Transport for London & Department for Transport

Crossrail Baseline Evaluation

Transport technical report supplement

Final | 3 May 2022

ARUP

Contents

1 Introduction

1.1 The Crossrail Baseline Evaluation

Arup were contracted by Transport for London (TfL) and the Department for Transport (DfT) to carry out a baseline evaluation of the impacts of Crossrail (the Elizabeth line) in terms of construction, transport, wider economy, and property & regeneration.

This report supplements the May 2022 Crossrail Baseline Evaluation Transport Report and covers transport surveys undertaken in Autumn 2017 to cover a number of gaps in coverage from secondary data sources. The surveys were specified to ensure that they could be repeated post-opening providing a valuable and consistent dataset for pre- and post-opening analysis.

1.2 Context

The baseline transport analysis reported in the 2017 Interim Report and in the 2022 final transport technical report concentrated on existing transport data, either publicly available, or sourced from TfL and DfT. Wherever these data would support, time series data was reported from 2007 until the latest available year, reflecting the period from immediately before Royal Assent of the Crossrail Act of 2008 up to the opening of through-running Elizabeth line services in 2022[1].

The main datasets assessed for the 2017 Interim Report were:

- the National Travel Survey (NTS);

- London Travel Demand Surveys (LTDS);

- Travel in London (TIL);

- Central Area Passenger Counts (CAPC);

- Rolling Origin Destination Surveys (RODS);

- DLR loading and crowding data;

- DfT Rail statistics; and

- the Isle of Dogs cordon survey

- Canary Wharf Employees Survey.

Whilst the 2017 Interim Report includes some detailed analysis of time series data from the sources above, the intention of the 2018 report is not to repeat this

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[1] For the purposes of this report, when we refer to the planning and construction of the railway we refer to the project as 'Crossrail' but for references to the future operational railway and its stations we use 'Elizabeth line' throughout.

analysis with a further year's data but to draw on datasets/analysis not reported in the 2017 Interim Report.

In terms of the transport workstream these are:
- Presentation of findings from transport surveys undertaken in Autumn 2017; and
- Presentation of initial findings from the Office of Rail and Road (ORR) Origin-destination (OD) matrix datasets.

1.3   Background to Autumn 2017 Transport Surveys

One of the key datasets used in the 2017 was TfL's Rolling Origin-Destination Surveys (RODS). This provided valuable time series data on several metrics relating to London Underground, inter alia, growth in boarders by line and station, journey purpose, journey length, journey times by station and route and routeing characteristics.

However, whilst RODS and other data sources provided valuable data to inform the baseline, it was evident that the Crossrail Baseline Evaluation would benefit from some selected primary data collection. The justification for undertaking the surveys can be summarised as:

- Gaps in data coverage including ultimate origins and destinations, journey purpose, lack of routeing data, demographics, and need for / use of step-free access;

- RODS covers LUL only with no corresponding datasets for National Rail stations – Paddington, Liverpool Street and Stratford NR stations are of key interest to this analysis;

- Whilst the RODS database is to be maintained, the actual RODS surveys ceased in 2016. Since then, there has been a transition to a replacement system (NUMBAT);

- RODS surveyed between 15 and 30 stations each year, stations of interest were therefore likely to have been surveyed several years previously;

- Other alternative datasets, including TfL's EDMOND mobile phone based data and Oyster data were either in a relatively early stage of development or have proved difficult to source; and

- Changes in methodology with some data sources e.g. use of Oyster with LENNON data.

Care was undertaken in terms of specification and documentation of the fieldwork, data cleaning analysis, and reporting, to ensure that the survey could be repeated post-opening providing a valuable and consistent dataset for pre- and post-opening analysis.

Following the analysis of data presented in the 2017 Interim Report and discussions between TfL, DfT and Arup, it was agreed that a targeted survey covering selected stations that would either be directly served by the Elizabeth line or be sufficiently close to be impacted by Elizabeth line services would be

extremely beneficial. At the time of the surveys, it was felt that Autumn 2017 would be the latest available window for such surveys, prior to the then planned opening of the Paddington to Abbey Wood service in December 2018 and the TfL Rail service between Paddington main line and Heathrow in Spring 2018.

The findings of these surveys are set out in the Survey section of this report. Of key importance is the fact that the true value of these surveys will be realised when they are repeated post-Elizabeth line opening. This report sets out some headline findings, but the survey method and results will be securely stored to enable subsequent surveys to replicate the method and allow in depth analysis of results.

1.4　　　Background to use of the ORR OD Matrices

The 2017 Interim Report noted that subsequent reports would include a more detailed analysis of passenger movements based on datasets such as LENNON and Oyster. As an alternative to LENNON, we have reviewed the ORR Origin Destination Matrices; the methodology for developing these OD matrices processes LENNON data to provide national origin destination matrices; this is reported annually in publicly available reports from 2010 onwards[2].

One major advantage of the ORR methodology is that it combines LENNON data with Oyster 'clicks' thereby combining the two data sources and giving a more complete and consistent picture of rail journeys in the London context. It should be noted that the process has evolved over the last few years with potential inconsistency between years, although methodological changes are carefully documented in each annual report.

At the time of this 2018 Interim Report, ORR had provided data for the purposes of this study for London, the South East and East for 2016-17 to ensure that the dataset was suitable for use in the CBE work. This report presents some initial analysis of these data for 2016-17; the final report will present a fuller analysis of these data from 2010 onwards.

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[2] For 2015-16 this is reported in: http://orr.gov.uk/__data/assets/pdf_file/0020/23951/origin-destination-matrix-2015-16.pdf

2 Autumn 2017 Transport Surveys

2.1 Introduction

The baseline evaluation survey was undertaken on Monday – Thursday mornings during a neutral period[3] between 25th September and 9th November 2017 with the objective of the survey being to sample passenger journeys to, from and through a selection of stations on the existing rail and Tube network that the Elizabeth line will interface with in the future.

The survey was designed to be fully repeatable following Elizabeth line opening to allow a comparison of the journey patterns and effect of the introduction of the Elizabeth line. Not all station flows were surveyed, just those that were considered most likely to be impacted by the Elizabeth line introduction.

As part of the development of the surveys, a pilot survey was carried out at Whitechapel station on Wednesday 30th August 2017. This gave the opportunity of refining the questionnaire and survey approach.

For the pilot and main survey, fieldworkers handed out self-completion questionnaires along with freepost envelopes, distributed at defined points within and around the entrances of stations and at some interchange locations at certain stations. Questionnaires were distributed between the hours of 07:00 and 12:00 to capture both a peak and inter-peak sample. The overall aim was to hand out surveys to 20% of the predicted footfall with the aim of obtaining a 15% response rate from those handed out.

2.2 Stations

In total, 14 stations on the Elizabeth Line were surveyed, as well as Oxford Circus due to its proximity to future Elizabeth line station entrances at Bond Street and Tottenham Court Road. Stations and lines surveyed are set out in Table 1.

Table 1 Stations surveyed

Station surveyed	Services and lines surveyed
Barbican	Circle, Hammersmith & City and Metropolitan LU lines
Bond Street	Central & Jubilee LU lines
Canary Wharf	Jubilee LU line
Ealing Broadway	GWR Suburban & Heathrow Connect and Central & District LU lines

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[3] A neutral period is defined as a period unaffected by school/bank holiday, special events or other significant surveys.

Farringdon	Thameslink and Circle, Hammersmith & City and Metropolitan LU lines
Liverpool Street	Central, Circle, Hammersmith & City and Metropolitan LU lines
Moorgate	Great Northern and Circle, Hammersmith & City, Metropolitan LU lines
Oxford Circus	Central LU line
Paddington	Bakerloo, Circle, Hammersmith & City and District LU lines
Stratford	TfL Rail, Central & Jubilee LU lines and DLR (via Poplar only)
Tottenham Court Road	Central and Northern LU lines
Whitechapel	District, Hammersmith & City and Metropolitan LU lines
Paddington National Rail	GWR suburban, Heathrow Connect and Heathrow Express
Liverpool Street National Rail	TfL Rail only

2.3   Survey questionnaire

The survey captured the following details of passenger journeys:

- Journey purpose;

- Origin and destination;

- Routeing and reason for route choice;

- Frequency of making journey;

- Ticket type;

- Access and egress mode;

- Use of mobility aids or other equipment; and

- Demographic profile (age, gender, disability, employment status).

2.4 Responses

In total, over 56,000 questionnaires were handed out across the 14 stations with over 8,700 returned. Following cleaning and validation, 7,950 questionnaires went forward to the analysis stage. This is set out by station in Table 1.

2.5 Weighting

Weighting against observed data was undertaken to correct the proportions of survey responses by 15-minute time period for each station..

Where weights were particularly low or high (< 0.33 or > 3), which typically occurred in segments with low sample sizes, weights in the adjacent time periods were examined to ascertain whether it was feasible to combine them in order to restrict the range of weights. Wherever possible, this has been kept to whole hour periods, e.g. 7-8, 8-9, etc.

Table 2. Questionnaire hand out rate by station.

	Questionnaires Distributed	Complete questionnaires Returned	Response rate	Valid Responses following cleaning and validation	% (Valid/Total)	Revised response rate - post screening
Barbican	2,307	368	16%	341	93%	15%
Bond Street	5,408	901	17%	840	93%	16%
Canary Wharf	4,838	799	17%	742	93%	15%
Ealing Broadway	4,058	672	17%	610	91%	15%
Farringdon	5,435	952	18%	873	92%	16%
Liverpool Street	3,257	362	11%	324	90%	10%
Moorgate	3,630	778	21%	734	94%	20%
Oxford Circus	4,587	610	13%	553	91%	12%
Paddington	2,714	530	20%	480	91%	18%
Stratford	7,276	704	10%	594	84%	8%
Tottenham Court Road	3,888	651	17%	596	92%	15%
Whitechapel	3,087	385	12%	324	84%	10%
Liverpool Street N Rail	3,121	386	12%	357	92%	11%
Paddington N Rail	2,757	643	23%	583	91%	21%
Total	56,363	8,741[4]	16%	7,951	91%	14%

2.6   Analysis and Results

This section sets out headline results covering:

• A summary of demographic findings for all stations, noting any stations where demographics stand out as being different to the other stations;

• A summary of high-level 'survey wide' findings;

• A summary of cross-station patterns, trends and any unique findings by station;

• Outputs for groupings of similar stations – this uses a categorisation of stations generally used by LU for station planning purposes, namely 'City',

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[4] Note that this is slightly lower than the total quoted in the TRACSIS December 2017 Fieldwork & Technical Report as the TRACSIS number corresponded to the total forms actually returned, some of which were rejected as they were blank, badly damaged, or only partially completed.

'Shopping' 'Suburb' and 'Terminus' stations[5]. Whilst these might not be the best descriptors for some of the stations surveyed (Stratford is classified as suburban, for example) it is helpful to group the stations for analysis purposes;

- Visualisation of the origin/destination 'catchment' of selected station; and

- Visualisation of the most common interchanges for each station and routeing through the network, noting that at a number of stations, such as Stratford, not all interchange movements were surveyed.

2.6.1   Demographics

An analysis of responses to the demographic questions has been undertaken at a survey-wide level with any 'outliers' noted.

