# Unravelling hyperlocal public transport connectivity from strategic assignment models

Howard Wong*[1,2], Kiran Balendra[1], Ela Lewicka[1], Clare Norris[1]

[1] Transport for London, United Kingdom

[2] Centre for Advanced Spatial Analysis, UCL, United Kingdom

## SHORT SUMMARY

Public transport (PT) complements walking and cycling to help cities reaching for sustainability. However, strategic PT models often lack the spatial granularity to reveal the local-level connectivity to support proximity-based planning. This study proposes a method that enhances the strategic model travel times by attaching them to a hyperlocal spatial unit using the street network and network analysis. With London as the case study, we have refined the granularity of the travel time results between 4,400 modelling zones to between 160,000 hyperlocal spatial units. We then applied the detailed travel times to reveal the hyperlocal connectivity from each spatial unit to measure the access to schools and time taken to reach a fixed number of schools. This framework can be flexibly adapted for strategic models of other cities and to test the future transport and urban scenarios.

Keywords: Connectivity, hyperlocal, proximity-based planning, public transport, strategic modelling

## INTRODUCTION

The notion of a 15-minute city (Moreno et al., 2021) is to encourage the development of a liveable urban space where most day-to-day amenities are in proximity and reachable by sustainable transport modes. PT plays an important role by providing the connectivity to extend people's reach and for people who cannot walk or cycle too far (Poorthuis & Zook, 2023). To assess the efficacy of the PT network, transport planners use strategic models to quantify the network usage and travel times. However, these strategic models lack the spatial granularity to support proximity-based planning like a 15-minute city.

Strategic PT assignment models abstract the real-life spatial, temporal and operational details to speed up the modelling process (Tavassoli et al., 2020). A city is split into modelling zones that the model can be calibrated using population-based surveys. The zones are homogenised so that the occupants and their activities within each zone are expected to have the same geodemographic attributes. Therein lies the problem of variable zone sizes. Firstly, zones covering less-populated areas will be bigger than those of more densely populated areas. Secondly, it is difficult to assess the connectivity in short durations when the modelled travel times are influenced strongly by zone sizes and the locations of the zone centroids. Strategic models by themselves thereby do not have the spatial granularity to support the assessment of the local-level connectivity. Yet, they are fast to run and easy to modify, useful for testing scheme appraisals and future planning.

The objective of this study is to derive a method that enhances the travel time output of a strategic PT assignment model with further spatial details to assess the hyperlocal connectivity across a city.

The proposed method uses network analysis techniques by creating a network that connects the PT travel times derived from a strategic model, the walking network and a hyperlocal spatial unit. The network is then used to calculate the travel times among the units. To demonstrate the methodology, our case study investigates the connectivity of primary, secondary and tertiary schools in London using 100m x 100m units, PT travel times from the Railplan strategic model and the OpenStreetMap (OSM) walk network. We calculate the travel times for all unit-unit OD. The result is a hyperlocal understanding of the school connectivity using the primal and dual access (Cui & Levinson, 2020).

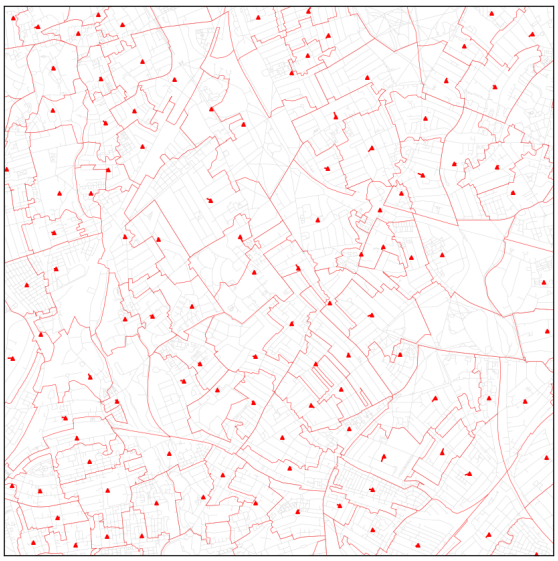
Our contribution is a replicable methodology that enhances the spatial granularity of the travel times from strategic-level PT models to support the hyperlocal connectivity assessment. The method can be

used by transport and urban planners to appraise the PT intervention schemes as well as the placement and distribution of amenities. Granular connectivity data is also a crucial component for accessibility studies that further consider geodemographic and socioeconomic attributes.

