GLA Economics - Accessibility and Employment Forecasts

A report by Volterra Partners, April 2016

Volterra

1 Introduction

How future employment growth is distributed geographically is important for the London Plan and long term planning generally. The London Plan adjusts its trend-based employment growth forecast using a process known as triangulation taking account of:

1. **The historic trend** – what is the predicted growth of each borough based upon previous trends?
2. **Site capacity** – how much development is an area able to accommodate?
3. **Transport accessibility** – how will future accessibility change and how might that affect the distribution of employment?

The historic trend in employment provides the basis for the London Plan forecasts; these may then be adjusted in the light of variations in site capacity and transport accessibility. Transport changes are generally delivered in large projects in specific locations which take many years to plan and deliver, these projects can shape where future development takes place. Past trends in transport accessibility are therefore not a good measure of where future changes in development will occur.

This process has been followed since 2004. Figure 1 describes the broad approach.

2 Data

Outputs from the London Transportation Study (LTS) model enable the quantification of transport accessibility between all zones in Greater London for a base year (2011) and a future year (2031). Those model outputs allow:

- The calibration of a base year relationship between transport accessibility and employment density. This base year relationship shows the correlation between transport accessibility and employment density.
- Quantification of future accessibility for the future year. These take into account both changes in transport supply (improvements to existing services, creation of new services such as Crossrail 1) and changes in transport demand from growth in population and employment which increase crowding on both road and rail.

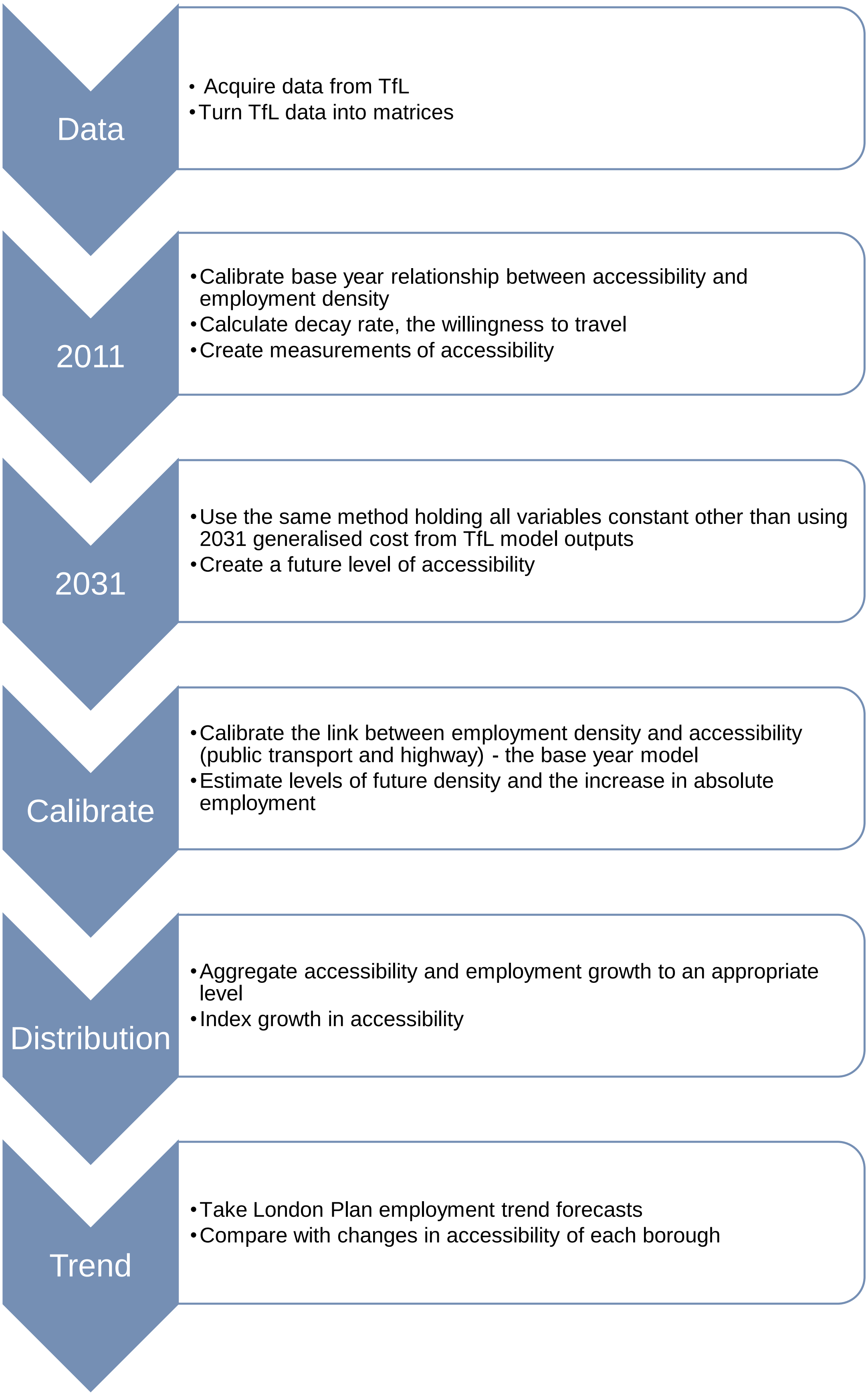
The TfL data can be used to plot future accessibility changes by individual transport zone which can then be aggregated up to a borough level – the geographic scale at which the London Plan is applied.

TfL provided travel time and generalised cost data for each origin destination (OD) pair for a base and a forecast year (2011 and 2031 respectively):

- Public Transport (PT) generalised cost of travel;
- PT demand;
- Highway (HW) generalised cost of travel;
- HW demand;
- 2011 Population and Employment by LTS zone;
- Percentage of green space in each zone.

The generalised cost (GC) of travel is the generalised time taken to travel plus any financial costs expressed in generalised minutes; allowing time and monetary costs to be expressed in a single value. The 2031 generalised cost was generated by TfL using employment forecasts produced in July 2015.

Figure 1: Process Chart



3 2011 Base Year Calibration

The first stage of the process is to calibrate the 2011 base year. The base year is important because it is real: it shows the existing relationship between transport accessibility and development density. Any changes to the "trend-based" London Plan forecasts use the existing 2011 relationship to determine how much future transport changes might change the distribution of employment.

The base year relationship is determined by a gravity model calculation which looks at the costs of travel (time and money) between all zone pairs as well as the numbers of jobs and residents in each zone.

Definition of Accessibility

The density of employment is closely linked to access to labour. Accessibility to population (labour) is measured using the following formula using a decay rate.

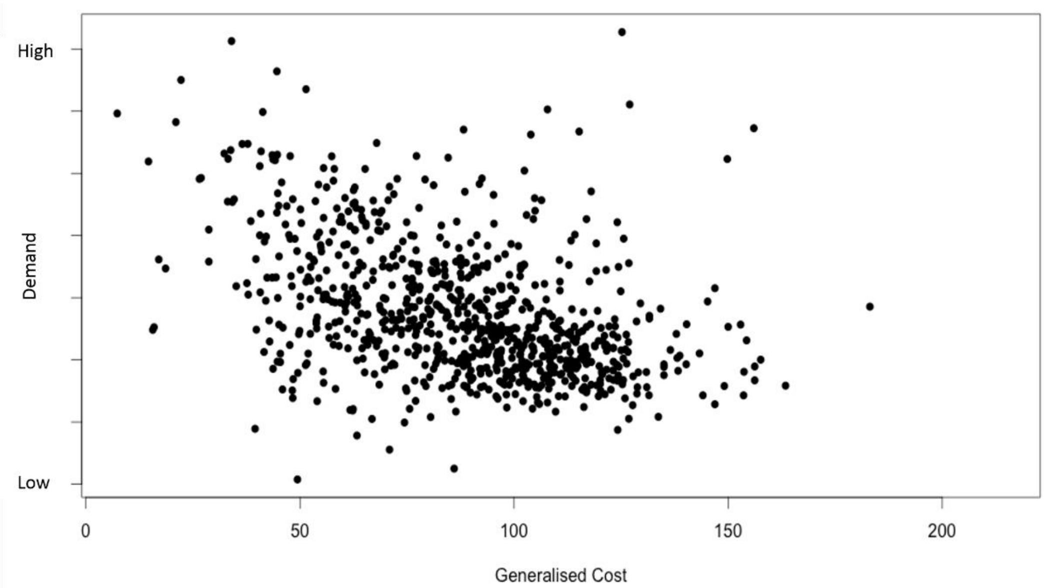
$$Access\ to\ Population = \sum Population * \exp(DR * Generalised\ Cost)$$

This is done for each OD pair separately for both Highway and Public Transport modes. The data is then summed to produce an 'accessibility' score for each zone which is then correlated to actual employment densities.

Decay Rate

The decay rate represents people's willingness to travel. It is based on the distribution of trips according to the GC of travel. In general terms people prefer to make short trips rather than long ones, but there are exceptions, as discussed below.

Figure 2: Example of a component of the decay rate



For each zone a log-linear model of the relationship between the GC of travel and the demand to travel to each zone was derived. As shown in Figure 2 this is a negative relationship with willingness to travel reducing as GC increases. An average of the coefficients is taken and applied to the formula above as the decay rate. This is done separately for both Highways and PT.

Using a uniform decay rate assumes that people's willingness to travel to each zone is the same. Figures 3 and 4 show that they can be very different. Figure 3 shows the distribution of trips according to GCs of trips to a typical outer London zone. It shows a steeply declining trip rate as GC increases, so many more people make trips to outer London destinations if the GC is less than 50 generalised cost minutes (gcm) and almost nobody makes a trip of more than 150 gcm.

