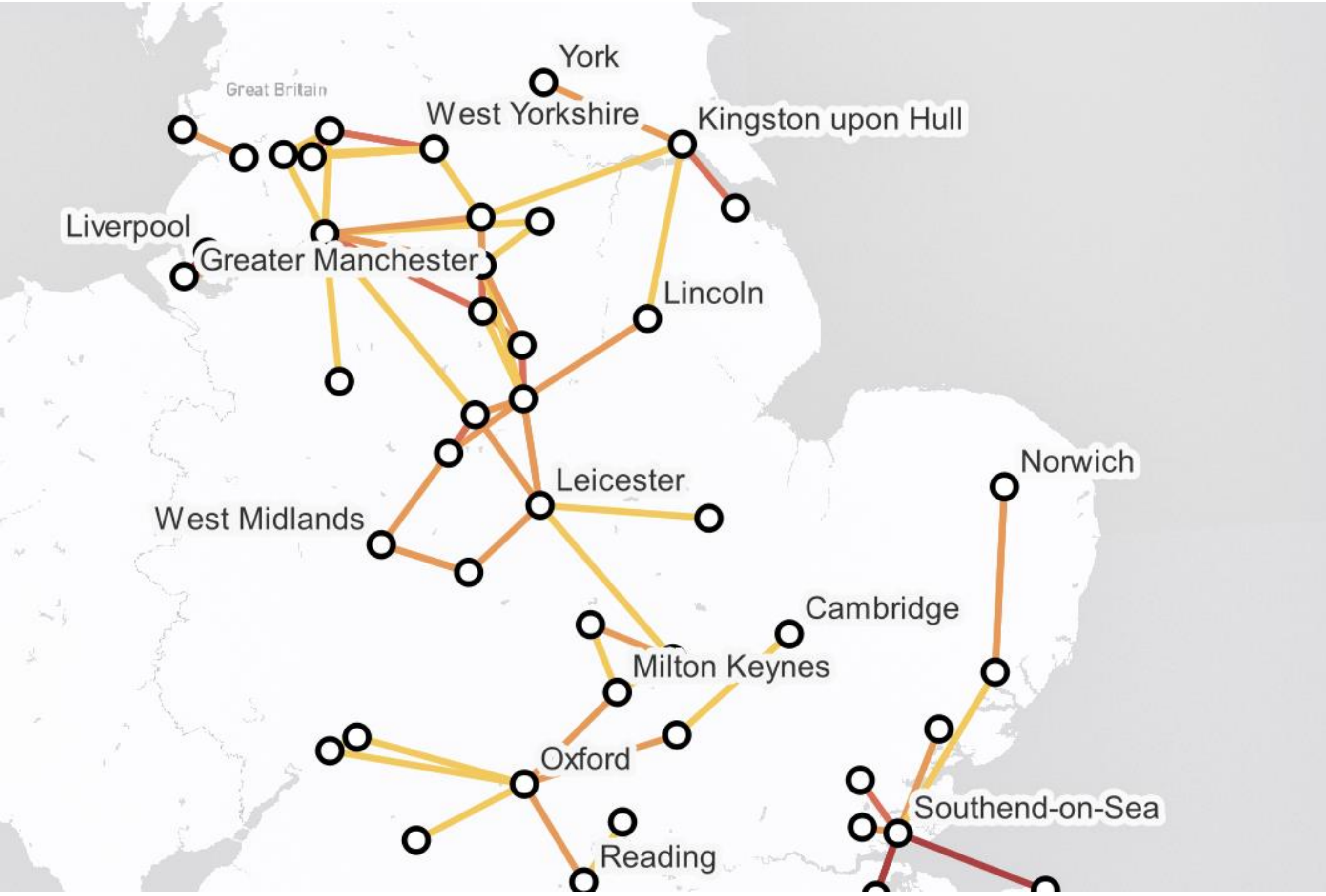
Final Report
August 2023

Interurban Transport Connectivity Assessment

Prepared for the second National Infrastructure Assessment



National Infrastructure Commission

steer

Final Report
August 2023

Interurban Transport Connectivity Assessment

Prepared by:

Steer
14-21 Rushworth Street
London SE1 0RB

+44 20 7910 5000
www.steergroup.com

Prepared for:

National Infrastructure Commission
Windsor House
50 Victoria Street
London SW1H 0TL

Contents

Figures

Tables

Annexes

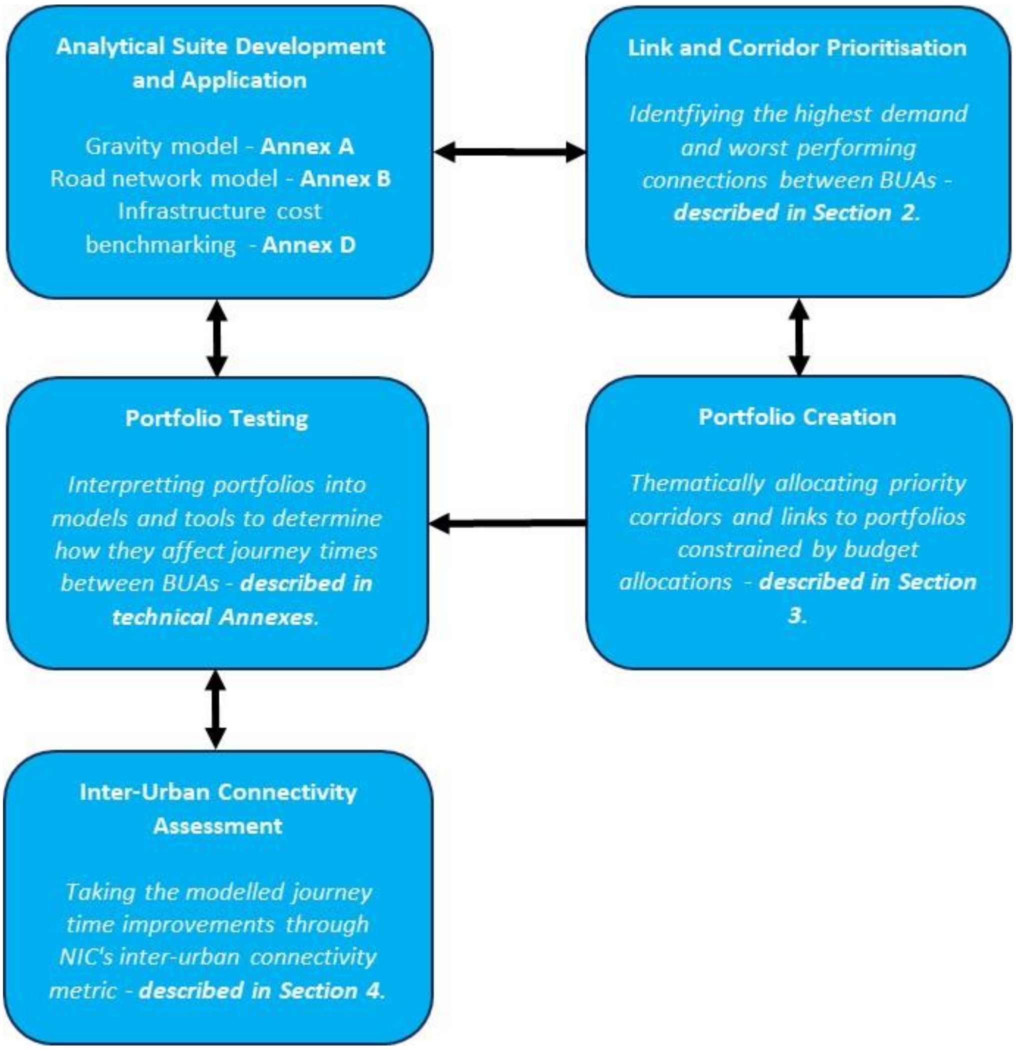
1 Introduction and Method Overview

Project overview

1.1 The National Infrastructure Commission (NIC) commissioned Steer to support their analysis on the benefits and opportunities from improving inter-urban connectivity as part of a wider suite of work as part of the 2nd National Infrastructure Assessment.

1.2 The project seeks to understand how improving the road network could support improvements to inter-urban connectivity. To do so the method followed the process outlined in Figure 1.1.

Figure 1.1: Project methodology



1.3 The NIC had previously identified two lists of priority places for non-freight travel, focusing on different aspects of levelling up and economic growth. List A identified places which are poorly connected and currently have low levels of economic output, where transport investment could help to bring their economies towards the national average. Whereas List B identified places which are fast growing but currently poorly connected, where transport improvements could support the continuation of that rapid growth. All journey pairs where at least one end was in list A or B were considered.

1.4 For freight, List C included all Built Up Areas (BUAs) with substantial warehousing space and those with major ports and inland freight terminals. These freight locations were treated separately in the analysis with a ringfenced budget for freight enhancements.

1.5 The project used both List A and B BUAs together and filtered to those with a population above 25,000 people. Using the analytical tools developed for the project (described below) the theoretical demand between these places (and important places for freight) was derived; using that demand the worst performing road links and corridors which connected the BUAs were identified; portfolios of potential investment packages to address the network problems were assembled; and finally these were passed through the NIC's connectivity methodology to determine the potential inter-urban benefit from each portfolio.

1.6 The outputs of this process were fed into recommendations from the NIC for the second National Infrastructure Assessment.

Supporting analytical tools

1.7 For the purposes of this project, Steer has developed a number of bespoke analytical tools. The methodologies followed for creating these tools are contained in **Annexes A to C** of this report:

- A simplistic gravity model to simulate the theoretical demand for movement between BUAs.
- A road network model to determine the assignment of demand, to assess journey times between BUAs and theoretical demand on each link.
- A set of infrastructure cost assumptions built up from outturn benchmark costs from published data.

2 Network Assessments and Prioritisation

Overview

2.1 After building the analytical tools and models, the first phase of the project aimed to identify priority inter-urban corridors and network links where the current service quality is poor. Steer's analysis identified corridors (defined by the connection between two built up areas (BUA) over 25,000 in population or smaller BUA's which were specifically identified as freight nodes) and individual network links.

Tests to identify priority links and corridors

2.2 The first task was to identify locations in the road network which were both important for inter-urban connectivity and had demonstrably poor performance. The intention being to find locations which could be prioritised for potential investment later in the methodology. Two tests were conducted:

A) Weaknesses in existing infrastructure: identifying where average speeds on specific links in the current road network are poor and potential inter-urban demand is high.

B) Poorly connected places: seeking to understand where there are potential failings in the network which result in journeys between BUAs which are particularly slow or indirect.

2.3 Journey times by road were estimated by using the model described in **Annex B.** The data used to establish the network's fixed speeds[1] is an annual average speed, over 24 hours, for each link of the network. Low speeds are therefore likely to be the result of either road conditions or persistent congestion, rather than simply limitations in peak capacity. To create the model we used the most recent data available, which was for 2021. This is still likely to show some residual impacts of the pandemic reducing traffic levels and increasing average speeds. The results therefore may not fully reflect network performance in 'normal' times.

Freight

2.4 For freight, matrices from DfT's National Transport Model (NTM) were used to understand where freight demands are highest. Additional BUA zones (below the residential population threshold) were also added to the road network model to represent major freight destinations and attractors which do not have substantial resident populations. Maximum freight speeds are lower than for cars and smaller vehicles, so this has been factored into the analysis.

2.5 Reliability of journey times was identified as being another key factor for freight movements. Generally, the closer average road speeds are to free-flowing traffic the more reliable we would expect journey times to be, particularly where speeds have reduced as a result of

[1] DfT network speed data: CGN04 and CGN05

congestion rather than road quality, as is the case for much of the SRN/MRN. Links where average speeds are below maximum HGV speeds are particularly likely to affect the reliability of freight journeys: the list of freight priorities identifies links where speeds are below that threshold and freight demand is high.

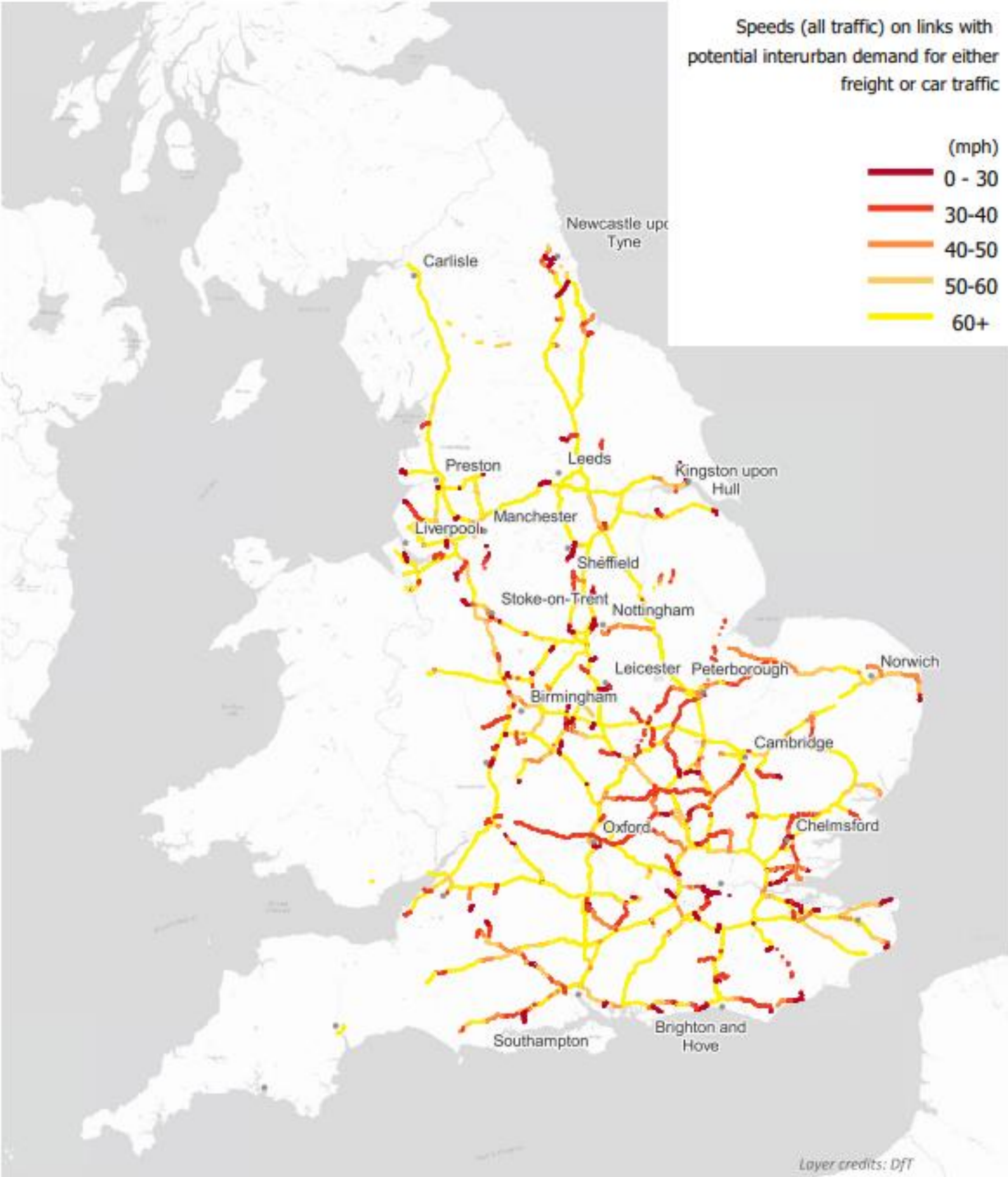
Network Tests: Outputs

2.6 For each category maps were produced which show the highest priority corridors and links, before considering the feasibility or cost of intervention. These prioritised lists have then been added into portfolios based on different themes and priority characteristics. For details on how we prioritised the corridors, see **Annex D**.

