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PRISM 2011 Base

Mode-Destination Model Estimation

James Fox, Bhanu Patruni, Andrew Daly, Sunil Patil

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Prepared for Mott MacDonald

The research described in this report was prepared for Mott MacDonald.

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Preface

PRISM West Midlands is a travel demand model forecasting system which was developed by RAND Europe and Mott MacDonald on behalf of the seven metropolitan districts in the West Midlands Metropolitan Area, the Highways Agency and Centro. The model system is required to be responsive to a wide range of policy levers, and to assess the impact of different policies on specific segments of the population. The original model development was undertaken between 2002 and 2004, with a base year of 2001, and a number of enhancements have been made to the model system since 2004, including adding incomes to the model, and an improved treatment of cost sensitivity and updating the base year to 2006.

In the PRISM Refresh project, the demand and network models in PRISM have been more fundamentally updated to reflect a 2011 base year. RAND Europe's role was to re-estimate the demand models using household interview data collected between 2009 and 2012, and deliver to Mott MacDonald an operational demand model implementation that can run together with the network models in the overall PRISM model system. The work was again undertaken on behalf of the seven metropolitan districts in the West Midlands Metropolitan Area, the Highways Agency and Centro.

This report documents the development of the updated mode-destination models. Models have been developed for 14 travel purposes, all of which represent travellers' choices of travel mode and destination. The models for some travel purposes also include the choice of access mode and station for train and metro travel, allowing park-and-ride travel to be explicitly represented. However, bus park-and-ride travel is not modelled. Choice of time of day of travel for car drivers is also incorporated to allow representation of peak pricing policies and the impact of increased congestion in the peak periods. For other models of travel, all-day demand is allocated to the model time periods using fixed factors.

There are two other RAND Europe products associated with this study:

- the Task 2 report, documenting the development of travel frequency and car ownership models
- the Task 3 report, documenting the implementation of the new demand models.

This report is aimed at readers who wish to gain a detailed understanding of the mode-destination choice models implemented in the PRISM model system. It describes the scope of the models, the variables that impact on the predicted mode and destination choices, and the sensitivities of the models to changes in travel costs and times. Familiarity with disaggregate choice models and transport models more generally is useful in understanding this document.

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Abbreviations

CBD: Central Business District

EB: Employer's Business

HB: Home-Based

HI: Household Interview

IVT: In–Vehicle Time

LOS: Level of Service (provided by transport networks)

NHB: Non-Home-Based

OD: Origin-Destination

PD: Primary Destination

P&R: Park-and-Ride

PRISM: Policy Responsive Integrated Strategy Model

PT: Public Transport

SD: Secondary Destination

SP: Stated Preference

VoT: Value of Time

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We would like to acknowledge the contributions of Mike Oliver and Majid Adeeb of Mott MacDonald, who have supplied all of the input data used in the estimation of the mode-destination models, and who have been responsive and helpful in responding to queries on the data.

We would also like to acknowledge the Quality Assurance comments provided by Charlene Rohr and Hui Lu of RAND Europe, Mott MacDonald and the PRISM Project Management Group.

CHAPTER 1

Introduction

This report documents the re-estimation of the mode-destination models in PRISM to reflect a 2011 base year. Mode-destination models have been developed for eight HB (HB) purposes:

- commuting
- home–business
- home–primary education
- home–secondary education
- home–tertiary education
- home–shopping
- home–escort
- home–other travel, which includes visiting friends, personal business and recreation and leisure

The representation of a separate model to reflect home–escort travel is a new feature in the PRISM 2011 base system; otherwise the HB model purposes represented are as in the original version of PRISM.

A total of six different non-HB (NHB) purposes are represented. This is significantly more segmentation than was used in the original version of PRISM which is made possible because in the 2009–2012 household interview (HI) data, much better information on NHB trips has been collected.[1] The six NHB purposes are:

- detours made during commute tours to work-related detour locations
- detours made during commute tours to other non-work-related detour locations
- detours made during HB tours for purposes other than commuting to non-work-related detour locations
- tours made from work-related locations to other work-related locations
- tours made from work-related locations to non-work-related locations
- tours made from non-work-related locations to other non-work-related locations.

Section 2.1.2 explains in more detail how the different types of NHB travel can occur.

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[1] In the 2001 HI used to develop the original version of PRISM, NHB travel was significantly under-reported and so NHB travel was modelled using road-side interview data, and only car driver trips were represented.

The remainder of this document is structured as follows. Chapter 2 sets out key modelling assumptions, defining what is meant by a HB tour and a NHB trip, and detailing the definitions of the model base year, travel purposes, modes and time periods represented in the models. This chapter includes a discussion of the decision to represent a separate escort travel purpose in the new version of PRISM.

Chapter 3 details the level-of-service (LOS) information that has been supplied from 2006 PRISM highway and public transport (PT) networks to provide time and cost information for input to the model estimation procedures. This chapter also details the car cost information that has been assembled, and explains how information on PT fares from Centro's 2005 PT model has been incorporated in the estimation procedure.

Chapter 4 documents the model specifications, describing the mode and destination alternatives, the different terms that have been tested in the utility functions, how the park-and-ride (P&R) and car driver time of day choice models have been incorporated into the overall model structure, and the structural tests that have been undertaken to determine the relative sensitivities of the different responses represented in the mode-destination models.

Chapter 5 describes the model results, detailing the cost specifications used in the final models, the specifications for the LOS variables, the significant socio-economic terms, the destination effects included, the results from the P&R models, and the results from the time of day choice models for car drivers.

Chapter 6 presents the model validation. The models have been validated by comparing the implied values of time (VoTs) output from the model and model elasticities to guidance values published in WebTAG, and by comparing observed and predicted tour lengths.

Finally, Chapter 7 presents a summary of the re-estimation work.

CHAPTER 2 Modelling assumptions

This chapter sets out the key assumptions used to define the scope of the PRISM mode-destination models. It starts with a discussion of the basic modelling units used, describing how travel has been modelled using a combination of HB tours, NHB tours and non-home-based detours. The model base year is defined, and then the travel purposes and modes that have been represented in the models are specified based on analysis of the 2009-2012 HI data.

2.1 Modelling units

2.1.1 Home-based tours

The modelling unit for the HB mode-destination choice models is *home-based tours*. A tour is a series of linked trips starting and finishing at the same location. A HB tour is therefore a series of linked trips starting and finishing at the traveller's home.

