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Connectivity analysis – a new measure of United Kingdom of Great Britain and Northern Ireland transport infrastructure

Submitted by the Government of the United Kingdom of Great Britain and Northern Ireland

Summary

This document highlights a new method of completing "connectivity" analysis, recently developed by the United Kingdom of Great Britain and Northern Ireland, improving upon previous official statistics on journey times. It sets out the methodology and presents example outputs for feedback and comment. The document encourages countries to share their experiences and consider whether similar analysis for their nations would add to the inland travel evidence base.

I. Background

1. Since 2014, the United Kingdom's evidence base for understanding transport connectivity and access to key services has been derived from the Journey Times statistical series.[1] Although innovative when they were first employed, the methodology and technologies used in the production of these statistics involved very lengthy processing times and a large amount of dedicated resource to generate. Over time this meant the statistics developed an increasingly large lag between the period they related to and their publication. Restrictions on access to relevant information technology resources during the COVID-19 pandemic further disrupted production of the statistics beyond this.

2. Recognising these limitations of these statistics and methodology, the United Kingdom Department for Transport has been working to produce an alternative evidence base and has since developed the "Model of Connectivity". The model has been designed to be used for both monitoring and appraisal purposes to understand the impact of policy interventions. Both the historic Journey Times statistics series and the new Model of

[1] www.gov.uk/government/collections/journey-time-statistics.

Connectivity have a similar objective – to provide data giving an indication of ease of access to critical services.

II. Methodology for the Model of Connectivity

3. The Model of Connectivity calculates your ability to get where you want to go. It measures the opportunity to travel to various destinations, weighted by people's overall preference of how to get there. Separate connectivity scores are available for six destination types:

- Business
- Education
- Entertainment
- Shopping
- Visiting friends
- Health.

4. They are available for four modes of transport:

- Walking
- Cycling
- Public transport
- Driving.

5. The connectivity scores are based on an index of zero to 100 where 100 is assigned to the most connected Output Area. Urban areas, where there are higher densities of popular destinations, tend to have higher connectivity scores. These scores are baselined on 2022, allowing the publication of results for other years to be compared over time. Provisional outputs from the Model of Connectivity will shortly be published for 181,000 Output Areas[2] in England and Wales. Scores for Scotland and Northern Ireland are in development. Future iterations will calculate scores for every 100 square metres by 100 square metres in England and Wales.

6. This work defines connectivity as an individual's ability to reach their desired destinations. It measures the opportunity to travel to various locations, weighted by people's overall proclivity to take those options. It aims to capture as many methods of travel, destination types and people's preferences as possible. As with all metrics, it does not attempt to cover all factors relating to travel and is not designed to show how many people actually take different routes. Nor is it a transport model: there is no trip assignment or convergence processes.

7. The model calculates a connectivity score for each combination of:

- Purpose of travel
- Time of day
- Mode.

8. There are three central components:

(a) The transport network and timetables: this includes all roads, road speeds, cycle paths, walkways, pavements and bridleways, for example;

[2] Output Areas are typically made up of between 40 and 250 households and had a usually resident population between 100 and 625 persons: www.ons.gov.uk/methodology/geography/ukgeographies/censusgeographies/census2021geographies#output-areas-oas.

(b) Destinations: these are classified with a "purpose" and a "sub-purpose". Each purpose has one or more sub-purposes. For example, shopping has the sub-purposes: bank, gardening retail, petrol retail, retail generic, retail shop, royal mail infrastructure and foot retail. This breakdown helps the connectivity score to reflect utility more effectively because the formula gives diminishing returns within each sub-purpose. This means that a variety of destinations is rewarded;

(c) Data on how far people tend to travel by each mode to each destination.

9. In line with the above, input data includes road and walking networks, including information on buildings, from the United Kingdom's national mapping provider, travel patterns from our National Travel Survey, job locations and population estimates from our National Statistical Office, typical road speeds collected for separate Official Statistics published by the Department, and public transport timetables.

10. The model works in several stages for a given mode and starting Output Area. The stages are:

(a) Find the node in the transport network closest to the starting Output Area centroid. This is the "start node";

(b) Calculate travel times between the start node and every other node on the network that can be reached in an hour;

(c) Assign a value to each node in the network for each sub-purpose of travel. Values are based on the buildings close to that node. For example, a node beside a large office will have a high score for business.

11. Each node contributes to the score of an Output Area. This means having nodes with lots of nearby locations of value (e.g. lots of jobs) that are quick to get to will achieve a high connectivity score.

