Appraisal Framework Module 4.

Surface Access: Heathrow Airport Northern Runway Extension Appendices

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Contents

1 Introduction

1.1 Background

1.1.1. The Airports Commission (AC) was established in 2012 by the UK Government to examine the need for additional UK airport capacity and to recommend how any additional capacity requirements can be met in the short, medium and long term. The Commission is due to submit a Final Report to the UK Government by summer 2015 assessing the environmental, economic and social costs and benefits of various solutions to increase airport capacity, considering operational, commercial and technical viability.

1.1.2. A key milestone in the AC's operational life was the delivery in December 2013 of an Interim Report. Following a general call for evidence, the Interim Report detailed the results of analysis of the capacity implications of forecast growth in UK aviation demand and a preliminary appraisal on a long-list of proposals put forward by scheme promoters to address the UK's long-term aviation connectivity and capacity needs – this work is described as Phase 1. The associated appraisal process identified three short-listed options, two focussed on expanding Heathrow Airport and one on expanding Gatwick through the provision of a second runway. These short-listed options were to be further developed and appraised during Phase 2, with further phases of work programmed in the run-up to the submission of the Final Report in the summer of 2015.

1.1.3. Shortly after its inception, the AC issued tenders for support contracts to engage independent technical advice on a range of aspects of the Commission's work. Jacobs together with sub-consultants Leigh Fisher and Bickerdike Allen Partners were appointed as the sole supplier on the Airport Operations, Logistics and Engineering Support Contract (ref: RM1082), which runs throughout the AC's lifespan up until the summer of 2015.

1.1.4. This document summarises the methodology employed by Jacobs and the assumptions used to develop surface transport demand forecasts for Heathrow Airport with a Northern Runway Extension in place. It is supported by a Technical Appendix, which includes detailed information about the calibration of models used to generate forecasts and assess the capacity implications.

1.2 Study scope

1.2.1. Under the terms of the RM1082 support contract, Jacobs were commissioned to develop the aforementioned Phase 2 assessment with respect to surface transport for a potential Northern Runway Extension at Heathrow. This assessment focussed specifically on three key elements as follows:

- Estimating the net airport passenger and employee surface transport demand associated with the Northern Runway Extension, accounting for expected growth in demand to and from the airport in its current form;
- Identifying surface transport measures to meet net airport-related demand associated with the Northern Runway Extension, accounting for capacity implications related to background growth and non-airport travel demand;
- Assessing the engineering feasibility and high-level cost of the surface transport measures identified to meet forecast travel demand.

1.2.2. The ultimate aim of the study was to provide guidance to the AC on the feasibility and likely surface transport issues associated with delivering the Northern Runway Extension at Heathrow. The terms of reference covered an assessment of forecast demand in 2030. Reporting for the Phase 2 surface transport assessment was defined as follows:

- the Methodology Statement describes the methodology employed by Jacobs to develop surface transport demand forecasts for the Northern Runway Extension – this summary is supported by:

    - a Technical Appendix, which includes detailed information about the calibration of models used to generate forecasts and assess the capacity/level of service implications;
- the Assumptions Log defines the assumptions used to develop the forecasts;
- the Appraisal Report details the results of the assessment undertaken and draws key conclusions on the impacts of the Northern Runway Extension at Heathrow.

1.2.3. This document includes the Methodology Statement and supporting Technical Appendix, and the Assumptions Log. All documents should be read for a full understanding of the approach employed by Jacobs to deliver Phase 2 Heathrow surface transport assessment.

2 Methodology Statement

2.1 Overview

2.1.1. The approach to forecasting surface transport demand for Heathrow airport with the Northern Runway Extension can be broken down into a number of key stages as follows:

- Estimating total peak-hour demand to and from the airport;
- Allocating total peak-hour trips between the airport and geographic regions in the UK;
- Assigning rail trips to/from different geographic regions to different rail corridors;
- Allocating a main mode of travel to each person trip;
- Assigning road-based trips to the strategic road network accessing Heathrow Airport; and
- Assessing the internal road network layout proposed for Heathrow Airport.

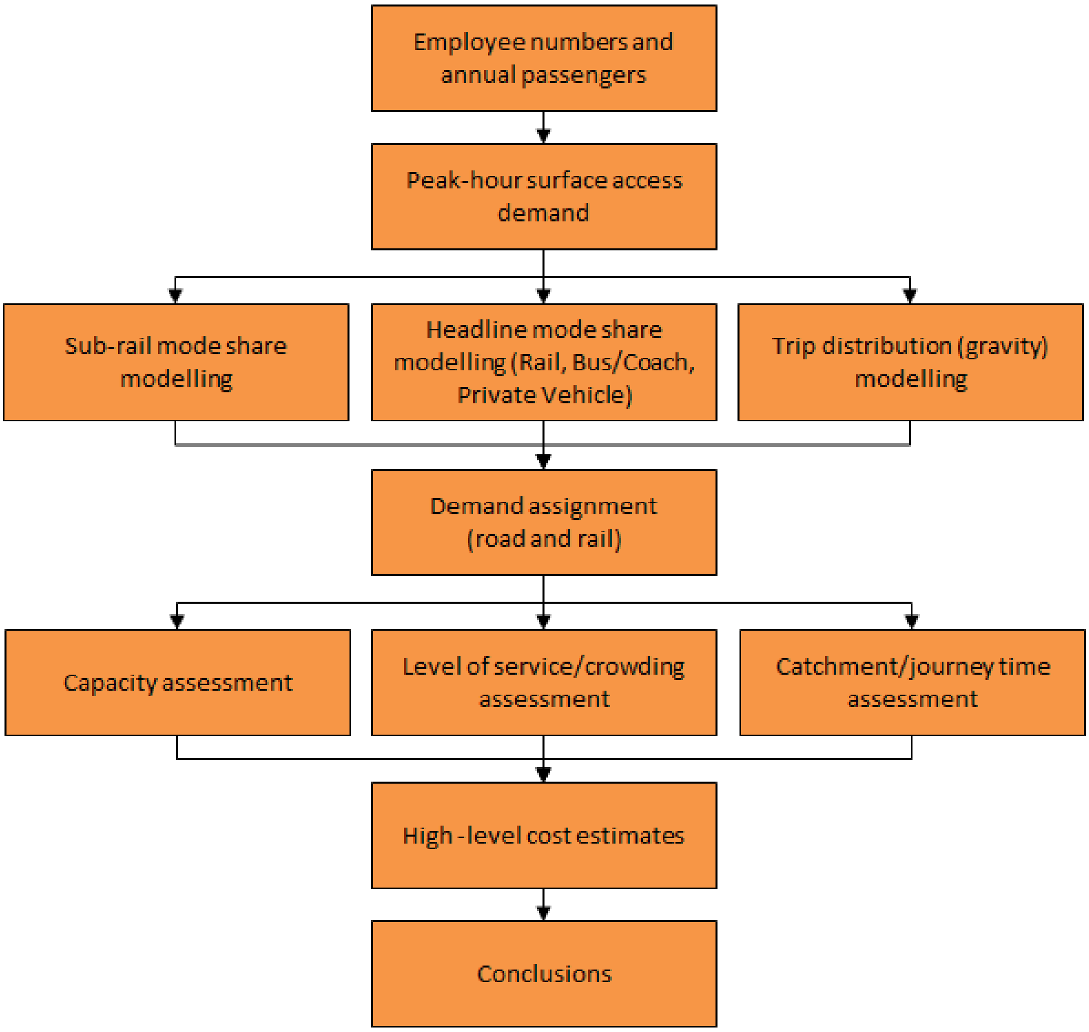
2.1.2. This methodology is summarised diagrammatically in **Figure 1**.

2.1.3. Surface transport demand in this context was considered to include trips made to and from the airport by both air passengers and employees based on-site and in direct airport-related employment in the immediate vicinity of the airport. Passengers and employees were considered separately before being combined for the analysis of rail mode choice and road routes.

2.1.4. This section details the development of a calibrated base year demand model and an ‘extended baseline with SRA’ scenario including the surface access requirements for the Northern Runway Extension at Heathrow, and is structured as follows:

- Inputs – presents the datasets used and assumptions used in the development of the surface access model;
- Methodology – details how the above inputs and assumptions were used to develop the model and analyse the outputs;
- Analysis – presents the outputs of the model calibration process.

Figure 1: Airport surface transport demand forecasting methodology overview



2.2 Inputs

2.2.1. A number of input data sets and referenced sources were used in the development of the surface access demand model. **Table 1** presents the Headline Input Assumptions and their source.

2.2.2. In addition to the Headline assumptions a number of sources were used in the development of the surface access model to provide journey time, distance and cost information by mode of transport as well as observed data to calibrate the modelled responses. These sources and uses are as follows:

- CAA survey data 2012 – used in the calibration of the surface access model;
- Google maps – provided journey times and distances for the development of generalised costs;
- TfL Journey Planner website – provided journey times, frequencies and number of interchanges for bus travel for the development of generalised costs;
- National Express Website – provided journey times, frequencies and costs for coach travel for the development of generalised costs;
- Car sub-mode assumptions – various websites including Heathrow's parking website and long-haul taxi firm websites to provide costs for development of car based generalised costs; and
- National Rail and TfL websites – provided rail and tube times, frequencies and costs for the development of the rail generalised costs.

2.2.3. All the data described above was presumed accurate (subject to logic checks), as was any information (or confirmation of the absence thereof) provided by the AC and other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

2.2.4. In addition to the data raised above, parameter values were selected for the base year and future year surface demand models taken from various sources. Where no appropriate values could be sourced, sensitivity testing was undertaken with appropriate values.

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Table 1: Headline input assumptions

Input		Passenger Value	Passenger Ref.*	Employee Value	Employee Ref.*
Annual (Unconstrained)	MPPA (2012)	70,000,000	4.4.1.1	75,000	4.4.1.1
	MPPA (with Northern Runway Extension)	103,600,000	4.4.1.1	90,000	4.4.1.1
	MPPA (2 runway)	82,500,000	6.2.6.5	72,100	1.7.1.1
	Connecting Passengers	35%	3.2.1.5	-	-
	non-connecting Passengers	65%	3.2.1.5	-	-
Daily	% Passengers on test day	0.30%	4.4.1.2	57%	4.4.1.2
Daily person trip (2012)	Daily person trip (passengers)	136,500.00	Calculated	-	-
	Daily person trip (Employee)	-	-	88,000	Calculated
Daily person trip (2030)	Daily person trip (passengers)	202,020.00	Calculated	-	-
	Daily person trip (Employee)	-	-	104,000	Calculated
Directional Flow	To airport	50%	Professional Judgment	50%	Professional Judgment
	From airport	50%		50%	
Peak Hour flow	To airport	8%	Traffic at BAA airport 2010	9.7%	Heathrow Employment Survey 2013
	From airport	5%		2.7%	
Passenger Split by Purpose	Business	33%	2012 CAA data	-	-
	UK Leisure	39%		-	-
	Foreign Leisure	29%		-	-
Employee Mode Split (2013)	Private car	-	-	47%	Heathrow Employment Survey 2013
	Bus/Coach	-	-	32%	
	Rail	-	-	11%	
	Other	-	-	10%	
Car occupancy Rate	Employee Car	-	-	1.0	
	Passenger Car	1.5	2012 CAA data	-	-
Rail Meet and Greet factor	To airport	2.55%	2013 CAA data	-	-
	From airport	2.55%	2014 CAA data	-	-
Value of Time (2012)	Business	69.19	LASAM	69.185	LASAM
	Leisure	26.99	LASAM	26.99	LASAM

* Unless otherwise stated, section numbers relate to Heathrow's submission - taking Britain Further - Volume 1

2.3 Modelling methodology

2.3.1. Once the inputs had been defined as summarised above, a series of steps were then undertaken to develop the surface access models. These are described in this section and are summarised as follows:

- estimating total peak-hour demand to and from the airport;
- allocating total peak-hour trips to and from the airport to geographic regions in the UK through a distribution model;
- allocating a main mode of travel to each person trip through a main mode choice model;
- assigning rail trips to/from different geographic regions to different rail corridors through a rail sub-mode model;
- assigning road-based trips to/from the airport to the strategic road network serving the airport.

2.3.2. Peak hour demand for travel, both employees and passengers, is taken directly from the headline assumptions presented in **Table 1** and follows the flow process presented in **Figure 2,** whereby the total passengers and employees are converted to a daily trip and then peak hour demand both to and from the airport.

2.3.3. Following the development of peak-hour demand, the origins of both employees and passengers were derived through the development of a distribution gravity model in combination with observed distribution patterns. 2012 CAA survey data was used to identify a District-level zoning system at a two-tier level with a full mainland UK zoning system of 361 zones, 72 of which were used to represent travel conditions within the full model. **Figure 3** and **Figure 4** present the CAA 2012 district plan and the Heathrow zone plan.

Figure 2: Heathrow airport demand

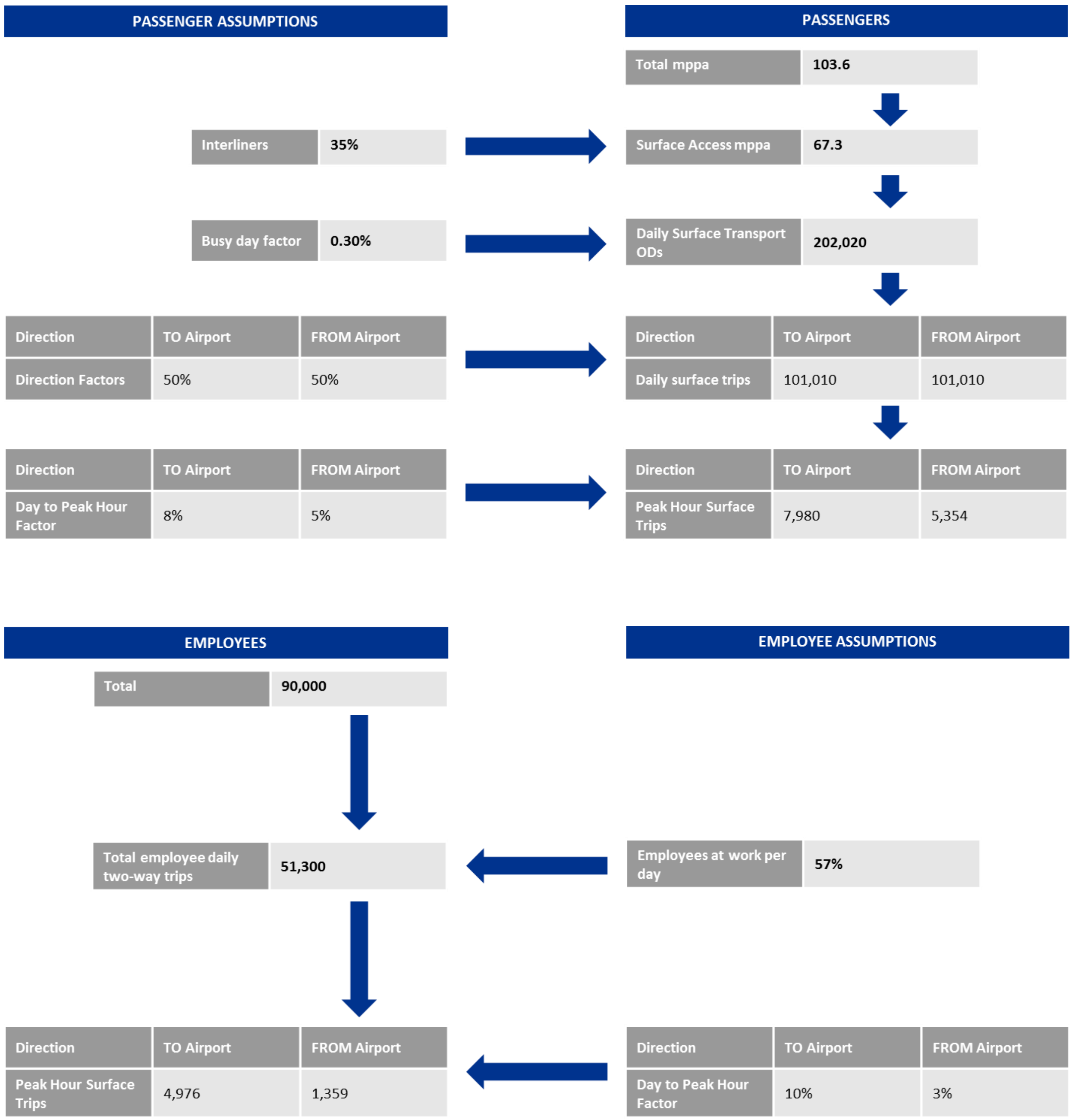


Figure 3: CAA district zone map

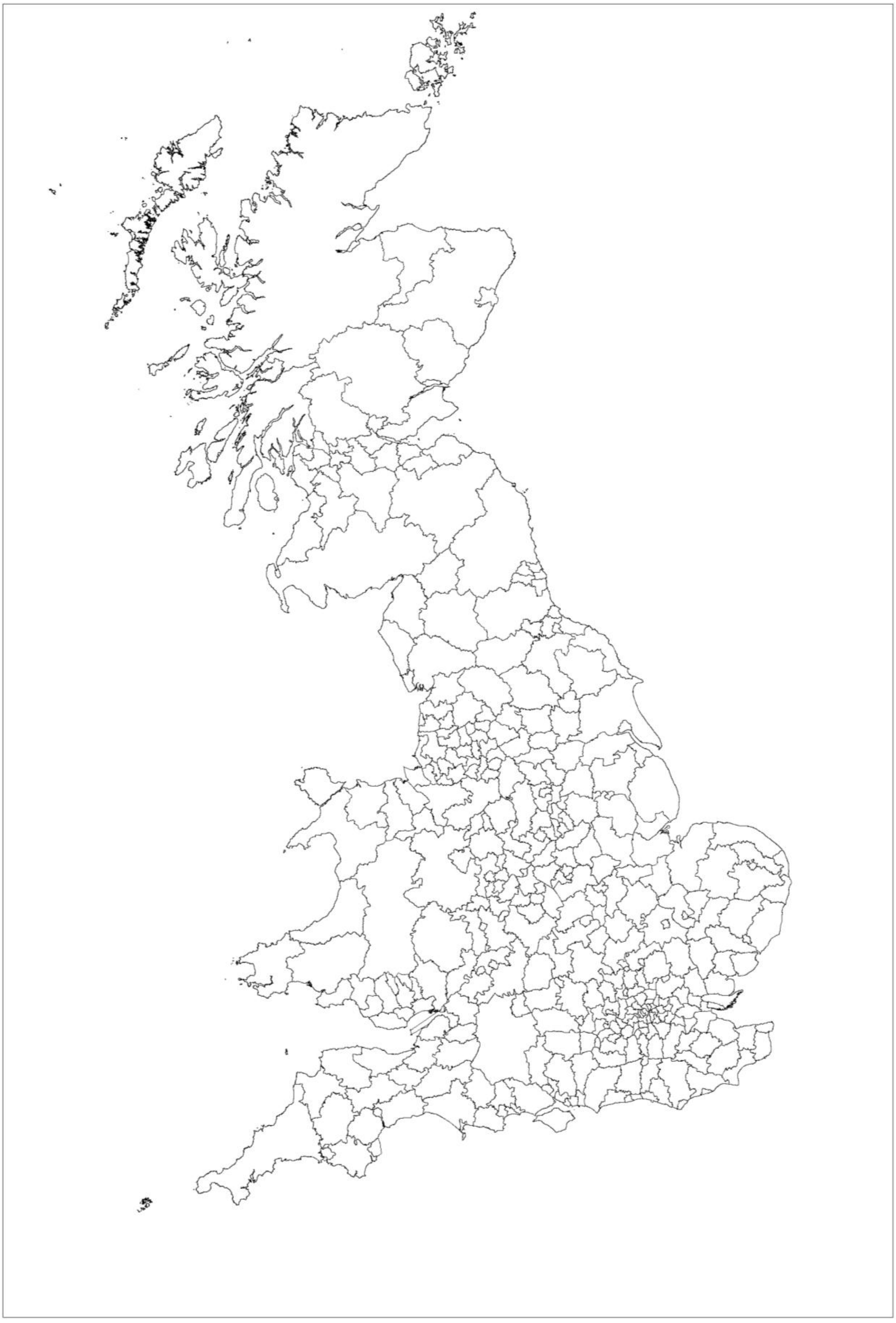
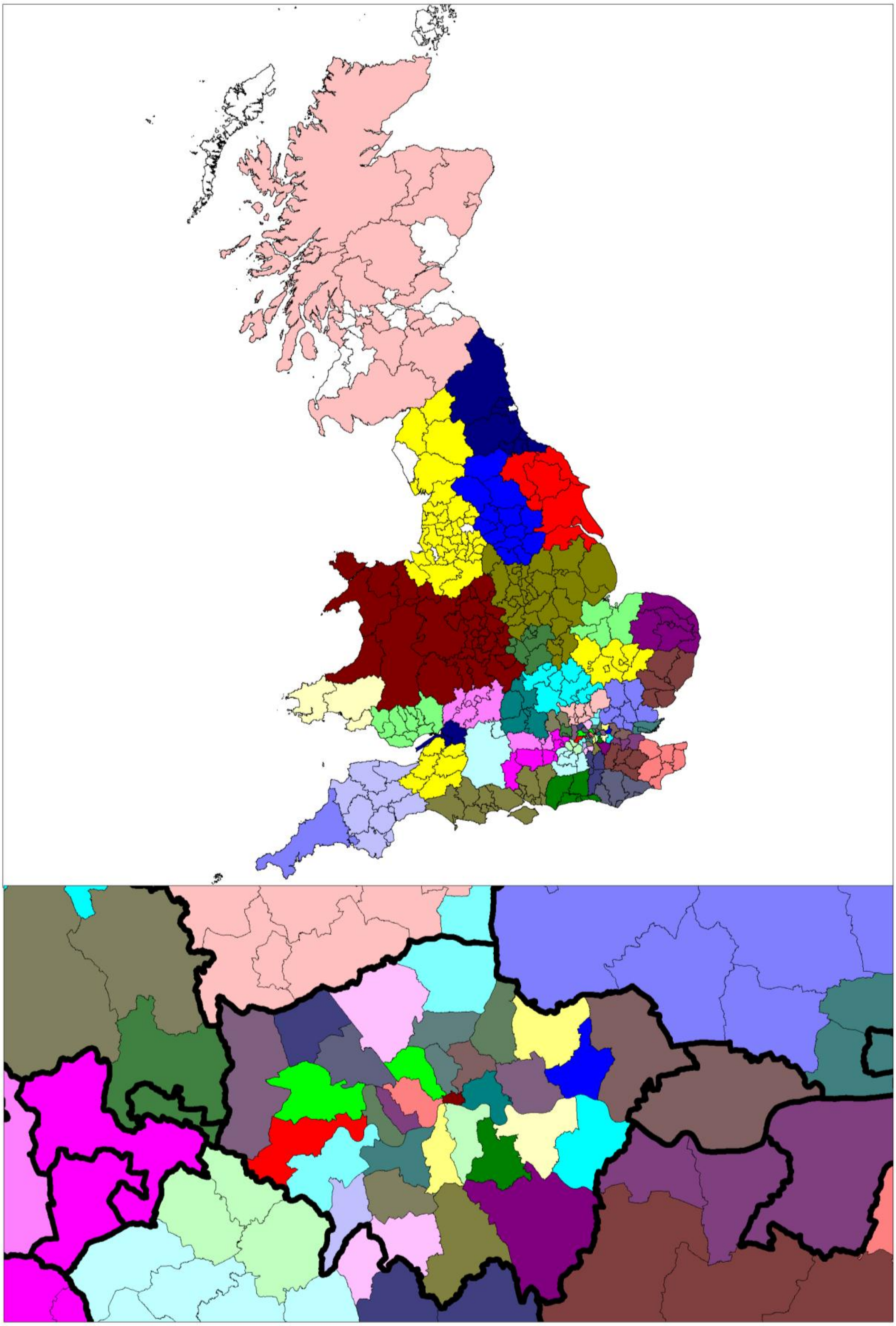
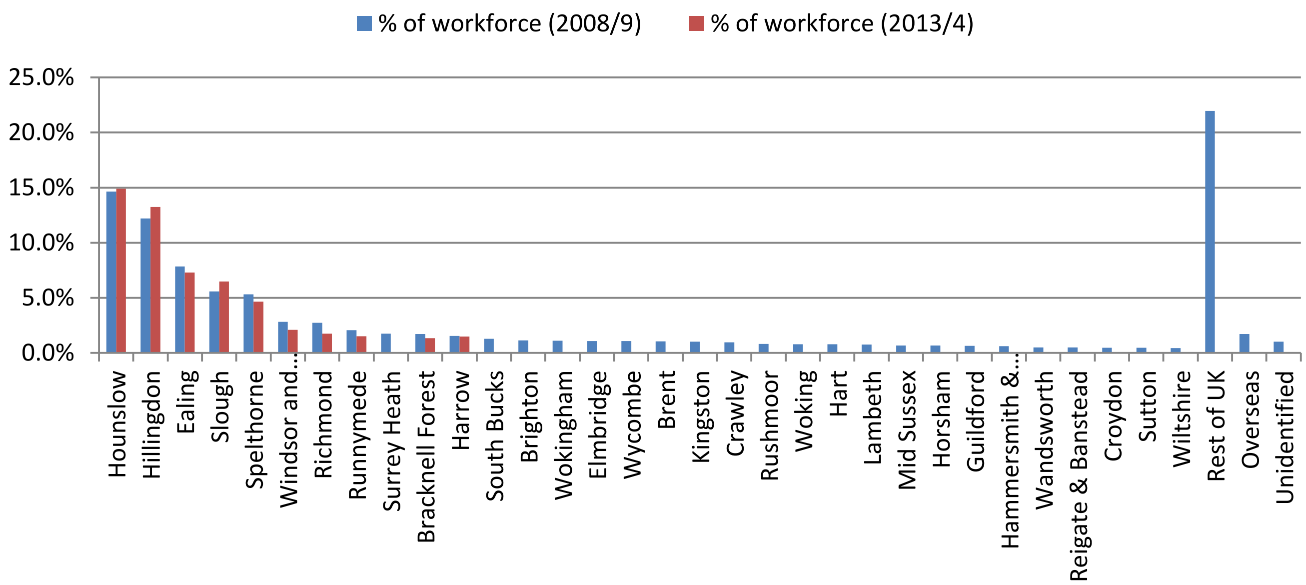


