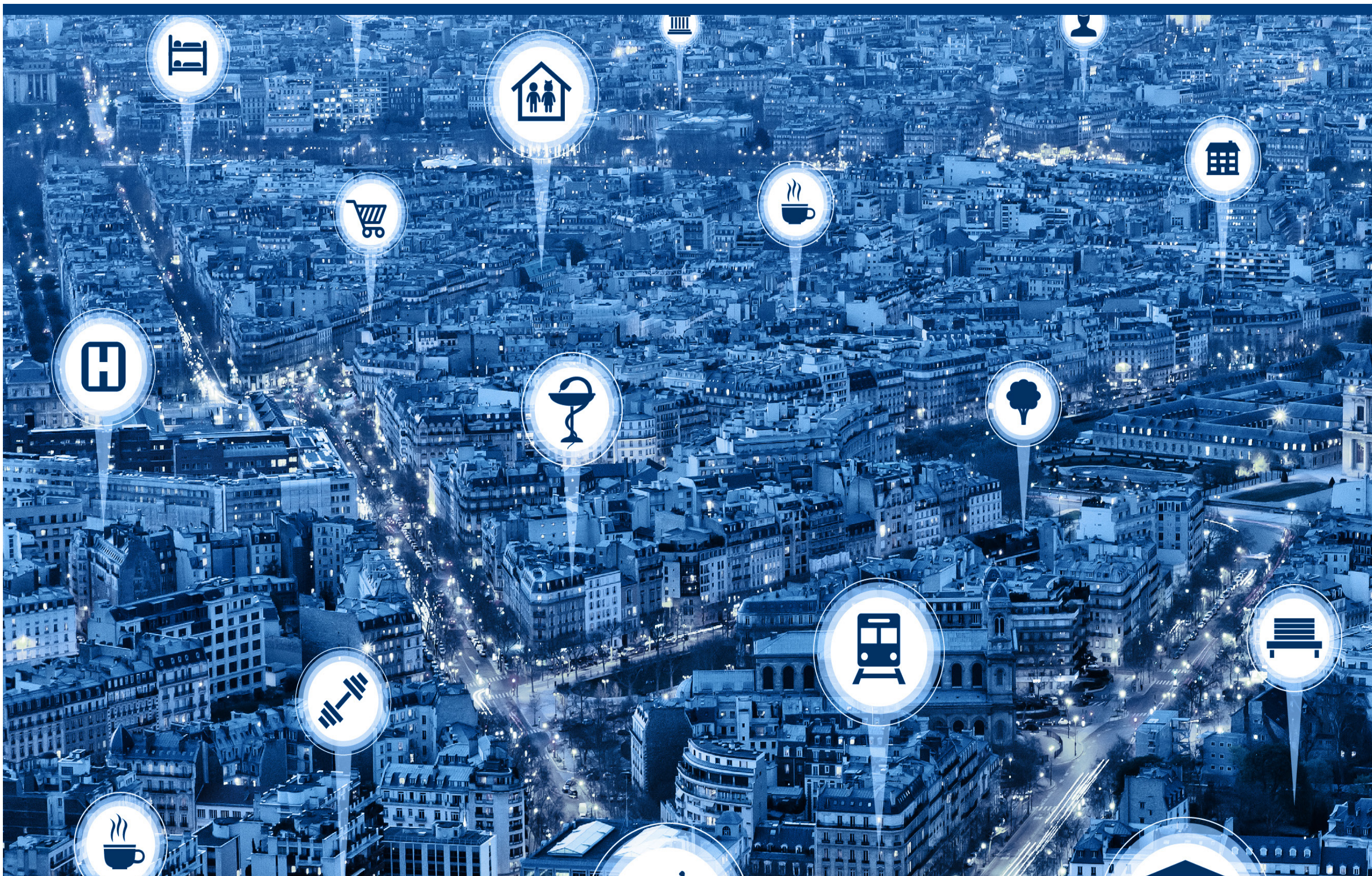

London's Accessibility Indicators: Strengths, Weaknesses, Challenges

Discussion Paper

Aliasgar Inayathusein

Transport Appraisal and Modelling, Transport for London

Simon Cooper

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International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

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Table of contents

Introduction

This paper provides an overview of Transport for London's (TfL) suite of connectivity tools and methodologies. Connectivity is the term used within Transport for London to describe measures which may in other places be referred to as accessibility indicators. Collectively these indicators describe the extent to which users are able to access the transport system and travel freely between locations to access jobs and services. They measure the level of connectivity which the transport system provides for citizens.

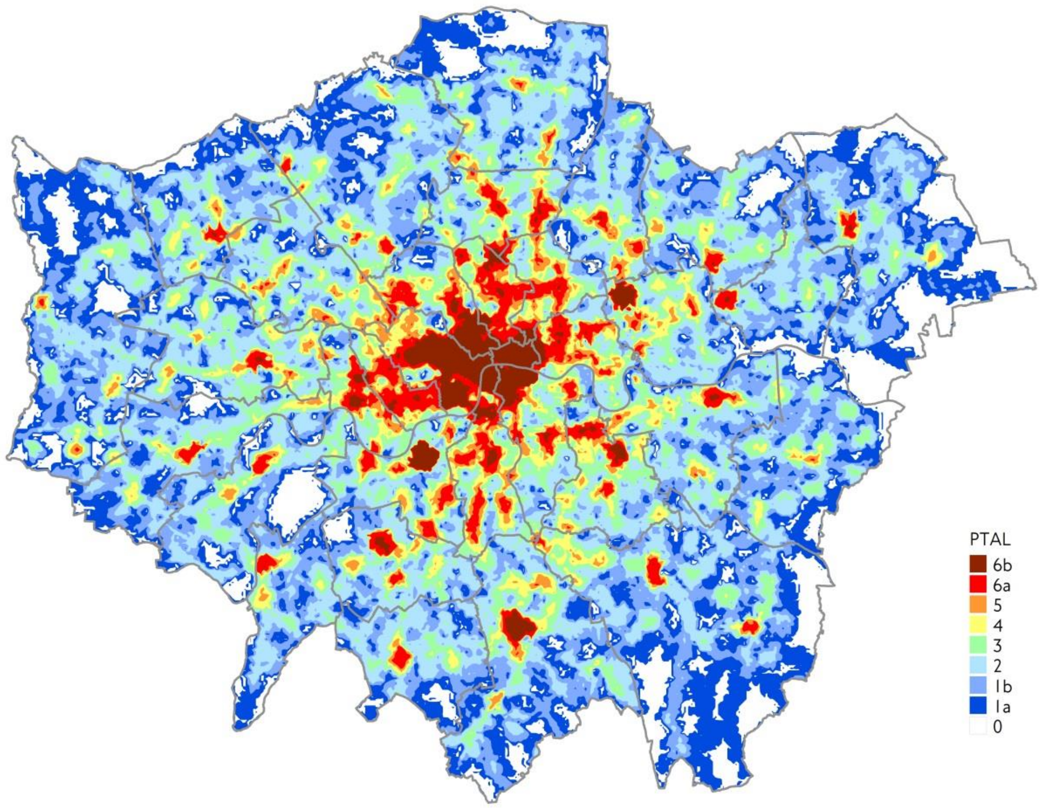
The first section of this discussion paper presents background material explaining London's current and future challenges that highlight the importance of connectivity analysis. The next section provides an overview of each of the existing connectivity tools explaining the purpose of each tool, calculation methodology, strengths, limitations and example use cases. This is followed by a section that discusses new measures currently under development. The final section offers discussion through a series of questions around unresolved challenges and areas for improvement.

London is a dynamic and dense city which has the challenge of accommodating a population of 8.7 million people and 26.7 million daily trips. This is expected to grow further by 2041 with an estimated population of 10.5 million and 32 million trips[1] being made.

London is around 1 600 km^2 in size with a dense public transport system serving much of the city. Inner and Central areas are well served by radial rail links, high frequency bus services as well as a significant and increasing amount of high quality cycling infrastructure. The Central area and some parts of Inner London are served by a cycle hire scheme. The public transport offer is more limited in Outer London but still caters well for radial travel in to the centre through rail links and travel to and around town centres via bus services. The Public Transport Accessibility Level map below highlights the differing public transport provision throughout London with those at level 6b having the highest level of access to public transport service and those at level 0 having the lowest.

The new Mayor's Transport Strategy[2] (MTS) currently published in draft, puts at its core reducing the need to use cars in order to promote healthier and more sustainable travel choices. The key aim is to change the way people travel so that by 2041, 80% of all Londoners' trips will be made on foot, by cycle or by public transport. This would be an increase of 16 percentage points from today's 64% share and in trip terms, an increase of trips made by sustainable modes of around 50%. This ambitious target will be met through promoting a "healthy streets" approach to policy making whereby health outcomes will be prioritised in planning London's transport system. Further, the MTS looks to prioritise provision of a good public transport experience whilst creating new homes and jobs.

Figure 1. Greater London Public Transport Access Level Map



It is worth noting that London has also achieved many successes in the past few decades when it comes to sustainable travel. The mode share comparison chart given below in Figure 2 shows how London went from having the lowest public transport mode share of the selected major European cities in 1995 to having the highest in 2012. The subsequent chart in Figure 3 highlights the principle reason for this change: a strong and consistent growth in the use of all public transport modes in the last 15 years in excess of population growth and a steady fall in car driver trips over the same period.

This shift has been achieved through a consistent effort made across all areas to promote sustainable transport. Initiatives have included significant upgrades to bus, rail and London underground capacity, introduction of road user charges with the Central London congestion charging zone and more recently an ultra-low emissions zone (ULEZ) charge, as well as over GBP 1 bn investment in cycling. Alongside infrastructure investment, TfL champions sustainable planning policies for development in London and works with businesses and schools to offer travel planning services promoting sustainable travel options.

Figure 2. Public transport mode share across selected European cities

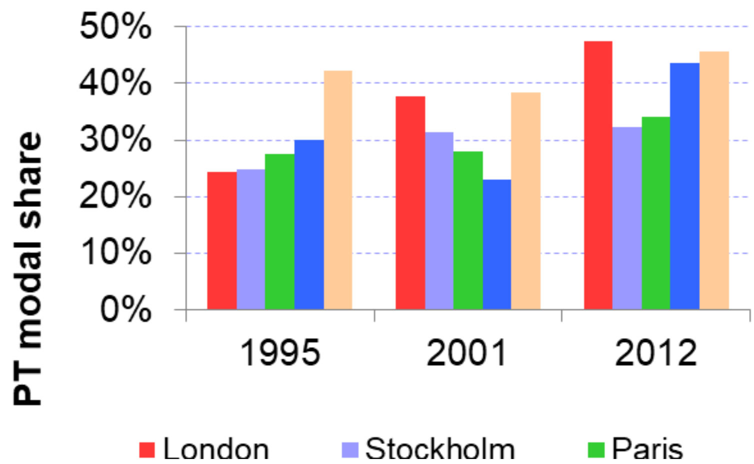
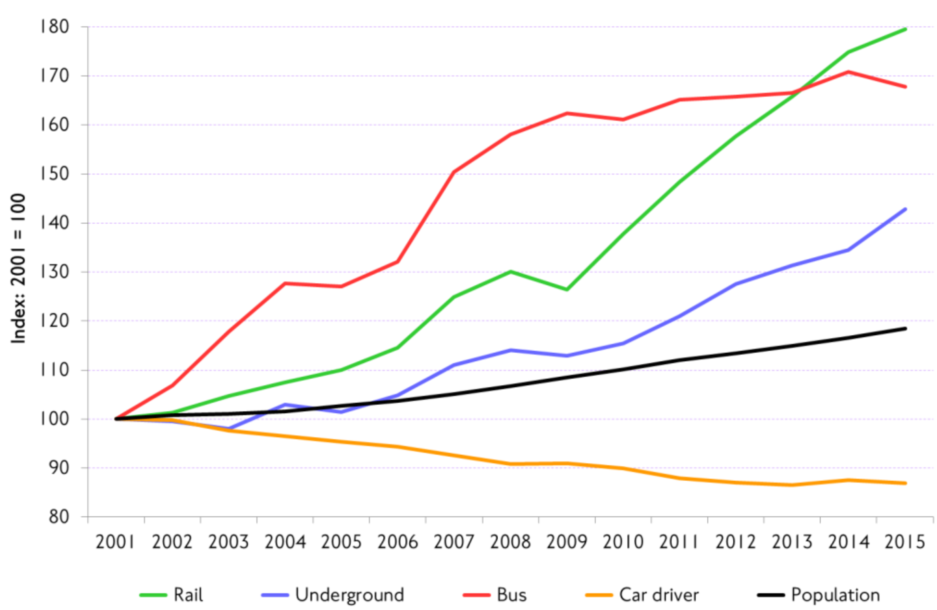


