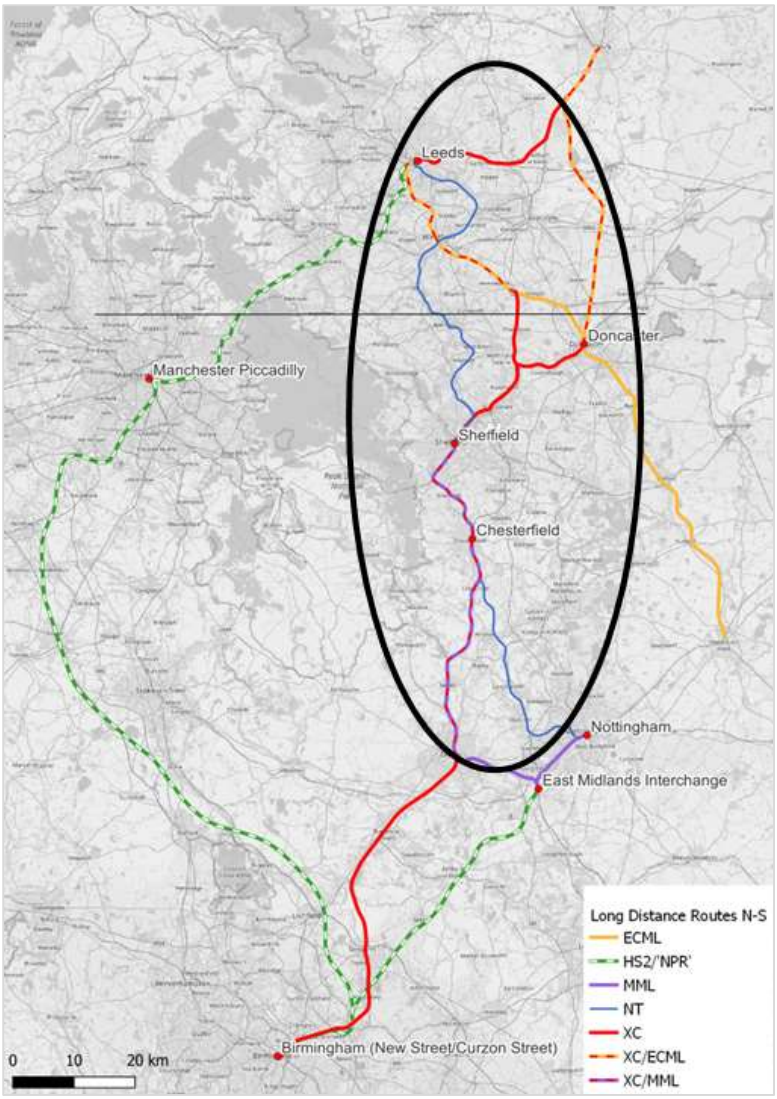

Figure 1 - The IRP "connectivity gap"

Phase 1 – Opportunities in Advance of HS2/NPR

There are a series of benefits that can be achieved through completion of infrastructure enhancement that has already started, and rolling stock replacement, and these can be seen as the key first phase of a long term programme. They include:

- Completion in full of Midland Main Line electrification, and infill from Sheffield to Moorthorpe (South Kirkby) for services towards Leeds
- New service patterns and rolling stock following completion of the various phases of Transpennine Upgrade
- Return to pre-COVID frequency of Cross Country services (ie the reinstatement of the hourly Newcastle – Reading service)
- New and/or longer trains on Cross Country services to improve quality and increase seating capacity
- An enhanced East Coast Main Line timetable (including potentially a 3rd hourly service London – Leeds, extended to Bradford) using the infrastructure already delivered (such as the Werrington diveunder and the remodelling of King's Cross station throat)
- Consistent use of 3 car Class 195 rolling stock on the Nottingham – Leeds
- Investigating the possibility of a second hourly fast Sheffield – Leeds on existing infrastructure as was being contemplated prior to the pandemic.

Phase 2 – Deliver the Missing Gap

A new, fast new or upgraded route between Sheffield and Leeds along with new 'T' station in Leeds would plug the key gap in the IRP proposition. There are several options for achieving the new link between Sheffield and Leeds, but the one preferred is the delivery of the section of HS2 route between Leeds and Clayton, along with an upgrade of the existing line between Clayton and Sheffield. Whilst disruptive to construct south of Clayton, north of there it would be much less disruptive to the existing railway than other options.

In addition, the best option for Sheffield – York – North East would be an electrification infill scheme to Doncaster to allow access to the East Coast Main Line for HS2 services (the ECML would have been upgrade under the IRP plans).

A high level "order of magnitude" cost for this package would be c.£4.1bn.

The first port of call to address the capacity limitations of the northern approaches to Sheffield would be signalling alterations to achieve headway reduction (ie to increase throughput). This could potentially deliver up to 3 or 4 additional paths per hour without needing to 4-track the immediate northern approaches.

This package would unlock key gaps in IRP provision, and would deliver major journey time and frequency improvements between:

- Sheffield and Leeds
- Sheffield and the North East
- East Midlands and Leeds/North East

The new route could also be used to bring London HS2 services to Leeds by extending London – Sheffield HS2 services.

Phase 3 – Further Increments

The following further increments would build on the benefits of Phase 2. There are three elements that would achieve this:

- Upgrading and electrifying the Erewash Valley line (c.£2bn) would support delivery of further faster Birmingham – Sheffield and Birmingham - Leeds services (options that avoid Sheffield - eg via "Old Road" through Barrow Hill - are examined in this report but are not recommended)
- Upgrading the Nottingham – Newark line (c.£1bn) would enable a major improvement in East Midlands – Leeds/North East services (via the upgraded East Coast Main Line included in the IRP)
- Reopening the Leamside Line (c.£1.1bn) would enable freight to be diverted off East Coast Main Line and support delivery of all the above (and NPR) through creating capacity for more express services to the North East

Benefits

Key benefits of this approach include:

- Flexible infrastructure which will accommodate future services requirements
- Faster journey times from Birmingham to Leeds, Birmingham to Sheffield York and the North East
- Much needed improved connectivity between the West and East Midlands, Chesterfield, Sheffield, Leeds and the North East

- Increased capacity in Leeds station improving performance across the national network and the benefit of incorporating new track which is less disruptive to passengers than upgrade as a result of some services transferring to a new station.
- Electrification and upgrades from Sheffield to Moorthorpe as an early phase leading to performance and journey time improvements and enabling electrified Sheffield-Wakefield-Leeds services
- Additional capacity on the ECML leading to improved journey times to the North East and increased capacity north of York for long distance and local services
- Delivering the journey time from North East to London committed to in the IRP

This proposal also:

- enables the release of the Chesterfield Staveley Depot site for development
- unlocks the uncertainty for investors in Leeds
- better connects Sheffield and Leeds
- builds on the already committed schemes in the Integrated Rail Plan
- increases capacity and connectivity between Nottingham, Derby, Chesterfield, Sheffield, Leeds, York, Northallerton and Newcastle
- would lead to the removal of safeguarding between East Midlands Parkway and Clayton junction.

Key Points and Timeline

The box below summarises our recommendations, and these are shown on the timeline overleaf. Of course, the delivery of the phases does not need to be as precisely sequential as is suggested here.

1. **Secure the pre-HS2 benefits, including MML electrification, frequency restoration and new rolling stock**
2. **Secure the benefits delivered by IRP**
3. **Argue for a new/upgraded railway between Sheffield and Leeds and Sheffield and York and the new station in Leeds (increment #1)**
4. **Argue for upgrade of Erewash Valley line (increment #2)**
5. **Argue for upgrade of Nottingham – Newark and Leamside Line (increment #3)**
6. **Total estimated cost £8.2bn**

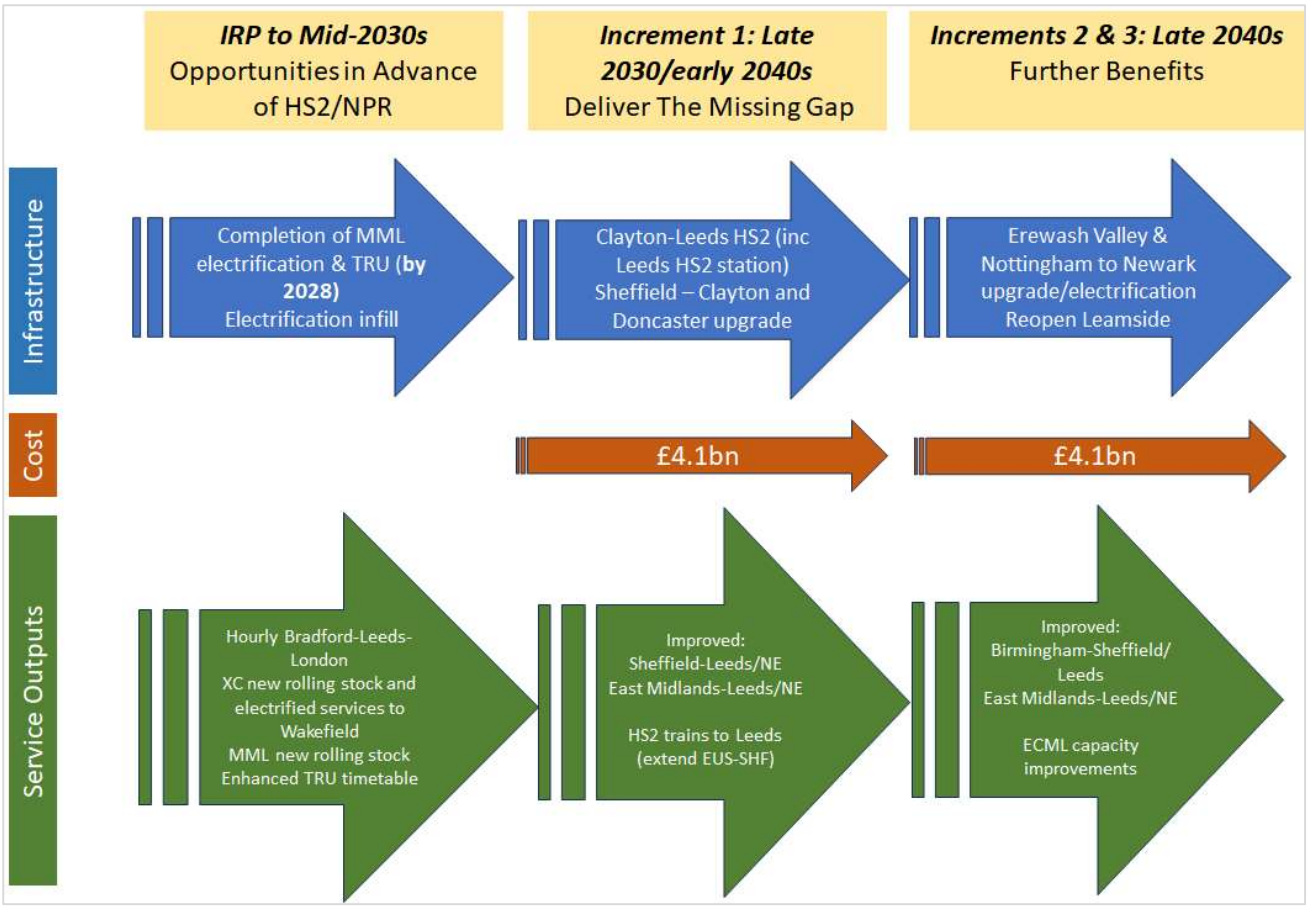

Figure 2 - Indicative timeline and sequencing

Cost Comparison with Full HS2 Eastern Leg

The saving to government in today's prices of the increments recommended here is circa £7.4bn compared with the full HS2 eastern leg, as estimated in the table below.

The phased approach to delivery means that the spend is phased, however unlike the eastern leg in full. With this proposal benefits are also delivered sooner on a phased basis with each phase of infrastructure.