Weaknesses in existing network

2.7 The priority locations for improvements to existing road infrastructure were identified on a link level rather than based on the corridors. Figure 2.1 shows the speeds for the links with the highest demand: more than 5,000 theoretical trips per day. Some of the slowest parts of the network, such as those within the M25 and other urban areas, are those which have little prospect of substantial improvement for the reasons described above. But there are other areas where improvements are more plausible, such as the East Midlands and South Coast.

Figure 2.1: Road network speeds for high demand links

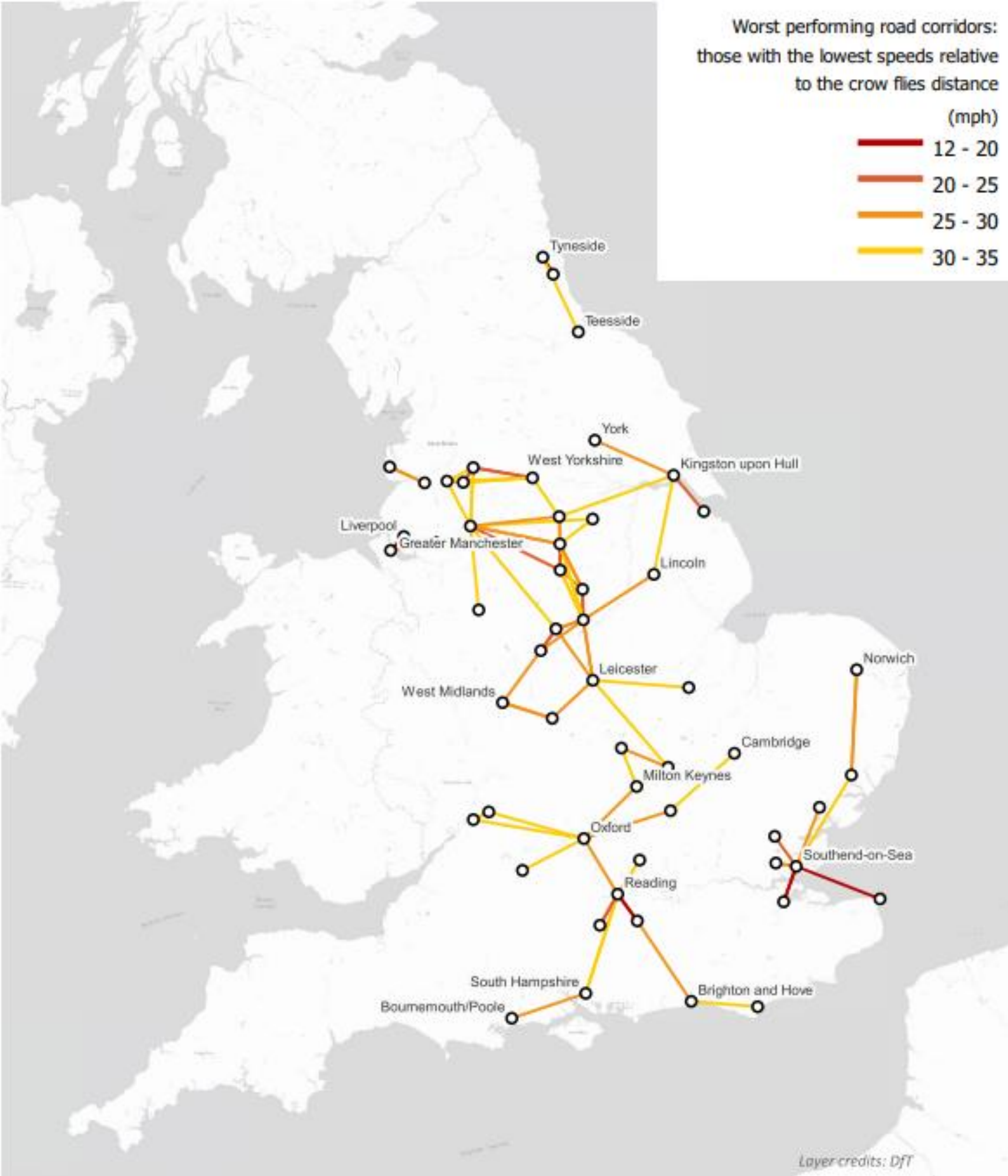


Poorly connected places

2.8 The figures below identify corridors with a high level of theoretical demand and the largest gap between the estimated crow flies journey time and the network journey time; i.e. the ‘poorly connected places’ test described earlier. Some of the flows identified are clearly reflecting where low urban speeds increase journey times; e.g. flows to London. However, there are other clusters which highlight poor connectivity between places, such as the South Pennines and between the East and West Midlands.

2.9 This test was conducted prior to any feasibility or cost considerations being applied. Hence some corridors are flagged where creating a new connection (e.g. a new direct tunnel or bridge, or road across an AONB) would in reality be implausible. These were filtered out later in the process.

Figure 2.2: 'Poorly connected places'

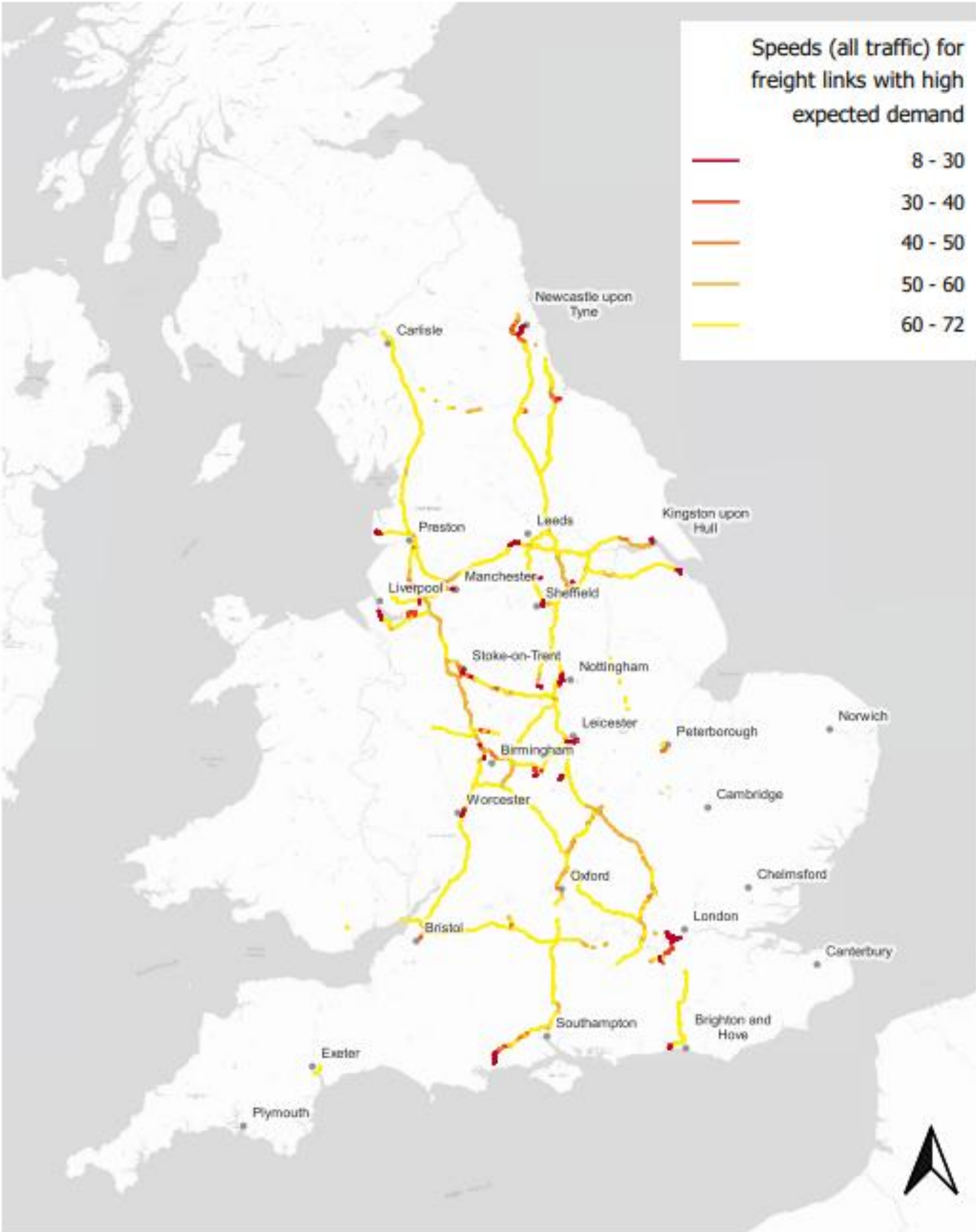


Freight improvements

2.10 Figure 2.3 shows links with high HGV demand and average speeds below 56mph, the HGV speed limit. For HGVs this shows observed demand rather than theoretical demand, so the highest demand routes are likely to already be dominated by those where speeds are most reliable. Links with high demand despite low speeds are those where there is no viable alternative. This shows some issues which are likely to be particular problems for freight, such as connectivity around Southampton.

2.11 Demand in the NTM matrices is dominated by the volume of intermodal traffic between cities. The models therefore didn't show comparatively high volumes of HGVs on the routes to some ports. This meant that in the freight-only tests some routes to ports did not meet the demand thresholds necessary to be designated as a priority to be included in subsequent portfolio testing. The obvious ones being routes to Dover and Felixstowe. However, those routes perceived to be important for connections to ports did still come out of the non-freight tests described above. Hence although those routes aren't in the freight-only portfolios they are still included in the connectivity assessment.

Figure 2.3: Freight speeds on links with highest HGV demand



3 Portfolio Creation

Overview

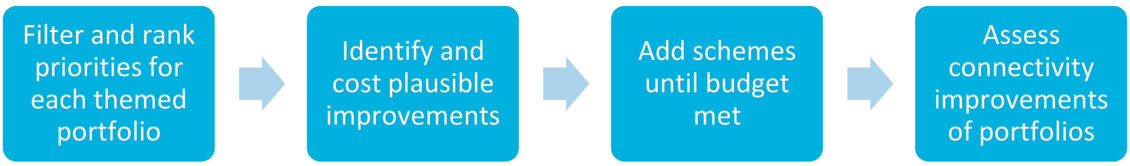
3.1 Using the analysis to identify the priority links and corridors described in Section 2, the next phase of the project was to allocate these priorities into potential investment portfolios and to test the effects these improvements could have on connectivity.

3.2 Committed enhancements such as the largest schemes in the RIS2 programme were added into the network models at this stage in order to avoid duplication of enhancements. For more details see **Annex D**.

3.3 Six portfolios were designed to give an illustrative view of the impact of different strategic investment choices. This involved dividing the priorities into themes (although some priorities could be in more than one portfolio), then identifying and developing high level costs of possible interventions in those areas. The impact of these portfolios of interventions were then assessed using the NIC's connectivity metric.

3.4 This stage of the work aimed to identify indicative options for future development and policy choices, to provide a high-level understanding of the impact of different priorities. The portfolios developed are intended to be indicative and illustrative rather than detailed programmes.

3.5 To turn these priorities into a realistic scheme development pipeline would require a far more detailed feasibility assessment and business case/value for money assessment and time-specific analysis than was possible for this project. In addition, some routes may be priorities for reasons other than inter-urban connectivity, e.g. to address particular resilience issues or specific issues within a local context.



Portfolio themes

3.6 To develop the portfolios each was designed to be distinct and reflect differing investment philosophies. A baseline, unweighted portfolio was created which simply prioritised the worst-performing sections of the network above a certain level of demand, with no input to target improvements towards specific regions. A modified version of this was created with spending weighted between regions to identify the difference this made to connectivity[2].

3.7 The alternative portfolios, testing different prioritisation approaches, were based off the weighted portfolio but could also have been applied at a national level.

3.8 Each alternative portfolio was modified from the regionally weighted portfolio using a set of variables:

- Non-radial links between smaller places, rather than connectivity into London.
- The weighting of funds between improvements to the existing network and larger investments targeted at addressing substantial gaps in the network.
- The length of corridors considered, ranging from places which are relatively close together and likely to benefit from agglomeration to longer distance routes of more strategic importance.
- The weighting of performance relative to demand. This sought to answer whether improvements to corridors and links with very high demand, with potentially higher baseline speeds, have a larger or smaller effect than the baseline portfolio. Here the thresholds of demand and/or network performance were varied to create inputs to the portfolios.

3.9 These variables were used to create six portfolio themes. A detailed summary of how the criteria were applied is covered in **Annex D**.

Table 3.1: Portfolios for testing

Portfolio	Description
Portfolio 1 – Baseline priorities (unweighted)	This focused on the routes with the lowest performance compared to the crow flies journey time, and the worst performing rail links above a set demand threshold.
Portfolio 2 – Baseline priorities (regionally weighted)	This focused on the routes with the lowest performance compared to the crow flies journey time, and the worst performing rail links above a set demand threshold, with spending weighted between regions.
Portfolio 3 – Orbital focus (regionally weighted)	This excluded improvements on key routes into London, prioritising non-radial infrastructure
Portfolio 4 – New orbital links (regionally weighted)	This used the same criteria as portfolio 2, but weighted the budget in favour of major new links over improvements to existing road and rail infrastructure
Portfolio 5 – Long distance journeys (regionally weighted)	This focused on longer distance journeys over 50miles
Portfolio 6 – Demand driven regionally (weighted)	This set a higher threshold for performance than the other portfolios and prioritised based on demand rather than performance

- [2] The regional funding allocation reduced the budget allocated to the Southeast by 50% compared to the national unweighted portfolio and redistributed this to regions in the North and Midlands which did not seen strong connectivity benefits in the national unweighted portfolio.

Portfolio budgets

3.10 An illustrative budget was set for all portfolios, to ensure connectivity improvements could be compared on a like for like basis. This was based on recent levels of enhancement spending. It is not intended to suggest an optimal or desired level of funding. Although the budgets were indicative, they were derived using some analysis of current trends and what's already committed, in order to reflect plausible future spending limits.

