NATIONAL
INFRASTRUCTURE
COMMISSION

Rail Needs Assessment for the Midlands and the north

Modelling and Data Annex

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Introduction

Introduction

The National Infrastructure Commission (NIC) has been asked to carry out an assessment of the Rail Needs for the Midlands and the north.

This annex sets out the modelling undertaken by the Commission to support this assessment, including the key assumptions and parameters used in the modelling. This annex does not cover the approach to any modelling outputs that have been used to inform the assessment, which have not been produced by the Commission (eg. modelling by scheme developers to estimate the impact of schemes on journey times).

A full list of the data sources used in the modelling are available in chapter 4 of this annex.

The Commission's assessment of the rail needs in the Midlands and North is based on a multi-criteria assessment of different rail packages.

Each package has been assessed against a number of criteria, some of which have been informed in part by the Commission's modelling, and some which have been informed by qualitative analysis, alongside modelling and analysis provided as part of the initial call for evidence.

The modelling covered in this annex has helped the Commission to assess packages against the following criteria:

1. Economic growth and competitiveness:
   - Productivity (through rail agglomeration impacts)
   - Connectivity
2. Sustainability and quality of life:
   - Amenity benefits from services concentrated in cities
   - Natural capital
   - Lifecycle carbon (CO_2e) emissions

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Methodology for assessing the impacts of packages

2.1 Approach

Rail interventions are necessary but not sufficient to drive economic transformation in cities and regions in the UK. Rail investments have the potential to deliver wider economic benefits, but without other factors in place, these benefits may not be realised.

However, this means that it is difficult to assess the full economic impact of proposed rail investments. The Commission has developed a new methodology to assess the potential benefits of rail investment packages.

Conventional approaches to cost benefit analysis aim to assess the impact of transport interventions in isolation, focussing on the marginal impacts of the intervention on economic growth.[1] This avoids claiming that rail investments will deliver benefits that are due to other factors, but fails to fully capture more dynamic interactions between transport and economic growth. Some have argued that this leads public investment to be channelled into areas that are already doing well, because the effects of transport alone are highest there, creating a further self-reinforcing cycle of divergence.[2]

An alternative is to assume that other factors, such as skilled employment or urban transport, will be in place and rail investment is the final piece of the puzzle that will enable wider transformational benefits. However, this approach fails to capture either the costs or the probability of success of those other necessary factors, likely leading to exaggerated results.[3]

Ideally, it would be possible to assess the impacts of all the relevant factors and interventions jointly. However, this is very complex:

- even if full information on all the interventions were available, it is difficult to assess their effects in combination
- relevant decisions (e.g. on skills, housing, local transport, and rail) are made by different decision-makers at different levels of government with different objectives, so there is not a clearly defined package of interventions to assess
- there is too much uncertainty, as social and economic changes will occur in ways that cannot be predicted in advance.

[1]National Infrastructure Commission (2019), Capturing the value of urban transport investments
[2] D Coyle and M Sensier (2018), The Imperial Treasury: appraisal methodology and regional economic performance in the UK. Bennett Institute for Public Policy working paper no: 02/2018
[3]G Duranton and A Venables (2018), Place-Based Policies for Development, World Bank Policy Research Working Paper 8410

Approaches using complex 'black box' models may seek to capture the interactions, but lack transparency. None of these approaches are therefore suitable for assessing transformational changes, and therefore aren't appropriate to use for this assessment.[4]

The Commission's approach

The Commission has therefore developed an alternative methodology for the Rail Needs Assessment. Instead of trying to directly assess the effect of rail interventions on growth, which presents challenges (as set in the previous section), the Commission's methodology takes the more straightforward approach of assessing the potential for rail investments to support both economic growth and competitiveness, and sustainability and quality of life (see table to right). Whether that potential is realised will depend on other factors, many outside the scope of the Commission's remit.

Table 2.1 sets out the criteria that have been used to assess packages against economic growth and competitiveness, as well as sustainability and quality of life. Each of the criteria are explored in more detail below.

Table 2.1 : Criteria used to assess packages

Criteria	
Economic growth and competitiveness	Productivity (through rail agglomeration impacts)
	Connectivity
	Unlocking investment in land around stations*
Sustainability and quality of life	Amenity benefits from services concentrated in cities
	Impact of rail freight on congestion and carbon emissions*
	Natural capital
	Lifecycle carbon (CO_2e) emissions
	Reliability*

**Impact does not rely on modelling by the Commission, and is therefore not covered in this annex*

More detail on the justification behind the Commission's methodological approach is available in the interim report to this study.

[4]G Duranton and A Venables (2018), Place-Based Policies for Development, World Bank Policy Research Working Paper 8410

2.2. Estimating the productivity impacts of agglomeration

The Commission's approach to quantifying the potential economic growth impacts from rail investments is based on the approach set out in *Capturing the Value of Urban Transport investments*.

The Commission's productivity analysis quantifies two economic benefits from the increase in density in city centres from increased capacity:

a) Direct user impact - Increase in wages from any workers using released rail commuting capacity and accessing higher wage jobs

b) Indirect impact - Increase in productivity from higher city centre density, through agglomeration[5]

The wage premium is estimated by calculating the difference in mean wage between the wider travel to work area and the city centre for each city in the agglomeration analysis. However, some of this premium will be due to a different composition of skills, occupations and sectors for workers in the city centre compared to those in the wider area.

A worker moving to the city centre might be expected to capture the portion of the wage premium that is due to agglomeration benefits, but not the portion that reflects the composition or 'sorting' effect. A sorting effect adjustment is applied to reduce the observed wage premium to account for this.

The increase in productivity through agglomeration is calculated using an elasticity approach based on the change in employment density from new rail commuting capacity.

A full list of assumptions and parameters used to estimate these productivity impacts is available from slide **11.**

[5]Ahlfeldt and Pietrostefani (2019) The economic effects of density: A synthesis, Journal of Urban Economics – vol. 111, (93-107). Available here

Places included in the analysis

The Commission's approach, as set out in *Capturing the value of urban transport investments*, starts from an assumption that, in growing cities, new transport capacity is fully used. For rail, this implies that additional capacity does not lead to a reduction in crowding, but rather to an increase in the number of passengers carried. The assumption that new capacity is fully used will only be valid in the largest cities where rail is a significant commuting mode and where demand is growing.