Figure 4: Heathrow Zone Plan



2.3.4. Employee trips to/from Heathrow were sourced from Heathrow airport employment surveys undertaken in 2008/9 and 2013/4, with the latter undertaken by Ipsos Mori on behalf of the airport operator. All Heathrow employee home locations recorded during these surveys are summarised at district level in **Figure 5** – data was only provided in the 2013/4 report for the top 10 districts, which included Bracknell Forest and Harrow but excluded Surrey Heath. Due to the lack of detailed information the 2013 data was used to forecast the trip distribution of employees to Heathrow; no adjustment was made to the forecast year.

Figure 5: All Heathrow employees by district of residence (2013/4)



Sources: HAL (2009), 'Heathrow: On-airport Employment Survey, 2008/09 - Summary report';
HAL (2014), 'Taking Britain further, Heathrow's plan for connecting the UK to growth TECHNICAL SUBMISSION VOLUME 2' (p315)

2.3.5. Passenger trip distribution, rather than using observed distributions, was calculated through the development of a gravity model with allowance for the user to select either using observed CAA 2012 trip distribution patterns or calculated through the generalised cost.

2.3.6. To assist in the development of a passenger gravity model the CAA data included two fields related to passenger country of residence (categorised as either 'UK' or 'foreign') and overall journey purpose (categorised as either 'business' or 'leisure'), allowing the data to be sub-divided into these four categories to refine the analysis.

2.3.7. In order to calibrate the four gravity models, explanatory variables were investigated and then calibrated with the minimum generalised cost of travel by mode selected as the disutility function. The explanatory variables selected were as follows:

- Total resident population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total working population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total employee jobs – sourced from the ONS Annual Business Inquiry for 2009 and 2012, also available on the ONS website;

- Total employee jobs in the hospitality sector – assumed as a proxy variable influencing foreign leisure trips, and also sourced from the ONS Nomis website; and

- 2012 income - taken from National Trip End Model estimates.

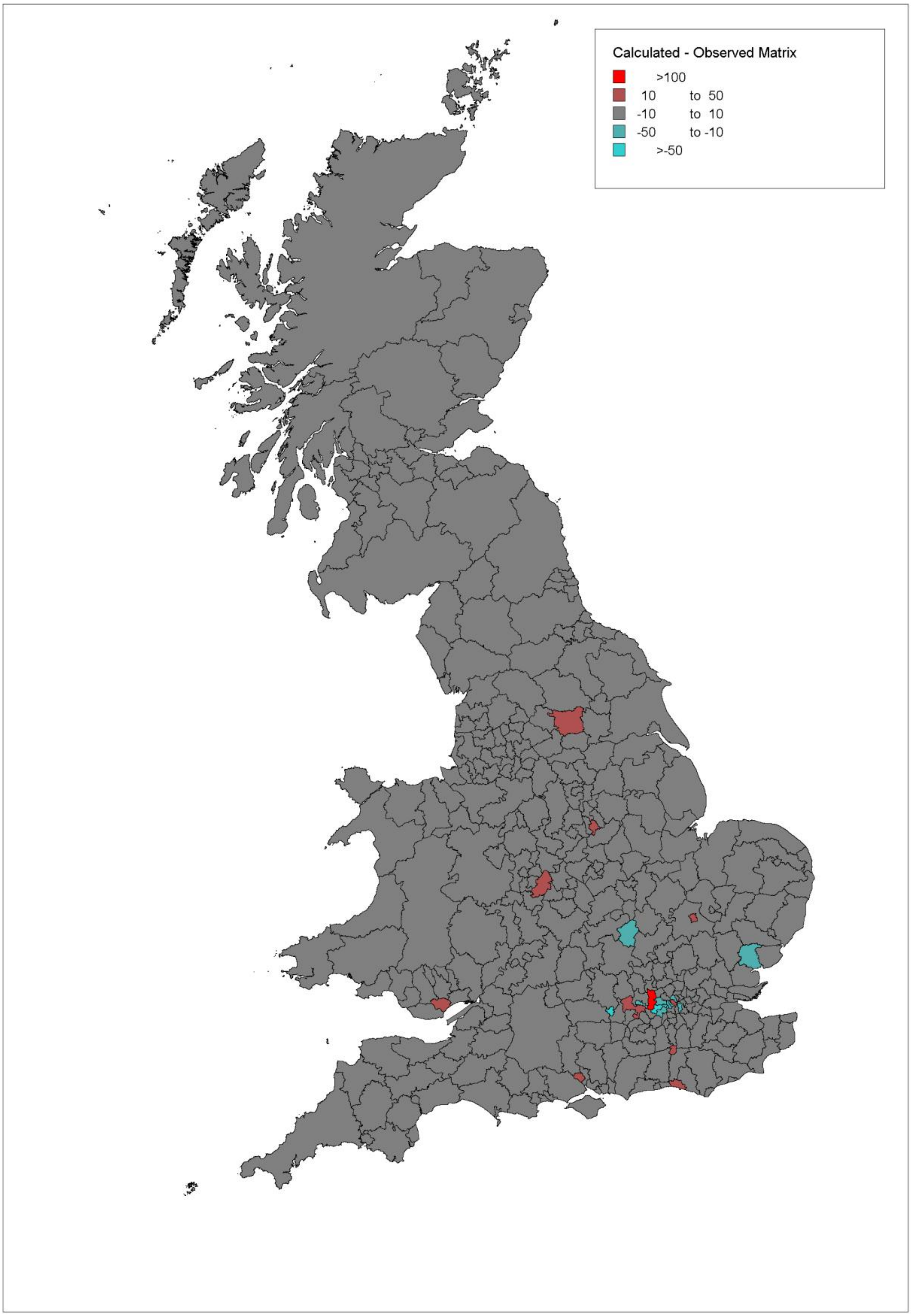
2.3.8. The analysis and calibration results are presented within the Technical Appendix at the end of this document, while the summary of the distribution model calibration is shown below in **Table 2**.

Table 2: Trip distribution calibration results

Trip type	RSQ f(A)	Working pop	All jobs * income	Hosp. jobs	Generalised Cost
Business Foreign	0.77	53,687,090	91,054,319		0.71
Business UK	0.68	0.57	2.18		1.01
Leisure Foreign	0.89			1	0.75
Leisure UK	0.70	1.53	0.00		0.80

2.3.9. Following the development of the trip distribution model the generalised costs were calculated and the comparison of the observed distribution and calculated distribution in the 2030 ‘Extended Baseline with SRA’ scenario is presented in **Figure 6**.

Figure 6: Distribution difference plot – predicted against observed



2.3.10. Based on the distribution analysis, the observed distribution was selected for the 'Forecast year scenario. This is due to the limited differences presented between the forecasted changes and the observed 2012 distribution.

2.3.11. A logit model was then developed to predict the level of patronage on proposed rail services to Heathrow in the rail network and the amount of traffic on the road network. A rail mode choice logit model was developed for the base year 2012 and was calibrated to the CAA passenger survey data. In addition, a main mode choice mode was developed to assign a main mode of travel to each district.

2.3.12. To avoid sample bias, Olympic-related trips were removed from the CAA database before this analysis was undertaken to minimise the risk of the results being skewed by travel choices related to atypical journeys.

2.3.13. The development of a logit model for this purpose was considered particularly important due to the likely difference in rail fare that would apply to a dedicated airport express service when compared with standard rail options. The observed CAA data for Heathrow, which was used to calibrate the base Heathrow model, reinforces the importance of fare. In total only 32% of rail passengers used the Heathrow Express service to access the airport compared to 65% using the tube. In addition, a significantly higher proportion of business rail passengers (51%) used Heathrow Express when compared with leisure passengers (23%).

2.3.14. The base logit model was developed at a district level to ensure consistency with the trip distribution model. The Heathrow CAA data was analysed and an initial sift was undertaken to remove districts that generated less than 20,000 total annual rail passenger trip origins, or were based on less than 20 survey records. This was to ensure that the model calibration was focussed on the key rail trip generators and was not hampered by observed mode share data based on very few interview records, which could skew the results.

2.3.15. Hillingdon was removed from the data-set following analysis that indicated a high proportion of trips originating in the borough were already at the airport and were using Heathrow Express services to move between terminals, thus skewing the overall rail mode share from the borough. Following the removal of Hillingdon and the exclusion of origins based on less than 20 survey records described above, a total of 10.6m rail trips were left in the base model, which amounted to 87% of all rail trips recorded in the CAA survey.

2.3.16. In addition, all observed mode proportions below 1% were excluded from the analysis to avoid skewing the results.

2.3.17. Once the district-level framework was established, a representative 'busy' station was then identified in each borough based on a qualitative high-level assessment. Wherever possible, a prominent tube or bus station was selected as a representative station in London boroughs, while in other districts, the main railway station or coach station in the district was identified.

2.3.18. Four rail sub modes were identified in the base year and are listed below:

- Tube;
- Heathrow Connect;
- HEX (PT access); and
- HEX (Taxi Access).

2.3.19. The rail sub-mode model's generalised costs were derived using sources listed in **Table 1** with lambda values calibrated to improve the fit of the model to the CAA 2012 survey data. Mode comfort factors were identified to adjust the generalised costs to account for non-monetised affects to generalised cost. Full analysis of the calibration process and results are detailed within the Technical Appendix at the end of this document. Table 3 below presents the R-square results for the rail sub-mode model.

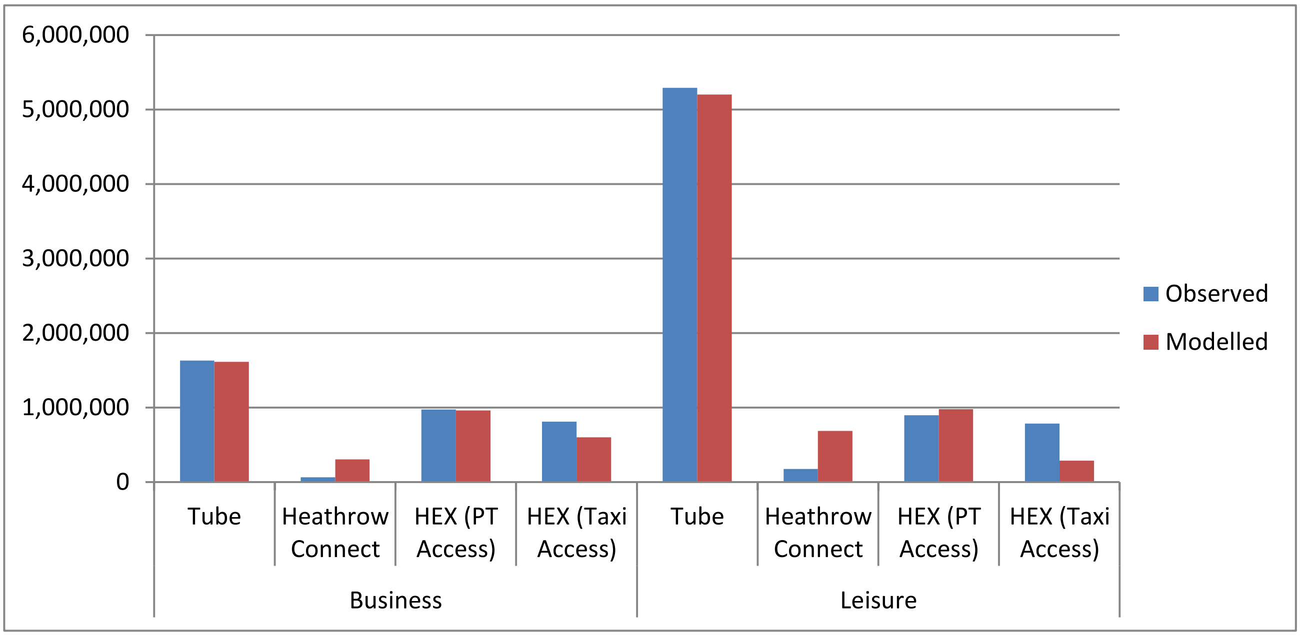
Table 3: Rail Sub Mode calibration results

Region	Business				Leisure			
	Tube	Heathrow Connect	HEX (PT Access)	HEX (Taxi Access)	Tube	Heathrow Connect	HEX (PT Access)	HEX (Taxi Access)
RSQ London	0.94	0.33	0.97	0.98	0.99	0.78	0.98	0.98
RSQ All Zone	0.95	0.36	0.97	0.98	0.99	0.77	0.97	0.98

2.3.20. The poor relationship derived for Heathrow Connect was partly due to the limited number of districts that generated observed trips, particularly for business purposes. This appears in itself linked to a general lack of awareness of the service among many passengers – no districts generated more than a 3% mode share for Heathrow Connect among business rail passengers. This service will be discontinued in future and so was not considered critical in the calibration process.

2.3.21. **Figure 7** summarises the differences between observed annual passenger trips to Heathrow by rail mode and the outputs from the calibrated 2012 base model. The graph indicates that overall, the model forecast for total trips by mode is very close to the observed, with the biggest difference being for business trips by Heathrow Express (secondary PT mode).

Figure 7: Modelled v observed total annual rail passenger trips to Heathrow by mode and journey purpose (2012)



2.3.22. Composite costs from the rail sub-mode model are then passed up into the main mode choice model with the following main mode choices identified from the 2012 CAA data:

- Car;
- Bus and Coach; and
- Rail.

2.3.23. Car demand was apportioned based on the 2012 CAA data into a further 4 sub-categories for each district to provide a better fit of generalised cost, these were:

- Kiss and fly passengers;
- Park and fly – short stay;
- Park and fly – long stay; and
- Taxi.

2.3.24. Generalised costs were calculated with additional mode-specific adjustment factors applied to account for non-monetised effects on generalised costs within London and the rest of the UK. Lambda values were then calibrated to improve the fit to the 2012 CAA data. **Table 4** below presents the calibration results of the main mode choice model.

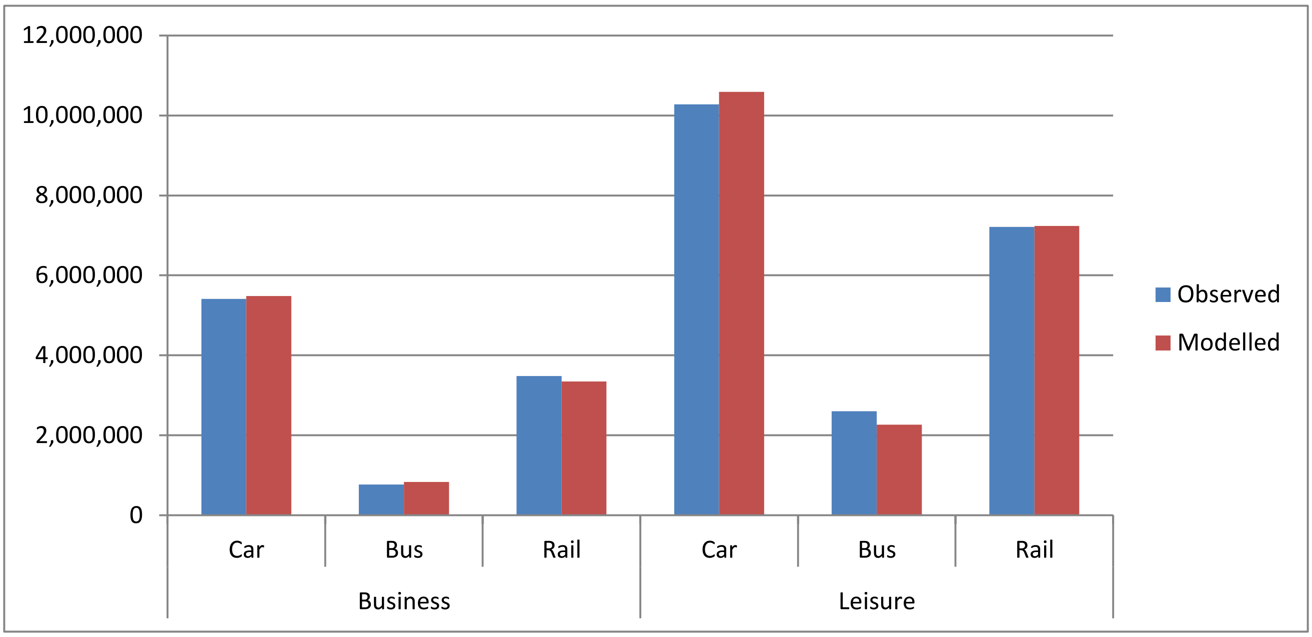
Table 4: Main Mode calibration results

Region	Business			Leisure		
	Car	Bus and Coach	Rail	Car	Bus and Coach	Rail
RSQ London	0.92	0.65	0.97	0.88	0.14	0.92
RSQ All Zone	0.90	0.29	0.96	0.86	0.29	0.91

2.3.25. The poorer relationship derived for Bus and Coach was mainly due to the limited number of districts within London that generated observed trips, particularly for business purposes. For the rest of the UK there are large differences in coach use with either very low, negligible usage compared to districts with for example Newcastle, which has a high Business coach use of 39.6% with a very high Generalised Cost compared to York, which has only 19.5% business use with comparable Generalised Costs. Coach and Bus fares tend to be the cheapest, markedly from districts outside of London. If income bandings were available for the CAA data this would likely provide a better fit for this mode of transport.