Figure 3: Decay rate to outer zone

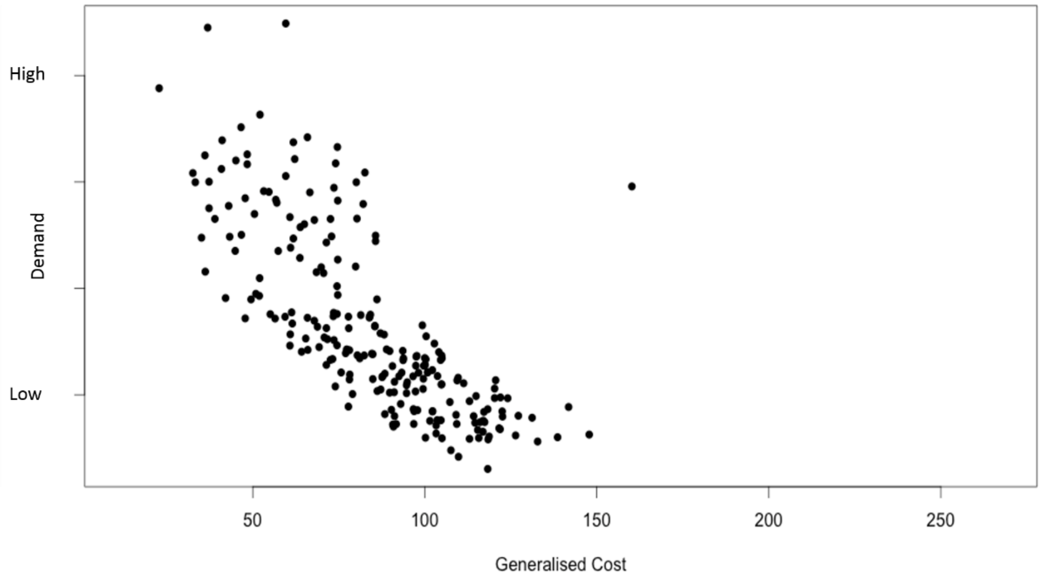
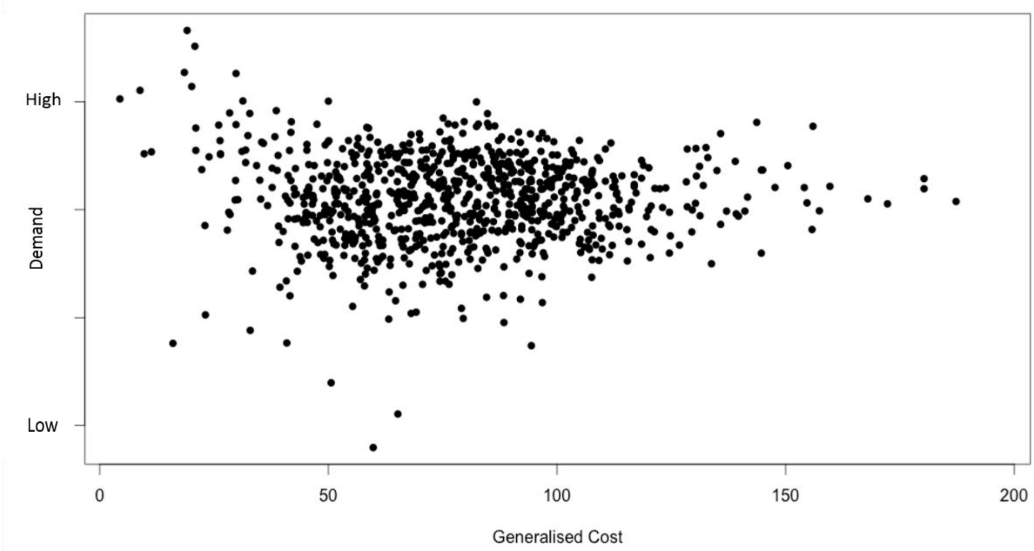


Figure 4: Decay rate to central zone

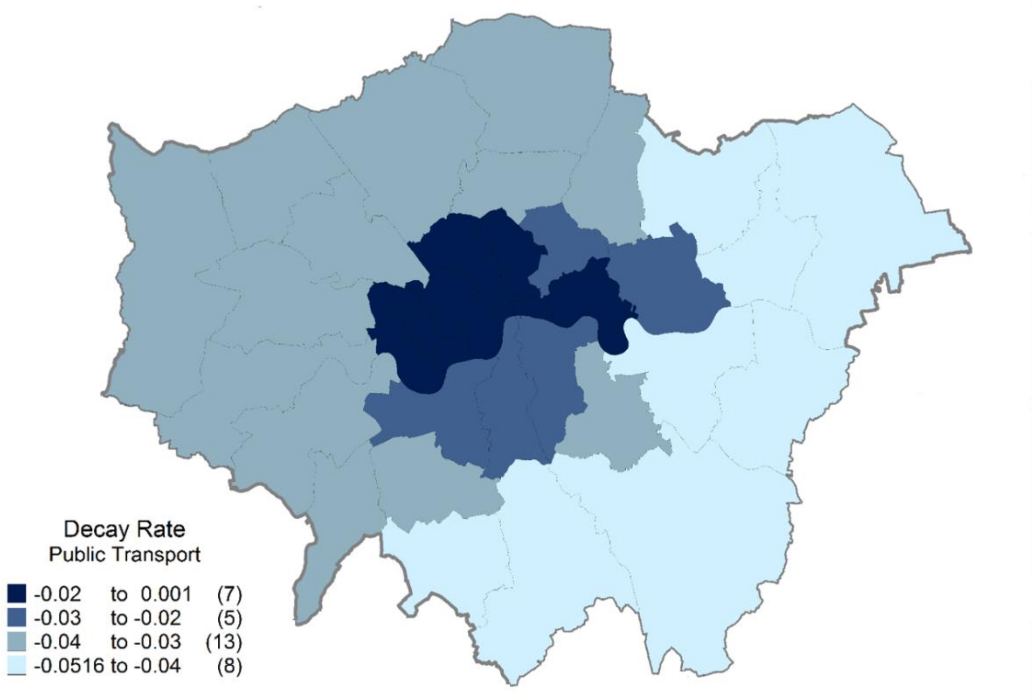


Travelling to a central zone has a smaller decay rate coefficient than travelling to an outer zone. People are much more willing to travel further to locations where earnings are higher and/or where specialist services are available. Thus the decay rate in Figure 4 is close to zero, in the morning peak period people are just as likely to travel to central London if GC is 50 as they are if GC is 150 two examples make this clear:

- Commuting distances to the City are much higher than commuting distances to outer London locations. Higher salaries in central London make it worthwhile to commute longer distances.
- The same is true for retail. Nobody would drive 15 miles to visit a convenience store, but people do travel long distances to visit the major stores on Oxford Street and specialist suppliers on Bond Street.

For this study, decay rates have been averaged at a borough level (the same level of geography used for the London Plan). Figure 5 shows the average of the decay rates for each borough.

Figure 5: PT Decay Rates



Mode Shares

In order to take appropriate account of Highway and Public Transport accessibility the two measures are weighted according to their share of travel for each OD pair. This produces strong weights for trips on PT into the centre and for highway when making orbital trips.

Figure 6 shows the calibration between accessibility and employment density by transport zone across Greater London. With PT and HW combined, accessibility explains 60% of the variations in employment density across Greater London. It is possible to get a slightly higher calibration (70%) by excluding highway accessibility and using PT only, but using both modes is the preferred approach.

Figure 6: Final Zone calibration

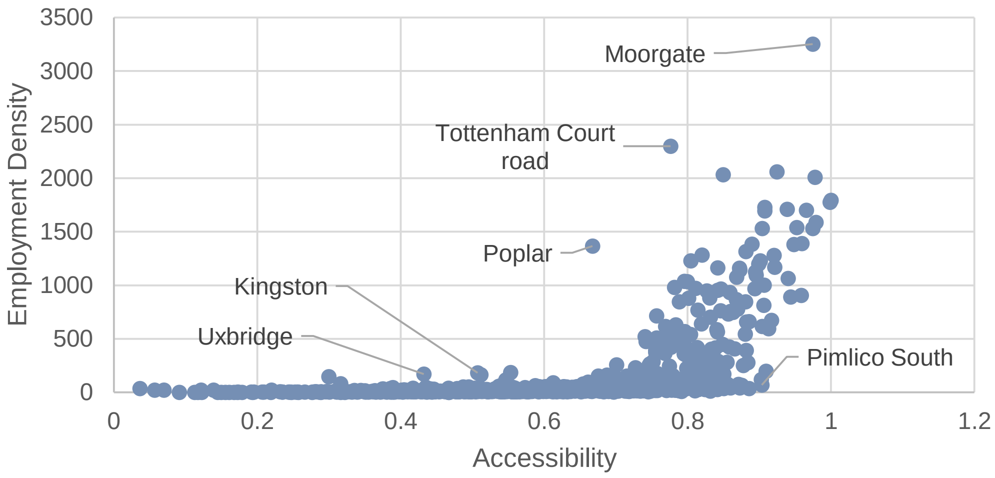


Figure 6 shows larger variations in density when accessibility is high and less when accessibility is low. The only areas with low accessibility and relatively high employment density are regional shopping centres such as Kingston and Uxbridge. Areas of high accessibility range from Moorgate and Tottenham Court Road, which have high employment densities, to Vauxhall and Waterloo, areas with low employment densities (although Vauxhall is currently undergoing dramatic development and plans for increased employment at Waterloo are underway).