This element of the Commission's methodology has therefore only been applied to a subset of cities within the region that meet all of the following criteria:

a) The city is on route of any of the schemes in the packages
b) The travel to work area serving the city centre has a population of greater than 400,000
c) The city centre is sufficiently dense

The following city centres are therefore included in the Commission's agglomeration analysis:

- Birmingham
- Bradford
- Coventry
- Derby
- Leeds
- Liverpool
- Manchester
- Newcastle
- Nottingham
- Sheffield

Table 2.2 Productivity analysis: Key assumptions and parameters

Parameter	Assumption or Value	Source(s)
Wages	Local Authority mean wages used. For city centres, each city centre was mapped to a local authority, and the mean wage of that local authority was used as the city centre mean wage. For the wider travel to work area, each LSOA in the TTWA was mapped to a local authority. Mean wages for the TTWA were then estimated by weighting the mean wage in each LSOA by employment in each LSOA (see below for employment estimation).	Wage data: Annual Survey of Hours and Earnings (ASHE) (ONS, 2019). Accessed via nomis here Workday population from 2011 census (accessed via nomis here). Converted to 2019 using local authority level employment between 2011 and 2019 from ASHE.
Employment	Estimated at LSOA level using local authority level workplace employment from the Annual Population Survey, which is then mapped to city centres. For TTWAs, this is then converted to LSOA level employment by multiplying LA level employment by LSOA's share of total LA workday population for TTWAs. The total for each TTWA was then calculated by adding up estimated employment in each LSOA.	Annual Population Survey – workplace analysis (ONS, covering 2019 Calendar year). Accessed via nomis here. Workday population from 2011 census (accessed via nomis here). Converted to 2019 using local authority level employment between 2011 and 2019 from ASHE.
Employment growth	Linked to local authority level subnational population projections, using the same approach of estimating LSOA shares based on workday population.	Subnational population projections, 2018-based (ONS), Link.

Table 2.2 Productivity analysis: Key assumptions and parameters (continued)

Parameter	Assumption or Value	Source(s)
City centre boundary	City centres have been defined using previous work undertaken for the Commission to define the area in the city centre where transport capacity is most constrained. Bradford, Nottingham and Derby were not included in that work, so the Commission has adopted the same principles to define the city centre LSOAs for those cities.	Steer Davies Gleave for the National Infrastructure Commission (2018), Urban Transport Analysis: Capacity and Cost Link.
Sorting effect adjustment	50% of premium	Assumption
Growth in wage premium and productivity effect	Grows with labour productivity as per Office for Budget Responsibility projection. Trend continues after 2068 to end of appraisal period in line with the OBR's March 2019 projection.	OBR's Long Term Economic Determinants Data (March 2019 version). Link.

Table 2.3 Productivity analysis: Approach to ranges

Parameter	Assumption or Value	Source(s)
Elasticity - % increase in productivity for a 1% increase in employment density	Central value of 0.05. Low and High values of 0.022 and 0.076 respectively. TAG economy weighted average (0.044) and SERC central value (0.049) also tested.	Central Value from Gibbons & Graham (2018), Urban Capacity and Economic Output: Report for the National Infrastructure Commission, Link. Low and High values from SERC (2009). Strengthening economic linkages between Leeds and Manchester: feasibility and implications: full report. Link. TAG economy weighted average from Graham D.J., Gibbons S. and Martin R. (2009) "Transport Investment and the Distance Decay of Agglomeration Benefits", Centre for Transport Studies, Imperial College, mimeo, November 2009. Link.

2.3. Estimating the amenity benefits of agglomeration

The Commission's analysis also captures the consumption impacts of agglomeration. [6] For the same set of cities used to estimate the productivity benefits, the Commission's analysis assumes rail capacity contributes to population density in these city centres, resulting in increased amenities.

The impact the change in population density has on the value of amenities in the city centre is quantified using elasticities from new research for the Commission undertaken for this study.[7]

Table 2.4: Elasticity estimates used[13]

Area	Elasticity – change in value of amenities from a 1% increase in population density
North and Midlands	0.015
Birmingham	0.019
Coventry	0.013
Liverpool (greater Liverpool)	0.014
Manchester	0.019
Leeds	0.013
Newcastle	0.019
Sheffield	0.014

[6]Glaeser, Kolko, Saiz (2000) *Consumer City,* Working Paper 7790, National Bureau of Economic Research. Link: https://www.nber.org/papers/w7790
7 AitBihiOuali, Laila (2020), Effects of population density changes on the value of amenities in the United Kingdom: Evidence from the Rail Plan for the Midlands and the north of England, published alongside this report

Table 2.5 Amenity analysis: Key assumptions and parameters

Parameter	Assumption or Value	Source(s)
Value of Amenities per City Centre	Calculated using the average value of amenities per household across the Midlands and North (£9,121 /household/year). The population in each city centre is then divided by the average number of people per household in the UK (2.37) which is then multiplied by the £9,121 value to get the annual value of amenities in each city centre.	Average Number of People per household in the UK from ONS (2020) Household and Population projections. Link. Population estimates by LSOA from 2011 census, and then projected to 2019 using growth from the relevant LA (from LA level 2019 population estimates). Link. Value of amenities from AitBihiOuali, Laila (2020), Effects of population density changes on the value of amenities in the United Kingdom: Evidence from the Rail Plan for the Midlands and the north of England, published alongside this report
Elasticity used	Elasticities for each city used (as per table 2.4 in previous slide). For Nottingham, Derby and Bradford, no specific elasticity was calculated – so the elasticity for the Midlands and North sample is used.	Elasticities from AitBihiOuali, Laila (2020), Effects of population density changes on the value of amenities in the United Kingdom: Evidence from the Rail Plan for the Midlands and the north of England, published alongside this report
Growth in amenity values over time	No growth in household level or city centre level values	Assumption

Table 2.5 Amenity analysis: Key Assumptions and Parameters (continued)

Parameter	Assumption or Value	Source(s)
Population in city centre	As city centres have been defined at LSOA level, LSOA level population projections were estimated by applying the local authority projected growth rate to the LSOA 2018 population.	2018 population estimates from ONS (2020) Lower layer Super Output Area population estimates – Mid-2019 version. Link. ONS (2020) Population projections for local authorities (2018 based). Link.

Table 2.6 Amenity analysis: Approach to Ranges

Parameter	Assumption or Value	Source(s)
Scaling factor: how rail capacity contributes to population density in city centres	50% central, 30% low, 70% high. Scaling factor to represent the fact that commuter capacity is likely to contribute towards population density (which in turn, improves amenities). This factor scales the amount of new capacity coming into city centres to represent the fact that this will not all represent new customers for local amenities.	Assumption

2.4. Connectivity analysis

Overall Approach
The connectivity metric captures how well connected places in the region are to each other, and then how this improves with each package. The measure is weighted by population and travel time and captures the fact that people are less time sensitive when it comes to longer journeys.