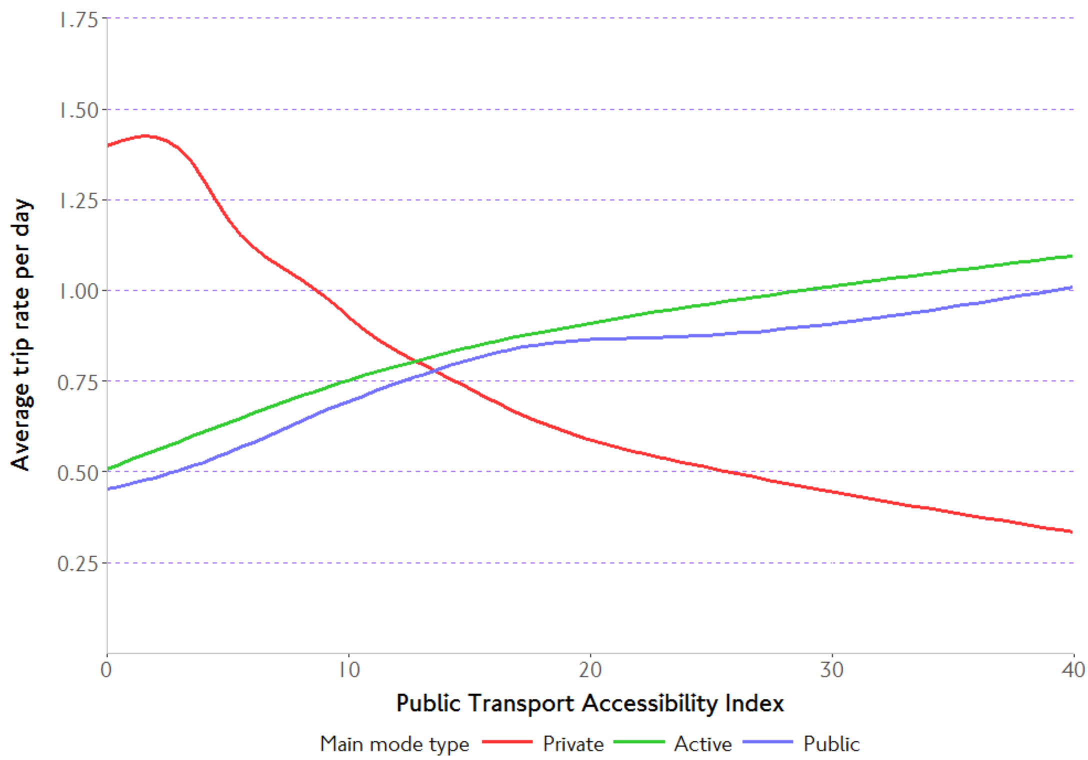
Figure 3. Growth in journey stages on selected modes, 2001-15



In order to plan the transport network as well as commercial and residential development in London, connectivity analysis is key. This type of analysis, and the focus of this paper, enables TfL to understand where and to what extent sustainable transport options are available throughout London in accessing jobs and other amenities. This is important as the availability of public transport alternatives is obviously a clear driver of public transport mode share. Increased public transport use also correlates to higher use of active modes (walking and cycling) as these are often used as access and egress modes. This is shown in the chart below which shows the relationship between public transport access levels and active mode shares.

Overall, connectivity analysis plays an important role in informing London's approach to planning development and providing new infrastructure. The rest of this paper will explore this theme in greater detail.

Figure 4. Average trip rates in London by Public Transport Access Index



Existing connectivity measures

This section explains the connectivity measures and indicators that TfL has developed and maintains. They can be categorised into four distinct groups based on their comparable methodologies:

- access to the public transport network
- access through the network - measuring location-based catchment statistics
- access through the network - measuring London-wide catchment statistics
- access through the network to specific opportunities and services (ATOS).

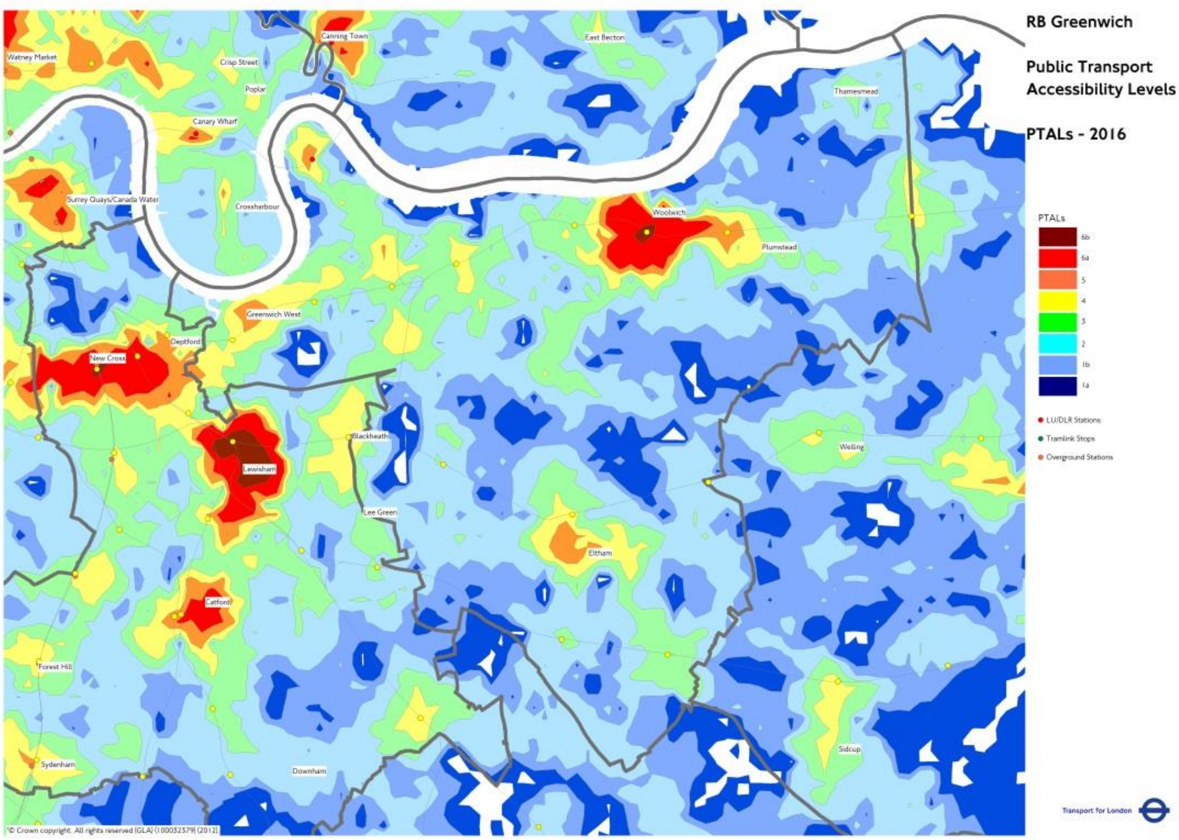
In this section we also include an overview of WebCAT our web-based connectivity assessment toolkit which brings some of these measures together into a single interactive mapping application.

PTAL

Purpose

Public Transport Access Level (PTAL) is a well-established though relatively simple method of measuring access to the public transport network in London. It is the only measure that has been formally accepted and used on a statutory basis. For any location in London they combine walk access time to the public transport with service availability at network access points (stations, bus stops etc.) within a given catchment. A Public Transport Access Index (PTAI) is calculated from this data and allocated to a series of levels where PTAL 0 represents the lowest and PTAL 6b represents the highest level of connectivity.

Figure 5. PTAL map of the Royal Borough of Greenwich



Calculation methodology

PTAL can be calculated for a single location or for a grid of points using the same methodology. They can highlight those areas with low transport network density relative to others on a consistent basis. A grid may cover a development site, an opportunity area, an individual borough or the whole of Greater London (Figure 1). Mapping the results provides a simple and intuitive view of the density of London's public transport network that is understandable to a wide range of users. A sample map for the London borough of Greenwich is given in Figure 5.

There are four main data components which are needed to create a PTAL dataset and are itemised in Table 1.

Table 1. PTAL data components

Dataset	Description
Point(s) of interests (POIs)	These are the geographically defined locations where the calculation is performed. They can either be individual points, a series of points representing key locations or a regular grid.
Service access points	These are also known as SAPs and represent the locations where you can access the public transport network in London: bus stops, rail and tube station entrances, tram stops etc.
Walk network	This is used to calculate the walk distance/times between the points of interest and the network access points. Walk networks could represent the existing network or a future walk network based on a masterplan or other data source.
Valid service frequency data	A database of selected service frequency data which itemises each service (and its frequency) that stop at each SAP, based on their unique service/stopping pattern. The service data could represent the current network or a modified network that includes proposed routes and schemes.

With access to the appropriate datasets, the PTAL calculation method can be broken down into a series of stages which are itemised in Table 2.

Table 2. PTAL calculation process

Stage	Description
Calculate walk access time	From the point of interest(s) (POI) to nearby service access points (SAPs - bus stops, station entrances etc.) via the walk network. Bus SAPs are only included in the calculation within 640 m and rail SAPs within 960 m of the POI. Distance is converted to time by assuming an average walk speed of 4.8 kmph. Thus 640 m is equivalent to an 8 minute walk and 960 m is equivalent to a 12 minute walk.
Link walk times with service frequency data to create a "walk + frequency" output file	In a database walk times are joined with route frequency data using the common SAP identifier. Output the file including the following attributes: GridId, SAPId, RouteMode, RouteCode, vph
Calculating PTAL	Import the "walk + frequency" output file into a spreadsheet to perform the following processes: • For each route calculate total access time combining: walk time + service wait time + a mode-based reliability factor. • Convert total access times to an "equivalent doorstop frequency (EDF)" to compare the benefits offered by routes at different distances. • For each grid point, remove all duplicate records (retaining the one with the highest EDF). Note: a single POI may be able to access a single route at more than one location within the maximum walk distance. • Sum all EDFs with a weighting factor in favour of the most dominant route for each mode. This gives the access index (AI) score of each service. • Sum AIs by grid point to give the PTAI (Public Transport Access Index).

The PTAI is converted to the PTAL using the ranges specified in Table 3.

Table 3. PTAL ranges

PTAL	Access Index range	Map colour
0 (worst)	0	
1a	0.01 – 2.50	
1b	2.51 – 5.0	
2	5.01 – 10.0	
3	10.01 – 15.0	
4	15.01 – 20.0	
5	20.01 – 25.0	
6a	25.01 – 40.0	
6b (best)	40.01+	

Usage

PTAL is TfL's most widely used connectivity indicator partly explained by their use in the London Plan for a number of policy objectives. Although a relatively simple calculation they have the benefit of being applicable at both the strategic or site level. Outlined below are the key areas where the measure is used.

London Plan

TfL adopted and promoted PTAL in the early 2000s as a means to provide a consistent and agreed methodology for measuring access to the public transport network across London. It became embedded in strategic local planning processes in London, as a result of its inclusion in the London Plan.

The London Plan is the statutory spatial development strategy for the Greater London area and is written by the Mayor of London and published by the Greater London Authority (GLA). It sets out a fully integrated economic, environmental, transport and social framework for the development of the capital over the next 25 years. As a statutory document (under the terms of the Greater London Act [1999]), it forms part of the development plan for Greater London. London boroughs' local plans need to be in general conformity with the London Plan, and its policies guide decisions on planning applications by councils and the Mayor. Consequently use of PTALs extends from GLA strategy to local borough operation. It should be noted that the plan is currently under-review and a new version will be issued in late 2017. The current plan identifies three policy areas where PTALs are utilised:

- prioritisation of the location of high-density employment generators in areas of high PTAL ratings 5 or above
- relating housing densities to PTALs – where areas with good public transport provision (higher PTAL) can support higher housing densities
- as a means to restrict car parking provision in areas of good transport access or high PTALs.