2.3.26. **Figure 8** summarises the differences between observed annual passenger trips to Heathrow by mode and the outputs from the calibrated 2012 base model. The graph indicates that overall, the model forecast for total trips by mode is very close to the observed, with the biggest difference being for bus and coach trips both for business and leisure. The model forecast overall was in line with the CAA data.

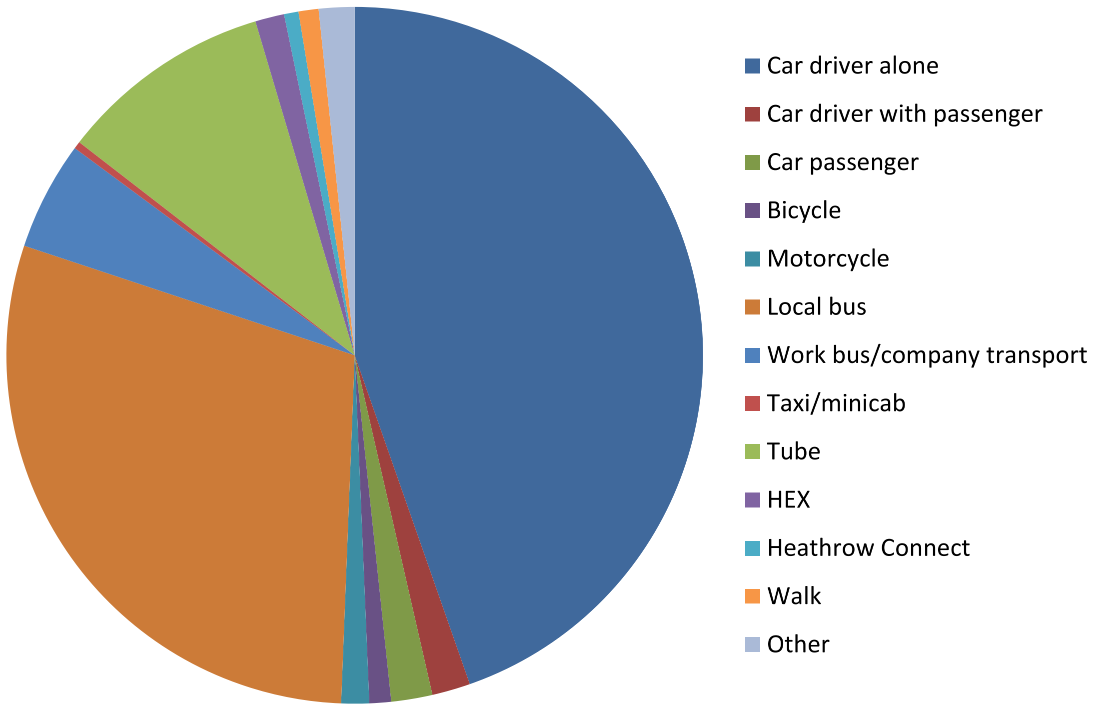
Figure 8: Modelled v observed total annual rail passenger trips to Heathrow by mode and journey purpose (2012)



2.3.27. Forecast surface access mode share for passengers was then calculated using updated generalised costs based on proposed and committed rail schemes. With the main mode choice model applying an incremental change in proportion applied to the observed 2012 proportions. At this stage a minimum car proportion of 10% was assumed to ensure that a minimum proportion of car-based trips were accounted for from all districts.

2.3.28. As shown in **Figure 9**, the updated Heathrow staff travel survey in 2013/4 indicates that car (including motorcycle and taxi) remains the main mode of transport for employees to the airport, accounting for 50% of all surface access trips, with the vast majority of those undertaken as single occupancy car trips. Bus (including work bus/company transport) accounted for a further 35% with rail accounting for 12% (10% by tube, 1% by Heathrow Express and 1% by Heathrow Connect).

Figure 9: Heathrow employee main mode of travel to work (2013/4)



Source: HAL (2014), 'Taking Britain further, Heathrow's plan for connecting the UK to growth TECHNICAL SUBMISSION VOLUME 2' (page 334)

2.3.29. Due to the lack of available data, main mode choice for employees was based on observed data with the change in mode share allocated globally.

2.3.30. For both passengers and employees the rail sub-mode proportions were derived directly from the forecast year sub-mode choice model. An incremental model was not possible for the rail sub-mode due to new services being introduced and therefore the sub-mode choice model remains an absolute choice model.

2.4 Analysis

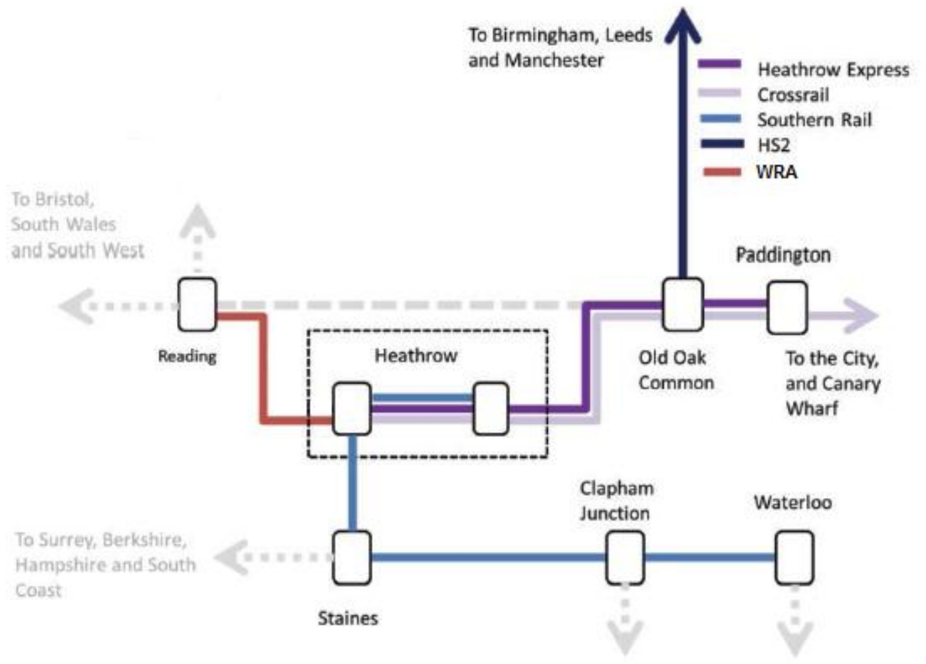
2.4.1. The application of the distribution and mode choice models outputs the number of trips by peak period to and from Heathrow; by mode, person type and location. Rail trips by sub-mode are then assigned to the rail network to provide volume to capacity ratios on key sections of the rail network.

2.4.2. The starting point of this assessment was to identify the 2030 'Opening Year' rail access baseline scenario. At the time of assessment, this constitutes any existing rail access and committed rail developments[1] that are expected to provide access to Heathrow by 2030. The baseline rail network includes Heathrow Express, HS2 Phase 1, Crossrail, Piccadilly Line and Western Rail Access to Reading.

[1] A 'committed rail development' is considered to be one that, at the time of assessment, has either full or outline planning permission, or is allocated in an approved Structure Plan or adopted/ finalised draft Local Plan.

2.4.3. The rail package proposed for Heathrow is described as an 'Extended Baseline with SRA' scenario. This package updates the baseline rail network by introducing Southern Rail Access and increased train frequencies. **Figure 10** shows a map of the rail network proposed for Heathrow and termed the 'Extended Baseline with SRA' scenario.

Figure 10: Forecast year rail access network



2.4.4. Both the baseline and 'Extended Baseline with SRA' rail network package are assessed in this analysis.

2.4.5. The Airports Commission and key surface transport stakeholders including the Department for Transport (DfT), the Highways Agency (HA), Network Rail (NR), and Transport for London (TfL) were consulted throughout the study to inform the findings.

2.4.6. Train capacities and background demand were identified following discussions with TfL and NR on the feasibility of operating the rail elements. Following on from the discussions, a capacity threshold of 85% total capacity (based on the train crush capacity) was identified as the network breakpoint. The airport-related and background demand were compared to this capacity threshold.

2.4.7. Car-based demand was further adjusted to account for car occupancies, with the amount of car trips to and from the airport accounted for. Note this includes empty return trips for both taxi and kiss and fly passengers.

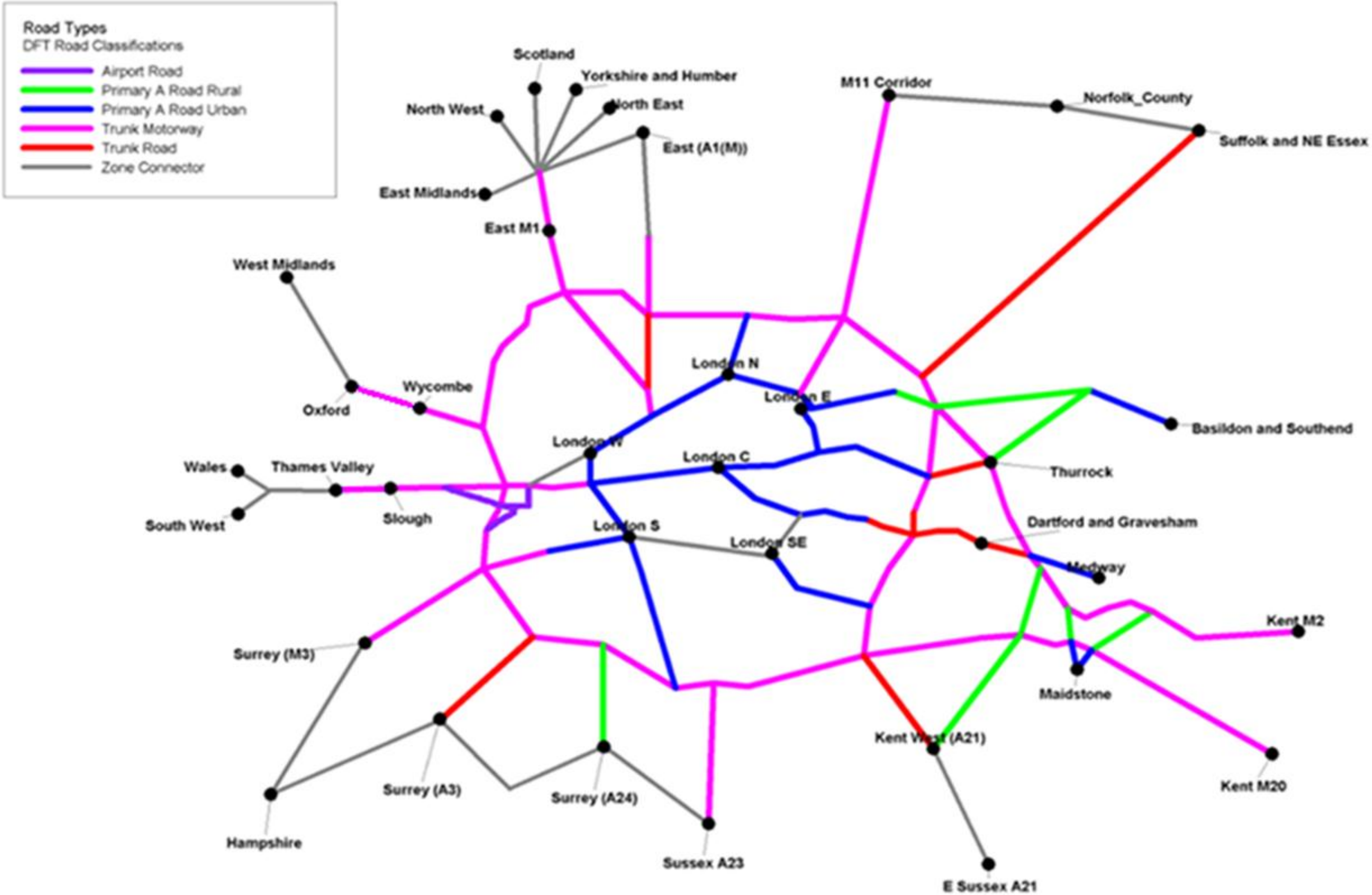
2.4.8. The highway network assessed constitutes the existing strategic road network serving Heathrow, relevant committed changes to the network and a number of interventions proposed by Heathrow. These interventions include:

- Construction of a new Southern Road Tunnel access to the Heathrow East node;
- Implementation of a new one-way access arrangement for the Heathrow West campus;
- Committed widening of M25 J16 to J23;

- Committed widening of M23 J8 to J9;
- Committed hard shoulder running of M4 J4B to J8;
- Committed hard shoulder running of M25 J5 to J7;
- Committed hard shoulder running of M25 J23 to J27;
- Committed hard shoulder running of M3 J2 to J4a; and
- Committed hard shoulder running of M4 J3 to J4.

2.4.9. **Figure 11** overleaf illustrates the highway network assessed.

Figure 11: Road network



3 Assumptions Log

3.1 Headline assumptions

3.1.1. This section summarises the main assumptions made in the surface access model. It groups these assumptions under the following headings:

- Access demand assumptions – those relating to the derivation of the forecast demand;
- Generalised cost assumptions – those relating the derivation of the generalised cost of journeys;
- Journey time assumptions – the journey times assumed by key rail sub-modes;
- Highway network assumptions – the road capacity and flow assumptions made in the highways analysis.

3.2 Airport access demand assumptions

3.1.2. The 2030 forecast passenger and employee demand for the airport is derived from the assumptions listed in Table 5 and Table 6 respectively. The sources of these assumptions are also specified within the tables.

Table 5: Surface transport assumptions for passengers

Parameter	Assumption	Source/Comment
2030 MPPA 2 Runways at Heathrow (No Expansion)	82,500,000	Source: Taking Britain Further - Volume 1. Heathrow's surface access proposal assumes a growth in passenger number to this value. Using the same growth provides a level ground for the comparison of the model outputs with Heathrow's.
2030 MPPA (Northern Runway Extension at Heathrow)	103,600,000	Source: Taking Britain Further - Volume 1. Heathrow's surface access proposal assumes a growth in passenger number to this value. Using the same growth provides a level ground for the comparison of the model outputs with Heathrow's.
Non-connecting passengers (%)	65%	Source: Taking Britain Further - Volume 1. The value presented by Heathrow is based on Heathrow airport traffic statistics.
Busy day factor	0.30%	Source: Taking Britain Further - Volume 1. The value presented by Heathrow is based on historical data.
Daily person trip	202,020	Source: Jacobs surface access model. The value is derived from the busy day factor, the total MPPA and the percentage of non-transit passengers.
Daily surface access 'to-from' factor	50% (to), 50% (from)	Assumption that trips on a busy day are split evenly by direction (to or from the airport)

Parameter	Assumption	Source/Comment
Peak hour time period	0700-0800	Source: BAA airport 2010. A 2010 report by the British Airports Authority (BAA) provided a daily profile of air passenger flight departure and arrival times, averaged for the peak month in the year (July). Analysis of this data indicates that the peak hour occurs between, 0700 and 0800 in the morning.
Peak hour % daily trips ‘to-from’ factor	7.9% (to), 5.3% (from)	Source: BAA airport 2010. Analysis of the daily profile of air passenger provided within the 2010 BAA report indicates that 8% of trips to and 5% of trips from the airport occur within this peak hour.
Passenger Split by Purpose ‘Business-Leisure’ factor	33% (business), 67% (leisure)	Source: Heathrow 2012 CAA data. An analysis of the 2012 CAA data indicates that 33% of air passengers through Heathrow are on business trips while the remaining 67% are on leisure trips.
Main mode split	48% (private car) 17% (Bus/coach) 36% (rail)	Source: Heathrow 2012 CAA data. Mode share derived from an analysis of the 2012 CAA data and assumed for the base year.
Business car occupancy factor	1.2 (Kiss+fly), 1.24 (Parked), 1.1 (Taxi)	Source: Heathrow 2012 CAA data. Factors derived from an analysis of the 2012 CAA data on group size.
Leisure car occupancy factor	1.56 (Kiss+fly), 1.73 (Parked), 1.77 (Taxi)	Source: Heathrow 2012 CAA data. Factors derived from an analysis of the 2012 CAA data on group size.
Empty taxi return trip factor	1.28	Source: Taking Britain Further - Volume 1. Heathrow assumed that 78% of all taxis have an empty return.
% Meet and Greet by rail ‘to-from’ factor	2.6% (to), 2.6% (from)	Source: Heathrow 2012 CAA data. Factors derived from an analysis of the 2012 CAA data.

Table 6: Surface transport assumptions for employees

Parameter	Assumption	Source/Comment
2030 Employees	90,000	Source: Taking Britain Further - Volume 1. Using the same growth provides a level ground for the comparison of the model outputs with Heathrow's.
Busy day factor	57%	Source: Taking Britain Further - Volume 1. This represents a busy day for the airport taking into account 7 day operation for the airport
Daily person trip	104,000	Source: Jacobs surface access model. The value is derived from the busy day factor and the total Employees.
Daily surface access 'to-from' factor	100% (to), 100% (from)	Employees are assumed to make one arrival and departure by the same mode. .
Peak hour - time	0700-0800	Source: Heathrow 2013 employee survey data. A 2013 report by Heathrow provided a daily profile of full and part-time employees arriving and departing Heathrow site in a test day. Analysis of this data indicates that the peak period occurs between, 0700 and 0800 in the morning.
Peak hour - % daily trips 'to-from' factor	9% (to), 3% (from)	Source: Heathrow 2013 employee survey data. Analysis of the daily profile of employees indicates that 9% of trips to and 3% of trips from the airport occur within this peak hour.
Main mode split	47% (private), 32% (bus/coach), 11% (rail), 10% (other)	Source: Heathrow 2013 employee survey data. Mode share derived from an analysis of the employee survey data. There is an even split of rail/bus in 2030
Car occupancy rate	1.1	Source: Heathrow 2013 employee survey data. Analysis of the survey data indicates an employee car occupancy rate of 1.04. However, this is increased to 1.1 to account for the policies proposed by Heathrow to encourage employee's mode shift. The value of 1.2 assumed by Heathrow was deemed unrealistic and so reduced.

3.3 Travel cost assumptions

3.1.3. The 2030 generalised cost of journeys to and from the airport is calculated for each district in the model using the assumptions listed in Table 7. The sources of these assumptions are also specified within the table.

Table 7: Travel cost assumptions

Parameter	Assumption	Source/Comment
Business value of time	69.19	Source: LASAM model. Level of uncertainty in VOT and cost in model, likely to increase at a similar rate. A growth in the value of time is likely to have negligible impact on the mode choice if there is a simultaneous growth in travel fares. Thus, VOT and fare are kept the same as present values.
Leisure value of time	26.99	Same as the Business value of time
Parking Cost of short stay	24.9 (business), 10.6 (leisure)	Source: Heathrow airport. Value calculated based on parking duration of 1 for business trips and 3 for leisure trips
Parking Cost of long stay	21.3 (business), 10.7 (leisure)	Source: Heathrow airport. Value calculated based on parking duration of 3 for business trips and 7 for leisure trips
Average Interchange time	5mins	Assumption that it takes 5mins to interchange between rail services.
Kiss + fly set down time	10mins	Assume 10mins for set down of kiss + fly passengers.
Fares (indices to 2014 base)	100	Source: Website of rail service providers. Growths in fares are likely to have negligible impact on the mode choice if there is a simultaneous growth in value of time. Thus, Fares like VOT are kept at present values.

3.4 Journey time assumptions

3.1.4. The 2030 journey time for rail services are based on published plan and on similar existing lines. The journey times assumed are summarised in Table 8.

3.5 Highway network assumptions

3.1.5. A number of assumptions were made relating to the highway network. These are outlined in Table 9.

Table 8: Journey time assumptions

Station		Journey Time (minutes)	Source/Comment
Cross Rail	Whitechapel	38	Source: Crossrail official website. The travel times on the website are expected to be an accurate representation.
	Tottenham Court Road	30	
	Liverpool Street	35	
	Paddington	24	
	Bond Street	27	
	Farringdon	32	
	Ealing Broadway	15	
	Canary Wharf	39	
	Stratford	43	
	Romford	62	
	Old Oak Common	20	
	Abbey Wood	53	
	Maidenhead	26	
	Reading	38	
	Hayes and Harlington	5	
Western rail	Reading	33	Professional Judgement Values based on similar existing lines.
	Twyford	26	
	Maidenhead	21	
	Slough	14	
Southern Rail	Waterloo	51	Professional Judgement Values based on similar existing lines.
	Clapham Junction	43	
	Richmond	33	
	Staines	17	
	Twickenham	-	
	Feltham	-	
Heathrow express	Paddington	15 in 2014 18 in 2030	Source: Heathrow airport official website. The travel times on the website are expected to be an accurate representation.