Costs in Current Prices	**£bn**	
HS2 Eastern leg	30.8	SLC estimate of £26bn from 2021 Sub-Optimal Scenarios report plus 2 years' inflation
MML and ECML upgrade and Birmingham to EMP leg	(15.2)	IRP £12.8bn plus 2 years' inflation
Additional connectivity	(8.2)	SLC June 2023 report
Saving to Government	7.4	

Figure 3 - Cost comparison with full HS2 Eastern Leg

Single Page Summary of Recommended Phasing

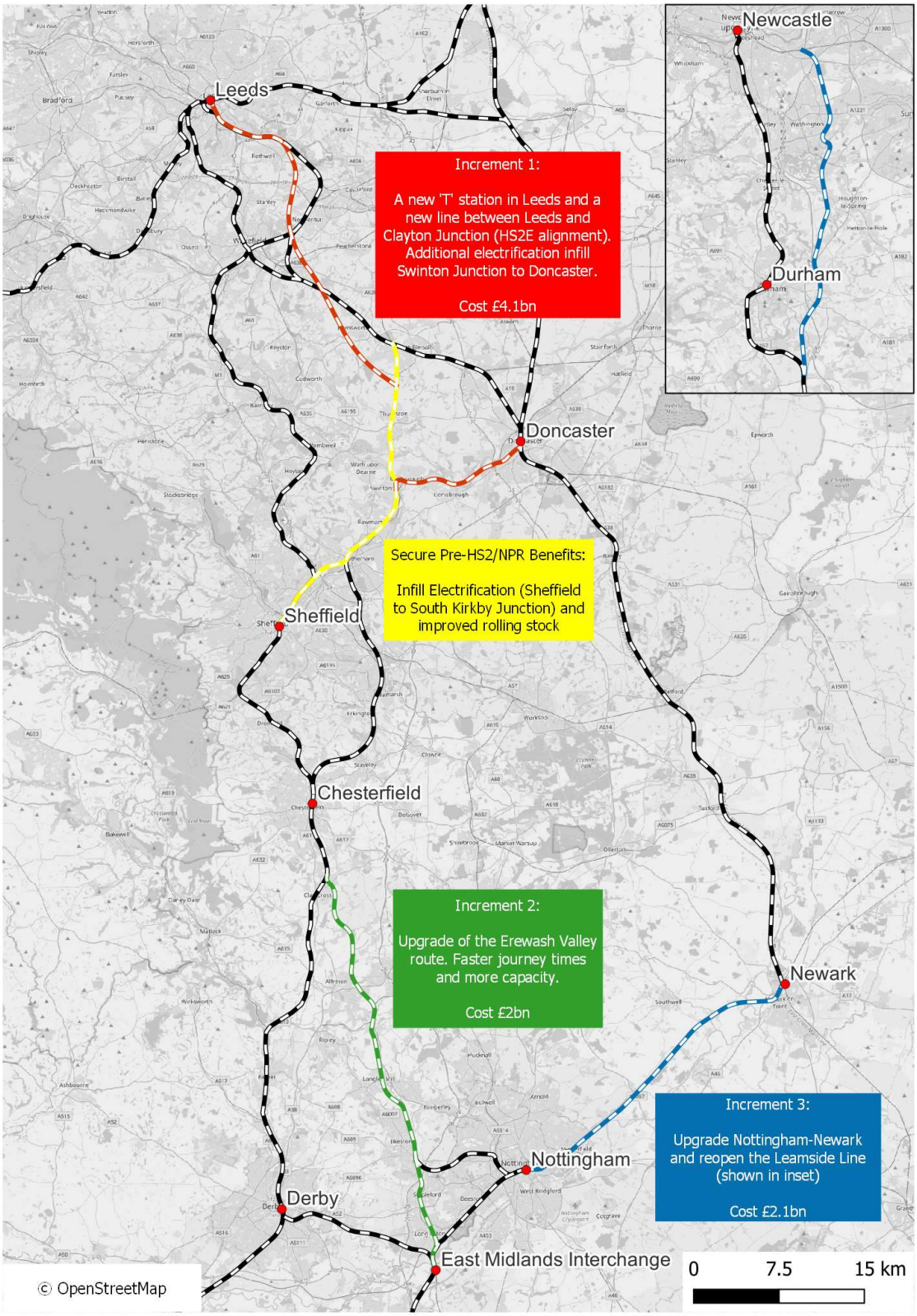

Figure 4 - Summary of recommended phasing

1 Introduction

1.1 Background

The map below is taken from the IRP HS2, and seeks to illustrate potential journey time benefits delivered by the scheme. The extent of new and upgraded infrastructure is apparent, as is the key "connectivity gap" north of Sheffield.

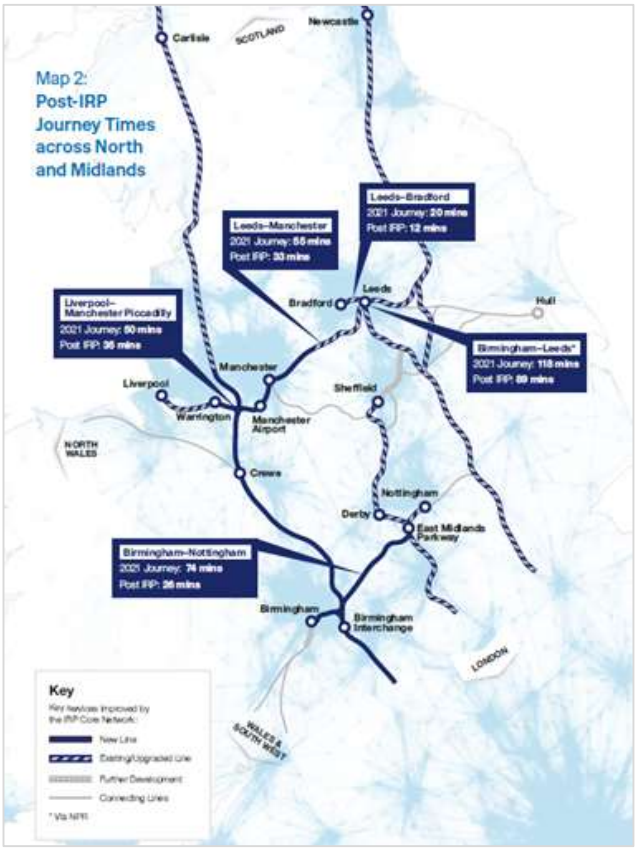

Figure 5 - IRP enhancement map

1.2 The Brief

The overarching aim of this study is to identify a solution to increase capacity and connectivity between Birmingham, the East Midlands and Sheffield, Leeds, York and the North East, together with high-level indicative costs for the upgrades. In particular, the work will reflect:

- The impact of the IRP on journeys from the West Midlands to the North East corridor
- The aspirations of NPR to improve journeys between Sheffield and Leeds which, critically, are not included within the IRP recommendations
- The impact of HS2 services on the existing Midland Mainline services.

2 Problem Definition

2.1 Existing Long-Distance Services

The figure below summarises the long-distance services of relevance to the study. Included in the schematic are:

- Transpennine services (both northern and southern routes)
- East Coast Main Line trains from London up the main spine to Newcastle and via the branch to Leeds
- Midland Main Line services from London to Nottingham and Sheffield
- Cross Country services from Birmingham to the North East; and
- Northern Railways' service from Nottingham to Leeds.

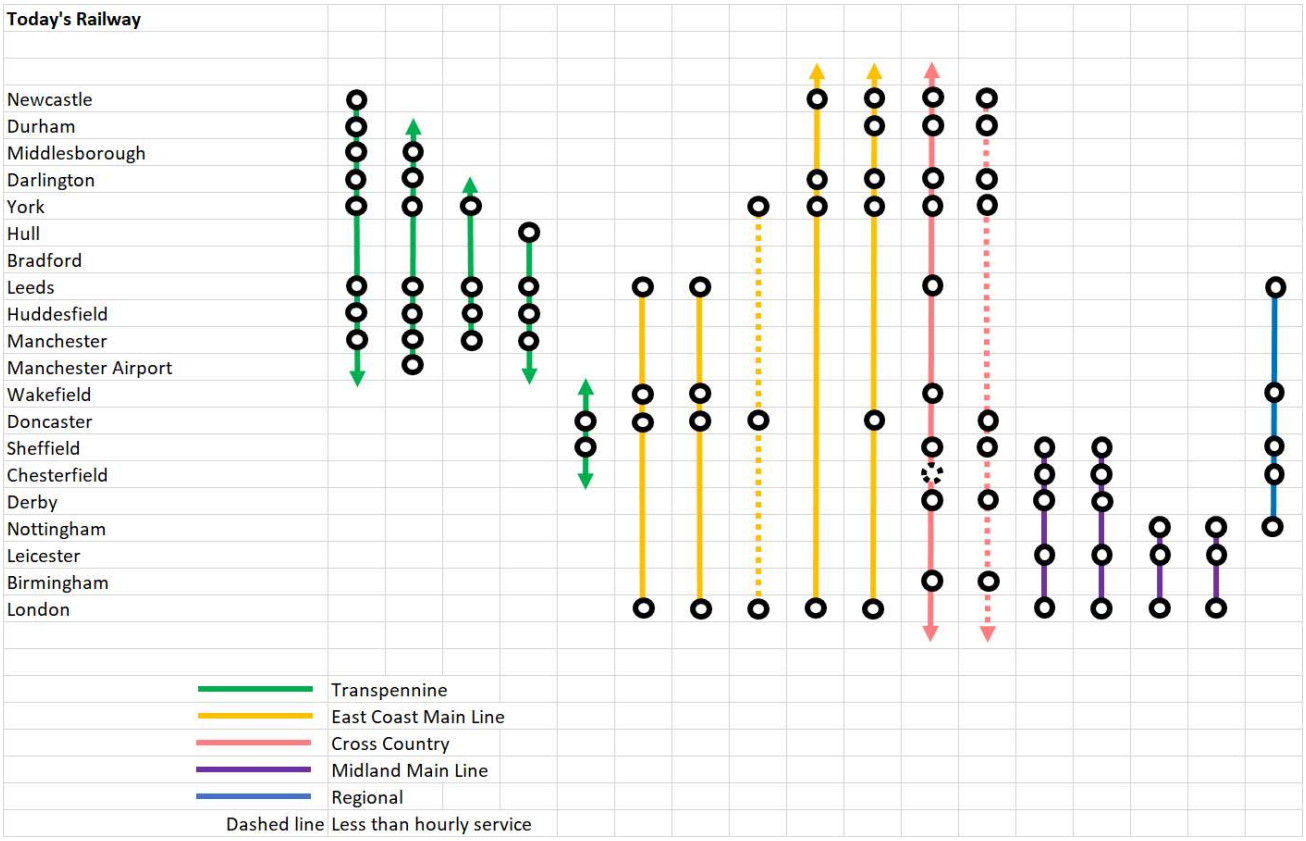

Figure 6 - Current Typical Hourly Long-Distance Service Pattern

The services that appear as dotted lines are those that have not been fully reinstated post-Covid. The diagram is not intended to be a full representation of long-distance services. Open Access services (e.g. Grand Central to Bradford and to Sunderland) are not included due to their more tenuous status. East Midlands Railway's East Anglia-North West service is also not included here although it does provide additional capacity between Nottingham and Sheffield.

2.2 Weaknesses and Connectivity Gaps

The weakness illustrated on the map from the IRP at Figure 5 is also evident from looking at the current long distance services shown topologically below.

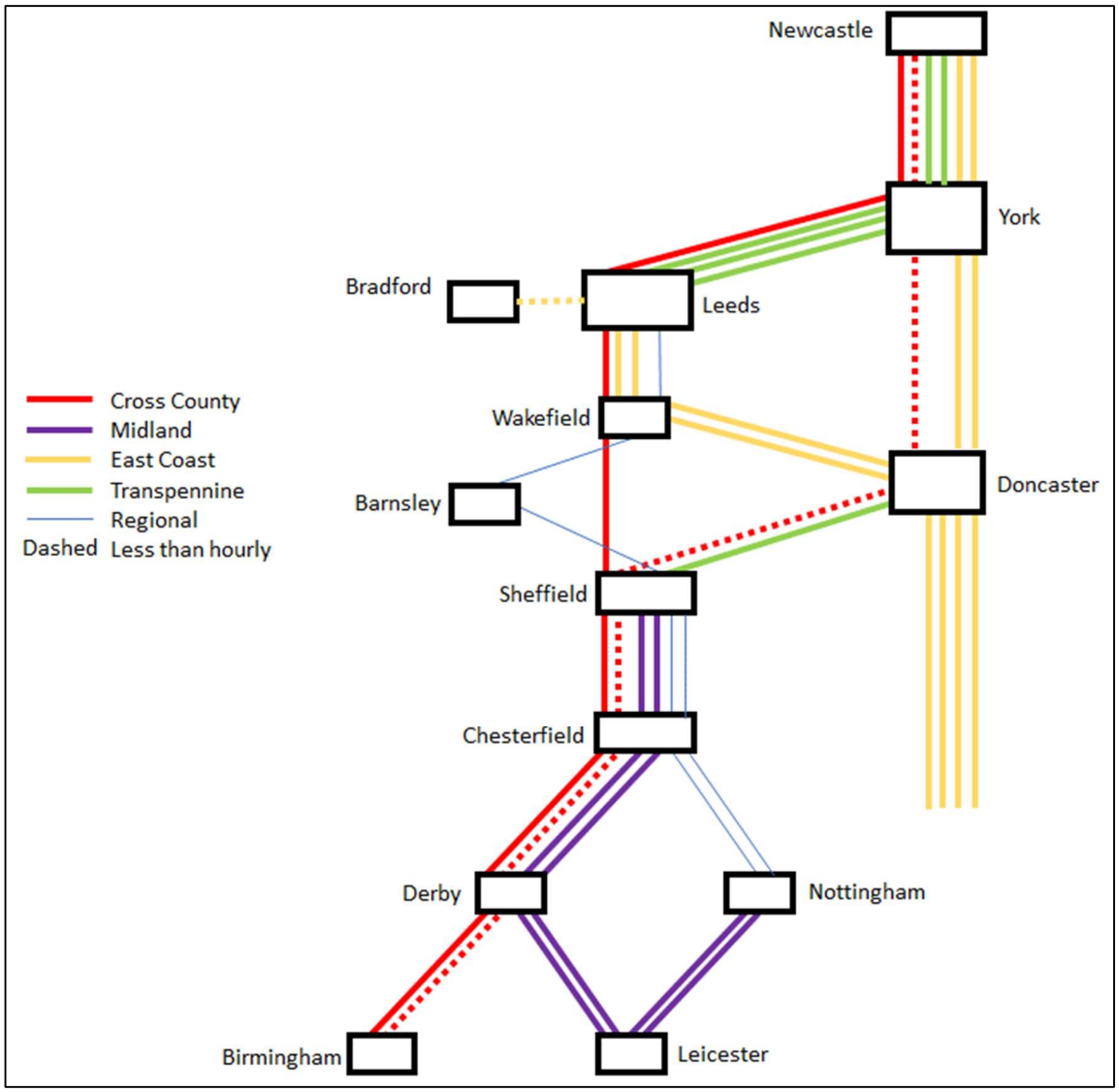

Figure 7 - Topological Map of Long-Distance Services

The weaknesses that emerge from this topological representation of the long-distance services are:

- Poor frequency from Birmingham to Leeds
- The routing of the Cross Country services via Leeds and via Doncaster creates a differential in journey times which reduces the effective frequency of services between Birmingham and York/North East
- Poor frequency of fast services between Sheffield and Leeds (and also slow journey time for these "fast" services)

- Poor service levels from Leicester/Nottingham to destinations north of Sheffield
- Issues of on-train capacity manifest most strongly in overcrowding on Cross Country services on many sections of route
- Emissions from widespread diesel operation

2.3 Objectives

Taking the identified weaknesses from the previous sub-section, the principal objectives become defined as reducing Generalised Journey Time on the flows subject to the study. Generalised Journey Time (GJT) is a helpful measure of travel journey time as perceived by passengers. It combines formulaically using standard industry rules on-train journey time, frequency and interchange penalty (if a change of trains is required). The key objectives are:

- Reduce GJT Birmingham to Leeds
- Reduce GJT Birmingham to North East
- Reduce GJT Sheffield to Leeds
- Reduce GJT Sheffield to North East
- Reduce GJT East Midlands to North/North East

There are also secondary objectives to:

- Increase seat capacity
- Reduce diesel operation to contribute towards decarbonisation agenda

The figure below takes these objectives and summarises the principal constraints that exist to achieving them. The three constraints that occur repeatedly through this table are:

- the northern approaches to Sheffield station
- the route between Sheffield and Leeds
- the approaches to, and capacity within, Leeds City station.

Objective	Constraints
Improve GJT* West Midlands - Leeds	Birmingham New Street (in advance of HS2) Sheffield station and approaches Leeds station and approaches Sheffield – Leeds line capacity
Improve GJT West Midlands – North East	Birmingham New Street (in advance of HS2) Sheffield station and approaches York station north end Differential journey time (via Doncaster v Leeds)
Improve GJT Sheffield – Leeds	Sheffield station and approaches Leeds station and approaches Sheffield – Leeds line capacity
Improve GJT Sheffield – North East	Sheffield station and approaches York station north end Differential journey time (via Doncaster v Leeds)
Improve GJT East Midlands – North	Current service class 195 Sheffield station and approaches
Link Bradford to long distance network	Journey time Bradford – Leeds Leeds station and approaches
On-train capacity	5 car Voyagers only has 256 seats
Rail decarbonisation	Rolling stock and electrification extent

Figure 8 Objectives and Constraints

2.4 Previous Studies

In addition to the IRP, there are a number of other studies that have considered similar ground, including:

- HS2 East: Sub-Optimal Scenarios (SLC)
- The "Credible Ambition" Option (SLC)
- Strategic Alternatives to HS2 East (Mott MacDonald for DfT)
- East Midlands to Leeds Opportunities for Midlands Connect (Mott MacDonald for Midlands Connect)
- ECML: Benefits of Investment Report (Systra for East Coast Mainline Consortium)
- Sheffield – Leeds: What's Next (Greengauge 21)

Where these studies have suggested solutions we have used them to help defline options.

3 Methodology

3.1 Overview

The methodology employed for this study is comprised of three interrelated pieces of work:

- Route section analysis
- Infrastructure analysis
- Service pattern analysis

These are shown on the graphic below.

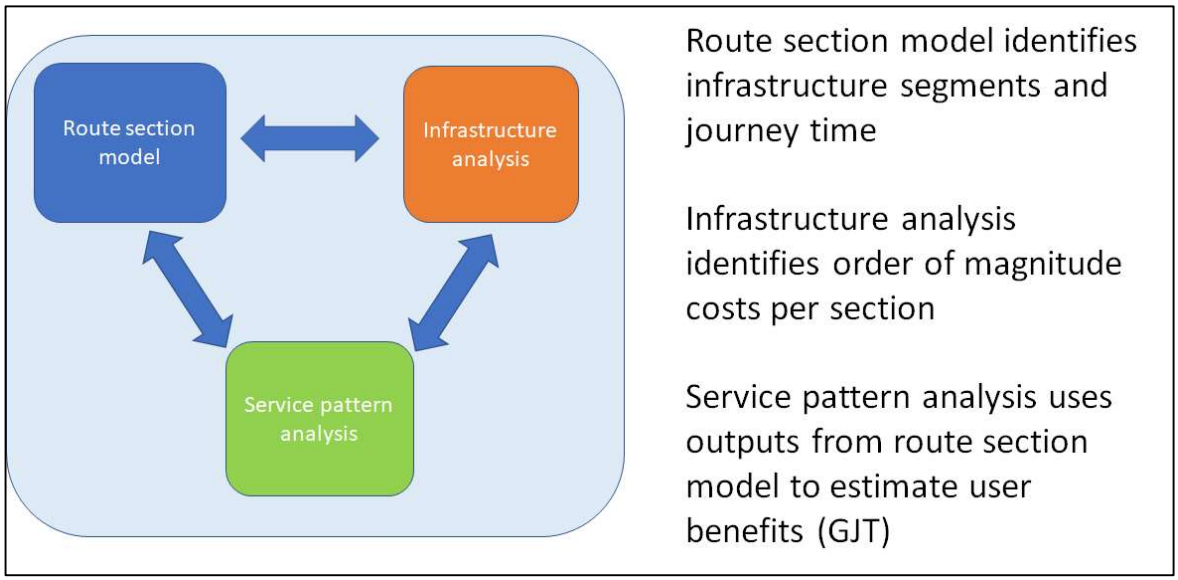

Figure 9 - Simplified graphic of study methodology

3.2 Route Section Analysis

The route section analysis used a GIS base to digitise the routes of relevance to the study as shown in the following figure.

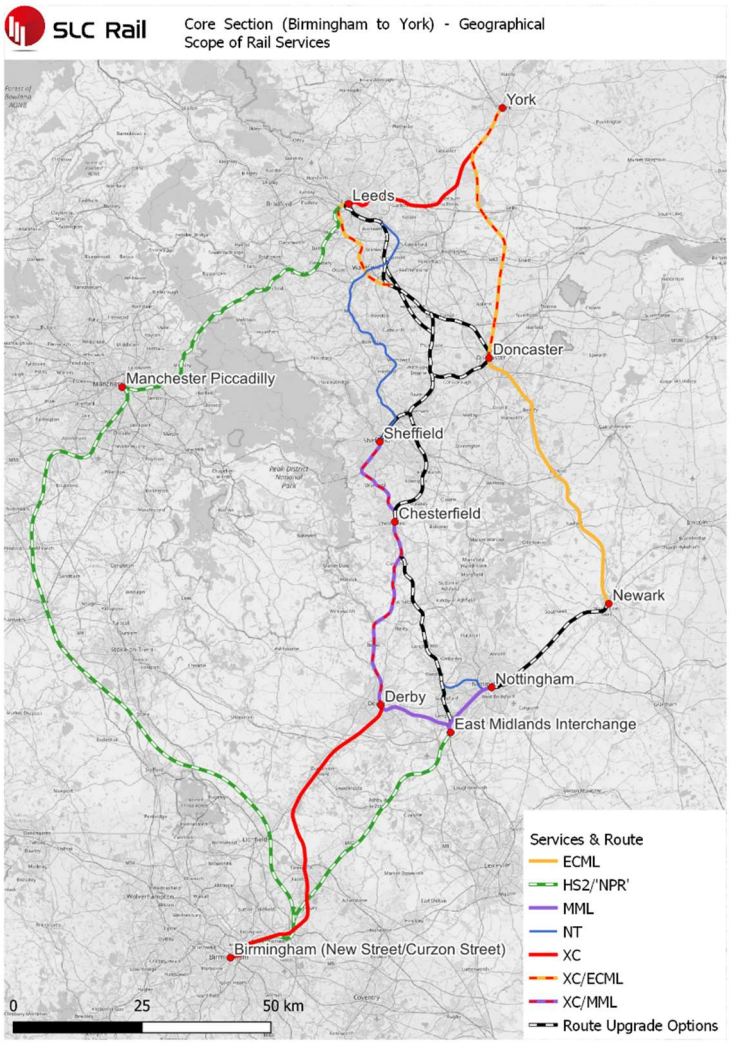

Figure 10 - Model Core Area[1]

This includes the classic network (routes currently used for passenger services and those that might be upgraded for use by passenger services) and new high-speed sections (elements of the committed HS2 scheme and sections of the eastern leg that might form part of a solution to the problems of connectivity identified in the previous section). One of the benefits of using a GIS platform is that it produces relatively accurate section lengths which, when analysed in conjunction with running times can provide a helpful sense check against line speeds.

A spreadsheet model was developed using the route sections as building blocks to code up existing and potential future services. Each route section was given a unique identifier as shown in the example extract below.

[1] Not NPR as preferred by stakeholders, but illustrative of IRP proposal

SectionID	SectionDescription	Scenario	LookupRef	Netwo	JT	Dist (Kı	Ave Sp
C-01	EMD to DBY	Base	C-01Base	Classic	11	15.6	52
C-02	DBY to Clay Cross	Base	C-02Base	Classic	14	32.1	83
C-03	Trowell South Junc to Clay Cross	Base	C-03Base	Classic	14	27.4	71
C-04	Clay Cross to CHD	Base	C-04Base	Classic	3	6.7	81
C-05	CHD to Tapton Jnc	Base	C-05Base	Classic	1	0.9	33
C-06	Tapton Jnc to SHF	Base	C-06Base	Classic	11	18.8	62
C-07	SHF to Masborough Stn South Junc	Base	C-07Base	Classic	6	8.8	53
C-08	Tapton Jnc to Masborough Stn Sou	Base	C-08Base	Classic	13	24.4	68
C-09	Masborough Stn South Jnc to Swint	Base	C-09Base	Classic	4	7.9	72
C-10	Swinton to DON	Base	C-10Base	Classic	11	13.2	44
C-11	Swinton to Clayton	Base	C-11Base	Classic	4	9.3	85
C-12	South Kirkby Junc to Hare Park Junc	Base	C-12Base	Classic	4	10.1	92
C-13	Hare Park Junc to WKF	Base	C-13Base	Classic	6	6.4	39
C-14	LDS to Micklefield Junc	Base	C-14Base	Classic	10	15.8	57
C-15	Clayton to South Kirkby	Base	C-15Base	Classic	1.5	3.7	90

Figure 11 – Example: model route sections

Journey times across each section were validated against the Working Timetable and assumed to be for fast running (i.e. with no deceleration/acceleration for station stops). Station stopping penalties were then included separately to give flexibility in coding up service patterns.

Origin-Destination services were coded as an amalgam of route sections as shown in the figure below. This was repeated for all O-D combinations across the study area. The figure illustrates (in the 'Section' column) the use of 'C' codes for route sections and 'S' codes for station stops. The example shown here is the base journey from Birmingham to Leeds.

Scenario	Origin	Destination	SectionOrd	Section		JT	Dist (Kr
Base	BHM	LDS	1	C-22	Base	33.0	66.0
Base	BHM	LDS	2	S-01	Base	8.0	0.0
Base	BHM	LDS	3	C-02	Base	14.0	32.1
Base	BHM	LDS	4	C-04	Base	3.0	6.7
Base	BHM	LDS	5	S-04	Base	1.5	0.0
Base	BHM	LDS	6	C-05	Base	1.0	0.9
Base	BHM	LDS	7	C-06	Base	11.0	18.8
Base	BHM	LDS	8	S-05	Base	4.0	0.0
Base	BHM	LDS	9	C-07	Base	6.0	8.8
Base	BHM	LDS	10	C-09	Base	4.0	7.9
Base	BHM	LDS	11	C-11	Base	4.0	9.3
Base	BHM	LDS	12	C-15	Base	1.5	3.7
Base	BHM	LDS	13	C-12	Base	4.0	10.1
Base	BHM	LDS	14	C-13	Base	6.0	6.4
Base	BHM	LDS	15	S-06	Base	2.0	0.0
Base	BHM	LDS	16	C-33	Base	13.0	16.1

Figure 12 - Service coding example

This process was repeated for each of the future year scenarios to give a comprehensive set of journey times between O-D pairs given differing packages of route upgrade.