The **age and gender** profile of respondents as shown in Figure 1, indicates a peak in the 25-44 age group and with more female respondents in both this and the 45-60 age group. Males are more predominant in the 16-24 age group although this is a relatively small proportion of the demand.

Outliers include Canary Wharf and Tottenham Court Road, which showed a higher proportion in the 25-44 age group due to large concentrations of retail and office employment and Paddington which has a relatively large proportion in the 60+ age group. This is reinforced by the employment status breakdown which shows a large proportion of retired respondents at Paddington, reflecting the longer distance, one-off nature of these journeys with origins in the west of England, Wales and the Thames corridor.

These findings exhibit a close similarity to other TfL research particularly the 2011 Central London Termini Study. The demographic analysis has also been compared with the corresponding 'Early', AM Peak' and 'Midday' time periods from the RODS 2017 dataset. Whilst the latter does not split age group by gender, the profile is similar, albeit with a slightly greater proportion in the 16-24 age group and a correspondingly smaller proportion in the 45-59 age group.

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[5] This categorisation is generally used by LU for station planning purposes. For the stations surveyed these are:
City – Farringdon, Moorgate, Canary Wharf, Barbican and Liverpool St
Shopping - Tottenham Court Road, Oxford Circus and Bond St;
Suburb – Whitechapel (inner), Stratford and Ealing Broadway (both outer)
Terminus - Paddington

Figure 1. Age and Gender profile: All respondents
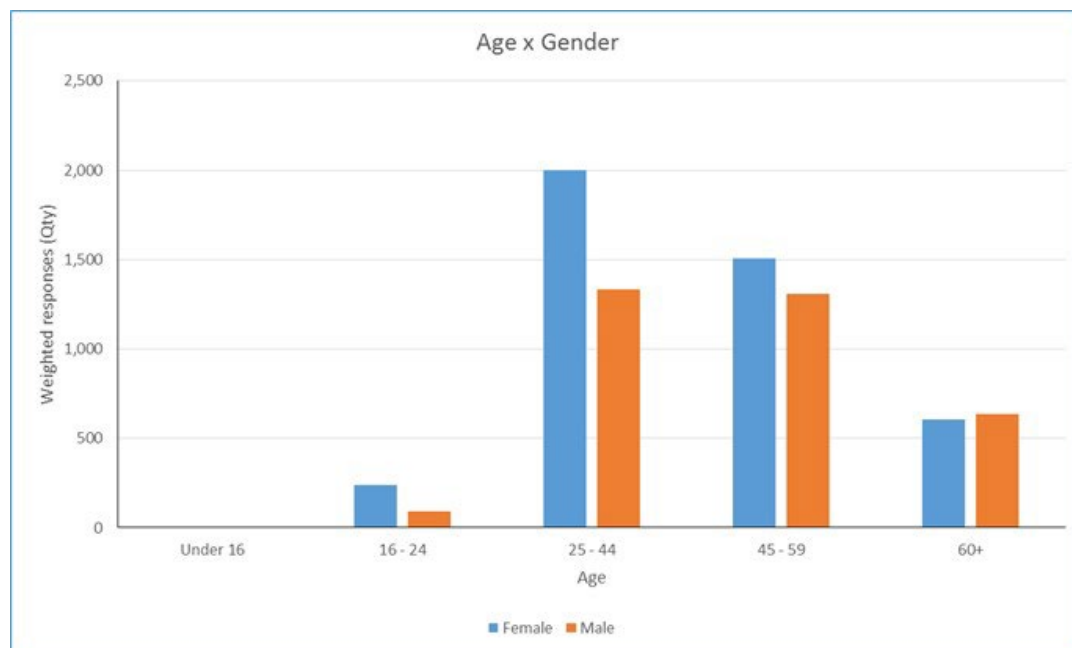
The **employment status** analysis indicated that almost 90% of respondents were either in full or part-time work with 7% retired and 2% students. As noted, Paddington exhibits a higher proportion of retired respondents, reflecting longer-distance discretionary trips and Whitechapel a higher proportion of students, reflecting the proximity to the Queen Mary University of London incorporating Barts and The London School of Medicine and Dentistry.

Around 87% of respondents reported no **physical or mental impairment** with a further 7% either not stating or preferring not to disclose. This leaves around 6% with a stated physical or mental impairment. Mobility impairment was reported by 2% of respondents, with categories covering hearing impairment, mental health condition, serious long-term condition or a combination of the above making up the remainder.

This compares with slightly higher London-wide figures[6] of 6.8% of all adults aged 16+ years with a mobility impairment, although it should be noted that these numbers relate to the total population rather than the travelling population which helps to explain the lower percentages in this survey.

2.6.2   Departure time and journey purpose

Departure time (from home) and journey purpose at a survey-wide level is set out in Figure 2 and Figure 3. This illustrates a number of points:

- The peak hour is 07:00-08:00, followed by 08:00-09:00 and 06:00-07:00 – home to work journey purpose dominates across these periods;

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[6] https://data.london.gov.uk/dataset/disability-and-mobility-london derived from Life Opportunities Survey wave 1 2009-2011

- Home to work trips dominate in the period up to 09:00, after which they decrease significantly, reflecting the peak for commuter travel;

- Home to personal business, shopping and other purposes become much more prevalent after 09:00, generally increasing later in the survey period;

Figure 2. Journey purpose by departure time. Weighted response
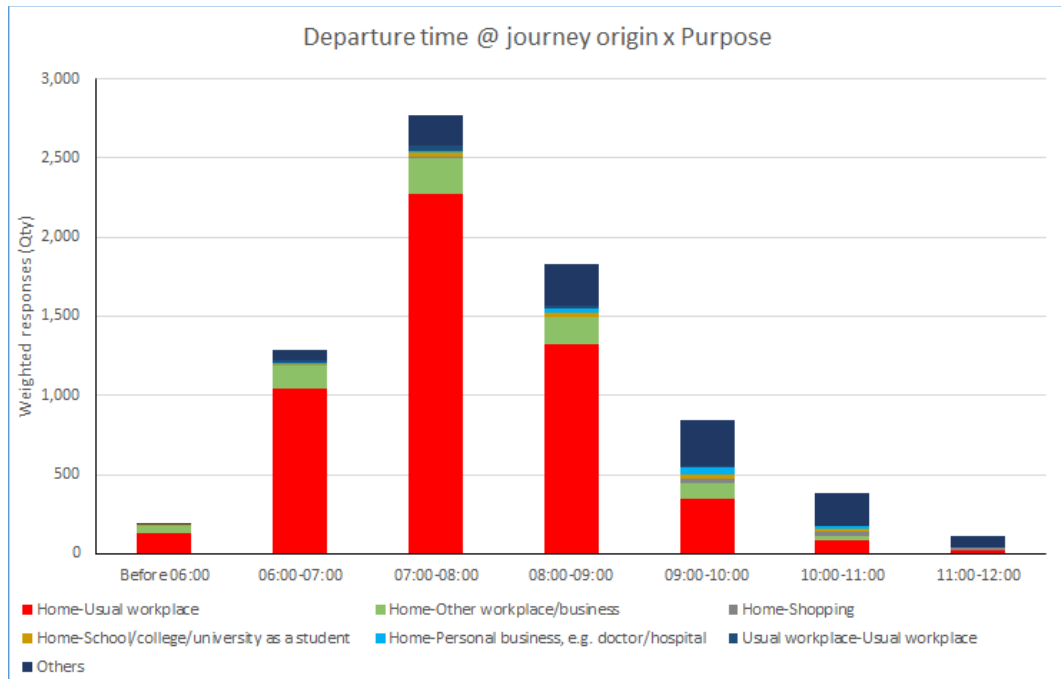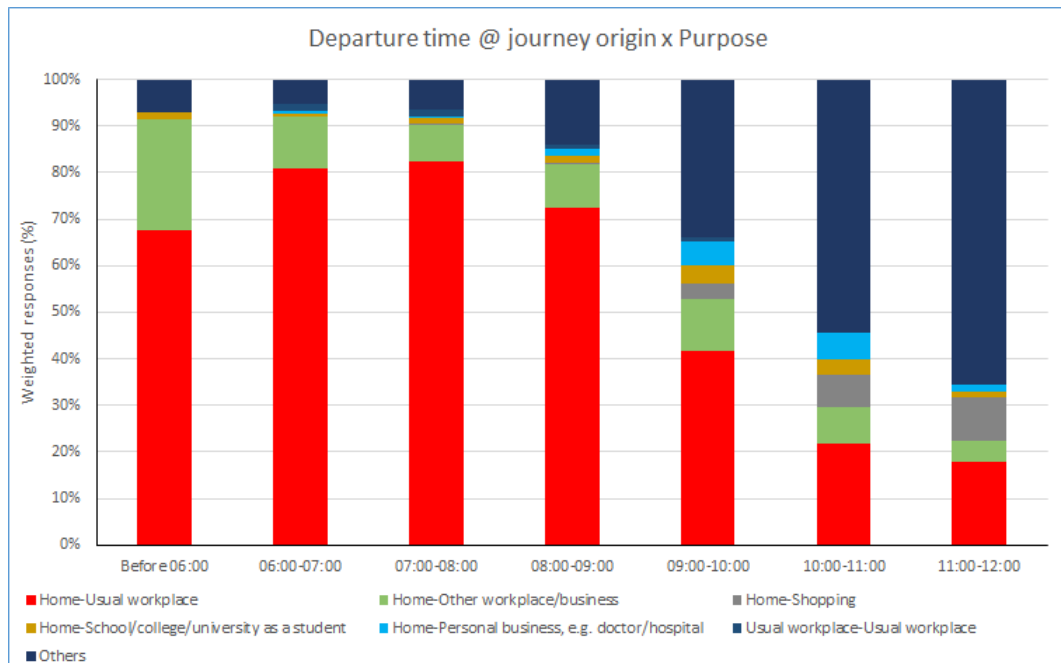

Figure 3. Journey purpose by departure time. Percentage

The analysis is repeated in Figure 4 to Figure 7 for each sub-group of stations. Of particular note are:

- The absence of shopping trips (grey) at the city stations;

- Similar profiles of home to work trips at city, suburban and shopping stations;

- The higher occurrence of tourist-based trips (orange) for termini stations reflecting longer distance one off trips;

- A high proportion of home to other workplace trips (green) for termini stations reflecting much longer distance work trips coming into London from further afield; and

- A more varied pattern of trips into termini stations with a much larger selection of trip purposes.

The nature of Elizabeth line services could result in a more varied picture of trip purpose when Elizabeth line services commence due to the wider catchment areas and opening up of new journey opportunities.