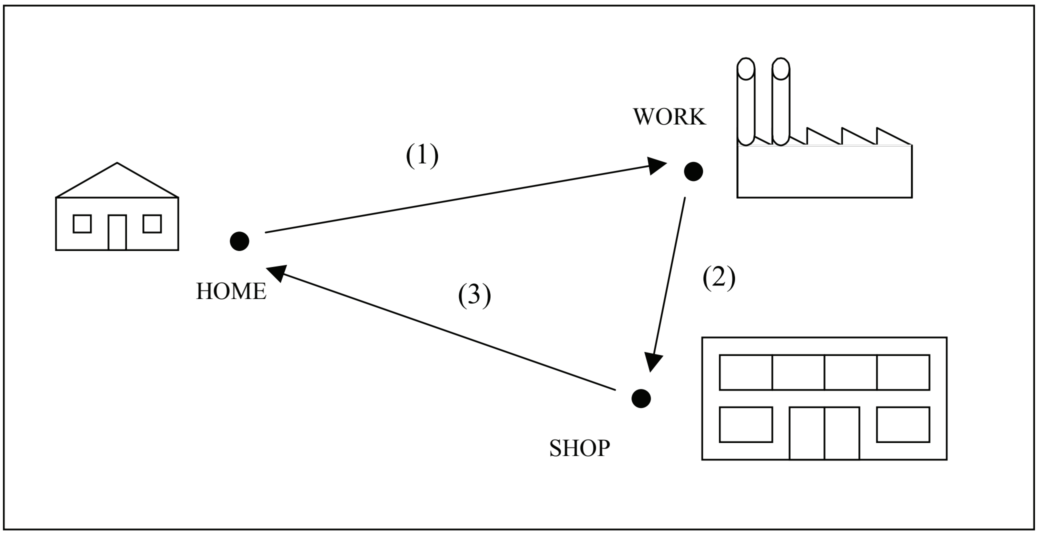
The tour-based approach has a number of advantages over conventional trip-based approaches:

- Tour-based approaches model the choice of mode and destination as a function of network conditions on both the outward *and* return legs of the tour, whereas trip-based approaches model each leg independently.
- Tour-based approaches model the choice of mode for the entire tour, e.g. if an individual drives to work they are highly likely to drive home again. Because trip-based approaches model each leg independently, the relationship between outward and return leg modes is usually ignored.
- Similarly, tour-based approaches model the choice of destination for the entire tour, i.e. the outward leg arrives at the same location that the return leg originates from. This linkage is not present in trip-based approaches.
- Tour-based approaches allow the modelling of time period choice to take account of the time needed at the destination to carry out the activity appropriate to the trip purpose, e.g. work or shopping.
- NHB travel can usually be related to the (HB) travel which occurs before and after in a tour-based approach. By contrast, in a trip-based approach NHB trips typically are forecast independently of HB travel, which is less realistic.

- Tour-based approaches are embedded in an activity-based framework – they reflect the fact that travel is a derived demand, driven by the need for activity participation. The link to activities is much less clear in the trip-based approach.

When a traveller makes a direct trip from the home to an out-of-home destination and back home again, determining the purpose of the tour is straightforward. However if two or more out-of-home destinations are visited, it is necessary to define the *Primary Destination* (PD) in order to define the main purpose of the tour. This problem is illustrated in Figure 1.

Figure 1: Tour example



In this example, a worker travels directly to work in the morning, but on the way home he diverts to the shops. Thus, either the workplace or shopping destinations could be the PD.

To determine the PD, the following purpose hierarchy was employed:

1. work
2. employer's business
3. education
4. other purposes

In the example given in Figure 1, work is higher in the hierarchy than shopping and so the work location forms the PD and work is specified as the purpose of the tour. If there are ties after applying the purpose hierarchy, then the destination at which the most time was spent is taken as the PD. If there were still ties after the purpose hierarchy and maximum time criteria were applied, then of the tied destinations the destination furthest from the home was taken as the PD; if there were still ties after the purpose hierarchy, maximum time and maximum distance criteria were applied, then the first tied destination visited was taken as the PD (this only happened in a few cases).

The trip from the home to the PD is termed the outward-leg and the trip from the PD back to the home is termed the return leg. If both outward and return legs are observed in the HI data, then the tour is described as a *full tour*. It is assumed in the HB modelling that the traveller makes a direct trip between the home and PD for both tour legs, so that in Figure 1 the detour to the shopping destination not represented as part of the tour. However, detours are modelled as NHB trips. In 85% of fully-observed tours direct trips are in fact made in both directions.

If only an outward leg or a return leg is observed, then the tour is referred to as an outward half tour or a return half tour. Some half tours are observed in the HI data, i.e. chains of trips that start outside the home and return to home, or chains of trips that leave home but do not return in the 24 hour period in which the survey is undertaken. However, half tours form a low percentage of the data[2] and are therefore not included in the mode-destination models, on the basis that higher levels of error are associated with the purpose, mode and other information for half tours, which in some cases are incompletely recorded full tours. However, to ensure that the total volume of travel predicted is consistent with that observed in the 2009–2012 HI data, outward half tours are included in the frequency models that are documented separately in the Task 2 report.

The process used to identify the samples of home-based tours and NHB trips from the 2009–2012 HI data is termed *tour building*. The tour building analysis is documented in detail in Appendix A.

2.1.2 Non-home-based trips

Only NHB trips associated with full HB tours have been used for estimation of the NHB mode-destination models.

Linked trips that were made during the course of a HB tour but did not depart from or arrive at home were defined as NHB trips. The travel associated with these trips can be modelled within the tour-based approach in two ways:

1. PD-based tours, i.e. a series of linked trips starting and finishing at the same PD, for example if an individual makes a lunchtime trip to the shops (and back to work) during their work day.
2. NHB detours made during the outward or return legs of home-based tours, i.e. a single trip to or from the PD, for example if an individual makes a diversion on their trip back home to pick up a child from school.

These two cases are illustrated by the examples in the following figures. In Figure 2 trips (2) and (3) form the PD-based tour. In Figure 3, trip (2) forms the NHB detour.

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[2] Just 2.5% of the tours observed in the 2011/12 HI data were half tours.