Figure 7 shows the same relationship at a borough level.

Figure 7: Final zone calibration aggregated to borough level

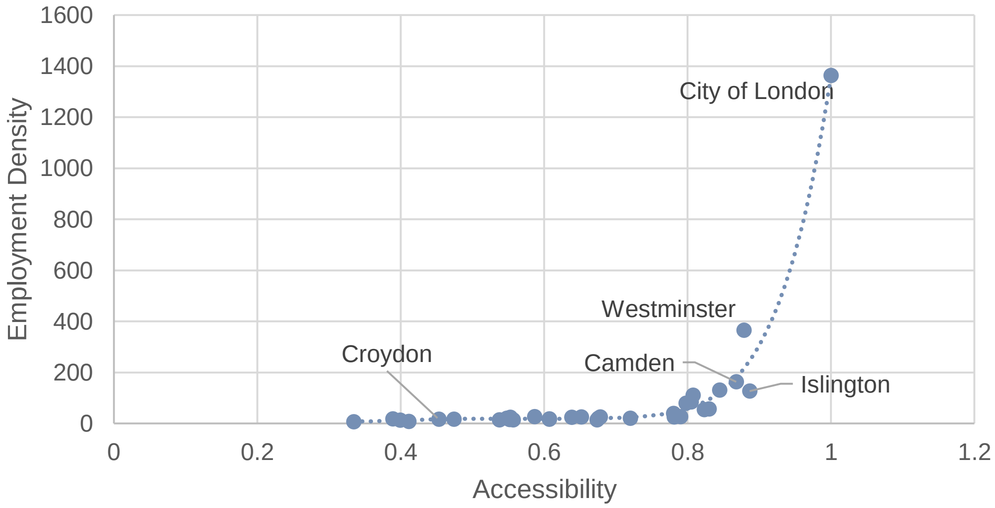


Figure 8: Population and employment relationship

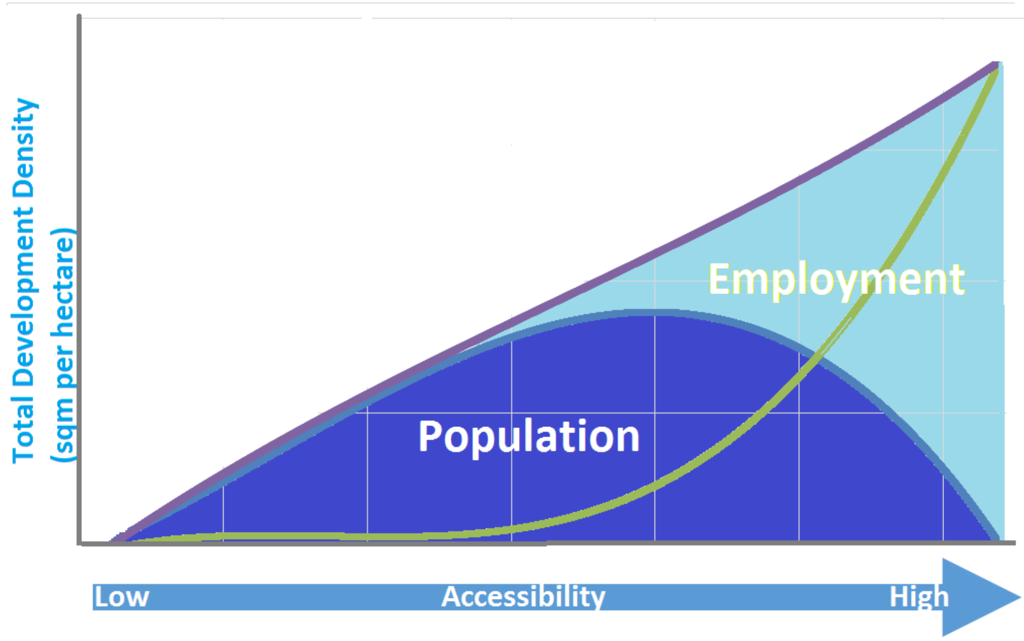


Figure 8 shows the relationship between population and employment density. As accessibility rises at lower levels population density rises, while only small increases in employment density are seen. However, as accessibility reaches very high levels, employment density increases rapidly and population densities decline; here residents are priced out of the market due to the high value of commercial space.

Areas with high accessibility are attractive to employers due to their larger catchment area for both workers and customers. This encourages higher development density and increases land values and rents.

4 Future Changes in Accessibility

Data from 2011 shows a strong relationship between transport accessibility and employment density. This chapter considers how future changes in transport accessibility are likely to affect future patterns of employment growth.

Future predictions are made by replacing the 2011 base year zone to zone GC matrices (PT and HQ) with the 2031 GC matrices. This provides a measure of the change in transport accessibility provided by the expected supply changes, albeit with some additional crowding from the demand growth between 2011 and 2031. The 2031 forecasts include all committed/funded TfL schemes, a list of those scheme sis provided in Appendix B.

Using 2011 demand, the use of borough specific decay rates produces the most sensible figures and ones consistent with the London Plan. These measures of accessibility will capture both the willingness to travel to the centre via PT and the attractiveness of outer boroughs to trip makers. We therefore continue to use these measures of accessibility.

Distribution

The distribution of future employment growth will be driven by the change in accessibility to each particular zone. Figures 9 - 11 show the changes in accessibility between 2011 and 2031 for highways, public transport and the two combined.

Figure 9: Changes in Highway accessibility (%) 2011-2031

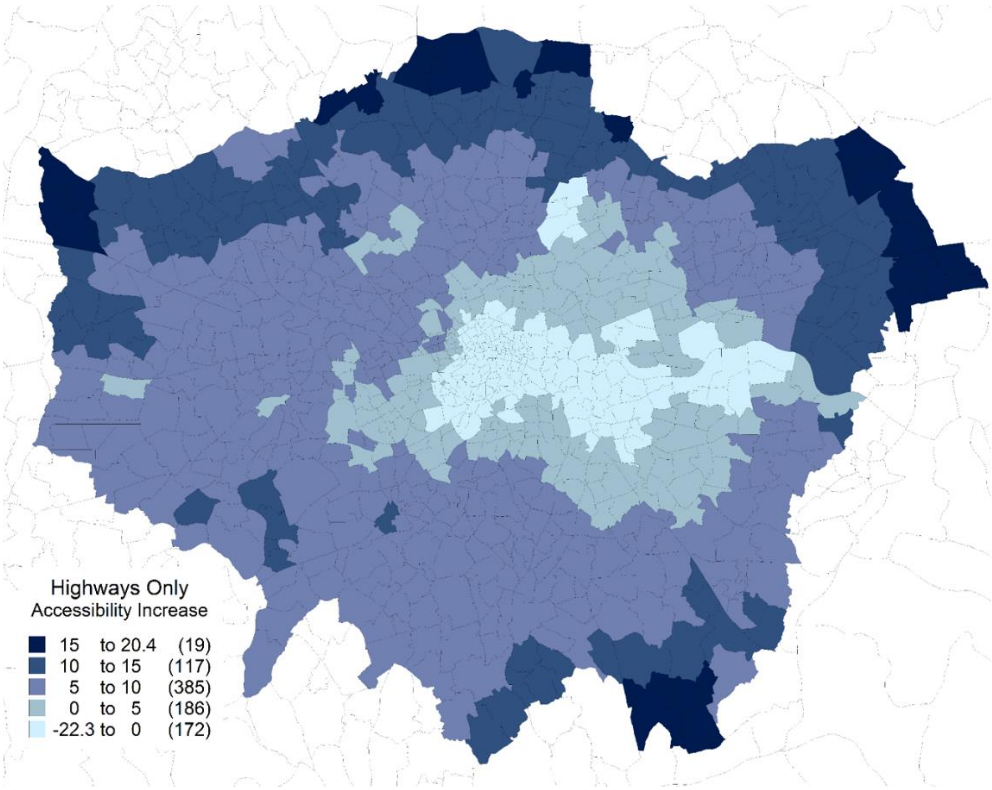
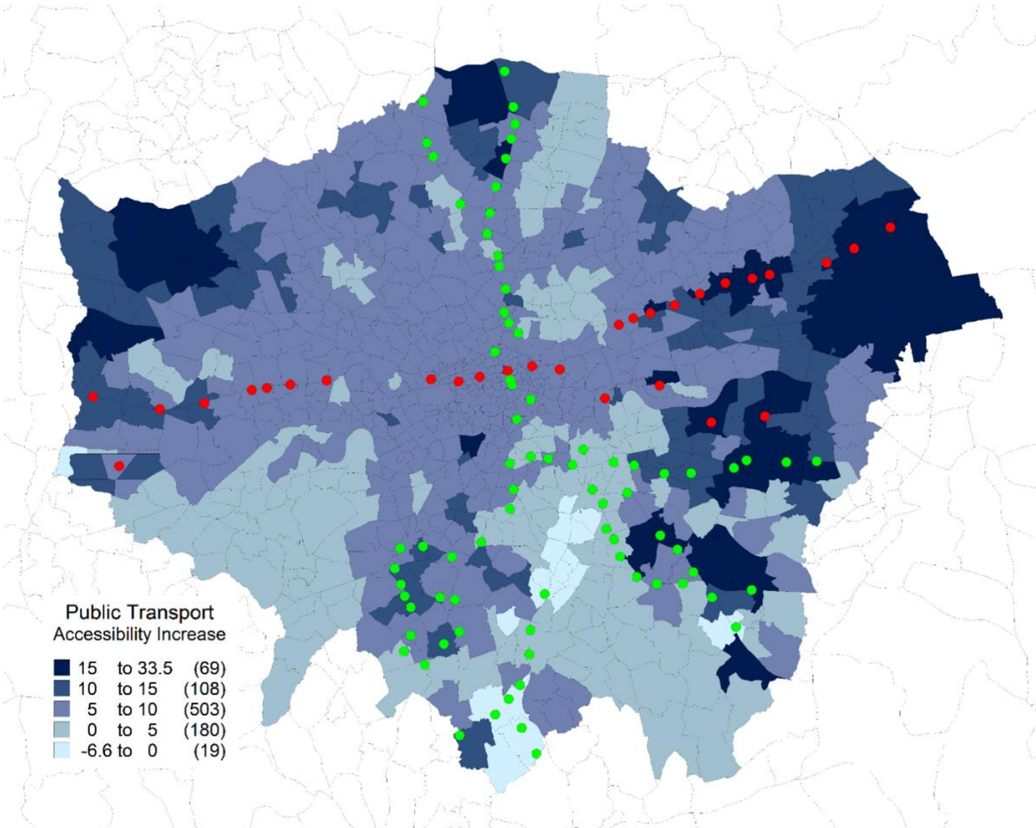