Figure 4. Journey purpose by departure time for station groupings – City Stations
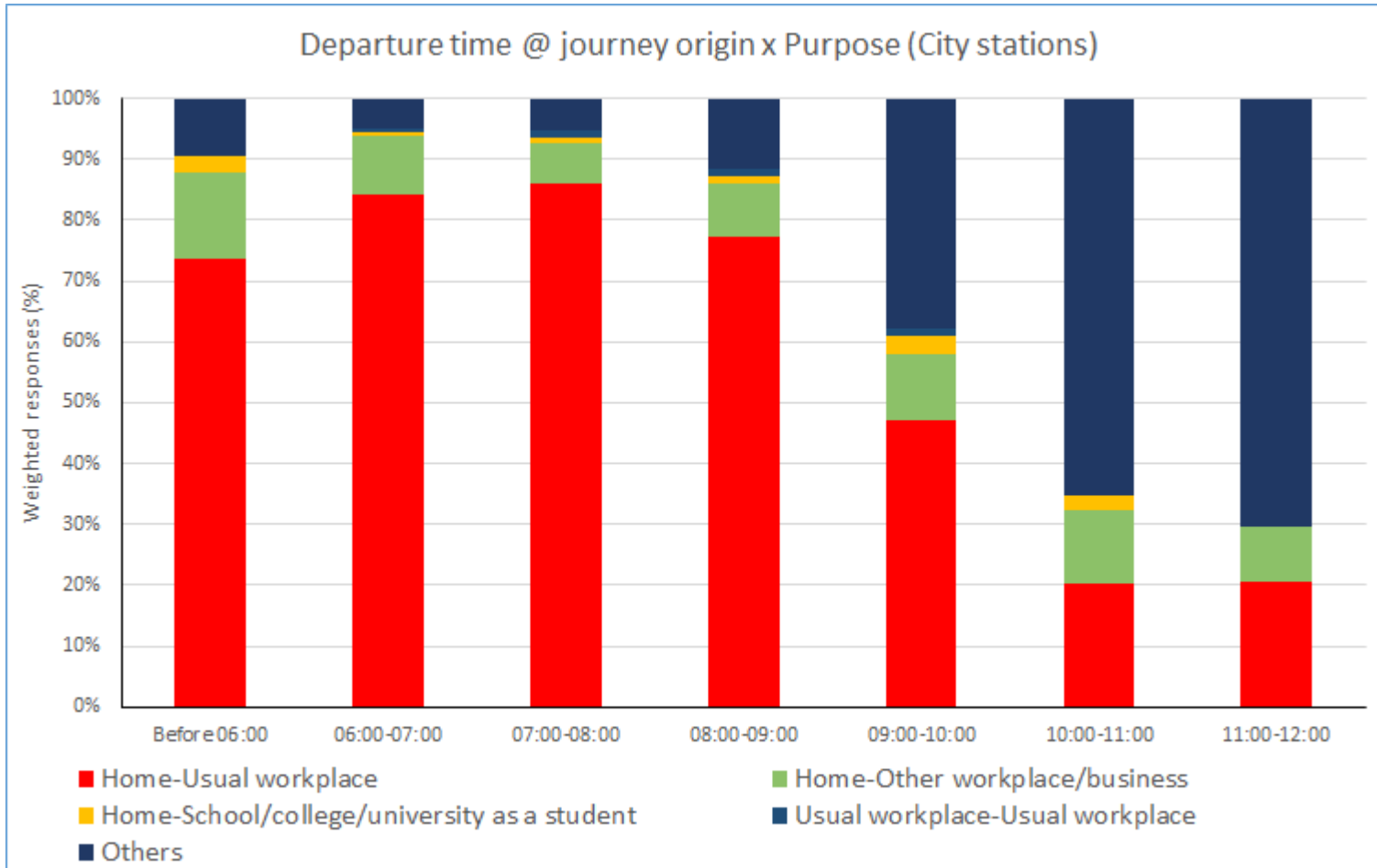
Figure 5 Journey purpose by departure time for station groupings – Shopping Stations

Departure time @ journey origin x Purpose (Shopping stations)

Legend:
- Home-Usual workplace
- Home-Other workplace/business
- Home-Theatre/concert venue/special event
- Home-Shopping
- Home-School/college/university as a student
- Home-Personal business, e.g. doctor/hospital
- Usual workplace-Usual workplace
- Usual workplace-Other workplace/business
- Other workplace/business-Usual workplace
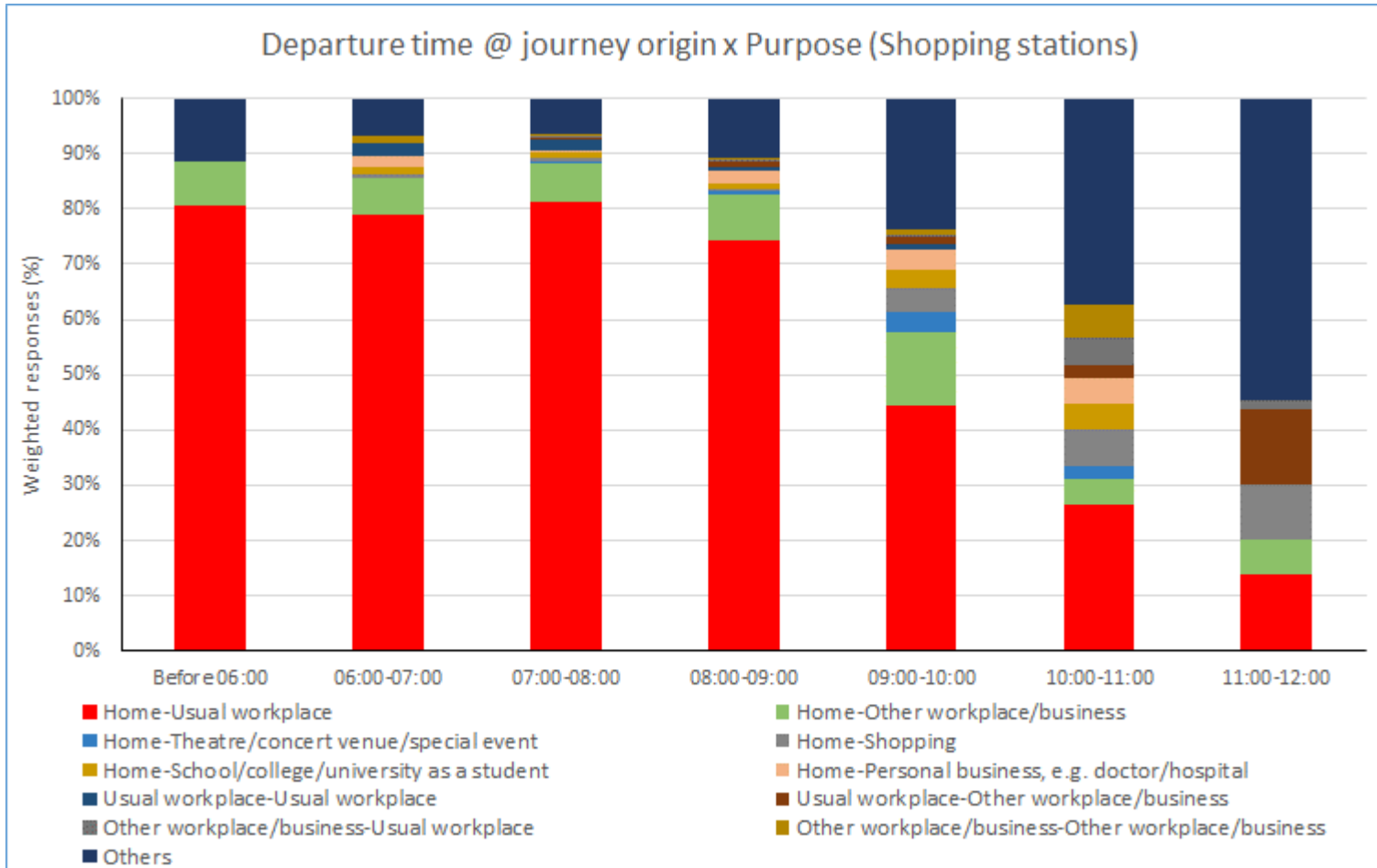- Other workplace/business-Other workplace/business
- Others

Figure 6 Journey purpose by departure time for station groupings – Suburb Stations
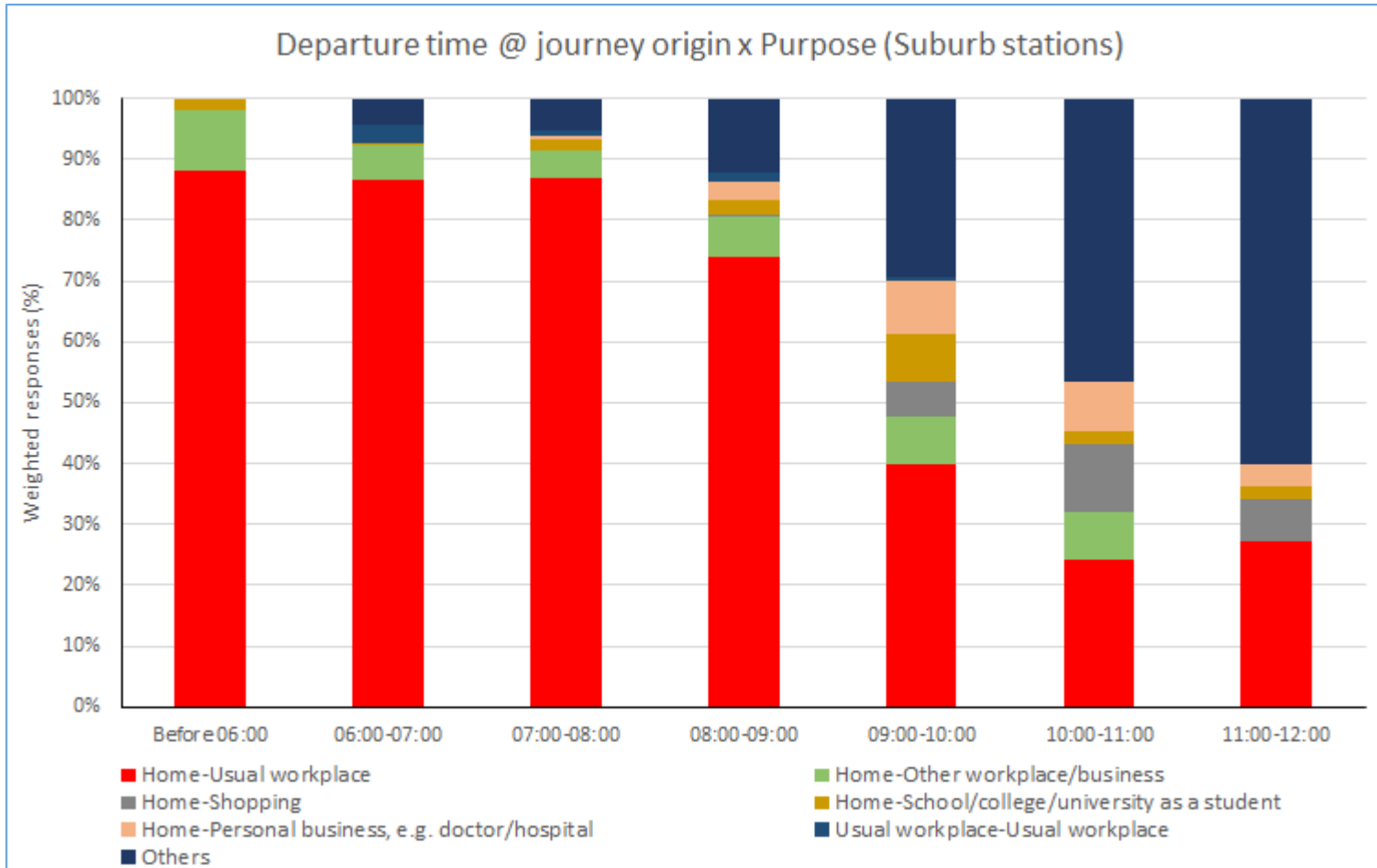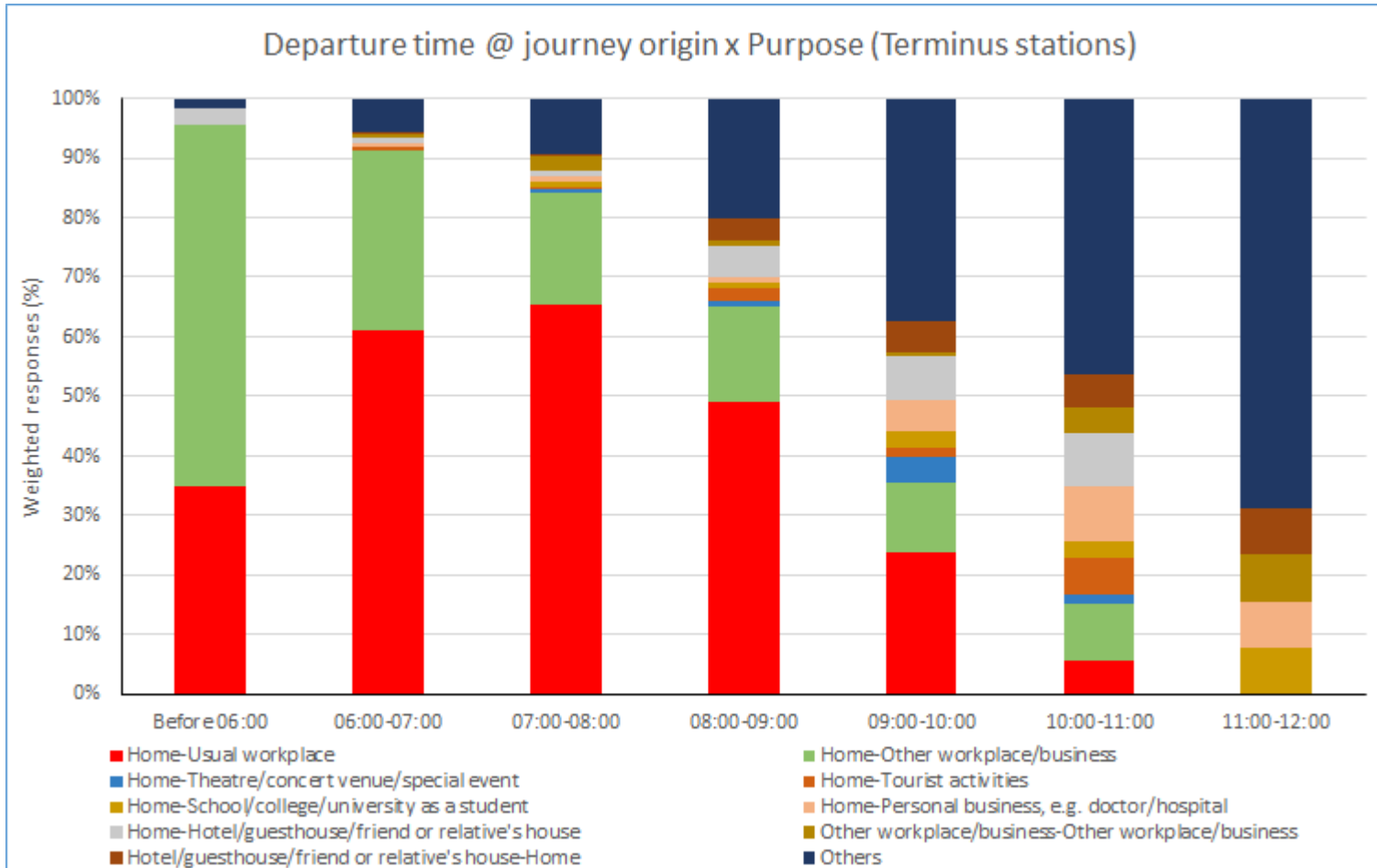
Figure 7 Journey purpose by departure time for station groupings – Terminus Stations