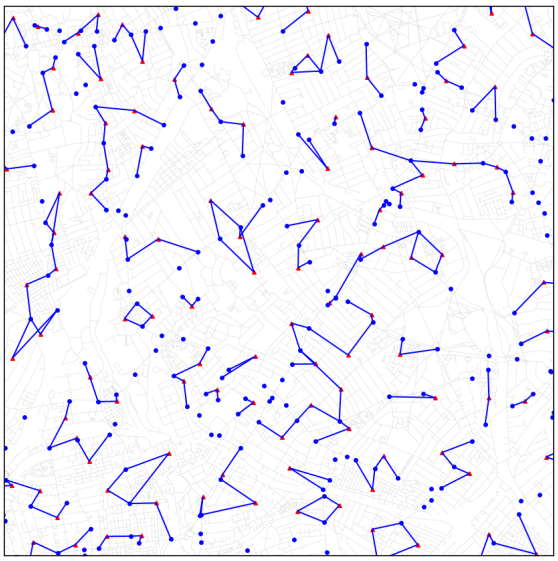
## METHODOLOGY

Our proposed methodology harnesses the agility of the strategic transport model and enhance its spatial granularity. A key feature of strategic assignment models is speed and flexibility to simulate many service and demand scenarios. Strategic models divide their coverage area into contiguous modelling zones to reduce the spatial complexity assuming that the occupants and their activities within each zone to have the homogenous geodemographic and behavioural attributes. Each modelling zone has a point where journeys start and end—a Modelling Zone Centroid (MZC). PT services are modelled by PT Service Access Points (SAP) connected by links that represent the service stopping and timing patterns in the schedule. A SAP can represent one or more bus stops or a rail station entrance. The MZC and the SAP of the PT network are connected to the model's walking network to allow flows to move across MZC and SAP and henceforth across the whole model. Figure 1 shows how the modelling zones, MZC and SAP may be laid out and connected. The assignment model is fast at calculating the travel times across the network from the origin MZC to the destination MZC. Each OD has an MZC-MZC travel time.

The model area can be divided into polygons with associated centroids, Transport Analysis Zones (TAZ). To assess local-level accessibility, TAZs should be smaller in size than the modelling zones and have a consistent size to minimise the effect of zone sizing on travel times. Various spatial units have been used in the literature for accessibility studies, including Census output areas (Verduzco Torres & McArthur, 2024) and regular hexagons (Vale & Lopes, 2023).

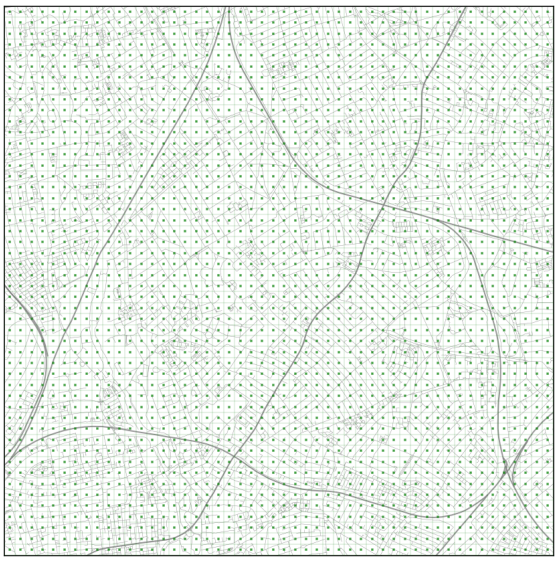


Modelling zones (polygons) and their MZC (triangles) are connected to the street network using centroid connectors (short red lines)

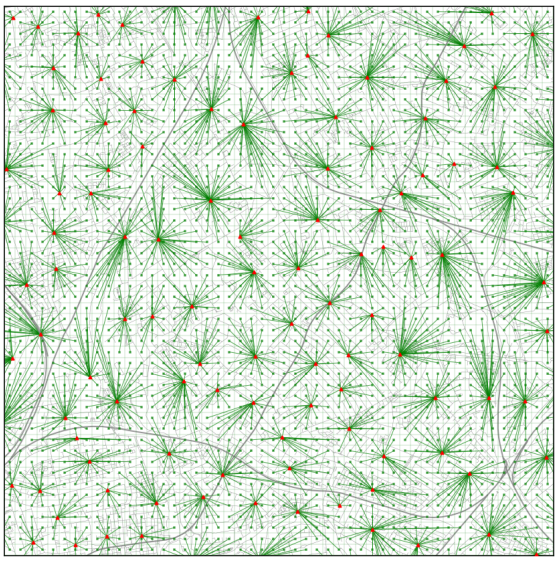


Flows from MZC (red triangles) joins the PT services at SAP (blue dots). The nearest 2 SAP for each MZC are shown here connected (blue lines).

**Figure 1 How the modelling zones in a strategic model, their centroids and the PT SAP are laid out and connected spatially.**



Here is a separate layer of hyperlocal TAZ polygons (green polygons) and their centroids (green squares) tessellated the whole city.



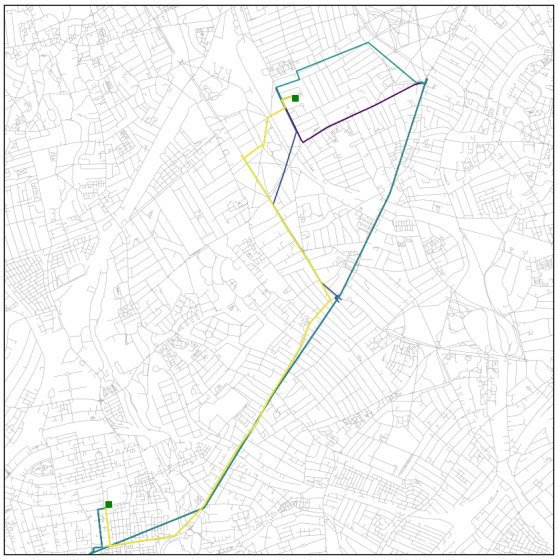
Merging the layers together, we can link each TAZ to nearby MZC by walking distance (TAZ-MSC). The nearest MZC are connected by green lines here.