Figure 2: PD-based tour example

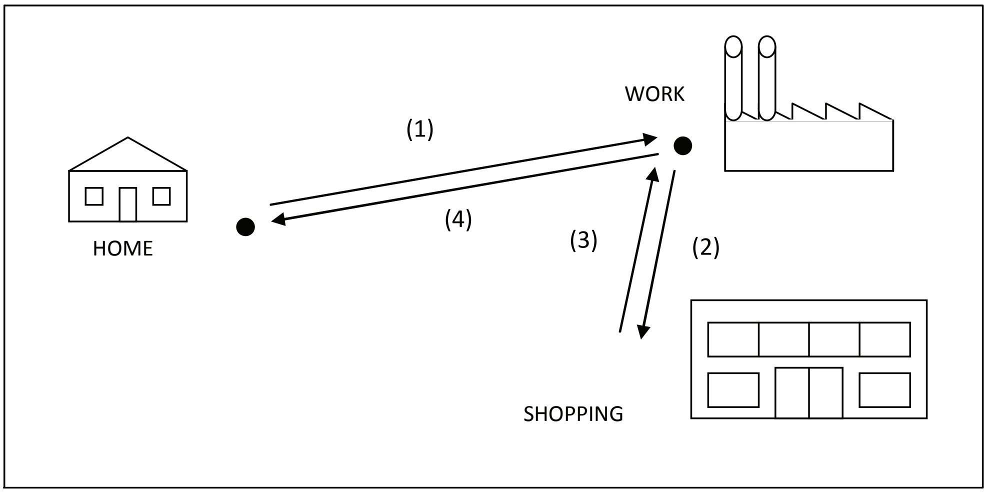
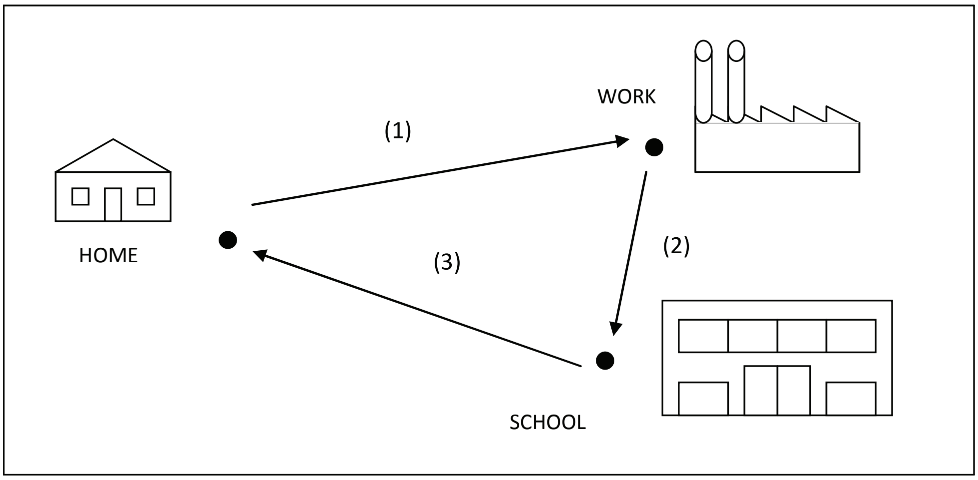


Figure 3: NHB detour example



In case 1, the purpose of the PD-based tours was determined by identifying a *Secondary Destination* (SD). Most PD-based tours comprised a direct return to the PD such as PD–EB[3]–PD for which the SD was readily determined. These are referred to as 'simple tours'. However, in some cases chains of three or more trips were observed, such as PD–other–EB–PD. For these cases the SD was identified based on the same rules that have been used for identifying the PD. These are referred to as 'complex tours', and for these tours only direct return travel between the PD and SD is modelled. Modelling each leg of complex tours separately adds significant complexity to the modelling and is not justified by the low volumes of data.

The purpose for detours (case 2) was also determined by identifying the purpose at the SD. Most NHB detours comprised a direct trip to or from the PD, such as home–escort-PD or PD-escort-home, for which the SD was readily determined. For cases where more complex

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[3] EB denotes Employer's Business.

chains of trips were observed, such as home–escort-shop-PD, the SD was identified based on the same rules that have been used for identifying the PD.

Taking the detour example given in Figure 3, the observed trip pattern is home–work–school–home. The modelling approach models a direct return tour to the PD, i.e. home–work–home, and the detour from the PD to the SD, i.e. work–school. The assumption is that on average the distances PD–home and SD–home will be approximately equal, and thus modelling work-home rather than school-home for the return leg gives a reasonable approximation of the actual pattern of travel observed.

In model application, NHB travel will be forecast as a function of the predicted HB travel. The introduction of this linkage represents a significant improvement relative to the current version of PRISM, where HB and NHB travel are predicted independently.

2.2 Base year

The model base year is 2011, which is a Census year and allows data from the 2011 Census to be used for the base year implementation once the full and relevant Census data become available. All costs have been expressed in 2011 prices.

The main dataset used for the estimation of the mode-destination models was West Midlands HI data collected between 2009 and 2012. The original plan was to collect 2,200 interviews per financial year from April 2009 to March 2012, giving a total of 6,600 which allowing for some loss of data for non-completed and non-usable surveys would provide approximately 6,000 useable surveys for development of the models.

The surveys actually commenced in November 2009, later than originally planned following an extended design and pilot period, and a desire to avoid school holidays. Despite the late start, 2,200 surveys had been collected by the end of March 2010 as per the original target. Surveying continued from April 2010 onwards without a break, but in 2011 the target for the number of clean surveys was reduced from 6,000 to 5,000 because of budgetary constraints. It is noted that the HI data was only collected in school term time, and so the models developed from the HI represent travel behaviour in school term time only.

Table 1 summarises the numbers of clean household interviews that were collected by year.

Table 1: Household interviews undertaken by year

Year	Interviews	Percent
2009	238	4.7 %
2010	3,459	68.8 %
2011	1,027	20.4 %
2012	306	6.1 %
Total	5,030	100.0 %

Over two-thirds of the interviews were undertaken in 2010. It has been assumed that this sample of people interviewed between 2009 and 2012 can be used to estimate behavioural model parameters that are representative of 2011 travel conditions. However, to take account of significant increases in fuel costs during the period over which the HIs were collected, car costs have been calculated separately by interview year. The differences in the car cost calculations are discussed further in Section 3.1.2.

Ideally, LOS measures relating to 2011 travel conditions would have been used in the estimation of the model parameters. LOS measures in this context means matrices of travel times, distances, wait times, PT fares and so on taken from assignments of demand matrices to highway and PT networks. However, it was not possible for Mott MacDonald to develop the new 2011 networks within the timescales available for the demand model development. Therefore, Mott MacDonald supplied the best LOS information that was available at the time of model development. LOS was taken from the latest available version of PRISM, which uses a 2006 base, and for PT fares were taken from Centro's 2005 model because the 2006 base PT models in PRISM do not model fares. It is possible that subsequent to the completion of this project the final model specifications will be re-estimated using 2011 LOS to provide improved parameter estimates. Some discussion of the changes between 2006 and 2011 on the West Midlands transport networks is given in Chapter 3.