Table 9: Highway network assumption

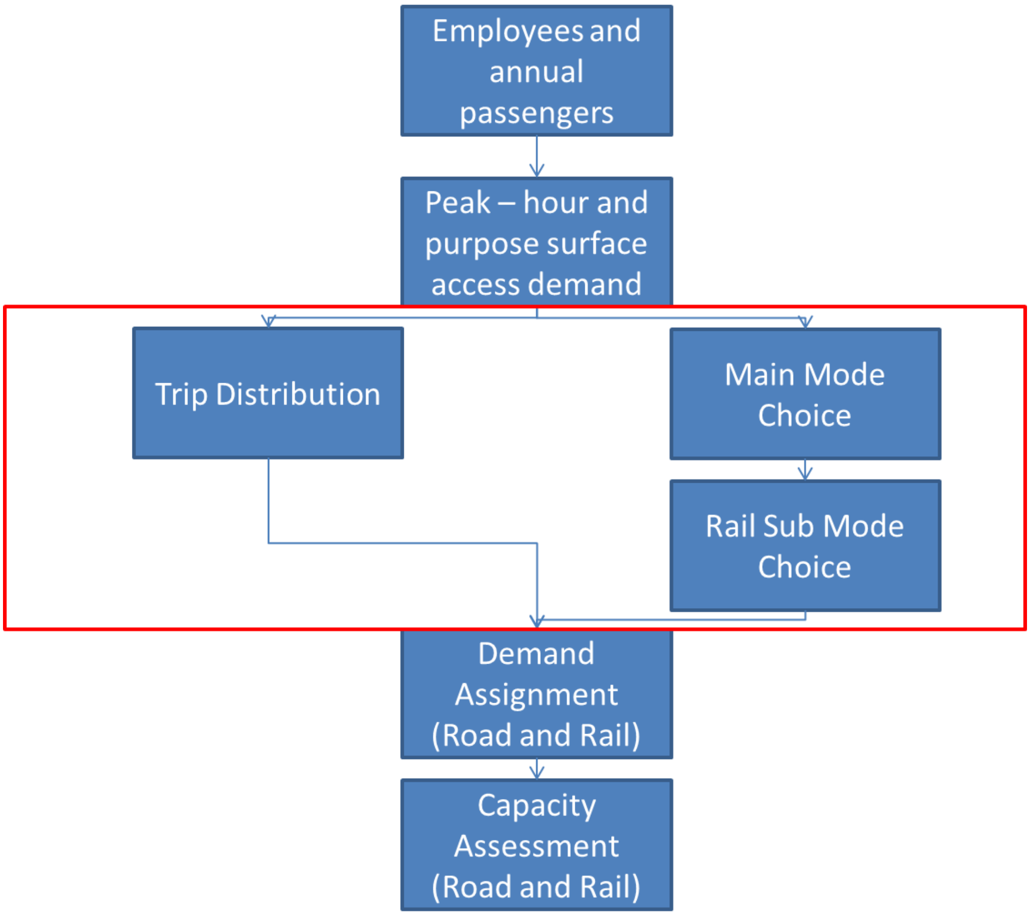
Parameter	Assumption	Comment /Source
Highway lane Capacity	2000 PCU/ hour/ lane	Source: WebTAG guidance The capacity of 2000 PCUs is representative of the capacity associated with the motorways and trunk roads in the strategic network based upon an average proportion of HGV users.
Highway Peak hour flow factor	6.88%	Source: TRADS Website Value derived from the analysis of a sample day profile on some key sections of road.
Background Traffic growth factor	1.3 – 1.4	Source: National Transport Model As the most appropriate data set available, it forecasts traffic growth on a range of road types in a range of land use area type within various regions of the UK.
2030 Terminal proportion	42% (Heathrow east), 58% (Heathrow west)	Source: Taking Britain Further - Volume 1. It is assumed the demand for the terminals will be proportionate to the design capacity. Heathrow predicts that the east and west terminal will cater for up to 70million and 55million passengers per annum by 2040.

Appendix A: Technical Note

Overview

This Technical Appendix details the development, calibration and fitness for purpose of the key components of the Heathrow Surface Transport Access Demand model. **Figure 1** presented the overarching structure. The focus of this note is highlighted within the red box presented in **Figure 12** below.

Figure 12: Airport surface transport demand forecasting methodology overview – Technical Appendix focus



Civil Aviation Authority Survey Data from 2012 was utilised as the main source of calibration data for our demand model whilst other sources, highlighted within **Section 2.2**, were used to develop components of the model.

The Department for Transports WebTAG guidance documentation was used throughout the development of the demand model as best practice, where appropriate, simplifications were made to this advice and will be detailed within this report.

The remainder of this note will be structured as follows:

- Model structure – will detail the structure of the various choice models and the formulation of the models;
- Rail sub-mode model – will present the input data, selection of variables, calibration results;

- Distribution Model – will present the input data, selection of variables, calibration results;
- Main Mode Choice Model – will present the input data, selection of variables, calibration results; and
- Sensitivity testing – presents the results of a series of modelled sensitivity tests.

Model structure

The Heathrow surface access demand model was developed in order to predict changes in responses for access to Heathrow Airport based upon changing travel costs. The premise of variable demand modelling is that any change in travel cost, through traffic intervention or changes in travel demand, is liable to either induce or suppress demand response changes. The proposed rail improvements within London and changes to Heathrow would likely make journeys quicker for rail users compared to car use and as such users would potentially switch mode of transport or generate more trips from areas previously not directly accessible.

The demand model responses identified for the Heathrow surface access demand model are as follows:

- A rail sub mode model – to predict the proportion in travel users selecting one rail mode over another;
- A distribution model – to provide a change in origin to Heathrow Airport subject to changes in travel costs to the Airport; and
- A main mode choice model – to provide a change in main mode share for trips using Heathrow Airport.

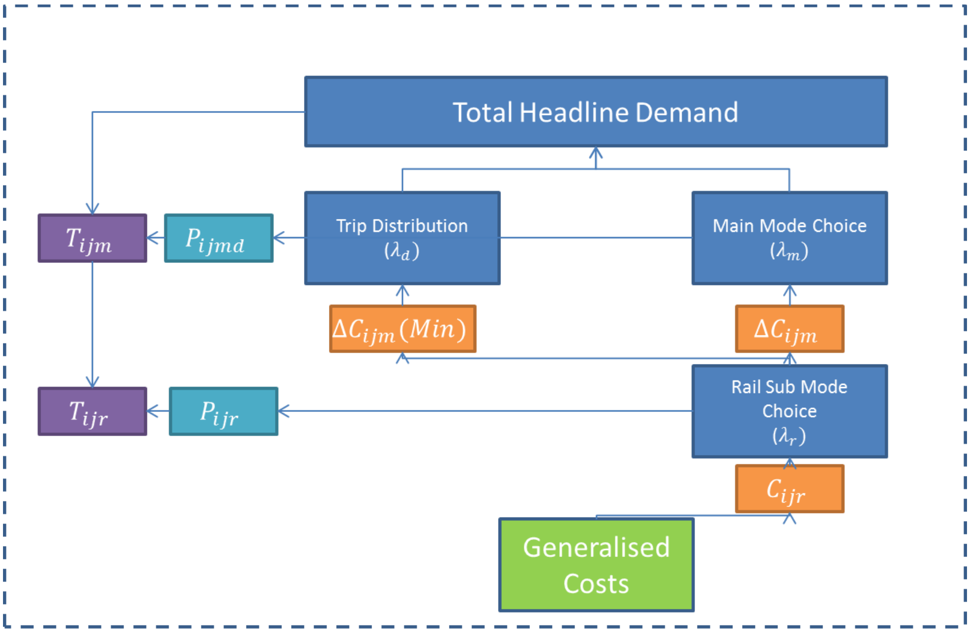
WebTAG Unit M2 Section 1.3 recommends an incremental hierarchical choice model which calculates the changes of travellers liable to make one choice over many alternatives based on changes in travel costs. However, due to the rail sub mode choice model providing numerous new rail services an absolute choice model was required to provide the choice of one rail service over another.

Overall travel demand to Heathrow Airport was not considered be subject to inducement or suppression through levels in access capacity within rail and road infrastructure. Peak hour demand for travel, for both employees and passengers, is taken directly from the headline assumptions as presented within **Section 2.3**.

To assist in the development of a demand model the CAA data included two fields related to overall journey purpose (categorised as either ‘business’ or ‘leisure’) with each model being calibrated for each purpose.

The structure of the demand model is presented overleaf within **Figure 13**.

Figure 13: Detailed Airport surface transport demand structure



i	Origin	C_{ijr}	Generalised Cost	(λ_r)	Rail Lambda
j	Destination	ΔC_{ijm}	Composite Cost	(λ_m)	Mode choice Lambda
m	Main Mode	P_{ijr}	Proportion of rail trips from origin I to destination j using rail mode r	(λ_d)	Destination Lambda
r	Rail Sub Mode	P_{ijmd}	Proportion of trips from origin I to destination j using mode m and destination d	T	Trips

As presented above generalised costs from various rail modes of transport are calculated and are input at the lowest level of the structure. These feed into a rail sub mode model which predicts the proportion of rail trips using each sub mode. At this stage composite costs for rail trips are calculated and are passed up to the distribution and main mode choice models which use the composite costs derived to predict the proportion of trips travelling to Heathrow by mode for each origin. Following this the headline trips are then input and the number of trips by mode, destination and rail sub mode are calculated.

Generalised Cost

In order to provide inputs into each model, Generalised Costs were derived which combined journey times, journey distances, interchanges and any tolls/fares included in the model into a standard unit of generalised time based on two parameters.

The two parameters are the pence per minute (ppm) and the pence per kilometre (ppk) associated with each user class, and are used in the following formula to determine generalised cost for public transport users:

$$GeneralisedCosts_{minutes} = JourneyTime_{minutes} + \left(\frac{1}{ppm}\right) * Fare_{pence}$$

Generalised cost formulation for car users are as follows:

$$GeneralisedCosts_{minutes} = JourneyTime_{minutes} + \left(\frac{ppk}{ppm}\right) * JourneyDistance_{km} + \left(\frac{1}{ppm}\right) * Toll_{pence}$$

Toll values for cars were developed using observed sub mode shares for car with the following sub mode options, as determined by the CAA data:

- Kiss and fly passengers;
- Park and fly – short stay;
- Park and fly – long stay; and
- Taxi.

Parking length of stay and value of stay assumptions are presented below within **Table 10**:

Table 10: Parking assumptions

Assumption	Description of Value	Value	Source
Parking Length of Stay (Business)	Short Stay (days)	1	Professional Judgment
	Long Stay (days)	3	
Parking Length of Stay (Leisure)	Short Stay (days)	3	
	Long Stay (days)	7	
Parking Cost of stay (Business)	Short Stay	£24.90	http://www.heathrowairport.com/
	Long Stay	£10.60	
	Additional Fees	£0	
Parking Cost of stays (Leisure)	Short Stay	£21.30	
	Long Stay	£10.70	
	Additional Fees	£0	

Taxi fares within London boroughs were derived through distances and costings taken from the TfL website, outside of London fares were taken through various long haul taxi firm websites.

Generalised costs were built up using the observed proportions of each car sub mode and the relevant toll associated with each sub-mode.

The values of the ppm and ppk parameters within the demand model were based on values from Heathrow's LASAM model and are presented below in **Table 11**.

Table 11: Values of Time and Operating Cost

Parameter	Purpose	Pence per minute	Pence Per km
Value of Time (2012)	Business	69.19	11.79
	Leisure	26.99	5.39

Formulation of model

Generalised Costs are passed up the structure of the hierarchical choice model by the composite costs (also termed 'logsums'); so that the choices made higher up reflect the choices below. The sequence of the calculations requires that the composite cost be calculated for each level starting from the bottom of the hierarchy and working its way up. The formula used for the calculation of the composite cost for incremental models is presented below as specified within WebTAG Unit M2 Appendix D. Composite costs are derived in this instance following the calculation of the rail sub mode only.

$$C^{y-1}_{comp} = -\frac{1}{-\lambda^{y}} \ln\left(\sum_{x} \frac{T^{y}_{x}}{T^{y}_{tot}} \exp(-\lambda^{y} C^{y}_{x}) \right)$$

Where:

ΔC^{y-1}_{comp}	is the composite cost summed over the choices x in stage y
λ^{y}	is the choice sensitivity parameter for choice y
ΔC^{y}_{x}	is the generalised cost of choice x given choice y
T^{y}_{x}	is the number of trips choosing x at stage y
T^{y}_{tot}	is the total number of trips available at stage y

As detailed within Section 2.3, 4 models were required to adequately model distribution choice. Explanatory variables were investigated to combine with the minimum generalised cost of travel by mode selected as the disutility function and were as follows:

- Total resident population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total Working Population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total employee jobs – sourced from the ONS Annual Business Inquiry for 2009 and 2012, also available on the ONS website;
- Total employee jobs in the hospitality sector – assumed as a proxy variable influencing foreign leisure trips, and also sourced from the ONS Nomis website; and
- 2012 income - taken from National Trip End Model estimates.

The selection of explanatory variables is detailed further later in this appendix.

Based upon the above 3 functions of attraction, f(a), for each district to Heathrow Airport were required:

Business Foreign and Leisure UK: $f(a) = \frac{\alpha P \times \beta I}{G^{\gamma}}$

Business UK: $f(a) = \frac{\alpha P \times \beta T}{G^{\gamma}}$

Foreign leisure passengers: $f(a) = \frac{\delta H}{G^{\gamma}}$

Where: G = Generalised cost to the airport;
P = Working Population;
I = Jobs*Income;
T= Total population; and
H = hospitality jobs

For the mode choice models, rail sub mode and main mode choice models the following logit formulation is required:

$$p_{r/i} = \frac{T_{i*r}\exp(-\lambda^r C_{i*r})}{\sum_{Allr} T_{i*r}\exp(-\lambda^r C_{i*Allr})}$$

Where:

$p_{r/i}$ - are the proportions of trips using one choice over other choices;

$\lambda^r C_{i*r}$ - are the Costs and Lambdas for each mode;

$Allr$ - are all rail sub modes and main modes; and

T - is the number of trips in that mode

Rail sub-mode model

As indicated earlier in this document, Olympic-related trips were removed from the CAA database before this analysis was undertaken to minimise the risk of the results being skewed by travel choices related to atypical journeys.

The development of a logit model was considered particularly important due to the difference in rail fare that applies to HEX when compared with standard rail services.

The observed CAA data for Heathrow, which was used to calibrate the base Heathrow model, reinforces the importance of fare. In total only 32% of rail passengers used the Heathrow Express service to access the airport compared to 65% using the tube. In addition, a significantly higher proportion of business rail passengers (51%) used Heathrow Express when compared with leisure passengers (23%).

Rail sub-mode model structure

The base logit model was developed at a district level to ensure consistency with all other choice models. The Heathrow CAA data was analysed and an initial sift was undertaken to remove districts that generated less than 20,000 total annual rail passenger trip origins, or were based on less than 20 survey records. This was to ensure that the model calibration was focussed on the key rail trip generators and was not hampered by observed mode share data based on very few interview records, which could skew the results.

The resulting districts and observed rail mode shares by journey purpose are shown in **Table 12** and provided the framework for the development of the model. As indicated, the data revealed that a significant number of trips made on Heathrow Express used taxi as a secondary mode, and these were separated from trips with secondary public transport modes due to significant differences in the cost of the secondary trip in each case. A small number of trips by Heathrow Express did not indicate a secondary mode (including some within walking distance of Paddington Station) and these were allocated to PT and Taxi proportionally in each borough – consideration was given to splitting Westminster into two zones to account for the Paddington walk catchment but it was felt that this would not significantly impact on the model outputs and so Westminster was retained as a single zone.

Hillingdon was removed from the data-set following analysis that indicated a high proportion of trips originating in the borough were already at the airport and were using Heathrow Express services to move between terminals, thus skewing the overall rail mode share from the borough. Following the removal of Hillingdon and the exclusion of origins based on less than 20 survey records described above, a total of 10.6m rail trips were left in the base model, which amounted to 87% of all rail trips recorded in the CAA survey.

Once the district-level framework was established, a representative ‘busy’ station was then identified in each borough based on a qualitative high-level assessment. Wherever possible, a prominent tube station was selected as a representative station in London boroughs, while in other districts, the main railway station in the district was identified.

Table 12: Heathrow rail passenger trip origins by final mode and journey purpose (2012)

Origin District	Area	Business				Leisure			
		Tube	Heathrow Connect	HEX (PT)	HEX (Taxi)	Tube	Heathrow Connect	HEX (PT)	HEX (Taxi)
Barking and Dagenham	London	86%	0%	14%	0%	97%	0%	3%	0%
Barnet	London	68%	0%	27%	5%	91%	0%	3%	6%
Bexley	London	44%	0%	56%	0%	42%	21%	37%	0%
Brent	London	52%	2%	30%	16%	74%	5%	14%	7%
Bromley	London	33%	4%	63%	0%	99%	0%	1%	0%
Camden	London	47%	2%	30%	22%	76%	1%	10%	13%
City of London	London	26%	1%	46%	28%	58%	1%	32%	9%
Croydon	London	67%	0%	33%	0%	93%	0%	7%	0%
Ealing	London	77%	22%	1%	0%	82%	16%	2%	0%
Enfield	London	55%	0%	45%	0%	100%	0%	0%	0%
Greenwich	London	38%	0%	35%	27%	71%	0%	29%	0%
Hackney	London	65%	2%	19%	14%	78%	1%	17%	4%
Hammersmith and Fulham	London	92%	1%	5%	3%	96%	0%	3%	1%
Haringey	London	57%	0%	32%	12%	97%	1%	1%	1%
Harrow	London	71%	0%	29%	0%	100%	0%	0%	0%
Havering	London	87%	0%	0%	13%	95%	5%	0%	0%
Hillingdon	London	0%	0%	0%	0%	0%	0%	0%	0%
Hounslow	London	81%	7%	0%	12%	93%	1%	6%	0%
Islington	London	55%	0%	18%	27%	81%	1%	9%	9%
Kensington and Chelsea	London	71%	0%	14%	15%	80%	1%	8%	11%
Kingston upon Thames	London	66%	0%	34%	0%	100%	0%	0%	0%
Lambeth	London	60%	0%	29%	12%	88%	1%	8%	3%
Lewisham	London	53%	5%	31%	11%	88%	1%	10%	1%
Merton	London	90%	0%	9%	1%	93%	0%	7%	0%
Newham	London	80%	0%	6%	14%	89%	3%	8%	0%
Redbridge	London	77%	0%	23%	0%	92%	1%	7%	0%
Richmond upon Thames	London	86%	0%	8%	6%	95%	2%	2%	1%
Southwark	London	41%	3%	40%	17%	82%	0%	12%	6%
Sutton	London	88%	0%	12%	0%	55%	0%	45%	0%
Tower Hamlets	London	44%	0%	47%	9%	78%	2%	16%	4%
Waltham Forest	London	59%	0%	41%	0%	95%	0%	3%	2%
Wandsworth	London	61%	0%	31%	8%	94%	0%	5%	1%
Westminster	London	30%	2%	30%	39%	53%	4%	17%	26%
Nottingham	Rest of UK	61%	0%	33%	6%	86%	0%	14%	0%
Cambridge	Rest of UK	78%	0%	20%	2%	79%	8%	12%	0%
Colchester	Rest of UK	66%	0%	12%	21%	88%	0%	10%	2%
Peterborough	Rest of UK	75%	0%	25%	0%	90%	2%	5%	2%
Manchester	Rest of UK	58%	10%	32%	0%	53%	33%	13%	0%
Brighton and Hove	Rest of UK	100%	0%	0%	0%	98%	0%	0%	2%
Canterbury	Rest of UK	72%	0%	28%	0%	97%	0%	3%	1%
Crawley	Rest of UK	100%	0%	0%	0%	0%	0%	0%	0%
Oxford	Rest of UK	28%	16%	50%	6%	0%	0%	0%	0%
Bath and North East Somerset	Rest of UK	10%	0%	61%	29%	10%	16%	50%	24%
Bristol, City of	Rest of UK	4%	0%	37%	59%	55%	9%	22%	14%
Exeter	Rest of UK	0%	0%	56%	44%	45%	0%	26%	29%
Plymouth	Rest of UK	7%	0%	74%	19%	4%	1%	78%	17%

Origin District	Area	Business				Leisure			
		Tube	Heathrow Connect	HEX (PT)	HEX (Taxi)	Tube	Heathrow Connect	HEX (PT)	HEX (Taxi)
Cardiff	Rest of UK	36%	8%	41%	15%	35%	2%	54%	9%
Swansea	Rest of UK	17%	0%	58%	25%	23%	0%	57%	20%
Birmingham	Rest of UK	63%	0%	32%	4%	78%	0%	20%	2%
Leeds	Rest of UK	89%	0%	11%	0%	50%	0%	45%	4%
York	Rest of UK	82%	0%	18%	0%	85%	0%	15%	0%
Chelmsford	Rest of UK	56%	0%	31%	12%	97%	0%	3%	0%
Coventry	Rest of UK	84%	0%	0%	16%	45%	0%	52%	3%
Cheltenham	Rest of UK	0%	0%	60%	40%	92%	0%	5%	3%
Basingstoke and Deane	Rest of UK	0%	0%	0%	0%	0%	0%	0%	0%
Milton Keynes	Rest of UK	71%	0%	20%	10%	16%	4%	80%	0%
Swindon	Rest of UK	0%	0%	40%	60%	37%	63%	0%	0%
Guildford	Rest of UK	0%	0%	0%	0%	0%	0%	0%	0%
Wycombe	Rest of UK	100%	0%	0%	0%	72%	0%	28%	0%
Slough	Rest of UK	0%	0%	0%	0%	0%	100%	0%	0%
Southampton	Rest of UK	100%	0%	0%	0%	80%	3%	18%	0%
Windsor and Maidenhead	Rest of UK	0%	73%	0%	27%	61%	23%	15%	0%
Reading	Rest of UK	80%	7%	12%	0%	45%	26%	30%	0%
Newcastle upon Tyne	Rest of UK	100%	0%	0%	0%	83%	0%	17%	0%
Southend-on-Sea	Rest of UK	65%	0%	35%	0%	86%	7%	7%	0%
Edinburgh, City of	Rest of UK	100%	0%	0%	0%	69%	0%	31%	0%
Hastings	Rest of UK	100%	0%	0%	0%	100%	0%	0%	0%
Dartford	Rest of UK	100%	0%	0%	0%	100%	0%	0%	0%
Sevenoaks	Rest of UK	75%	0%	25%	0%	63%	0%	37%	0%
Norwich	Rest of UK	0%	0%	86%	14%	71%	0%	24%	5%
Spelthorne	Rest of UK	91%	9%	0%	0%	0%	0%	0%	0%
St Albans	Rest of UK	27%	0%	73%	0%	100%	0%	0%	0%

Source: CAA 2012 Heathrow passenger survey data, analysed by consultant

Generalised Costs (GCs) were then calculated from each representative station to Heathrow Airport for each of the mode options identified in the table. This calculation was based on a number of key data inputs, as follows:

- In-train times were estimated using the National Rail and TfL journey planner websites, and were divided by category of service for each leg of the journey (i.e. tube, commuter rail, long-distance rail etc.);
- The number of interchanges required to make each journey was counted, and a flat 5 minutes clock time was assumed per interchange;
- Platform wait times at stations were based on half the rail frequency sourced from the National Rail website for trips from outside London, with generic times applied for journey legs beginning in London based on the category of service being used;
- Taxi wait times were assumed to be a flat 2 minutes;
- Train fares were based on an assumed single ticket to Zone 6 for London trips, with the National Rail website used to estimate fares from areas outside London;

- Fares within London where calculated using the appropriate Oyster peak hour single fares on all services which accept Oyster Tickets (including rail services which operate outside the zonal structure). On services where oyster fares were not available for all or part of the journey the peak time single fare was used as calculated on the Nation Rail website. Where appropriate a combination of these fares was used.