It is calculated by combining:

- The share of the population in the destination, as a proportion of the population of all destinations in the metric (this excludes the origin population)
- The journey time between the destination (j) and origin (i)
- Frequency of rail services between the destination and origin
- The decay parameter

$\text{Connectivity}_i = \sum$ share of population in destination j * EXP(journey time between i and j * -decay parameter)

The journey time is calculated by combining:

- The in-vehicle time on the fastest service between the origin and destination
- The 'expected wait time':
    - ➢ This captures the 'average' time each passenger would expect to wait at the station if they arrived at any point during the hour
    - ➢ It is calculated as 60 minutes divided by the service frequency per hour, divided by two.
    - ➢ This is calculated in the same way for direct and interchange services (ie. Interchange would have the sum of the expected wait times, one for each train)

Service frequencies, and in-vehicle times have been provided by scheme promoters. See section 4 for more detail on this.

Scope of places included

The Commission's connectivity measure captures how connected places in the Midlands and North are to:

a) Travel to Work Areas in the Midlands and north with a population over 150,000 people

b) Scottish cities

c) Key International Airports in the midlands and north

d) Other places outside of the Midlands and North

Two Travel to Work Areas (TTWAs) (Warrington and Wigan, and Wolverhampton and Walsall) are split into the four separate places and considered separately in the analysis.

There are 6 TTWA where a single place has been chosen to represent the TTWA that is made up of two places as the TTWA is sufficiently represented by the larger place (such as Durham and Bishop Auckland – Durham station only, Wakefield and Castleford – Wakefield stations only).

A full list of the places included in the Commission's connectivity measure are listed on the next slide.

Table 2.7: List of places included in the Commission's rail connectivity measure

Barnsley	Huddersfield	Telford
Birkenhead	Hull	Wakefield
Birmingham	Kettering	Warrington
Blackburn	Leamington Spa	Wigan
Blackpool	Leeds	Wolverhampton
Blyth and Ashington – (Morpeth station)	Leicester	Walsall
Bradford	Lincoln	Worcester
Burnley	Liverpool	York
Burton upon Trent	Manchester	Edinburgh
Chester	Mansfield	Glasgow
Chesterfield	Middlesbrough	Aberdeen
Coventry	Newcastle	Inverness
Crewe	Northampton	Dundee
Derby	Nottingham	Perth
Doncaster	Peterborough	Stirling
Dudley – (Sandwell & Dudley station)	Preston	Birmingham Airport
Durham	Scunthorpe	Manchester Airport
Grimsby	Sheffield	Bristol
Halifax	Shrewsbury	London
Harrogate	Stafford	Cardiff
Hereford	Stoke-on-Trent	Southampton
	Sunderland	Cambridge

Table 2.8 Connectivity analysis: Key assumptions and parameters

Parameter	Assumption or Value	Source(s)
Population (for weighting)	TTWA population estimated using ONS mapping of TTWAs to LSOA areas, and summing the estimated LSOA-level population for each TTWA.	LSOA level population in 2019 - ONS Lower layer super output area population estimates. Link.
Population growth (once projection ends)	The LSOAs were mapped to a local authority and then the local authority projected growth rate was applied to the LSOA. The 2018 LSOA population estimates were then projected forwards to 2043 using this growth rate. From 2044-2050, local authority population grows at the 2043 rate (the last year before the projection ends).	Projections – ONS subnational population projections, 2018-based. Link. Assumption
Weighting for airports	Since airports do not have a population, their weight has been derived by comparing rail usage at airport stations with cities in the region, and using a proxy population based on the population of cities with comparable rail usage. 780,000 has been used, which is the rounded average population of Coventry, Leicester, Wolverhampton and Nottingham.	Office of Rail and Road, 2018-19 Station entries and exits. Link. LSOA level population as above.
Population for Scottish places included	Current population was calculated by calculating the population of each TTWA as a proportion of the population of Scotland (using the 2016 TTWA population estimates). This was projected to 2020 using the LA level population growth over that period.	ONS (2016), Travel to work area analysis in Great Britain. Link.

Table 2.8 Connectivity analysis: Key assumptions and parameters (continued)

Parameter	Assumption or Value	Source(s)
Distance decay	0.01 based on fitting the exponential decay function to the business travel usage-by-travel time data (excluding journeys of less than 30 minutes).	Commission calculations using data from 2002 – 2017 from the National Travel Survey Table 0308 (2020), Link.
Population for combined TTWAs	The LSOAs were mapped to major towns and cities using a lookup. By summing the LSOA population estimates, the relative population for each town/city within the TTWA was calculated.	LSOA level population in 2019 - ONS Lower layer super output area population estimates. Link.

Table 2.9 Connectivity analysis: Approach to ranges

Parameter	Assumption or Value	Source(s)
Distance decay – range	High: 0.05 based on the value used in previous work by Prospective labs for the Commission. Low: 0.002 is chosen as it provides the inverse of the high sensitivity (i.e. using one fifth of the central value where the high value is five times the central).	Prospective. Link

2.5. Lifecycle carbon emissions analysis

The Commission has estimated the lifecycle carbon dioxide equivalent emissions for each scheme, and therefore each package. This involves three key sources of carbon emissions for each scheme:

1. Embodied carbon dioxide emissions from producing the materials used in the rail infrastructure
2. Land use change emissions associated with transportation to site, and releasing of carbon from soils
3. Traction and signalling emissions from operating the infrastructure

In the absence of detailed specifications for these projects, the Commission has estimated the lifecycle emissions using a combination of data from previous rail lifecycle carbon assessments, and assumptions on emissions and fuel efficiency.

Embodied carbon emissions

For the embodied carbon emissions from the materials used to construct rail infrastructure, the Commission has taken previous estimates of the amount of concrete, iron and steel to construct rail projects, on a per km of single track basis.