Development area planning

PTALs are frequently used in strategic transportation studies as a means to show the impact of transport and walk network improvements within a development site and can contribute towards the case for higher density housing. The measure has been used extensively to assess the level of public transport provision in areas identified for development. In the London Plan, the largest of these are designated as opportunity areas. Generally, these are areas suitable for accommodating large-scale development to provide a substantial amount of new employment and housing.

VNEB (Vauxhall, Nine Elms, Battersea) Opportunity Area is a regeneration area that spans 227 hectares of central London on the south bank of the Thames, extending from Lambeth Bridge in the north, to Chelsea Bridge in the south. The area's comprehensive transport assessment included PTAL analysis within the report. Figure 6 shows current PTALs, whilst Figure 7 shows PTALs in the future centred on Battersea Power Station. Differences between the two maps are mainly due to the inclusion of:

- the Northern Line extension to Battersea Power Station (extension of an existing tube line)
- increased bus frequencies and stops across the area
- improvements to the walk network in the area which also impact severance across the area.

Figure 6. Current PTAL map for the VNEB Opportunity Area

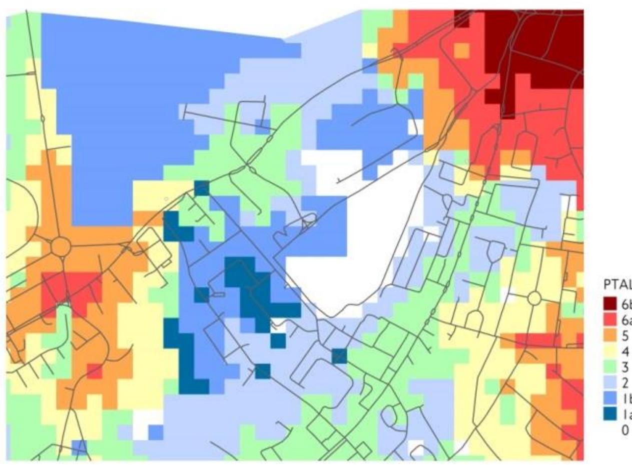
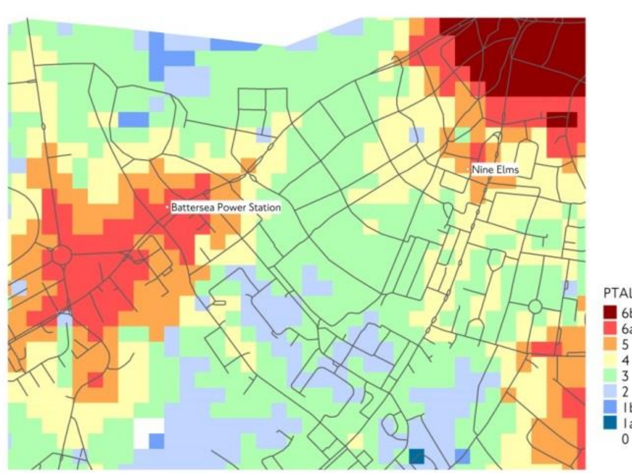


Figure 7 shows that in the vicinity of Battersea Power Station these enhancements will result in a rise to PTAL 6a: a significant factor to achieving higher density development in this area.

Figure 7. Future PTAL map for the VNEB Opportunity Area



General transport planning

In addition to the specific examples given above, PTAL is also a useful London-wide measure of connectively for a variety of studies:

- Prioritising a series of sites in terms of their proximity to the public transport network. Examples have included rating NHS health service locations in terms of their PTAL rating: the most preferred locations being ones with access to good public transport provision.
- Providing a consistent connectivity measure for network planning: highlighting areas for further investigation. Figure 8 for example, shows PTAL data displayed by mode only. Blue areas are those with access to bus and rail services, whilst red areas are those with access to bus services only. This map shows there are significant areas in inner London with access to bus services only and may warrant further investigation in terms of new scheme development or scheme option selection.
- Combining with other data sources to support evidence based policy making decisions across TfL. Figure 9 gives one example of combining transport mode share ward level data (derived from TfL's Household Travel Demand Survey) with PTAL data. This shows how active modes increase and car-based trip decrease as the PTAL "rises" across London.

Figure 8. Rail and bus connectivity in London

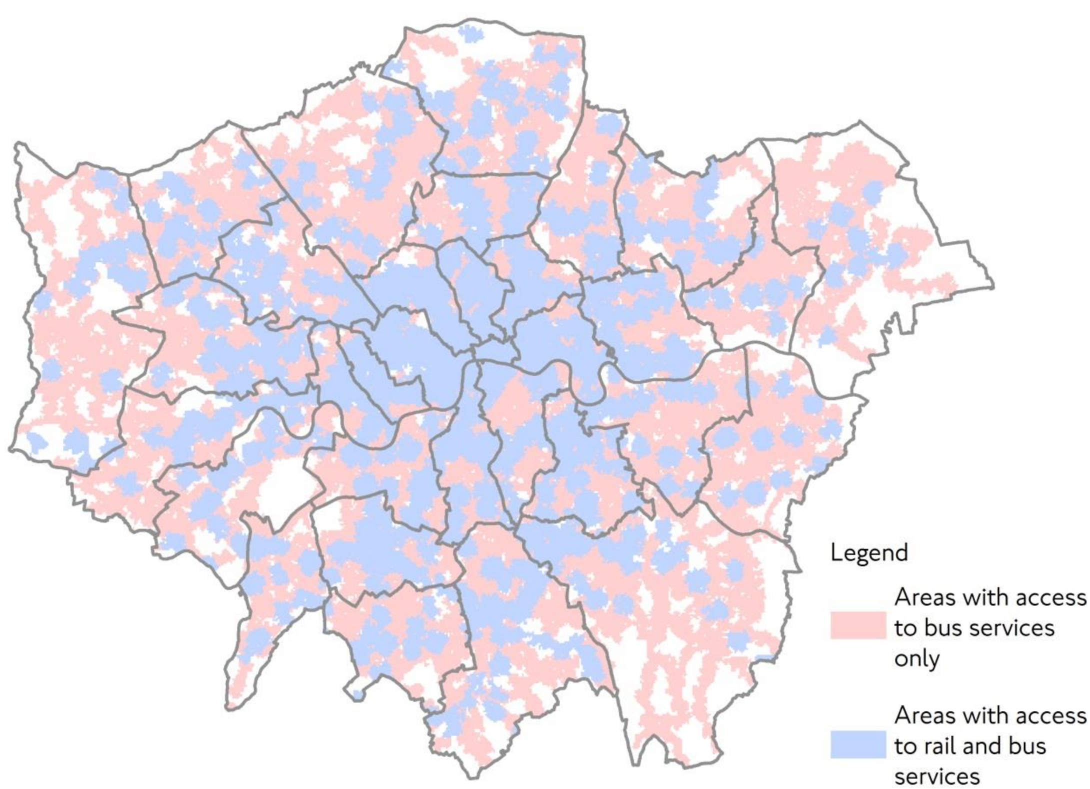
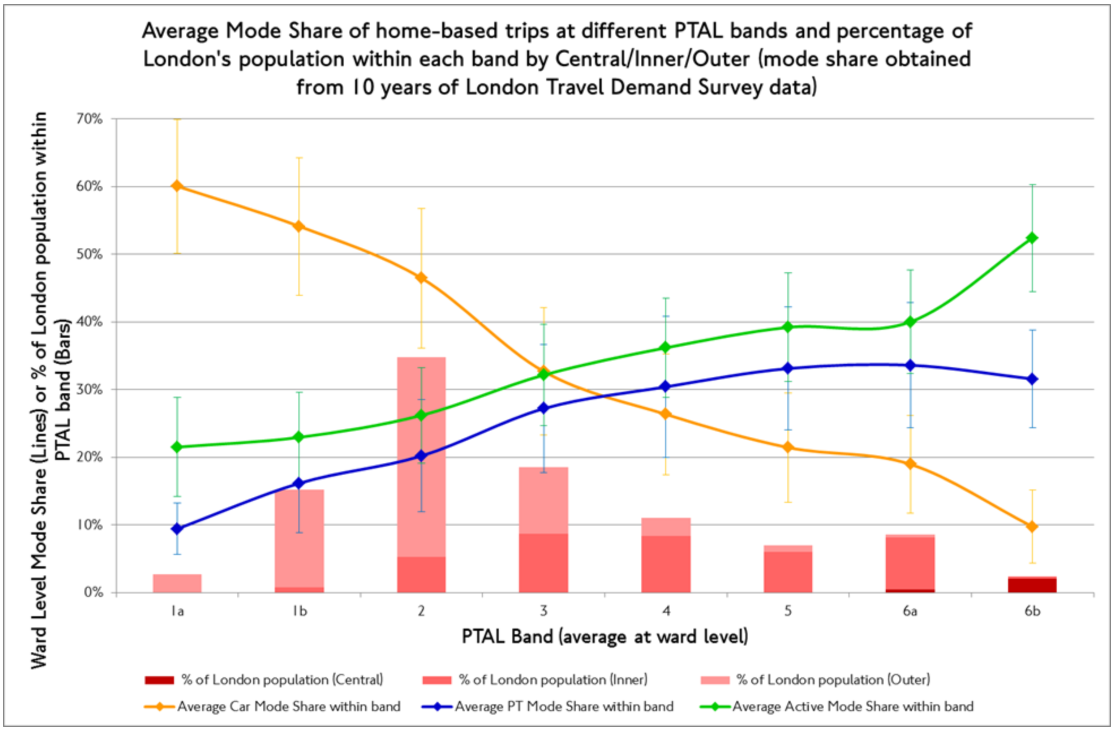


Figure 9. Mode share and PTALs



Strengths and limitations

Key strengths of the PTAL methodology include:

- The output is intuitive and is relatively easy to interpret. The level of transport provision in different areas of London can be compared in a simple yet consistent manner.
- The simplicity of the calculation method allows users to calculate values for individual locations themselves using a spreadsheet.
- They can be calculated at a micro or macro level. They are currently calculated for a 100 m grid of points across London. These results can also be translated into contours to produce a London-wide and individual borough-wide PTAL maps – such as the example given above in Figure 5.
- Acts as a good proxy for access to services and jobs in urban areas. With a well-connected transport network such as that found in London, those areas with a higher PTAL score will in most cases be able to reach a wider range of service locations than those with a low score.
- Provide a means of identifying the impact of changes to the walk and/or public transport network at a local level with easy to interpret output.

Limitations of the PTAL methodology include:

- PTAL methodology only considers access to the public transport network. It does not take into account how far you can travel through the network.
- Since there are only nine PTAL categories, places with the same PTAL can still have significantly different characteristics from each other in terms of their level of connectivity. Similarly a new scheme may raise the index value but still remains within the same category. In these cases the use of the index values themselves may be a better approach.
- PTAL is more limited as a measure of the benefit offered by large strategic projects such as new rail schemes as it only recognises improvements within a relatively local walk catchment. In these cases a measure based on travel time analysis may be more suitable.
- PTAL only includes walk time and service frequency explicitly in the calculation. Therefore any schemes or interventions that improve station capacity, step-free access, reliability, or vehicle capacity will have no impact on the level.
- PTAL considers the frequency of services during the morning peak on a weekday. There are cases where it could be more suitable to look at the level of connectivity at another time of the day or during the weekend, for example around a shopping centre.

Location-based catchment analysis

Purpose

This type of analysis is conceptually simple yet very powerful. It uses travel time mapping and associated catchment data to provide additional assessment of connectivity, either by all public transport modes, or a specific mode, or by car. The concept of travel time mapping uses a series of time intervals to map travel times from or to a selected location. Such analysis can be enhanced by associating the travel time bands with an appropriate count (sum) of population, employment or other services e.g. hospitals, schools, retail locations) that are located within these time bands. This type of analysis has been made available to a wider audience via our interactive web-based connectivity assessment toolkit WebCAT[3] which is discussed later in this section.

It should be noted that TfL has not formalised an actual indicator using location-based catchment analysis, rather it has focused on providing a suite of measures that can be adapted to fit the individual users' requirements.

Calculation methodology

Travel time data is derived from our strategic transportation model called Railplan. This model covers London and the south-east, and assesses the likely routes and service choices of public transport users, and the resulting flows, journey times and levels of crowding in and around London.