- Taxi journey times and fares were estimated to Paddington using Google Maps and information from the Public Carriage Office on average taxi fare by distance – an assumed congestion factor was then applied based on information on delay in TfL's Travel in London Report 6, with a manual adjustment to account for use of bus lanes by black cabs.

The following parameters were then applied to calculate GC for each mode choice based on the inputs described above – the values derived for these parameters are described in the following section on model calibration:

- Comfort factors were applied to in-vehicle time to reflect the different quality of the services available, with low factors applied for perceived high-quality options such as Taxi and Heathrow Express;

- A factor was applied to wait times and interchange times;

- Values of time of 69p per minute for business trips and 27p per minute for leisure trips were applied to convert total fare estimates for each journey to generalised minutes – these values were sourced from research developed to understand potential rail passenger trips to airports using HS2;

- Mode Constants were applied to the total GC derived for each mode by journey purpose to account for variables not included in the modelling.

The resulting GCs derived for each mode by district were then used to predict mode shares using a multinomial logit model formula, with a lambda value calibrated to determine the sensitivity of passengers to GC.

Base model calibration

A number of tests were used in the process of calibrating the base logit model, which was undertaken with the assistance of the MS Excel Solver tool. The first was to ensure that the relationships between modelled and observed annual passenger numbers by mode and journey purpose, expressed in R-Square values, were as high as possible. In addition, the approach focussed on keeping the differences between the total forecast and observed number of trips by each mode to a minimum.

Some of the factors used to calculate GC by different modes were held constant during the calibration process to ensure that the final parameters applied to sub-rail mode share in 2030 models could be justified based on sense checks. These included the following:

- Comfort factors applied to in-vehicle journey time, which were held as follows:

- 1.0 for Tube, Overground, DLR, Heathrow Connect, and other London commuter rail services;

- 0.8 for long-distance rail services;

- 0.65 for Heathrow Express;

- 0.5 for Taxi;

- Platform wait time factor: 2.0;

- Interchange time factor: 2.0;

The values assigned for platform wait times and interchange times are within standard ranges often used to calculate GC and are referenced in DfT WebTAG documentation. The comfort factors were defined by assuming a reference value of 1 for rail options identified as offering a standard level of service (such as tube and commuter rail), and then reducing values relative to this benchmark for 'premium' services assumed to offer a more attractive level of service. For example, taxi was assumed to be the most comfortable and therefore the most attractive mode due to the direct, door-to-door nature of the journey and the space provided for luggage. Heathrow Express was assumed to be the next most comfortable mode, with long-distance rail identified as the third most comfortable option.

The key variables that were therefore changed during the calibration process were the lambda values in the logit model formula and the mode constants. The Solver tool was used to maximise R-Square values and minimise errors in total passenger numbers by mode by firstly adjusting lambda values. Mode constants were then subsequently adjusted to account for any significant residual errors.

The final derived lambda values were 0.028 for business passengers and 0.026 for leisure passengers (which are typical values for a logit model of this nature and are within ranges identified in WebTAG), and the mode constants applied are summarised in **Table 13**.

Table 13: Mode constants applied in calibrated 2012 Heathrow rail mode choice logit model

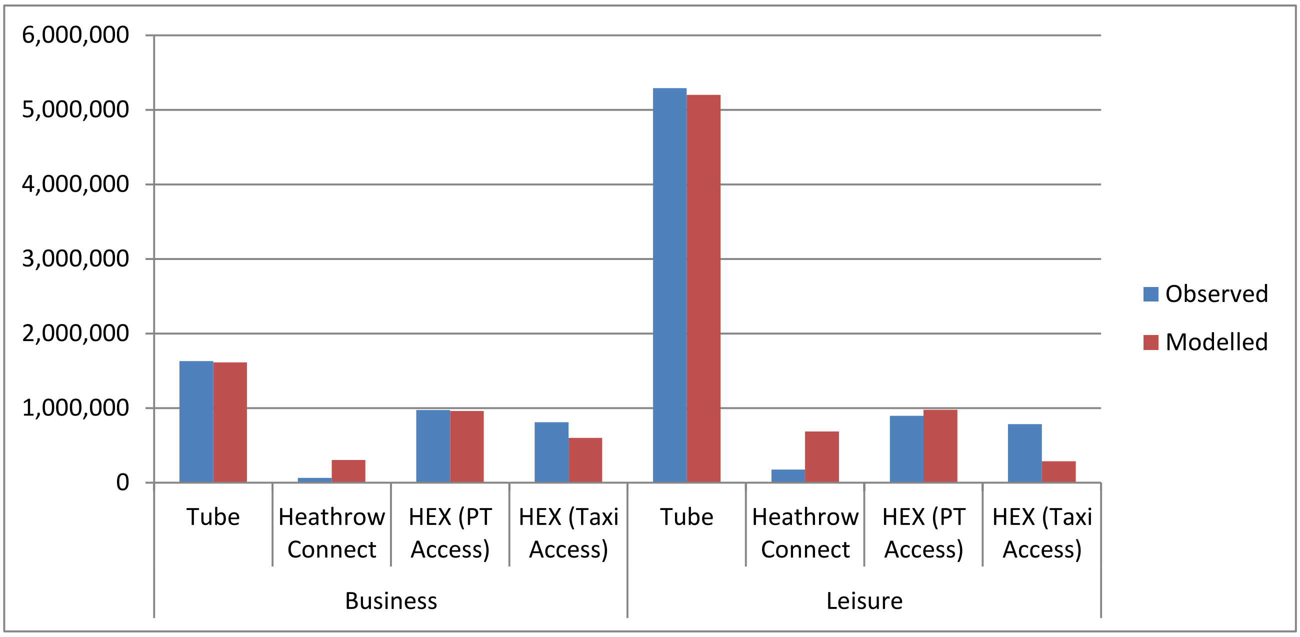
Mode Factors	Business	Leisure
Tube	1	1
Heathrow Connect	1.45	1.28
HEX (PT Access)	1	1
HEX (Taxi Access)	0.94	0.81

The mode constant values indicate two key elements of the observed mode shares that the GC calculations could not fully explain. The first was the popularity of taxi trips linking to Heathrow Express, particularly among leisure passengers, and so the mode constant lowered GC for these trips to make them more attractive. An implicit assumption in mode share modelling is that passengers are aware of all the options available to them to make a particular journey. Taxis were particularly well used by foreign leisure passengers who may not be fully aware of all the rail options available to them, or who may place a higher value on a direct, door-to-door journey than UK leisure passengers. In addition, some visitors to London may view black cabs as an experience as well as a mode of transport, and the mode constants for taxis were applied to account for the impact of such factors.

In contrast, the second element was the low observed use of Heathrow Connect services, particularly among business passengers. Anecdotal evidence suggests that there is little knowledge of the existence of Heathrow Connect services among airport passengers as the service is not widely advertised. As a result, the mode constants were adjusted to reduce the attractiveness of these trips.

Figure 14 summarises the differences between observed annual passenger trips to Heathrow by rail mode and the outputs from the calibrated 2012 base model. The graph indicates that overall, the model forecast for total trips by mode is very close to the observed, with the biggest difference being for business trips by Heathrow Express (secondary PT mode).

Figure 14: Modelled v observed total annual rail passenger trips to Heathrow by mode and journey purpose (2012)



The graphs in **Figure 15** to **Figure 18** summarise the other element of the calibration process – the relationship between modelled and observed passenger forecasts by district for each mode. The graphs illustrate a very strong correlation between modelled and observed with R-Square values of 0.95 or above for all relationships with the exception of those derived for Heathrow Connect services.

Figure 15: Modelled v observed annual tube passengers to Heathrow (2012)

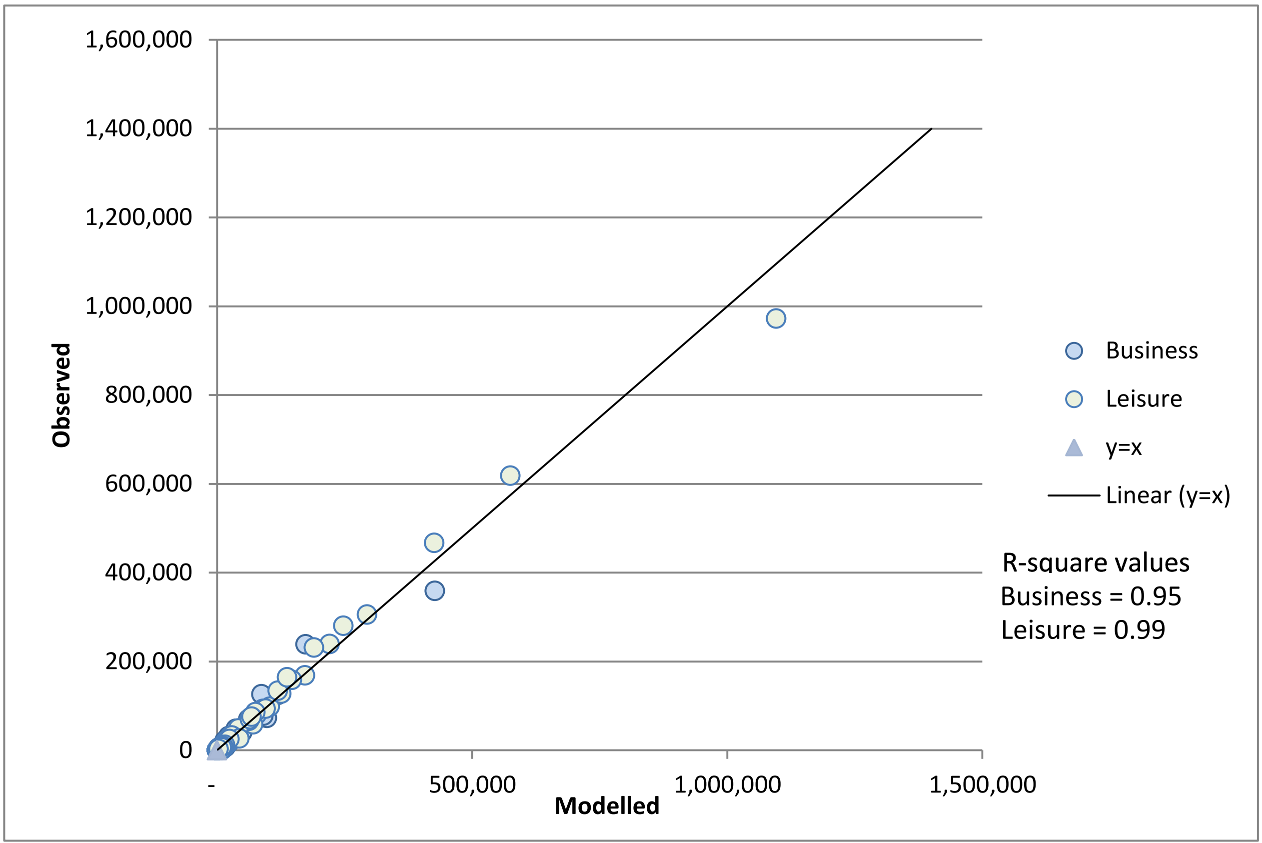


Figure 16: Modelled v observed annual Heathrow Connect passengers to Heathrow (2012)

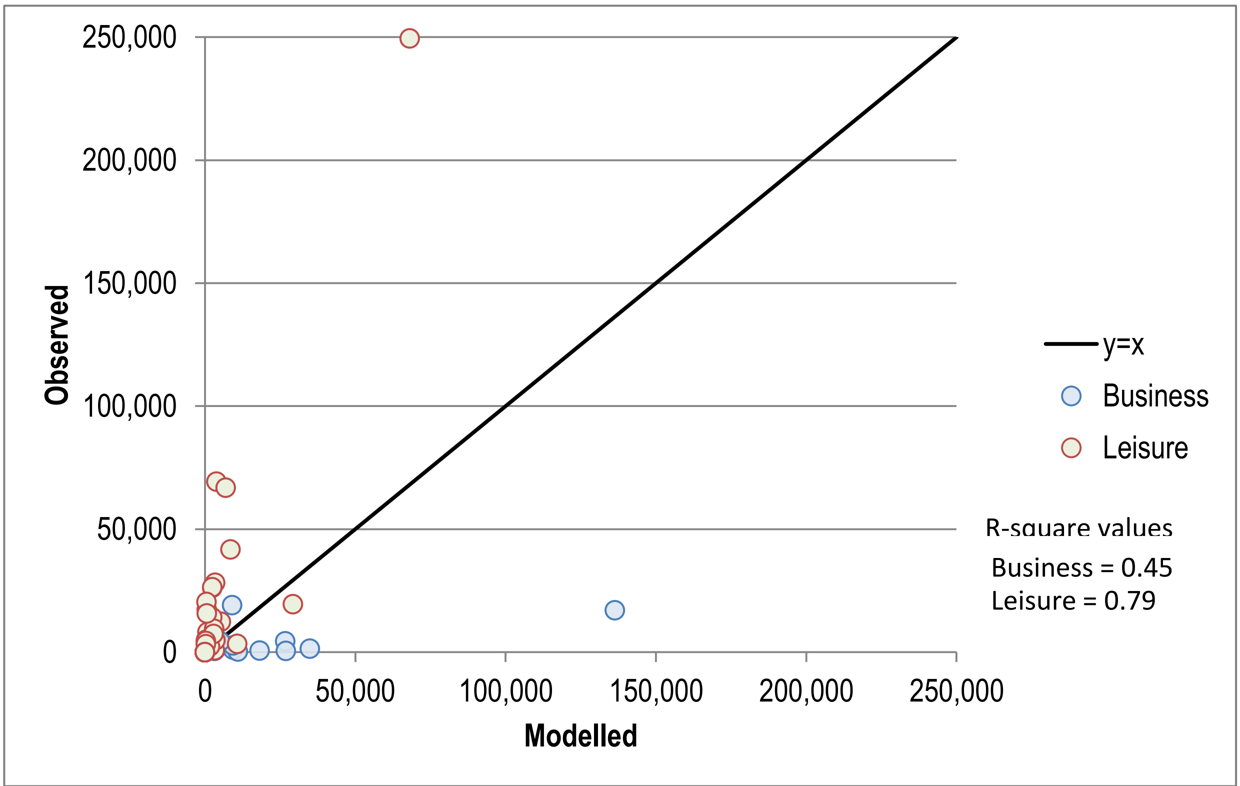


Figure 17: Modelled v observed annual Heathrow Express passengers (with secondary PT mode) to Heathrow (2012)

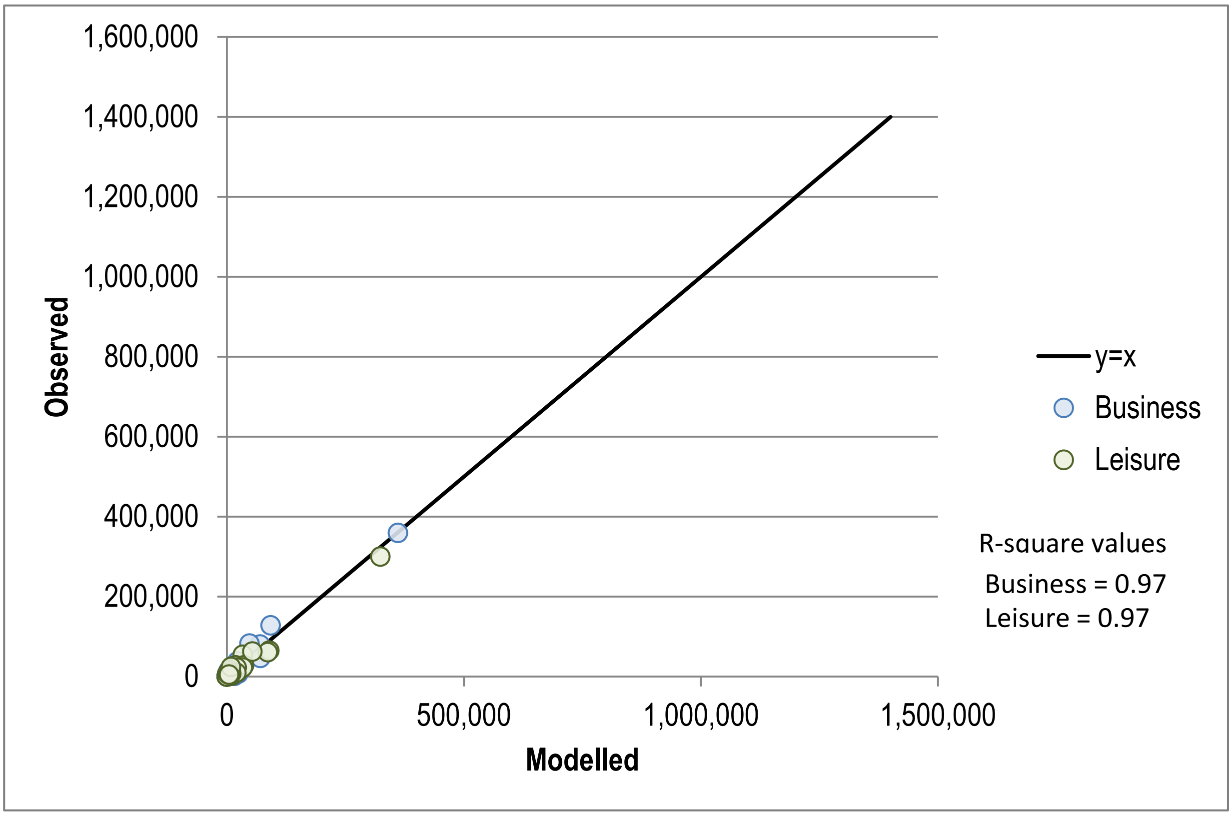
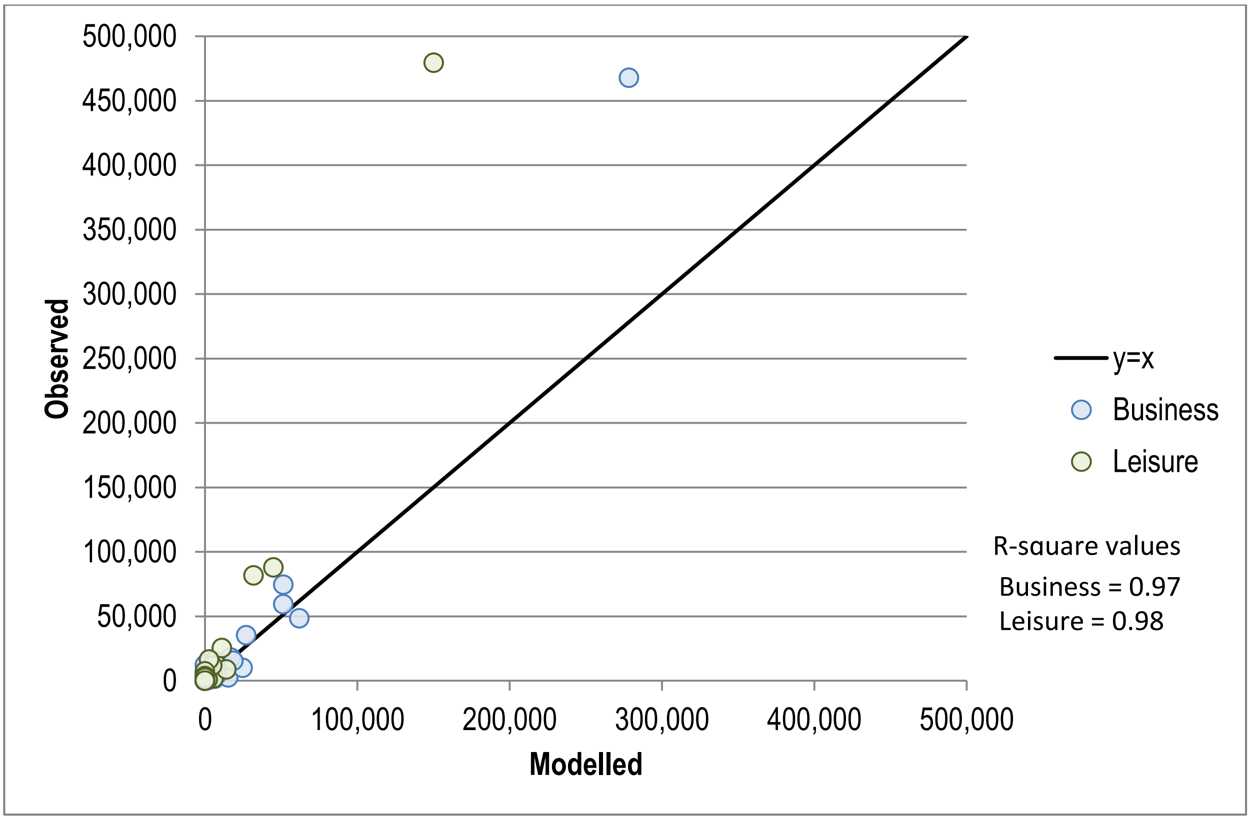


Figure 18: Modelled v observed annual Heathrow Express passengers (with secondary taxi mode) to Heathrow (2012)



The poor relationship derived for Heathrow Connect was partly due to the limited number of districts that generated observed trips, particularly for business purposes. This appears in itself linked to a general lack of awareness of the service among many passengers – no districts generated more than a 3% mode share for Heathrow Connect among business rail passengers. Only 3% of business passengers from Westminster used the service compared to 38% who used the Tube, despite Paddington being located within Westminster and the two route options having similar clock times and fares from many parts of the borough.