The Commission has used the following estimates for the following types of projects:

Used for	Materials estimate used
New track/lines (eg. HS2 western leg)	Average amount of materials per single track km (from HS2 phase 1 and phase 2a environmental statements)
Station upgrades	Soham station upgrade (from the RSSB carbon tool)
Electrification	GWR electrification (from the RSSB carbon tool)
Route upgrades	Transpennine upgrade estimate (from the RSSB carbon tool)

Table 2.10 Lifecycle carbon analysis: Key assumptions and parameters

Parameter	Assumption or Value	Source(s)
Land use change emissions	For all schemes, assumed to be the same value per single track kilometre (stk). Land use emissions per stk calculated as the total land use emissions for HS2 Phase 1 and 2a, divided by the total track length.	Land use emissions for HS2 Phase 1 and 2a from environmental statements (Link – Phase 1 , Link – Phase 2a).
Iron and Steel/Cement emissions per tonne of material	Emissions per tonne of material in 2020 have been calculated as the sectoral emissions in 2018 divided by the total tonnes of material produced in 2018. Emissions per tonne of material in 2050 reduce by the same proportion as the percentage reduction between sectoral emissions in 2018 and sectoral emissions in 2050, to get emissions per tonne in 2050. Annual emissions per tonne of material reduce between 2018-2050 by the same amount each year through linear extrapolation.	Current sectoral emissions – BEIS Greenhouse Gas Inventory (2020). Link. Sectoral emissions in 2050 from the 'further ambition' scenario in the Climate Change Committee's net zero analysis (2019). Link.
Energy use from track and signalling equipment	Total rail sector emissions in 2018 were taken from BEIS GHG inventory (3.16MtCO2e).Combined emissions from traction were taken from ORR estimates (estimated at 3.04MtCO2e for 2018). The residual emissions (138KtCO2e) between the two were assumed to be for signalling and track energy use. Using BEIS' long run marginal emissions factor for the industrial sector (2018) – signalling and track electricity consumption was calculated (estimated at 0.4TWh). This was then divided by the total length of track in the UK in 2018, to generate an emissions factor of 28.3MWh per km of track per year.	Rail sector emissions – BEIS Greenhouse Gas Inventory (2020). Table 19. Link. Traction emissions – ORR estimates of energy consumption and co2 emissions (2020). Link. Electricity emissions factor from Green Book Supplementary guidance on valuing ghg emissions, data tables 1 – 19, table 1. Link.

Table 2.10 Lifecycle carbon analysis: Key assumptions and parameters (continued)

Parameter	Assumption or Value	Source(s)
Energy use for traction	all electrified rolling stock is assumed to have a fuel efficiency of 16.3 kWh/km. This is based on an average of the fuel efficiency of modern electric rolling stock (across EMU class, modern 331 and modern 397, and locomotive 68 rolling stock types).	Assumption based on expert advice from the ORR
Electricity emissions factor	From 2020 – 2050, this analysis assumes combined cycle gas turbines are the marginal generator, and therefore uses this as the electricity emissions factor (350gCO2e/kWh). From 2050 onwards, given the government's commitment to net zero emissions, these marginal emissions are assumed to be 0.	Emissions factor from analysis underpinning the Commission's research on the costs of highly renewable power systems. Link.

2.7. Natural Capital Analysis

The Commission has quantified some of the natural capital impacts for each scheme, and used this information to calculate the total natural capital impact for each package.

This has been calculated by the total land lost per package, measured in hectares, and the total monetary value lost. This covers land lost due to new track only, and does not cover the hectares lost from new stations, upgrades or electrification.

The total monetary value lost is a sum of the following ecosystem services:

- Farm profit
- Timber profit
- Farm GHG sequestration value lost
- Forest GHG sequestration value lost
- Recreation value

The total land and monetary value has been quantified using the Natural Environment Valuation Online Tool (NEVO) developed by Exeter University, Defra and NERC.

NEVO divides the UK into 2km squares and provides estimates of the value of each ecosystem service listed above, along with the total hectares of land in each square.

Approach

For each scheme the Commission has mapped where new rail track is likely to be built onto each 2km square.

All new track is assumed to be built within 2km of existing track. The exception to this is HS2 schemes, where route information is available (link).

Table 2.11 Natural capital quantified analysis: key assumptions and parameters

Parameter	Assumption or Value	Source(s)
Width of new track	All new track is assumed to be 21.5 metres wide.	Assumption
Land lost due to new track	Same amount in each 2km by 2km square. Assumed to be 2km * track width, meaning that the value lost is 1.075% of the value in each square, per year.	Assumption
Growth in value of ecosystem services	Where the value of ecosystem services in an area is 0, this is assumed to stay at 0 over the whole appraisal period. Values stay at 2030 values, with no growth in the real value of the ecosystem services.	Assumption

3

Methodology for assessing the costs of packages

3.1. Introduction

In the Commission's assessment of the rail needs in the Midlands and North cost data has been provided by scheme promoters and has included:

- Different cost base years
- Differing assumptions around optimism bias & risk.
- Other areas of scheme detail & scope.

However, to ensure consistency the Commission has

- Converted all costs into 2019/20 prices
- Calculated a central, low and high cost estimate for each scheme
- Removed promoter optimism bias and applied the Commission's own evidenced-based optimism bias factors to produce low and high costs estimates for each scheme. The Commission's application reflects the type and maturity of each scheme assessed.

The Commission has also included cost allocations for three generic categories:

- Electrification
- Digital Signalling
- Early Wins.

Cost Base Year

The Commission has used GDP Deflator information to rebase from the developer supplied cost base year to 2019/20 to obtain a broadly consistent set of costs for use in the Rail Needs Assessment.

These figures are set out in the table below.

Table 3.1 GDP deflator

Year	GDP deflator	Year	GDP deflator
2020	1.000	**2033**	0.639
2021	0.966	**2034**	0.618
2022	0.934	**2035**	0.597
2023	0.902	**2036**	0.577
2024	0.871	**2037**	0.557
2025	0.842	**2038**	0.538
2026	0.814	**2039**	0.520
2027	0.786	**2040**	0.503
2028	0.759	**2041**	0.486
2029	0.734	**2042**	0.469
2030	0.709	**2043**	0.453
2031	0.685	**2044**	0.438
2032	0.662	**2045**	0.423

Optimism Bias, Risk & Ranges

Schemes have been supplied to the Commission with different levels of optimism bias applied by their promoters.

The Commission has reviewed each scheme within its assessment, to understand what the level of optimism bias is.

Where differing levels of risk are included, this has been reviewed.

To enable a high level cost range to be used in the assessment, the Commission has been informed by research commissioned from Oxford Global Projects on Reference Class Forecasting,[8] and by the cost ranges developed within the Northern Powerhouse Rail workstream.

[8] Oxford Global Projects for the National Infrastructure Commission (2020) Reference class forecasts: rail projects, published alongside this report

3.2. Approach

The Commission has used the following approach:

For the 'Central' case the Commission has used the developer supplied 'central' risk figure, and the developer supplied Optimism Bias percentage rate.