2.6.3 Frequency and journey purpose

The analysis of journey frequency and journey purpose is illustrated in Figure 8 for the period 07:00-10:00, Figure 9 for the period 10:00-12:00 and Figure 10 to Figure 13 for the station sub-groups. This demonstrates:

- The dominance of home to usual workplace trips in the 5 or more days/week group for both the 07:00-10:00 and 10:00-12:00 time periods

- The dominance of home to usual workplace trips in the 1 to 4 days/week group for the 07:00-10:00 period;

- The limited number of trip purposes (work, education, others) in the 07:00-10:00 period compared with the much more varied purposes in the 10:00-12:00 period;

- The very small proportion of home to work trips (light blue) for once a fortnight or less frequent trips but the increasing occurrence of home to personal business (light pink) as trip frequency reduces;

- The increasingly large proportion of home to other workplace (green) as trips become less frequent, reflecting infrequent business trips;

- The increasing proportion of shopping trips (grey) for less frequent trips reflecting the discretionary nature of these trips; and

- The absence of any shopping trips in the 07:00-10:00 peak period, irrespective of frequency.

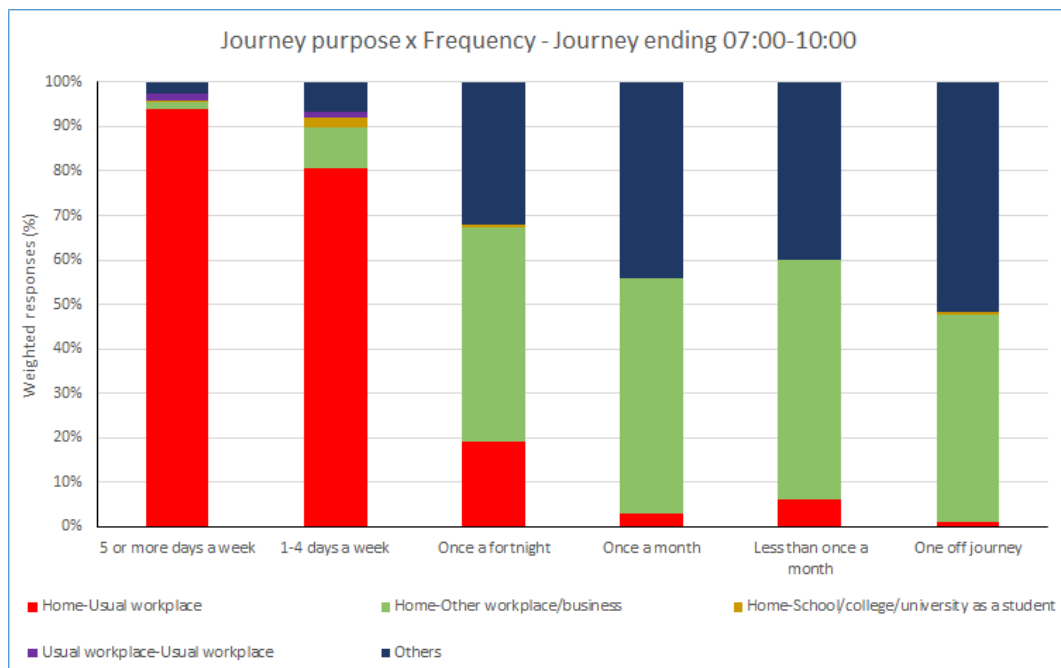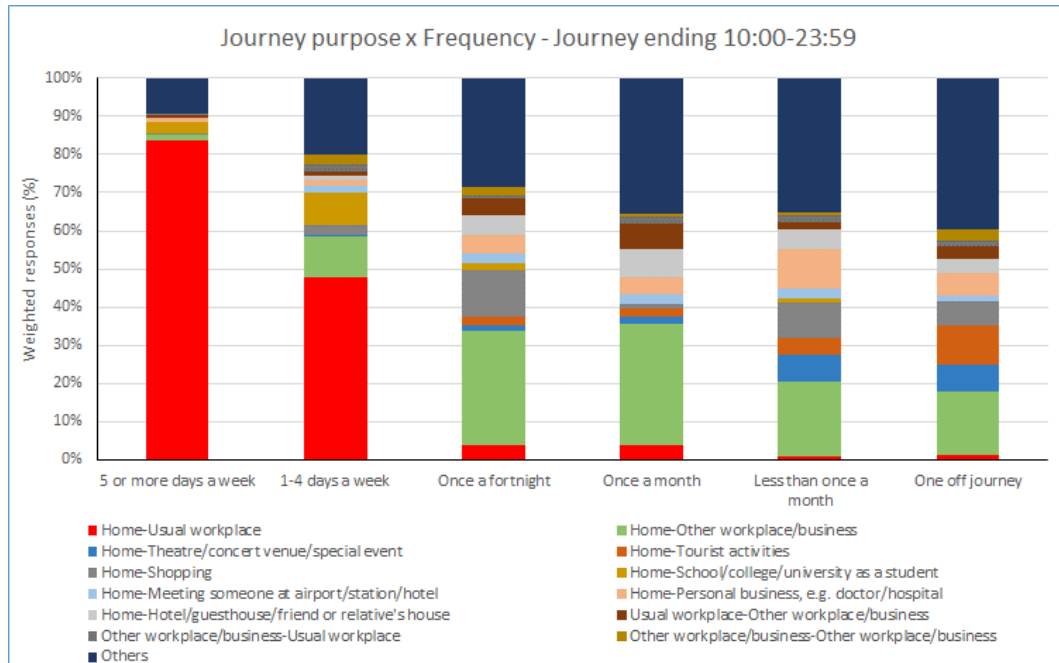Figure 8. Frequency and journey purpose 07:00-10:00

Figure 9. Frequency and journey purpose 10:00-12:00

The station groupings analysis, as set out in Figure 10 to Figure 13, indicates some interesting findings, namely:

- City stations are almost entirely dominated by home to work trips (light blue), but with increasing proportions of 'Home to other workplace' trips (green) for less frequent trips;

- Non-city stations have a wider variety of non-work trips (education, work to work for example);

- Shopping trips (grey) recorded at suburban and shopping stations and then only for relatively infrequent (less than one a fortnight) journeys;

- Shopping and terminus stations have a more varied pattern of trips than city or suburban stations with a much larger selection of trip purposes except for trips occurring on 5 or more days/week which are predominantly home to work trips;

- Greater occurrence of hotel and tourist related trips (orange and light grey) for terminus stations in the less frequent categories.

A separate analysis of the 07:00 to 10:00 and 10:00-12:00 time bands by station group indicated a much lower variety of purposes with most of the discretionary trips (shopping, hotel, tourist-related) missing from this time band.