The fare for Heathrow Connect trips is considerably lower than Heathrow Express for trips to the airport from Paddington – an average of £9.90 was assumed in the modelling compared to £21 for Heathrow Express. In contrast an assumed journey time of 41 minutes and an average service frequency of 30 minutes compares poorly with equivalent values of 15 minutes for both journey time and service frequency for Heathrow Express.

An initial analysis of the Generalised Cost of both options from Paddington using a leisure value of time of 27p per minute, a factor of 2 for average wait time, and no factors applied for comfort suggests that both services should be equally attractive for leisure passengers. Even accounting for an enforced interchange at Terminals 1, 2 and 3 for Heathrow Connect passengers travelling to Terminals 4 and 5 and a reduced comfort factor, the analysis of Generalised Cost included in the modelling does not generate a mode share forecast as low as the observed for Heathrow Connect.

Due to the low number of passengers using Heathrow Connect, it was felt that the poor relationship derived for the service in the base logit model was not a significant issue in the context of the strength of the relationships derived for other modes. Furthermore, Heathrow Connect services are due to be discontinued when Crossrail services begin operating to and from Heathrow.

The parameters developed for the Heathrow model were subsequently applied to GC calculations developed for potential rail options to Heathrow to estimate the rail mode share for each option.

Following the application of the rail sub mode, the generalised costs and calculated proportions were converted to a composite cost to feed into the distribution and main mode choice models.

Distribution model

The headline rail passengers from Heathrow airport were then distributed across the UK using a gravity model calibrated with Heathrow 2012 CAA survey passenger data and Heathrow 2008/9 employee survey data.

As stated within Section 2.3 of the main methodology note this analysis was undertaken at district level, including the 33 London boroughs and the remaining 328 districts and unitary authority areas in the UK. The CAA passenger data and employee data already contained fields identifying trip and home location at this level, which facilitated the process. The CAA data also included two fields related to passenger country of residence (categorised as either ‘UK’ or ‘foreign’) and overall journey purpose (categorised as either ‘business’ or ‘leisure’), allowing the data to be sub-divided into these four categories to refine the analysis.

Identifying variables influencing airport passenger trip origins

In the gravity model, accessibility to and from the destination is a key determining factor of trip origin. Ideally this would be represented by the generalised cost of a journey to the airport from each district, weighted by key variables such as car ownership.

In addition, passenger trip origins are influenced by different population-based variables depending on the trip purpose and passenger characteristics. For example, districts with a high resident population or a high number of jobs may be expected to generate significant numbers of airport trips by UK residents, with location of jobs a more important factor influencing the origin of business trips due to the propensity of passengers to travel directly between the airport and their place of work. In contrast, foreign leisure passenger trip origins are unlikely to be influenced by resident population distribution and are more likely to be related to the distribution of, for example, hotel rooms.

As with the calculation of accessibility, an ideal gravity model would take into account a range of other variables associated with population-based factors, including for example socio-economics (which would account for the likelihood of financial service jobs in the City of London/Canary Wharf generating more airport business passenger trips than blue collar jobs in outer London, or affluent areas generating more trips than those in poorer areas). However, developing a model to this level of complexity was outside the scope of this study and as a result, three population-based variables were assessed as determining factors influencing passenger and employee trip origins:

- Total resident population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total Working Population – mid-year population estimates for 2009 and 2012 were sourced from the Office of National Statistics (ONS) Nomis website, to match the year of the CAA survey and the Heathrow employment survey data;
- Total employee jobs – sourced from the ONS Annual Business Inquiry for 2009 and 2012, also available on the ONS website;
- Total employee jobs in the hospitality sector – assumed as a proxy variable influencing foreign leisure trips, and also sourced from the ONS Nomis website; and
- 2012 income - taken from National Trip End Model estimates.

For the future year 2030 models, population and job forecasts provided by the GLA (for London) and DfT NTEM (for the rest of the UK) replaced the base-year numbers described above. The proportion of total jobs in the hospitality sector was assumed to remain constant in the base and future-year models.

Based upon the formulas presented earlier in this document, foreign business and UK leisure passenger trip origins were related to the spread of both working population and a combination of total jobs and income with UK business using total population, while foreign leisure trips were related only to the spread of hospitality jobs. It should be noted that 2012 population data was used for passenger trips while 2009 population was used for employees, to match the respective dates of the survey data.

Base model calibration

The constants identified in the formulae above were then adjusted using the MS Excel Solver tool to achieve the highest possible R-Square value for f(a) when compared with the relevant Heathrow passenger and employee trip origins by district. The final constant values and corresponding R-Squares, assuming an intercept of 0, are summarised in **Table 14**.

Table 14: Co-efficients and RSQ values for calculation of function of accessibility for Heathrow trip categories

Trip Type	RSQ f(A)	Working Pop	All Jobs * Income	Hosp. Jobs	Generalised Cost
Business Foreign	0.77	53,687,090	91,054,319		0.71
Business UK	0.68	0.57	2.18		1.01
Leisure Foreign	0.89			1	0.75
Leisure UK	0.70	1.53	0.00		0.80

The constant values shown in the table indicate that the distribution of both business UK passengers and UK leisure passengers was more closely related to the spread of working population than to jobs, with jobs and population being a major determining factor for business foreign trips compared to the generalised costs. In addition, the low values of the constant for generalised cost for foreign passengers generally reflect the fact that passenger distributions are spread across a large area of the UK.

The graphs in **Figure 19** to **Figure 22** illustrate the strength of the relationship derived with f(a) for each of the four trip types, demonstrating a close correlation in the case of Leisure trips and Business foreign trips but a weaker relationship for business UK passengers. In the latter case the overall R-Square value is reduced by significant outliers such as Westminster and Kensington & Chelsea, which generate significantly higher volumes of business trips than predicted using the gravity model formula based purely on population, jobs and distance from the airport, possibly due to the international nature of businesses located within these boroughs.

Figure 19: Trip origin v accessibility for Heathrow business foreign passengers (2012), by UK district

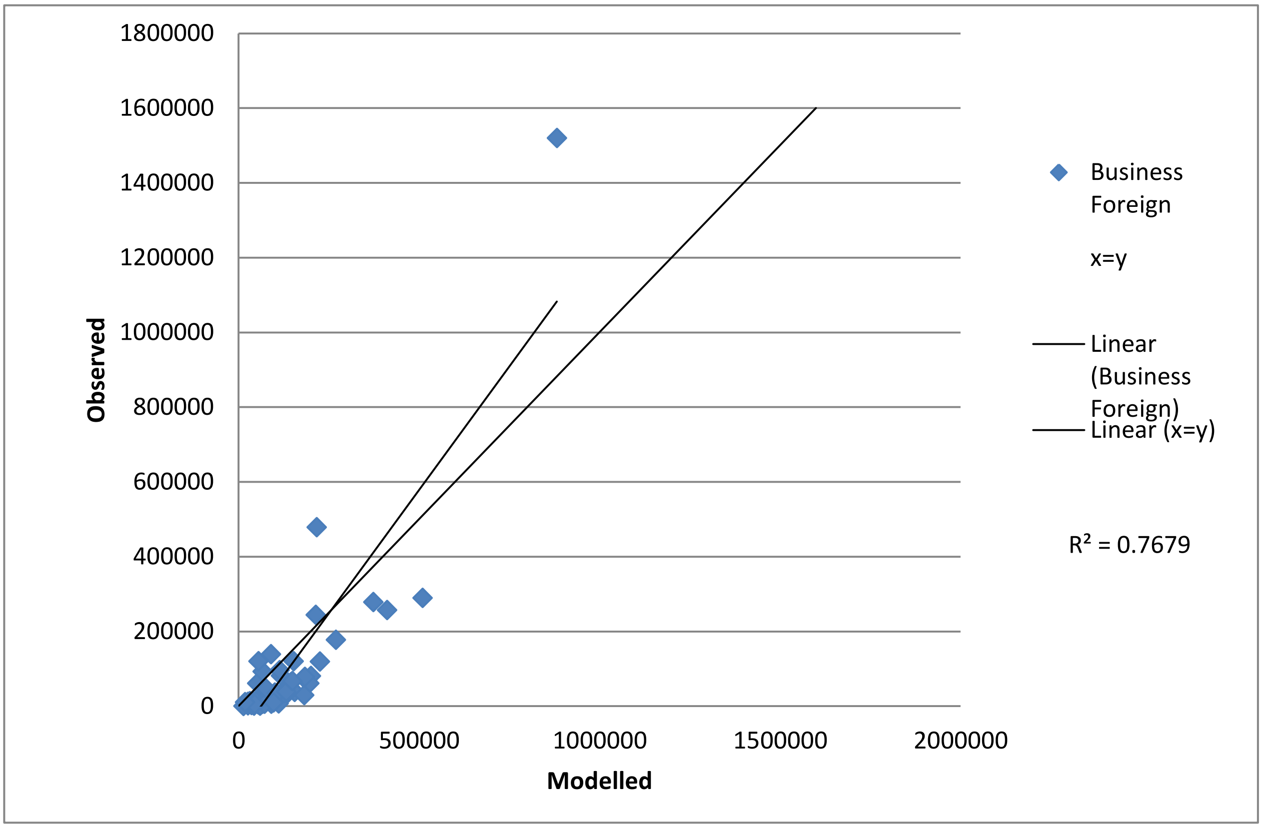


Figure 20: Trip origin v accessibility for UK resident Heathrow Business passengers (2012), by UK district

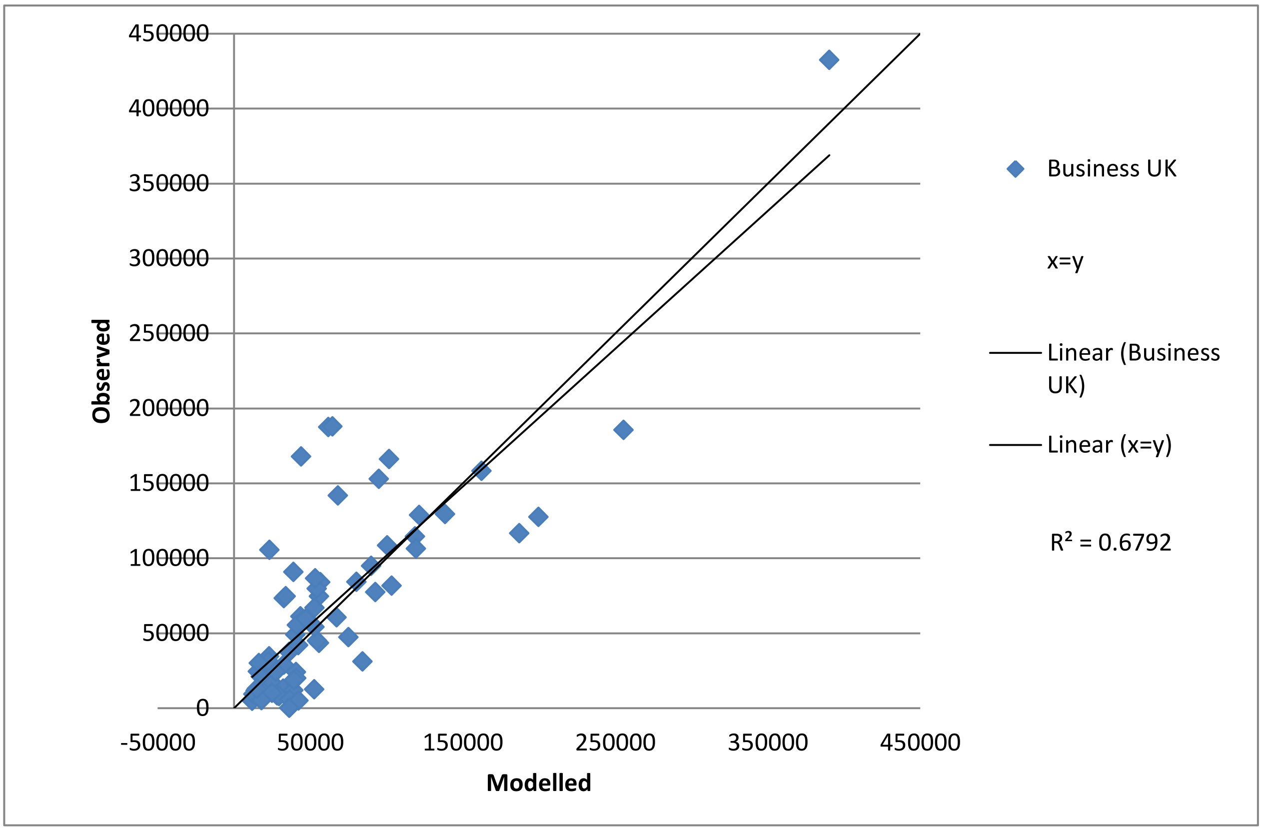


Figure 21: Trip origin v accessibility for foreign resident Heathrow leisure passengers (2012), by UK district

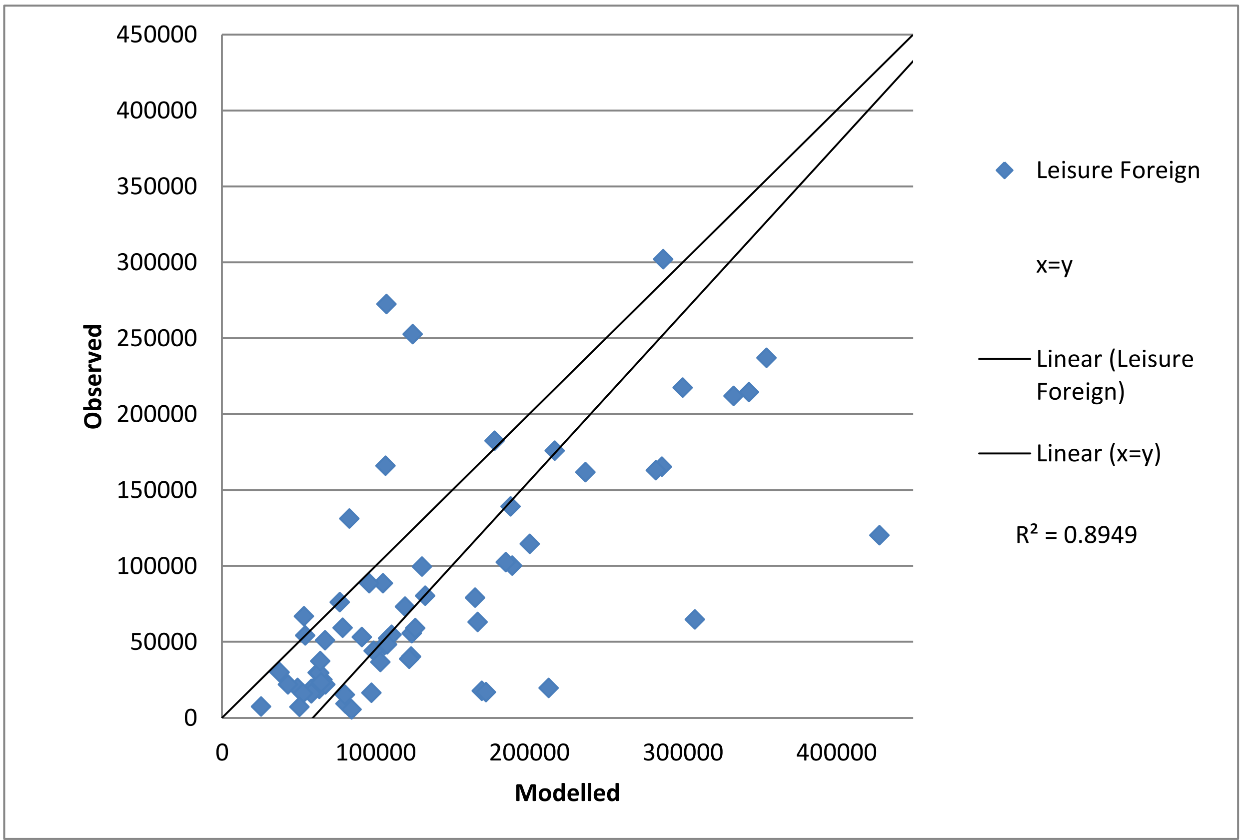
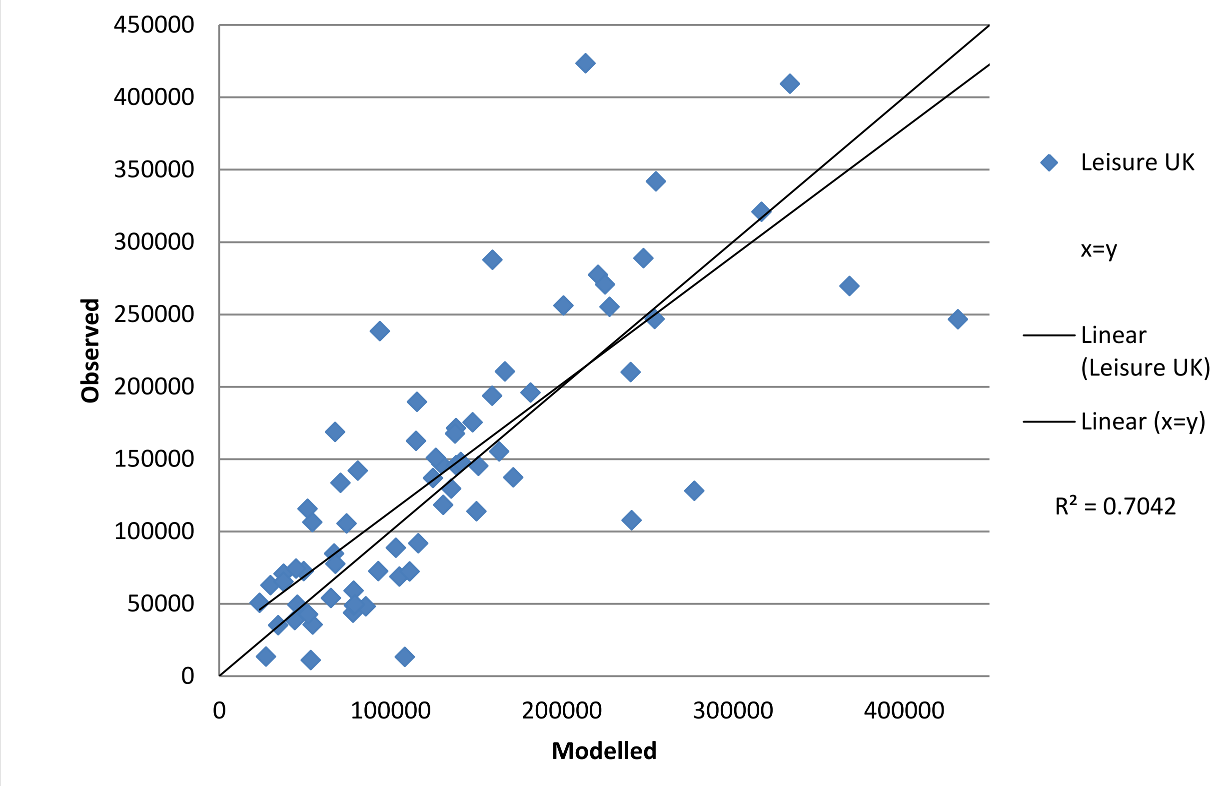


Figure 22: Trip origin v accessibility for Heathrow Leisure UK Passengers (2012), by UK district



To account for the outliers in the passenger relationships derived, residual values for each of the districts were calculated using the equations identified on the graphs. These values were then re-applied to each district in the Heathrow forecasts.

Through the development of the forecast surface access demand model it was deemed suitable, given the lack of information to the contrary, to allow for the observed 2012 distribution. This was formed on the basis that the destination of the airport selected is likely not to be determined through surface access but with the availability of flights at a given airport.

Main mode model

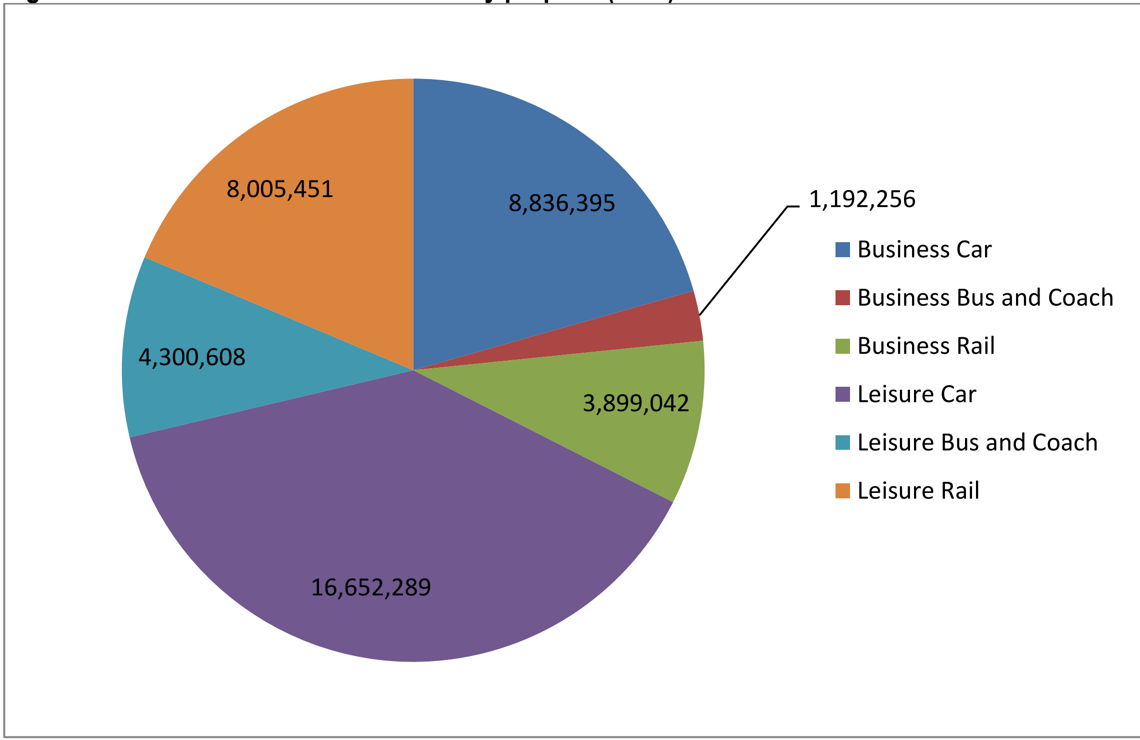
The development of a main mode logit model was deemed to be an important component of the surface access model given the large investment in rail infrastructure spending within London and the South. As such, accessibility and the likelihood of passengers switching to more sustainable modes should be accounted for within our surface access model.