12. Further technical considerations include:

(a) For each Output Area, the score contributed by each node is added together and transformed using logarithms. The logarithm captures the diminishing utility of similar locations. This is done for each sub-purpose. The score for each purpose and mode of travel is the sum of scores for all sub-purposes;

(b) For the purpose of Business, an agglomeration multiplier is incorporated because in denser areas the average job is more productive;

(c) For the first year of outputs, scores are scaled to be between zero and 100. This will provide a baseline for future years: some areas may exceed 100 in the future if their connectivity goes above the most-connected Output Area in 2022;

(d) The overall connectivity for an Output Area is the weighted sum of all connectivity scores for each time of day, purpose and mode. Weights are the proportion of total trips made by each of these as recorded in the English National Travel Survey (NTS)[3] between 2011 and 2020 inclusive.

13. The United Kingdom has been able to develop and deploy the above methodology through the use of cloud computing, providing the ability to scale horizontally to enable high volumes of calculations. The majority of the methodology has been implemented in the Python programming language, with certain components using the more performant Rust language to reduce computation times. More detailed methodology documents are expected to be published on the United Kingdom Government website in Spring 2024.

III. Initial results

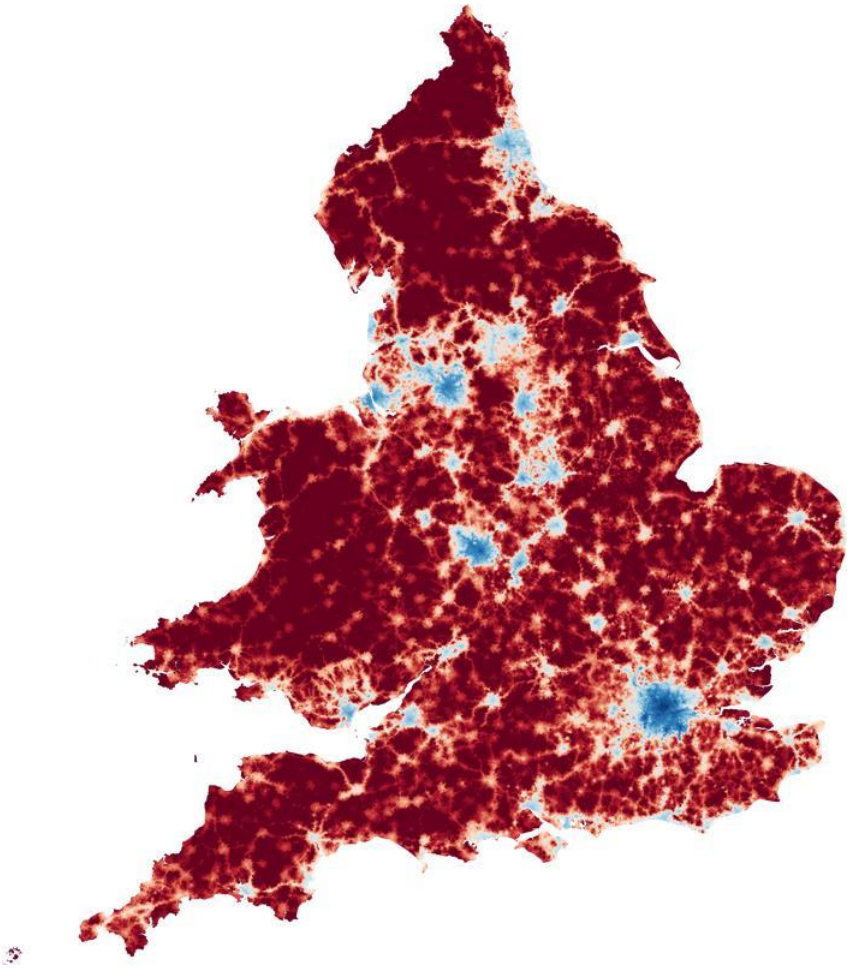
14. Having deployed the above methodology through the Model of Connectivity, the final calculation of the connectivity score itself is necessarily complex. However, at a basic level the score itself is a product of the number of destination types (and number of individual

[3] www.gov.uk/government/collections/national-travel-survey-statistics.

destinations for each of those destination types) that can be accessed within a minimum time window, usually one hour. For those destinations, the derived value of that connection is factored into the score based upon factors such as the expected usage of individual destination types reached, based upon real travel behaviours. Value also considers factors relating to the "size" of that destination, for example in the case of business destinations this would be the number of estimated jobs that are accessible. For any geographic location that falls within the scope of the analysis, scores for the different journey purposes and modes of travel considered can be combined to give an overall connectivity score for that location.

15. At the time of writing, a full set of results from the United Kingdom Model of Connectivity have yet to be published. However, initial results provide the visualisation shown in figure 1 of the spread of transport connectivity scores across England and Wales. Areas with high connectivity scores are marked in blue, while areas with low scores are indicated in red.