**Figure 2 Hyperlocal TAZ layer can be linked to the MZC using the shared walking network.**

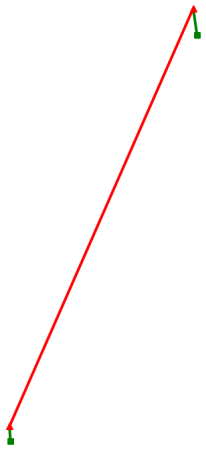
We then build a travel-time weighted network based on the MZC, SAP, the walking network, the MZC-MZC PT travel times from the strategic model and then cojoining the TAZ to its walking network (Figure 2). This model can now route from any TAZ to any other TAZ.

With a potentially much larger number of TAZ-TAZ OD pairs, we carry out further abstraction to our model. First, each MZC-MZC OD is represented by a single edge using the PT travel time from the strategic model as the edge weight. Second, the access walk time from each TAZ to nearby MZC are pre-calculated using the street network and represented as TAZ-MZC edges. Third, we specify that each TAZ-TAZ PT movement can only travel through one origin TAZ-MZC edge, one MZC-MZC edge and one destination TAZ-MZC edge (see Figure 3). Travel time calculation for all TAZ-TAZ OD can now be done using general path finding algorithms like Dijkstra's.

The resultant travel times can be sensitive to the TAZ-MZC walk access times. A challenge in this network set up is that there may be "double-walking" as MZC-MZC from the strategic model has already included some walking time from origin MZC to origin SAP and likewise at the destination end. To overcome this, we have created an offset for each TAZ-MZC by estimating the walking time from MZC to the nearby SAP. The average MZC-SAP walking times are removed from the associated TAZ-MZC as an offset (see Figure 4).



OpenTripPlanner returns five possible itineraries from origin TAZ at the bottom to destination TAZ at the top.



The TAZ-TAZ movement can be represented in a more abstracted form in the walk and PT network with TAZ-MZC (green lines) and MZC-MZC (red line).

**Figure 3 Travel route options between two TAZ can be abstracted to three straight edges with travel times as weights**

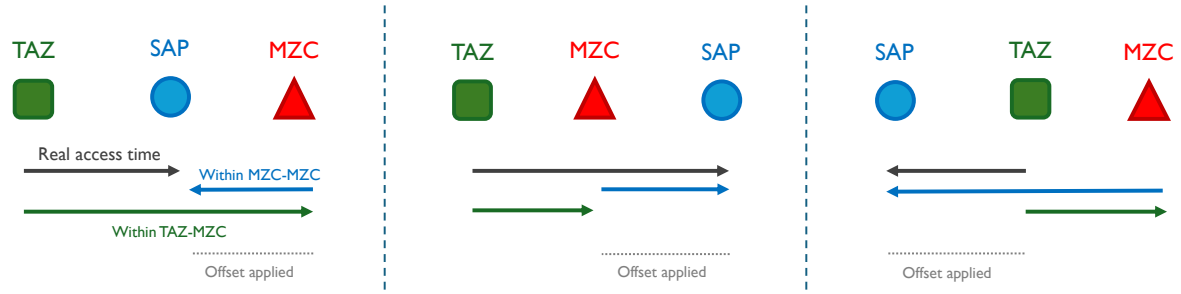



**Figure 4 The three scenarios that require PT access time offset**

## CASE STUDY

We have applied this methodology to quantify the connectivity of schools in London as a case study. Railplan is the strategic PT assignment model for London (https://tfl.gov.uk/corporate/publications-and-reports/strategic-transport-and-land-use-models). This case study uses the service schedule of 2023 AM and the PT travel times are calculated using headway-based assignment. We use the grid of 100m squares previously used for PTAL (https://gis-tfl.opendata.arcgis.com/datasets/0646faf45243463aa04ca685e598f471) as the hyperlocal TAZ. The street network and the locations of the schools (nursery, primary, secondary and tertiary) are extracted from OpenStreetMap.

Inside the Greater London boundary, Railplan has 4,409 MZC and 15,030 SAP. There are also 159,451 100m squares as TAZ and 2,828 of which have at least a school in them. Among these, there are 26bn possible TAZ-TAZ OD, 22m MZC-MZC OD of which 5m of them have travel time within 60 minutes. Each TAZ is connected to the nearest 5 MZC within 4km for possible route options. The TAZ-MZC are adjusted for the "double-walking" using the offsets derived from the walking times from each MZC to the nearby 5 SAP. This has generated 3.7bn valid TAZ-TAZ OD with less than 60 minutes of PT travel times.