2.3 Purposes

In the 2001 HI data used for the original PRISM development work, employer's business and NHB travel were under-reported and as a result it was not possible to develop models from the 2001 HI data for these purposes. Therefore a key focus in the new tour building analysis was to check whether there were sufficient volumes of data for these purposes in order to estimate models given that the total number of households sampled in 2009–2012 was 5,000, less than half the number interviewed in 2001 (11,700).

2.3.1 HB purposes

Table 2 presents a comparison of the total number of HB tours observed in the 2009–2012 data to the samples in the 2001 HI data.

Table 2: Comparison of HB tour samples

PD Purpose	Full tours 2009–2012 HI data	Full tours 2001 HI data	2009–2012 sample as a % of 2001 sample
usual work place	4,215	7,736	54.5 %
employer's business	152	141	380.8 %
not usual work place	385		
education	2,903	4,650	62.4 %
shopping	1,865	5,177	36.0 %
other travel	2,661	4,054	109.5 %
escort	1,779		
Total	13,960	21,758	62.9 %

Escort was recorded using a single purpose code in the 2009–2012 HI, so there was no information available about the nature of the trip that is being escorted. Note that escort travel was not recorded separately in the 2001 HI data.

In general, the numbers of tours available for model estimation are around half those available from the 2001 data, with some variation, consistent with the lower number of households sampled. The exceptions are employer's business and other travel, which are discussed in more detail below.

The following sub-sections discuss how employer's business travel has been defined, consideration of modelling an additional escort purpose, and how education travel has been split into separate primary, secondary and tertiary education purposes.

Defining employer's business travel

Work-related tours are observed for commuting to the usual workplace, travel to another workplace and travel for employer's business. The last two categories have relatively small numbers of tours and the question arises as to whether they can be pooled together for estimation of the models. A first comment would be that the costs of the journey might usually be met by the employer in either case.

If tours classified as travelling to the 'not usual workplace' are to be classified with employer's business, then from Table 2 the total number of employer's business tours available for model estimation is 537, a substantial increase on the number of tours observed in the 2001 HI data despite the significant reduction in the number of households that have been sampled. This number should be sufficient to allow an employer's business tour model to be developed. However, if tours travelling to 'not usual workplace' locations were not classified as employer's business then the samples of employer's business tours would have been insufficient to allow an employer's business tour model to be developed.

Additional analysis was undertaken to investigate the validity of pooling not usual workplace tours with employer's business tours. The mode shares for employer's business and not-usual workplace tours are summarised in Table 3 (taken from the tables presented in Appendix A).

Table 3: Mode shares for commute and employer's business tours

Mode	Usual workplace	Not usual workplace	Employer's business
rail P&R	0.0 %	0.0 %	0.0 %
train	3.3 %	2.7 %	4.3 %
metro	0.4 %	0.0 %	0.0 %
bus	13.3 %	7.4 %	10.3 %
car driver	63.4 %	73.9 %	75.9 %
car passenger	7.8 %	10.4 %	4.3 %
taxi	0.5 %	0.0 %	0.0 %
cycle	1.6 %	0.7 %	0.0 %
walk	9.7 %	5.0 %	5.2 %
Total	100.0 %	100.0 %	100.0 %

The mode shares for not-usual workplace tours are more similar to employer's business tours than to commute tours across a number of modes, specifically:

- car driver has a higher share than for commute tours
- bus has a lower share than for commute tours
- walk has a lower share than for commute tours

Additional analysis was undertaken to compare activity durations by tour purpose, and the (mean straight-line) distance of the PD from the home. This analysis is presented in Table 4.

Table 4: Mean and median activity durations and distance from home to the PD

	Activity duration (min)		Distance from home (km)	
PD Purpose	Mean	Median	Mean	Median
work	408	480	8	5
not usual work place	353	400	23	9
employer's business	304	300	27	6
education	369	400	3	1
shopping	75	60	4	2
other travel	116	90	6	3
escort	14	5	2	1

Table 4 demonstrates that the mean activity duration of not-usual work place tours (353 minutes) is slightly closer to the mean duration of employer's business tours (304 minutes) than to the mean activity duration for work tours (408 minutes). Furthermore, the mean distances from home tend to be much longer than for other purposes in both cases: 27km for employer's business and 23km for not-usual work place compared with just 8km for work. For all the purposes the mean activity durations and median activity durations are reasonably close except for escort, where we observe a greater variation in the mean and the median activity durations due to a few tours where the activity duration is much higher than the median value.

Overall on the basis of the mode share, activity duration and distance from home it seems reasonable to merge tours to not-usual workplaces with employer's business tours to boost the volume of employer's business tour records.

The ability to model employer's business travel from the 2009–2012 HI data is a significant improvement on the original 2001 base version of the model, where because of insufficient samples of employer's business tours in the 2001 HI data it was necessary to model employer's business travel for car drivers only using road-side interview data.

Modelling escort travel

In the 2001 HI data used to develop the original version of PRISM, escort travel was not allocated a separate purpose code and therefore it was not possible to determine which tours involved an escort element. However, escort travel was distinguished in the 2009–2012 HI data and a noticeable observation from the tour building undertaken using the new HI data was the substantial sample of escort tours. An escort tour is a tour made solely for the purpose of escorting someone to or from a destination.

The mode shares of these escort tours are presented (along with the mode shares for other travel purposes) in Table 115 in Appendix A. This table shows that the mode shares for escort tours are dominated by car driver and walk, and the mode shares are quite different from those used for other travel (with which they were merged in the previous version of PRISM). Therefore in the PRISM 2011 base, these tours have been modelled separately from other travel. Ideally, analysis would be undertaken to examine the linkage between escort trips and tours made by other household members, but such analysis is not possible within the resources available for the current work. Representing escort trips separately means that an additional HB travel purpose is distinguished in the base PRISM model for 2011.

Representing escort travel separately in implementation allows better forecasts of changes in escort travel to be represented. By establishing a link between frequency of escort travel and personal and household characteristics including the presence of children, household size and car availability, more accurate forecasts of changes in escort travel can be obtained. Furthermore, representing escort travel separately allows the impact of changes in the location of employment and education attractions on the distribution patterns for escort travel to be better forecast.