3.11 For further details see **Annex D**.

Table 3.2: Portfolio budget allocations

Improvement category	Budget (£bn, 2022 prices) – all other portfolios	Budget (£bn, 2022 prices) – Portfolio 4
Improvements to existing network	39.7	19.9
Poorly connected places	10.0	29.8
Freight - improvements to existing network	12.4	12.4
Total	**£62.1**	**£62.1**

Feasibility assessment and sifting

3.12 For the corridor improvements, an initial filtering exercise aimed to identify corridors where potential improvements were not feasible. For example, those where links passed through highly mountainous terrain or over large bodies of water. This is inevitably a subjective process, as very few improvements would be technically 'impossible' rather than simply 'unlikely' based on cost or political grounds. The bar for feasibility was therefore set fairly high, and only excluded a small number of corridors which were likely to be disproportionately expensive and consume a large amount of the portfolio budget. This was undertaken on the basis of professional judgement.

3.13 This feasibility testing process also aimed to identify road corridors where it was felt that improvements to inter-urban links would likely not have a substantial effect on overall journey times, where primary reason for slow connectivity between places is the highly congested part of the journey on the periphery of urban areas. These were excluded on two grounds: firstly, the low likelihood that road capacity improvements in congested urban areas, where there is likely to be a high level of induced demand, will meaningfully increase speeds.

Assumptions for intervention improvements

3.14 For the remaining corridors, possible interventions were identified which could feasibly improve journey times. This was a high-level exercise based on consideration of the existing network and possible scope for improvements, using the collected data, professional expertise and knowledge of existing proposals. It was not aiming to estimate or model the effects specific 'schemes' may provide. The improvements modelled are highly approximate routes and upgrades developed through a desktop research process.

3.15 Where new links were proposed it was assumed that new roads could be travelled at a speed of 58mph (the current SRN average) and where existing roads were being improved speeds on the affected link was increased by a benchmark of 20%.

3.16 Demand in the NTM matrices is dominated by the volume of intermodal traffic between cities. The models therefore didn't show comparatively high volumes of HGVs on the routes to some ports. This meant that in the freight-only tests some routes to ports did not meet the demand thresholds necessary to be designated as a priority to be included in subsequent portfolio testing. However, those routes perceived to be important for connections to ports did still come out of the non-freight tests described above. Hence although those routes aren't in the freight-only portfolios they are still included in the connectivity assessment.

Costing the interventions

3.17 Benchmark costs were then applied to each intervention, using the method specified in **Annex C.** The method varied costs based on the type of improvement being provided and whether or not the location was in a location near to a site that could be deemed environmentally sensitive.

3.18 Interventions were identified for each portfolio until the total budget available for each category was filled. The contents of each complete portfolio are included below.

Final Portfolio Composition

3.19 The following maps of indicative network interventions are intended as illustrations of different thematic ways to allocate funding pots aimed at improving inter-urban connectivity.

Portfolio 1 – Baseline priorities

3.20 This focused on the routes with the lowest performance compared to the crow flies journey time, and the worst performing road links above a set demand threshold.

Figure 3.1: Portfolio 1 Map

Portfolio 2 – Regional Baseline

3.21 This focused on the routes with the lowest performance compared to the crow flies journey time, and the worst performing road links above a set demand threshold, with spending weighted between regions.

Figure 3.2: Portfolio 2 Map

Portfolio 3 – Orbital Focus

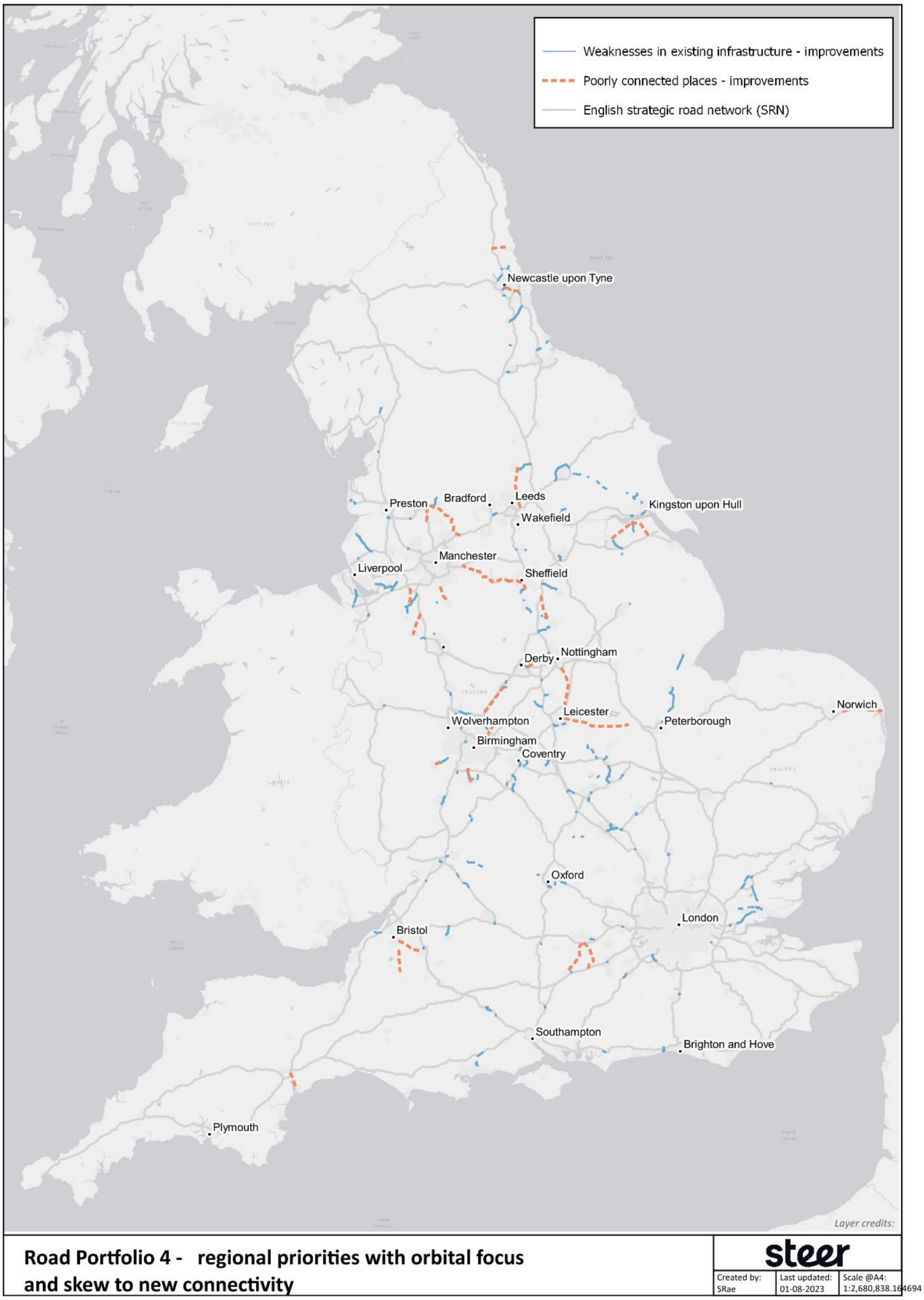
This excluded improvements on key routes into London, prioritising non-radial infrastructure.

Figure 3.3: Portfolio 3 Map

Portfolio 4 – new orbital links

3.22 This used the same criteria as portfolio 2, but weighted the budget in favour of major new links over improvements to existing road infrastructure.

Figure 3.4: Portfolio 4 Map



Portfolio 5 – Long distance journeys

3.23 This portfolio focused on longer distance journeys of more than 50 miles.

Figure 3.5: Portfolio 5 Map

Portfolio 6 – Demand driven

3.24 This set a higher threshold for performance than the other portfolios and prioritised based on demand rather than performance.

Figure 3.6: Portfolio 6 map

4 The Connectivity Assessment

Calculating the NIC's Connectivity Metric

4.1 The final step of the project was to determine the scale of connectivity change as a result of the portfolios. To do so the network improvement assumptions for each portfolio were run through the road network model and rail network tool. The journey times between BUAs were then fed into the NIC's connectivity metric comparing changes under each of the portfolios and under a baseline of the current network with existing commitments, eg RIS2, accounted for.

4.2 The metric provides a comparable measure of the connectivity between different built-up areas. It establishes an average of the connectivity between each built up area and all other places, weighted by the demand (population) in each place and using a distance decay parameter to reflect the impact of travel times on willingness to travel. This is normalised relative to the physical proximity of demand and population by dividing it by the estimated crow-flies connectivity; assumed to be a straight line at 50kmph between places (note this is different to the 50mph used in producing the spatial analysis of the current network).

4.3 For more details on the metric see the Commission's current discussion paper[3] and its forthcoming update.

4.4 In very simple terms connectivity for any place (BUA) can be expressed as: ***Connectivity of a place by a given mode = Connectivity to all other places by observed speeds of that mode / Connectivity to all other places by crow-flies speed (50kph in a straight line).*** Connectivity is measured using the NIC's methodology. This calculation results in a ratio of observed speed vs crow-flies speed. A figure less than 1 shows that overall that demand weighted travel speed is less than 50km h^{-1} to all other places, a ratio greater than 1 would signify a demand weighted travel time of more than 50km h^{-1}.

4.5 The calculations have used all BUA places above 25,000 people but the results have been summed up to Government Regions to give a picture of inter-urban connectivity for all the BUAs in each region. These regional figures therefore simplify a high level of underlying variation at an individual BUA level.

Results and conclusions

Committed Schemes Scenarios

4.6 As described earlier in this report, the models have had two core scenarios developed:

- A base scenario, i.e. network configurations and journey times as per today's network performance; and

[3] https://nic.org.uk/app/uploads/Transport-Connectivity-discussion-paper.pdf

- A committed schemes/do-minimum scenario which accounts for the largest/most impactful road schemes in the RIS2 programme.

4.7 The following demonstrates the accessibility changes from the baseline to the committed schemes scenarios:

Table 4.1: Change in regional road accessibility from the baseline to the committed schemes scenario

Region	Regional Accessibility (ratio of connectivity using observed speed vs crow flies speed)		
	Baseline Scenario	Committed Schemes Scenario	Connectivity change
London	0.52	0.52	0.06%
South East	0.85	0.85	0.05%
South West	1.18	1.18	0.05%
East of England	0.72	0.72	0.05%
East Midlands	0.99	0.99	0.04%
West Midlands	1.13	1.13	0.04%
Yorkshire and The Humber	1.11	1.11	0.04%
North West	1.04	1.04	0.03%
North East	1.17	1.17	0.05%

4.8 In the base scenario some regions are clearly better connected than others, but most (outside of London) hovering around a ratio of 1, meaning on average BUAs within the region have connectivity that is close to the crow-flies speed. However, the East of England and the South East do appear to have demonstrably poorer accessibility than the rest of England. This is due to the comparatively sparse nature of the Strategic and Major Road Networks in these regions. London's connectivity appears poor because of the extent of the urban area, where speeds to get to the centre are much lower than on the orbital strategic road network.

4.9 As can be seen from the results, the large RIS2 schemes included in the committed scenario have overall very little impact at a regional level. This is to be expected as although the schemes included are the most impactful of the RIS2 programme, in the grand picture of the overall road network they do not represent a significant change.

4.10 However, this is likely to be a slight underestimate of the impact of the RIS2 programme because only 10 schemes were modelled and the full benefits of schemes often relate to resolving peak time congestion, improving safety and reliability, that is not fully represented in an average daily speed (further described later in this report).

Portfolio Results - Regions

4.11 The following tables present the results of the portfolio testing. Here the results are presented as change in connectivity for a region, based on the weighted average of connectivity scores for the BUAs within that region; using the committed schemes scenarios as a comparison.

Table 4.2: Regional connectivity change from road investment assumptions

Region	Connectivity change relative to the RIS2 committed schemes scenario					
	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
London	9.0%	8.4%	9.1%	8.2%	8.5%	8.6%
South East	8.3%	7.3%	7.8%	7.3%	7.4%	7.0%
South West	12.1%	12.7%	13.8%	12.8%	11.5%	12.4%
East of England	5.2%	4.2%	4.4%	4.2%	4.5%	4.2%
East Midlands	6.2%	6.3%	6.8%	7.1%	6.8%	6.3%
West Midlands	6.3%	6.9%	7.7%	7.0%	6.9%	6.7%
Yorkshire and The Humber	6.9%	7.1%	7.1%	7.7%	6.5%	6.5%
North West	4.0%	3.8%	3.7%	5.0%	3.9%	3.7%
North East	9.9%	10.2%	12.9%	13.4%	10.4%	12.9%
National	**8.0%**	**8.1%**	**8.9%**	**8.6%**	**7.9%**	**8.1%**

4.12 The largest overall benefit, albeit not significantly, is in Portfolio 3, which targets non-radial connectivity between places. This is likely because the orbital links included deliver benefits to a larger number of regional connections relative to the radial links in Portfolio 2. However, the portfolios all perform broadly similarly, with some underlying variation between regions and places. This is as a result of the method which was used to create the portfolios rather than reflecting an 'upper limit' on connectivity improvements. Some further refinement could see greater separation between the performance of each portfolio.

Portfolio results – 10 largest BUAs

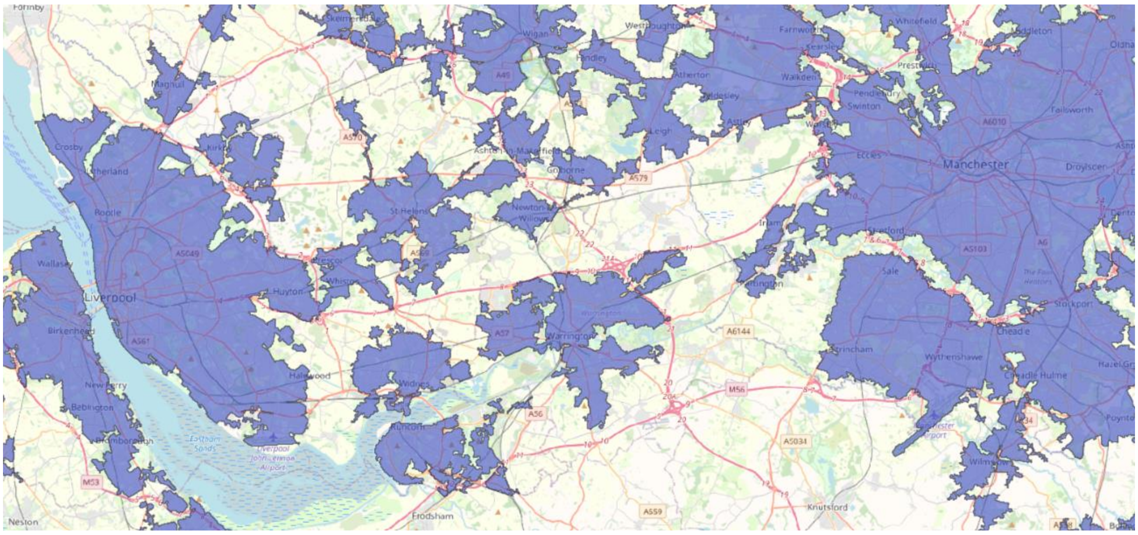
4.13 As well as looking at the results regionally, individual cities or BUAs can be picked out of the data. Looking at the ten largest BUAs outside of London, they are generally significant beneficiaries of all the portfolios, with some exceptions.