Figure 10. Frequency and journey purpose, City stations
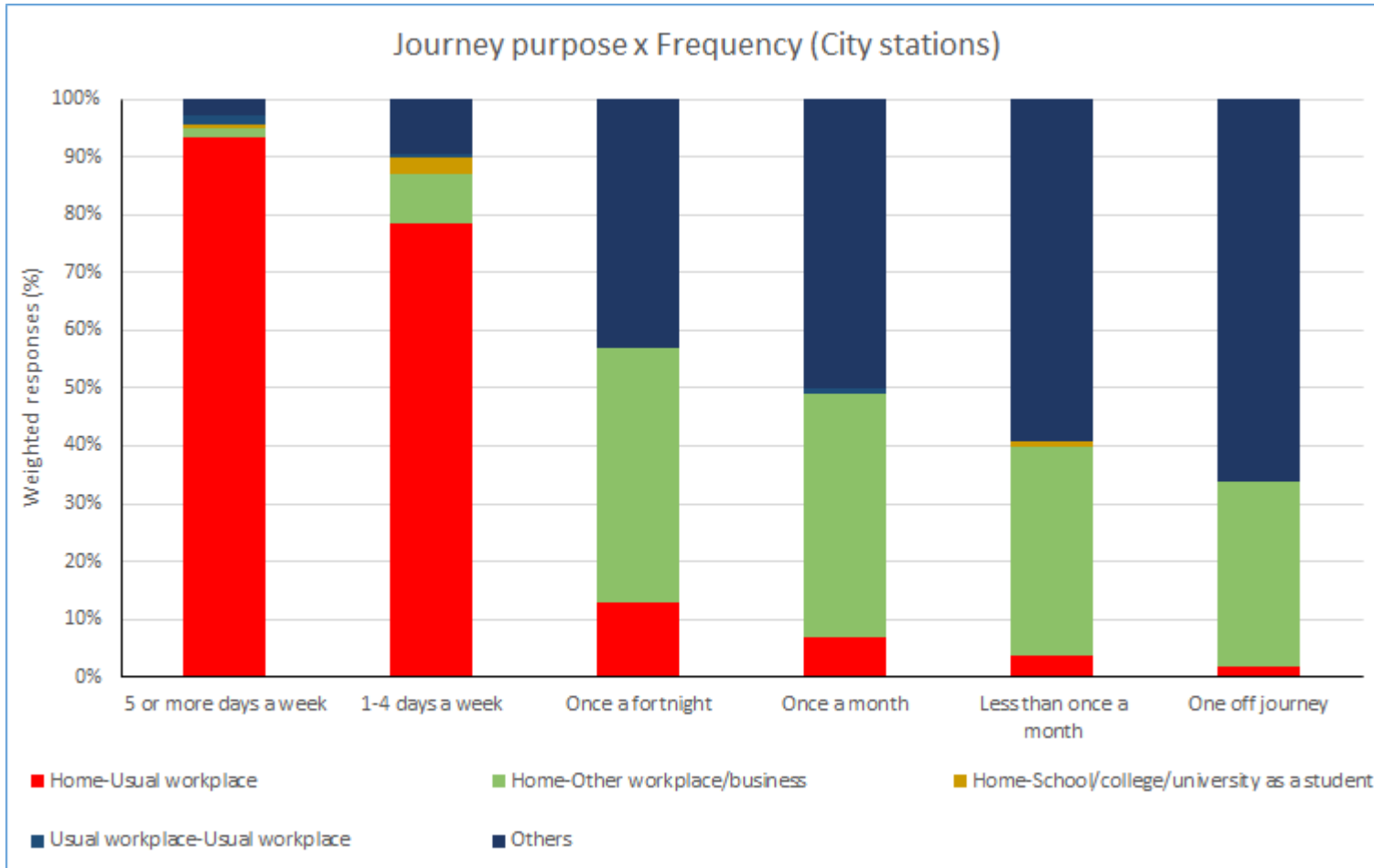
Figure 11. Frequency and journey purpose, Shopping stations

Journey purpose x Frequency (Shopping stations)

Legend:
- Home-Usual workplace
- Home-Theatre/concert venue/special event
- Home-School/college/university as a student
- Usual workplace-Usual workplace
- Other workplace/business-Usual workplace
- Others
- Home-Other workplace/business
- Home-Shopping
- Home-Personal business, e.g. doctor/hospital
- Usual workplace-Other workplace/business
- Other workplace/business-Other workplace/business

Figure 12. Frequency and journey purpose, Suburb stations

Journey purpose x Frequency (Suburb stations)

Legend:
- Home-Usual workplace
- Home-Other workplace/business
- Home-Shopping
- Home-School/college/university as a student
- Home-Personal business, e.g. doctor/hospital
- Usual workplace-Usual workplace
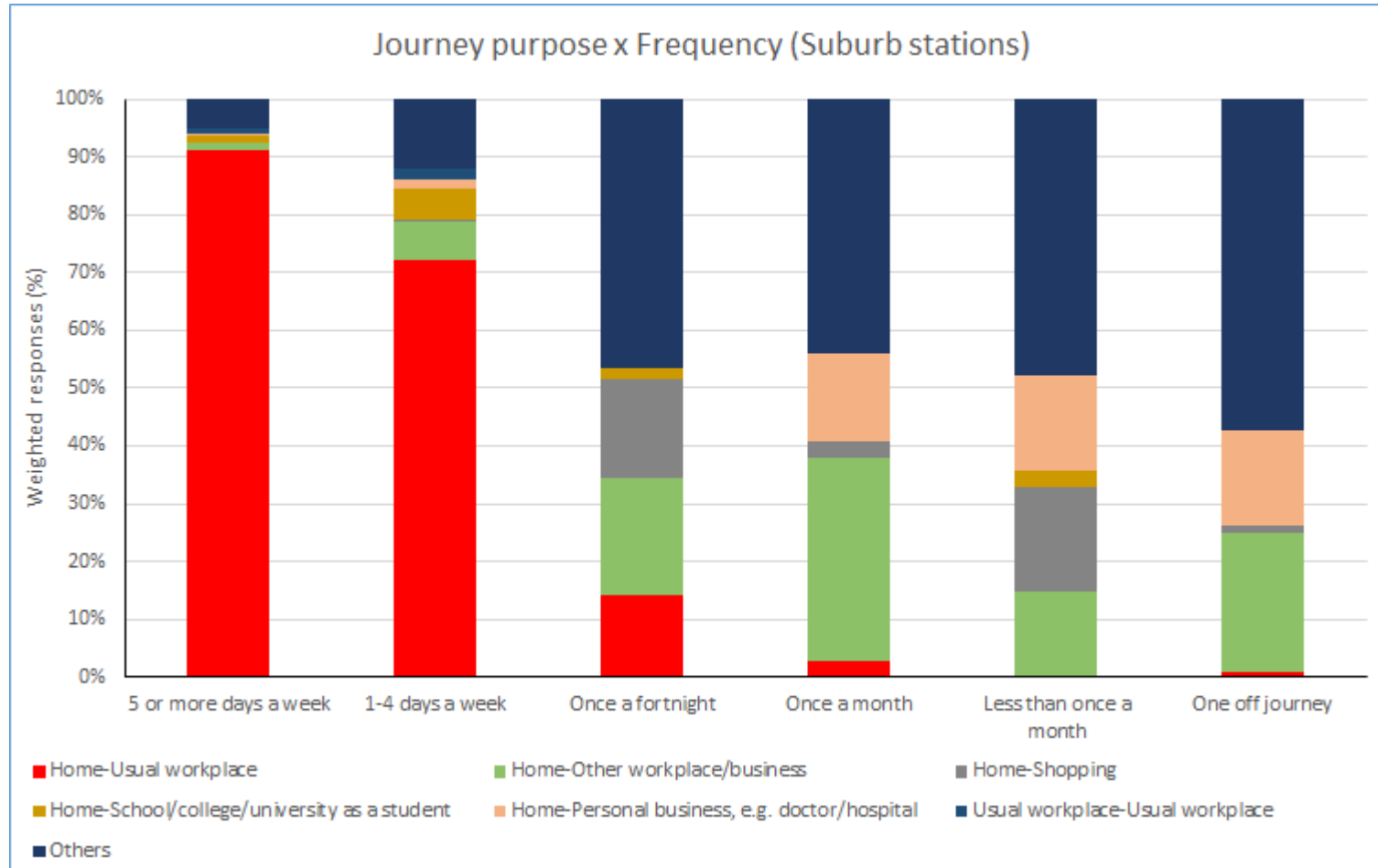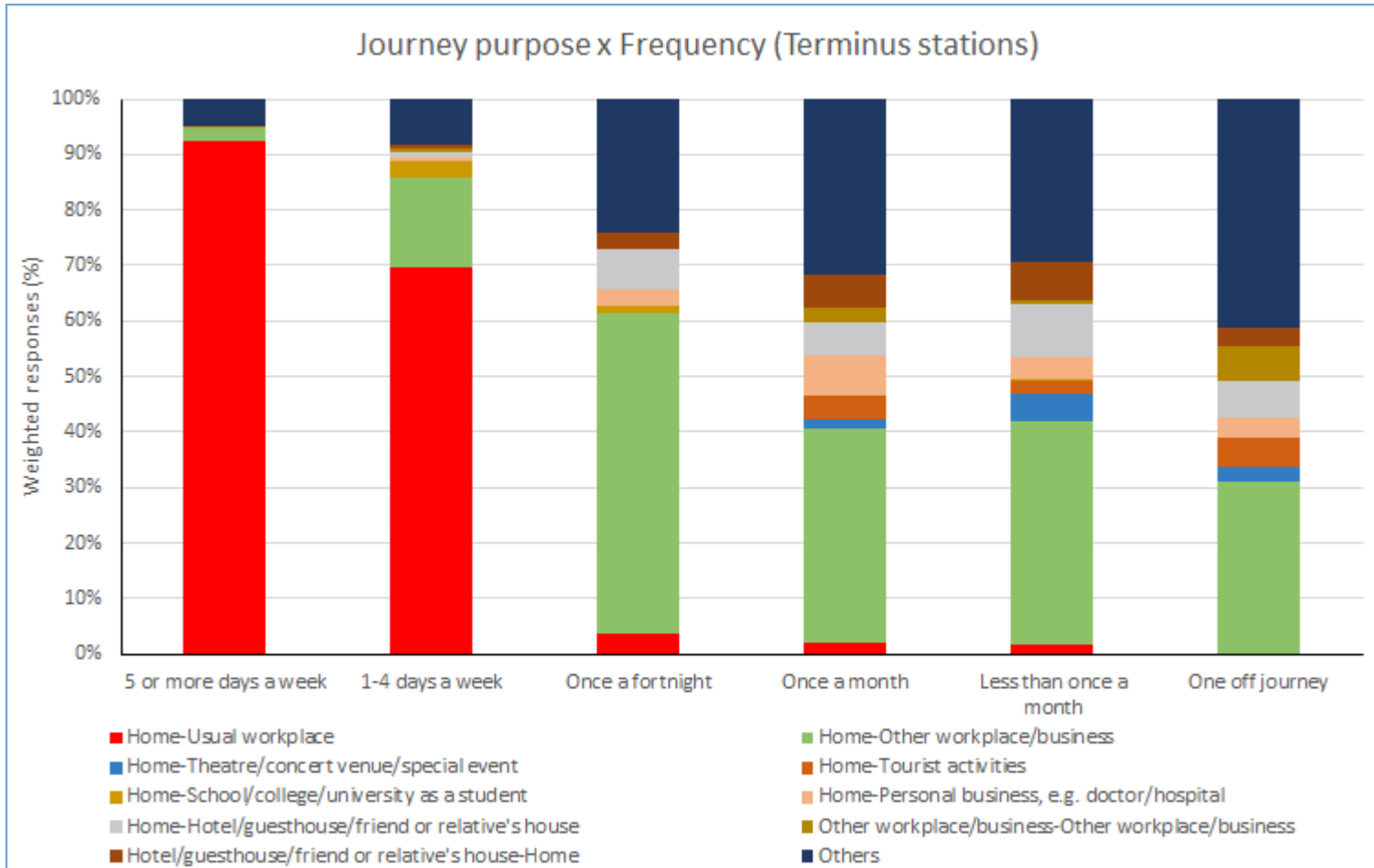- Others

Figure 13. Frequency and journey purpose, Terminus stations

2.6.4   Cross Station patterns & trends

Journey time analysis indicated that around 80% of journeys were less than 1.5 hours with a further 12% between 1.5 and 2 hours. The breakdown by station time in Table 2 indicates that:

- Journey times into terminus stations are significantly longer than other stations with around 35% greater than 2 hours, compared to between 5% and 10% for the other stations; and

- Shopping stations exhibit the shortest journey times with around 35% less than 45 minutes, with terminus stations having less than 10% of journeys under 45 minutes.