We have validated the calculated TAZ-TAZ journey times by comparing 3,541 OD against OpenTripPlanner (OTP) using the same street network and the PT schedule derived from a GTFS feed of the same period. The r-squared value is 0.58. The red line on the graph in Figure 5 indicates the parity and the blue line is the fitted line using the proposed method. It suggests that OTP is faster for shorter journeys and the proposed method is faster for journeys that take longer time. Journey times from both methods are estimated using very similar inputs but different methodologies.

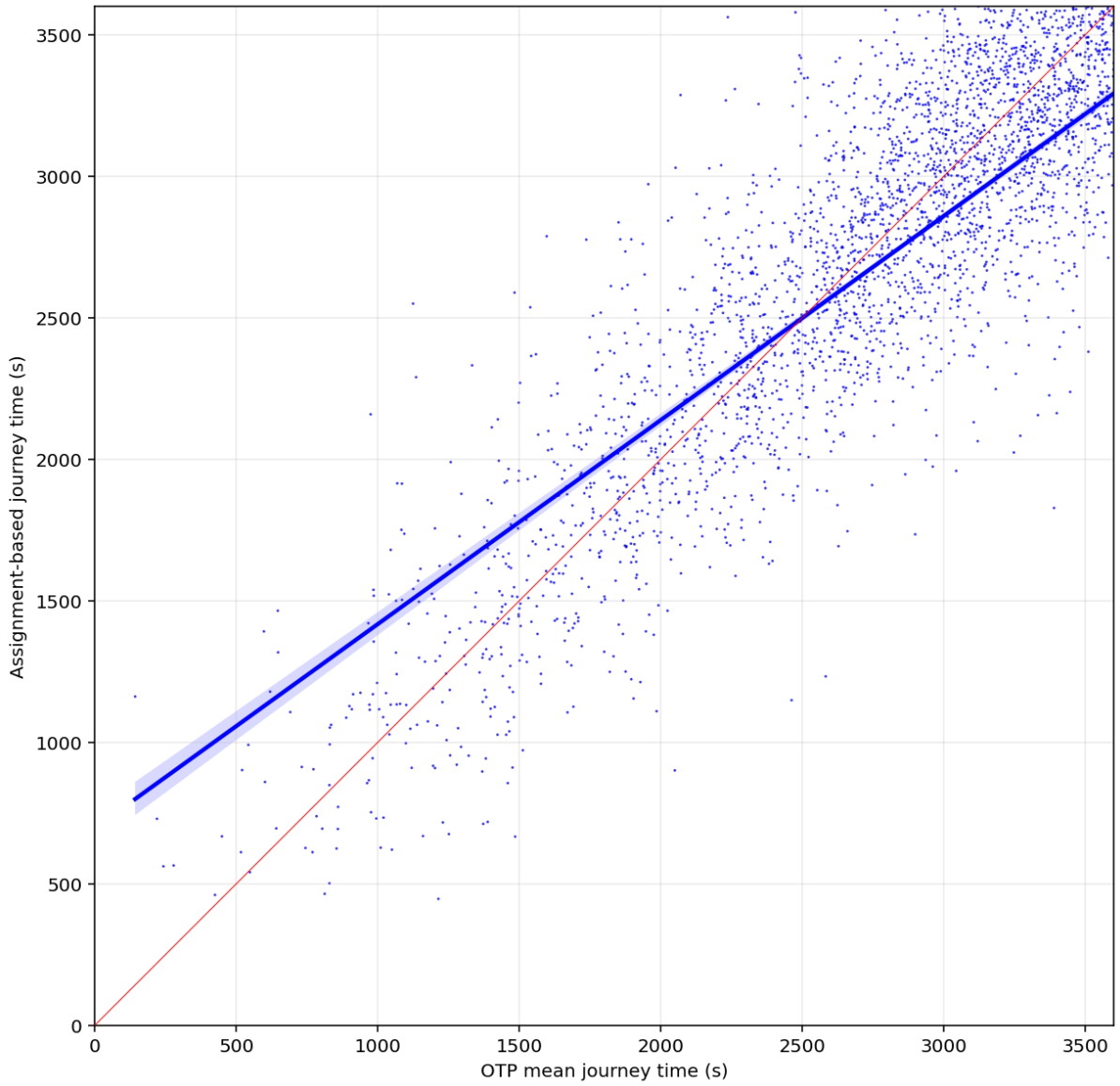



**Figure 5 comparison between the assignment-based and OTP journey times for selected TAZ-TAZ OD in London**

## RESULTS AND DISCUSSIONS

To demonstrate the value of the hyperlocal details available from this method, we use it to compare the PT access to schools in London. We want to answer three questions from this dataset:

- How many schools can each TAZ reach within 15 minutes using PT? (primal access)
- How long does each TAZ take to reach at least 2 schools using PT? (dual access)
- Are there any populated TAZ that cannot reach a school within 15 minutes of walk or PT?

Figure 6 below shows the number of schools reachable within 15 minutes by PT. Darker colours indicate more school can be reached with the number of schools accessed capped at 30. The granular spatial details available using the hyperlocal units can clearly reveal the rivers and open space in London that no schools or population are expected. Whilst the locations of the schools (blue dots) are distributed evenly across the city, the PT network intensifies the connectivity in central and inner London and stretches out along some main corridors in the north and south. Buses also provide a vital role in extending the local connectivity that is visible in outer west London. Figure 7 zooms into an inner-city neighbourhood (Tooting, indicated by the black square in Figure 6). The hyperlocal granularity is more revealing on the severance created by railway lines to the walk network and the connectivity at a neighbourhood level.