Figure 10: Changes in PT accessibility (%) 2011-2031



NB: red dots are Crossrail stations and green dots are Thameslink stations

Figure 11: Changes in PT and Highway accessibility (%) 2011-2031

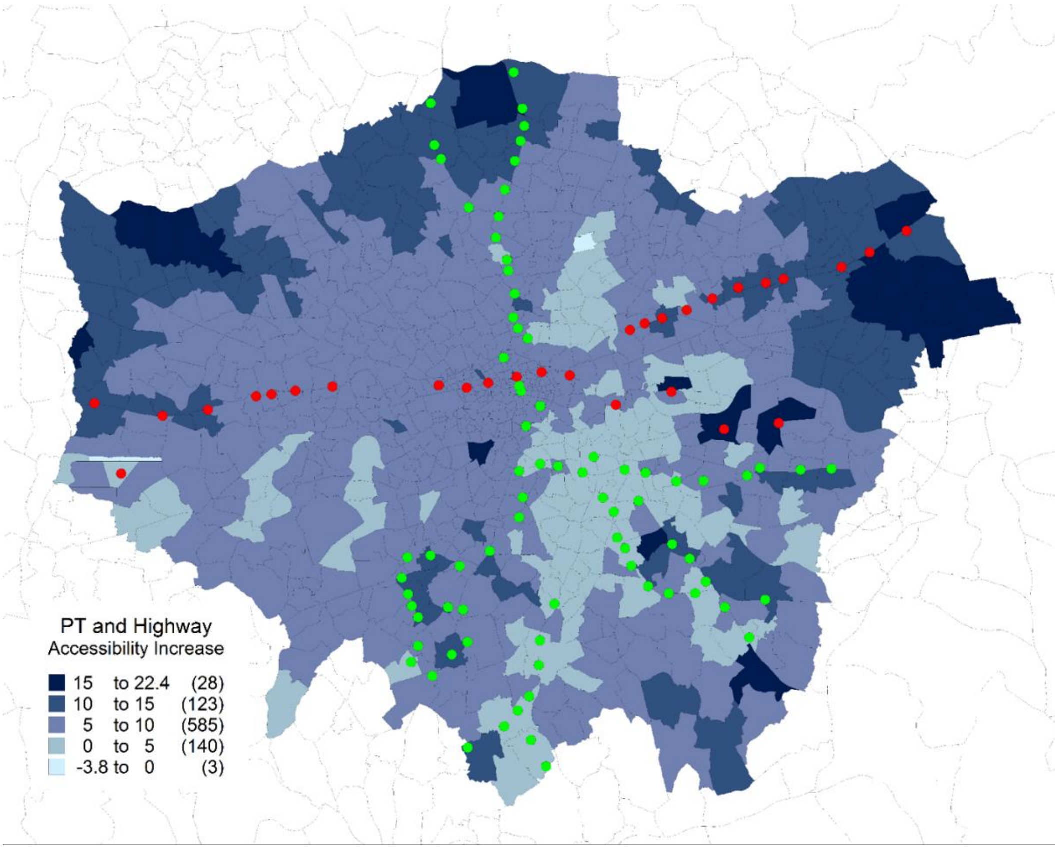


Figure 9 shows increases in highway accessibility in the north and especially north west London. These are driven by improvements to the M25 and the North Circular. Highway accessibility declines in central and inner east London. Public transport accessibility improvements follow the two main rail improvements, Crossrail and Thameslink, although many other improvements are included, notably the LUL upgrade programme. Figure 11 shows the combination of changes in public transport and highway accessibility. Overall, Figure 11 shows central and north west London to be the main beneficiaries, with east London gaining from Crossrail. South of the river improvements in accessibility are smaller and restricted largely to Thameslink and the SE branch of Crossrail.

5 Public Transport Capacity Constraint

Accessibility:density is a useful tool for analysing the impact of transport accessibility changes on development density. A potential constraint on increases in employment is the impact of crowding. Employment growth at a destination with very busy links may be constrained because people are not prepared to put up with the level of crowding (on rail) or journey time and unreliability (on highway) to commute to this destination. The transport models do consider on-train crowding by increasing the generalised cost of using a crowded service, but do not take full account of capacity constraints. The LTS model:

- Has no absolute capacity constraint on rail or bus, such that every passenger can always board the first train/bus. This leads to some loadings in the model in excess of actual or operational rail capacity.
- Does not model capacity constraints at stations.
- Has no link between level of on-train/bus crowding and either dwell times or overall journey times.

There is no easy way to take account of public transport crowding including all the points listed above. This analysis suggests a simple approach, based on studying links across a number of cordons. There are a number of limitations to this, these are identified within the report. This analysis is intended to provide a simple approach to identifying where capacity constraints on the London Underground and National Rail network might bite. The focus has been on central London.

There are a number of approaches to measuring crowding, including Select Link Analysis for public transport and ratio of free-flow over actual time for highway. The only data that was available for this analysis was link flows, so those have been used to look at cordon data around specific areas.

Cordon Analysis

The crowding analysis compares demand and capacity of inbound links across a number of cordons. The benefit of this approach is that it is easily understood and gives an idea of crowding into the densest employment areas in London. The following cordons are analysed in this analysis:

- Central Activities Zone (CAZ);
- London Borough of Camden;
- City of London;
- London Borough of Tower Hamlets;
- City of Westminster;
- Isle of Dogs.

Only inbound rail links have been considered because the model covers the AM peak period. This data is available for 2011, 2031 and 2041 (2041 only adds Crossrail 2 to the 2031 scenario) thus capacity and crowding is compared across these years. Between 2031 and 2041 the only scheme assumed to be introduced is Crossrail 2.

Definition of capacity

This analysis is based on a single definition of capacity, Planning Guidance Capacity (PGC). PGC assumes that the seating and standing capacities are not 100% utilised. It is assumed that only 67% seat and 40% of "crush" standing capacities are utilised to give PGC.

PGC is defined as:

$$PGC = (67\% * seat) + [40\% * (crush - seat)]$$

Where:

$seat$ = seating capacity

$crush$ = crush capacity (seating + standing capacity)

PGC is not the only definition of capacity, it is represents a "target" level of crowding, but one that is exceeded on almost every underground line in the peak hour on a daily basis.

Quantifying crowding

Crowding is defined as the ratio of demand over PGC. As the data is for the AM peak period, and there is a recognisable peak hour where crowding is at its worst, we apply a factor to both demand and supply to calculate peak hour crowding. As supply (capacity) is relatively fixed, demand (flows) increases relative to supply in the peak hour. TfL indicate that the peak hour comprises 54% of the peak period demand, but only 33% of supply; crowding in the peak hour is much higher than across the peak period.

In addition to this we also apply a reliability factor to take into account delays and cancellations. The factor applied across all lines is 94% which is the factor for London Underground services, the factor for National Rail services is 93% although using the London Underground factor for all links is a reasonable assumption. Demand for the peak hour is calculated as:

$$Crowding = \frac{dpfact * flows}{PGC * rel/spfact}$$

Where:

$dpfact$ = demand peak factor

$spfact$ = supply peak factor

rel = reliability

Using the above we derived a percentage of demand over PGC for each link in 2011, 2031 and 2041. A link is defined as a "black" link by TfL if the ratio is 150% or larger.

Limitations to this approach

There are two main limitations to the cordon approach. First, as crowding in a cordon is an average of all demand and capacity across the cordon, the crowding measure underestimates crowding if some links into the cordon are not as busy as others. Thus, links approaching the City cordon from the east are busier than those from the west. From the west many users have already alighted in the West End, but from the east demand is at its peak. If the overall crowding figure for the City cordon is a simple average this underplays the level of crowding actually experienced by passengers. The results also show crowding weighted by demand. Thus if more people experience the crowded conditions this number will be relatively larger. The top five most crowded links for each cordon are highlighted which further mitigates this problem.

Second, the cordon analysis only shows the crowding for the link crossing the cordon. If a particular link into the cordon is crowded, but links prior to this are not, this could suggest the capacity constraint is not as significant as it would appear with the cordon analysis. To try and address this issue maps of links into a number of cordons are presented to give a better picture of crowding leading up to the cordons.

Cordon Results

The results from the cordon analysis in the AM peak hour are shown below. Arrows indicate the change between periods.