Table 3. Journey times by station grouping

Journey time	All stations	City	Suburban	Shopping	Terminus
Up to 45 minutes	24%	24%	23%	35%	8%
45-90 minutes	54%	57%	62%	52%	34%
90 minutes to 2 hours	12%	12%	10%	8%	23%
2 hours to 3 hours	7%	5%	3%	3%	18%
Greater than 3 hours	3%	2%	1%	2%	17%
Total	100%	100%	100%	100%	100%

Journey time data were also analysed on an individual station basis with mean and quartile analyses presented in Table 3. This supports the analysis on journey times by band in Table 2 and indicates that those LU stations not served by national rail services have the shortest mean journey time, generally varying between 60 and 70 minutes. Paddington stands out as the station with the longest journey times, reflecting the wide range of destinations served via the Great Western Railway services. City and suburban stations appear to exhibit consistent mean and median journey times with shopping stations having the lowest and terminus stations the highest journey times.

Table 4. Journey time analysis by station (Minutes)

Station	Mean	First quartile	Second quartile (Median)	Third quartile
Barbican	69	39	55	78
Bond Street	65	26	41	70
Canary Wharf	69	42	61	85
Ealing Broadway	67	41	63	84
Farringdon	73	42	64	89
Liverpool Street	89	52	76	111
Moorgate	69	34	59	89
Oxford Circus	70	37	52	79
Paddington	125	65	107	150
Stratford	76	44	61	94
Tottenham Court Road	60	36	51	70
Whitechapel	67	34	51	78
Liverpool Street NR[7]	67	38	49	101
Paddington NR	125	63	91	140
Station groupings				
City stations	73	41	61	91
Shopping stations	65	32	48	75
Suburb stations	70	41	59	85

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[7] Surveys at both Liverpool Street and Paddington were undertaken for both national rail and underground passengers and are reported separately

Terminus stations	125	64	99	145
All	77	40	61	92

In terms of number of interchanges:

- 30% of journeys were direct with no interchange;

- 47% of journeys required 1 interchange;

- 18% of journeys required 2 interchanges; and

- 5% of journeys required 3 or more interchanges.

The top 5 origin stations at each survey station are set out in Table 5, with those origins considered to be in scope for potential transfer to Elizabeth line services italicised. This indicates that the most common origins for several stations (Bond Street, Canary Wharf, Farringdon, Moorgate and Oxford Circus) are in areas not directly served by the Elizabeth line. These are generally stations with important north-south LU lines (Northern, Jubilee, Victoria lines) which also serve different geographical markets to the east-west Elizabeth line.

However, it should be recognised that, whilst these stations are the top 5 origins for each survey station, in general, they make up only a small percentage of origins to each station. This reflects the wide range of origins that these stations serve and an indication of the connectivity offered by the public transport network in London.

There are some exceptions to this, namely:

- Liverpool Street LU, where Chelmsford, Romford, Colchester, Chadwell Heath and Brentwood all contribute between 6% and 4%

- Stratford, where Romford contributes 5% of passengers;

- Ealing Broadway, where 80% of origins are from Ealing Broadway itself reflecting the fact that this is the one station surveyed where entry flows are considerably higher than exit flows in the morning;

- Paddington LU where Reading contributes 11% with Maidenhead and Bath Spa contributing 4%;

- Farringdon where St Albans and Harpenden contribute 5% and 3% respectively;

- Paddington NR with Reading at 5%;

- Liverpool Street NR with Romford, Gidea Park, Harold Wood and Brentwood at 19%, 12%, 11% and 10% respectively (although only platforms 15, 16 and 17 (TfL Rail) surveyed).

Those stations with their top 5 stations likely to be in scope for transfer to the Elizabeth line are largely as expected and include Ealing Broadway, Paddington, Tottenham Court Road, Liverpool Street, Whitechapel and Stratford.

Table 5. Top 5 Origin stations by surveyed stations

Station	Top 5 origins[8]
Barbican	Harrow-on-the-Hill (2%), ***Stepney Green (2%), Bow Road*** (1%), Finchley Road (1%) & Harold Wood (1%)
Bond Street	Willesden Green (3%), West Hampstead (3%), North Greenwich (2%), Cannons Park (2%) & Stanmore (2%)
Canary Wharf	North Greenwich (2%), Clapham Junction (1%), West Croydon (1%), Denmark Hill (1%) & West Hampstead (1%)
Ealing Broadway	***Hayes & Harlington (1%), West Drayton (1%), Southall (1%),*** East Acton (1%) & Greenford (1%)
Farringdon	St. Albans (5%), Harpenden (3%), Bedford Midland (2%), Pinner (1%) & Finsbury Park (1%)
Liverpool Street (LU)	***Chelmsford (6%), Romford (4%), Colchester (4%), Chadwell Heath (4%) and Brentwood (4%)***
Moorgate	Morden (3%), Oakleigh Park (1%), East Finchley (1%), Harrow-on-the-Hill (1%) & Stevenage (1%)
Oxford Circus	Brixton (4%) Shepherd's Bush (4%), Walthamstow Central (3%), Queen's Park (3%), Ealing Broadway (2%)
Paddington (LU)	***Reading (11%), Maidenhead 4%), Bath Spa (4%), Twyford (3%)*** & Swindon (2%)
Stratford	***Romford (5%), Chelmsford (4%), Chadwell Heath (4%), Gidea Park (3%), Harold Wood (3%)***
Tottenham Court Road	East Finchley (4%), Archway, (3%), ***Stratford (3%), Ealing Broadway (2%)*** & Finchley Central (2%)
Whitechapel	Leytonstone (4%), East Ham (3%), Barking (3%), Forest Hill (2%) & Hornchurch (2%)
Liverpool Street N Rail	***Romford (19%), Gidea Park (12%), Harold Wood (11%), Brentwood (10%) & Chadwell Heath/Stratford (both 5%)***
Paddington N Rail	***Reading (5%), Ealing Broadway (3%), Maidenhead (3%), Slough (3%)*** & Didcot Parkway (3%)

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[8] Those origins considered to be in scope for potential transfer to Elizabeth line services in bold italicised font

Figure 14, Figure 15 and Figure 16 show the top 20 origins[9] for Liverpool Street, Paddington and Canary Wharf respectively and illustrate that:

- Paddington serves a west-focussed, long distance rail market but with some origins in south west London;

- Liverpool Street has a greater dispersion of journeys reflecting its connectivity to the city and west end and a wider range of origins than Paddington; and

- Canary Wharf has a concentration of east and north-east London and Essex origins but with some notable origins to the south and west.

Figure 14. Liverpool Street Underground and rail – top 20 origins

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[9] These are represented using standard deviation rather than absolute values, as standard deviation shows the variation around the mean, meaning it is easier to pick out differences in station use.

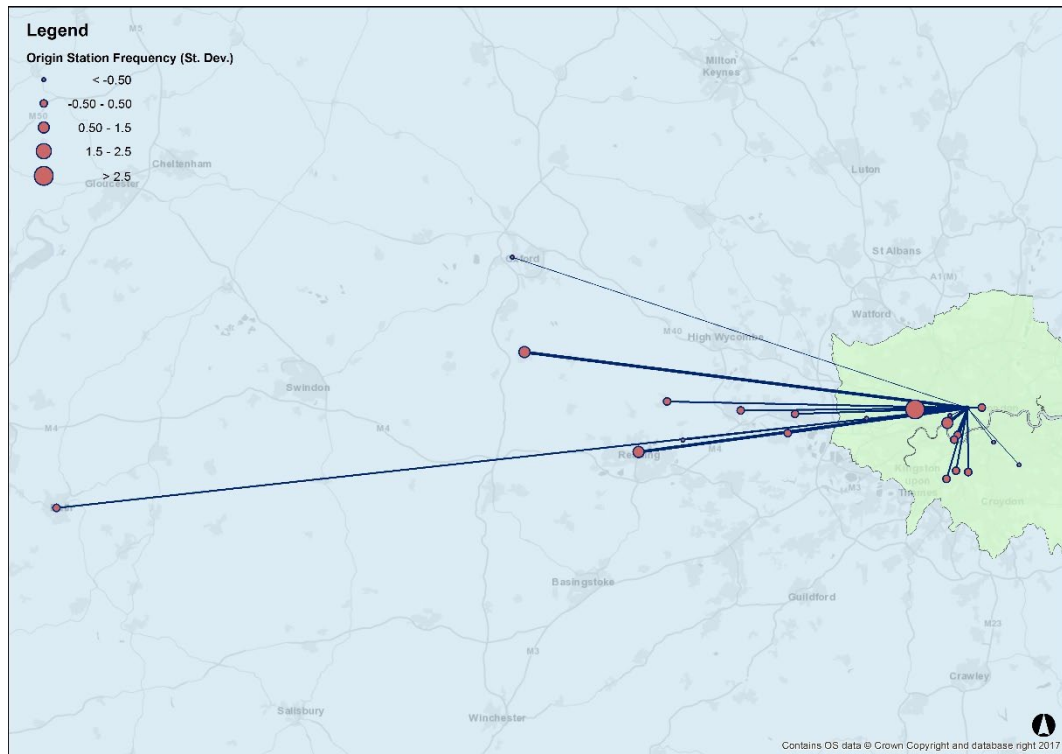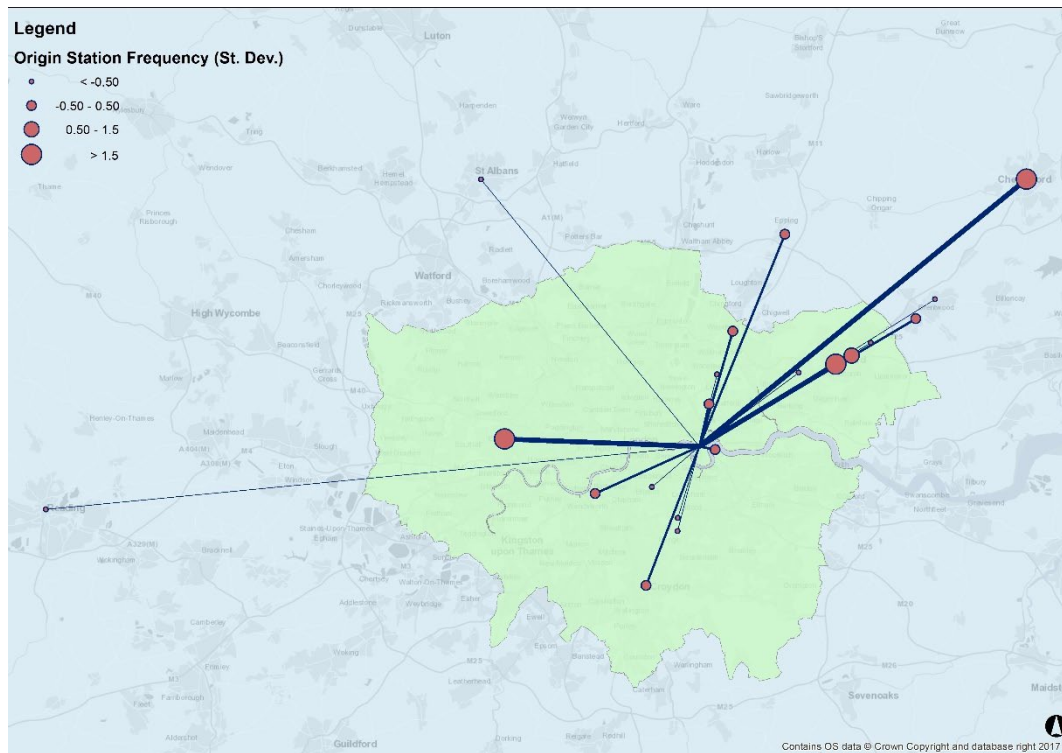Figure 15. Paddington Underground and rail – top 20 origins

Figure 16. Canary Wharf – top 20 origins

2.6.5   Routeing

The survey captured routeing information by recording the locations where passengers interchanged between their origin and destination. The routeing and main interchange locations associated with each station is summarised in Figure 17 to Figure 19 and covers the complete 07:00-12:00 time period.