Splitting education travel

In the original version of PRISM, separate travel models for travel for primary, secondary and tertiary education purposes were developed. Splitting education travel in this way enabled the significant variation in mode share and trips lengths between the three education types to be represented in the modelling.

Substantial differences in mode share and trip length were also observed in the 2009–2012 HI data and therefore the splitting of education travel into these three purposes has been maintained in the 2011 base version of PRISM. However, in the 2009–2012 HI age information was collected in bands, rather than age in years, and therefore it was necessary to revise the definition of secondary and tertiary education travel so that the age bands used could be defined by the 2009–2012 HI data. Table 5 compares the revised and original definitions.

Table 5: Revised age definitions for education travel

Education purpose	Revised definition PRISM 2011 base	Original definition PRISM 2001 base
Primary education	5-11	5-11
Secondary education	12-16	12-18
Tertiary education	17+	19+

Summary of HB tour purposes

In summary, eight HB tour purposes have been modelled in the 2011 base version of PRISM, including an additional escort purpose that was not modelled in the original version of PRISM:

1. commute
2. employer's business
3. primary education
4. secondary education
5. tertiary education
6. shopping
7. escort
8. other travel (i.e. all HB travel not covered under purposes 1-7)

2.3.2 NHB purposes

As discussed in Section 2.1.2, two types of NHB travel can occur in the course of HB tours: PD-based tours and NHB detours. Separate purposes have been defined for each of these types of NHB travel. NHB purposes have also been defined separately for travel that is work-related (to the main workplace, the not usual workplace, or to an employer's business location) and for all other travel. The volumes of NHB travel are not sufficient to provide as detailed a purpose segmentation as has been used for HB travel.

Three purposes have been defined to model PD-based tours, taking advantage of the purpose hierarchy that assigns work-related destinations as the PD whenever they occur:

1. PD-based tours made from work-related PDs to work-related SDs
2. PD-based tours made from work-related PDs to other SDs
3. PD-based tours made from other purpose PDs to other SDs.

Three further purposes have been defined to model NHB detours:

4. detours made during work-related PD tours to work-related SDs
5. detours made during work-related PD tours to other purpose SDs
6. detours made during other purpose PD tours to other purpose SDs[4].

The sample sizes of PD-based tours and NHB detours observed in the 2009–2012 HI are detailed in full in Appendix A. In summary, these were sufficient to allow the estimation of NHB travel models from the trip records observed in the 2009–2012 HI data.

The ability to model NHB travel from the 2009–2012 HI data is a significant improvement on the original 2001 base version of the model where, because there were insufficient samples of NHB trips in the 2001 HI data, it was necessary to model NHB travel for car drivers only using road-side interview data. Building on the lessons learnt from the 2001 HI survey, the interviewers employed to collect the 2009–2012 surveys were briefed to prompt individuals to record all travel including NHB, and it is clear from the tour building analysis that these efforts have been successful in ensuring a higher fraction of NHB travel data was collected.

2.4 Modes

Up to four different modes of travel were recorded for each trip made in the 2009–2012 HI data. In order to define a main mode and a secondary mode for each tour leg in a systematic manner, mode hierarchies have been applied to the modes recorded for each of the journeys that comprise the outward and return tour legs. These hierarchies have been specified following RAND Europe's experience in a number of studies, and are designed to maximise the volume of public transport tours. The hierarchies are detailed in Table 6 and Table 7.

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[4] Note that because of the purpose hierarchies employed, it is not possible to make a detour from an other PD to a work-related SD.

These hierarchies are applied as follows. First the main mode hierarchy is applied to all modes recorded for the trips comprising the tour leg. Once the main mode has been determined, the secondary mode is determined by applying the secondary mode hierarchy to the *remaining* modes. It is possible that only one mode is used throughout the tour and therefore for no access mode to exist, for example a direct journey by car. If several secondary modes are used, the secondary mode hierarchy is used to identify a single secondary mode for the tour leg. Note also that the secondary mode may be used after the main mode, and so in some cases the secondary mode identified will actually be an egress mode for the tour leg.

Table 6: Main mode hierarchies

	Main mode
1	train, P&R
2	train
3	metro
4	bus or coach
5	school bus
6	car driver
7	motorcycle
8	car passenger
9	taxi
10	cycle
11	walk

Table 7: Secondary mode hierarchies

	Secondary mode
1	car driver
2	motorcycle
3	car passenger
4	taxi
5	bus or coach
6	school bus
7	metro
8	train
9	train, P&R
10	cycle
11	walk

Cycle and walk are placed lowest in the hierarchies, as if these modes are used during a multiple journey tour leg it is judged to be reasonable that they will be used to access/egress the main or secondary modes. If both PT modes and other modes are used during a given tour leg, the hierarchies have been specified so that PT modes are treated as the main mode, and the other modes are treated as the secondary mode. This approach maximises the volume of PT tours available for model estimation, and is consistent with the approach used to model car access to train and metro for some model purposes, where there is explicit treatment of both highway access and PT main mode legs. The order of the three PT modes in the main mode hierarchy, with train above metro, and metro in turn above bus or coach, is consistent with the hierarchy of these modes in the PT network models. So if an individual is observed to use both train and bus during a tour leg, the main mode is train, and the tour is modelled using train LOS that may include bus as a possible access and egress mode.

The main and secondary modes are determined separately for outward and return legs in the tour building analysis.

Analysis of the samples of full HB tours revealed that only 68 school bus tours were observed, and therefore as in the current version of PRISM these have been merged with bus.

In the model estimation procedure, it is assumed that the main mode determined for the outward tour leg can be used to model mode choice for the tour as a whole. To investigate the validity of this assumption, a cross-tabulation was run to compare the main modes of travel for the outward and return legs of full tours observed in the 2009–2012 HI data. This cross-tabulation is presented in Table 8.