Table 4.3: Changes in road accessibility for the ten largest BUAs

Ten largest BUAs	Committed Schemes Scenario Accessibility Score	Weighted Average Change in Connectivity					
		P1	P2	P3	P4	P5	P6
Bristol BUA	1.454	13.52%	16.28%	18.10%	16.19%	13.63%	13.61%
Greater Manchester BUA	1.052	2.59%	2.52%	2.73%	3.63%	2.53%	2.62%
Leicester BUA	0.914	7.65%	7.58%	8.08%	8.73%	7.93%	7.62%
Liverpool BUA	1.189	2.79%	2.67%	3.05%	3.43%	2.84%	2.76%
Nottingham BUA	1.037	7.24%	7.15%	7.58%	7.22%	7.60%	7.19%
Sheffield BUA	1.000	6.85%	7.09%	7.26%	10.29%	7.13%	6.87%
South Hampshire BUA	1.145	9.59%	9.14%	9.18%	9.22%	9.64%	9.06%
Tyneside BUA	1.092	10.74%	10.64%	15.52%	15.88%	11.21%	15.54%
West Midlands BUA	1.266	6.69%	6.78%	8.50%	6.91%	6.95%	6.84%
West Yorkshire BUA	1.197	6.43%	6.38%	6.39%	6.70%	6.36%	6.16%

4.14 The improvements from road connectivity are consistently felt across most of the top ten BUAs. The slight exceptions being Greater Manchester BUA and Liverpool BUA where the benefits of the portfolios are noticeably lower than for the other eight. This is likely due to the nature of the geography of the North West, where the BUAs are large and sprawling and come close to meeting/merging in places as shown in Figure 4.1. This means that a larger proportion of journey times between these places is determined by the performance of roads within urban areas.

Figure 4.1: BUA areas in North West



4.15 As described in Section 2, MRN road links which met the criteria for inclusion (in terms of demand and speed) but were wholly within a BUA boundary were removed from the analysis. This was to reflect that urban road links are likely to be prioritised for investment in public and active modes, rather than inter-urban road connectivity. The nature of the geography in and around Manchester and Liverpool BUAs meant that many links were removed for this reason, as the nature of urban congestion means the benefits of road enhancements would be limited. This has meant that there is less ability to improve interurban road connectivity in this region.

Alternative scenario – Connected and Autonomous Vehicles (CAVs)

4.16 In addition to the portfolios, NIC sought to understand the potential impacts from the role which CAVs may play in improving road capacities and speeds, in particular considering the potential for increases in speed on significant stretches of motorways and major A roads.

4.17 In this test a simple assumption was applied where anywhere in the road network which had average speeds above 60mph, they would be increased to 80mph. This was to simulate the proposition that CAVs may support safer higher speeds in free-flowing traffic. The full potential impacts of CAVs are not yet known and hence this was the only assumption used.

4.18 No consideration has been given to other dependent factors such as: the ability of cars to drive safely at these speeds, the level of take-up of CAVs and how long this takes, and whether the road infrastructure needs to be upgraded to enable these travel speeds.

Table 4.4: Outputs of the CAV Scenario Test

Region	Regional Connectivity (ratio of connectivity using observed speed vs crow flies speed)		Connectivity change
	Baseline Scenario	CAV Scenario	
London	0.52	0.54	4.6%
South East	0.85	0.89	4.7%
South West	1.18	1.28	9.1%
East of England	0.72	0.73	1.7%
East Midlands	0.99	1.02	3.4%
West Midlands	1.13	1.18	4.4%
Yorkshire and The Humber	1.11	1.15	4.0%
North West	1.04	1.05	1.1%
North East	1.17	1.26	7.7%

4.20 As can be seen, the CAV assumptions generate benefits of a comparable scale to the portfolios tested earlier. This demonstrates the potential for this future technology to support inter-urban connectivity.

4.21 The benefits are not felt evenly across all regions. This is due to some regions having more of the current network operating at or near free-flow speeds, hence the CAV assumption benefits those parts of the network more highly. Where the network is more consistently congested or slow, the CAV assumption has less of an impact.

Limitations to the method

4.22 There are some limitations to the method and the tools available which are likely to impact the results of this analysis. Albeit it was not the intention of the project to provide an accurate and robust measure of exact connectivity improvements. All of the tools/models developed, and the overall method were proportionate to the required outputs for the project.

4.23 For the road network analysis the main limitation is how the model cannot account for wider network benefits from individual intervention assumptions. The network consists of links with fixed speeds. An intervention is coded in by either adding a new link with an assumed fixed speed or to manually lift the speed of the targeted existing link to account for an improvement. A highway model, more typically used for detailed appraisals of individual projects uses capacity and speed/flow curves in the assignment. This would give a wider area of benefit as an intervention typically reduces queues and delays over that affect a wider area of the network.

4.24 Further, for new roads there is typically a reassignment benefit resulting from trips using the new road and reducing congestion elsewhere in the network. Neither of these effects are accounted for in the analysis used for this project, as it is presenting a static picture of connectivity rather than forecasting future demand. The method is therefore likely to be underestimating the overall connectivity benefit in these cases, but neither does it directly account for the impact of any induced demand over time which would reduce journey time benefits, although urban roads where this was expected to be a significant factor were excluded from the analysis.

4.25 Finally, there is a simplifying assumption made for the cost assumptions used to build the portfolios which may mean that cost estimates could vary substantially if detailed work is undertaken. The outturn costs used to build-up potential scheme costs for the portfolios tended to be for relatively large SRN schemes which may not reflect costs for smaller schemes on the MRN. This has been reflected with ‘high’ benchmarks used for SRN interventions and ‘mid-range’ estimates for MRN interventions; but specific costs for MRN schemes would help refine the portfolios.

A Gravity Model Methodology

A simple gravity model has been developed for this project as a means of generating theoretical demand for economic interaction between Built Up Areas (ONS Defined) across the UK. It is not intended to be a true reflection of demand: it is instead intended as more of a tool to compare theoretical demand and a means to assign that demand to the highway network tool also developed specifically for this project. Therefore, the model has not been calibrated and validated, although some assurance and sensitivity testing have been performed.

Model Development

The gravity model is a destination constrained model. It matches the number of workers from each origin to jobs in destination zones. The mathematical form of the model ensures that all jobs in destination zones are filled. The model zones are only the ONS BUAs: there are no intermediate zones.

The calculations of the model are built upon two levels of choices. First, given an OD pair from origin zone i to destination zone j, the model calculates the probability for a worker to travel or not, based on the travel disutility U_{ij}. This first choice is modelled using a binomial logit model. The parameters θ_i and Δ_i are empirically calibrated.

$$P_{ij} = \frac{e^{U_{ij} * \theta_i}}{e^{U_{ij} * \theta_i} + e^{\Delta_i}}$$

The probability P_{ij} is then fed into the gravity calculation, by multiplying this probability by the number of workers in that origin zone. This produces the 'accessible workers' $\mathrm{O_i} * \mathrm{P_{ij}}$ from each origin zone to the destination zone. For each destination zone, based on the number of 'accessible workers' from each origin zone, the model will calculate a 'accessible weight' $\mathrm{W_{ij}}$ for each origin zone.

$$\mathrm{W_{ij}} = \frac{\mathrm{O_i} * \mathrm{P_{ij}}}{\sum_i \mathrm{O_i P_{ij}}}$$

The second level of choice is to decide for each job in the destination zone, where the worker will come from to fill that job. In order to do this, the gravity model distributes the jobs from the destination to origins based on the accessible weights, and it ensures that all jobs are distributed to origins.

$$\mathrm{T_{ij}} = \mathrm{D_j} * \mathrm{W_{ij}}$$

Each of the above steps create the following generic form of the gravity model:

$$\mathrm{T_{ij}} = \mathrm{O_i} * \mathrm{D_j} * \frac{1}{\sum_i \mathrm{O_i P_{ij}}} * \mathrm{P_{ij}}$$

In terms of data, the destination zone D_j is the number of jobs from census. The origin zone O_i is the number of workers from census. The U_{ij} is the journey time between origin i and destination j multiplied by a utility scaler S. $U_{ij} = car\ journey\ time * S$. The trip matrix T_{ij} is interpreted as if everyone uses car to commute to work and car journey time is the only factor that affects their commuting decision, then T_{ij} is the expected trip matrix.

The data used in the model are as follows:

- England & Wales Workforce: ONS - QS601EW - Economic activity
- Scotland Workforce: Scotland's Census 2011 - KS601SC - Economic activity
- England & Wales Jobs: ONS - Business Register and Employment Survey - Employees
- Scotland Jobs: ONS - Business Register and Employment Survey - Employees Count
- Car journey times for the base model have been fed in from the highway network model built for this project, which uses DfT link-based speed data as an input.
- Car journey times as the 'crow-flies' have also been used in a model scenario. These were derived via a zone centroid to centroid distance multiplied by a standard 50mph assumption.

Model assurance and sensitivity testing

Given the purpose of the model was to only supply a theoretical demand level, which could be used to generate an input for the highway network model, there was no real need to fully validate the gravity model. For more precise applications the outputs of models such as this would be compared with real data such as census journey to work data. However, this was not necessary for this project. Despite this some assurance checks and sensitivity testing was undertaken to give confidence that the model was producing sensible results and was sensitive to changes in journey times between BUAs in a plausible way.

A relatively low demand threshold has been set to reflect the uncertainty within the model, and given that commuting trips are being used as a proxy for all demand.

Selecting parameters for the deterrence curve

The parameters for the deterrence curve θ_i and Δ_i and the utility scaler S were developed in another model built by Steer. That was the Northern Economic and Land Use Model 3.1 (NELUM3.1) built by Steer in 2018 for DfT and TfN. NELUM3.1 was calibrated to 2018 commuting data provided by TfN. After calibration, the model was shown to be performing well, with the 'goodness-of-fit' ratio reaching 0.9; where 1 is a perfect fit to the true data.

We then translated the parameters from NELUM3.1 to the NIC gravity model by superimposing the centroids for the NIC model zones on top of NELUM zones. The NELUM zone closest to the NIC zone was used as a donor for parameters to use as a basis for the new NIC model. Therefore, although the NIC model itself was not calibrated it has utilised parameters from a donor model which had previously been shown to calibrate well against real data.

Sensitivity tests

Sensitivity tests were carried out to investigate how the NIC gravity model performs when journey times between zones are changed. Four sensitivity tests were undertaken, as listed in the table below.

The first two tests investigated the overall responses of the model. First the crow flies travel time was increased or decreased by 20%. When travel time was increased by 20%, there was a general pattern that intra-zonal trips increased, and inter-zonal trips decreased. This is because workers in the model are shifting to shorter distance commuting trips. When travel time decreased by 20%, the opposite was observed: workers shifted from intra-zonal trips to inter-zonal trips. The conclusion was that the overall behaviour of the model is reasonable and intuitive.

Test 3 focused on testing the response of trips from/to large zones, for example, the largest cities. Using Manchester as an example: after increasing the travel time from/to Manchester to/from all other zones, the trips from/to Manchester dropped as expected. At the same time the number of intra-zonal trips in Manchester increased. This is because there were unfilled jobs when workers did not commute into the city anymore, and these jobs still needed to be filled. Workers in Manchester then filled the intra-zonal jobs.

Test 4 focused on testing key corridors. Using the Manchester to Warrington corridor and the Glasgow to Hamilton corridor as examples the test increased the journey time between them by 20%. Trips from Manchester to Warrington and from Glasgow to Hamilton both dropped. Meanwhile, it was also observed that trips from other nearby zones to Warrington and to Hamilton increased. This is because the empty jobs in Warrington and Hamilton needed to be filled, and workers from other nearby zones filled these jobs.

Table A-1: Gravity Model Sensitivity Tests

Test number	Test description	Compare to the base case
1	all zone pairs GJT increase by 20%	Intra-zonal trips increased (up to 65%, mainly from 20 - 40%). Inter-zonal trips decreased. Workers changed to shorter distance commute
2	all zone pairs GJT decrease by 20%	Intra-zonal trips decreased (up to -45%, mainly around - 30%). Inter-zonal trips increased. Workers changed to longer distance commute.
3	all zones to/from Manchester GJT increase by 20%	Trips from all other zones to Manchester decreased. Manchester intra-zonal trips increase. Trips from Manchester to other zones decreased.
4	Manchester to Warrington, Glasgow to Hamilton GJT increase by 20%	Trips Manchester to Warrington dropped by 14%. People from other nearby zones refilled the jobs in Warrington. Trips from Glasgow to Hamilton dropped by 7%. People from other nearby zones refilled the jobs in Hamilton.

B Road Network Model Development

Introduction

This note outlines how Steer created a simplistic highway network model for use within NIC Interurban Transport Analysis project. The model was needed to provide a means of assigning theoretical inter-urban demands from the gravity model into a network. The assignment was used to determine which links in the network carried the greatest levels of inter-urban traffic, and hence are of most interest to the NIC. Later in the project the model was also used to test the performance of the network with some assumptions of improvements to key locations coded in. Finally, the model was also used to assign DfT National Travel Model freight demands to determine route choice when looking at freight trips between built up areas.

The network model is bespoke to this project and developed in an intentionally simplistic way. It was not calibrated to real data and does not use link capacity in the assignment, instead it uses a link-based, fixed-speed assignment using real DfT link-speed data.

Data sources

To build the network Table B1 below shows the data sources utilised.

Table B1: Data Sources

Data set Name	Source	Description
Average speed, delay and reliability of travel times on SRN (CGN04)	DfT	Worksheet CGN0404d contains link level road speeds across the SRN.
Average speed and delay on local 'A' roads (CGN05)	DfT	Worksheet CGN0503e contains link level road speeds across major a-roads.
SRN Network	DfT	GIS file showing network used to represent CGN0404d data
Local A Road Network	DfT	GIS file showing network used to represent CGN0503e data
OS Open Roads	Ordnance Survey	GIS file showing road centre lines for all roads in the UK

Network Development

An initial review of the data sources was undertaken to establish its suitability for the developing the road network.

The key requirement for the road network was that the dataset must be topologically correct in that each link should connect with its associated adjacent link with no gaps. If there were gaps in the source data, the network will not be able to be assigned.