The main features can be summarised as

- Direct (no interchange) journeys for most stations account for between 30% and 40% of total journeys except for:

  o those stations where interchange movements were explicitly surveyed and captured separately (i.e. between platforms at Oxford Circus, Stratford and Canary Wharf);

  o Ealing Broadway where nearly 60% of journeys are direct, reflecting direct access from the Central and District lines;

- The most common interchanges to surveyed stations on the sub-surface lines are other sub-surface stations reflecting general ease of interchange and key rail stations (Kings Cross, Moorgate, Liverpool Street) along this corridor;

- There are only a few instances of stations where a significant proportion of passengers interchange at two specific stations before reaching their destination. The exceptions are:

  o Whitechapel where 10% of passengers interchange firstly at Stratford then undertake the cross-platform interchange from the Central to District Lines at Mile End prior to arriving at Whitechapel;

  o Oxford Circus where 43 % of passengers undertake the first interchange and 23% their second interchange

Figure 17. Main Interchange Locations for LU surveyed stations (Barbican, Canary Wharf, Bond Street, Ealing Broadway)
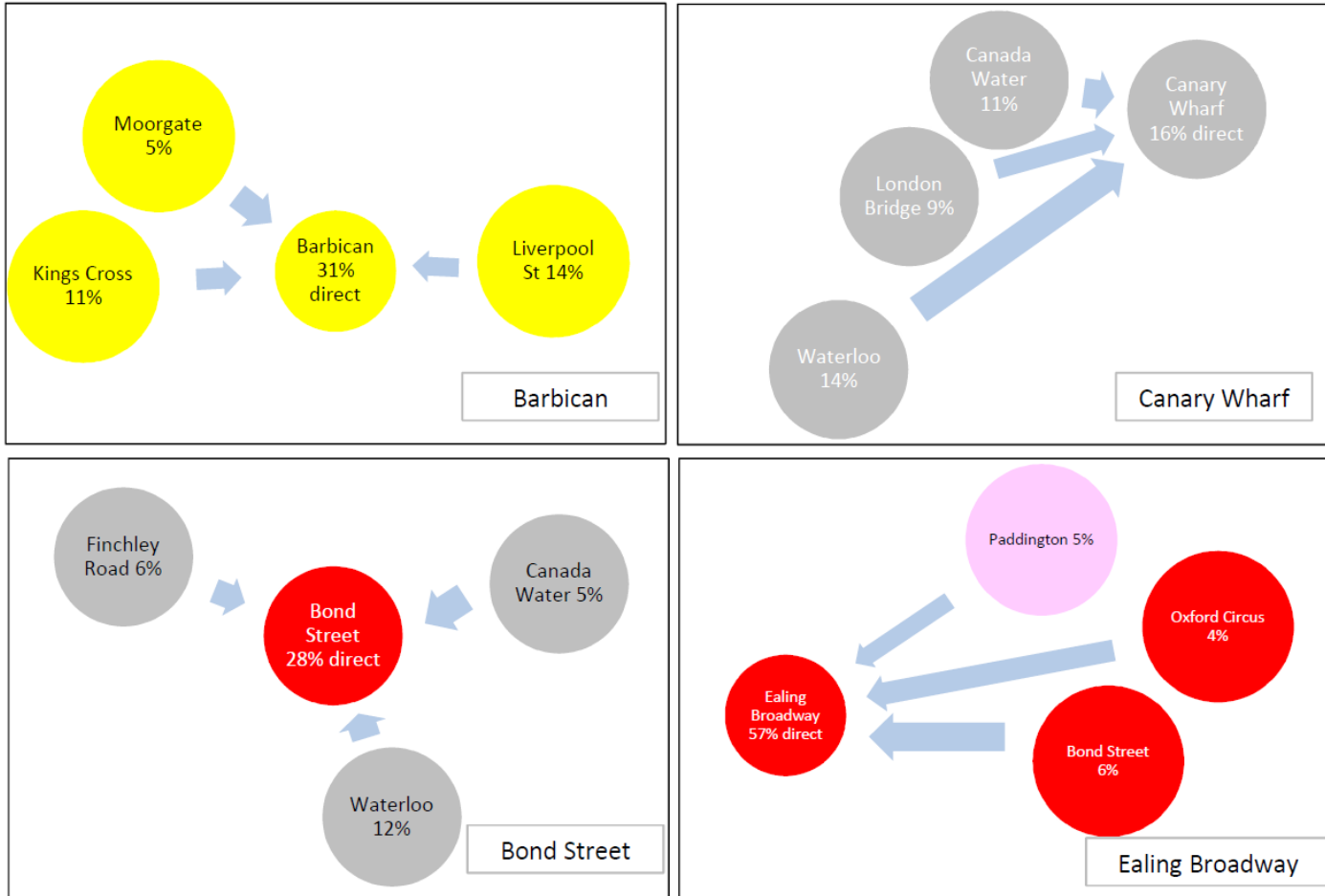
Figure 18. Main Interchange Locations for LU surveyed stations (Stratford, Tottenham Court Road, Mile End, Liverpool Street)
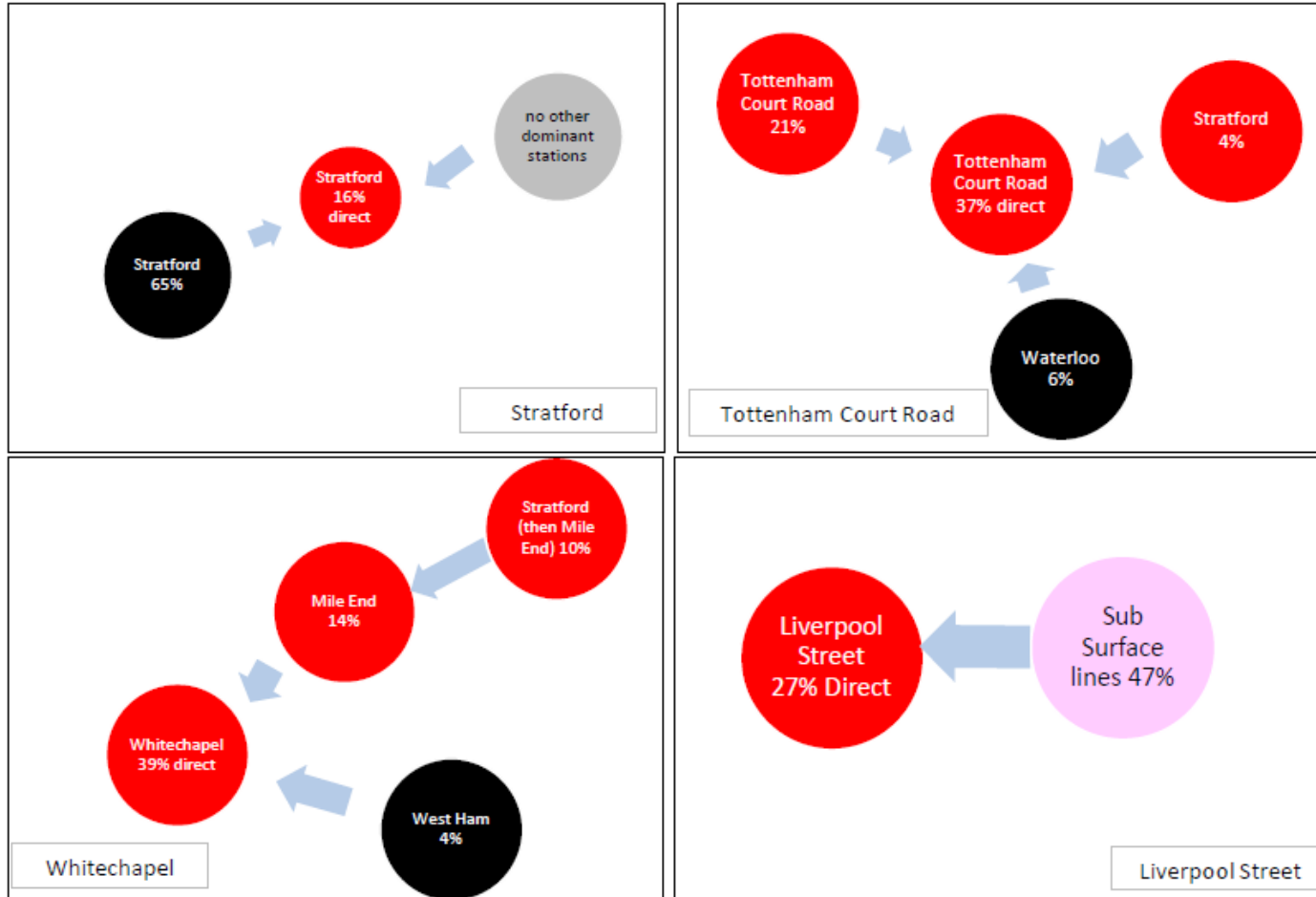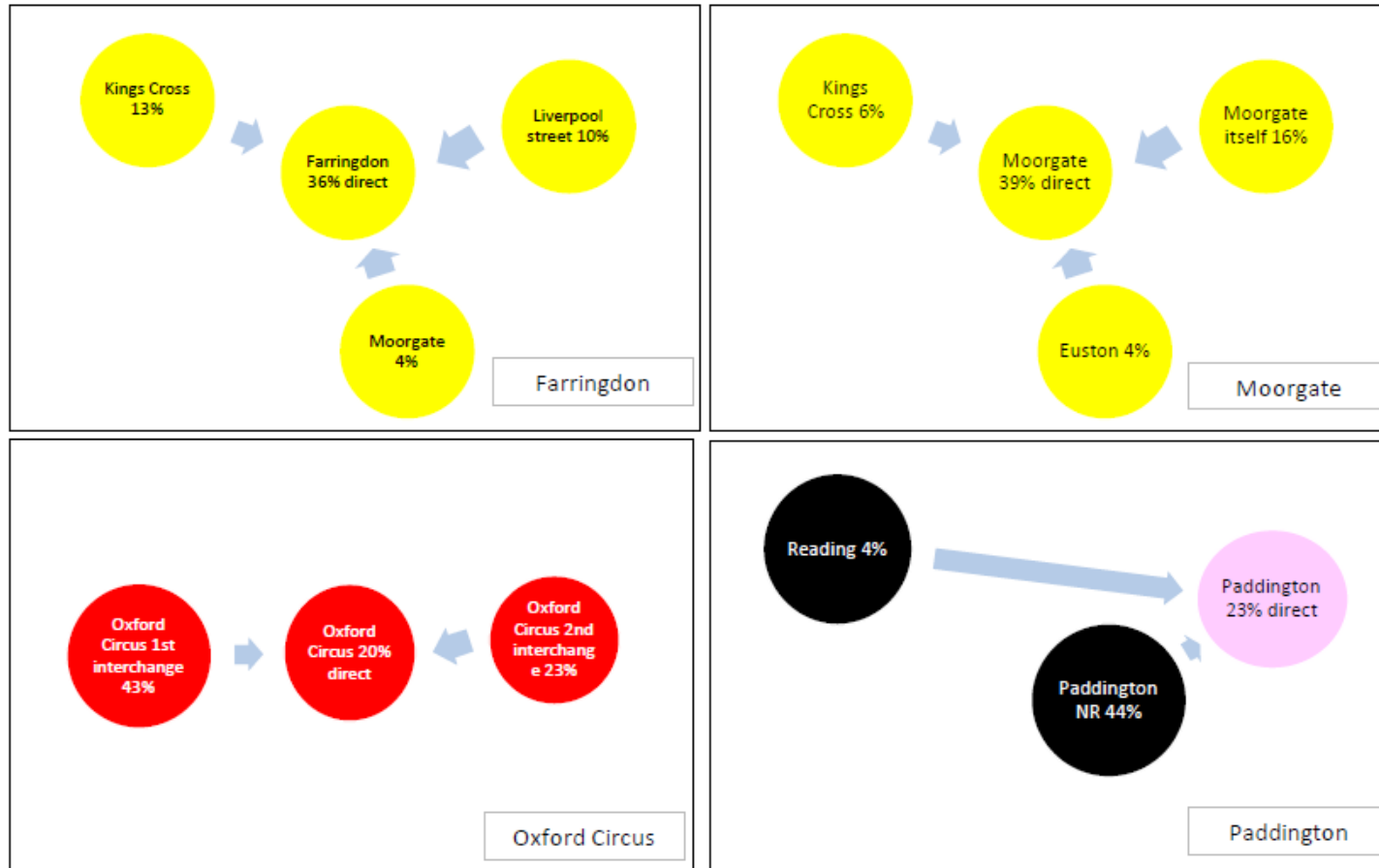
Figure 19. Main Interchange Locations for LU surveyed stations (Farringdon, Moorgate, Oxford Circus, Paddington)