Table 8: Outward and return main tour mode cross-tabulation, full tours only

		ret_mode												
		PRRail	Train	Metro	Bus/Coach/ WorkBus/PR Bus	School Bus	Car-Driver	Motorcycle	Car- Passenger	Taxi	Cycle	Walk	Other/none/do not know	Total
out_mode	PRRail	1	0	0	0	0	0	0	0	0	0	0	0	1
	Train	0	220	0	10	0	1	0	9	3	1	3	1	248
	Metro	0	0	40	3	0	0	0	0	0	0	0	0	43
	Bus/Coach/WorkBus/PR Bus	0	12	1	1829	7	2	0	116	24	0	35	2	2028
	School Bus	0	0	0	8	54	0	0	5	0	0	1	0	68
	Car-Driver	0	6	0	1	0	5493	0	28	2	0	9	6	5545
	Motorcycle	0	0	0	0	0	0	16	0	0	0	0	0	16
	Car-Passenger	0	5	2	95	3	24	0	1768	9	1	132	1	2040
	Taxi	0	1	0	8	0	0	0	10	71	0	6	0	96
	Cycle	0	0	0	0	0	0	0	1	0	146	0	0	147
	Walk	0	0	0	36	2	12	0	121	24	0	3426	0	3621
	Other/none/do not know	0	0	0	0	0	1	0	3	0	0	0	104	107
Total		1	244	43	1990	66	5533	16	2061	133	148	3612	113	13960

For 13,168 out of 13,960 tours (94.3%) the outward and return main modes are the same. Furthermore, the numbers of tours off the main diagonal tend to balance out, so that using the outward mode to define the mode for the tour as a whole would not introduce an overall bias. For example, a significant number of cases where the outward main mode is car passenger have a different return main mode (2,040−1,768=272, 13% of the total). However, the total numbers of tours where car passenger is the main outward and return mode are very similar (2,040 and 2,061, so only different by 21 tours) and so the cases off the main diagonal more or less balance. An important exception to this is taxi, which is more frequently used as a mode of travel for the return leg of a tour than on the outward leg, and therefore using the outward mode share will underestimate the overall mode share. However, as taxi tours comprise less than 1% of the total the impact of the symmetry assumption would be minimal.[5]

Overall, the analysis demonstrates that assuming symmetry between the main modes used for the outward and return is a reasonable assumption.

Only 16 motorcycle tours were observed, and therefore as in the current version of PRISM motorcycle tours have been dropped from the mode-destination models.

Taxi has a mode share of less than 1% for all purposes except other travel. Given the difficulties in assembling appropriate taxi cost information, and the lack of current policy interest in taxi, it was agreed with the PRISM Management Group that taxi tours would

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[5] Because of their low volume, taxi tours have been dropped from the model as described in this section.

be dropped from the modelling. This is a change from the original version of PRISM, where taxi was included as a mode alternative.

Therefore a total of seven main modes have been represented in the PRISM 2011 base model, one fewer than in the original version of PRISM following the omission of taxi:

1. car driver
2. car passenger
3. train
4. metro
5. bus (including school bus)
6. cycle
7. walk

The car driver mode includes light vans with an unladen weight of 1.5 tonnes or less. Large vans were recorded together with lorries in the 2011 HI data, and have therefore been excluded from the definition of the car driver mode – instead they form part of the 'other/none/do not know' cells in Table 113. Any tours where 'large van/lorry' is the main mode have been excluded from the model estimation process. Large van and lorry tours are not included in the car base matrices, as movements by these modes are represented separately in the freight base matrices.

It is noteworthy that only one tour is observed in Table 8 where the individual has recorded the main mode as 'rail P&R' in the household interview data. However, from Table 114 in Appendix A, we observe that of the 248 tours where train is the main mode, 35 (14%) have car driver as the access mode. Therefore train tours where the access mode is car driver can be determined by looking at the access modes chosen, as well as by identifying individuals who explicitly record that they use rail P&R.

2.5 Times of day

Four time periods are distinguished in the modelling:

- AM peak: 07:00 – 09:30
- inter-peak: 09:30 – 15:30
- PM peak: 15:30 – 19:00
- off-peak: 19:00 – 07:00

These time period definitions were provided by Mott MacDonald based on the profile of highway demand across the day observed from Automatic Traffic Count data. It is noted that these time period definitions are unchanged from those used in the original 2001 base version of PRISM.

Tour legs have been classified into time periods using the mid-point timings – the point half-way between the departure and arrival times for the tour leg. Mid-point timings are used so that the most representative LOS for the tour leg can be used. For example if a tour leg departs right at the end of the AM peak, and most of the tour leg actually occurs in the inter-peak period, then using the tour leg departure time to define the appropriate LOS would not provide representative LOS.

For model estimation, separate highway LOS has been used for each of these four time periods. For PT, separate LOS has been supplied for AM peak and inter-peak periods. PM peak LOS, which is not available in the 2006 model, has been defined as the transpose of the AM peak LOS and it has been assumed that the inter-peak LOS can be used to model the off-peak period. The highway and PT LOS is described in more detail in Chapter 3.

For all models purposes except education travel and non-work-related NHB travel, the mode-destination models predict the choice of time period for car drivers. For education and non-work-related NHB travel, and for all modes other than car driver, the models predict all-day demand which is then split into model time periods using fixed factors calculated from the 2009–2012 HI data. For education and non-work-related NHB travel purposes, there are insufficient car driver data in the HI data to calibrate a time period choice model, and no information was collected in the 2003 West Midlands Stated Preference survey on time of day choice (described further in Section 4.5) to allow the placement of car driver time period choice relative to mode and destination choice to be imported.

It is emphasised that because the HI data were collected during school term time only, the models best represent travel behaviour on an average weekday in school term time.

2.6 Zone system

The mode-destination models have been estimated using the new 2011 base PRISM zoning system. This new zoning system is largely based on the original 2001 zoning system, and for most areas there is no change between the old and new zoning systems.

The main change to the zoning system has been greater disaggregation of zones in main centres so that the new zone system maps one-to-one with the zone system used by Centro in their PT model, which will now be introduced into the PRISM as part of its PT model structure. Typically one old PRISM zone has been split into three new zones. The centres where this greater disaggregation has been applied are:

- Birmingham
- Sutton Coldfield
- Coventry
- West Bromwich
- Solihull
- Walsall
- Wolverhampton

Additional disaggregation was also applied in Dudley including Merry Hill, which as well as giving a direct mapping to the Centro zoning system allowed the shopping mall to be separated from Brierley Hill centre.

In a number of other areas, zones have been disaggregated in anticipation of future developments, such as the proposed Curzon Street station for HS2. The development of the new zoning system is documented in more detail by Mott MacDonald (2012).

The new 2011 base PRISM zoning system has a total of 994 zones, an 11% increase on the 898 zones used in the original 2001 PRISM zoning system. These 994 zones comprise:

- 697 core area zones, covering the West Midlands Metropolitan Area;
- 254 intermediate area zones, covering all of Warwickshire and Telford & Wrekin, and parts of Staffordshire, Shropshire and Worcestershire; and
- 43 external area zones, 20 of which cover the part of the West Midlands region not covered by the core and intermediate area zones, and 23 of which cover the rest of Great Britain.