On inspection it was noted that the DfT SRN network matched successfully to the CGN0404d data however, the GIS file had a number of gaps around SRN junctions, see figure 1 on as an example. It was also noted that when adding the representation of the A road network the SRN did not align, see Figure B1. This meant that these layers could not be used in their current form, meaning an alternative method was needed to associate DfT speeds with a fully complete/connected road network.

Figure B1: DfT Network showing gaps on the SRN network

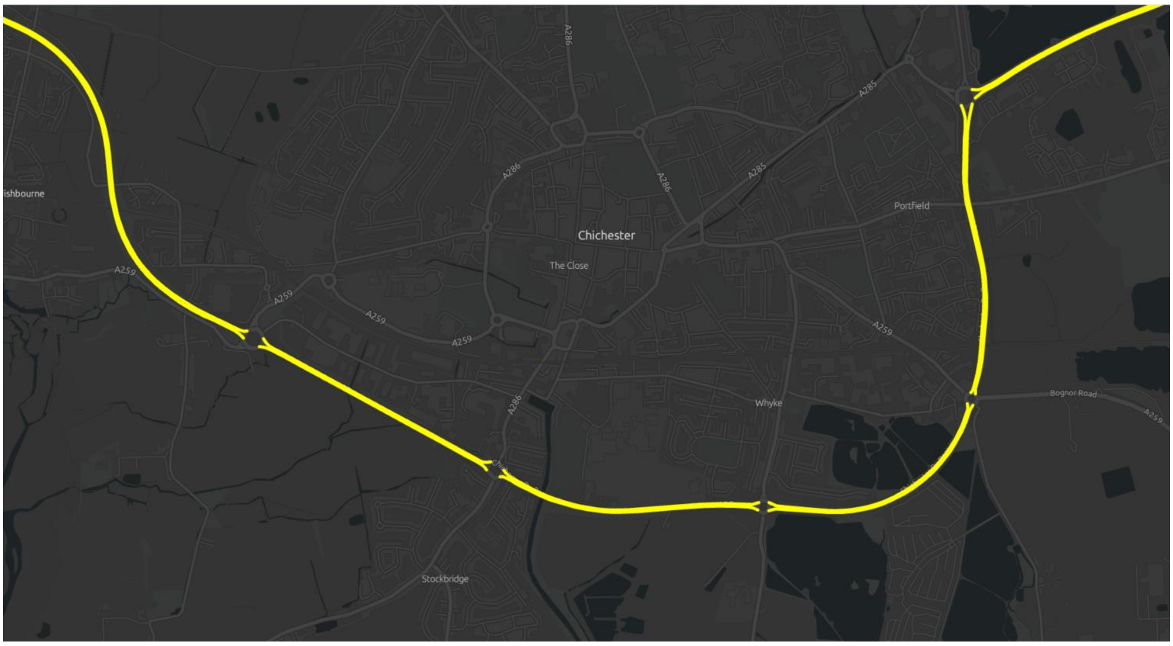


Figure B2: DfT showing A Roads and SRN Network not connecting

Ordnance Survey provide an Open Data set called OS Open Roads; this is a topologically correct road network that covers Great Britain. Within the database there is an attribute that flags if the road link is part of the SRN, whilst an MRN representation is available from DfT on data.gov website.

It was decided that this data was needed to improve the geographic representation of the network. A process was therefore needed to link the two datasets together, the follow steps outline the steps taken to clean and tidy the excel data and apply this to the OS Open Roads data set:

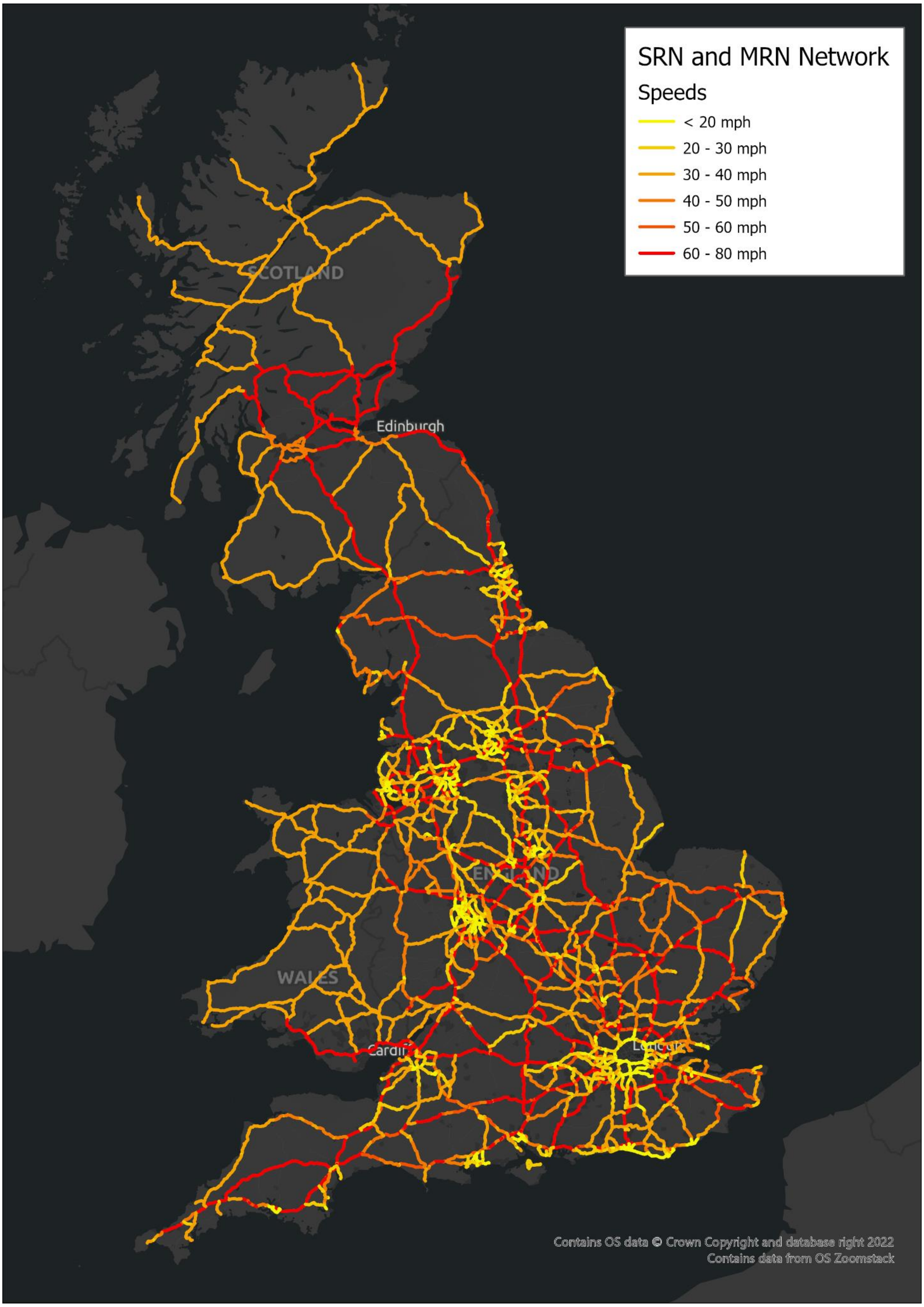
- In table CGN0404 remove all links that do not report a speed value.
- Match table GCN0404 to the supplied DfT data based on the 'Link Name' attribution.
- Use a representation of the SRN from Ordnance Survey's Open Roads Database
- For each link in the OS SRN network calculated the midpoint of the link and map this data set.
- Perform a spatial join matching the OS SRN mid points to the closest DfT dataset and assign that speed to the network.
- A similar process was then undertaken for the A Roads layer

As the DfT data did not include speeds for roads in Wales and Scotland, manual edits were performed to the speed data in these regions to assign speeds based on similar roads in England.

One issue with this approach was that the DfT's speed data did not provide a directionality and the OS Open Roads data set only uses a centreline to represent the road. The model would require a fully bi-directional network in order to assign the BUA to BUA matrix. On inspection of the speed data supplied by DfT in table CGN0404d it was noted that as the speeds are an annual average there was very little difference by road link direction. It was therefore decided that this dataset would provide the best geographic representation of the road network that contains good representative speed data for the link.

Figure B3 shows the final network.

Figure B3: SRN and MRN network with speed data



Demand Assignment

The completed network was built in GIS software and then fed into VISUM for the purposes of assigning demand.

The zone structure for the model followed the same ONS 'Built Up Area' (BUA) structure as the gravity model. The zones were connected to the network as a single connection from the BUA centroid to the nearest point on the road network.

BUA to BUA journey times were taken from a dummy assignment of the model and fed to the gravity model, which in turn used these to produce the theoretical BUA to BUA demand. The network model assigned these demands to produce the link flows used later in the project methodology to prioritise locations for improvement.

Similarly, the gravity model fed the network model with an alternative demand matrix, based on crow-flies journey times. These were also assigned in the network and used to compare link demand between the two scenarios.

In order to produce the data for the freight elements of the project methodology the network model was fed freight demands derived from the DfT's National Travel Model, where a zone correspondence look-up converted NTM zones to BUAs for the NIC models. Once assigned again the model was used to show where the highest levels of demand in the network were.

Finally, the last step of the project took assumptions on link improvements (both committed from the RIS2 programme and interventions for portfolio testing) and made changes to the fixed speeds in the network to approximate improvements once an intervention had been delivered. In all six new network scenarios were developed to match the six tested portfolios. The network scenarios were all run with the same demands, but now the changed speeds could impact the assignment and zone to zone journey times. These new journey times were fed into the connectivity metric to determine the changes/improvements in inter-urban connectivity as a result of each portfolio.

C Infrastructure Costing Assumptions

The project required an assumption of scheme or intervention cost because the portfolios to be tested have cost constraints, both overall and at a regional level. It was not feasible to establish 'true' scheme costs for each of the locations identified in the corridor and link prioritisation process; it was therefore necessary to develop some proxy cost metrics which could be applied quickly and simply.

To develop the cost estimates Steer has utilised benchmark and outturn costs provided by various bodies to NIC, including: National Highways, Network Rail, the Infrastructure and Projects Authority and other publicly available sources.

These outturn costs were examined in an attempt to establish some more simplistic 'cost per km' or 'cost per junction' assumptions which could be used later in the project methodology. It is recognised that this approach is very simplistic and in reality any intervention at any of the locations identified in the prioritisation process would have many variables which may not align with the simplistic approach taken. However, for the purposes of the requirements for this project the approach was deemed sufficient.

Data sources and developing assumptions

To establish benchmarks for both road and rail projects the following data was utilised:

IPA Data

The data supplied by the IPA provided a baseline cost for the DfT's major road projects either completed or in the pipeline between 2013-2022. Many of these provide transport links for BUAs or examples of potential improvements to these links. The data was interrogated that following decisions made:

– Road Projects
- All road projects included in the data were assessed.
- Only two of these projects are complete.
-

Price base

- The IPA data provides a 'TOTAL Baseline Whole Life Cost (£m)' for each year the project is included in the portfolio. This figure was used for all cost analysis.
- The same indicator is used by the IPA for finished and incomplete projects. It should in theory be updated from business case costs for both live and finished projects, but data updates are not always regular. We have excluded incomplete projects except for where this is the only data available.

- The price base of this data can be unclear as it includes the financial cost spent to date, but forecast future costs are more ambiguous. This adds uncertainty to the rebased figures as we do not know what basis these costs have been produced on.
- For the majority of projects, the baseline cost was published in 2022, in these cases they were left unchanged.
- Where data is published in previous years, we have inflated by growth in the GDP deflator.

–

Table C1: IPA Road Projects Cost/km (2022 prices)

Area	Category	Sample size	Cost/km - min	Cost/km - average	Cost/km - max
Rural	Widening/Bypass/Road Improvement	4	£41.80	£73.82	£158.38
Developed	Widening/Bypass/Road Improvement	2	£21.11	£179.18	£293.57
Mixed	Widening/Bypass/Road Improvement	0	No data available		

National Highways POPE Data

We were able to conduct further cost analysis with data on major road projects. Using data from Post Opening Project Evaluation (POPE) of major schemes, made available by Highways England. This allows for a detailed breakdown of costs for road widening schemes, smart motorways, junction improvements and bypasses/new roads. This analysis followed the same format as the IPA data, using the Total Investment Cost to calculate a cost per km and cost per junction figure.

Inflation

- All projects from the POPE data give costs in 2002 prices.
- All prices have been inflated to 2022 prices using the GDP deflator.

Summary Cost estimates

Using all of the above data the following tables present the final benchmark cost assumptions which were used in the latter stages of the project. They were applied by taking assumptions on the length of network which required improvement and some approximations of what type of improvement might be required.

Table C6: Road data benchmark Cost/km (2022 prices)

Category	Sample size	Min Cost (£M) / km (£m)	Average Cost (£M) / km (£m)	Max Cost (£M) / km (£m)
Bypass	5	£13.28	£44.73	£76.35
Junction Improvement	5	£16.25	£16.25	£16.25

Road Improvement – mixed schemes	6	£8.52	£26.12	£83.47
Smart Motorway	9	£6.15	£11.15	£16.42
Widening	8	£9.36	£18.65	£29.49
Total	33	£6.15	£23.38	£83.47

The road costs were used in two ways:

- Firstly an assumption was developed on the number of junctions per km for both the SRN and MRN to account for road widening and junction upgrades on a 'per km' basis. To generate this assumption an large sample of the SRN and MRN was used.
- For interventions on the SRN the 'max cost' figures were used in order to be as cautious and robust as possible and in part to account for the significant rise in construction costs since many of the outturn projects had been developed. For interventions on the MRN the medium or 'average' cost figures were used, reflecting that the benchmarked schemes were all on the SRN which tend to be much larger than the major road network. Again, this could also be considered a cautious assumption given the scale of schemes on the MRN. Unfortunately, no outturn costs for large local major schemes could be sourced for this project.

Application of environmental criteria

In order to account for the requirement in the Environment Act of 2021 to include a biodiversity net-gain for all infrastructure projects, some assumptions were developed and applied to the benchmark costs.

Defra's impact assessment for the requirement of biodiversity net gain[4] gave a cost range of between £3,150 and £47,885 per hectare for non-residential development, with a central case estimate of £14,334. Recognising that transport projects are sometimes in more sensitive areas, we rounded this to £20k per hectare. Assuming that a project affects a corridor around 100m wide, this gives a cost per kilometre of £200k. This has been added to the road unit costs in each portfolio.

Additionally, where links or corridors are in locations near to environmentally sensitive areas we have increased costs to the upper end of our benchmarked range, reflecting the likely higher costs of these interventions.