3.3 Infrastructure Analysis

The high-level nature of this commission determines that the infrastructure appraisal and cost estimation are of a similarly high-level. In the first instance, each section of route that was identified as being suitable for upgrade was defined using the following criteria:

- New high speed line
- New station
- New 'regular' line
- New chord
- Junction grade separation
- Line speed increase (LSI)
- Electrification
- 4-tracking

High level costs were produced with reference to the following sources:

- Publicly available information such as HS2, NPR, Network Rail's Traction Decarbonisation Network Strategy (TDNS)
- Previous 2021 and 2022 SLC Engineering reviews undertaken for Leeds City Council
- Previous work by other consultants (eg Mott MacDonald's 2022 report for Midlands Connect – "Opportunities for Midlands Connect")
- International benchmarking reports (eg by PwC)

All of the above were used to 'triangulate' benchmark costs and uplifts were applied to inflate all costs to 2023Q2 prices. In many instances costs were derived from unit rates per mile/kilometre with route section lengths being validated using the GIS platform.

3.4 Future Service Pattern Analysis

Our analysis has been informed by a number of published sources. We have taken as a base the service patterns implicit within the IRP, though this is not always straightforward to understand, and we have undertaken additional research to establish what we believe to be an intended IRP service pattern. The IRP presents an HS2 service pattern and HS2/NPR journey times.

The Planet Framework Model Assumptions Report (V.10a) produced by HS2 for DfT has a view of the potential service pattern on the Midland Mainline to St. Pancras after delivery of HS2 East.

The Atkins "Strategic Alternatives" report[2] produced for DfT as part of the evidence base for the IRP gives us a future East Coast Main Line service pattern following the proposed IRP upgrade of that route.

We have incorporated advice from this project's client group on assumptions of NPR train service specification.

Finally, to generate options for analysis, we have included our own incremental service patterns over and above those inferred from the IRP.

[22] https://www.gov.uk/government/publications/strategic-alternatives-to-the-hs2-eastern-leg

4 Upgrade Costs

4.1 Definition of Route Sections

The core route sections considered in this report are shown on the map below. These are the lines (upgraded and new) which feature in the options we consider, over and above the core IRP enhancements. These latter are assumed as a given in our analysis (ie we have not costed items that are already included in the IRP).

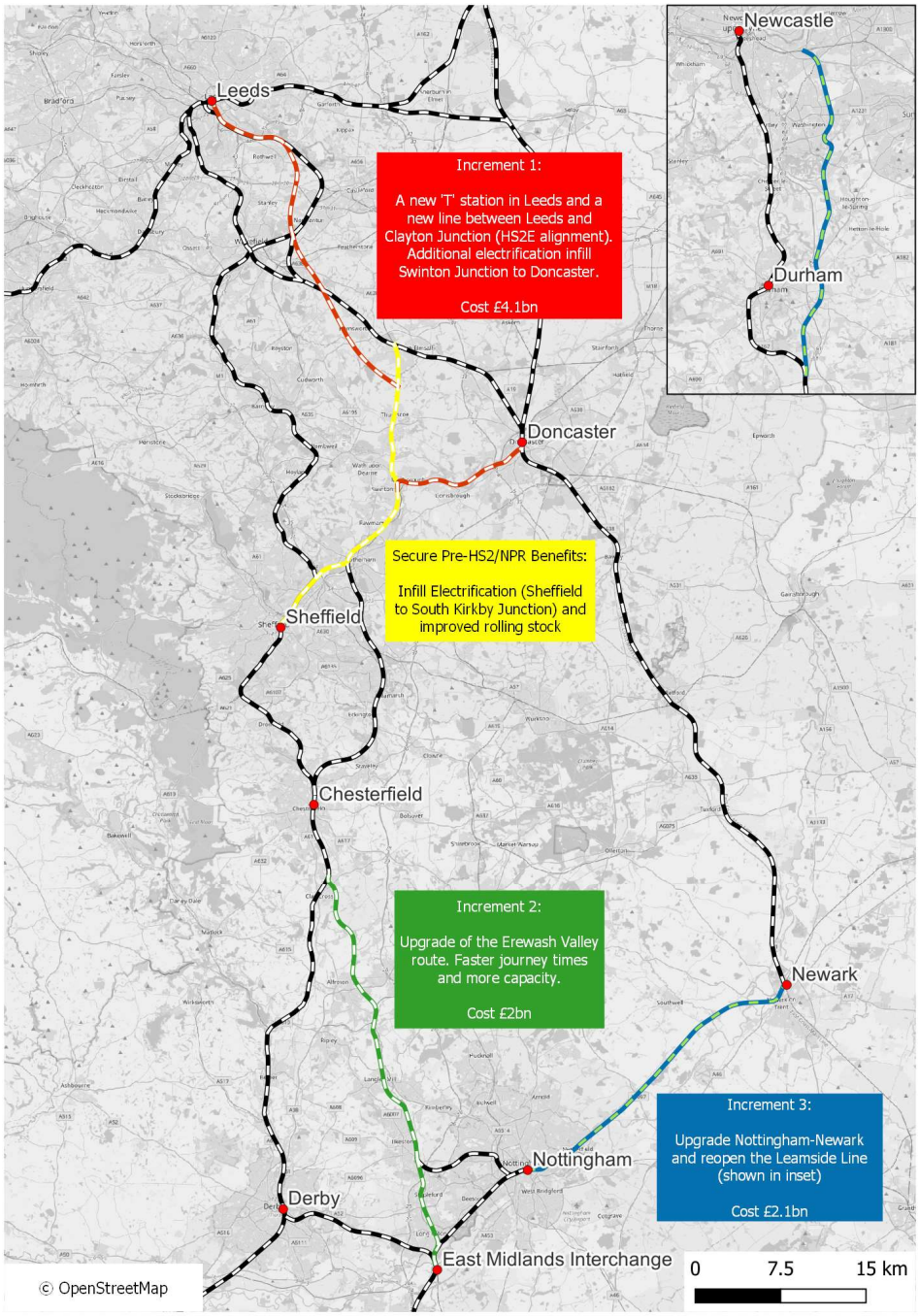

Figure 13 - Route upgrade/new build sections

4.2 Costings

The methodology for developing infrastructure costs is described in section 3.3 above. **It must be emphasised that these estimates are very high level and there is considerable uncertainty in the values generated. They should only be considered as a guide to order of magnitude and should not be quoted in any context other than with the caveats mentioned here.**

The table below summarises the intervention building blocks, scope and the method used to establish a cost benchmark in each case.

ID	Description	Scope	Methodology
1	Erewash Valley	LSI, 4-track, electrify	Scope matches 2021 SLC (routes 14+15+27)
2	The Old Road	LSI, 4-track, electrify	Scope matches 2021 SLC (route 17a)
3	Sheffield to Masborough Junction	4-track, electrify	Scope generally matches 2021 SLC (route 19). Assuming this does not incl A57 massive interface. Will need land acquisition (excl from costs).
4	Masborough Junction to Clayton Junction	LSI, 4-track, electrify	Scope matches 2021 SLC (route 20)
5	Swinton Junction to Doncaster	Electrify only	Benchmarked to TDNS assuming £2m/STK (medium to complex - river, over M1)
6	Clayton to Leeds Junction (HS2 route)	New HS line	Scope matches 2021 SLC (route 8) and in line with benchmarking for new HS line. Note - this will require land acquisition.
7	Leeds Junction to Leeds (HS2 station)	New HS line	Scope matches 2021 SLC (route 9) and in line with benchmarking for new HS line. Note - this will require land acquisition.
8	Leeds HS2 station	Station	Used 2021 SLC assumption (£570m per Curzon St) and pro-rata adjusted as Leeds is 5 platforms (Curzon St is 7 platforms), uplifted to 2023 rates.
9	Clayton to Church Fenton (S&K)	LSI, 4-track, electrify	Benchmarked to 2021/22 SLC averages for LSI (high end of range due to mining) plus electrification
10	Nottingham Station to Newark/ECML	LSI, electrify	Benchmarked to 2021/22 SLC averages for LSI (high end of range, many level crossings on route) and electrification
11	Hare Park Junction to Goose Hill Junction	Chord, grade-separation	Benchmarked to 2021 SLC averages for chords
12	Goose Hill Junction to Leeds HS2 station	LSI, 4-track, electrify	Benchmarked to 2021/22 SLC averages for LSI (high end of range due to mining, junctions, urban environment), electrification, 4-tracking
13	South Kirkby to Hare Park Junction	4-track, electrify	Benchmarked to 2021/22 SLC averages for electrification, 4-tracking (high end of range, route not previously 4-track)

16	Sheffield northern approaches	LSI, 4-track, electrify	Significant uncertainty, major complexity potentially requiring demolition of existing buildings (assumed any tunnel would be cut & cover)
17	South Kirkby to ECML new line	New non-HS line	Scope matches 2022 SLC (route 7)
18	Sheffield to Swinton Junction	Electrify only	Benchmarked to TDNS assuming £2m/STK
19	Leamside line	Reopen as 2 - track	Benchmarked to 4-tracking

Figure 14 - Summary infrastructure building blocks and benchmarking methods

This approach then leads to an order of magnitude cost for each route section based on this benchmarking. The results are shown in the table below.

ID	Description	Scope	Length (mi)	Cost (mil £)	Unit Cost (mil £ / mi)
1	Erewash Valley	LSI, 4-track, electrify	22.8	1,975	86
2	The Old Road	LSI, 4-track, electrify	14.8	750	50
3	Sheffield to Masborough Junction	4-track, electrify	5.3	575	108
4	Masborough Junction to Clayton Junction	LSI, 4-track, electrify	10.4	825	79
5	Swinton Junction to Doncaster	Electrify only	8.0	50	6
6	Clayton to Leeds Junction (HS2 route)	New HS line	13.0	1,200	93
7	Leeds Junction to Leeds (HS2 station)	New HS line	6.9	650	93
8	Leeds HS2 station	Station	N/A	450	N/A
9	Clayton to Church Fenton (S&K)	LSI, 4-track, electrify	18.9	1,100	58
10	Nottingham Station to Newark/ECML	LSI, electrify	17.7	1,125	63
11	Hare Park Junction to Goose Hill Junction	Chord, grade-separation	2.9	275	91
12	Goose Hill Junction to Leeds HS2 station	LSI, 4-track, electrify	11.3	1,000	89
13	South Kirkby to Hare Park Jn	4-track, electrify	6.1	350	57
16	Sheffield northern approaches	LSI, 4-track, electrify	0.3	300	965
17	South Kirkby to ECML new line	New non-HS line	5.1	300	59
18	Sheffield to Swinton Junction	Electrify only	10.4	75	6
19	Leamside line	Re-open	20.7	1100	53
				AVERAGE:	**76 ***

Figure 15 - Summary of benchmarked costs (to nearest £25m)

* Note that the overall average of £76m/mile is comparable to 2015 PwC international benchmarking study findings (£86m/mile for new high-speed infrastructure in a dense/urban environment in 2023 prices).

These building blocks were then combined depending on the option being considered, as described in the section below.

5 Service Development Options

5.1 Introduction

The following options have been assessed in this study:

Option 0: What can be done in advance of HS2 and NPR?

Option 1: Inferred from IRP

- 1a: no service enhancement north of Sheffield
- 1b: with maximum service enhancement north of Sheffield

Option 2: IRP plus East Midlands/Sheffield – Leeds/North East enhancement

- 2a: Sheffield – Leeds upgrade via Clayton route
- 2b: Sheffield – Leeds upgrade via Woodlesford route
- 2c: Erewash Valley upgrade plus Clayton route
- 2d: Erewash Valley upgrade plus Woodlesford route
- 2e: Erewash Valley, Old Road and Clayton route
- 2f: Erewash Valley, Old Road and Woodlesford route

Option 3: IRP plus Newark route

Option 4: Reopening Leamside line

Figure 16 - Options considered

Each of these options is considered below.

5.2 Cost of Each Option

Before considering the service development options, the table below shows how the cost building blocks shown in Figure 15 are combined to give a cost for each option.