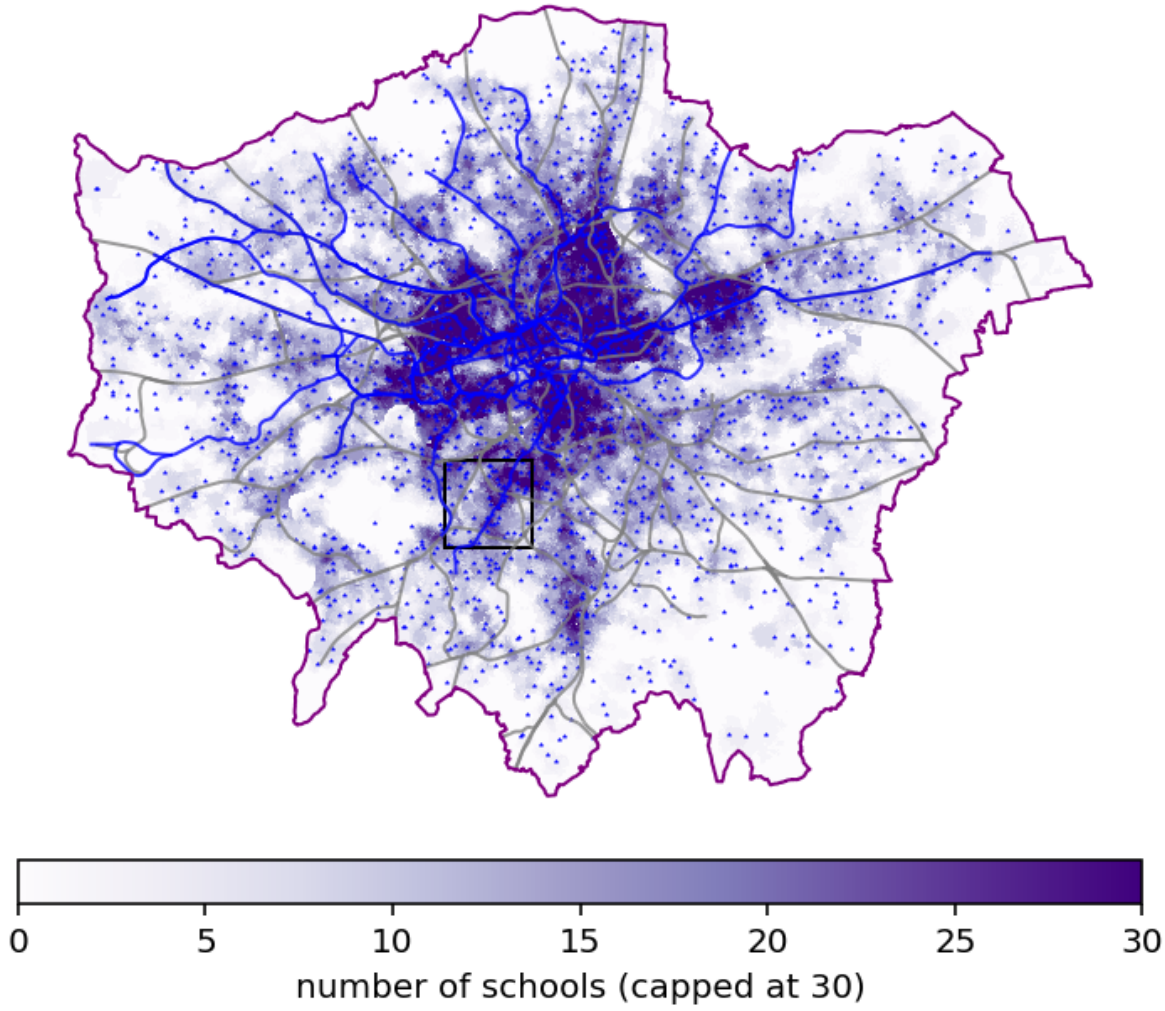



**Figure 6 The number of schools reachable within 15 minutes from each TAZ, the shading shows the number of schools reachable and the blue dots are TAZ with schools**