Figure I
Connectivity scores across England and Wales



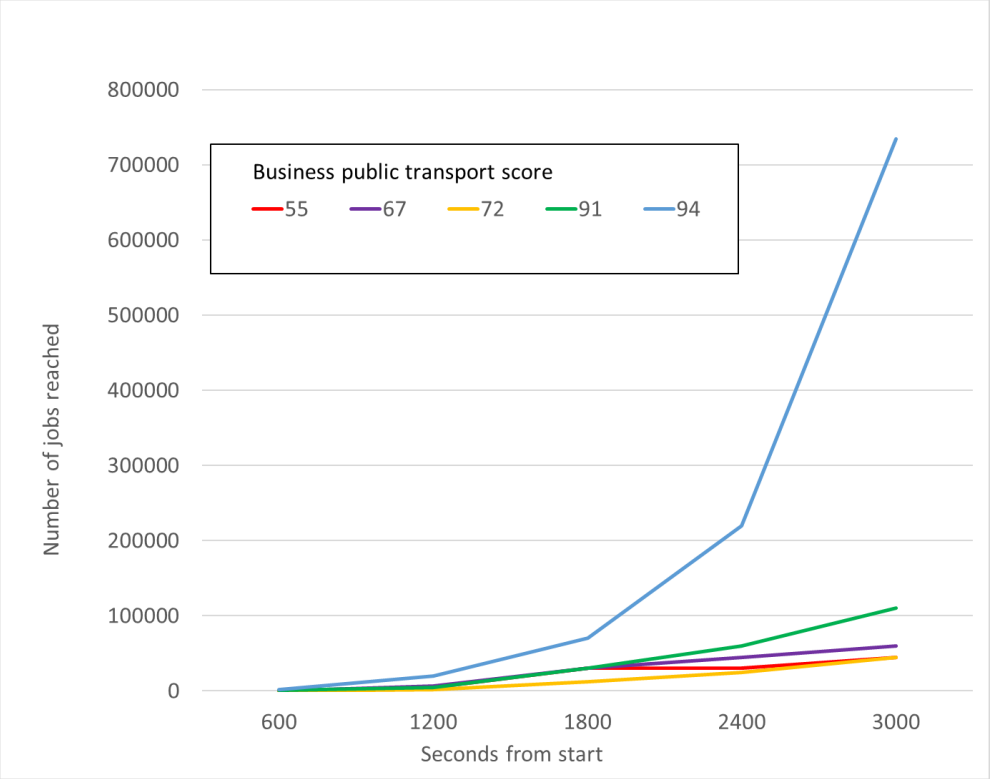
Source: United Kingdom Department for Transport (2024).

16. At a basic level, the results from the model are logical – in a United Kingdom context the locations shown in blue are the major conurbations, with London, Birmingham and Greater Manchester being particularly visibly seen to have high scores. Locations along major rail lines and motorway connections also score well.

17. Results for specific local areas will vary. To give an example of this, looking specifically at Business connectivity via public transport, the number of jobs reachable within certain travel times is shown in figure 2 for a small selection of Output Areas. An Output Area with a score of 94 is included, for which just over 700,000 jobs can be reached in 50 minutes or less, and 18,000 jobs can be reached in 20 minutes or less. For this Output Area, most of the score is being contributed by destinations further away, as there are so

many of them. This Output Area shown as the blue line. The red line shows an Output Area with a score of 55, where 4,000 jobs can be reached in 20 minutes, and 38,000 in 50 minutes.

Figure II
Relationship between travel time and number of jobs reached, for selected geographical locations



Source: United Kingdom Department for Transport.

IV. Discussion and concluding remarks

18. Through the development of this connectivity analysis, policy makers in the United Kingdom have new methods by which they can assess the relative performance of transport infrastructure in terms of its ability to enable the population to reach key destinations. It is expected to become a key measure of whether government infrastructure projects are successfully enhancing transport, and in turn growing the economy and improving passenger journeys.

19. The method itself is in its first iteration and is expected to evolve over the coming years. For example, the team are particularly considering how to best balance within the score, both the ability to reach a set number of destinations (typically in an hour) and the likelihood of the population wanting to make that journey. For example, if a business destination grows to encompass increased job availability, should that improve the score? If yes, is there an upper limit on how far that should grow, or should that score perhaps increase in a non-linear way?

20. This document aims to initiate a discussion within the Working Party regarding the usefulness of connectivity-type analysis to its work. Countries are invited to share their experiences with similar methods, whether in collaboration with private sector service providers or independently. With support, the Working Party may consider developing a standardized framework for collecting and analyzing data of this type.