For the 'Low' and 'high' range, the Commission has stripped out the developer supplied Optimism Bias, and, has used TfN/ Network Rail cost range for NPR, the Oakervee range for HS2 and applied Oxford Global Projects rates to other costs. This has provided the low and high indicative range for use in the assessment:

- HS2 Phase 2b: 50% to 70% uplift. These costs are based upon Oakervee for Phase 2b as that gives a split between eastern and western legs and adjusted for the recent DfT/ HS2 changes in specification to the western leg. The cost are broadly comparable with the most recent DfT/ HS2 costs. (Phase 1/2a central costs were used due to the relative maturity of these costs and as these sections are already in construction).
- Midlands Engine Rail. 55% to 119%. The OGP Strategic Outline Business Case rate range has been applied to the MER interventions to reflect the stage of development they have reached.
- NPR: broadly 48% to 99%. Network Rail derived average low and high rates have been applied to the NPR figures reflecting the stage of development the NPR interventions have reached. The Network Rail approach was based upon a detailed review of the risk factors for different elements of the NPR costs to give low and high confidence estimates.
- Commission developed interventions, 'Strategic Alternatives' & Electrification/Digital Signalling/Early wins. 55% to 119% applied from the OGP Strategic Outline Business Case work, to reflect the early stage of development/indicative nature of these interventions.

This delivers a cost range which includes a broad indicative assessment of the relative development of rail interventions across the Midlands and North which is evidence-based, and includes a consistent approach to the treatment of outturn costs based on experience from delivering similar projects.

3.3 Commission Scheme Estimates

In a small number of examples, where no detailed information was available, the Commission has developed its own indicative ‘low’ scale interventions for comparative purposes against other interventions. These are relatively ‘low’ scale interventions between:

1 Liverpool – Manchester. Electrification via Warrington Central from Hunts Cross to Trafford Park.

2. Leeds – Sheffield, electrification, limited line speed increase, limited platform lengthening and limited additional capacity(Loops).

3. Derby – Sheffield, electrification and limited platform lengthening at smaller stations.

4. Bradford Interchange – Leeds, electrification, limited platform extensions, limited linespeed increase through track realignment outside Bradford Interchange & additional capacity (Hammerton Street Loop).

The Commission has used existing reference case information available to it, for example around cost of electrification per single track kilometre, to develop indicative costs for comparative purposes based around electrification, smaller scale capacity increases and some limited line speed increases to inform the Rail Needs Assessment.

The costs used within the Rail Needs Assessment are based around rail industry knowledge using a broad range of recent projects and outturn costs, with the application of 40% Optimism Bias in the central scenario, which is consistent with Transport Appraisal Guidance (TAG) at the single option level.

These scheme estimates are largely focused on improvement to a line through electrification, rather than wholesale changes to railway controls, frequency, capacity or significant changes in train length.

4

Modelling and Data sources used

4.1. Overview

Given the scale and complexity of the UK rail network, much of the Commission's analysis has relied on data provided by other stakeholders. This chapter sets out where this data has come from, and what data has been used in the modelling for the Rail Needs Assessment.

There are four main data sources that have been provided from stakeholders which underpin the Commission's modelling:

- Capacity data
- Journey time and frequency data
- Cost data
- Track length data

This section discusses each of these in turn, including any assumptions made to convert the data into the correct format to apply to the methodology.

4.2. Capacity data

Capacity data has been used to estimate the amenity and productivity impacts of packages. The methodological approach (set out in Chapter 2) relies on estimates of released capacity on commuter services.

However, for the majority of the schemes in the packages, scheme promoters could not provide estimates of released commuter capacity only. The table on the next slide summarises the data the Commission has used for this analysis, and the source of that data.

To ensure consistency across schemes, the Commission therefore used the same data on total capacity for each scheme and applied the following assumptions to convert this to commuter capacity.

In all cases, the Commission has had to estimate released commuter capacity from daily total capacity:

- Other than for NPR, where estimates at peak were provided, daily total capacity has been converted to peak capacity. Daily total capacity has been divided by 16 hours, and then multiplied by three to get a 3-hour peak figure. Capacity at peak times is assumed to be the same per hour as at off peak times.
- Once the new peak capacity has been estimated for all schemes, the Commission has applied a 'one for one' rule –meaning that all peak capacity on new lines is assumed to result in an equal amount of capacity on commuting services. This is based on the logic that moving long distance services to new lines will free up train paths on the conventional rail network. Whilst a long distance train may be replaced by a shorter commuter train, with a more consistent service pattern with fewer train speeds, more trains can run in the 'freed up' path. Given these offsetting factors, one for one is a reasonable proxy. The impact of this assumption is explored in slide **48** of this annex.

- Where only seats have been provided (rather than seated + standing), the ratio between seated capacity to total capacity is assumed to be 0.7, calculated as the ratio from the HS2 Phase 2b data.

Scheme(s)	Capacity data used	Source
HS2 Phase 2b in full	Total daily seats + standing into city centres in capacity analysis	HS2 Ltd (from pfm v7.1)
Strategic alternatives to HS2, including ECML upgrade	Standard hour seats into selected city centres	DfT
Northern Powerhouse Rail Schemes	Peak seats + standing into city centres in capacity analysis*	TfN
Transpennine Route Upgrade	Standard hour seated + standing capacity into selected city centres	DfT
Midlands Connect schemes	Standard hour seats into selected city centres	Midlands Connect

The Commission received capacity estimates for HS2 Phase 2b in full. Therefore, for the Western leg only of HS2 Phase 2b, the Commission has had to estimate the western leg portion of the full 2b impacts.

This has been based on the following logic:

- For any stations on the Western leg (other than Birmingham) in the city centres included in the analysis, all of the capacity impact from the Phase 2b in full is assumed to be down to the Western leg.
- For Birmingham, 50% of the capacity impacts are assumed to be down to the Western leg of HS2. The 50% is calculated based on the number of trains per hour coming from each leg under the train service specification modelled by HS2 Ltd to provide the capacity estimates.

The outlined approach has resulted in the following estimates for released capacity on commuter services:

Table 4.1: Total seated + standing capacity into city centres at AM peak, total per package once all schemes completed (rounded to nearest 1,000)

	Long distance (25%)	Long distance (50%)	Regional (25%)	Regional (50%)	Upgrades focus
Birmingham	24,000	31,000	20,000	20,000	20,000
Bradford*	0	7,000	7,000	13,000	0
Coventry	1,000	1,000	1,000	1,000	1,000
Derby*	0	0	5,000	5,000	0
Leeds	33,000	47,000	21,000	42,000	12,000
Liverpool	2,000	2,000	14,000	14,000	2,000
Manchester	29,000	38,000	47,000	64,000	29,000
Newcastle	15,000	19,000	4,000	8,000	4,000
Nottingham*	0	2,000	7,000	7,000	2,000
Sheffield	7,000	7,000	4,000	16,000	3,000
TOTAL	**111,000**	**154,000**	**129,000**	**189,000**	**71,000**

*these are 0 in some cases as only direct impacts on capacity are captured in the numbers provided

4.4. Journey time and frequency data

Journey time and frequency data has been used to estimate the impact of each package on connectivity. The methodological approach (set out in Chapter 2) relies on in-vehicle journey time estimates and frequency data to calculate connectivity for each place, under each package.