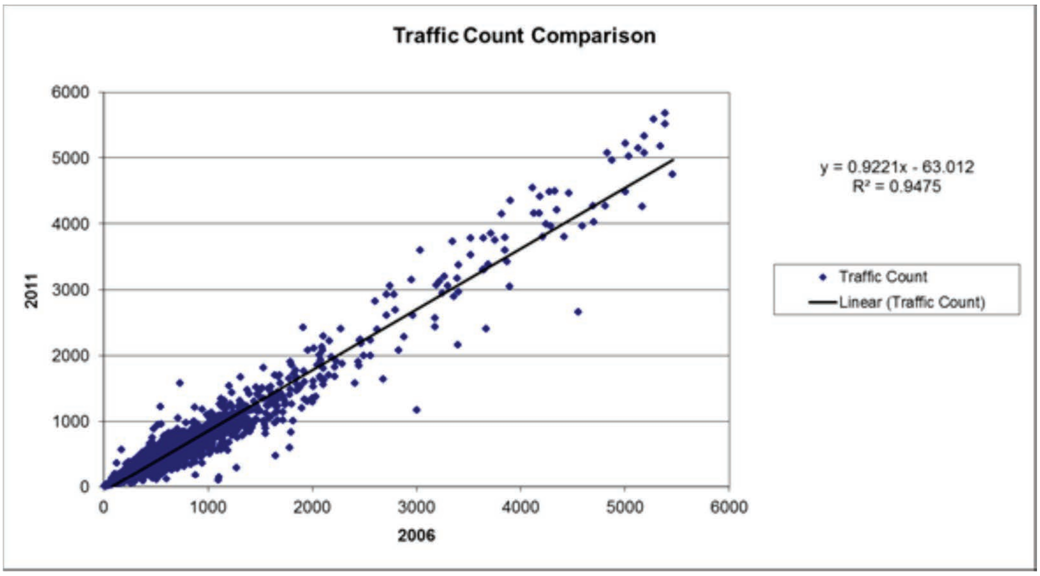
In addition to these 994 zones, dedicated zones will be added to model P&R sites. In model application, each station where P&R access is possible will be modelled using a dedicated P&R zone.

CHAPTER 3

Level of service data

In parallel to the work to develop the new PRISM 2011 demand models, Mott MacDonald and Centro (for PT) are developing 2011 highway and public transport networks and base matrices that will ultimately provide base year network level of service (LOS) information. However, this information will not be available within the tight timescales available for estimation of the demand model, and therefore LOS information has been provided from existing version of PRISM which uses a 2006 base year. Therefore the network LOS information used for model estimation represents 2006, rather than 2011, travel conditions. To give an indication on the impact of this assumption on the LOS information used for model estimation, Mott MacDonald has provided a comparison of highway count data between 2006 and 2011. This information is presented in Figure 4.

Figure 4: Comparison of 2006 and 2011 West Midlands traffic count data



It can be seen from the linear regression results presented in Figure 4 that traffic counts in 2011 are *lower* than those in 2006 on average, so traffic levels across the West Midlands have declined between 2006 and 2011. The impact of this for model estimation is that the highway LOS skims tend to overestimate the time spent in congestion relative to the actual travel conditions faced by individuals observed in the 2009–2012 HI data.[6]

3.1 Highway level of service

3.1.1 Network level of service

Highway LOS data were supplied by Mott MacDonald. This LOS information was generated by assigning 2006 base matrices to 2006 networks defined in the original PRISM zoning system, and then converting the LOS data into the new zoning system used for the current work. The procedure that was followed to generate the LOS was documented in Section 2 of Mott MacDonald (2012).

The following LOS information was supplied by Mott MacDonald for each origin-destination (OD) pair:

- free flow travel time
- congested travel time
- distance
- toll cost.

The LOS was supplied separately by four model time periods (defined in Section 2.5) and for the four highway assignment purposes, which are commute, business, education and other. For a given time period, differences in LOS may be observed between the four purposes because the assumed values of time used in the assignments differ. For example, business travellers are more willing to incur the additional costs associated with longer and/or tolled routes that offer journey time savings than non-business travellers.

No LOS data were supplied for intrazonal trips, i.e. trips that start and finish in the same zone. Therefore, LOS was imputed for intrazonal movements by RAND Europe. The intrazonal LOS was imputed by taking half the LOS to the nearest zone to provide an approximation of the time and distance associated with an intrazonal trip within the zone, consistent with the guidance provided in WebTAG Unit 3.10.2.

3.1.2 Vehicle operating costs

Vehicle operating costs have been calculated using the procedure set out in the October 2012 version of WebTAG Unit 3.5.6. Vehicle operating costs in WebTAG are calculated as two separate components:

1. Fuel or energy costs
2. other vehicle operating costs

The calculations used for these two components are set out in the following sub-sections. Because of recent volatility in fuel price levels, and the fact that the HI data were collected over the 2009–2012 period, variation in vehicle operating cost between years was taken into account. For example, average petrol prices increased from 102 pence per litre in 2009

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[6] More detailed analysis by Mott MacDonald has found that on average traffic levels on motorways have actually increased between 2006 and 2011, but average traffic levels on local roads have declined and this decline explains the overall decline observed in Figure 4.

to 132.1 pence per litre in 2012 (WebTAG 3.5.6). It should be noted that the vehicle operating cost calculations in the latest version of WebTAG 3.5.6 give costs in 2010 prices, and therefore the final piece of this sub-section explains how these costs have been inflated to 2011 prices.

Fuel/energy costs

In WebTAG Unit 3.5.6, fuel or energy costs are calculated using a function of the form:

$$C = a/v + b + cv + dv^2 \qquad (3.1)$$

where:

C is the fuel cost in pence/km

v = average speed in kilometres per hour (km/h)

a, b, c, d are parameters defined for each vehicle category.

WebTAG Unit 3.5.6 provides the fuel/energy cost parameters for 2010 and 2011 directly. These are replicated in Table 10 and Table 11. For 2009, the parameters for an average car have been calculated as an average of the 2009 parameters for petrol and diesel cars, using the 2009 petrol/diesel split given in WebTAG and the observed changes in efficiency between 2009 and 2010; these values are presented in Table 9. For 2012, values can be interpolated linearly from the 2010 and 2015 values presented in WebTAG; these values are presented in Table 12.