As with the distribution and rail logit models, the CAA 2012 survey data was used as the source of data. Through investigation of and as stated previously Olympic-related traffic was removed from the data set before calibration. This was due to high volumes of coach trips taking passengers to Newham which accounted for 35,000 trips or 35% of all bus trips heavily skewing the results.

Model structure

To accord with both the rail sub-mode and distribution model the 72 districts, 33 London Boroughs and 39 representative districts were selected from the survey data. The main mode choice model forms a nested logit model with composite costs from the rail sub mode model feeding in as an input for rail generalised costs. In addition through analysis of the mode travel to Heathrow within the CAA data the selection of Car, Rail and Coach with Bus were selected as main modes for the choice model. **Figure 23** below presents the observed numbers of passengers by final mode of travel and main purpose. Purpose was selected given the higher proportion of coach and bus use over car for leisure passengers compared to business trips.

Figure 23: Heathrow final mode of travel by purpose (2012)



The resulting districts and observed mode shares by journey purpose are shown in **Table 16** provided the framework for the development of the model. The proximity of the trip to Heathrow and availability of the tube network was also deemed to be considered a significant factor as shown within **Table 15** below with calibration parameters required to be separated out by location for London and the rest of the UK.

Table 15: Heathrow origins within London and outside by final mode and journey purpose for all Districts (2012)

Region	Business			Leisure		
	Car	Bus	Rail	Car	Bus	Rail
Inner London	40%	2%	58%	39%	5%	56%
Rest of UK	76%	12%	12%	66%	20%	14%

Source: CAA 2012 Heathrow passenger survey data, analysed by consultant

Table 16: Heathrow origins by final mode and journey purpose (2012)

Origin District	Area	Business			Leisure		
		Car	Bus	Rail	Car	Bus	Rail
Barking and Dagenham	London	52%	0%	48%	69%	0%	31%
Barnet	London	79%	0%	21%	73%	2%	25%
Bexley	London	73%	3%	24%	76%	7%	17%
Brent	London	74%	3%	23%	67%	7%	26%
Bromley	London	66%	6%	29%	81%	4%	15%
Camden	London	34%	1%	65%	35%	8%	57%
City of London	London	31%	1%	69%	22%	9%	69%
Croydon	London	85%	10%	6%	75%	12%	13%
Ealing	London	57%	1%	42%	62%	5%	33%
Enfield	London	82%	0%	18%	66%	1%	33%
Greenwich	London	48%	1%	50%	43%	12%	45%
Hackney	London	52%	1%	47%	39%	1%	60%
Hammersmith and Fulham	London	45%	0%	55%	42%	2%	56%
Haringey	London	69%	0%	31%	40%	4%	56%
Harrow	London	91%	4%	5%	89%	6%	5%
Havering	London	88%	0%	12%	71%	2%	26%
Hillingdon	London						excluded
Hounslow	London	68%	15%	17%	63%	16%	21%
Islington	London	24%	0%	76%	32%	5%	63%
Kensington and Chelsea	London	45%	3%	52%	45%	4%	50%
Kingston upon Thames	London	87%	8%	5%	76%	21%	3%
Lambeth	London	46%	2%	51%	36%	3%	61%
Lewisham	London	64%	3%	33%	49%	1%	50%
Merton	London	70%	0%	30%	69%	3%	28%
Newham	London	33%	0%	67%	49%	1%	50%
Redbridge	London	61%	0%	39%	73%	2%	25%
Richmond upon Thames	London	85%	7%	8%	75%	9%	16%
Southwark	London	48%	0%	51%	48%	1%	52%
Sutton	London	59%	6%	35%	79%	14%	7%
Tower Hamlets	London	48%	2%	50%	28%	2%	70%
Waltham Forest	London	41%	0%	59%	57%	2%	42%
Wandsworth	London	68%	0%	32%	62%	3%	35%
Westminster	London	36%	2%	62%	37%	5%	58%
Nottingham	Rest of UK	72%	14%	14%	50%	32%	18%
Cambridge	Rest of UK	66%	13%	20%	50%	33%	17%
Colchester	Rest of UK	70%	6%	24%	65%	11%	24%
Peterborough	Rest of UK	80%	3%	17%	51%	12%	37%
Manchester	Rest of UK	25%	20%	55%	35%	6%	59%
Brighton and Hove	Rest of UK	68%	25%	7%	43%	45%	12%
Canterbury	Rest of UK	75%	16%	9%	50%	19%	31%
Crawley	Rest of UK	49%	51%	1%	26%	65%	8%

Origin District	Area	Business			Leisure		
		Car	Bus	Rail	Car	Bus	Rail
Oxford	Rest of UK	43%	48%	9%	40%	55%	5%
Bath and North East Somerset	Rest of UK	58%	17%	25%	67%	25%	8%
Bristol, City of	Rest of UK	59%	23%	19%	39%	50%	11%
Exeter	Rest of UK	32%	38%	31%	45%	26%	29%
Plymouth	Rest of UK	42%	27%	31%	31%	48%	21%
Cardiff	Rest of UK	80%	8%	12%	33%	59%	8%
Swansea	Rest of UK	32%	32%	36%	55%	29%	17%
Birmingham	Rest of UK	64%	16%	20%	54%	34%	12%
Leeds	Rest of UK	13%	40%	48%	16%	29%	55%
York	Rest of UK	0%	19%	81%	34%	12%	54%
Chelmsford	Rest of UK	86%	2%	12%	80%	0%	20%
Coventry	Rest of UK	81%	10%	10%	30%	53%	18%
Cheltenham	Rest of UK	79%	13%	8%	61%	32%	7%
Basingstoke and Deane	Rest of UK	99%	1%	0%	80%	20%	0%
Milton Keynes	Rest of UK	84%	9%	6%	66%	25%	9%
Swindon	Rest of UK	84%	11%	5%	84%	14%	2%
Guildford	Rest of UK	92%	8%	0%	89%	10%	0%
Wycombe	Rest of UK	86%	13%	1%	92%	5%	3%
Slough	Rest of UK	95%	5%	0%	92%	8%	1%
Southampton	Rest of UK	62%	35%	2%	50%	48%	2%
Windsor and Maidenhead	Rest of UK	94%	5%	1%	93%	6%	1%
Reading	Rest of UK	75%	23%	2%	56%	41%	2%
Newcastle upon Tyne	Rest of UK	40%	40%	21%	19%	4%	77%
Southend-on-Sea	Rest of UK	76%	10%	13%	77%	5%	18%
Edinburgh, City of	Rest of UK	83%	0%	17%	39%	4%	57%
Hastings	Rest of UK	80%	0%	20%	73%	8%	19%
Dartford	Rest of UK	88%	0%	12%	83%	3%	15%
Sevenoaks	Rest of UK	93%	0%	7%	78%	3%	19%
Norwich	Rest of UK	84%	3%	12%	58%	32%	11%
Spelthorne	Staines	83%	14%	3%	86%	13%	2%
St Albans	St Albans City	89%	5%	6%	90%	7%	2%

Source: CAA 2012 Heathrow passenger survey data, analysed by consultant

Analysis of car based trips identified four distinct groups of car users, with varying costs associated with travel identified as Kiss and Fly, Car parking (both short and long stay) and Taxi. **Table 17** below highlights the overall proportion of trips by car mode to Heathrow.

Table 17: UK based Car use by type to Heathrow (2012)

Trip Type	Business				Leisure			
	Taxi	Kiss and Fly	Car Long Stay	Car Short Stay	Taxi	Kiss and Fly	Car Long Stay	Car Short Stay
Car Use	47%	21%	17%	15%	32%	41%	11%	16%

Source: CAA 2012 Heathrow passenger survey data, analysed by consultant

Once the district-level framework was established, a representative 'busy' station for both coach/bus and rail was then identified in each borough based on a qualitative high-level assessment. Wherever possible, a prominent tube station/ bus station was selected as a representative station in London boroughs, while in other districts, the main railway station/ coach stations in the district was identified.

Generalised Costs (GCs) were then calculated from each representative station to Heathrow Airport for each of the mode options identified in the table. This calculation was based on a number of key data inputs, as follows:

- Rail Generalised costs were derived directly through composite costs from the rail sub mode model;
- Car travel times and distances were derived through google maps with cost components identified separately with the formulation of generalised cost as detailed earlier in this document;
- Bus journey times, fares, interchanges and frequencies were derived from TfL websites for each of the 33 London Boroughs;
- Coach Journey times, fares and frequencies were derived from National Express website for the remaining districts outside London;
- Bus wait times were capped at 10 minutes; and
- Car set down times were set at 10 minutes.

The following parameters were then applied to calculate GC for each mode choice based on the inputs described above – the values derived for these parameters are described in the following section on model calibration:

- Main mode factors were applied by mode, purpose and location (London or rest of UK) to account for errors in the assessment of generalised costs which were used to improve the fit to CAA data; and
- An interchange penalty was applied to bus trips.

The resulting GCs derived for each mode by district were then used to predict mode shares using a multinomial logit model formula detailed earlier in this document, with a lambda value calibrated to determine the sensitivity of passengers to GC.

Base model calibration

A number of tests were used in the process of calibrating the base logit model, which was undertaken with the assistance of the MS Excel Solver tool. The first was to ensure that the relationships between modelled and observed annual passenger numbers by mode and journey purpose, expressed in R-Square values, were as high as possible. In addition, overall mode proportions by location and purpose were used to constrain the model to ensure a good fit in overall proportions.

The key variables that were therefore changed during the calibration process were the lambda values in the logit model formula and the mode constants. The Solver tool was used to maximise R-Square values and minimise errors in the proportion of passenger numbers by mode, purpose and location by firstly adjusting lambda values. Mode constants were then subsequently adjusted to account for any significant residual errors.

The final derived lambda values were 0.024 for business passengers and 0.030 for leisure passengers (which are typical values for a logit model of this nature and are within ranges identified in WebTAG), and the mode constants applied are summarised in **Table 18**.

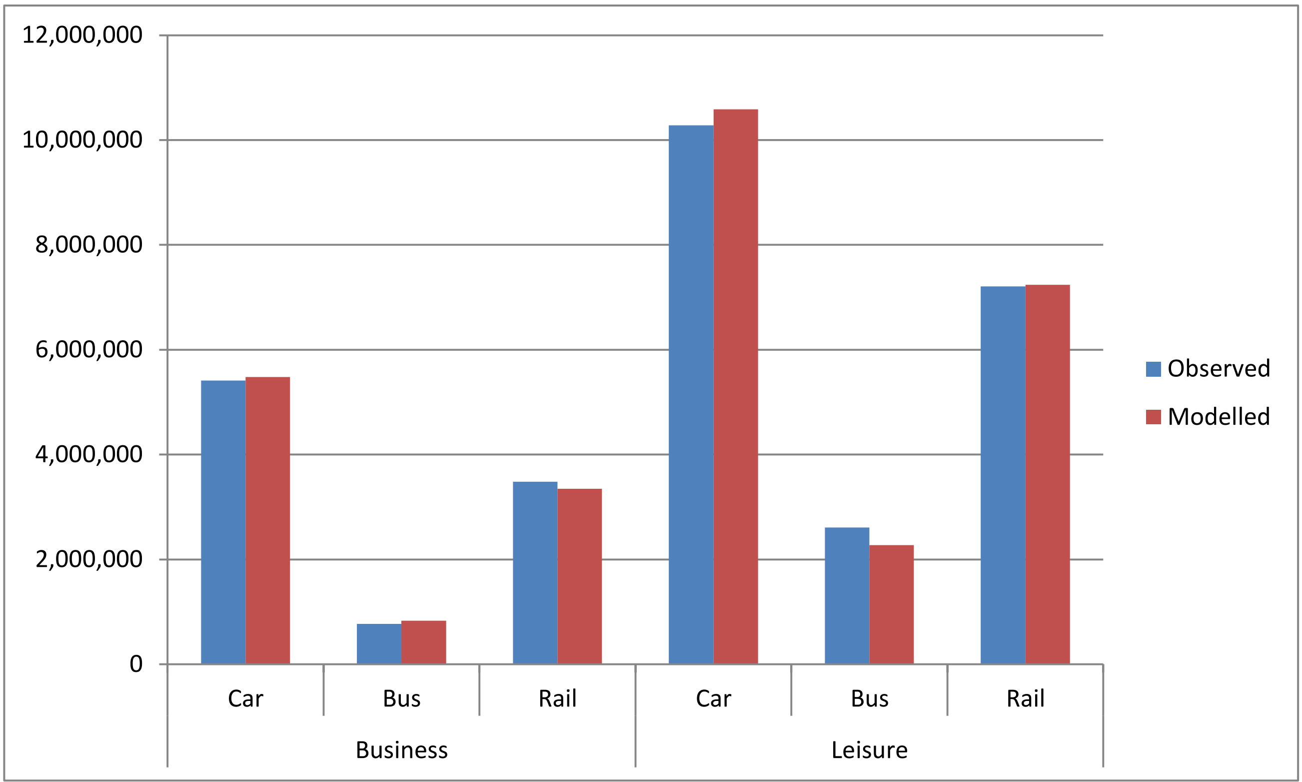
Table 18: Mode constants applied in calibrated 2012 Heathrow main mode choice logit model

Main Mode factors	London		Rest of UK	
	Business	Leisure	Business	Leisure
Car	0.98	0.86	0.82	1.03
Bus and Coach	1.06	1.09	1.19	1.08
Rail	0.92	0.93	1.11	0.90

The mode constant values indicate two key elements of the observed mode shares that the GC calculations could not fully explain. The first was overall the generalised costs for bus and coach were under predicted and did not account for the desirability of coach use compared to other modes. The second is that overall the adjustments required was, broadly speaking, within a range of 20% of the original values.

Figure 24 summarises the differences between observed annual passenger trips to Heathrow by mode and the outputs from the calibrated 2012 base model. The graph indicates that overall, the model forecast for total trips by mode is very close to the observed, with the biggest difference being for bus and coach trips both for business and leisure. The model forecast overall was in line with the CAA data.

Figure 24: Modelled v observed total annual rail passenger trips to Heathrow by mode and journey purpose (2012)



The graphs in **Figure 25** to **Figure 27** summarise the other element of the calibration process – the relationship between modelled and observed passenger forecasts by district for each mode. The graphs illustrate a very strong correlation between modelled and observed with R-Square values of 0.82 or above for all relationships with the exception of Bus and Coach use which has a poorer overall correlation.

Figure 25: Modelled v observed annual Car Passengers to Heathrow (2012)

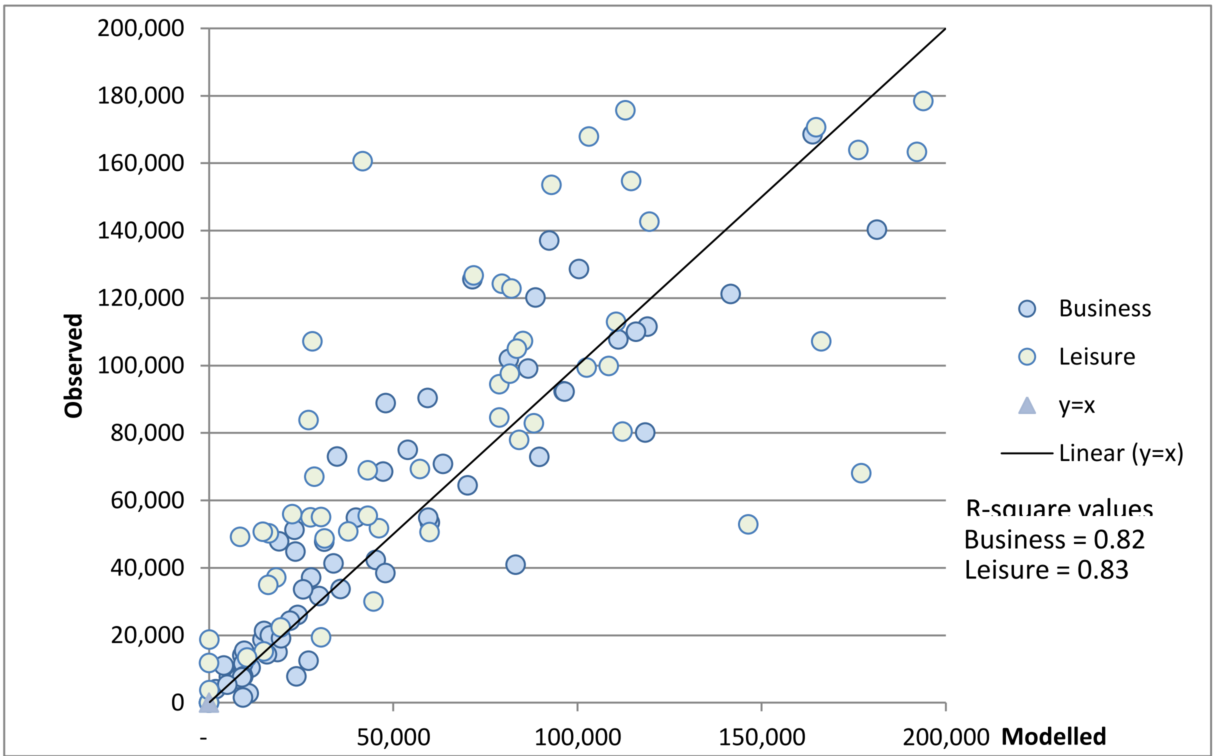


Figure 26: Modelled v observed annual Bus and Coach to Heathrow (2012)

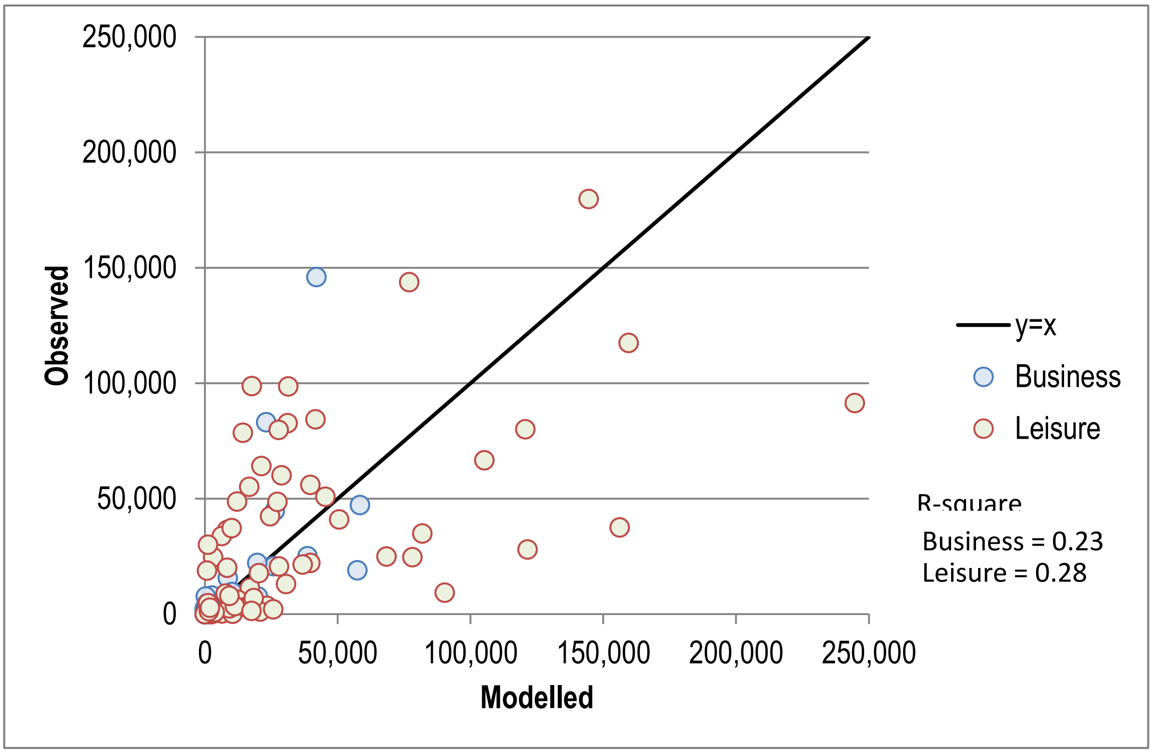
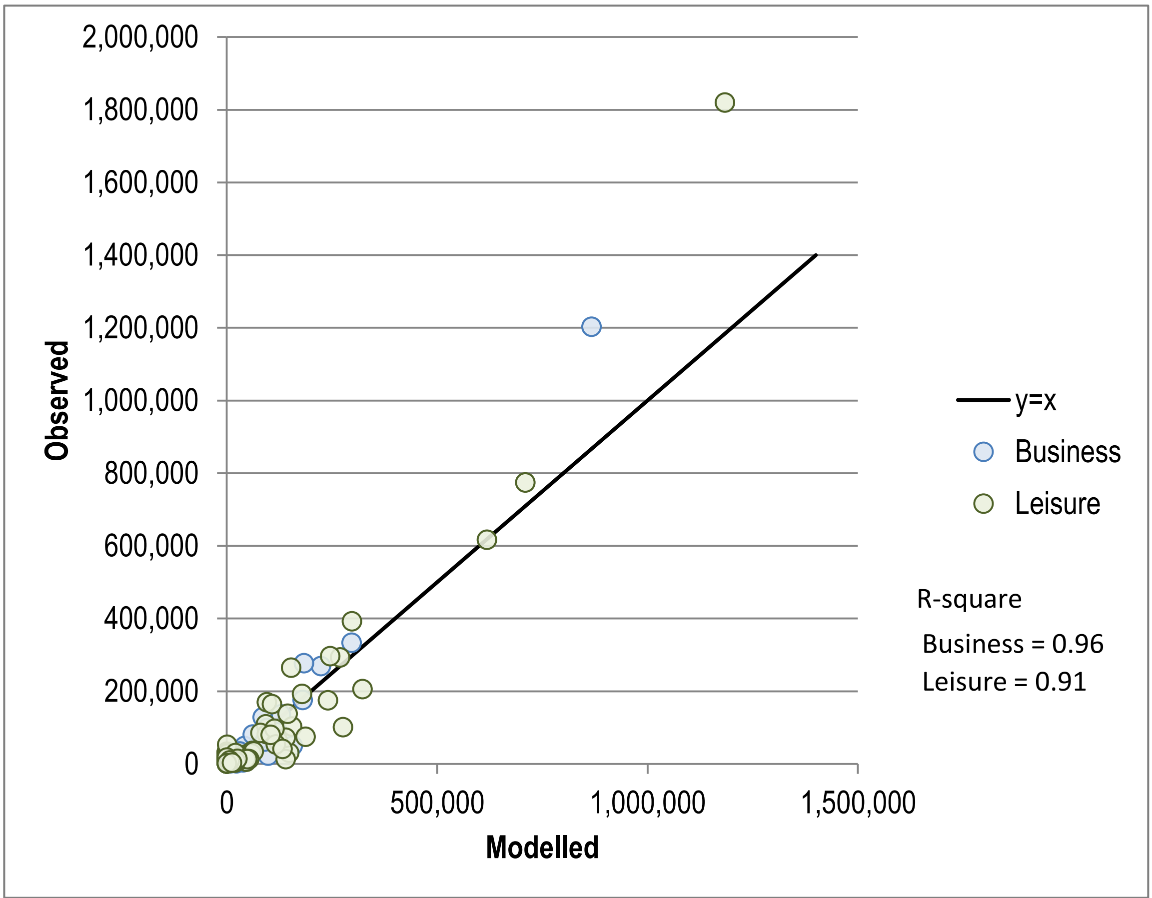


Figure 27: Modelled v observed Rail Passengers to Heathrow (2012)



The poorer relationship derived for Bus and Coach was mainly due to the limited number of districts within London that generated observed trips, particularly for business purposes. For the rest of the UK there are large differences in coach use with either very low, negligible usage compared to other districts, for example Newcastle, which has a high Business coach use of 39.6% with a very high Generalised Cost compared to York which has only 19.5% business use with comparable Generalised Costs. Coach and Bus fares tend to be the cheapest, markedly from districts outside of London, were income bandings available for the CAA data this would likely provide a better fit for this mode of transport.