Table 4.2 Time and frequency data

Scheme(s)	Data used	Source
HS2 Phase 2b in full	In-vehicle time and frequency data for most of the journeys in the Commission's analysis	HS2 Ltd (from pfm v7.1)
Strategic alternatives to HS2, including ECML upgrade	In-vehicle time and frequency data for journeys directly on-route	DfT
Northern Powerhouse Rail Schemes	In-vehicle time and frequency data for most of the journeys in the Commission's analysis	TfN
Transpennine Route Upgrade	In-vehicle time and frequency data for journeys directly on-route	DfT
Midlands Connect schemes	In-vehicle time and frequency data for journeys directly on-route	Midlands Connect

Table 4.2 sets out the data provided by stakeholders.

As connectivity is calculated for each place in the analysis (full list on slide 8), for the schemes where only a selection of places were provided, the Commission has estimated the impact on other journey times.

This has been estimated using the following principles:

1. Work out which origin-destination pairs are affected by the new scheme
2. Identify the key segment in the scheme that affects the pair's journey time.
3. Find the improved journey time of this segment by subtracting the do minimum from the do something journey time for the key segment.
4. Apply the journey time improvement to the origin-destination pair.

Similarly, the Commission has used the estimates provided by HS2 Ltd on the impact of Phase 2b in full to estimate the journey time impact of the western leg.

For this, the following logic has been applied:

1. Origin-destination pairs which would be affected by the absence of the eastern leg were identified and it was assumed the journey time between them would revert back to being the current journey time.
2. If a pair was not identified as being affected by the absence of the eastern leg, it was assumed that the journey time for the full Y would still stand.
3. Journey times for the full Y were calculated by:
    1. Identifying journey pairs that will not be affected
    2. Applying the journey time improvement to Edinburgh or Glasgow (depending on Eastern or Western leg) to journeys to other stations in Scotland
    3. Identifying stations near large cities which will be affected by the same bit of track as large cities and therefore the same journey time improvements
    4. Identifying the next best journey pair for the remaining journeys not captured in the above steps

4.5. Cost data

Data on the costs of developed schemes have been provided by the stakeholders set out in table 4.3.

Table 4.3 Costs data

Scheme(s)	Source
HS2 Phase 2b in full	HS2 Ltd (from pfm v7.1)
Strategic alternatives to HS2, including ECML upgrade	DfT
Northern Powerhouse Rail Schemes	TfN
Transpennine Route Upgrade	DfT
Midlands Connect schemes	Midlands Connect

For a select few schemes, that do not yet have cost estimates, the Commission has estimated their cost. For more detail on the approach taken for those schemes, see slide 30 to this annex.

4.7. Track length data

To estimate both the natural capital and lifecycle carbon impacts, the Commission has used data on the length of new track constructed for each scheme. Data used for each scheme are set out in table 4.4.

Table 4.4 Track length data

Scheme(s)	Data and Source
HS2 Phase 2b in full	HS2 phase 2b route maps from HS2 Ltd used to inform Commission calculations of proposed scheme track lengths.
Strategic alternatives to HS2, including ECML upgrade	Commission calculations based on current track distances between stations. Strategic alternatives route options including line upgrades, new stations and additional track maps provided by DfT.
Northern Powerhouse Rail Schemes	Ranges on track length provided by TfN.
Transpennine Route Upgrade	Track electrification lengths from Commission calculations based on scheme information from DfT and Network Rail.
Midlands schemes	Track length information from Commission calculations based on Midlands Connect business cases.

5
Results and Sensitivity testing

5.1. Overview

This chapter sets out the results from the Commission's analysis in more detail. This includes the results of sensitivity testing, which test altering some of the key parameters outlined in previous chapters. Several of the main results are presented as a range. The ranges are based on altering the assumptions listed in the table on the right.

The Commission has also undertaken sensitivity testing on a number of key assumptions. These have been designed to test the following:

1) **Relationship between connectivity and population** - What happens if more people move to places that benefit from new rail connections?
2) **Impact of assuming new long distance capacity releases the same amount of commuter capacity –** What happens if the relationship is different?
3) **Impact of transformational change on productivity impacts –** What happens if wages dramatically increase across the Midlands and North?

Impact	Range based on
Productivity	Relationship between density and productivity (elasticity). Low is based on 0.022 elasticity, and high on 0.076, based on values in SERC (2009). Strengthening economic linkages between Leeds and Manchester: feasibility and implications: full report. Link.
Amenity	Relationship between amenities and commuter capacity. Low value is 30% scaling factor, high is 70%.
Connectivity	Distance decay parameter. Low is 0.002 (1/5th of central) and high is 0.05 (link).
Natural Capital	The central, high and low values have been based on the price of timber (link), the average business farm income (link), the carbon prices (link), and the recreational value per visit (link).
Lifecycle carbon	For monetised estimates only – the carbon price used. Low end of range is the central carbon price (link), high is based on £300/t price by 2050, based on CCC/UKERC (link).

5.2. Headline Results

Table 5.1 Headline benefits across packages (undiscounted)*

Package	Economic growth and competitiveness		Sustainability and quality of life	
	Improvements to connectivity from faster journeys	Improvements to productivity in city centres over the 60-year appraisal period, undiscounted	Benefits from connecting people to city services, undiscounted	Environmental impact (combined quantified partial valuation of the loss of natural capital and monetised lifecycle carbon impact)
Focus on upgrades	7% - 9%	£18 – 30bn	£7 – 15bn	-£0.3 to -£0.2bn
Plus 25 per cent				
Regional links	9%-15%	£30– 51bn	£11 – 26bn	-£0.7 to -£0.5bn
Long distance links	10%-11%	£25 – 43bn	£10 – 22bn	-£0.7 to -£0.5bn
Plus 50 per cent				
Regional links	11%-19%	£41 – 71bn	£16 – 38bn	-£1bn to -£0.8bn
Long distance links	11%-12%	£33 – 58bn	£13 – 31bn	-£1 to -£0.7bn

* NB: Benefits from HS2 Phase 1 and 2a are not included in this table. Shading in this table is based on a ranking between the packages on the benefit divided by cost for each criterion.
Improvements to connectivity from faster journeys: Average percentage improvement in overall rail connectivity between places in the Midlands and North, including how connected these places are to Scotland, regional airports and key places in the south, calculated for the whole package in 2045 versus the winter 2019 timetable.
Improvements to productivity in city centres: Aggregate of productivity increase from agglomeration plus impact of workers moving to higher value jobs. £2019/20 prices, real terms, undiscounted, total over 60 years of benefits
Benefits from connecting people to city services: Aggregate of recreational impacts from improving access to city centres. £2019/20 prices, real terms, undiscounted, total over 60 years of benefits.
Loss of natural capital: Total monetary value of natural capital lost. £2019/20 prices, real terms, undiscounted, total from 2028 to 2098.
Lifecycle carbon emissions: Monetised lifecycle carbon impact calculated from million tonnes of Carbon Dioxide equivalent for each package. £2019/20 prices
Undiscounted figures represent 60 years of benefits at a constant annual rate.