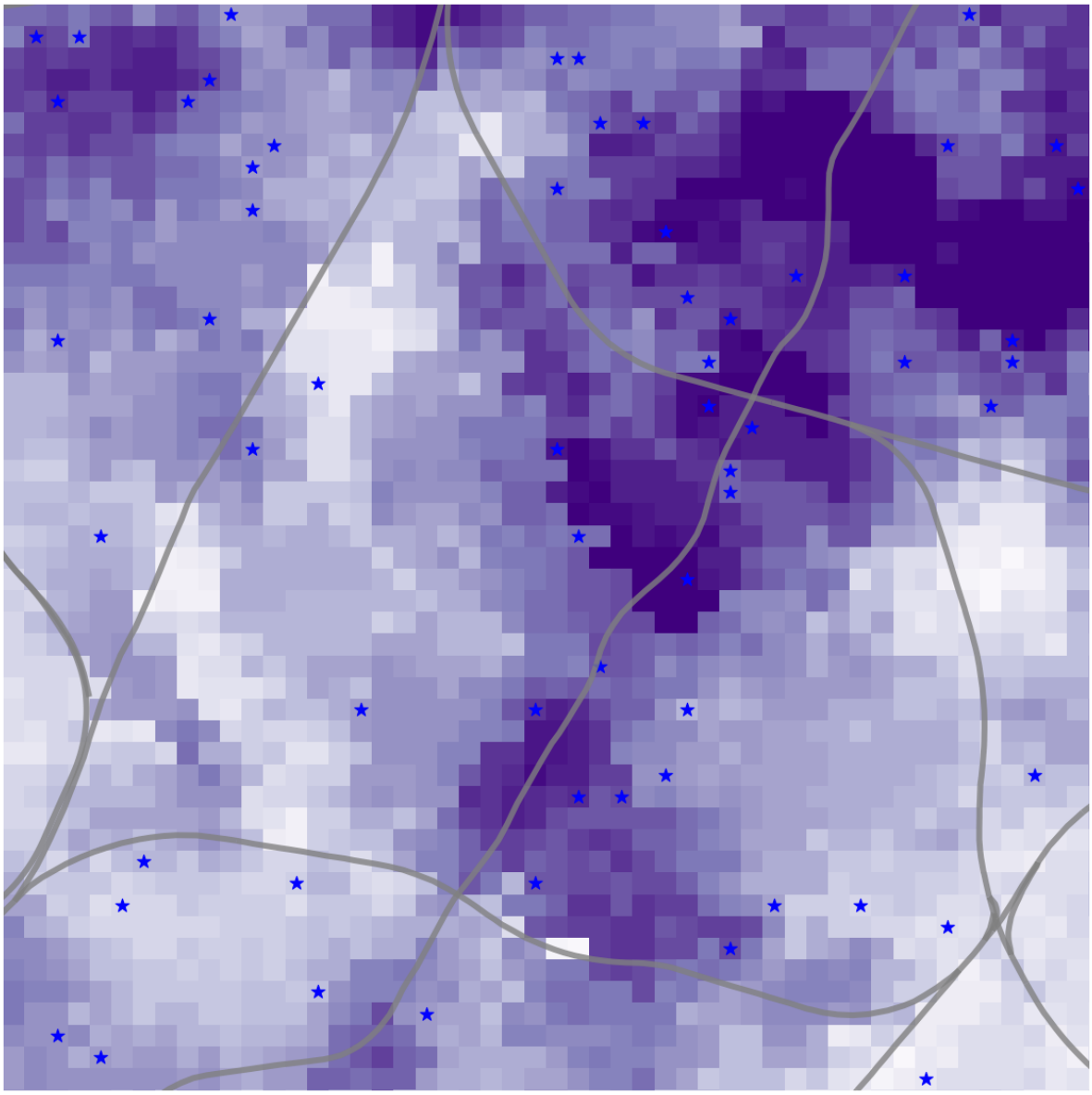


**Figure 7 a zoomed in area of south London highlighted in figure 6, demonstrating the hyperlocal graduation and severance of the school connectivity**

Figure 8 shows the time it takes from each TAZ to reach at least two schools using PT. The connectivity to schools is not a problem for most of central and inner London (red to orange colour). The TAZ in blue take a longer time to reach at least two schools, these are areas with lower population density and lower PT service provision. The high spatial detail enables us to highlight the value of the walking network and the coverage of the local PT to the connectivity of a broad range of schools.