4 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/839610/net-gain-ia.pdf

D Further methodological detail on portfolio development

Methodology for prioritisation of corridors and links

Prioritising road corridors and links

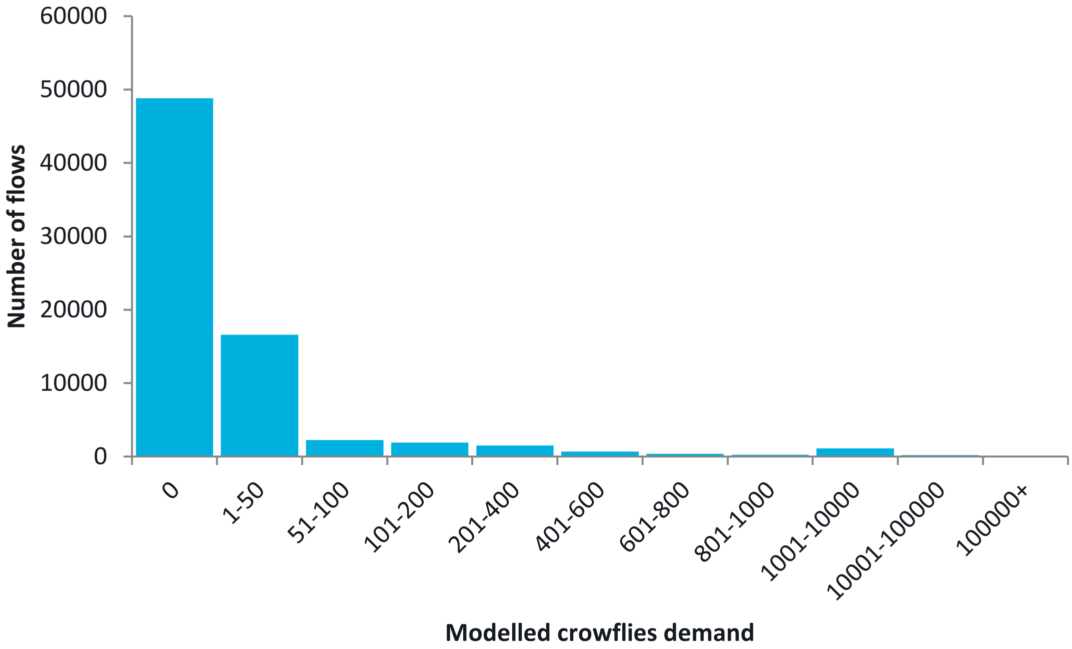
The prioritisation of road corridors aimed to identify the BUA pairs where there was the largest gap between the network journey times and the time taken if one travelled at 50mph in a direct line, i.e. as the crow flies. This suggests that either the best possible route between BUAs is significantly longer than a straight line or that the route is relatively direct but observed speeds are well below 50mph.

Reviewing the outputs of the gravity and network models, it became clear that we would need to set a demand threshold for the 'poorly connected places' analysis to avoid focusing on corridors which also have poor performance but where potential demand will always be low relative to other BUA-BUA pairs, e.g. between two small places a very long distance apart. However, the nature of the gravity model means that estimated demand is weighted towards places that are relatively close together, so setting this threshold too high risks excluding flows where there are potential connectivity benefits and substantial business travel could occur.

From our initial analysis we could see that the distribution of demand is very skewed: the majority of BUA pairs in the dataset had 0 demand. As shown in Figure D1 there are a small number of flows with very high levels of demand, but the majority were clustered at low values. This is due to the nature of the gravity model used, which follows accepted economic theory by placing a high weighting on locations which are close to each other; using a distance decay function. The function simulates the waning influence of demand to travel to a place as distance increases; which is a central tenet to agglomeration theory[5]. As described in **Annex A**, although the model has not been formally validated, it was constructed using parameters (including the decay function) donated from a previous model developed by Steer which was validated and shown to be a good fit to available data.

[5] Daniel Graham (2007): 'Agglomeration, Productivity and Transport Investment', *Journal of Transport Economics and Policy*

Figure D1: Distribution of crow flies demand



A similar approach was used to identify the 'weaknesses in existing infrastructure'. However, this time we considered the total daily demand on each link after assigning the full gravity model matrix. As with the 'poorly connected places' test a demand threshold was again set to focus on the highest impact flows. For this test a demand threshold of 5,000 reduced the number of links to a more focused list. Those links above the threshold with the lowest speeds were considered for prioritisation later in the process.

After running this test and mapping the initial results, it was clear that many of these high demand/low speed links were in relatively central areas of major cities. Although these urban MRN links clearly carry significant amounts of inter-urban traffic it was felt that they should be filtered from the analysis and not considered as priorities. This was due to the substantial downsides, and technical and political challenges, of building major new road capacity in urban areas. Although there may be slow speeds on these parts of the network, major cities are moving more and more towards prioritising public and active transport to move people around, as was identified by NIC in the first National Infrastructure Assessment. These particular parts of the network were therefore not considered further for potential improvements to support inter-urban connectivity by road. Where the SRN passes through urban areas this has been included in the analysis, given these roads are generally in less densely populated areas.

The impact of this filtering is likely to vary between cities: in particular the BUA boundaries for previously industrial Midlands and Northern cities can spread over wide areas, so more strategic links on the edges of their urban area have been excluded than is the case for cities with tighter green belts.

The NIC have identified two lists of priority places for non-freight travel, focusing on different aspects of levelling up and economic growth. Both contain the largest cities, and then focus on towns with specific characteristics: List A identifies places which are poorly connected and currently have low levels of economic output, where transport investment could help to bring their economies towards the national average. List B identifies places which are poorly connected and currently fast growing, where transport improvements could support the continuation of that growth and excludes London. Initial analysis was carried out separately for both lists. Upon reviewing the initial analysis outputs, it became clear that the results were very similar for the majority of the country but, as List B excluded London, the allocation of demand in the Southeast of England was highly unrealistic. Therefore, the remaining analysis and the prioritisation for portfolios used the combination of List A and List B but retains labelling so that the balance of priority improvements between lists could be identified.

Prioritising locations important for freight

The most important links for freight were identified by selecting the road links where demand between the freight priority locations was high and observed speeds were lowest. Since the network model is based on observed speed data, links where average speeds are significantly below the HGV speed limit of 56mph, and there is substantial HGV demand were deemed to be those which provide important connectivity without a viable alternative.

Accounting for committed schemes

Since this project is forward looking, the baseline networks were adjusted to account for the potential impact of schemes which are already committed. This also avoids the identification of priority areas for investment which are already targeted by planned investments.

For roads it was not proportionate to include all of the RIS2 schemes in our network model as many localised schemes and junction improvements would not have a substantial impact due to the structure of the model, which aggregates speeds on individual links. Following an initial prioritisation process ten schemes judged to have the largest potential impact on connectivity were included in an updated version of the network model. This focused on those schemes adding wholly new links (such as the Lower Thames Crossing and A303 Stonehenge tunnel) and those which were improving the largest sections of the network. Due to the pause and future uncertainty in the smart motorways programme, these were also excluded from the model.

The RIS2 schemes were coded by adding additional links to the network model where required, with their speed set to the national SRN average prior to Covid-19 (58mph). Where schemes were improving existing routes the speeds of those links were increased by 20%, using as a benchmark the improvements delivered by past RIS1 schemes such as the A14 improvements near Huntingdon. A full list of the RIS2 schemes included in the network model is in **Annex B.**

Where committed RIS2 schemes weren't modelled, they were still accounted for in the portfolio development process. If the network prioritisation flagged that a link could be a priority for investment (i.e. performance and demand thresholds were met) but a scheme was already in the RIS2 programme at the same location then these were manually removed from the portfolio tests.

Allocating links or corridors to the portfolios

Each subsequent portfolio started from the baseline of Portfolio 2 and added or changed filters in the database to create a new ranked list. This process was iterative, to ensure that the portfolios were sufficiently different, but that all the filtered lists contained enough improvements to meet the budget threshold. Each of the 'buckets' that made up the portfolio was treated slightly differently, reflecting their individual characteristics. The process of developing the portfolios was iterative in discussion with the NIC.

Considerations for road current network performance in creating the portfolios

After the initial sifting/prioritisation it could be seen that the highest demand, and worst performing links in the database were heavily concentrated in the Southeast and around major cities. This was the case even after excluding links within urban areas and in both List A and List B scenarios from the gravity model. Therefore, to give more regionally balanced results, the budget was split and allocated between each region on a population weighted basis.

Once all urban links were excluded very few links within the London region fell outside the Greater London BUA. It was decided therefore that the nominated budget for London would be reallocated between the other regions on the same proportional basis. This increased the number of opportunities for improvement brought into the regions for all portfolios.

For all portfolios, the initial testing picked out all links with speeds below 40 mph and demand above 5,000. However, for Yorkshire and Humber, and for the Northeast, regions with a lower number of interurban links, there weren't enough links meeting that threshold to fill-up the portfolio budget. For these regions the demand threshold was reduced, and maximum speed was increased to 50mph. This pulled more priority road links through into the portfolios in these regions.

Given the nature of the network model available to the study there was not sufficient data or time available to determine the links which carried journeys of the distance threshold set for Portfolio 5. Therefore the road priorities included in Portfolio 5 were the same as Portfolio 1. A methodology was considered to be able to identify the links in the network being used by either long or short distance inter-urban movements, but this would require new assignments of the network model, separating out the matrices by distance bands. However, this was not deemed proportionate in the time available. It was possible to filter by distance bands for rail and hence the rail priorities for these portfolios did differ.

Portfolio 6 set a higher speed threshold of 60mph for all regions and identified the links with the highest demand within each region.

Considerations for road corridors ('poorly connected places') in creating the portfolios

To establish the list of full road corridors for Portfolio 1 & 2 the following criteria were applied: Crow flies journey time was less than 0.7 of the modelled network journey time, e.g. those where network speeds were lower than 35mph. A minimum 'crow flies' distance of 20 miles was also set in order to focus on inter-urban connectivity, thereby excluding flows where a substantial portion of the journey was from the centroid to the edge of the urban area. Flows to and from Greater London were also excluded. The remaining corridors were then sorted in order of highest theoretical demand in order to identify priorities.

In the unfiltered priorities there was a clear pattern that corridors around the largest cities, primarily Greater Manchester, were dominating the lists. Therefore, in discussion with NIC it was decided that to create Portfolios 3 and 4 the principle applied for all portfolios of excluding links which supported demand to/from Greater London would be expanded to other major cities. This would support the creation of distinct portfolios which focused on connectivity between smaller, but still important, places.

Portfolio 5 set a higher minimum distance of 50 miles between BUAs for the corridors, although there was no minimum level of demand, recognising that the theoretical gravity model demand was less relevant for these longer distance flows. In addition a minimum population of 100,000 people for both the origin and destination ends of the corridor was set. These filters aimed to reflect that connectivity improvements for these longer distance routes were more likely to be viable when connecting larger places.

Portfolio 6 set a higher threshold for current performance, considering flows where the 'crow flies' journey time was less than 0.9 of the network journey time, and then prioritised based on demand.

Considerations for freight components of the portfolios

The approach for freight links was similar to road but set a much lower demand threshold of 100 HGV trips per link, as the available data was hourly rather than a 24 hour total. The speed threshold was set at 56mph, the maximum speed for HGVs, recognising that the ability to reliably travel at that speed was an important consideration for freight traffic. The overall priorities identified were already evenly distributed between regions, so it was not considered necessary to regionally weight the portfolios.

The same filters applied to the road priorities for Portfolios 3 and 4 to exclude radial links for major cities were also applied for freight. For Portfolio 5 a slightly different approach was applied compared to the road priorities. This was due to the different distribution of freight demand across the network. Portfolio 5 prioritised the SRN links, most likely to be used by freight for long distance journeys.

SRN links were more prominent in this dataset than for the road portfolio, as a result of the higher speed cap bringing in some roads which did not meet the poor performance thresholds set for the more general road priorities. This also meant that they made up a larger proportion of the top priorities: Portfolio 5 is therefore similar to Portfolio 2

Refining and populating the final portfolios

Following the iterative process of setting rules/thresholds/criteria for each portfolio and the road, rail and freight elements separately ranked lists of priorities were identified for each of the portfolios across the five funding pots identified.

For the road network gaps, this took the form of a list of corridors. For the road and freight improvements it was a list of links.

The final portfolios had a regional weighting applied in order to ensure benefits were targeted at the NIC's priority regions for growth and levelling up. This weighting was applied as follows:

Table D-1: Allocation of theoretical budget to each region

Region	% Road Spending	% of population
North East	4.8	4.7%
North West	23.8	13.0%
Yorkshire and The Humber	15.8	9.8%
East Midlands	13.7	8.6%
West Midlands	17.1	10.6%

East of England	6.9	11.1%
London	0.0	15.9%
South East	8.7	16.3%
South West	9.2	10.0%

Corridor improvements included in each portfolio

Table D-2: Portfolio 1 network improvement assumptions

Corridor		Category	Improvement type
Nottingham BUA	Derby BUA	Road corridor	New road
South Hampshire BUA	Bournemouth/Poole BUA	Road corridor	New road
Greater Manchester BUA	Burnley BUA	Road corridor	Road upgrade
Greater Manchester BUA	Crewe BUA	Road corridor	New road
Kingston upon Hull BUA	Scunthorpe BUA	Road corridor	New road
Kingston upon Hull BUA	Grimsby BUA	Road corridor	New road
West Yorkshire BUA	Burnley BUA	Road corridor	New road
West Yorkshire BUA	Harrogate BUA	Road corridor	Road upgrade
Greater Manchester BUA	Blackburn BUA	Road corridor	New road

Table D-3: Portfolio 2 network improvement assumptions

Corridor		Category	Improvement type
Nottingham BUA	Derby BUA	Road corridor	New road
Greater Manchester BUA	Blackburn BUA	Road corridor	New road
West Yorkshire BUA	Harrogate BUA	Road corridor	Road upgrade
Bristol BUA	Midsomer Norton/Radstock BUA	Road corridor	Road upgrade
Reading BUA	Farnborough/Aldershot BUA	Road corridor	Road upgrade
West Midlands BUA	Burton upon Trent BUA	Road corridor	Road upgrade
Greater Manchester BUA	Macclesfield BUA	Road corridor	New road
Tyneside BUA	Durham BUA	Road corridor	Road upgrade
Ipswich BUA	Norwich BUA	Road corridor	Road upgrade

Table D-4: Portfolio 3 network improvement assumptions

Corridor		Category	Improvement type
Nottingham BUA	Derby BUA	Road corridor	New road
Greater Manchester BUA	Burnley BUA	Road corridor	Road upgrade
West Yorkshire BUA	Harrogate BUA	Road corridor	Road upgrade

Bristol BUA	Midsomer Norton/Radstock BUA	Road corridor	Road upgrade
Reading BUA	Farnborough/Aldershot BUA	Road corridor	Road upgrade
Greater Manchester BUA	Crewe BUA	Road corridor	New road
Tyneside BUA	Sunderland BUA	Road corridor	Road upgrade
West Midlands BUA	Burton upon Trent BUA	Road corridor	Road upgrade
Ipswich BUA	Norwich BUA	Road corridor	Road upgrade