The Railplan model includes a detailed representation of the principal public transport services available in London including: National Rail, London Overground, London Underground, Docklands Light Railway, Tramlink and London Buses. In addition there is a detailed walk network to represent access to the public transport system as well as transfers between services through station interchange links.

The model includes public transport network information for the whole of London and its surrounding area. Specifically this includes all buses services within the M25 cordon as well as those that intersect and extend beyond the GLA border. All rail services are included within London as well as those that provide connections between London and the rest of the country.

Railplan divides London into 3 288 zones for which we can extract travel time matrices giving journey times for all combinations of origins/destinations. For this analysis we use non-generalised time to represent "real" journey time via the shortest route and exclude penalties and weightings that are utilised in the full generalised journey time (GJT) process.

Journey times include all elements of travel:

- walk time between the zone centroid and the transport network
- wait time for the public transport service
- in-vehicle time - time of the public transport mode
- interchange time.

Railplan represents average travel conditions in three time periods during a school term time weekday:

- AM Peak (07:00-10:00)
- Inter Peak (10:00-16:00)
- PM Peak (16:00-19:00).

Railplan can also provide travel time data for different forecast years. The base year represents the current state of the transport system (2011). Whilst future year transport networks have also been developed for the principal modelling periods 2021, 2031 and 2041. For example, 2021 includes the Elizabeth Line (Crossrail) and other service enhancements.

Usage

Location-based catchment analysis outputs are used widely throughout TfL and its stakeholder organisations as a way to demonstrate transport characteristics in a transparent way as well as a means to support evidence-based policy decisions.

Key uses include:

- Scheme optioneering – quantifying the additional number of jobs or people that can be reached with the construction of a new transport scheme using different station locations and network alignments.
- Identifying the catchment characteristics of a specific location – for example the number of jobs that can be reached from a residential site or the number of people who can access a new commercial site. The later could consider the total population that reside within 30 minutes to a shopping centre or the working age population that reside within a 45-minute commute to a new office development.
- Site selection and prioritisation based on the catchment characteristics. For example comparing the number of potential employees who could access one site compared to another.

Below we provide some examples of how this type of analysis has been used in practice.

Figures 10 and 11 give an example of how such analysis can be used to support the benefits of investment in new infrastructure. These screen–shots are taken from TfL's WebCAT tool and demonstrate the impact on transport connectivity that the Elizabeth Line will have on Abbey Wood. The map shows how travel times are reduced westwards along the Elizabeth Line's alignment with most of central London, accessible within 60-minutes travel time by 2021. This is underlined by the cumulative bar charts showing that currently 0.72 million jobs can be reached within 60-minutes travel time, but this will increase to 2.4 million by 2021.

Figure 10. Travel times from Abbey Wood using the current network with the associated cumulative bar chart showing 2011 jobs reachable within each time band

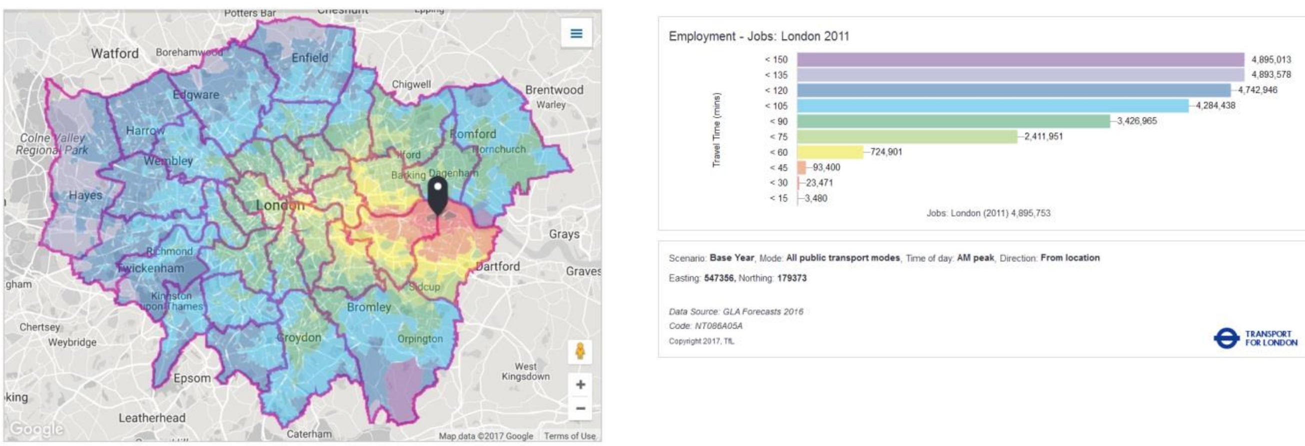


Figure 11. Travel times from Abbey Wood using the 2021 network with the associated cumulative bar chart showing 2021 jobs reachable within each time band

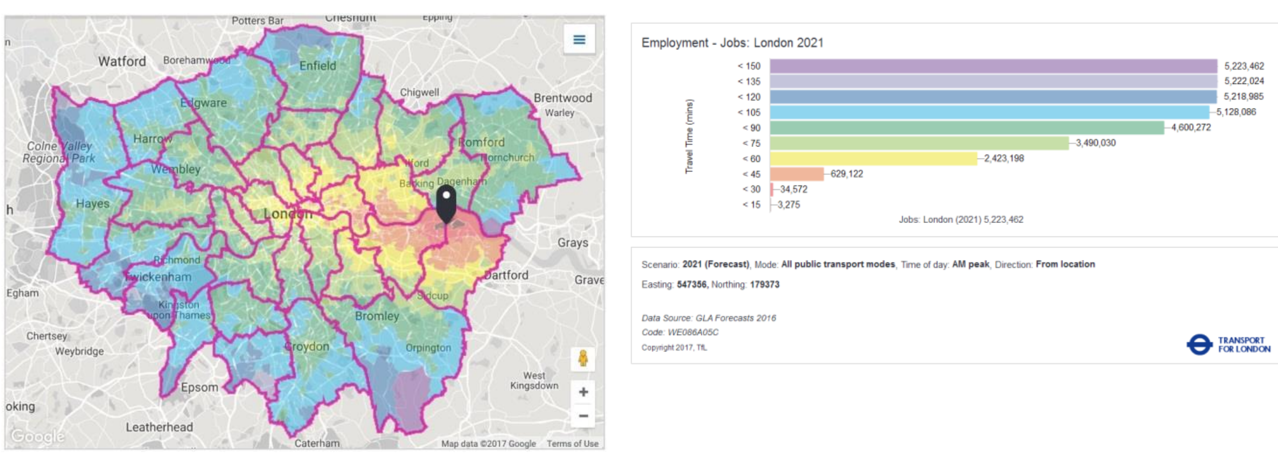


Figure 12 demonstrates how the results for two scenarios and one location have been displayed on a single map. The blue zone indicates travel time within 60 minutes to North Greenwich before construction of the Jubilee Line extension to Stratford. Whilst the red zone indicates the extent of the 60-minute catchment zone after its construction. In this example North Greenwich previously had limited connectivity so the impact of the Jubilee Line is greater than in areas where there is already a high level of connectivity (for example central London). As with previous examples travel time mapping could also be quantified in terms of the number of people or jobs within each catchment area.

Figure 12. 60-minute catchments to North Greenwich – with and without the Jubilee Line extension

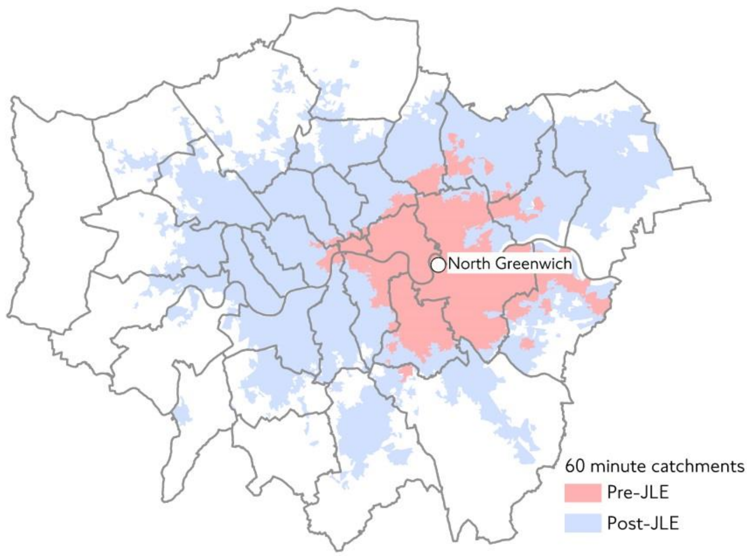


Figure 13 illustrates how travel time data can be displayed for multiple destinations. These could be, for example, a series of hospitals, schools, libraries or other service locations. The map shows the minimum travel time to any selected location, the underlying assumption being that people will travel to their nearest site.

Figure 13. Combined catchment areas for a series of service locations

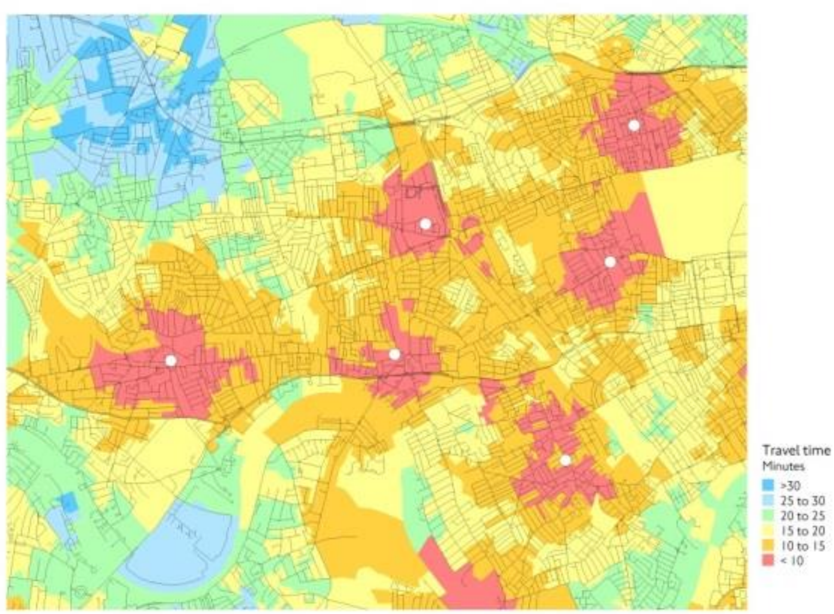
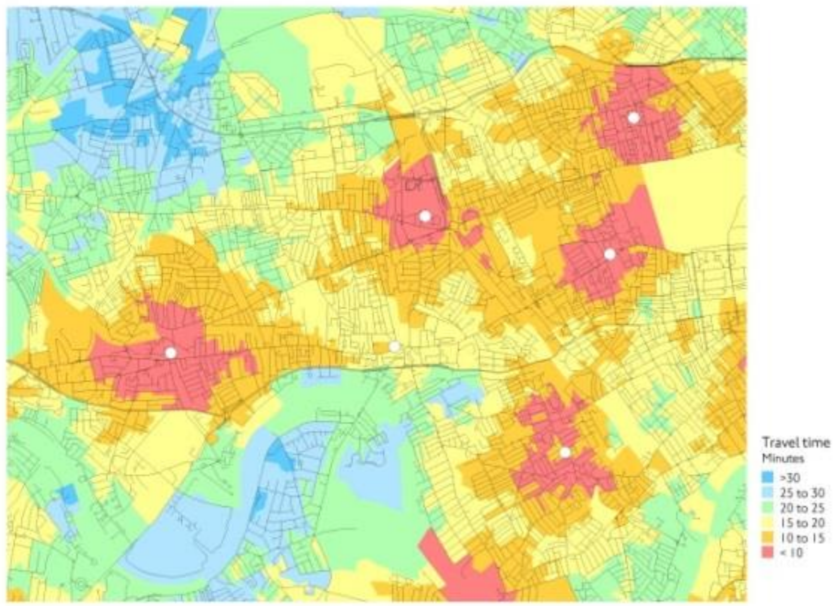


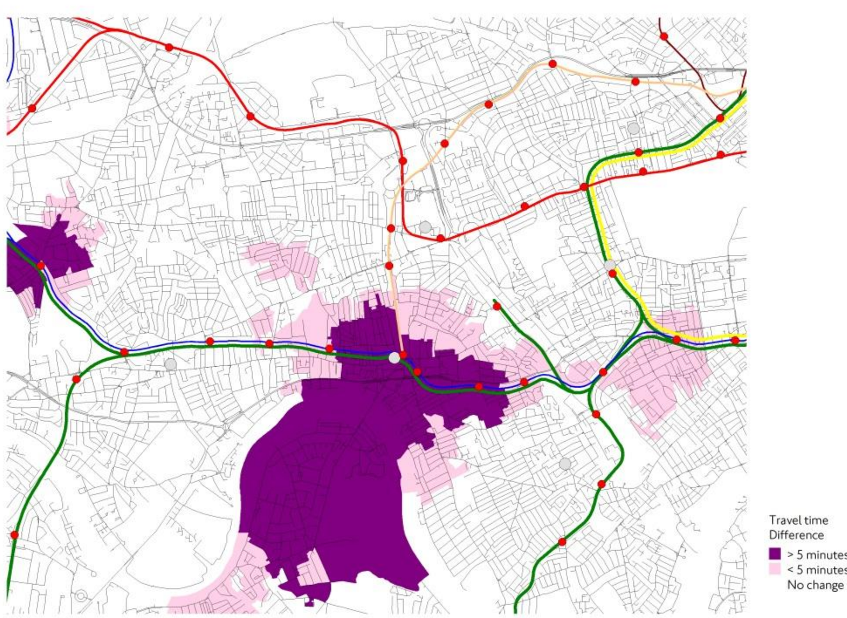
Figure 14 shows travel times to the future distribution of services where the central location is closed and travel times are based on the remaining locations.