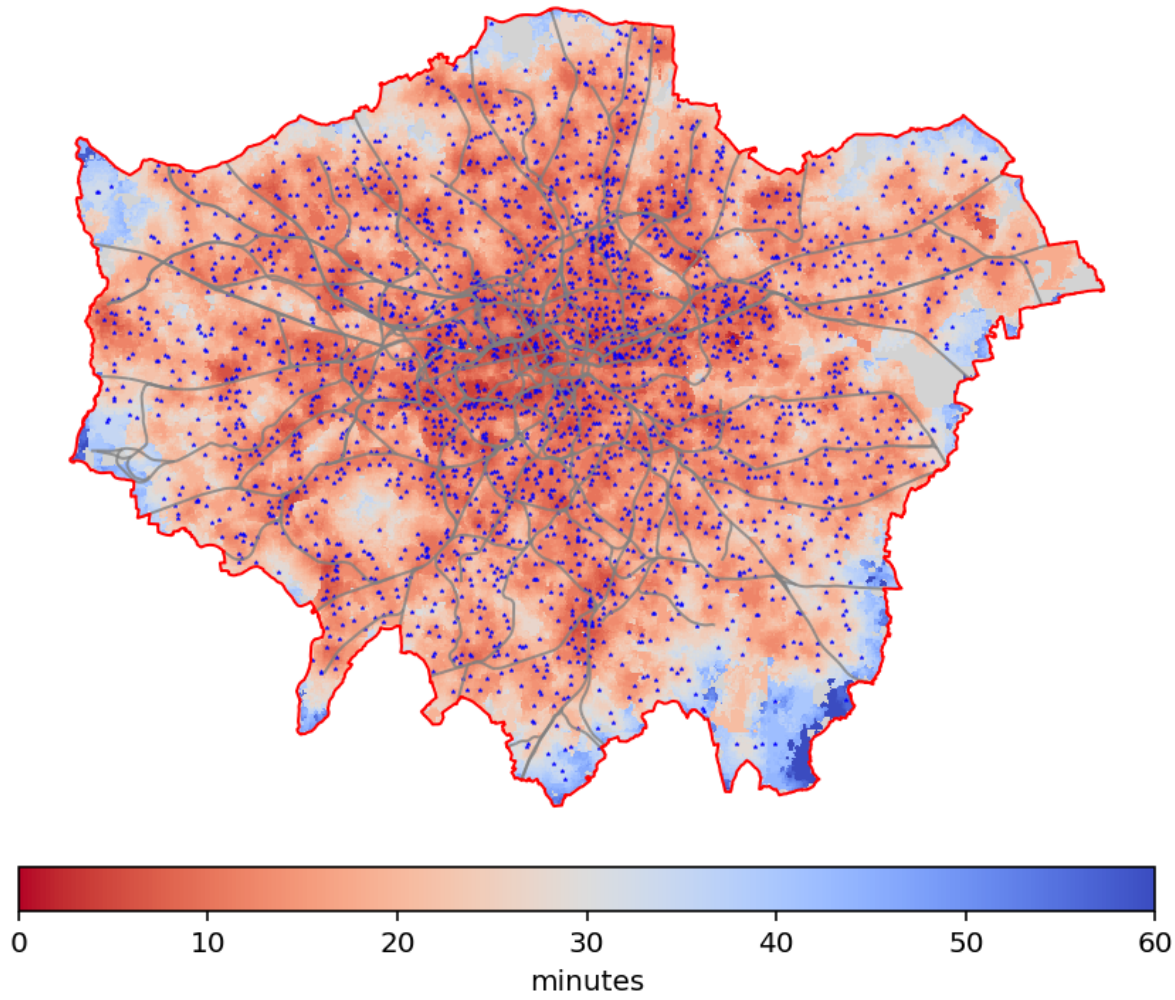



**Figure 8 Amount of time required to reach two schools from each TAZ, the grey lines are the metro and railway lines**

Lastly we want to identify any populated area that takes more than 15 minutes by walk or PT to any school. Figure 9 shows the TAZ with no residents (in grey), populated TAZ that can reach at least one school by PT (light blue) or not by PT but walkable (middle blue), and not reachable by PT or walk within 15 minutes (red). There are 2,088 TAZ in red amongst the 76,873 populated TAZ. Central and inner London have higher population density and a dense PT network and thus most TAZ can reach a school within 15 minutes. At the outer edge of London, particularly at the south end of Croydon (centre bottom of the map), Bromley (bottom right) and Havering (upper middle right) have pockets of TAZ that are further from schools.

Similar connectivity analyses use Census output area (OA) as the spatial unit. OA is the smallest unit available that can be used in conjunction with demographic information. However, by definition, all OA have population. By using more granular 100m squares, we can pinpoint small populated areas with poorer connectivity.