	Summary	Addl Trains - Sheffield N End	Addl Trains into Leeds (other than IRP)	Erewash	Old Road	Sheffield N End	Woodlesford route	Clayton route (HS2)	Swinton - Doncaster electrification	Leeds New (HS2) station	Nottingham - Newark	Leamside line	TOTAL
0	Opportunities in advance of HS2 and NPR	2	2	0	0	0	0	0	0	0	0	0	0
1a	Service as inferred from IRP and related documents	0	0	0	0	0	0	0	0	0	0	0	0
1b	As 1a, but with additional Sheffield services to Leeds and York	2	1	0	0	50	0	0	50	0	0	0	100
2a	Enhanced version of 1b, with HS2 East services extended to Leeds and York	5	4	0	0	1700	0	1850	50	450	0	0	4050
2b	As 2a but with alternative route into Leeds	5	4	0	0	1700	1600	0	50	450	0	0	3800
2c	Further enhancement with additional Sheffield - Leeds services starting at Birmingham Curzon Street	5	4	2000	0	1700	0	1850	50	450	0	0	6050
2d	As 2c but with alternative route into Leeds	5	4	2000	0	1700	1600	0	50	450	0	0	5800
2e	As 2c but with Birmingham - Leeds services missing out Sheffield	3	4	2000	750	50	0	1850	50	450	0	0	5150
2f	As 2e but with alternative route into Leeds	3	4	2000	750	50	1600	0	50	450	0	0	4900

3	New Birmingham - Leeds services routed via Nottingham, Newark and Doncaster	2	3	0	0	50	1600	0	50	450	1100	0	3250
4	Leamside line reopening to provide 9 tph + 1 additional freight path on ECML and enhance London – Newcastle services	-	-	0	0	0	0	0	0	0	0	1100	1100

Figure 17 - Cost per option

6 Issues Common to Options

6.1 North End of Sheffield Station

As noted above a key limiting factor is the lack of capacity for additional services at the north end of Sheffield station, and most specifically between the exit from the station and Nunnery Main Line Junction where the line towards Worksop diverges. This section of route is two tracks and in tunnel/cutting, making intervention to construct additional tracks very expensive.

All options that enhance services between Sheffield and Leeds/North East require a solution to this problem, and consideration has been given by stakeholders to:

- Diversion of some heavy rail services onto Tram network (Tram Train), and extension of this network to Doncaster
- Reopening of Sheffield Victoria and diversion of Worksop line trains away from Sheffield Midland (along with new Barrow Hill Line services)
- Reconstruction of railway between Sheffield Midland and Wincobank Junction

We have allowed £1.7bn in relevant options on slide 29, based on extensive construction of 4- line section.

The other issue, however, is how much additional capacity can be achieved through headway reduction. The current headways are three minutes, with two and a half minutes allowed in circumstances where two trains diverge or converge from/to difference directions at the junction.

The complicating factor is that there are currently two fewer local services each way per hour operating than was the case before the pandemic. The following table, therefore, shows how much capacity is consumed on this section with today's timetable (64%) and with the per-COVID .December 2019 timetable (78%). Typically, Network Rail would view 85% as the realistic maximum. The final two columns show how capacity utilisation reduces if the headway out of Sheffield to the North (at least to Wincobank Junction) is reduced to two and a half minutes. In these circumstances an additional four trains per hour could be operated over the December 2019 level before 85% capacity utilisation is reached.

	Current Headways		With Headway Reduction	
Frequency	**Dec 2019**	**May 2023**	**Dec 2019**	**May 2023**
Base	78%	64%	67%	54%
+1	83%	69%	71%	58%
+2	88%	74%	75%	63%

+3	93%	79%	79%	67%
+4	98%	84%	83%	71%
+5	103%	89%	88%	75%

Figure 18 - Capacity utilisation analysis at north end of Sheffield station

On this basis we believe there is merit in examining the practicalities of this approach in more detail. This headway reduction could, for example, potentially be achieved with digital (in-cab) signalling, and is likely to be more achievable than major infrastructure expansion works.

6.2 Leeds Station Capacity

Another factor common to all options is the capacity in and on the approaches to Leeds station. The IRP concepts are looking to expand capacity to accommodate IRP services (TRU, ECML and NPR). As Sheffield – Leeds NPR and extension of HS2 services to Leeds are not included in IRP the issue of need for further capacity at the station is still a serious and uncertain issue.

It is by no means certain that a resilient solution could be found to provide up to four additional services from the Sheffield direction into the existing station.

As proposed in our previous work ("Leeds Credible Ambition" in 2022) and in Mott MacDonald's work both for the DfT and Midlands Connect, the best available solution for this would appear to be to construct a new 'T' station as proposed under the HS2 East plans. This would enable services from the Sheffield direction to terminate clear of the existing lines and approach tracks, and would also enable the divert of the "Five Towns" services – ie those using the old Midland Railway routes into Leeds – to be diverted into the new station, freeing up capacity in the existing.

6.3 Impact of HS2 East on Midland Main Line Services

One of the issues in the brief for this study was for us to comment on the likely impact of HS2 East on the existing inter-city services to/from London St. Pancras on the Midland Main Line.

The issue here is that, once open, HS2 will provide the .core service between Sheffield, Derby, Nottingham and London, with journey times around 30 minutes faster than today. The current service of four trains per hour through Leicester exists in order to provide fast services to Derby and Sheffield (two) and Nottingham (two). It may be that Leicester, in itself, may not in the future justify the current level of fast service that it does today by virtue of the need to connect London with destinations further north. So, for example, the quantum to London could be reduced or journey times could be increased to provide more stops at stations south of London, thereby improving their connectivity. A similar issue applies at Coventry, for example, in relation to services between Birmingham and London.

The HS2 business case assumptions are set out in the latest version of the Planet Framework Model (PFMv10a). This has the following service services assumed for the Midland Main Line:

Service name	Origin-Destination	Calling pattern	Notes / Rolling stock
EM002	STP-NOT	STP-MHR-LEI-LBO-EMD-NOT	Additional call at LBO and only uses 810 5c
EM003	STP-NOT	STP-LTN-BDM-WEL-KET-MHR-LEI-LBO-EMH-BEE-NOT	Additional call at HS2 Toton (EMH)
EM004	STP-DBY	STP-LEI-DBY	Truncated at DBY and uses 810 5c only
EM005	STP-SHF	STP-LEI-LBO-EMD-LGE-DBY-CHD-SHF	Converted to use 810 5c only

Figure 19 - Midland Main Line Planet assumptions

It can be seen that no change in quantum over today's service is assumed, but there a few additional stops and one of the Sheffield trains terminates instead at Derby. As at the time of writing Network Rail is also undertaking strategic advice work based on similar assumptions.

Therefore, we can say that currently there is no industry assumption that services on the Midland Main Line will materially reduce or have extended journey times once HS2 East has opened, although affected stakeholders will need to continue to keep this under review.

7 Option 0 – Opportunities in Advance of HS2 and NPR

The following graphic shows where these opportunities might exist.

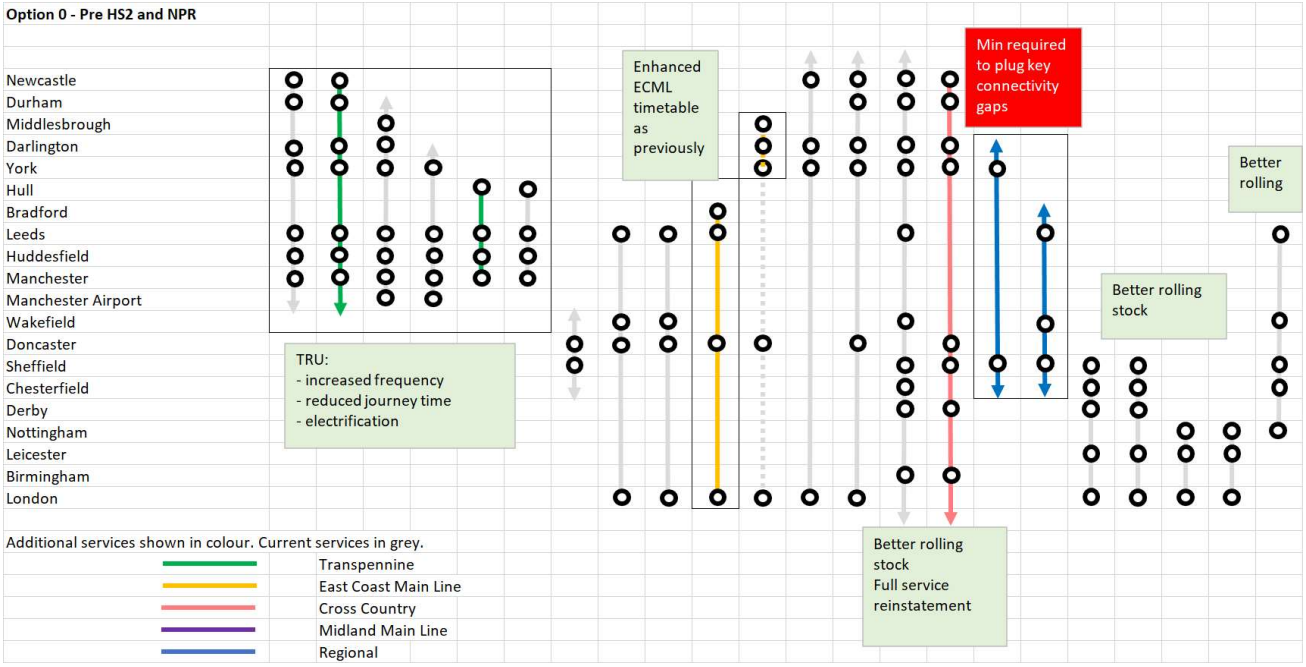

Figure 20 - Option 0 service diagram

As can be seen there are a series of benefits that can be achieved through completion of infrastructure enhancement that has already started, and rolling stock replacement. These can be seen as the key first phase of a long term programme. They include:

- Completion in full of Midland Main Line electrification
- New service patterns and rolling stock following completion of the various phases of Transpennine Upgrade
- Return to pre-COVID frequency of Cross Country services (ie the reinstatement of the hourly Newcastle – Reading service)
- New and/or longer trains on Cross Country services to improve quality and increase seating capacity
- An enhanced East Coast Main Line timetable (including potentially a 3rd hourly service London – Leeds, extended to Bradford) using the infrastructure already delivered (such as the Werrington diveunder and the remodelling of King's Cross station throat)
- Consistent use of 3 car Class 195 rolling stock on the Nottingham – Leeds
- Investigating the possibility of a second hourly fast Sheffield – Leeds on existing infrastructure (as was being considered in 2019)

8 Options 1a and 1b – Plan Inferred from IRP

It is not straightforward to infer the service patterns implied by the IRP. However, through use of the various sources described in section 3.4, it is possible to make a reasonable assessment of the picture. This is shown on the graphic below, and it effectively becomes a future baseline on which the HS2 East Partnership's preferred solution can increment.

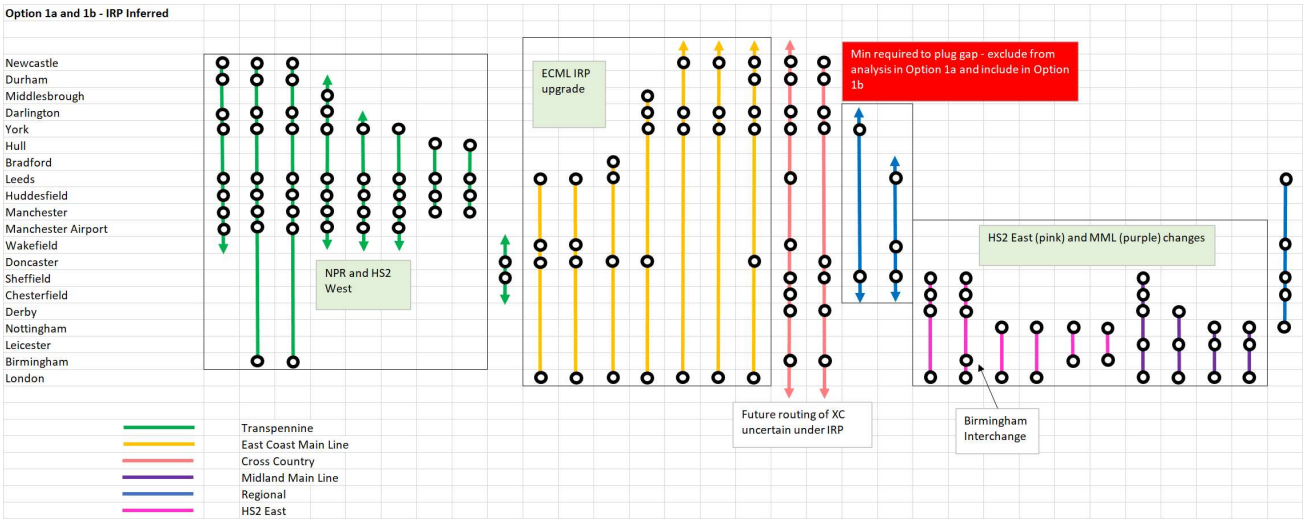

Figure 21 Options 1a/1b (IRP Defined)

The service diagram reflects completion of NPR, the IRP upgrade of the East Coast Main Line and HS2 East. Specifically, we infer the following projects from the IRP document:

- Completion of Midland Main Line electrification as far north as Nottingham and Sheffield
- Completion of TRU
- HS2 Phase 2b Euston – Manchester
- NPR - new lines extending to Warrington and Marsden, but not via Bradford
- Electification Leeds - Bradford
- Additional capacity in Leeds station to enable NPR to operate
- HS2 East as far north as East Midlands Parkway
- Capacity works at Trent Junctions, Nottingham station, and Sheffield station to support HS2 East services
- New rolling stock to operate MML services, HS2 services and NPR services

Against the objectives set out in this study, the IRP delivers improvements in Generalised Journey Time of **35 minutes between Birmingham and Leeds and 27 minutes between Birmingham and York/North East.**

Enhancements to ECML services include hourly Kings Cross - Bradford and hourly Kings Cross - Middlesbrough services. However, IRP does nothing for:

- Birmingham – Sheffield
- Sheffield – Leeds
- Sheffield – York and North East
- East Midlands – Leeds and North East

There is, perhaps, the opportunity for incremental benefits with relatively modest electrification infill and service extensions (subject to pathing into Leeds and through Doncaster), and these service options are shown in blue on the diagram above.