Table D-5: Portfolio 4 network improvement assumptions

Corridor		Category	Improvement type
West Midlands BUA	Redditch BUA	Road corridors	Road upgrade
Nottingham BUA	Derby BUA	Road corridors	New road
Norwich BUA	Great Yarmouth BUA	Road corridors	Road upgrade
Greater Manchester BUA	Burnley BUA	Road corridors	Road upgrade
West Yorkshire BUA	Harrogate BUA	Road corridors	Road upgrade
Bristol BUA	Midsomer Norton/Radstock BUA	Road corridors	Road upgrade
Reading BUA	Farnborough/Aldershot BUA	Road corridors	Road upgrade
Greater Manchester BUA	Crewe BUA	Road corridors	New road
Tyneside BUA	Sunderland BUA	Road corridors	Road upgrade
West Midlands BUA	Burton upon Trent BUA	Road corridors	Road upgrade
Greater Manchester BUA	Macclesfield BUA	Road corridors	New road
Kingston upon Hull BUA	Scunthorpe BUA	Road corridors	New road
Kingston upon Hull BUA	Grimsby BUA	Road corridors	New road
West Yorkshire BUA	Burnley BUA	Road corridors	New road
Greater Manchester BUA	Northwich BUA	Road corridors	New road
Bristol BUA	Bath BUA	Road corridors	New road
West Midlands BUA	Tamworth BUA	Road corridors	New road
Nottingham BUA	Leicester BUA	Road corridors	Road upgrade
Reading BUA	South Hampshire BUA	Road corridors	Road upgrade
Peterborough BUA	Leicester BUA	Road corridors	Road upgrade
Greater Manchester BUA	Sheffield BUA	Road corridors	Road upgrade
Exmouth BUA	Exeter BUA	Road corridors	Road upgrade
Tyneside BUA	Ashington (Northumberland) BUA	Road corridors	Road upgrade
Stoke-on-Trent BUA	Crewe BUA	Road corridors	Road upgrade

West Midlands BUA	Kidderminster BUA	Road corridors	New road

Table D-6: Portfolio 5 network improvement assumptions

Corridor		Category	Improvement type
West Midlands BUA	Redditch BUA	Road corridors	Road upgrade
Greater Manchester BUA	Burnley BUA	Road corridors	Road upgrade
Greater Manchester BUA	Derby BUA	Road corridors	Road upgrade
Brighton and Hove BUA	Bournemouth/Poole BUA	Road corridors	Road upgrade
Peterborough BUA	Grimsby BUA	Road corridors	Road upgrade
Norwich BUA	Grimsby BUA	Road corridors	Road upgrade
Horsham BUA	Bournemouth/Poole BUA	Road corridors	Road upgrade
Burnley BUA	Chesterfield BUA	Road corridors	Road upgrade
Tyneside BUA	Scarborough BUA	Road corridors	Road upgrade
Milton Keynes BUA	Cheltenham BUA	Road corridors	Road upgrade
Coventry BUA	Hereford BUA	Road corridors	Road upgrade

Table D-7: Portfolio 6 network improvement assumptions

Corridor		Category	Improvement type
West Midlands BUA	Redditch BUA	Road corridors	Road upgrade
Nottingham BUA	Derby BUA	Road corridors	New road
Norwich BUA	Great Yarmouth BUA	Road corridors	Road upgrade
Greater Manchester BUA	Blackburn BUA	Road corridors	New road
Kingston upon Hull BUA	York BUA	Road corridors	Road upgrade
South Hampshire BUA	Bournemouth/Poole BUA	Road corridors	New road
Tyneside BUA	Sunderland BUA	Road corridors	Road upgrade
Greater Manchester BUA	Macclesfield BUA	Road corridors	New road
West Midlands BUA	Kidderminster BUA	Road corridors	New road

Distribution of priorities within portfolios

The overall distribution of speed and demand within portfolios varies but without clear patterns. Higher speed links with lower demand levels are present in the regionally weighted portfolios, reflecting how the criteria were applied. These charts also show that many links, particularly those at the outlying ends of the distribution, are common to several portfolios.