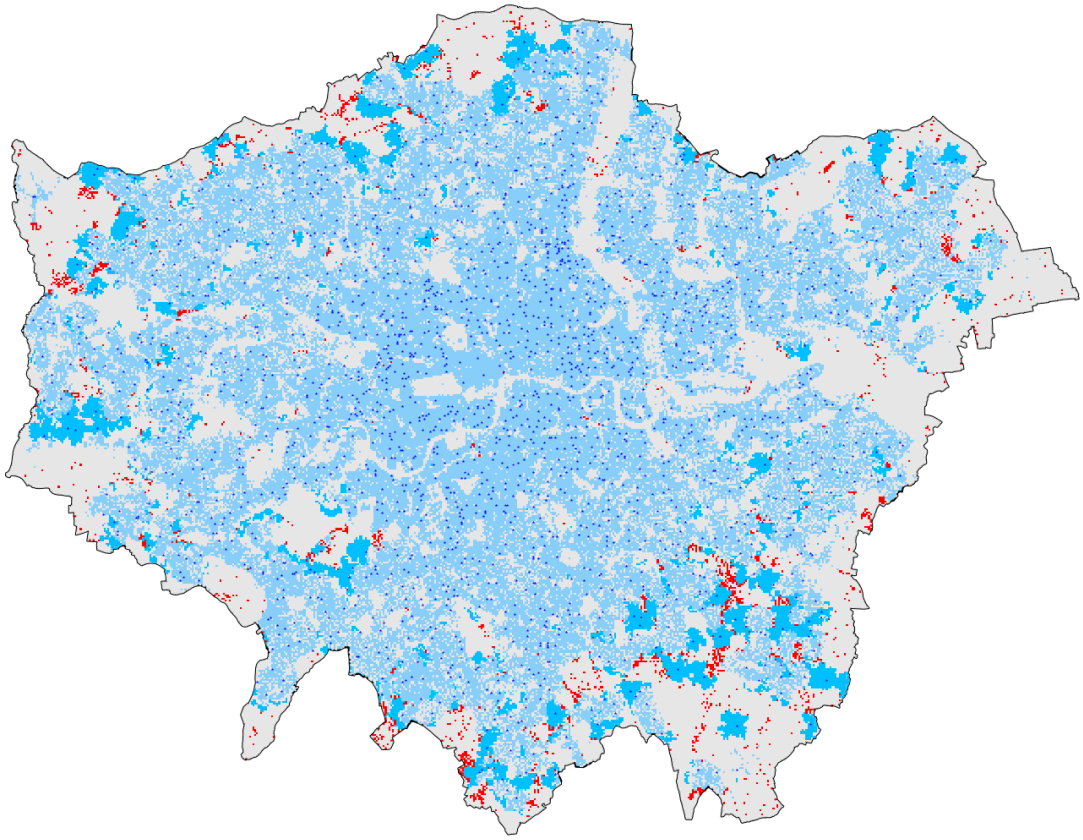


**Figure 9 TAZ that can reach at least one school by walk (in middle blue) or PT within 15 minutes (light blue) or not all (red), schools are in dark blue dots**

The proposed methodology can be further improved. The OSM street network may not include all permissive or informal walking paths (eg through a park) and may overestimate the PT access time.

The abstracted representation of the PT network to the 4,409 MZC may also result in overestimating the PT access times. More MZC in the strategic model may improve the accuracy of the access time and rely less on the offset process for the correction. One alternative is to use SAP instead of MZC. SAP are placed closer to the actual service stops and thus require fewer offsets. However, replacing 4,409 MZC with 15,030 SAP will yield a more complex strategic model and a much more complex hyperlocal model. Therefore it may diminish the replicability by disrupting and duplicating the existing strategic modelling workflow.

Another challenge is to improve the offset process to better represent the actual access distance from each TAZ to the PT service point. The current offset method is a relatively straightforward process that can be applied in most cases. But it cannot handle negative offsets, for instance when TAZ-MZC is shorter than MZC-SAP. Using SAP instead of MZC will reduce the impact of these cases.

Measuring the current connectivity to schools is only one of the many applications for such hyperlocal datasets. The use of the strategic model as the foundation for the PT travel time is to facilitate the testing of many future network supply scenarios. The hyperlocal details from this connectivity measure method enable transport planners to highlight and quantify the small-scale but local impact of transport interventions. Urban planners can use this to complement the environmental impact assessments, amenity and job distribution studies, accessibility and geodemographic analysis. As (Tavassoli et al., 2020) points out, many cities have their own version of a strategic model, our proposed approach to extend the spatial granularity of the result should be replicated elsewhere.

## CONCLUSIONS

To support the urban PT connectivity and accessibility analysis at hyperlocal scale, we have proposed a method that utilises the PT travel times from existing strategic assignment models and enhances their spatial granularity further using network analysis. The method amalgamates the spatial and time details from the assignment model, the walking network and a hyperlocal spatial unit (TAZ) into a single abstract network graph that can estimate the travel time of all TAZ-TAZ OD pairs. We have applied the method in London with 159,451 TAZ and in total 3.7 billion TAZ-TAZ OD pairs that can be completed within 60 minutes with PT. The travel times are used to assess the connectivity to schools using both primal and dual access and highlighting areas that cannot access to any schools within 15-minute of PT or walking. Beyond assessing connectivity to specific services, the framework can be used by urban and transport planners as a foundation for further accessibility analysis by incorporating demographic information and for testing accessibility against future transport and demand scenarios.

## REFERENCES


Cui, M., & Levinson, D. (2020). Primal and Dual Access. *Geographical Analysis*, *52*(3), 452–474. https://doi.org/10.1111/gean.12220

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. *Smart Cities*, *4*(1), 93–111. https://doi.org/10.3390/smartcities4010006

Poorthuis, A., & Zook, M. (2023). Moving the 15-minute city beyond the urban core: The role of accessibility and public transport in the Netherlands. *Journal of Transport Geography*, *110*, 103629. https://doi.org/10.1016/j.jtrangeo.2023.103629

Tavassoli, A., Mesbah, M., & Hickman, M. (2020). Calibrating a transit assignment model using smart card data in a large-scale multi-modal transit network. *Transportation*, *47*(5), 2133–2156. https://doi.org/10.1007/s11116-019-10004-y

Vale, D., & Lopes, A. S. (2023). Accessibility inequality across Europe: A comparison of 15-minute pedestrian accessibility in cities with 100,000 or more inhabitants. *Npj Urban Sustainability*, *3*(1), 55. https://doi.org/10.1038/s42949-023-00133-w

Verduzco Torres, J. R., & McArthur, D. P. (2024). Public transport accessibility indicators to urban and regional services in Great Britain. *Scientific Data*, *11*(1), 53. https://doi.org/10.1038/s41597-023-02890-w