Figure 14. Revised catchment areas for a series of service locations



Perhaps the most interesting output is Figure 15, plotting the increase in travel times caused by the closure of the central facility. As expected, the most significant increase in travel time (>5 minutes) occurs in the vicinity of the facility, although other areas are affected due to the configuration of the transport network. These outputs could also be arranged as a series of catchment statistics tabulating the impact on the resident population of the service reconfiguration. TfL has worked in collaboration with various service providers in London, including the NHS, providing travel time data and expertise to undertake this type of connectivity analysis.

Figure 15. Difference in travel times between the two scenarios (Figures 13 and 14)



Strengths and limitations

Key strengths of the methodology include:

- The output is easy to interpret and present to both professional planners and the general public.
- Provides an effective means of comparing the impact that transport interventions are likely to have on key indicators of economic growth (e.g. access to employment) or access to services.
- Individual or groups of modes can be analysed. For example travel times for the full network could be compared with those for the step-free network to highlight the differences in constraints experienced by step-free network users.

Key limitations of the methodology include:

- These model outputs are not well suited for looking at local changes to the network such as new local bus routes or improvements to walk networks. Travel times are based on the transport model zone distribution which typically divides each borough in London into about 100 zones. The outputs therefore are best suited for use at a strategic level considering the impact of major schemes and packages of schemes across London.
- Travel time analysis by its definition looks at travel times alone. When assessing the impact of new schemes, journey time reduction may not be the principal benefit. Other factors may be of greater significance: increasing network capacity, crowding reduction, enhanced passenger experience etc. For example: journey complexity involving numerous interchanges could be of greater significance for some user groups than achieving the fastest journey time.

London-wide catchment analysis

Purpose

Rather than simply generating travel time plots for individual locations, London-wide catchment analysis aggregates the catchment results for each zone/location in London (for example the number of jobs reachable within 45 minutes from each zone) and maps the calculated catchment statistic rather than the actual travel time values.

This method has been used most frequently in the London context with population and employment data to provide a strategic view of changes in connectivity across the city.

Calculation methodology

The data used in this analysis is derived from Railplan standard origin/destination non-generalised (real) travel time matrices. Travel times from and to every transport zone (over 16 million records) are stored in a matrix format and are imported into Excel with appropriate zone based population or employment statistics added to the matrix rows and columns. With this format population or jobs reachable within say 45 minutes for each zone can be calculated and the results plotted using a GIS.

Although the calculation method is simple there are a number of factors that should be considered when preparing the outputs:

- "To" or "from" the zone. Employment catchments will be of most interest for residential developments, i.e. quantifying the number of potential jobs for residents available within

45-minute travel time. Outputs will be based on travel time data "from" each zone. Population catchments will be of most interest where there are commercial/retail land uses, i.e. quantifying the number of people who can access each zone within 45-minute travel time. Outputs will be based on travel time "to" each zone.

- Selecting the most appropriate catchment time. 45 minutes has become the default TfL value when displaying the number of jobs reachable from each zone. Recent LTDS survey analysis suggests that 50 minutes is a more appropriate interval accommodating for longer commuting times.

Usage

The examples below demonstrate how this methodology can be applied as a useful indicator combining catchment variables with transport travel time datasets.

As a strategic indicator

Figures 16 and 17 show standard London-wide catchment analysis outputs produced by TfL using workplace statistics. These maps quantify for each zone in London the number of workplaces that can be reached within 45 minutes by public transport. Although the maps focus on London they include zones reachable beyond the London boundary. Such outputs provide a strategic indicator of connectivity in London and are used in the current Mayor's Transport Strategy document for this purpose. Comparing Figure 16 with Figure 17 shows improvements in the transport network as well as general growth in employment between 2015 and 2041.

Figure 16. Number of 2015 jobs reachable within 45-minute travel time using the full 2015 transport network from each zone in London

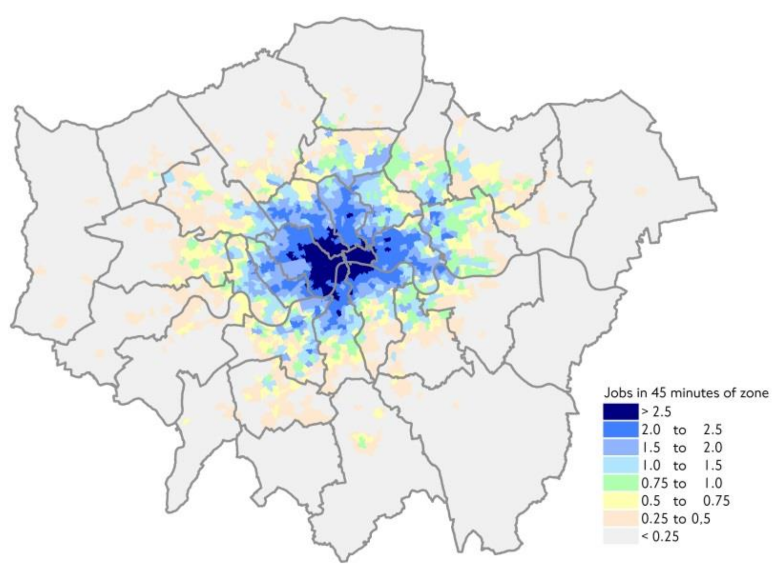
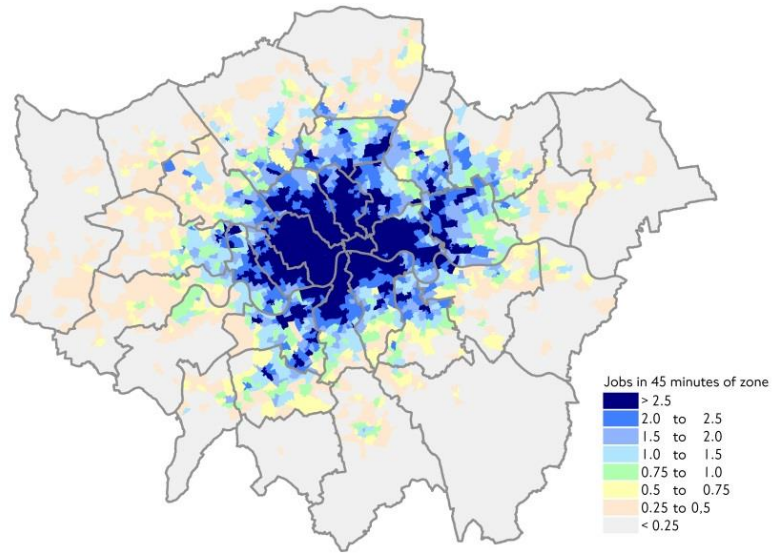


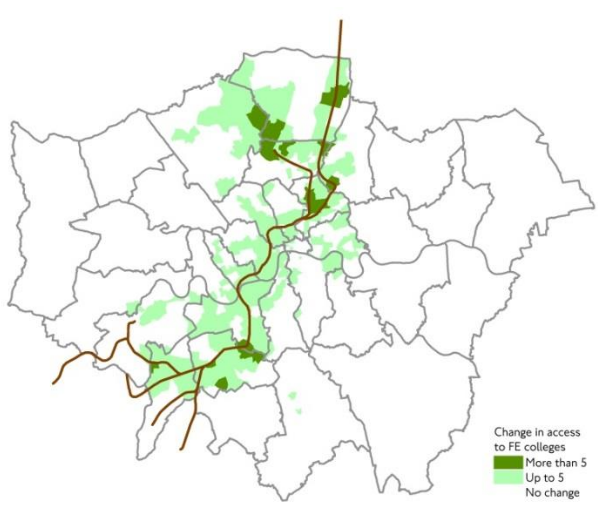
Figure 17. Number of 2041 jobs reachable within 45-minute travel time using the full 2041 MTS transport network from each zone in London



As a measure of access to services

London-wide catchment analysis can also be used as a method to quantify the number of services reachable within a given time period, replicating, to a certain extent the ATOS methodology which is discussed later. Rather than calculate travel times to specific locations this method quantities the total number of services that can be reached within a given time period. The example in Figure 18 is based on two scenarios (with and without Crossrail 2) and displays how many more further education colleges are reachable within 45-minute travel times of each zone when Cross rail 2 is operational.

Figure 18. Change in access to further education colleges in London after the introduction of Crossrail 2



Measuring step-free access

Travel time matrices based on standard travel times and step-free travel times for the same scenario can also be used with this method. TfL is committed to achieving an inclusive, accessible and affordable transport network that benefits all Londoners. Considerable efforts have been made to reduce the journey time differential between step-free and non-step-free journeys but this difference is still considerable and is reflected in the fact that disabled people travel less often, making 1.6 trips per person per day compared to 2.4 for those without a disability. The step-free network is a sub-set of the full public transport network, excluding those station walk links which involve negotiating any series of steps. This could make some stations inaccessible or reduce the number of interchange options resulting in longer journey times. A comparison of Figures 19 and 20 shows the impact on connectivity for users of the step-free network in terms of the reduced number of further education colleges reachable within 45-minute travel time.

Figure 19. Connectivity to further education colleges using the current full public transport network

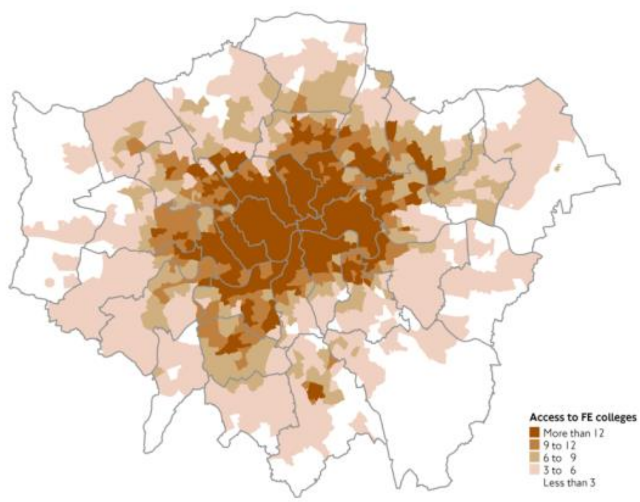
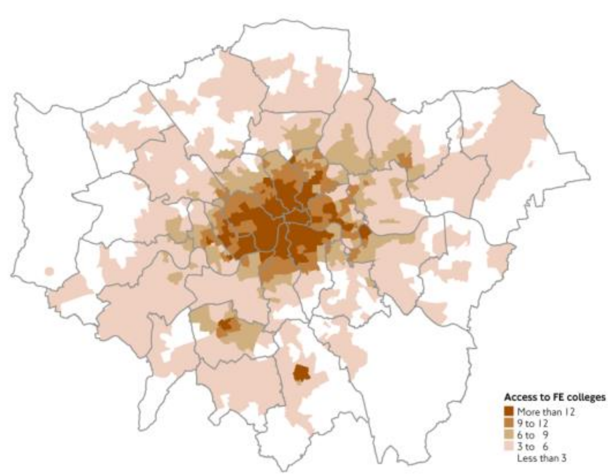


Figure 20. Connectivity to further education colleges using the current step-free network



Strengths and limitations

Key strengths of the methodology include:

- It provides useful indicator to demonstrate change in network connectivity across London at a strategic level rather than focusing on specific locations.
- This method is flexible and can be applied to a wide range of travel time datasets and catchment statistics.
- Displaying the number of service locations within a given time frame reduces the significance of proximity to a specific (nearest) service.
- Key limitations of the methodology include:
- Use of outputs from strategic models limits the granularity of the data to the zone sizes used in the model. Whilst the zoning system may provide sufficient granularity at a strategic-level, at the borough or local study level this may be too coarse.
- Developing thresholds for what represents "good" or "bad" connectivity is difficult and unresolved.
- This method provides a relative measure of connectivity. The absolute numbers could actually be meaningless: for example is having access to 1 million jobs worse than having access to 2 million jobs.