Table 1: Central Activities Zone

	2011	2031	2041
D	647,346	946,933	1,027,029
PGC	500,004	783,412	816,684
D:PGC	129%	121%	126%
D:PGC (demand weighted)	140%	130%	136%

Table 2: London Borough of Camden

	2011	2031	2041
D	304,694	485,607	516,041
PGC	259,477	455,574	467,749
D:PGC	117%	107%	110%
D:PGC (demand weighted)	137%	124%	128%

Table 3: City of London

	2011	2031	2041
D	270,753	411,652	449,076
PGC	227,375	380,876	405,501
D:PGC	119%	108%	111%
D:PGC (demand weighted)	131%	120%	122%

Table 4: London Borough of Tower Hamlets

	2011	2031	2041
D	221,823	340,232	369,537
PGC	252,909	367,436	381,000
D:PGC	88%	93%	97%
D:PGC (demand weighted)	117%	117%	122%

Table 5: City of Westminster

	2011	2031	2041
D	365,867	525,069	561,411
PGC	305,534	472,289	496,869
D:PGC	120%	111%	113%
D:PGC (demand weighted)	132%	121%	124%

Table 6: Isle of Dogs

	2011	2031	2041
D	55,005	101,853	109,240
PGC	43,466	79,322	79,322
D:PGC	127%	128%	138%
D:PGC (demand weighted)	140%	133%	142%

Tables 1-6 all show high levels of crowding. The majority show a similar pattern, with crowding across the cordon improving from 2011 to 2031, before deteriorating again in 2041. Only Tower Hamlets (with the Isle of Dogs a subset of this) has higher crowding in 2031, although this is starting from a lower base. This data indicates that the CAZ and Isle of Dogs are the most crowded cordons and whilst the CAZ improves marginally over the modelled years, the Isle of Dogs gets slightly worse.

The top five most crowded links for each cordon, in 2011 and 2031, are presented in the following tables. These figures indicate:

- The compositions of the top five changes over the two periods. Some links (e.g. Whitechapel to Canary Wharf) can be explained by a new line (such as Crossrail), others are due to changes in relative levels of crowding across existing links;
- Crowding appears to slightly improve between 2011 and 2031 for many of the links that remain in the rankings for both years;
- Links on Crossrail (Canada Water/Whitechapel to Canary Wharf) are largely black by 2031.

Table 7: Central Activities Zone

Line			2011	Line			2031
Vic	Highbury	Kings Cross	197%	Vic	Highbury	Kings Cross	196%
Sou	New Cross	London B.	184%	Cen	Bethnal G.	Liverpool St	183%
SE	Deptford	London B.	178%	Vic	Finsbury P.	Kings Cross	172%
Cen	Bethnal G.	Liverpool St	178%	SWT	Queenstow'	Vauxhall	167%
Sou	B'sea Park	Victoria	176%	Vic	Euston	Kings Cross	163%

Table 8: London Borough of Camden

Line			2011	Line			2031
Vic	Highbury	Kings Cross	197%	Vic	Highbury	Kings Cross	196%
Nor	Tufnell P.	Kentish T.	181%	Cir	Baker St.	G. Portland	171%
Cen	Chancery	Holborn	173%	Nor	Tufnell P.	Kentish T.	169%
Sou	Cricklew'd	W. Hampst.	162%	Dis	Queens P.	Kilburn H.	147%
Cen	Oxford C.	TCR.	153%	Sou	G. Portland	Euston	146%

Table 9: City of London

Line			2011	Line			2031
Nor	London B.	Bank	193%	Nor	London B.	Bank	186%
W&C	Waterloo	Bank	178%	Cen	Bethnal G.	Liverpool St	183%
Cen	Bethnal G.	Liverpool St	178%	W-C	Waterloo	Bank	173%
Nor	Moorgate	Bank	157%	Nor	Moorgate	Bank	149%
Sou	Elep. & Ca.	Blackfriars	157%	XR	Whitechap'l	Liverpool St	141%

Table 10: London Borough of Tower Hamlets

Line			2011	Line			2031
Jub	Canada W.	Canary Wh.	174%	Cen	Stratford	Mile End	174%
Cen	Stratford	Mile End	165%	XR	Stratford	Whitechapel	167%
Cen	Stratford	Liverpool St	146%	Jub	Canada Wa.	Canary Wh.	158%
Jub	N. Greenw.	Canary Wh.	138%	Dis	West Ham	Bromley	147%
Dis	West Ham	Bromley	127%	Jub	N. Greenw.	Canary Wh.	144%

Table 11: City of Westminster

Line			2011	Line			2031
Vic	Warren St.	Oxford C.	205%	Vic	Warren St.	Oxford C.	192%
Jub	Waterloo	Westminster	179%	H-C	Acton	Paddington	161%
Sou	B'sea Park	Victoria	176%	Jub	Waterloo	Westminster	152%
H-C	Acton	Paddington	153%	Cir	Blackfriars	Temple	144%
Cir	Blackfriars	Temple	140%	Cir	Acton	Paddington	141%

Table 12: Isle of Dogs

Line			2011	Line			2031
Jub	Canada W.	Canary Wh.	174%	Jub	Canada Wa.	Canary Wh.	158%
Jub	North G.	Canary Wh.	138%	Jub	North G.	Canary Wh.	144%
DLR	Poplar	W. India	97%	XR	Custom H.	Canary Wh.	120%
DLR	W. Ferry	W. India	81%	XR	Whitechap'l	Canary Wh.	115%
DLR	Cutty Sark	Island Gar.	69%	DLR	Poplar	W. India	109%

Cordon results

Figures 12 and 13 map how crowded individual links are into the CAZ in 2011 and 2031. These figures highlight that many of the links from the north and south of the CAZ are at or near to capacity, whilst crowding from the east and west is less severe. The majority of links into terminals such as London Bridge and Kings Cross are highly crowded, although there are some visible improvements in the later years (this is particularly visible for links into London Bridge). Links into Vauxhall, Elephant & Castle, Euston, Kings Cross, Paddington and Liverpool Street have notable crowding in all years. Crossrail does not appear to make east and west links significantly less crowded.

Crowding into the Isle of Dogs is illustrated in Figures 14 and 15. This suggests there is a clear impact on crowding in the 20 year period, with links, particularly to the south of the Isle of Dogs, notably less crowded. It is possible that Crossrail releases the capacity on these routes.

Cordon Conclusions

It is difficult to draw robust conclusions from the capacity analysis. Our thoughts are:

- All areas tested are subject to crowding to a broadly similar degree;
- The majority improve between 2011 and 2031, before getting worse by 2041;
- Overall changes in crowding are not large.

This suggests that transport supply is broadly in line with demand. Crossrail and Thameslink are both delivered in stages of 2011-2031 so there are some good years ahead.