Table 5.2 Total costs and costs net of HS2 Phases 1 and 2a for each package (£bn, £19/20)

Package	Costs of package (£bn) (central)	Net costs of package without HS2 Phases 1 and 2a (£bn) (central estimate)	Net costs of package without HS2 Phases 1 and 2a (£bn) (range)	Net discounted costs, without HS2 Phases 1 and 2a (£bn) (central estimate)	Net discounted costs, without HS2 Phases 1 and 2a (£bn) (range)	Net discounted costs (£bn) without HS2 Phases 1 and 2a, electrification, digital signalling and 'early wins', (central estimate)
	Baseline budget					
Focusing on upgrades	81	44	(41-53)	32	29-39	21
	Plus 25 per cent					
Prioritising regional links	107	69	(64-85)	46	42-57	36
Prioritising long distance links	105	68	(64-77)	45	39-52	34
	Plus 50 per cent					
Prioritising regional links	130	92	(85-113)	60	54-73	49
Prioritising long distance links	128	90	(84-104)	59	52-69	48

Note: There is an allocation for traction decarbonisation (£10bn), railway control systems (£3bn) and early wins(£2bn) within the packages, reflected in the second to the sixth columns. However, the benefits of these have not been included in benefit and impacts calculations, so the last column provides the net costs associated with the benefit calculations.

Table 5.3 Headline impacts across packages (discounted)*

Package	Economic growth and competitiveness		Sustainability and quality of life		Costs
	Improvements to connectivity from faster journeys	Improvements to productivity in city centres, discounted	Benefits from connecting people to city services, discounted	Environmental impact (combined quantified partial valuation of the loss of natural capital and monetised lifecycle carbon impact), discounted	Net discounted costs without HS2 Phases 1 and 2a, electrification, digital signalling and ‘early wins’, central estimate
Focus on upgrades	7% - 9%	£7-12bn	£2-4bn	-£0.2 to -£0.1bn	£21bn
Plus 25 per cent					
Regional links	9%-15%	£12-20bn	£3-7bn	-£0.4 to -£0.3bn	£36bn
Long distance links	10%-11%	£10-17bn	£2-6bn	-£0.4 to -£0.3bn	£34bn
Plus 50 per cent					
Regional links	11%-19%	£16-29bn	£4-10bn	-£0.6 to -£0.4bn	£49bn
Long distance links	11%-12%	£13-23bn	£3-8bn	-£0.5 to -£0.4bn	£48bn

* NB: Benefits from HS2 Phase 1 and 2a are not included in this table. Shading in this table is based on an ordinal ranking between the packages on the benefit divided by cost for each criterion.
Improvements to connectivity from faster journeys: Average percentage improvement in overall rail connectivity between places in the Midlands and North, including how connected these places are to Scotland, regional airports and key places in the south, calculated for the whole package in 2045 versus the winter 2019 timetable.
Improvements to productivity in city centres: Aggregate of productivity increase from agglomeration plus impact of workers moving to higher value jobs. £2019/20 prices, real terms, discounted to 2020, total over 60 years of benefits
Benefits from connecting people to city services: Aggregate of recreational impacts from improving access to city centres. £2019/20 prices, real terms, discounted to 2020, total over 60 years of benefits.
Loss of natural capital: Total monetary value of natural capital lost. £2019/20 prices, real terms, discounted to 2020, total from 2028 to 2098.
Lifecycle carbon emissions: Monetised lifecycle carbon impact calculated from million tonnes of Carbon Dioxide equivalent for each package. £2019/20 prices.
Discounting uses the Green Book discount rate.

5.3. Detailed results: Connectivity

This section outlines the impact of each package on connectivity.

The connectivity improvement for each place under each package is combined into an overall connectivity improvement across all places in the analysis. This is calculated by the following steps:

1. The connectivity score (calculated as set out in slide 16) for each place in the analysis is multiplied by the percentage of 2020 population for each place to give a weighted connectivity score under each package.
2. The weighted connectivity scores under each package are then summed to give total score indexed to the current (i.e. current total = 100).
3. 100 is then subtracted from the total to give the percentage improvement from the current under each package.

Table 5.4 Current connectivity for each place in the analysis*

Place	Indexed Score	Place	Indexed Score	Place	Indexed Score	Place	Indexed Score	Place	Indexed Score
Barnsley	99	Crewe	132	Leamington Spa	114	Preston	109	Walsall	102
Birkenhead	96	Derby	127	Leeds	116	Scunthorpe	81	Worcester	89
Birmingham	136	Doncaster	118	Leicester	117	Sheffield	120	York	112
Blackburn	88	Dudley	123	Lincoln	79	Shrewsbury	93	Birmingham Airport	128
Blackpool	80	Durham	84	Liverpool	106	Stafford	133	Manchester Airport	107
Blyth and Ashington	67	Grimsby	64	Manchester	123	Stoke-on-Trent	126		
Bradford	95	Halifax	96	Mansfield	72	Sunderland	62		
Burnley	84	Harrogate	82	Middlesbrough	69	Telford	98		
Burton upon Trent	118	Hereford	73	Newcastle	76	Wakefield	116		
Chester	101	Huddersfield	109	Northampton	100	Warrington	123		
Chesterfield	119	Hull	75	Nottingham	104	Wigan	116		
Coventry	127	Kettering	104	Peterborough	104	Wolverhampton	126		

*population weighted average score = 100

5.4 Sensitivity test: What happens if population growth is linked to rail connectivity?

Approach and Rationale

The Commission's connectivity methodology weights places by population, based on exogeneous projections of population growth. The methodology assumes no relationship between rail connectivity and population.

This sensitivity tests the impact of assuming the two are linked; that population growth increases if rail connections become better. For this, the Commission has used an elasticity from the Centre for Economic Performance[9] which estimates that, for every 1% increase in centrality*, there is an 0.3% increase in population.

Impact

The overall impact of the sensitivity is very small. For all packages, the impact on the resulting change in connectivity affects the package level change in connectivity by less than 1%.