ATOS: Access to opportunities and services

Purpose

As already discussed, a significant limitation of the PTAL methodology is that it only considers access to the public transport network and does not take into account how far you can travel nor the opportunities and services that can be reached.

In planning terms an agreed catchment-based connectivity indicator that takes into account London's dense urban environment, could support decisions on the most appropriate location for new facilities as well as public transport services. Such a measure could help support the Mayor in setting regional priorities, as well as improve collaboration between transport providers, such as Transport for London (TfL), with service providers, such as the NHS, in London.

For these reasons TfL developed a London-specific connectivity measure of access to opportunities and services (ATOS) as a response to, and building on the UK's Department for Transport (DfT) 2007 initiative to publish core national accessibility indicators. Local authorities outside London were also required by the DfT to set a target for at least one local accessibility indicator as part of their Local Transport Plan. The indicators looked at the proportion of the resident population that can access a service within a certain time, for example: the percentage of 16-74 year olds within 20 minutes of an employment centre. In the case of London, the local authorities (boroughs) were not obligated to report on accessibility as Transport for London was and is accountable for ensuring good quality access. In addition, most of the indicators set by the DfT would be met within the Greater London area.

Although this measure was based on the DfT indicators, they were adapted to accommodate for London's characteristics. For example ATOS allows for a degree of choice as to which services users are likely to access.

Calculation methodology

Calculating ATOS involves a number of processes which are explained below.

Defining the origin points

ATOS requires a grid of points at an appropriate level of detail on which to base its calculations. ATOS zones combine 2011 Census Lower Super Output Areas (LSOAs) with Census Output Areas (COAs), where the former were felt to be too large, thereby giving greater granularity. This resulted in a total of 5 231 ATOS zones across London. Travel times are measured from each zone's population weighted centroid to approximate for where most people live within each zone.

Define the service/destination points

For the ATOS methodology we agreed a "basket" of key opportunities and services that were appropriate to London:

- Work: calculating average journey time to the nearest 10 000 low-qualified and high-qualified jobs
- Education: calculating average journey time to the nearest three primary schools, secondary schools and further education colleges
- Health: calculating average journey time to the nearest three general practice/doctors surgeries
- Quality food shopping: calculating journey time to the nearest town centre or supermarket
- Open spaces: calculating walking time to the nearest publicly accessible open space

Calculating travel times

For each origin point we calculate the walk time/distance to the 10 nearest destinations for each service set using a GIS network routing algorithm with a detailed London-wide walk network. For those origin/destination pairs that were beyond agreed walking distances (more than 10 minute walk [800 m]) we calculated the public transport travel times. Like our London-wide catchment analysis methods, travel time for ATOS is derived from the Railplan model. The 3 288 zones used in London are ideal for a strategic catchment-based measure but in the case of ATOS more detailed analysis is required based on point-to-point travel times. To accommodate for this requirement we use a variant of Railplan called CAPITAL. CAPITAL strips away the standard model zones and allows the user to extract Railplan travel times defined by their own origins and destinations. CAPITAL links Railplan with a GIS to consider the complete journey including walk time from the origin/destination to the PT network, service wait time, in-vehicle time, and interchange time. A typical CAPITAL run for ATOS would therefore calculate travel times from the LSOA centroid to the selected service locations.

Calculating the ATOS scores

The public transport travel times calculated in CAPITAL are combined with the complete walk based results in a spreadsheet. Any journey of less than 10 minutes is assumed to be a walk trip and for those longer than 10 minutes is assumed to be undertaken by public transport.

For the following services: GP surgeries, primary schools, secondary schools and further education, the average of the three fastest journey times is selected from a possible ten locations. Access to food shopping is based on the travel time to the nearest store or town centre (assuming that an individual will perform their main shop at one location and there are no capacity issues at the destination) whilst journey time to open space is derived from the walking time to the nearest location only.

This gives us a list of average or minimum travel times from each zone and by each service type. Service specific ATOS scores from A to E can then be derived using ranges based on the criteria given in Table 4.

Table 4. ATOS ranges

A	0 to (Mean – stdev)
B	(Mean – stdev) to Mean
C	Mean to (Mean+stdev)
D	(Mean+stdev) to (Mean+2 stdev)
E	> (Mean+2 stdev)

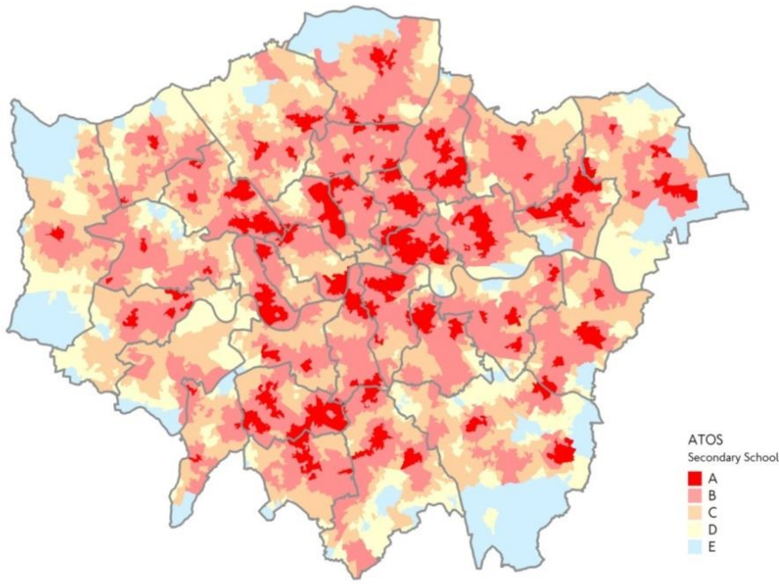
Thus level A has the best or quickest level of accessibility to services and level E the worst or slowest. It should be noted that the ranges derived for each service will differ according to the density of locations across London. ATOS Level A for GP surgeries ranges from 0 to 7 minutes whilst ATOS Level A for Further Education Colleges ranges from 0 to 22 minutes.

A composite score, combining individual service scores was created but resulted in an index that was difficult to interpret. This was achieved by combining the ranks of accessibility for each zone. The composite score was computed by totalling the ranked average times by zone for each service and then splitting the total ranks into five groups (A to E), where "A" was the 20% highest values and "E" the 20% lowest values.

Usage

ATOS results can be either plotted using GIS software or analysed in a spreadsheet. Figure 21 shows the ATOS scores based on average travel time to the three nearest secondary schools for each zone by walking only or by walking and public transport modes. In this example category A corresponds to an average travel time of up to nine minutes, whilst category E corresponds to an average travel time of over 23 minutes. TfL has produced similar plots for all the services groups given above.

Figure 21. Access to the three nearest secondary schools by public transport and/or walking

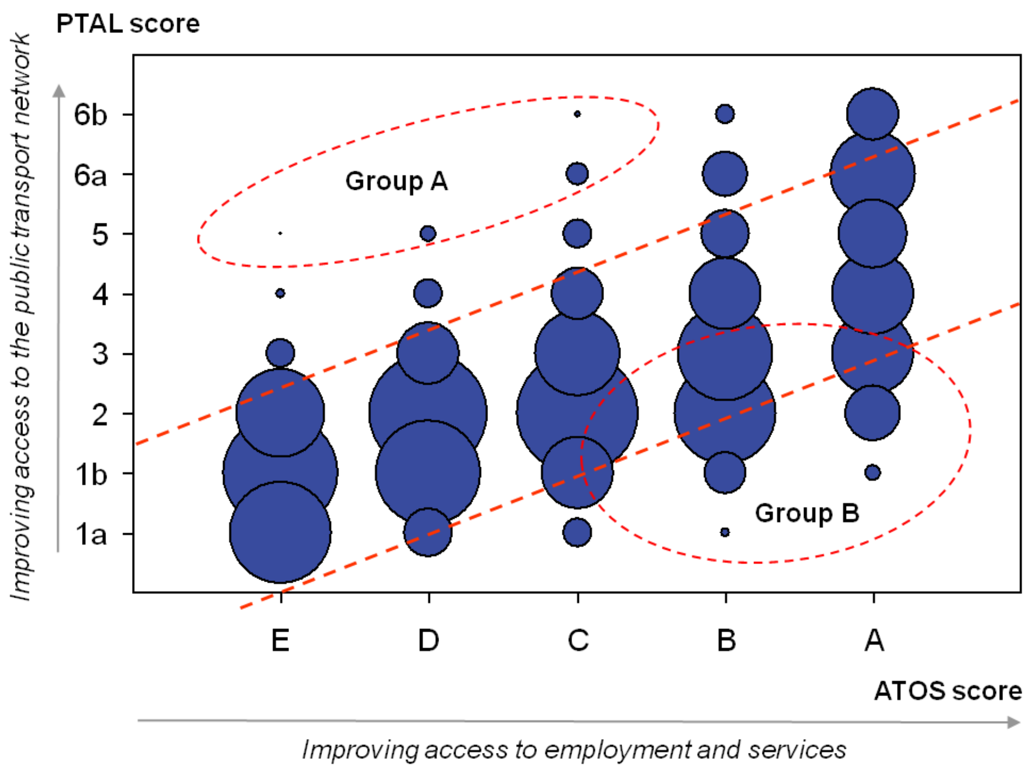


An important aspect of this work was to combine PTALs with ATOS to give a fuller picture of connectivity across London. Figure 22 shows there is a strong correlation between access to services and access to the public transport network. However, importantly, poor access to the public transport (e.g. PTAL 2 or 3) does not necessarily mean poor access to services.

The size of each blue circle represents the number of areas with a given PTAL/ATOS combination. Generally access to services improves with access to public transport, although the correlation becomes more diffused as access to services increases. So where there is good access to most services, public transport provision becomes less relevant.

Whilst some areas have poor access to services, despite having good access to the public transport network (Group A), a significant number of areas show good access to services despite poor access to the public transport network (Group B). This suggests services in these areas can be accessed by walking. TfL will investigate this approach further for assessing walking connectivity and the methodology is discussed further in the following section.

Figure 22. A comparison of accessibility when measured using PTALs and ATOS



Strengths and limitations

Strengths of the ATOS methodology include:

- Provides a transparent and understandable methodology for assessing connectivity to a basket of services across London on a consistent basis.
- Complements PTALs and can provide a more robust picture of connectivity
- Helps identification of areas where many services can be accessed by walking or cycling. The adoption of London's new Mayor's Transport Strategy and the move towards prioritising sustainable forms of transport is giving greater emphasis to this type of analysis.

Limitations of the ATOS methodology include:

- Measuring access to specific services adds an additional level of complexity to these indicators. ATOS includes travel times to the nearest three locations but does not consider service specific issues such as quality, capacity, public/private provision etc. Many people would consider these issues more important than proximity to a service and would be willing to travel as far as necessary to reach their desired location.
- The original analysis used time bands based on the mean and standard deviation of each service group. Thus each service group scores' would have a different definition dependent on the density of locations available. Different ranges made it difficult to combine individual service scores together in to one meaningful indicator. To ensure consistency and allow for time series analysis we have since used fixed time intervals.