Figure 12: Crowding in the CAZ 2011

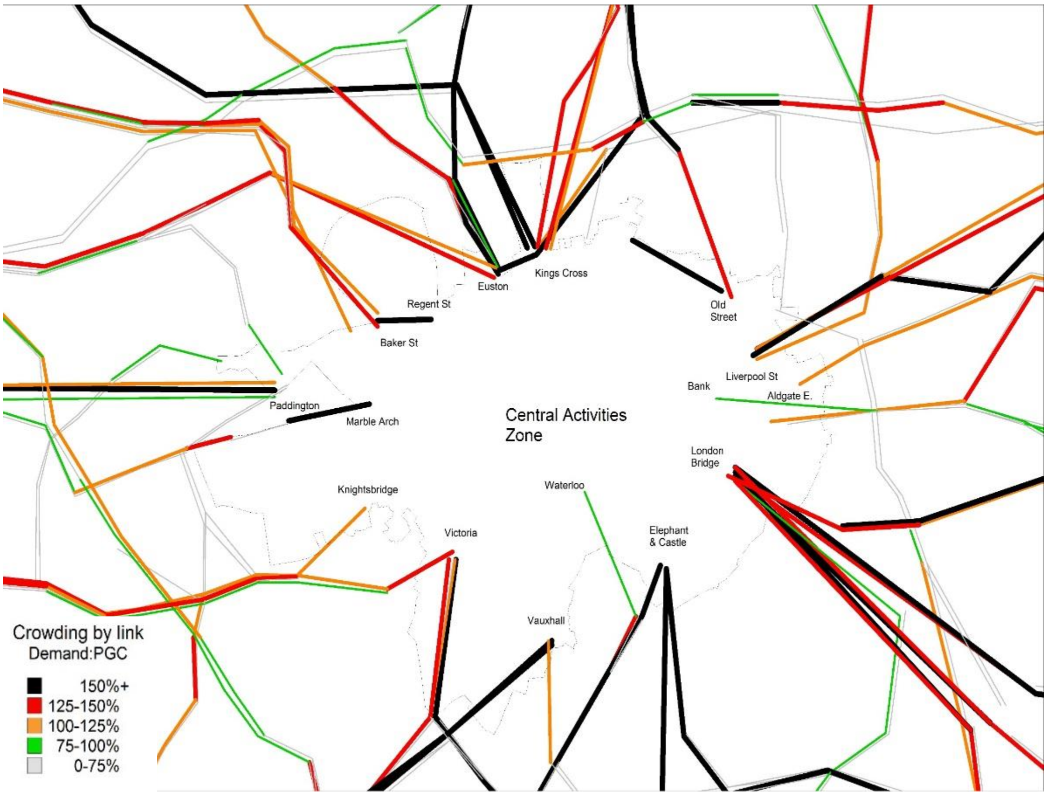


Figure 13: Crowding in the CAZ 2031

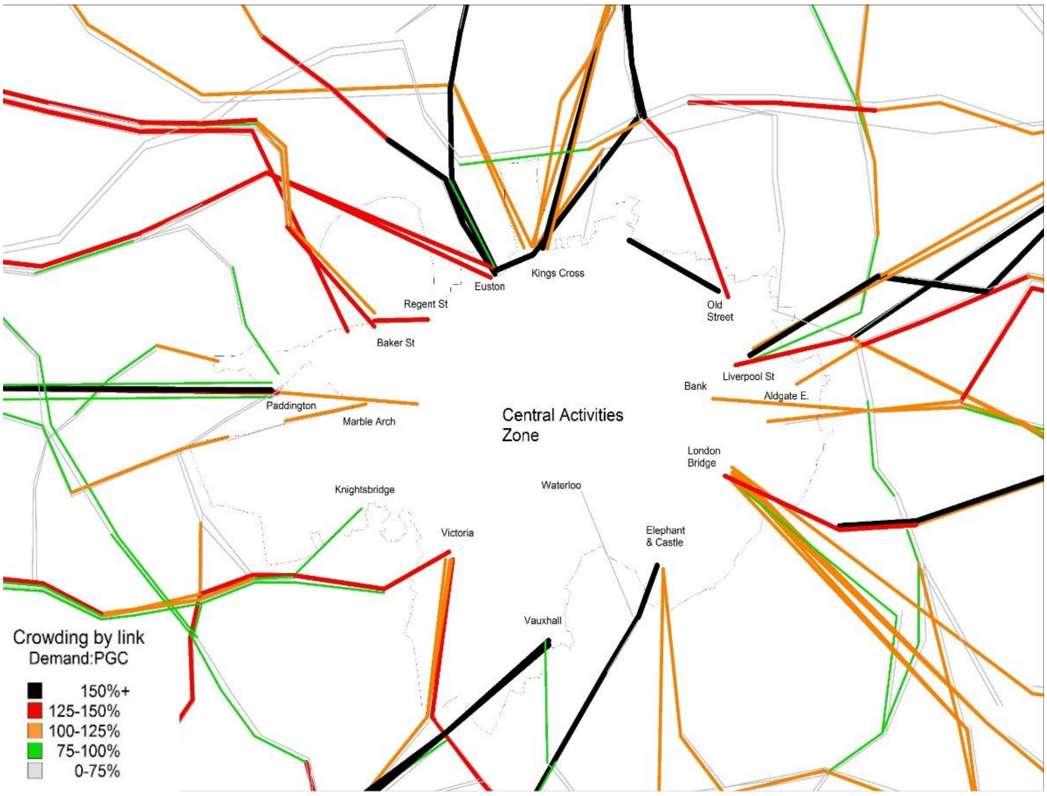


Figure 14: Crowding in the IoD 2011

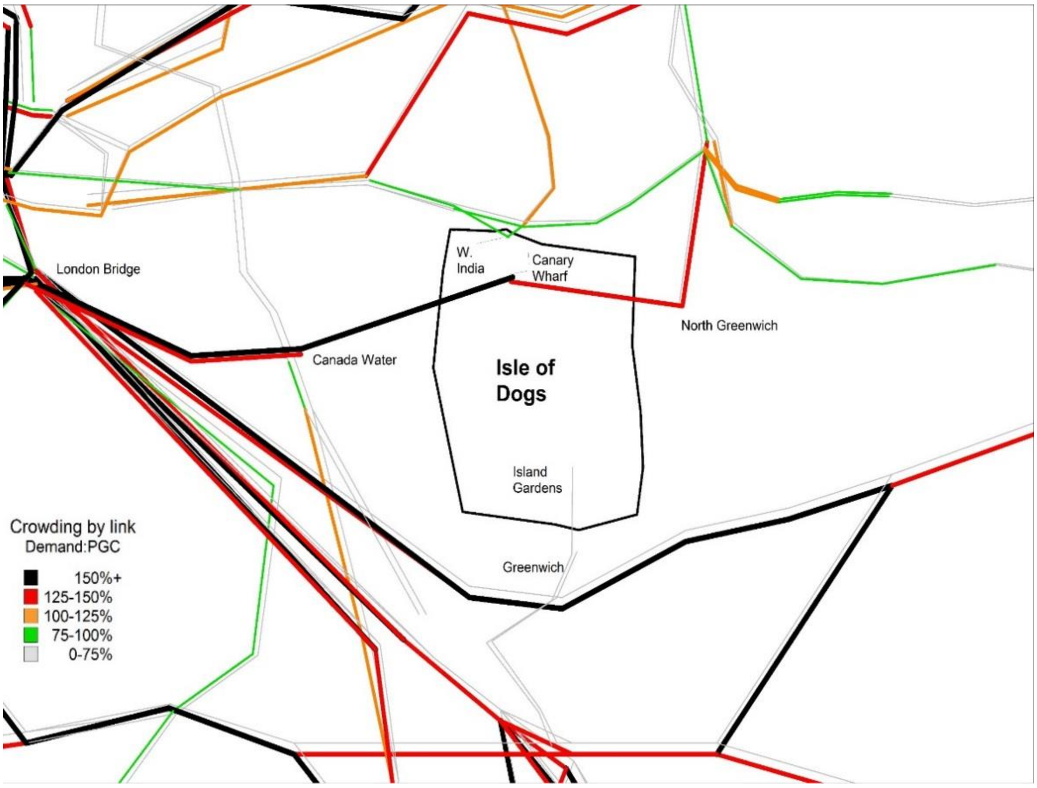


Figure 15: Crowding in the IoD 2031

6 Conclusions and Application

This section sets out a framework for using the accessibility changes estimated in this report as part of the GLA triangulation method. It is intended to be a straightforward method based on a number of options that will give the GLA flexibility in application.

It starts from the basis that London is a city with very strong links between transport accessibility and development density. That is why the triangulation approach is important, variations in accessibility have real impacts on how growth is distributed.

Accessibility Levels

Table 13 shows indexed levels of accessibility (PT and Highway) by borough, set so that the maximum value of accessibility is 100 (City of London 2031). The City is top, Islington second, Westminster third, Camden fourth and Tower Hamlets fifth. Accessibility changes are shown by geography in Figures 9, 10 and 11.

Table 13: Accessibility by borough (Indexed to maximum value in 2031)

Borough	Accessibility	
	2011	2031
Barking and Dagenham	50	54
Barnet	56	62
Bexley	37	40
Brent	63	68
Bromley	38	41
Camden	80	87
City of London	93	100
Croydon	42	44
Ealing	60	66
Enfield	52	56
Greenwich	56	60
Hackney	77	81
Hammersmith and Fulham	74	80
Haringey	72	78
Harrow	51	57
Havering	31	36
Hillingdon	36	40
Hounslow	54	58
Islington	82	89
Kensington and Chelsea	75	81
Kingston	51	54
Lambeth	76	81
Lewisham	63	65
Merton	59	64
Newham	73	79

Borough	Accessibility	
	2011	2031
Redbridge	62	68
Richmond	51	54
Southwark	75	78
Sutton	44	47
Tower Hamlets	78	83
Waltham Forest	67	71
Wandsworth	72	78
Westminster	81	88

How Might Accessibility Changes Drive Changes in Density?

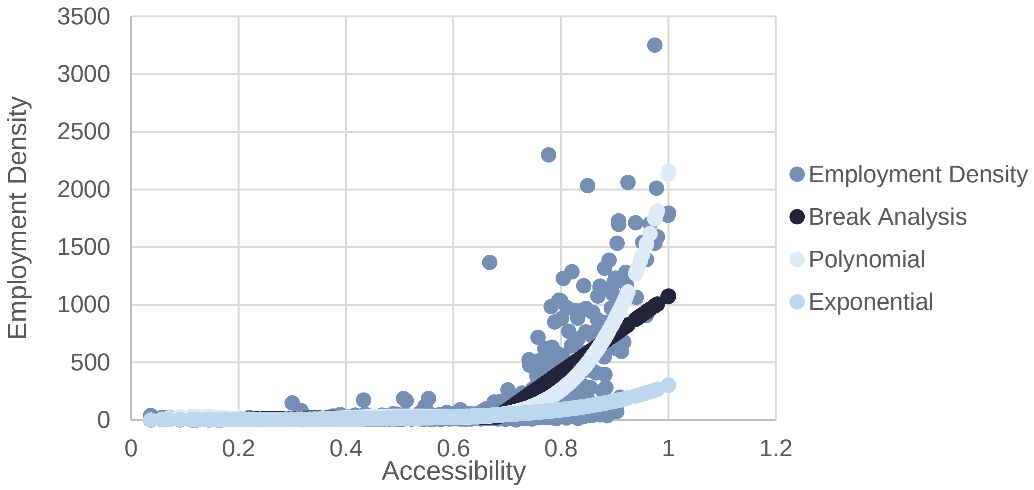
Chapter 2 described the base year (2011) analysis and the relationship between accessibility and density. Applying that to the future means using static cross-sectional analysis to predict future dynamic changes. That has some risks associated with it, but essentially assumes that over time future accessibility changes will result in similar development densities as those in 2011.

The curve(s) defining the relationship between accessibility is very flat for most of London, but changes dramatically in central London where accessibility reaches a peak. At high levels of accessibility the range and variance of density compared to accessibility increases rapidly. There are many zones with very high densities but also a number with very low densities. Over time we have seen many of the highly accessible but low density zones transformed including King's Cross, London Bridge and Paddington. Others are currently being developed, notably Vauxhall/Nine Elms and Elephant and Castle.