Figure D-2: Distribution of links allocated to Portfolio 1

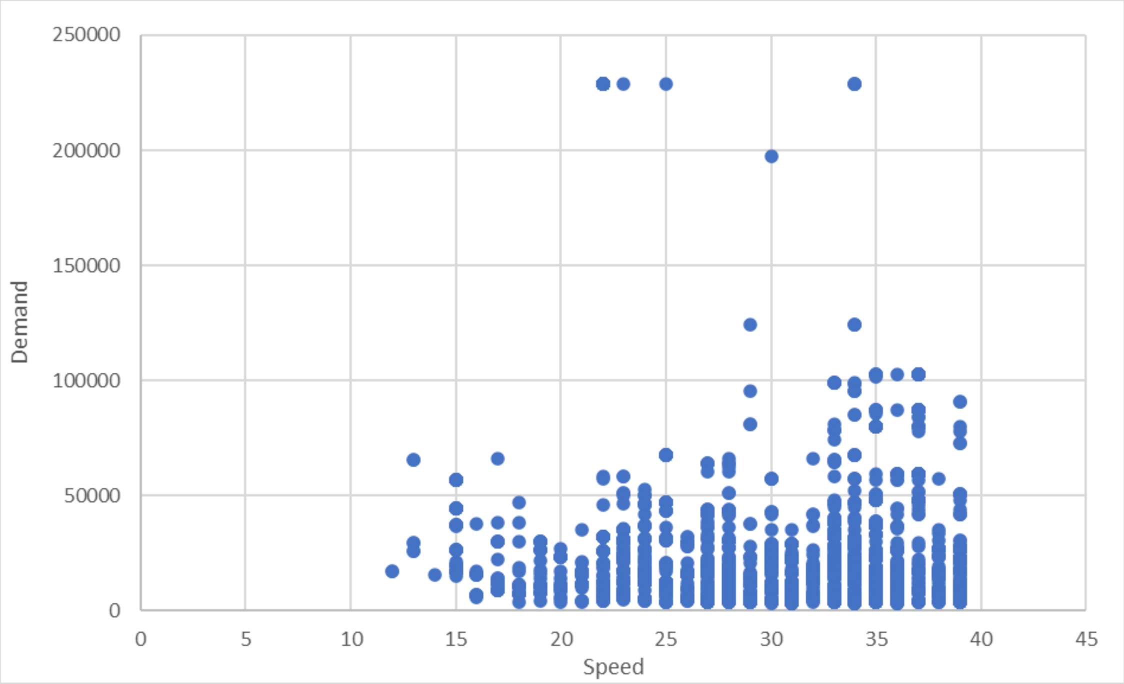


Figure D-3: Distribution of links allocated to Portfolio 2

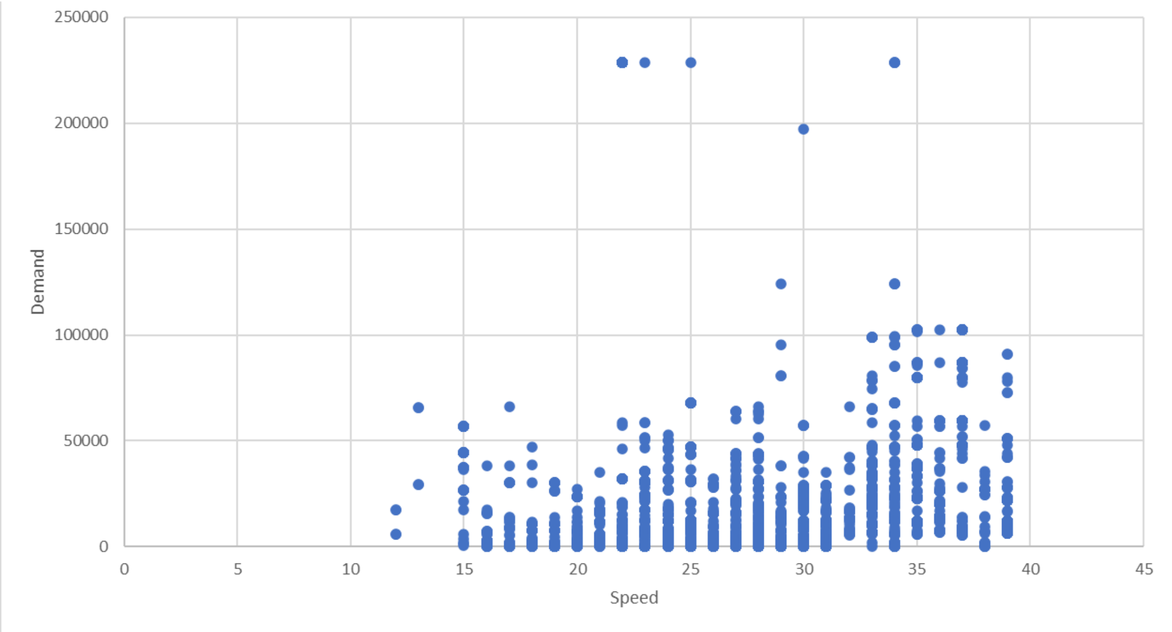


Figure D-4: Distribution of links allocated to Portfolio 3

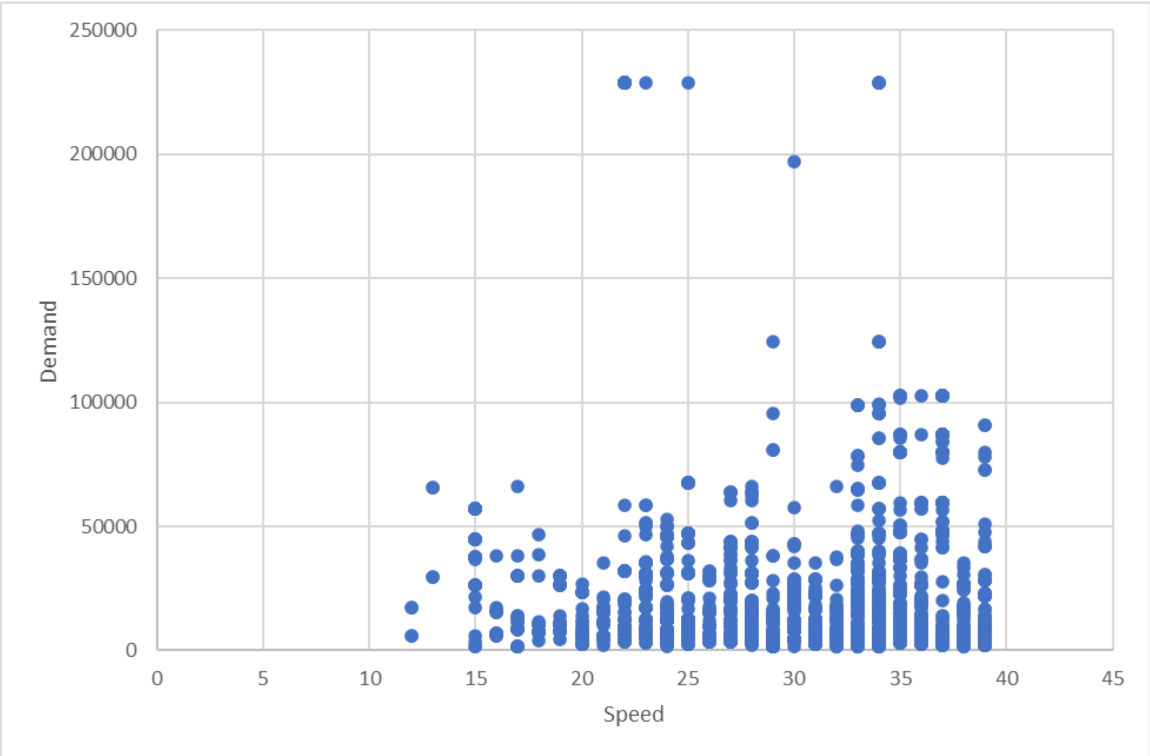


Figure D-5: Distribution of links allocated to Portfolio 4

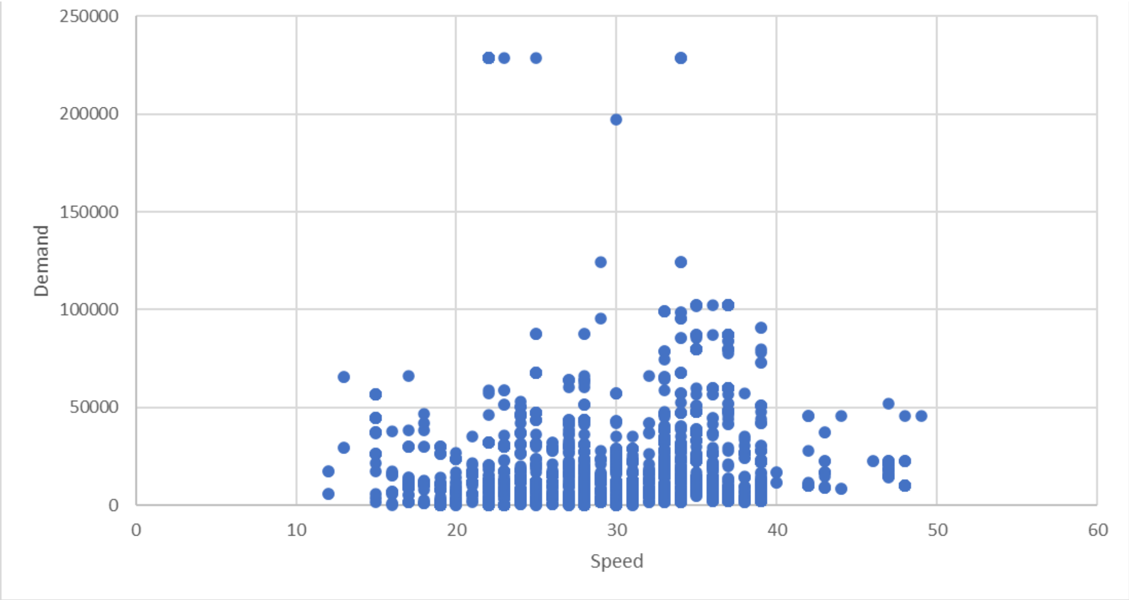


Figure D-6: Distribution of links allocated to Portfolio 5

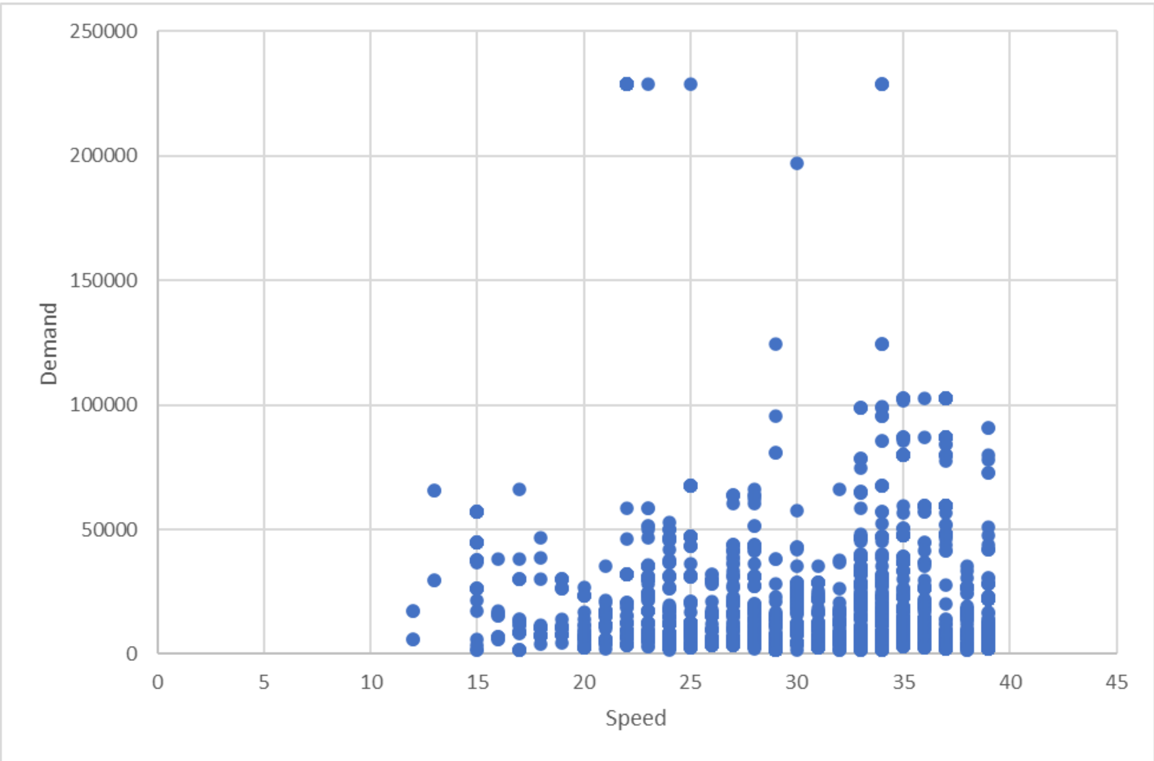
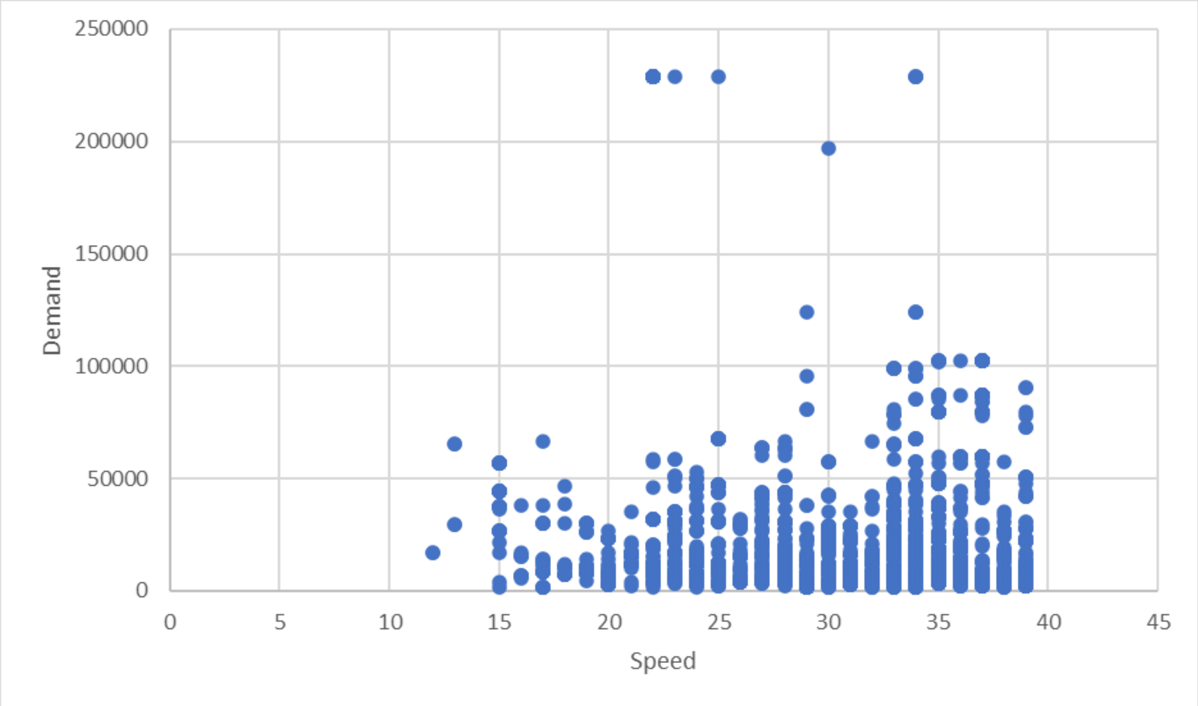


Figure D-7: Distribution of links allocated to Portfolio 6



Performance of the existing network also varies between regions. This means that the average quality of the links being improved does as well. Some analysis was carried out of the distribution of links within Portfolio 2 (the baseline portfolio) in order to understand how much the budget constraint was acting as a cap – eg are the majority of flows with substantial potential benefits to be gained affordable within the budget or are there others which could be improved?

This analysis has been carried out for the road link data. Corridor schemes have been identified to more restrictive set of criteria and there are only a very limited number of schemes in each region.

The average speed of links within the portfolios is similar between each region. Notably the North East has the highest average speed – this reflects the relatively uncongested nature of much of the SRN in the region.

It is also worth noting that many of the slowest links within each region have been excluded from the portfolios as they are MRN links within urban areas. This is likely drawing down the average speeds in some regions such as the North West and West Midlands.

The demand levels modelled vary substantially between regions and the minimum threshold for demand was adjusted to fit each region’s profile. The higher level of demand in some regions reflects that where regions have a lower level of spending in the portfolios the higher demand links have been prioritised. This is particularly apparent in the South West, where the average demand of all links is very low relative to those included in the portfolio.

Table D-8: – Average speeds within each portfolio

Region	Average speed of links in Portfolio 2	Average speed of all links in the region
East Midlands	31.81	40.82
East of England	30.23	44.83
North East	30.11	48.14
North West	27.06	38.59
South East	31.11	39.75
South West	32.26	39.24
West Midlands	30.26	38.53
Yorkshire and The Humber	31.30	38.87

Table D-9: – Average modelled demand within each portfolio

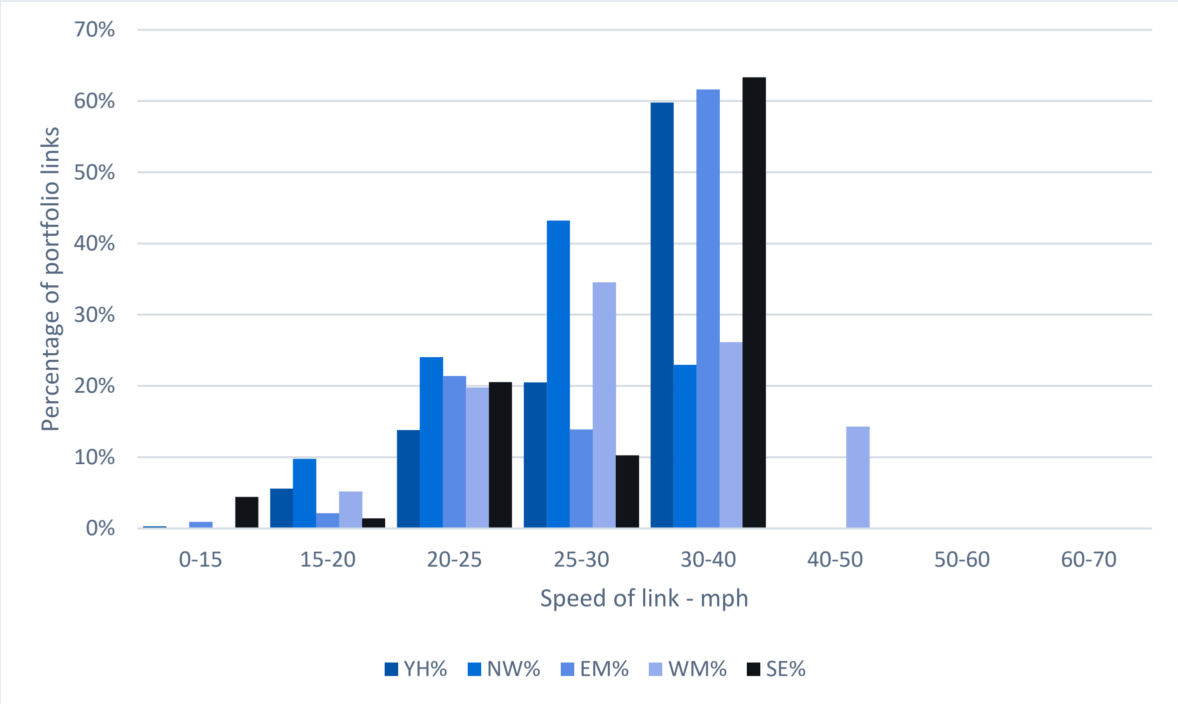
Region	Average demand of links in Portfolio 2	Average demand of all links in the region
East Midlands	13,841	5,940
East of England	31,667	15,543
North East	5,650	2,105
North West	4,107	4,018
South East	74,643	17,941
South West	16,622	2,578
West Midlands	16,123	3,202
Yorkshire and The Humber	6,494	4,651

Within each region the distribution of link speeds included in the portfolio varies considerably.

Figure D-8 shows a selection of regions and the distributions of speed within portfolio 2. However, there is not a clear distinction between the regions with higher levels of spend (in blue) and the South East, in black, with lower levels of spending. This largely reflects that the allocation of links to the portfolios is on a combined basis of speed and demand, with prioritisation largely on a demand basis where links are below the maximum speed threshold.

Where very low speed links have high demand this is likely to be because they are unavoidable links between major places. This can be seen in the portfolio for the North West, which is dominated by slower links than the other priority regions, consistent with the identification of low speed routes in the corridor analysis. This also reflects the distribution of links within the region and the scale of the North West's BUA areas – MRN links within the BUAs are excluded from the portfolio.

Figure D-8: – Distribution of links by speed within select region in Portfolio 2



The proportion of low speed (<50mph) links within each region which are included in the portfolios varies largely in line with the weighting of spending, but with some variation. The North East and Yorkshire and the Humber have relatively high proportions of their low speed links included within Portfolio 2 relative to their budget allocation. This suggests that these may be the regions least likely to benefit from additional spending allocated on the same basis as the portfolio. However many of these links may have very low levels of demand – this is particularly likely to be the case in the South West, which has a very large rural road network.

Table D-10: – Proportion of 'low speed' links in Portfolio 2

Region	%of low speed links in Portfolio 2	% Road Spending in Portfolio 2
South East	5%	8.7
South West	2%	9.2
East of England	4%	6.9
East Midlands	9%	13.7
West Midlands	8%	17.1
Yorkshire and The Humber	12%	15.8
North West	11%	23.8
North East	7%	4.8

E Decay Parameter Sensitivity Testing

The choice of decay parameter influences the overall connectivity of places. A larger decay parameter means that connectivity will be more weighted towards places which are closer together and longer distance flows have less of an impact.

The decay parameter used to generate the results in Section 4 of this report has been set at 0.020. Through trial and error this figure best replicated the results produced by the NIC's previous analysis. As a sensitivity test this was increased to 0.025; with the intention to determine what the effects were if distance decayed connectivity benefits to a lesser extent.

As would be expected, the test produces results with a lower overall magnitude (eg total connectivity is smaller) but the ranked order of BUAs is similar, albeit with a small number of exceptions:

Table E1 - BUAs with highest baseline road connectivity

	BUAs with highest connectivity			
Origin Name	Accessibility Ratio	Sensitivity Test Accessibility Ratio	Rank	Sensitivity Test rank
Plymouth BUA	1.78	1.62	1	2
Redruth BUA	1.66	1.35	2	5
Carlisle BUA	1.58	1.65	3	1
Exeter BUA	1.53	1.44	4	4
Bristol BUA	1.45	1.47	5	3
Truro BUA	1.40	1.14	6	44
Newton Abbot BUA	1.39	1.13	7	46
Teesside BUA	1.32	1.28	8	8
Taunton BUA	1.32	1.24	9	16
Bridgend BUA[6]	1.31	1.27	10	11

[6] Welsh and Scottish BUAs were included in the connectivity assessment to give an indication of the broader GB impacts of the portfolios.

Table E2 - BUAs with lowest baseline road connectivity

Origin Name	BUAs with lowest connectivity			
	Accessibility Ratio	Sensitivity Test Accessibility Ratio	Rank	Sensitivity Test rank
Inverness	0.28	0.20	1	1
Skegness BUA	0.50	0.41	2	2
Hertford/Ware BUA	0.54	0.44	3	3
Canvey Island BUA	0.55	0.46	4	4
Southend-on-Sea BUA	0.56	0.46	5	5
Medway Towns BUA	0.57	0.46	6	6
Bishop's Stortford BUA	0.57	0.47	7	7
Amersham/Chesham BUA	0.58	0.48	8	8
Holyhead BUA	0.58	0.49	9	9
Stanford-le-Hope BUA	0.60	0.50	10	10

We also tested whether this changed the impact of the different portfolios. The overall impact of each portfolio was similar, but slightly smaller:

Table E3 – Sensitivity test of decay parameter on portfolio results

	p1_change	p2_change	p3_change	p4_change	p5_change	p6_change
Higher decay sensitivity	8.3%	8.3%	9.3%	9.1%	8.1%	8.5%
Baseline	8.0%	8.1%	8.9%	8.6%	7.9%	8.1%

The impact of the portfolios across each region also varied but the overall conclusions were very similar: the best portfolio for a region with the original decay parameter was still the best or joint best with the higher parameter.

This is likely to change if more extreme changes were made to the parameter.

Control Information

Prepared by

Steer
14-21 Rushworth Street
London SE1 0RB
+44 20 7910 5000
www.steergroup.com

Prepared for

National Infrastructure Commission
Windsor House
50 Victoria Street
London SW1H 0TL

Steer project/proposal number

Client contract/project number

Author/originator

Sarah Rae

Reviewer/approver

Simon Statham

Other contributors

Mingfei Ma
Louis Baker
Mark Kerri

Distribution

Client: Steer:

Version control/issue number

Date

steer

QUALITY SYSTEM CERTIFICATION
DNV·GL
ISO 9001:2015