Table 5.5: Improvements to connectivity from faster journeys: Average percentage improvement in overall rail connectivity

	Focus on Upgrades	Regional links plus 25 per cent	Long distance links plus 25 per cent	Regional links plus 50 per cent	Long distance links plus 50 per cent
Main results	7%-9%	9%-15%	10%-11%	11%-19%	11%-12%
Sensitivity: linking population and connectivity	7%-8%	9%-16%	10%-11%	12%-20%	11%-12%

[9] Stephen Gibbons, Stephan Heblich and Ted Pinchbeck (2018) The Spatial Impacts of a Massive Rail Disinvestment Program: The Beeching Axe, Centre for Economic Performance Discussion paper no 1563. Link.

* The Commission has used connectivity, rather than centrality as the measure in this analysis

5.5 Monetising Connectivity estimates

As outlined in Chapter 2, the Commission's connectivity analysis does not focused on monetised time savings, and focuses on quantifying the improvement in connectivity from rail schemes.

The impact of improvements in connectivity from faster and more frequent long-distance journeys are not easily converted into monetary values, as a full assessment would need to include all transport modes, which lies beyond the scope of this study. To understand the value for money implications of this analysis, the Commission has estimated the monetary value of the connectivity benefits

Approach

The Commission has used estimates from research which estimates the productivity increase from increases in road connectivity.[10] This estimates the elasticity of wage per worker with respect to accessibility as 0.252.

This elasticity has then been scaled to adjust for the fact that there are far fewer rail than road journeys. [11]

The percentage change in connectivity for each package has then been applied to this adjusted elasticity to get the resulting change in wages. To estimate the change in output for the whole of the midlands and north, the Commission has used the mean wage in each region, multiplied by the number of workers.[12]

Productivity across the region is then assumed to grow at the rate of labour productivity growth, in line with the OBR's March 2019 Long term economic determinants.[13]

10 Stephen Gibbons, Teemu Lyytikainen, Henry Overman and Rosa Sanchis-Guarner (2019) 'New Road Infrastructure: the effects on firms', Journal of Urban Economics
11 Adjusted by rail journeys as a proportion of road (11%). From national travel survey (2020) Journey miles by mode.
12 Mean wages and number of workers from ONS Annual Survey of Hours and Earnings (2020) Table 5.7a, data covers the year 2019.
13 OBR's Long Term Economic Determinants Data (March 2019 version). Link.

5.6. Detailed results: Productivity

This section outlines the impact of each package on productivity. This has been estimated using the methodology outlined in chapter 2.

Table 5.6 Total productivity impacts over 60 years per city centre under each package (central estimate £bn, £19/20, real, undiscounted)

(£bn, £19/20)	Long Distance (+25%)	Long Distance (+50%)	Regional (+25%)	Regional (+50%)	Upgrades focused
Birmingham	9.6	12.3	7.7	7.7	7.7
Bradford	0.0	1.2	1.2	2.1	0.0
Coventry	0.3	0.3	0.3	0.3	0.3
Derby	0.0	0.0	2.2	2.2	0.0
Leeds	7.2	10.1	4.5	9.0	2.6
Liverpool	0.6	0.6	4.1	4.1	0.6
Manchester	10.5	13.8	17.1	23.3	10.5
Newcastle	4.0	5.3	1.0	2.3	1.0
Nottingham	0.0	0.5	1.7	1.7	0.5
Sheffield	1.9	1.9	1.1	4.1	0.7

5.7. Sensitivity test: Impact of assuming new long distance capacity releases the same amount of commuter capacity

Approach

The Commission has tested the sensitivity of the results to the assumption that new long distance capacity releases the same amount of commuter capacity. The assumption in the analysis is 'one for one' – ie. one new long distance space equals one new space of commuting capacity. This sensitivity tests how changing the one for one ratio to 0.8 to 1, and 1.2 to 1, has on the results.

Table 5.7: Total Productivity over 60 year's benefits, £bn 19/20 (undiscounted), sensitivities

Ratio (new long distance capacity: commuting capacity released)	Long Distance (+25%)	Long Distance (+50%)	Regional (+25%)	Regional (+50%)	Upgrades focused
Main results: 1:1 ratio	£25 – 43bn	£33 – 58 bn	£30 – 51bn	£41 – 71bn	£18-30bn
Sensitivity: 1:0.8	£20 – 34bn	£26 – 46bn	£24 – 41bn	£33 – 57bn	£14-24bn
Sensitivity: 1:1.2	£30 – 51bn	£39 – 69bn	£36 -61bn	£49-86bn	£21 – 35bn

Table 5.8 Total Amenity benefits over a 60 year lifetime, £bn 19/20 (undiscounted), sensitivities

Ratio (new long distance capacity: commuting capacity released)	Long Distance (+25%)	Long Distance (+50%)	Regional (+25%)	Regional (+50%)	Upgrades focused
Main results: 1:1 ratio	£10-22 bn	£13-31 bn	£11-26 bn	£16-38 bn	£7 - 15bn
Sensitivity: 1:0.8	£8-18 bn	£11-25 bn	£9 – 21bn	£13-30bn	£5-12bn
Sensitivity: 1:1.2	£12 – 27bn	£16 – 37bn	£14 -32bn	£19 – 45bn	£8-18 bn

5.8 Sensitivity test: Impact of transformational change on productivity impacts

Approach and Rationale
The Commission's productivity methodology considers the impact of higher city centre density on wages and productivity. This approach uses existing wages as a proxy for productivity, which grow in line with labour productivity.

This sensitivity captures the potential impact if the city centres in the analysis experience transformational changes in productivity.

The Commission has tested the impact of wages in these city centres increasing by 12% in northern city centres, 12% in the midlands and 14% in Yorkshire and the Humber. This is the difference* between the mean wage in these regions and the mean wage in the South East (excl. London), which performs highly compared to the current UK national average.

Impact
Whilst increasing wages does increase the size of these impacts, the difference in packages remains very similar to the Commission's main package analysis, as the Yorkshire, the North and Midlands have similar levels of wage differences to the South East (despite the differences in capacity added in different regions between packages).

Table 5.9 Total Productivity over a 60 year lifetime, £bn 19/20 (undiscounted), sensitivities

Results	Long Distance (+25%)	Long Distance (+50%)	Regional (+25%)	Regional (+50%)	Upgrades focused
Sensitivity: Transformational change	£28-48bn	£37-65bn	£34-57bn	£46-80bn	£20-33bn
Main results (no transformational change)	£25 - 43bn	£33 - 58bn	£30 -51bn	£41-71bn	£18-30bn

*Calculated as the difference in the regional mean gross hourly pay (excluding overtime) in 2019 from the ONS Annual Survey of Hours and Earnings (2020). Accessed via nomis. Link.