In order to recognise the uncertainty we have developed three alternative accessibility:density curves. Each of these has a different correlation for the base year and each produces a different forecast of employment change in central London. The combination of the three provides a range of answers rather than a single number. The curves are shown in Figure 16. The three curves and their distribution correlation with the pure GLA trend are:

1. Exponential curve (correlation 0.43)
2. Polynomial (correlation 0.66)
3. Break Analysis (correlation 0.40)

Figure 16: The three curves used to estimate the distribution of jobs



All three curves are statistically significant. The curve which gives results that are most alike the GLA trend forecast is the polynomial (correlation of 0.66). The steepness of this curve at higher levels of accessibility results in larger increase in employment in central locations. In contrast, the exponential gives a stronger share to the outer boroughs.

Break point analysis separates the data into two linear models at the point where there is a significant change in accessibility. The first linear model is relatively flat, so increases in accessibility have a relatively small impact on employment density, whereas the second model is far steeper and increases in accessibility translate into large increases in employment. The break point is generally around the zones on the boundary between outer and inner London.

As a result of this, the main impact of the different curves is on those areas surrounding the Central Activity Zone (CAZ). These areas are typically before the tipping point of the polynomial curve but after the break point. Thus these areas see higher employment growth under the break analysis curve. The exponential curve, on the other hand, does not get very steep at any point, so areas surrounding the CAZ, and those within the CAZ, see similar levels of employment growth.

Based on changes in accessibility to 2031, Table 14 presents the percentage of London's total employment growth that each borough is expected to receive according to each curve.

Capacity Constraints

The intention was to consider the feasibility of incorporating the effect of future capacity constraints on the distribution of future employment growth. In practice that has proved difficult to deliver, for a number of reasons:

- We were supplied with link capacity and flow data which we used to test cordons around specific locations as shown in Chapter 5. The most we could conclude from that analysis is that in general crowding across cordons reduces slightly between 2011 and 2031.
- Cordon data is difficult to rely on because the location of the cordon is unlikely to correspond to the peak crowding point.
- Highway capacity constraints are also difficult to quantify, given the large range of alternative routes available. However overall there is a small increase in

highway accessibility between 2011 and 2031, so again it seems unlikely that capacity constraints will be worse in 2031 than they are in 2011.

Our conclusion is that future transport capacity, assuming that all the planned schemes are delivered, is of the right scale to accommodate London's expected growth. If capacity was going to be incorporated in future applications it would need considerable input and effort from the TfL modelling team.

Distribution of Growth

The three accessibility:density curves give different geographic distributions of growth. The change in accessibility is not the right mechanism to use to forecast where employment will go, the accessibility:density curve provides the most suitable basis for the accessibility element of the triangulation process. These results are presented in Table 14.

Table 14: Borough allocation of 11-31 growth by curve type

Borough	Exponential	Polynomial	Break Analysis	Trend Distribution
Barking and Dagenham	1.5%	0.4%	0.4%	1.0%
Barnet	5.1%	1.2%	2.4%	2.0%
Bexley	0.6%	0.4%	0.1%	0.9%
Brent	4.0%	2.0%	5.0%	3.0%
Bromley	1.2%	0.1%	0.2%	1.8%
Camden	5.1%	7.8%	6.8%	8.4%
London, City of	2.2%	4.5%	1.2%	6.2%
Croydon	1.0%	0.2%	0.3%	2.9%
Ealing	4.2%	1.2%	2.3%	1.3%
Enfield	3.2%	1.2%	1.4%	1.5%
Greenwich	1.6%	0.0%	0.3%	2.6%
Hackney	2.6%	3.8%	3.9%	1.2%
Hammersmith and Fulham	3.1%	4.0%	4.8%	4.8%
Haringey	4.7%	5.5%	8.2%	2.5%
Harrow	2.5%	0.4%	0.8%	1.3%
Havering	1.4%	0.5%	0.3%	1.1%
Hillingdon	2.2%	0.4%	0.3%	4.4%
Hounslow	1.9%	0.3%	0.9%	2.1%
Islington	5.1%	8.9%	5.3%	6.5%
Kensington and Chelsea	2.4%	3.1%	3.8%	3.0%
Kingston	0.7%	0.1%	0.1%	1.4%
Lambeth	4.6%	6.5%	6.1%	2.6%
Lewisham	1.1%	0.4%	1.2%	2.4%
Merton	3.1%	1.9%	3.3%	1.8%
Newham	6.3%	8.8%	8.4%	1.7%
Redbridge	5.8%	5.3%	6.6%	1.9%
Richmond	0.9%	0.1%	0.2%	1.5%
Southwark	2.8%	3.7%	3.5%	7.4%
Sutton	0.7%	0.2%	0.1%	1.0%
Tower Hamlets	3.9%	6.4%	4.2%	3.8%
Waltham Forrest	2.9%	3.0%	3.5%	1.4%
Wandsworth	5.3%	6.8%	7.7%	4.0%
Westminster, City of	6.1%	10.6%	6.3%	10.5%

Appendix A: Tower Hamlets

Aggregating to a borough level averages out variations in employment density and accessibility apparent within a borough at zone level. To show this, this appendix presents the zonal data, using Tower Hamlets as an example, to give an idea of the variation present throughout London and how this can affect outcomes.

Figure 17: Employment Density in Tower Hamlets 2011 (Numbers = Zone Number)

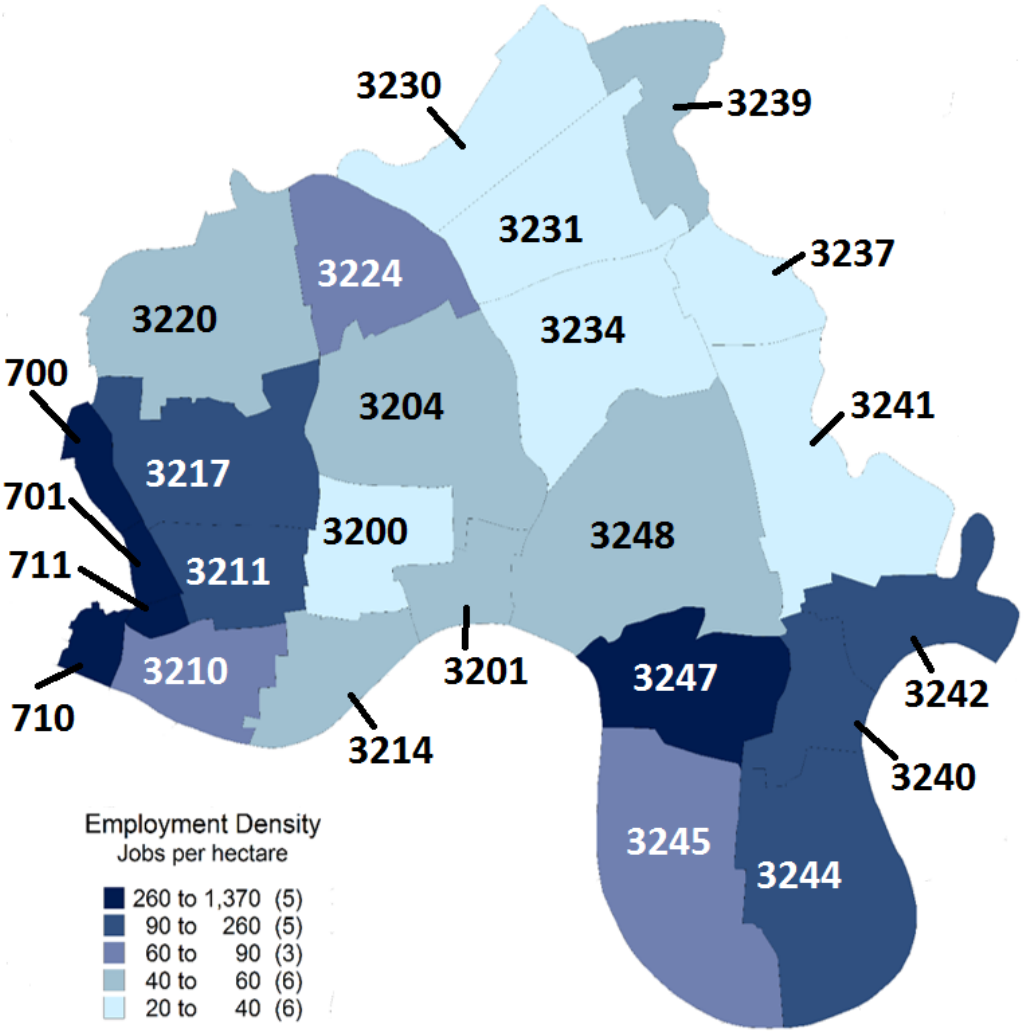
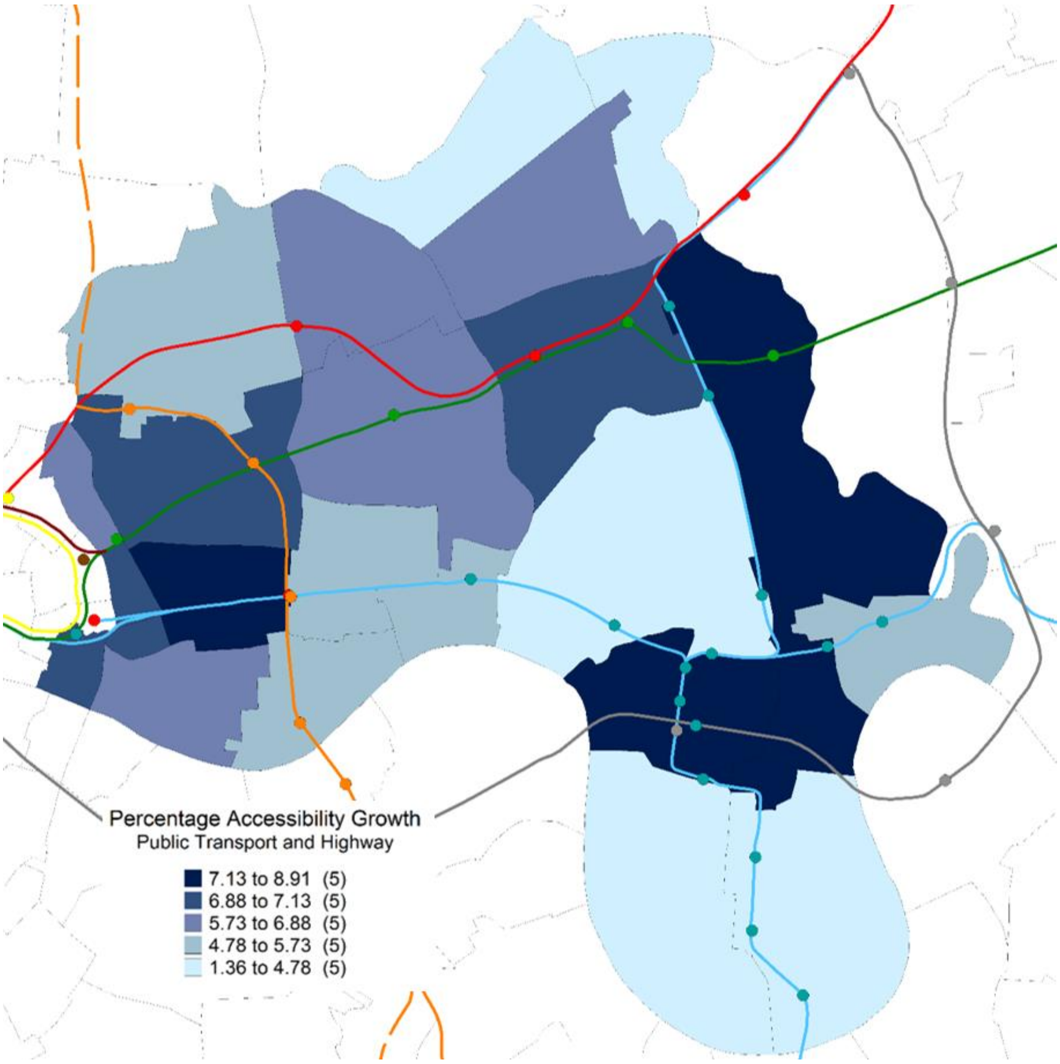