- High service density in London means that many facilities are available locally and can be reached by walking, cycling or by bus. In these cases the impact of the wider transport network (rail, underground etc.) would be less significant. This should be considered if a measure such as ATOS is used to assess the impact of future strategic transport schemes.

Combined, these limitations have resulted in TfL not progressing development of the ATOS indicator in its current form. The preference is to undertake ad hoc location-based catchment analysis where the origins and service destinations are more fully understood and defined.

WebCAT

Purpose

The most recent innovation TfL has made to its connectivity planning toolkit is the development and release of an interactive mapping tool: WebCAT. TfL's Web-based Connectivity Assessment Toolkit is available on the organisation's public web-site at tfl.gov.uk/webcat. A short promotional video highlighting its key features and uses is also available at Youtube WebCAT video. WebCAT has been designed to make our suite of connectivity tools, data and analysis more easily available to a wide audience, primarily professional planners, but its simple and intuitive interface is also designed to be of use to the general public.

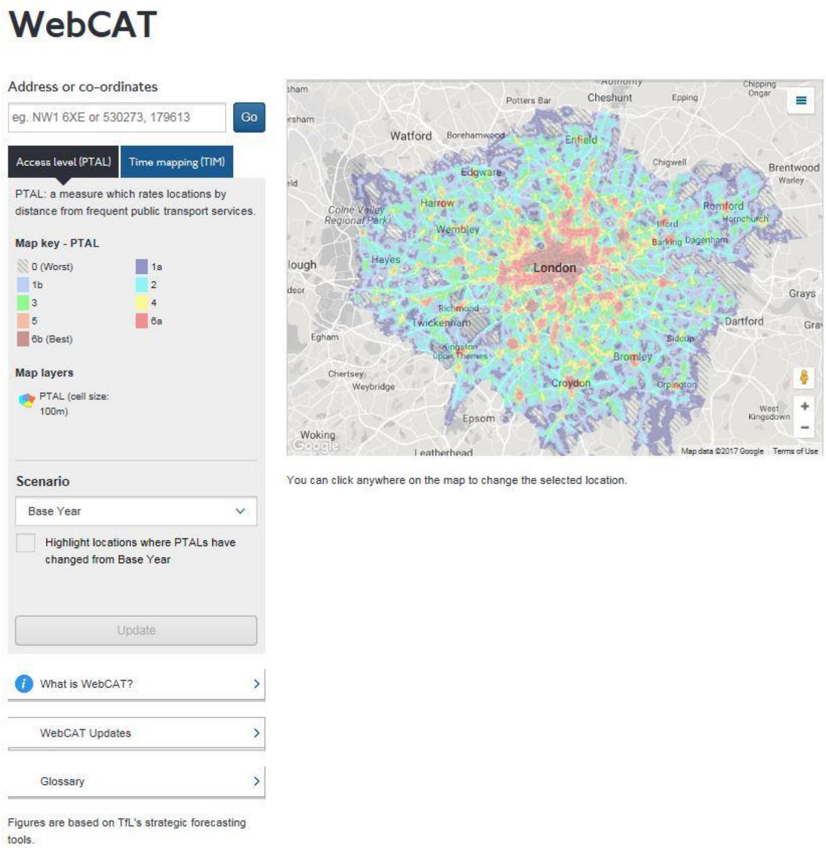
The London Plan obliged TfL to provide Public Transport Access Levels (PTAL) information to boroughs and developers as part of the policy to ensure sustainable residential housing densities across London. In response TfL commissioned the development of an interactive web-site (WebPTALs) that calculated PTALs for any user-selected location in London. The contract for WebPTALs ceased in 2015 offering the opportunity to develop a more ambitious web-site that included a wider variety of connectivity tools and data. This formed the rationale for the development of WebCAT.

WebCAT offers two principal ways of measuring transport connectivity: PTAL and location-based travel time mapping/catchment analysis. It is driven by an interactive mapping interface where the user is expected to search or click on the map to return connectivity information (grid-based PTALs or travel time plots) for their chosen location.

WebCAT core functionality and data includes:

- PTAL: London-wide isochrones or locally as 100-metre grid cells
- Interactive travel time mapping (TIM): offering a range of travel time variables
- Cumulative bar charts: population, jobs or services reachable within the travel time intervals displayed on the map
- Comparison tool: compare travel time outputs for different travel time variables
- Variable time bands
- Maps and reports for the chosen location/analysis

Figure 23. WebCAT default screen screen-shot



WebCAT functionality gives access to a wide range of travel time and catchment datasets:

- PTAL calculated for the base/current year + 2021 and 2031
- Travel time mapping offers the following options:
  - scenario/year current, 2021 and 2031
  - mode: all public transport modes, bus only, cycle only, step-free
  - time period: morning peak, inter-peak, evening peak
  - direction: to or from the chosen location

Catchment datasets include the following:

- total population 2011, 2021 and 2031
- households 2011, 2021 and 2031
- working age population 2011, 2021 and 2031
- economically active 2011, 2021 and 2031
- pensioners 2011, 2021 and 2031
- jobs/workplaces 2011, 2021 and 2031
- service locations

- town centres: metropolitan, major, district
- educational: primary schools, secondary schools, further education
- health: GP surgeries, emergency (A&E) departments, pharmacies

Through WebCAT, TfL has endeavoured to offer relatively simple functionality that is useful to both professional planners as well as the general public. The comprehensive list of WebCAT datasets demonstrates the power and flexibility of the application in terms of the user being able to tailor analysis to fit their individual requirements.

Measures under development

As stated in the introduction, the new Mayors Transport Strategy (MTS) places a significant emphasis on shifting the travel mode split from car towards more sustainable modes of transport: public transport, cycling and walking. This will also be reflected in our suite connectivity measures where we will need to include cycling and walking as equally valid modes of transport.

The MTS places an emphasis on "good growth" stating that this should ensure "that people living in new housing in central, inner and outer London have options other than to drive to the shops, to school or to work. It means offering people across London – existing residents and new ones – the benefits of walking, cycling and public transport use that has been available in some parts of London for years."

Walking and cycling connectivity will contribute towards the evidence base to ensure that "as London grows, a greater proportion of people will live in locations that are well connected to employment and other opportunities by walking, cycling or using public transport."

One example of this approach is already provided in WebCAT by the inclusion of cycling travel times alongside other modes. The user can extract catchments statistics on a similar basis to those generated for the full public transport network. WebCAT can also demonstrate that cycling is a realistic alternative to other transport modes by comparing cycle travel times with public transport travel times.

This section now discusses additional new connectivity measures under development that accommodate cycling and walking.

CYTAL

Purpose

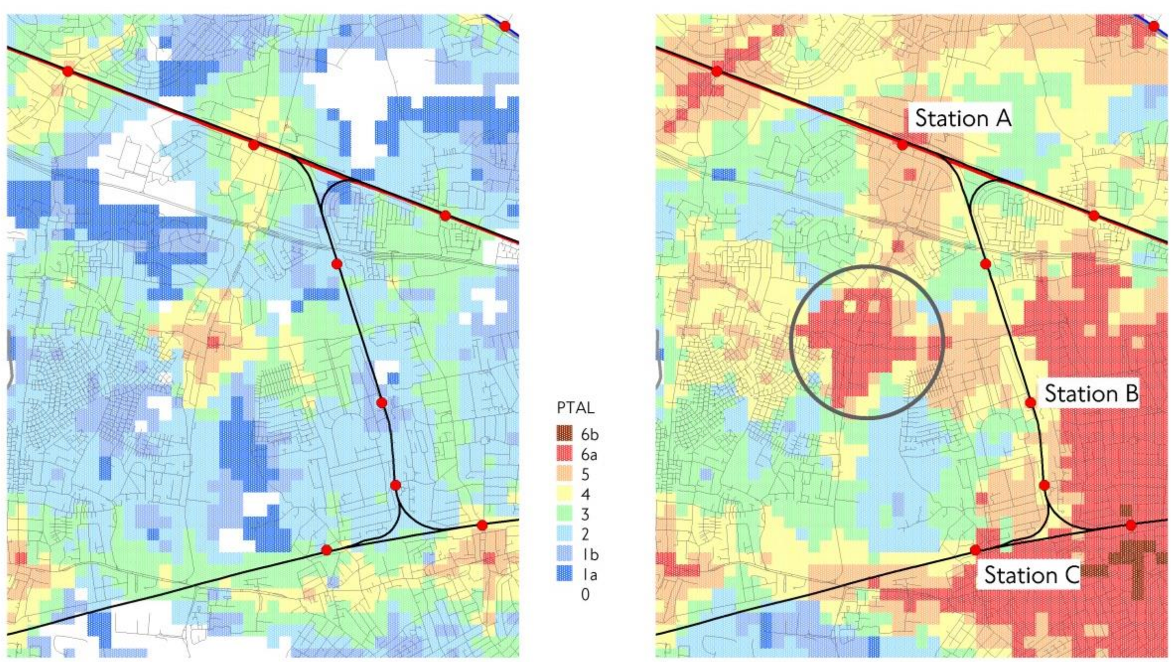
Cycle Access Level (CYTAL) has been proposed as a means to encourage more sustainable residential housing densities in London, specifically in areas with PTALs 0 to 2. CYTAL extends the PTAL catchment area by including cycling as an access mode in addition to walking.

Using the standard PTAL methodology PTAL locations 0 to 2 will in most cases be beyond the maximum walk distance (960 m – 12 minutes) to rail or underground stations. Rather than extend the walk distance, the purpose of CYTAL is to substitute the walk access mode with the cycle mode. Faster access time by bicycle means a maximum cycle time of 12 minutes could translate to a maximum cycle distance of 2.6 km at an average speed of 13 km/h. This would expand the access catchment area and raise the potential for including more stations and services in the PTAL/CYTAL rating.

Calculation methodology

Figure 24 demonstrates how the CYTAL methodology could be applied in residential areas of London in order to raise PTAL and support more sustainable residential densities. PTAL and CYTAL are calculated using a 100 m grid of points across the study area in Ealing, an outer London suburban borough. The standard PTAL map shows that there are many residential areas with low PTAL scores mainly due to limited access to bus services only. By inclusion of cycling as an access mode, connectivity levels rise across the study area. The highlighted central area rises to PTAL 6 as a result of the addition of the three local stations (A, B and C) in the calculation.

Figure 24. PTAL (left) and CYTAL (right) outputs for a typical suburban area in London (Ealing)



Methodological issues to be resolved

The concept of CYTAL is relatively simple but the methodology raises a number of issues and assumptions that will need refining during the development of CYTAL.

- *Maximum cycle access distance*. For the purposes of this example we have assumed a maximum cycle distance of 2 600 m and an average cycle speed of 13 km/h. We intend to undertake further analysis of survey data from the London Travel Demand Survey (LTDS) to establish the most appropriate maximum distance for station access. It is envisaged that the maximum distance will be relatively short because in this context cycling is only being considered as an access mode. A longer journey time where the final destination could be reached directly would undermine the purpose of this measure. We will also investigate if a minimum cycle distance should be defined. In circumstances where the station is within say 50 m of the origin point it is unlikely that an individual would using a bicycle and would instead walk. In the example above we used 250 m as the maximum walk distance to stations but this assumption is open to review.

- *Accommodating for inner and outer London*. It is envisaged that this measure will be most useful in outer London residential areas with low PTAL scores where access by bicycle to a local station could be a real advantage. In inner London the concentration of opportunities and services in a relatively small area means that the most convenient mode of transport could be bicycle without the need to access a station to reach the final destination. Furthermore in inner London there are more locations with PTAL 6a or above – the highest levels. Applying this methodology would not therefore result in a significant increase in the PTAL/CYTAL. Furthermore good existing walking access to public transport will mean that cycling is more likely to be used as a main mode rather than an access mode. As part of on-going analysis we will investigate using LTDS data to establish the difference between access distance to stations in inner and outer London and incorporate these assumptions into the final methodology.
- *Access to bus services*. CYTAL does not include access to bus services by bicycle. It is assumed that bus services would be accessed by walking only.
- *Cycle infrastructure.* The main purpose of this method is to highlight areas where the existing PTAL is low but by including cycling as an access mode, the PTAL could potentially be raised. It should be noted that the measure does not take into account the availability of cycle infrastructure: the provision of cycle parking at either the origin or destination or the suitability of the cycle network for undertaking these trips. Furthermore no factor is included to accommodate for the time it takes to park the bicycle.