3 Rail passenger Analysis - ORR Origin Destination Matrices

3.1 Background

To date, transport data have been considered at an aggregate level (London-wide, borough level, line level), using publicly available data. However, the 2017 Interim Report noted that analysis using more fine-grained data, such as LENNON and Oyster/ODX, would be used to refine the analysis.

Arup undertook a review of LENNON and alternative data, and concluded that the Office of Rail and Road Origin-Destination Matrix would provide the best available source of data in the London Travelcard Area, on the basis that it was based on LENNON data but was further refined by ORR using:

- Data from Transport for London (TfL)'s Oyster Clicks Model (OCM);

- The latest methodology on allocation of demand to London terminus stations; and

- Application of 'Season ticket journey allocation' adjustments.

Data was therefore requested from the ORR for the 2016-17 financial year covering London, the south east and east regions (The OD matrix covers the whole of the country). The rationale behind obtaining 1 year of data was to ensure that it provided usable results with the potential to consider additional years for the final report.

These data have been analysed to obtain origin-destination movements corresponding to a subset of stations corresponding to the future London transport network which can be used to compare post-opening movements between future Elizabeth line stations. In addition, further movements have been analysed based on where TfL's Railplan model predicts significant flow changes, including:

- Movements from the Great Western Main Line catchment area into Paddington;

- Movements into Liverpool Street from east London, Essex and further afield;

- Movements into Waterloo, primarily from the Windsor and Eton lines;

- Movements into Fenchurch street; and

- Movements from beyond Abbey Wood (Gravesend) into south London rail termini.

This analysis is reported below. Whilst these results are of interest for understanding baseline conditions, the real value will come from analysing a consistent set of ORR OD matrices for the post-Elizabeth line opening to observe where there have been changes and how closely these correspond to expected changes.

3.2   Analysis

The data were provided by ORR as annual demand between origin and destination. To validate the numbers, the total origins and destinations from the ODM for each station was compared with the ORR 2016-17 estimates of station usage[10]; this indicated an exact match, indicating that the ODM data were as expected and suitable for further analysis. Station usage estimates are shown for all future Elizabeth line stations on the NR network for 2016-17 in Figure 20.

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[10] http://orr.gov.uk/statistics/published-stats/station-usage-estimates

Figure 20. ORR Station Usage estimates – 2016-17

ORR Station usage estimates 2016-17 - Crossrail NR stations only
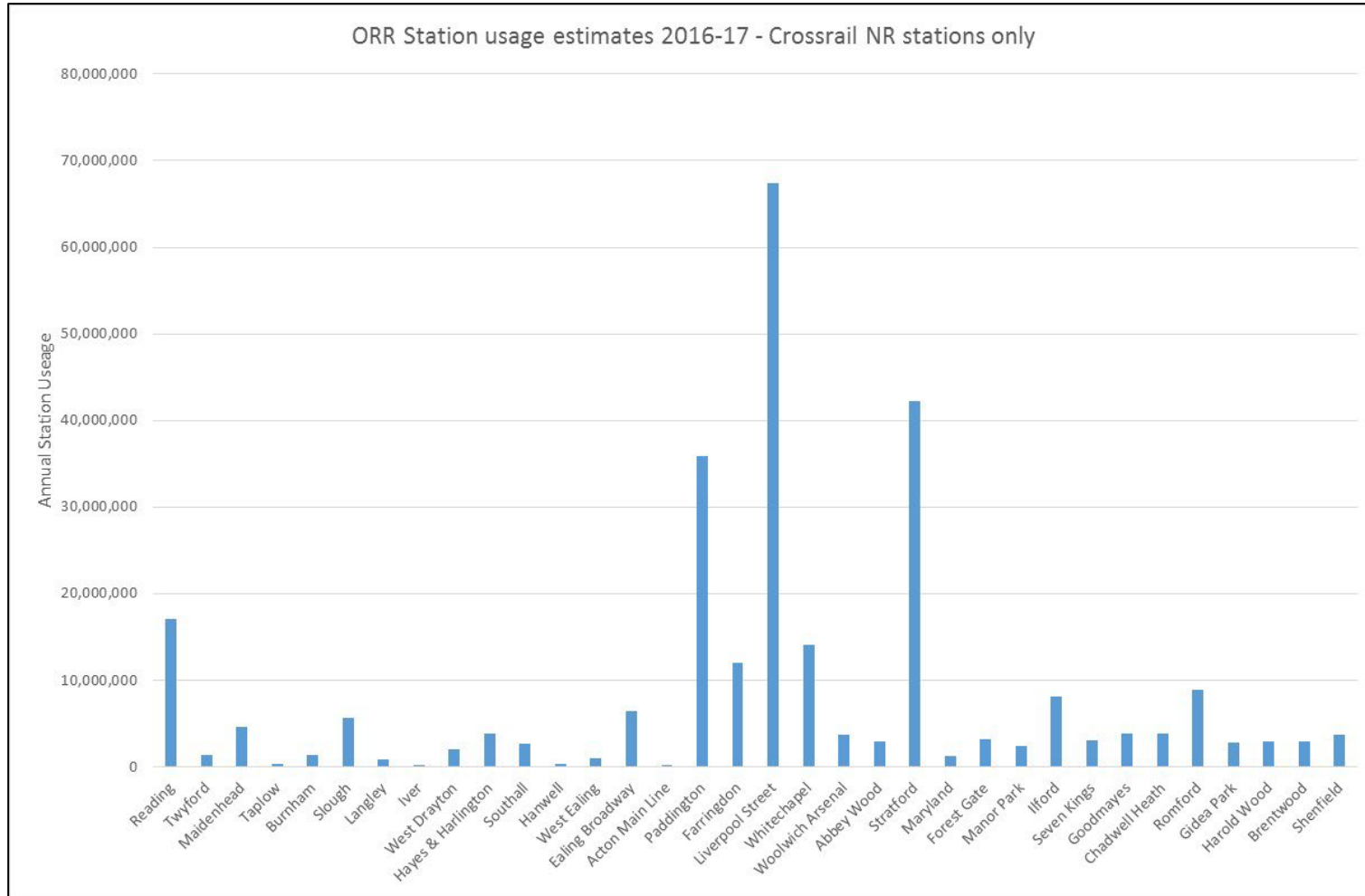
The ODM data were interrogated and the top ten origins extracted for Paddington and Liverpool Street, together with termini stations for rail lines forecast to be impacted by the Elizabeth line, namely Waterloo and Fenchurch Street; for the purposes of this analysis, Victoria, Charing Cross, Cannon Street and London Bridge were combined as these were of secondary importance. This is set out in Table 6 which demonstrates, as expected, the importance of Paddington for stations west of London and Liverpool Street and Fenchurch Street for stations east of London.

Table 6 – Top 10 origins for selected London Termini Stations, 2016-17

London Paddington	%	London Waterloo	%	London Liverpool Street	%	London Fenchurch Street	%	Victoria, Cannon Street, Charing Cross, London Bridge	%
Reading	14.1%	Clapham Junction	6.4%	Stansted Airport	7.3%	Upminster	10.6%	East Croydon	5.4%
Slough	6.9%	Surbiton	4.8%	Chelmsford	6.6%	Benfleet	9.7%	Gatwick Airport	5.3%
Maidenhead	6.5%	Wimbledon	4.6%	Stratford	4.8%	Leigh-on-Sea	8.2%	Lewisham	2.7%
Oxford	5.3%	Woking	3.9%	Romford	4.2%	Grays	7.7%	Bromley South	2.4%
Ealing Broadway	4.6%	Putney	3.3%	Colchester	3.3%	Basildon	7.5%	Brighton	2.3%
Hayes & Harlington	4.4%	Guildford	3.0%	Shenfield	2.9%	Barking	7.1%	Clapham Junction	1.7%
Didcot Parkway	4.3%	Richmond	2.8%	Billericay	2.8%	Laindon	6.2%	Orpington	1.7%
Southall	3.3%	Earlsfield	2.7%	Ilford	2.7%	Chalkwell	4.7%	Sevenoaks	1.6%
Bristol Temple Meads	3.2%	Basingstoke	2.1%	Bishops Stortford	2.3%	Chafford Hundred Lakeside	4.1%	Hither Green	1.2%
Swindon	3.0%	Twickenham	2.0%	Wickford	2.0%	Southend East	3.4%	Tunbridge Wells	1.2%