9 Options 2a and 2b – Delivering the Missing Gap

As described in sections 1 and 2.2 above, the key weakness in both the current service provision and in the IRP service proposals shown in option 1a and 1b is the "missing gap" between Sheffield and Leeds.

A fast new or upgraded route between Sheffield and Leeds along with new station in Leeds would plug the key gap in the IRP proposition, especially when also linked with an upgrade between Sheffield and Doncaster for access to York and North East.

Two alternative means of upgrading the route into Leeds have been identified. The first variant shown in Option 2a, assumes that the section of HS2 from Clayton into Leeds is constructed. The second, variant Option 2b, assumes an upgrade of the classic network from Clayton via South Kirkby and along the ECML spur as far as Hare Park Junction. From here a new chord is required to link onto the route via Normanton and Woodlesford into Leeds. This is the option put forward by Mott MacDonald in their Strategic Alternatives work for DfT and in their work for Midlands Connect.

The two options are shown indicatively below.

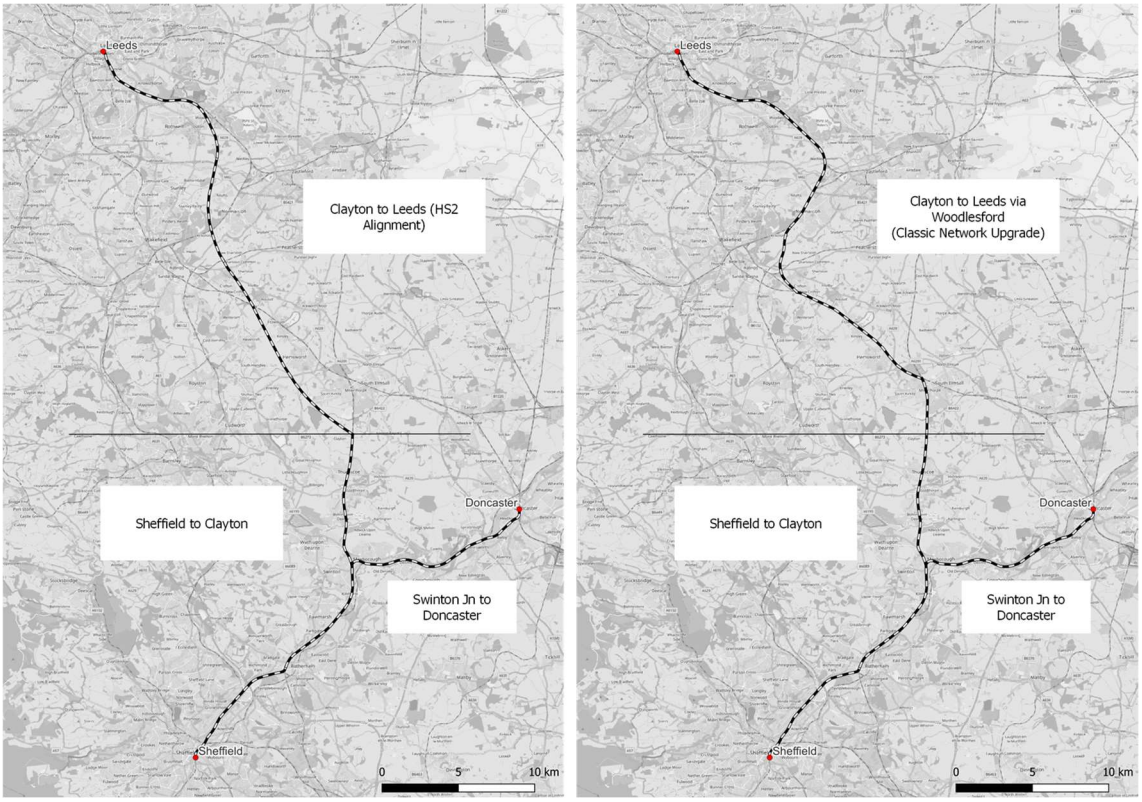

Figure 22 - New fast line Sheffield - Leeds: Option 2a (left) and 2b (right)

In both cases more capacity is required at Leeds to accommodate the new services using the line. To achieve this we have assumed that the HS2 station at Leeds (the 'T' station) must be built (albeit that the specification – such as platform lengths – could be reconsidered for its amended role compared to that under the full HS2 East scheme). An additional benefit is that the Five Towns service (Castlefield/Knottingley) and the longer distance services using the Midland Lines into

Leeds via Barnsley and Wakefield Kirkgate could be diverted into the new station, providing further much needed capacity in Leeds City station.

This proposition results in the following service pattern.

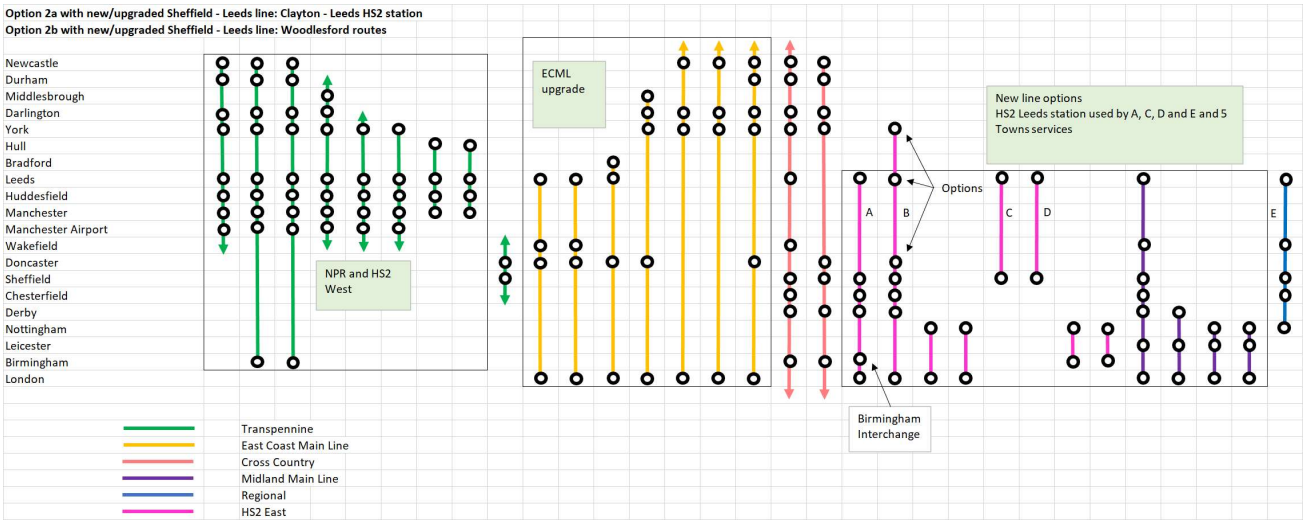

Figure 23 - Option 2a/2b service diagram

The differences between this and the IRP inferred service pattern shown in Option 1 (Figure 21) are the new and extended services shown in pink, with opportunities for NPR frequencies between Sheffield and Leeds and/or enhanced connectivity between Sheffield, York and the North East.

This service pattern would also allow for potential new stations at Rotherham Main Line and Dearne Valley, to be served by some or all of trains A, B, C & D as well potentially as other current services.

The graphs below show the improvement in GJT (in minutes) delivered by the IRP (in blue) and incrementally by these options (in orange).

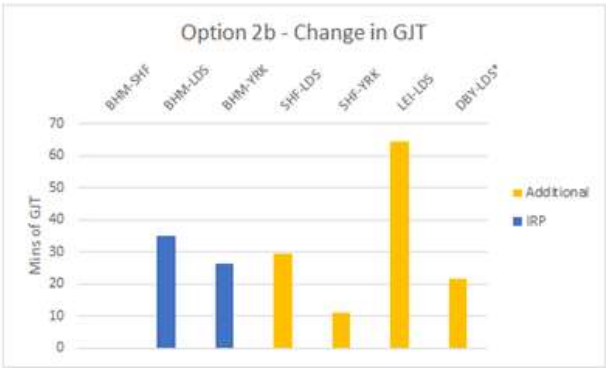

Figure 24 - Options 2a/2b changes in Generalised Journey Time

As can be seen the benefits for Sheffield – Leeds, Sheffield – York/North East and the East Midlands – Leeds are significant, and it is our view that this proposition, "delivering the missing gap" should be at the core of HS2 East Partnership's ask. The order of magnitude costs for these options are £3.8bn to £4.1bn.

10 Options 2c and 2d – Incrementing with the Erewash Valley

These options add to Options 2a and 2b an upgrade of the Erewash Valley line between East Midlands Parkway/Trent Junctions and Chesterfield. This is shown on the maps below. As with 2a and 2b, Option 2c includes the Clayton – Leeds HS2 line and 2d includes the Woodlesford line upgrade.

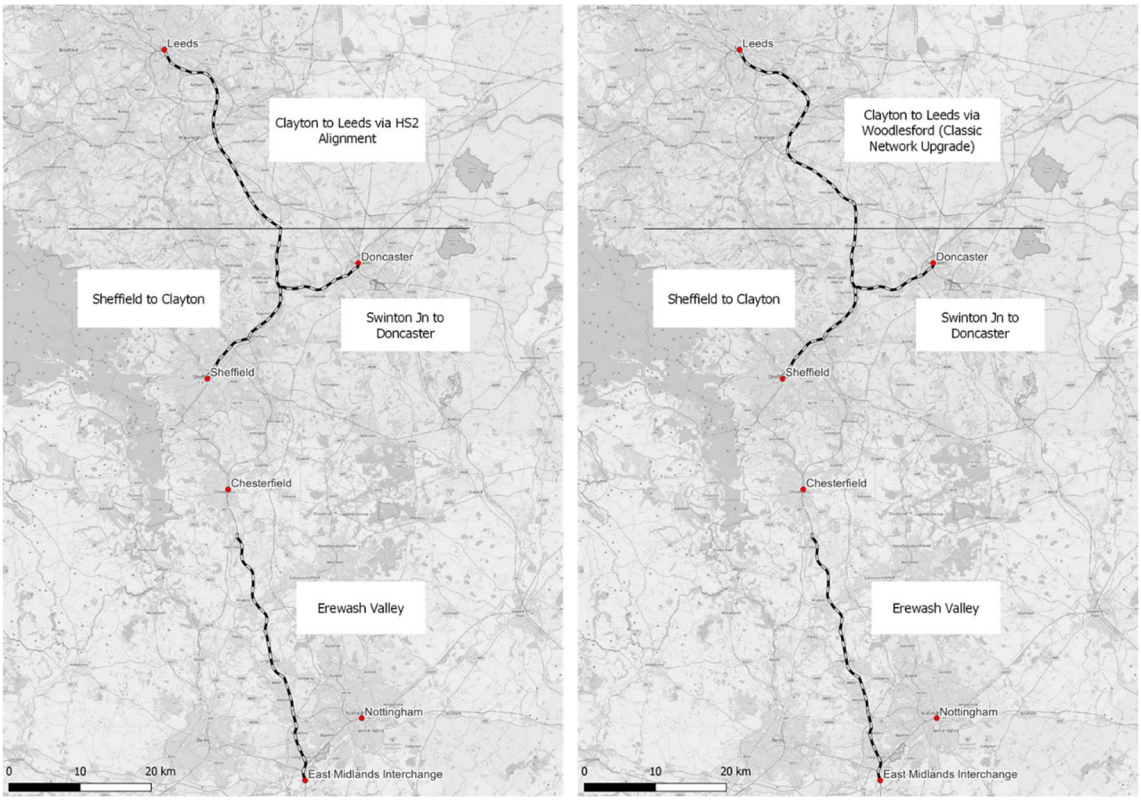

Figure 25 - Option 2c and 2d infrastructure upgrades

The benefit of the approach is that it allows the extension of the Sheffield – Leeds services in Options 2a and 2b to start from Birmingham Curzon Street via HS2 (see pink services on the diagram below). This further enhances Generalised Journey Time between Birmingham and Leeds beyond that achieved in the IRP inferred Option 1 via Manchester.