Potential usage

We envisage that CYTAL is a methodology that would be used on an ad-hoc basis, in specific cases where residential property developers and planners could see the potential for cycling friendly development and where public transport connectivity is possibly limited. As a strategic measure, it is expected that CYTAL would highlight areas that could support such developments. It would form part of a suite of evidence and resources to help inform discussions between planners, developers and other stakeholders.

Walking connectivity

Purpose

New walking connectivity measures will be based on work already undertaken for the ATOS measure discussed previously and will be particularly relevant for residential areas. Walking connectivity indicators will aim to show how many, as well as the range of opportunities and services, that can be reached by walking for any chosen location in London.

Calculation methodology

Using a detailed walk network (based on Ordnance Survey ITN + Urban Path links) with a GIS network algorithm we can generate shortest path routes between given origins and destinations, applying an average walk speed to distance to give a walk time. Origin points could be defined as a regular grid of points at 100 m intervals and destination points a series of service locations. One example of this approach are the PTAL calculations in WebCAT where we calculate walk times from each grid point to nearby transport network access points within specified maximum walk distances. Further outputs at a detailed granular level could be based on walk time to a range of service locations including: primary schools, GP surgeries, libraries, sports facilities, open space, food shopping and local town centres.

Like the proposed CYTAL methodology we still need to agree a number of assumptions based on existing (TfL's London Travel Demand Survey LTDS) or commissioned survey results. These include:

- average walk speed – should we consider different walk speeds for different user classes
- maximum walk distances to individual services
- actual and perceived distance.

LTDS outputs show that the average "walk all the way" trip length is 0.65 km across London and the majority (82%) of such trips are less than a kilometre in length.

Potential usage

We have already produced exploratory analysis calculating walk distance to a number of key locations: town centres and stations. An example output is given in Figure 25 showing walking distance to town centres. The shaded areas show high, medium and low access based on distance. The 960 m interval relates to the maximum walk distance used in the PTAL methodology. The 1 500 m interval was considered an acceptable maximum distance for this analysis but this will need to be supported by further field work to establish appropriate intervals.

Similar analysis has also been used to investigate how the ATOS datasets (based on walking only) could be combined with PTAL data. Figure 26 divides walk times to food shopping locations (defined as the nearest supermarket or town centre) and PTAL scores into two categories each. PTAL levels 4, to 6 and PTAL levels 0 to 3. Good access to food shopping is defined as within 15-minute walk time from any location in London, whilst poor access is more than a 15 minute walk.

Combining and plotting these results identifies four distinct areas

- Area A: PTAL 4 to 6 with good access to local food shopping – dark red
- Area B: PTAL 4 to 6 with poor access to local food shopping – pink
- Area C: PTAL 0 to 3 with good access to local food shopping – light blue
- Area D: PTAL 0 to 3 with poor access to local food shopping – dark blue

Of particular interest is Area C. In these locations there could be the potential for prioritising policy interventions such as those related to TfL's "Healthy Streets" objectives by encouraging more walking trips to local services.

Figure 25. Walking distance to town centres in London

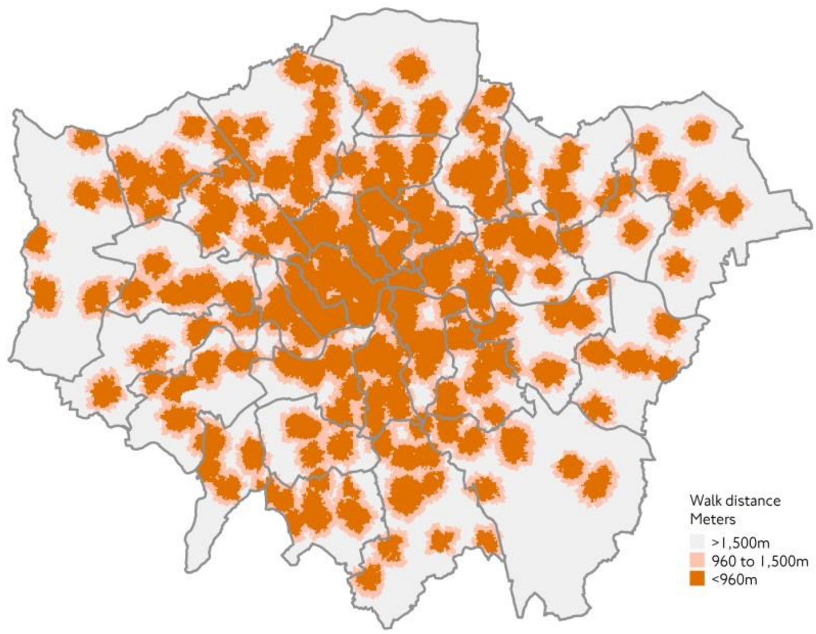
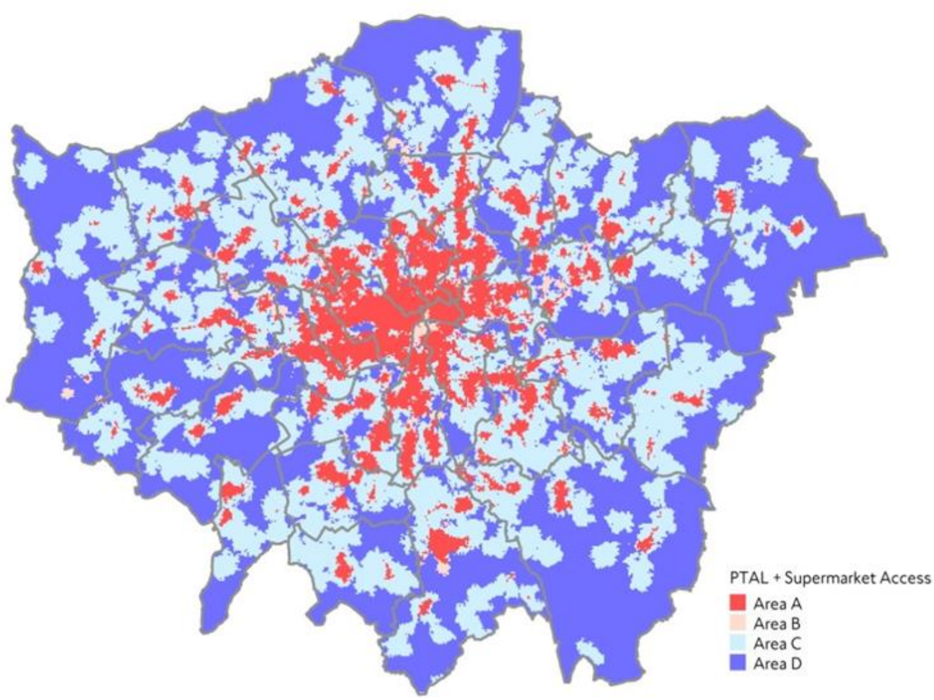


Figure 26. Combining PTAL and walking access to food shopping



Conclusions: Challenges and opportunities

By means of a conclusion, this section presents some of the challenges and opportunities that have arisen whilst developing TfL’s suite of connectivity tools and WebCAT. It also includes some of the topics raised at the ITC workshop on “Improving planning and investment through the use of accessibility indices”. We do not necessarily provide the answers but instead provide topics for further discussion.

Communicating technical concepts to a non-technical audience

WebCAT presents a good example of how TfL’s travel time outputs, derived from complex strategic assignment models, have been made accessible and relevant to both a technical and non-technical audience. Time Out magazine recognised that “it’s used for planners to look at how well areas are connected when planning new buildings. But it’s actually a surprisingly useable tool.”[4]

However, the website does include measures that require more complex interpretation such as ATOS and catchment analysis. Furthermore, we have found it difficult to develop simple measures that define, for example, how cycling connectivity changes with infrastructure investment. Traditional measures rely on travel time improvement whereas cycling investment typically leads to better quality infrastructure rather than reduced journey times directly. Without using complex measures that trade off various ambience characteristics associated with cycling, it will be difficult to develop meaningful measures.

Discussion question: What is the right balance between providing technical detail and complex measures vs ease of interpretation? Which are the key audiences for these types of measures?

Updating our datasets

The transport network datasets used in our connectivity work are derived from our strategic transportation models. The advantage of this is that networks describing future conditions can be produced with limited effort and on a consistent basis to the current year networks. However, the limitation of this approach is that models are updated on a two-three year cycle and so can become out of date quickly, especially where the network is changing significantly.

Discussion question: Is there a benefit to using more real time data to base our connectivity analysis on? What could these datasets be and do the benefits outweigh the cost?

Private modes/highway times

Currently WebCAT does not include private modes of transport. Although it is relatively easy to generate highway and public transport travel time matrices, it is more difficult to provide an acceptable comparison as both operate under different assumptions. For example parking search time and availability is not included within private mode travel time but could be a significant factor in some locations. Furthermore the public transport travel times we use for our connectivity analysis and in WebCAT are based on real/non-generalised time (which does not take crowding and associated factors into account), whilst the value of our highway data is that they are based on congested times.

Discussion question: How important is inclusion of highway measures? How can we mitigate concerns around comparability of public and private modes? How useful are highway measures in promoting the use of sustainable transport?

Connectivity is not just about journey time

TfL's travel time connectivity measures are in most cases based on fastest journey time. However, for many users this is not always the key issue. Journey complexity for example, reducing the need to interchange is often a more important factor. A longer journey that does not require interchange to another service is often preferable to one that is faster. Our step-free analysis has considered some of these issues but TfL will need to expand this analysis further and produce agreed outputs.

Another significant constraint to connectivity experienced by some users is the cost of travel especially when getting to work in central London in the morning peak. WebCAT includes bus as a separate mode which goes someway to accommodate for this issue but TfL will need to investigate further how fares could be incorporated into an indicator that is both transparent and intuitive.

Discussion question: How useful are measures that build in non-journey time attributes? Which use cases would this be required for? What are the associated challenges?

Formalised connectivity indicators vs ad hoc analysis

With WebCAT, TfL has endeavoured to offer relatively simple functionality that is of relevance to a wide range of users: professional planners as well as the general public. The comprehensive list of WebCAT datasets demonstrates the power and flexibility of the application in terms of the user being able to tailor analysis to fit their individual requirements. Except for the PTAL measure, TfL has not provided any formal indicators that quantify good or bad connectivity, leaving this interpretation to the individual user based on their knowledge of the location chosen and the purpose of the analysis. For example a residential property developer could generate a travel time map (based on all modes from the location) and employment catchment statistics to demonstrate how many jobs could be reached from a new housing development. Alternatively a commercial developer may be more interested in how many potential customers could reach a new retail site within the same area. Thus both users require different analysis for potentially the same location.

Discussion questions: Are formalised connectivity indicators required for all circumstances? Should we develop more flexible tools that allow users to undertake their own analysis within agreed parameters?

Notes

1 Mayors Transport Strategy 2017 (https://www.london.gov.uk/what-we-do/transport/our-vision-transport/draft-mayors-transport-strategy-2017)

2 https://www.london.gov.uk/what-we-do/transport/our-vision-transport/draft-mayors-transport-strategy-2017

3 www.tfl.gov.uk/WebCAT

4 https://www.timeout.com/london/blog/tfl-has-a-tool-that-works-outhow-long-it-takes-to-travel-to-anywhere-in-london

London's Accessibility Indicators: Strengths, Weaknesses, Challenges

The paper provides an introduction to London's context and the need for accessibility indicators. It overviews existing indicators developed and used by Transport for London, including: PTAL, ATOS (Access to Services) and catchment- based measures, as well as giving an introduction to TfL's online web portal for connectivity assessment: WebCAT. There is also a review of calculation principles, a summary of user cases and an analysis of the strengths and weaknesses of each method. A second section describes indicators (e.g. PTAL incorporating cycling, and walking catchment analysis) that are currently under development as part of TfL's commitment towards prioritising healthy streets and sustainable modes of transport. The final section focuses on challenges and opportunities identified during the development of these indicators.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
T +33 (0)1 45 24 97 10
F +33 (0)1 45 24 13 22
contact@itf-oecd.org
www.itf-oecd.org

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