The parameters developed for the Heathrow model were subsequently applied to GC calculations developed for 2030 options to Heathrow to estimate main mode share for each option. Changes in mode share proportions between 2030 and the base 2012 predicted model were then applied to the observed 2012 CAA data. It was felt that the poorer relationship derived for the Bus and Coach trips in the base logit model was not a significant issue in the context of the strength of the relationships derived for other modes. Furthermore, due to the incremental application of mode choice the affects were based upon relative changes in generalised costs and not absolute predictions.

At the incremental stage it was decided that a cap of 10% car use by district should be retained as a minimum car use level by mode through professional judgement.

Sensitivity testing

Through the development of Heathrow's surface access demand model, parameters were selected for use within the base 2012 logit model as well as the selection of appropriate values for future year. In addition the sensitivity of the demand model was tested for various key components in order to ascertain the models flexibility to assess options. The following sensitivity tests were undertaken through the model development process:

- Value of Time for future year;
- Employee public transport mode share;
- Parking charges;
- Various congestion elements within the car generalised costs;
- Wait times for bus travel;
- Employee car occupancy;
- Passenger car occupancy; and
- Alternative CAA Airport demand and Interlining data.

For each of the sensitivity tests the full surface access demand model was run with key metrics of the model outputs extracted which are presented below within **Table 19**.

Table 19: Key model metrics for sensitivity testing

Metric	Mode	Sections/Periods
Main Mode Share	Car	All
	Bus	All
	Rail	All
Rail Demand	SRA	Richmond - Heathrow
		Heathrow - Richmond
	WRA	Slough - Heathrow
		Heathrow - slough
	Tube	Acton - Heathrow
		Heathrow - Acton
	Cross Rail	Hayes - Heathrow
		Heathrow - Hayes
	HEX	OOC to Heathrow
		Heathrow - OOC
No. of Highway links with V/C above 1		CBL
		EBL
No. of Highway links with V/C above 0.85		CBL
		EBL
Total Car Pax In peak Hour		
Total Car Employee		

Each of the sensitivity tests is discussed in turn in the remainder of this note.

Value of Time

The value of time identified for use within the base year calibration was based upon values selected from Heathrow's LASAM model. Future year pricings of rail, toll and congestion within the road network were unknown at the time of production and as such any change in value of time would impact upon mode choice within the model. The value of time for the 2030 surface access model was retained at base year values to account for the lack of certainty in other pricings within the model inputs. To ascertain the level of change this retention of base year value of time the surface access model was iterated through a series of values of time above the base year value with their results recorded and presented in **Table 20** below.

Table 20: Value of Time Sensitivity Test

VoT Factor	Output Matrix		% Change				
			1.1	1.2	1.3	1.39	1.5
Main Mode Share	Car	All	2%	4%	5%	6%	7%
	Bus	All	-2%	-4%	-6%	-7%	-7%
	Rail	All	-2%	-3%	-4%	-5%	-5%
Rail Demand	SRA	Richmond - Heathrow	-3%	-7%	-10%	-12%	-14%
		Heathrow - Richmond	-4%	-7%	-10%	-13%	-15%
	WRA	Slough - Heathrow	-1%	-1%	-2%	-2%	-2%
		Heathrow - slough	-1%	-1%	-2%	-2%	-2%
	Tube	Acton - Heathrow	-3%	-6%	-8%	-10%	-12%
		Heathrow - Acton	-3%	-6%	-9%	-11%	-14%
	Cross Rail	Hayes - Heathrow	-4%	-6%	-9%	-11%	-13%
		Heathrow - Hayes	-4%	-7%	-9%	-11%	-14%
	HEX	OOC to Heathrow	12%	22%	32%	40%	49%
		Heathrow - OOC	12%	22%	31%	39%	48%
No of Highway links with V/C above 1		CBL	-4%	-4%	-4%	-4%	-4%
		EBL	0%	0%	0%	0%	0%
No of Highway links with V/C above 0.85		CBL	0%	0%	0%	0%	0%
		EBL	0%	0%	0%	0%	0%
Total Car Pax			1%	2%	3%	4%	5%
Total Car Employee			0%	0%	0%	0%	0%

The conclusions we can draw from the adjustment of value of time is that the switch from public transport to private transport is greater than the switch from rail than bus and coach, which is to be expected given the higher times for coach trips compared to rail trips. In addition the impact on the strategic road network is low with only one road link being affected. Another key finding is that an increase in value of time results in a greater number of passengers on the higher priced Heathrow Express diverting from other rail modes.

Employee public transport mode share

Employee mode share for future years was assessed within the Heathrow surface access model whereby the current public transport mode share of 43% was incrementally increased up to a maximum of 60% to assess the impact on the road and public transport network. The findings were that the impact was minor with small absolute changes to the rail patronage and only one road section switching to being below capacity from above. As such it was decided to retain the base year proportion of public transport use, but retain the relative change in rail from bus share as predicted by the main mode choice model.

Parking charges

As detailed in **Table 17** of this report, park + fly in 2012 for Heathrow passengers equates to approximately 30% of all car trips. As such the parking cost makes up a large proportion of their travel costs. A sensitivity test was undertaken to assess the effect of parking price on the level of car use within the model. A range either side of the base year value per day was selected to account for any price increase and decrease with respect to inflation. The results are presented below within **Table 21** which shows the relative elasticity of car trips compared to the cost of parking. This shows that an increase in parking cost of £20 will results in an 8% mode shift from car trips.

The 2030 Heathrow surface access demand model retained the base year parking costs.

Table 21: Parking Charges Sensitivity Test

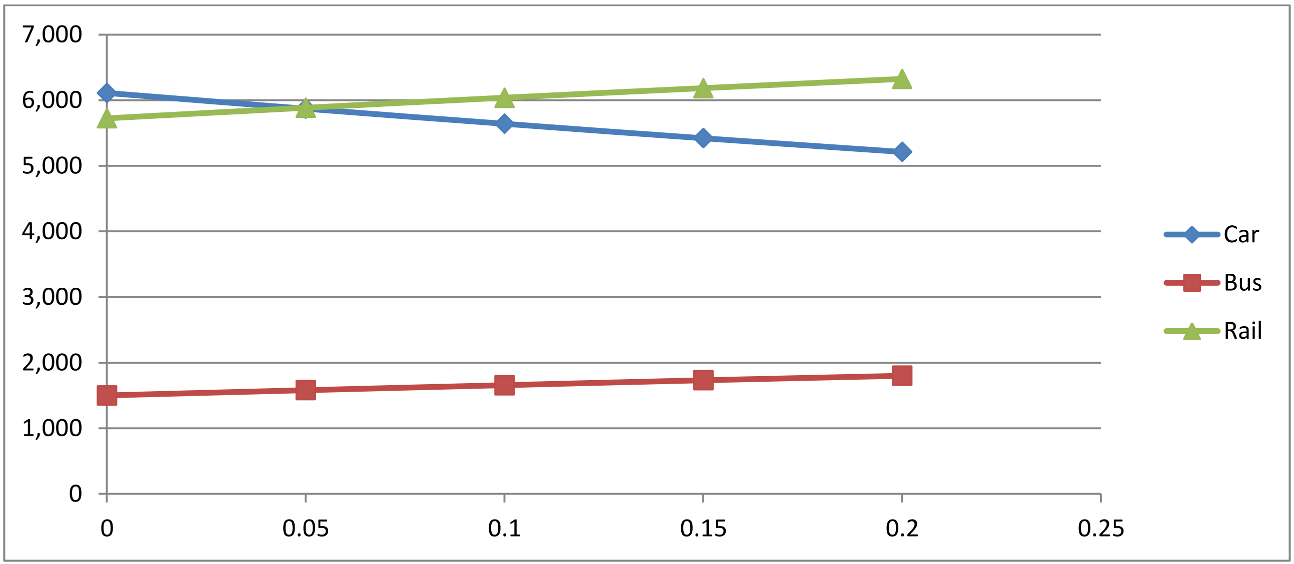
Metric	Sensitivity Test				
Car Trips	Q0	D1	D2	D3	D4
	6,111	6,245	6,033	5,930	5,830
Parking cost per day	P0	P1	P2	P3	P4
	£21.3	£15	£25	£30	£35
Elasticity		E1	E2	E3	E4
		-0.06249	-0.08037	-0.08864	-0.09671

Highway congestion

Various sensitivity tests were conducted to assess the level of congestion that it would be appropriate to apply to the forecast model. Firstly delay per km additions to travel times were assessed, with results showing a disproportionate affect for trips outside of London which would likely not receive the same level of delays for much of their journey. A more realistic proportional increase in journey time was assessed with increments per district applied to car based journey times. Increments up to 20% increase in overall journey times were selected with the resultant predictions of passengers by mode presented overleaf within **Figure 28**. The results show that we would expect to see a shift in car use to public transport of around 7% per 20% increase in congestion levels.

Based upon the level of uncertainty in predicting future year congestion levels and the assumption to retain the base year value of time in the future, these affects will likely offset each other to some extent. Therefore it was decided to retain the base year levels of congestion within the surface access demand model. Furthermore, using current congestion levels induces the "worst case" public mode share for the rail capacity analysis.

Figure 28: Congestion Sensitivity tests

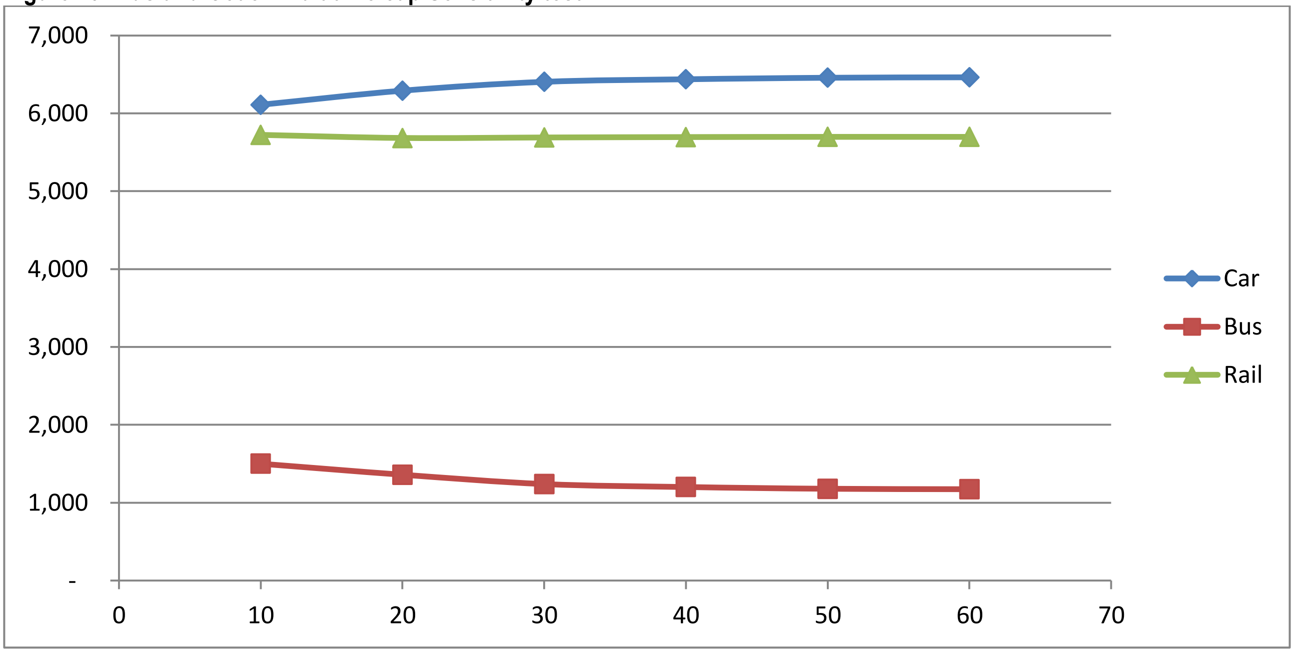


Wait times for bus travel

As discussed earlier, bus and coach waiting times were capped at 10 minutes to account for passengers booking in advance or knowledge of the timetables. Sensitivity tests were run to assess the impact of increasing this cap. Increments from 10 minutes to 60 minute were iteratively modelled with the results presented within **Figure 29** below. The results show that increasing the wait time cap switches bus trips to cars trips up to around 30 minutes, where the impact tails off. This can be attributed to the large proportion of bus frequencies that are twice per hour.

Based on the relative insensitivity to wait time caps, the 2030 demand model uses the 10 minute cap times for buses and coaches.

Figure 29: Bus and Coach Wait time cap Sensitivity test



Car occupancy

Car occupancy for the Base 2012 demand model was taken from the CAA 2012 survey data for passengers and the 2013 Heathrow Employee Survey for employees. Separate sensitivity tests were undertaken adjusting the employee and passenger car occupancy with the results assessed and presented below in **Figure 30** and **Figure 31** respectively.

Figure 30: Employee Car Occupancy Sensitivity test

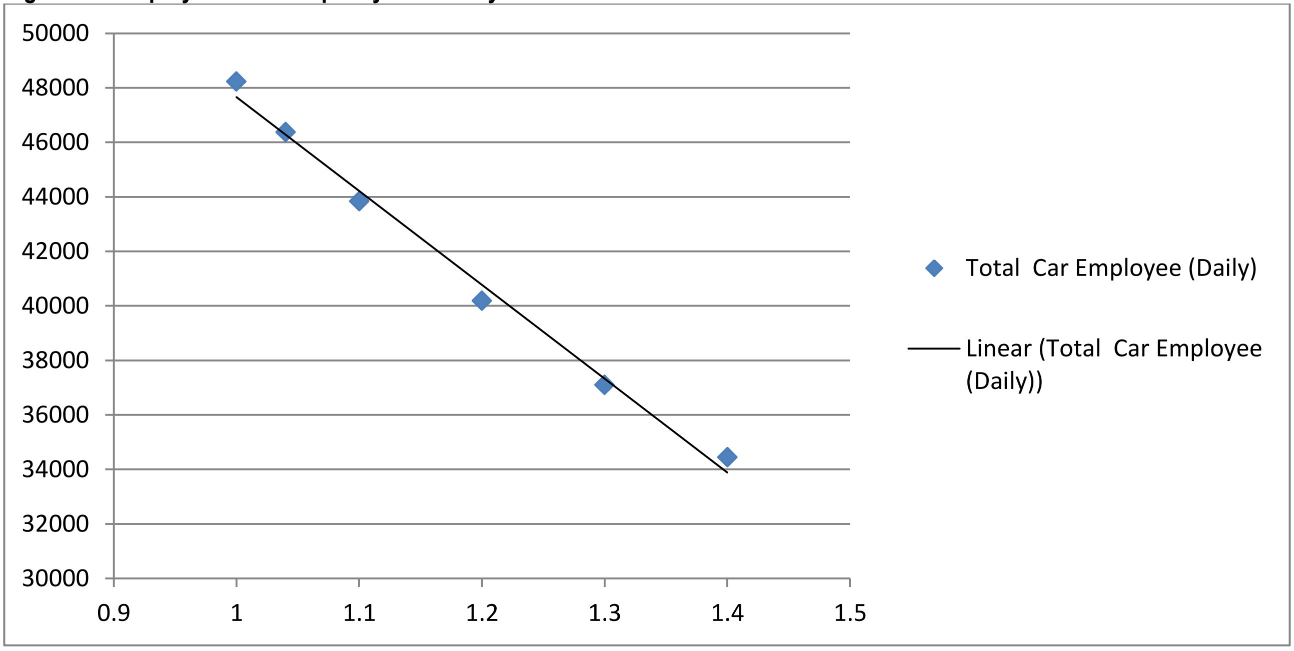
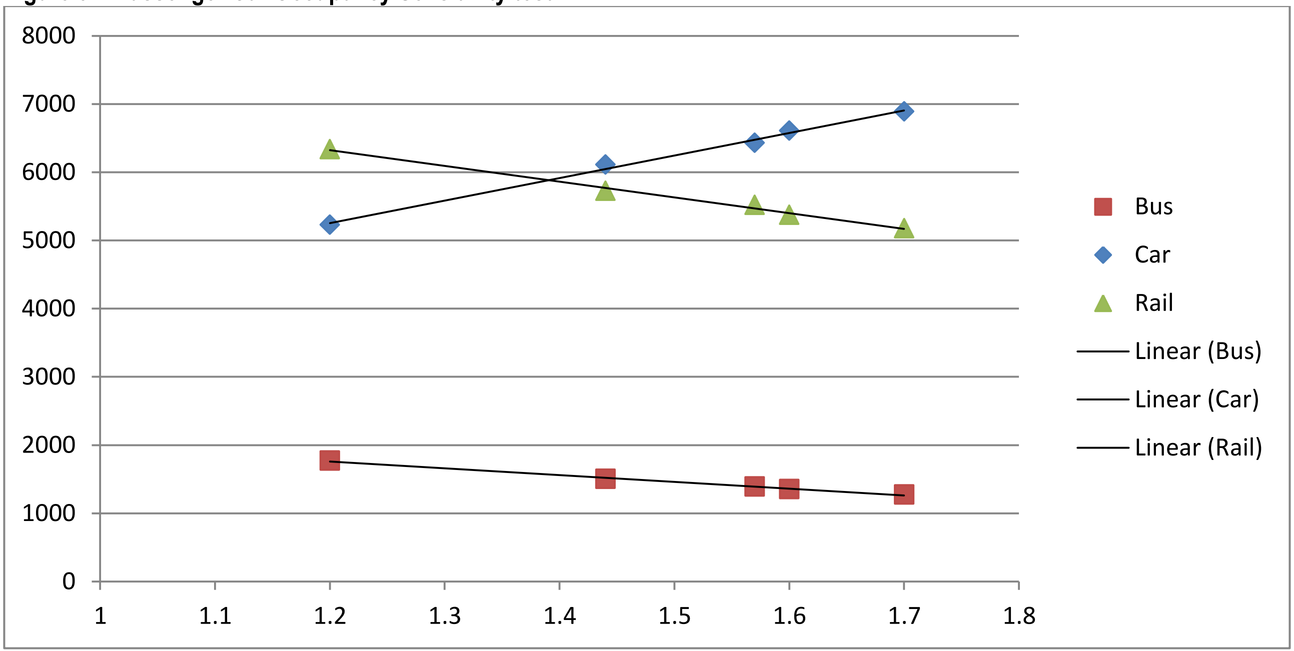


Figure 31: Passenger Car Occupancy Sensitivity test



As the demand model for employees does not include a main mode choice element, the application of car occupancy has a linear impact on the number of car trips, with a 10% increase in employee occupancy reducing employee car trips by 10%. For passengers, the impact of car occupancy affects the generalised costs for car trips and as a result a mode shift towards car passengers occurs. Based on the analysis passenger car occupancy was retained at current levels with improvements in travel planning allowing for a 10% improvement in employee occupancy.