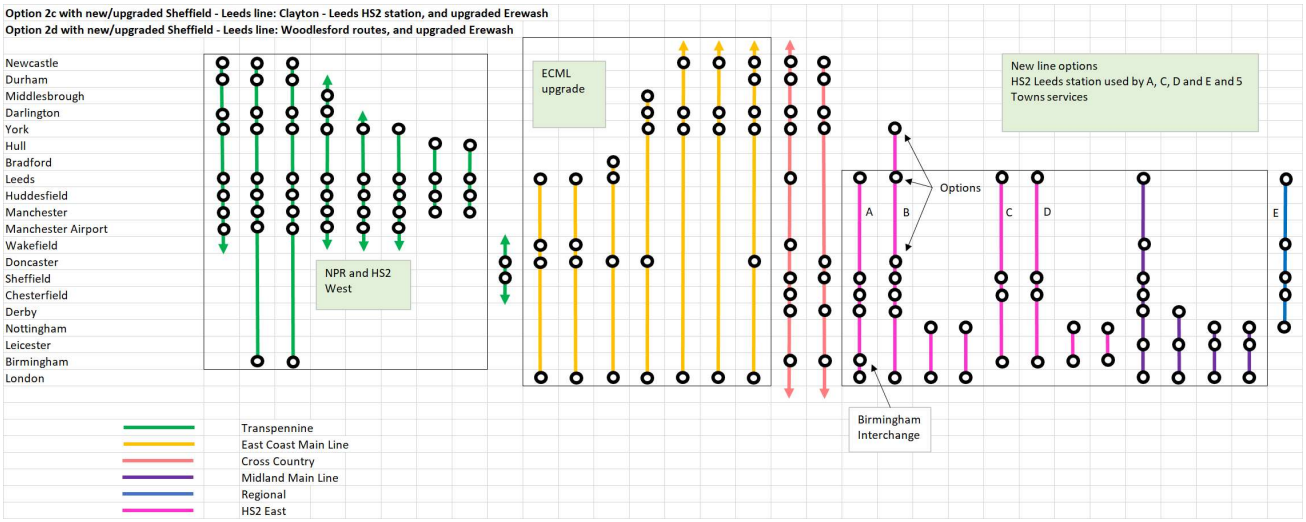

Figure 26 - Option 2c and 2d service diagrams

In terms of Generalised Journey Time, the graphs below show the improvement in GJT (in minutes) delivered by the IRP (in blue) and incrementally by Options 2c and 2d (in orange). These latter include the benefits also delivered by Options 2a/2b as the only difference in 2c and 2d is the addition of the Erewash Valley.

Figure 27 - Option 2c/2d Generalised Journey Times

Our view is that this option should be considered as an increment that could be delivered on top of/after Option 2a/2b. The total cost of these options is between £5.8bn and £6.1bn, but the increment over Options 2a/2b is £2bn.

11 Options 2e/2f – Alternative Avoiding Sheffield

These options replace significant expenditure on the northern approaches to Sheffield with an upgrade of the Old Road between Chesterfield and Rotherham via Barrow Hill. The impact of this is faster services between Birmingham and Leeds, but fewer services between Sheffield and Leeds. For this reason it is not an option that is widely supported by stakeholders although it has been included in a number of option studies, including the Strategic Alternatives Study for DfT by Mott MacDonald.

The upgraded infrastructure is shown below. The difference between 2e and 2f is the route into Leeds assumed as for 2a/2b and 2c/2d.

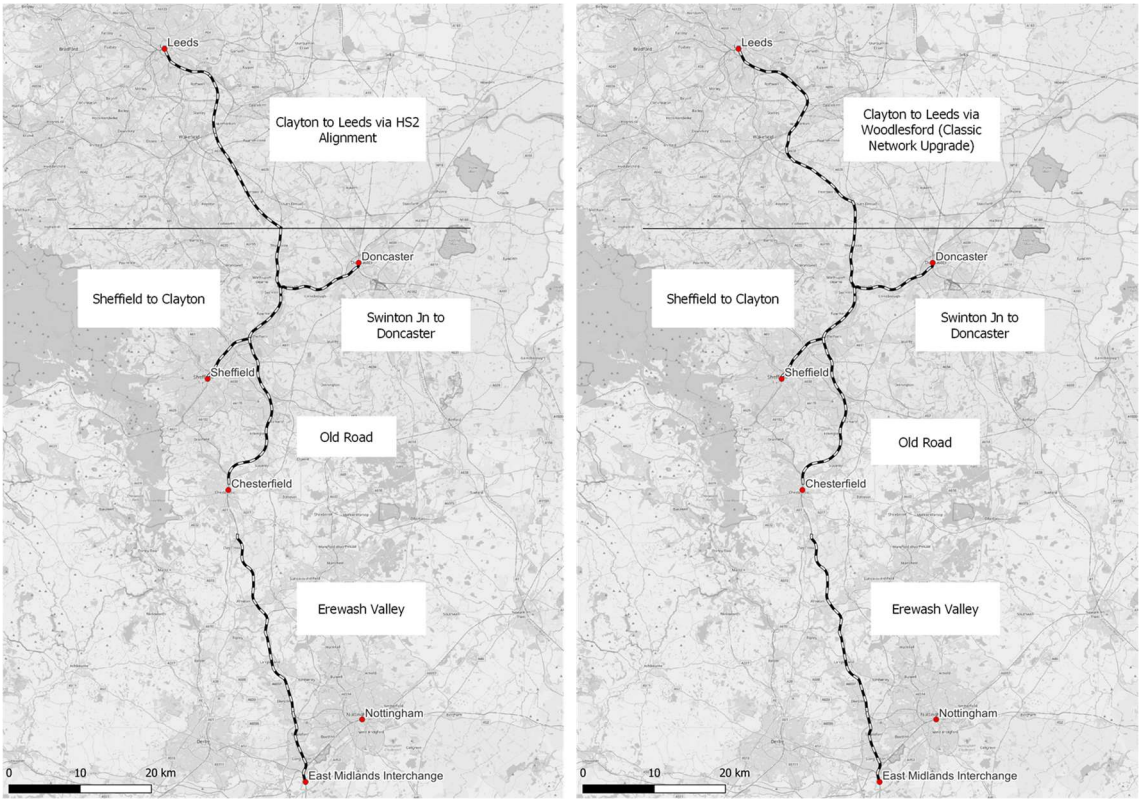

Figure 28 - Option 2e/2f infrastructure upgrades

The service pattern diagram for these options is shown below.

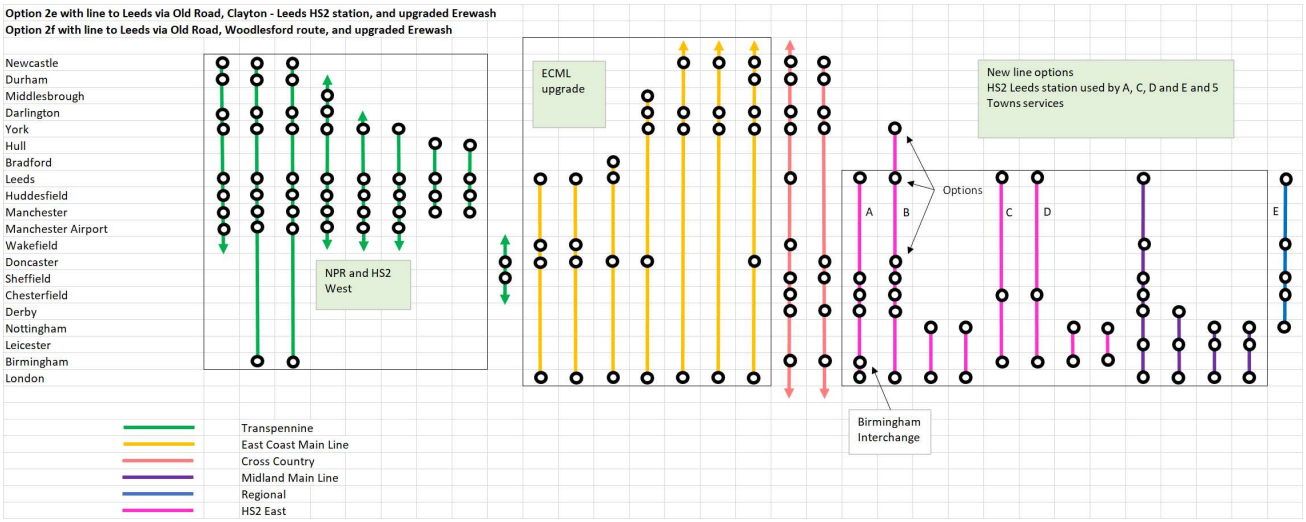

Figure 29 - Option 2e/2f service pattern diagram

The relevant things to notice are the two pink trains labelled C and D. These no longer call at Sheffield.

The graphs below show the improvement in GJT (in minutes) delivered by the IRP (in blue) and incrementally by these options (in orange).

Figure 30 - Option 2e/2f Generalised Journey Times

The cost of these options is between £4.9bn and £5.1bn. These are lower than for Option 2c and 2d because the cost of upgrading the Old Road is more than offset by the saving from avoiding substantial infrastructure works at the north end of Sheffield and between Sheffield and Wincobank.

Nevertheless, this option does not have the support of the client group because it does not address the key weaknesses in Sheffield's connectivity. Also the benefit to Birmingham – Leeds GJT of avoiding Sheffield is relatively small (c. 6 minutes) and insufficient to justify the disbenefit.

12 Option 3 – Via Newark

This option upgrades the Nottingham – Newark line in order to accommodate fast HS2 service. These are the Birmingham Curzon Street – Nottingham services envisaged in the IRP, but extended via the Newark area and then along the ECML (upgraded under IRP to 140 mph) before reaching Leeds via the Woodlesford route. This option was one of those considered by Mott MacDonald for the DfT and also features in Greengauge 21's work.

The infrastructure upgrades are shown on the map below.

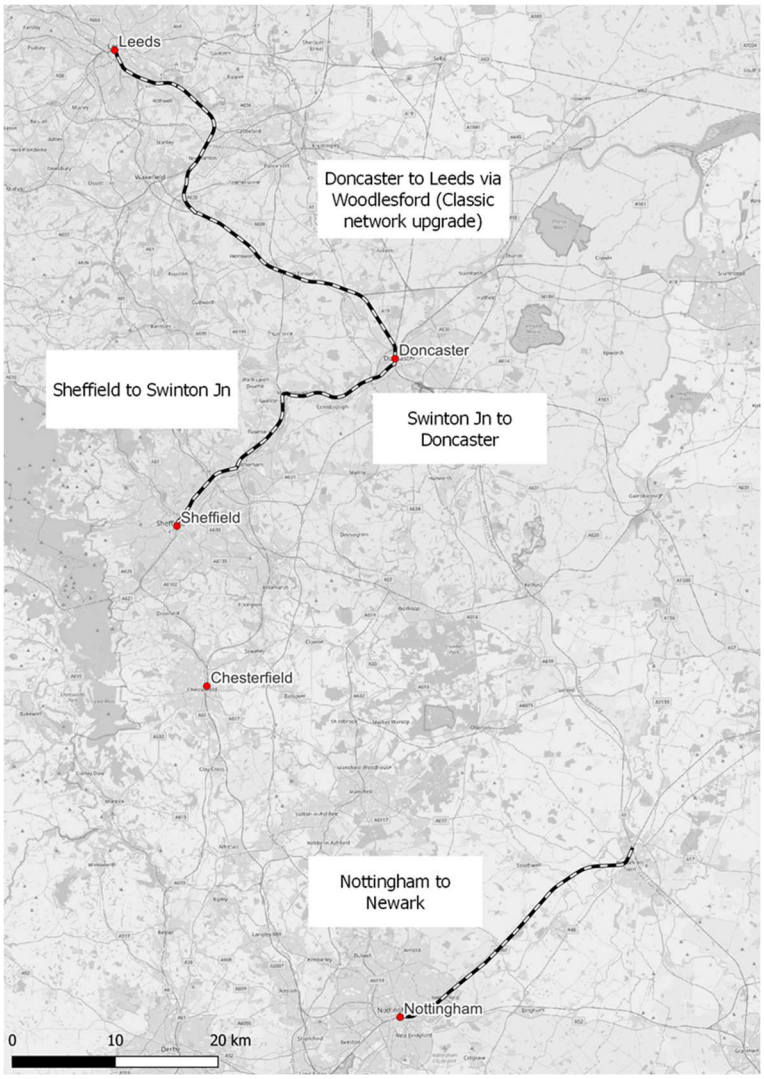

Figure 31 - Option 3 infrastructure upgrades

The associated service pattern is shown below.