Figure 17 maps employment density in Tower Hamlets by zone. Here high levels of density are represented by darker shades of blue. This shows the densest zones are found near Canary Wharf and to the west of the borough, where it borders the City of London. The zone containing Canary Wharf (3,247) is the densest in Tower Hamlets and apart from the zones along the City Fringe, employment in the rest of Tower Hamlets is at relatively low densities.

The high level of employment density at Canary Wharf was facilitated through a combination of the DLR and Jubilee Line Extension. Crossrail will increase this accessibility connecting both the City and the Isle of Dogs, enabling further increases in employment density.

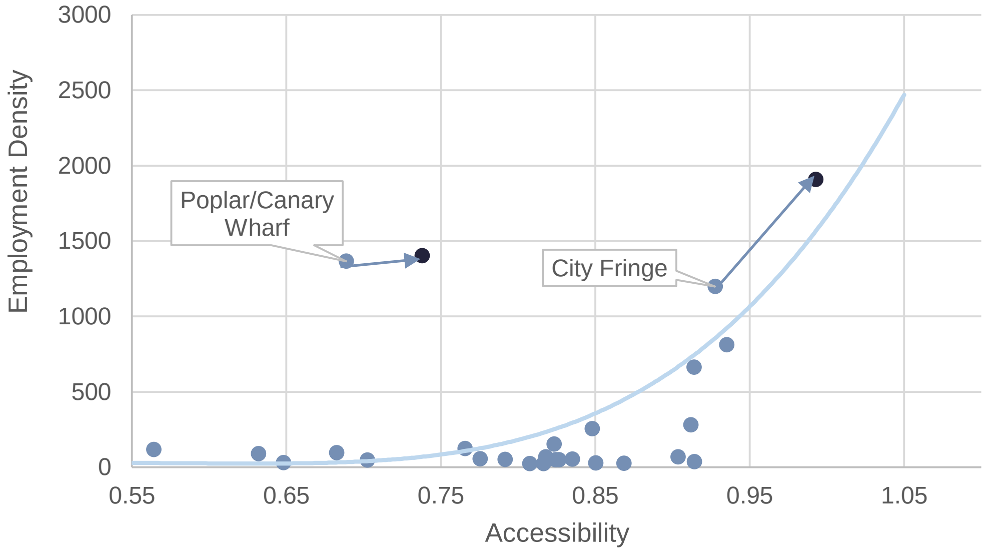
Figure 18: Percentage increases in accessibility 2011-2031 – PT and Highway



The dark blue zones in Figure 18 show the zones that receive the highest increases in accessibility between 2011 and 2031. Zones with the highest increases in accessibility correspond with the zones that currently are the densest, suggesting that the areas that grow the most in accessibility are the areas with existing clusters of employment.

Based on increases in accessibility presented above, the model predicts that employment density will increase to the east/north-east of Canary Wharf and development on the City of London fringe will continue.

Figure 19: Relationship between employment density and accessibility to population, Tower Hamlets zones only (polynomial curve)



NB: Light Blue = 2011 data and Dark Blue = 2031 forecast

Pulling both the employment density (Figure 17) and the accessibility together (Figure 18), Figure 19 charts the Accessibility:Density relationship for all zones within Tower Hamlets with the modelled curve (polynomial). On this, the two densest zones, the zone containing Canary Wharf[1] and a City Fringe zone (Tower Hill), are highlighted as these are a good example of how two zones with similar levels of employment density can be subject to differing outcomes in the model.

Figure 19 shows that the City Fringe zone is one of the most accessible zones in Tower Hamlets, whereas Canary Wharf is significantly less accessible. Despite this, both these zones have similar levels of employment density. Low accessibility given its density means that Canary Wharf is an outlier (reflected by the distance from the curve) and other factors apart from transport are driving high densities here. Put simply, the model is a better predictor of employment density within the City Fringe zone than Canary Wharf.

The problem with this is that despite both zones receiving similar increases in accessibility to 2031, the model predicts significantly lower employment growth in Canary Wharf relative to the City Fringe zone. This can be seen by the arrows in Figure 19 which show the estimated increase in employment density based on the increase in accessibility to population. The initial position of a zone relative to the curve will determine how the model forecasts its growth. This may lead to strange results for outliers, although these generally average out when aggregated to borough level.

The variations of accessibility and employment density within Tower Hamlets are a good example of the variation within boroughs throughout the model. Canary Wharf is one of the more extreme examples of an outlier in London and is shown here to illustrate variation within the model.

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[1] Hereby described as Canary Wharf. This zone is named Poplar in the model.

Appendix B: Public Transport Scheduled Schemes

The public transport schemes listed in Table 15 are those which affect the accessibility change. The majority of these schemes are completed by 2016; therefore the impact these schemes will have on the distribution is likely to have occurred before 2031.

In the cordon analysis the only extra scheme between 2031 and 2041 is Crossrail 2.

Table 15: Public Transport scheduled schemes

Mode	Scheme	Year
National Rail	Chiltern Evergreen 3 Phase 1	2011
National Rail	HS1 Enhancements	2011
National Rail	East Coast Timetable Recast (Eureka)	2011
Bus	East London Transit	2011
Overground	Extend all class 378's to 5 car	2016
Overground	Devolution - West Anglia Inners	2016
Overground	Clapham Jn (SLL) including changes to Southern services	2016
National Rail	Chiltern Evergreen 3 Phase 2	2016
National Rail	HLOS1	2016
National Rail	London Midland Project 110 (Full)	2016
National Rail	Thameslink KO1.1	2016
National Rail	West Coast Pendolino Lengthening (35x11car, 21x9car)	2016
National Rail	New Lea Bridge station	2016
National Rail	West London Line (Southern) services enhanced capacity (up to 8 car)	2016
DLR	Poplar - Stratford 3 car upgrade	2016
DLR	Interpeak service enhancements (BSP A)	2016
DLR	North Route Double Tracking Phase 1 (Base Service Plan B)	2016
Tramlink	Therapia Lane 2012	2016
Tramlink	Wimbledon higher frequency	2016
Bus	Capacity redistributed	2016
Bus	Additional global capacity	2016
Bus	600 vehicle replacement	2016
Interchange	Hackney Interchange	2016
Interchange	East Croydon new entrance	2016
Overground	Gospel Oak - Barking Electrification and longer (4 car) trains	2021
National Rail	Crossrail 1 (Maidenhead / Heathrow - Shenfield / Abbey Wood)	2021
National Rail	Crossrail 1 to Reading	2021
National Rail	Thameslink Upgrade including changes to Moorgate, Kings Cross, Southern and South Eastern services	2021
National Rail	Midland Main Line Electrification	2021
National Rail	Great Western Electrification - Suburban	2021
National Rail	Great Western Electrification - Long Distance	2021
National Rail	HLOS2 - East West Rail (Aylesbury - Milton Keynes, Oxford - Bedford)	2021
National Rail	HLOS2	2021

Mode	Scheme	Year
National Rail	West Anglia CP5 upgrade (Stratford - Angel Road)	2021
National Rail	IEP on ECML replacing IC125 & IC225	2021
Underground	Subsurface	2021
Underground	Croxley Link	2021
Underground	Northern Line	2021
Underground	Victoria Line	2021
Underground	Jubilee Line	2021
Underground	Piccadilly Line	2026
Underground	Bakerloo Line	2031
Underground	Central Line	2031