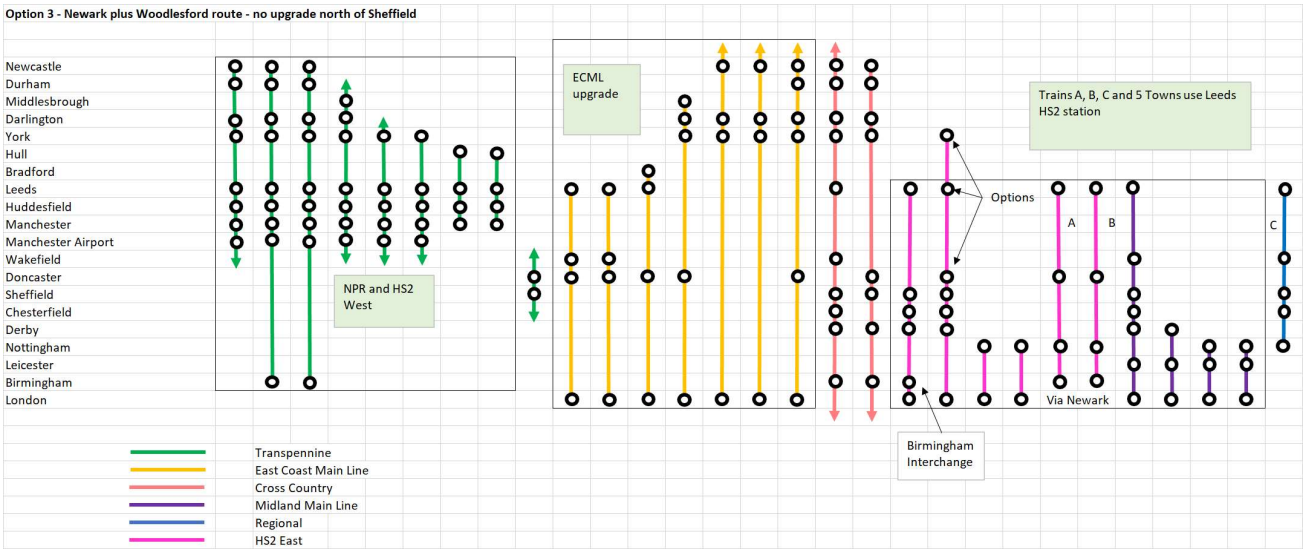

Figure 32 - Option 3 service pattern diagram

The key point to note from the above are the trains labelled A and B, which are the services operating via the Newark area. Note that the service provision between Sheffield and Leeds is lower in this option because only a relatively modest upgrade north of Sheffield is included.

The graph below shows the improvement in GJT (in minutes) delivered by the IRP (in blue) and incrementally by these options (in orange).

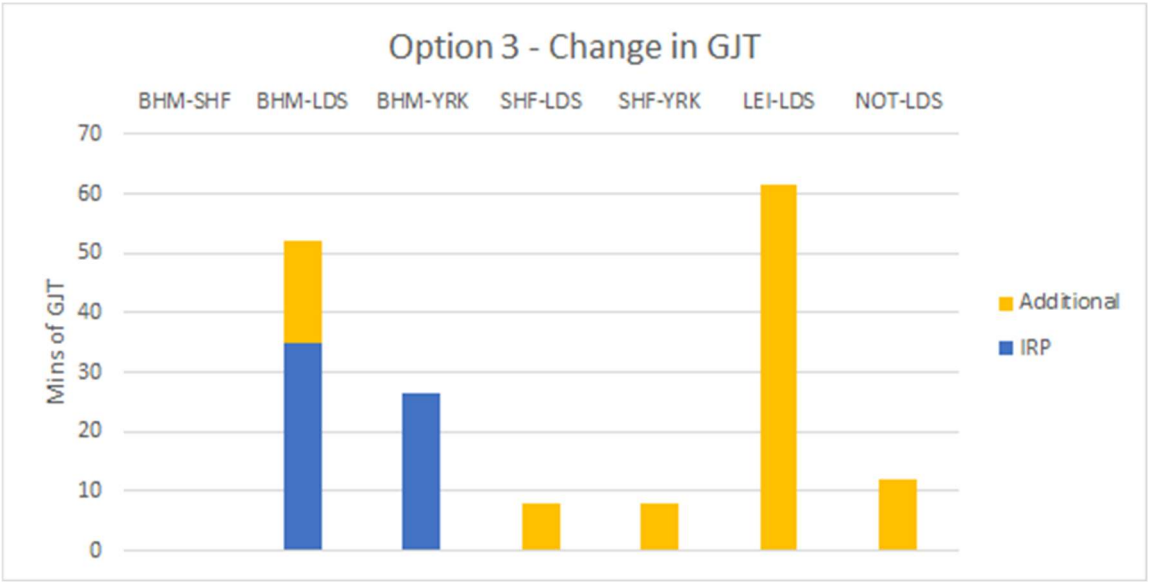

Figure 33 - Option 3 Generalised Journey Time

The key points to note here are that:

- the Birmingham - Leeds benefit is less than it is for options via Sheffield or the Old Road as the journey times are longer
- there is benefit for East Midlands – Leeds greater than in other options

It is worth noting that If this route were used for London – Leeds via HS2, Nottingham and the ECML it would be no faster than current Kings Cross – Leeds services on the ECML for the same number of station calls – it is a long way round.

The cost of this option is £3.3bn, of which £1.1bn is incremental on top of the cost of the Woodlesford route.

Nevertheless, this option could credible form a later phase in order to deliver enhancements between the East Midlands and the North.

13 Option 4 – Leamside Line

The ability to achieve the full NPR outputs north of York and the IRP ambition of Newcastle-London journey times of circa 150 minutes is dependent on a solution to provide sufficient alternative capacity for freight. This is especially true of the two-track section of the ECML between Northallerton and Newcastle, which is currently limited to six trains per hour plus one hourly freight path.

The IRP states that work will be carried out to address bottlenecks on the ECML to accommodate 7 or 8 trains per hour. It assumes this can be done without the Leamside Line, but there is uncertainty around how that can be achieved without impacting reliability and performance.

The phased reopening of the mothballed Leamside Line is an opportunity to release capacity on the ECML route to achieve 9tph plus an hourly freight service, while improving journey times on long distance services to the North East. This would provide the option to, for example, extend the HS2 service from York specified in this report's proposed service patterns on to Newcastle.

The North East is currently pursuing a phased approach to restoring the Leamside Line, with the inclusion of passive provision for heavy rail traffic in the proposed extension of the Tyne & Wear Metro to Washington as the first stage.

The only realistic alternative to Leamside that would provide similar benefits is full Newcastle-Northallerton four-tracking. No reliable costings are available for this solution, but we expect it would carry a prohibitive cost in comparison.

Figure 34 - Location of Leamside line

The cost is estimated at £1.1bn, and is considered as a key increment to the other proposals/options discussed in this report.

For example, the service diagram below shows options for extension of HS2 services as far as the North East.

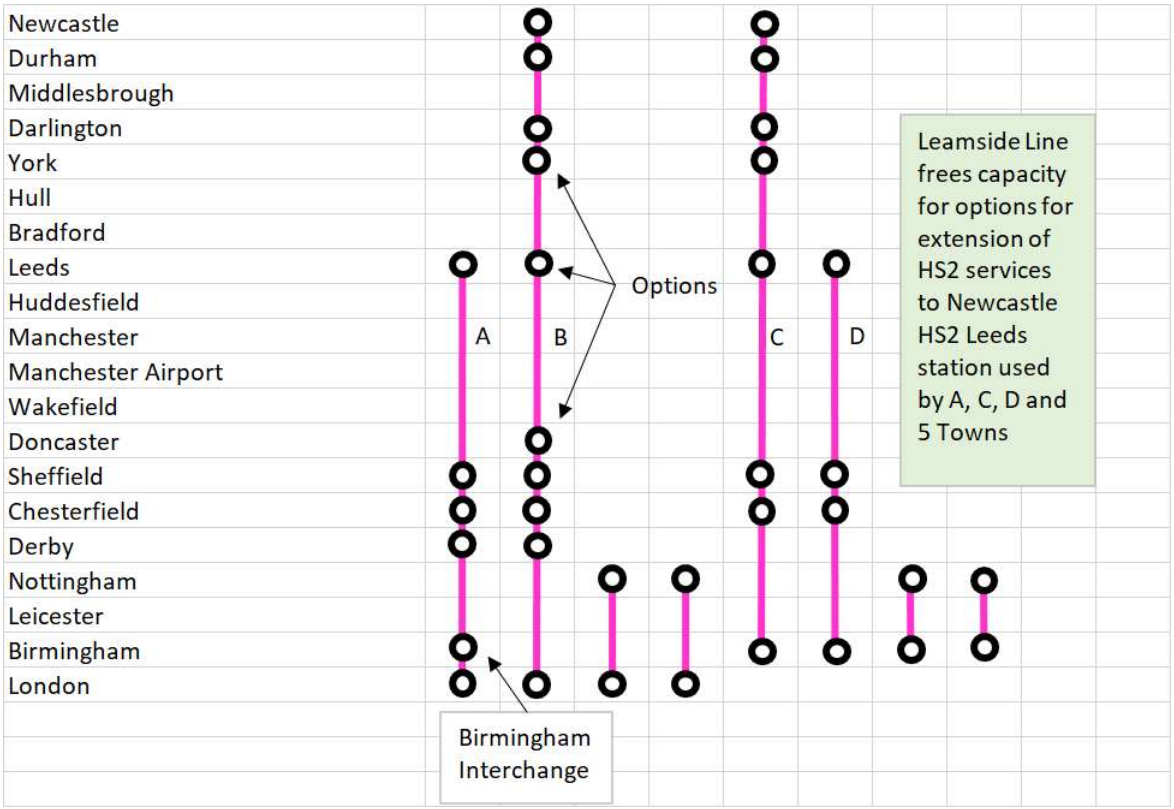

Figure 35 - Options for extension of HS2 services to North East following Leamside line reopening

14 Recommendations

14.1 Key Points - Summary

1. Secure the pre-HS2 benefits, including MML electrification frequency restoration and new rolling stock

   Argue for MML electrification to include infill electrification Sheffield to Moorthorpe (South Kirkby)

2. Secure the benefits delivered by IRP

3. Argue for a new railway between Clayton and Leeds and upgraded railway between Sheffield and Clayton and an upgraded railway for Sheffield to York and the North East, plus the new T shaped station in Leeds (increment #1)

4. Argue for upgrade of Erewash Valley line (increment #2)

5. Argue for upgrade of Nottingham - Newark and Leamside Line (increment #3)

6. Total estimated cost £8.2bn

14.2 Phase 1 - Opportunities in Advance of HS2/NPR

The recommended steps are:

- Completion of full Midland Main Line electrification
- New service patterns and rolling stock - completion of TRU
- Return to pre-COVID frequency on Cross Country (ie reinstate hourly Newcastle - Reading)
- New or increased rolling stock on Cross Country services to improve quality and increase seating capacity
- Enhanced East Coast Main Line timetable (including potentially 3rd service London - Leeds and Bradford)
- Consistent use of 3 car Class 195 rolling stock on Nottingham - Leeds
- Introduce the 2nd hourly fast Sheffield - Leeds service on existing infrastructure
- Plus a quick win, involving infill electrification from Sheffield to Moorthorpe (South Kirkby)

14.3 Phase 2 - Deliver the Missing Gap

A new, fast, route is needed between Sheffield and Leeds along with new 'T' station in Leeds, along with Sheffield to Doncaster upgrade for access to York and North East.

These unlock key gaps in IRP provision. It:

- Delivers NPR Sheffield - Leeds
- Major journey time and frequency improvements Sheffield - Leeds, Sheffield - North East, East Midlands - Leeds/North East
- New route could also be used to bring London HS2 services to Leeds by extending London - Sheffield HS2 services

The incremental costs over the IRP are £4.1bn (order of magnitude).

All the above options have in common the challenge of northern approaches to Sheffield, but headway reduction could potentially deliver up to 3/4 additional paths/hr without needing to 4-track the immediate northern approaches.

14.4 Phase 3 – Further Increments

Upgrading and electrifying Erewash Valley (c.£2bn) would, in addition, deliver further faster Birmingham - Sheffield and Birmingham - Leeds benefits.

Options that avoid Sheffield (eg via "Old Road" through Barrow Hill) are not recommended.

Upgrading Nottingham - Newark (c.£1bn) would enable major improvement in East Midlands - North East (via the upgraded East Coast Main Line included in the IRP.)

Reopening Leamside Line (c.£1.1bn) would enable freight to be diverted off East Coast Main Line and support delivery of all the above (and NPR) through creating more paths to the North East.