Table 9: Fuel/energy cost formulae parameter values for an average car, 2009 values in 2010 prices

Purpose	*a*	*b*	*c*	*d*
Work	69.533	4.434	−0.02157	0.000262
Non-work	79.963	5.099	−0.02480	0.000301

Source: Tables 10, 11a, 11b and 13 WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

Table 10: Fuel/energy cost formulae parameter values for an average car, 2010 values in 2010 prices

Purpose	*a*	*b*	*c*	*d*
Work	75.067	4.874	−0.02438	0.000290
Non-work	88.204	5.727	−0.02865	0.000340

Source: Table 10a, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

Table 11: Fuel/energy cost formulae parameter values for an average car, 2011 values in 2010 prices

Purpose	*a*	*b*	*c*	*d*
Work	79.423	5.315	−0.02780	0.000319
Non-work	95.308	6.378	−0.03336	0.000383

Source: Table 10b, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

Table 12: Fuel/energy cost formulae parameter values for an average car, 2012 values in 2010 prices

Purpose	a	b	c	d
Work	73.954	5.078	−0.02752	0.000308
Non-work	87.619	6.020	−0.03266	0.000364

Source: Interpolated from 2010 and 2015 values presented in Table 14, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

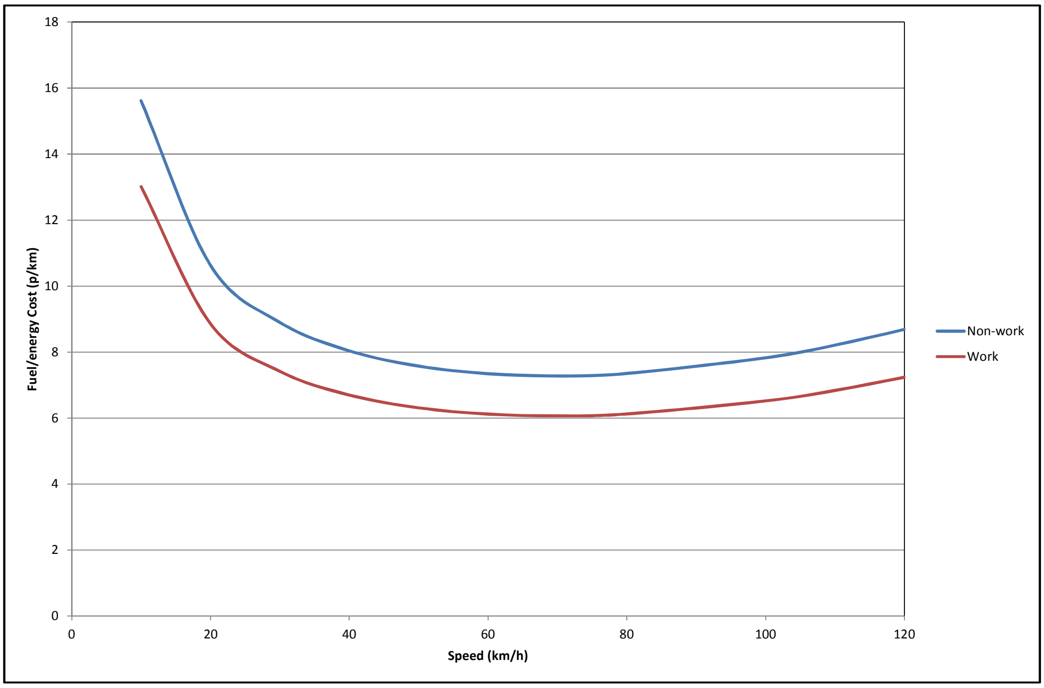
It is noted that the 2012 values, determined by interpolating from 2010 and 2015 values, imply a reduction in fuel/energy costs relative to the 2011 values, whereas the 2011 values show significant increases compared to the 2010 values. This occurs because the 2010 and 2011 values are-based on observed data, whereas the 2012 values are predicted based on an interpolation of the *predicted* changes over the 2010 to 2015 period. However, close to 90% of the HIs were collected in 2010 and 2011, and using separate parameter values for these two years means that the significant increases in fuel costs between 2010 and 2011 have been taken into account.

The values for work-related travel are used to model employer's business travel, and exclude Value Added Tax (VAT). The values for non-work-related travel are used to model all other travel purposes, and include VAT.

It is noted that while in 2010 it is assumed that there are no electric cars in the fleet when calculating the values for an average car, the parameter values from 2011 onwards do take account of the predicted impact of electric cars.

Figure 5 shows how fuel or energy cost (p/km) varies with speed for work and non-work-related purposes in 2011, using the values from Table 11.

Figure 5: Variation of the fuel/energy cost with speed (2011 values in 2010 prices)



In model estimation, the fuel or energy cost formula has been applied to calculate the car costs for the outward and return legs of tours, and for NHB detours. The average speed is calculated from the distance and congested travel time information from the highway network LOS for each OD pair for the tour leg or NHB detour. The highway LOS information varies according to the four model time periods, and so for tour legs and detours made in peak periods where there is more congestion, average speeds are lower, and the fuel cost per kilometre is higher if the average speed falls below 60km/h.

Other vehicle operating costs

WebTAG Unit 3.5.6 notes that '*the elements making up non-fuel vehicle costs include oil, tyres, maintenance, depreciation and vehicle capital saving (only for vehicles in working time)*'. The non-fuel elements of vehicle operating costs (VOC) are calculated using a function of the following form:

$$C = a1 + b1/v \qquad (3.2)$$

where:

C is the cost in pence per km travelled

v is the average speed in km/h

$a1$ is the parameter for distance related costs defined for each vehicle category

$b1$ is the parameter for vehicle capital saving defined for each vehicle category (this is only relevant to working vehicles)

Table 16 of WebTAG Unit 3.5.6 details the non-fuel VOC parameters for 2010 and 2015 for cars being used for work-related travel and non-work-related travel (values are presented for five year intervals, rather than annually). These parameter values give costs in 2010 prices. As the parameters by fuel type are assumed to be invariant over time, the petrol and diesel parameter values are the same, and electric vehicles are only included in the calculations from 2011 onwards, the 2010 values can also be used for 2009 records Following the advice given in paragraph 1.3.40 of WebTAG Unit 3.5.6, values for 2011 and 2012 have been determined by interpolating linearly between the 2010 and 2015 values. Table 13 to Table 15 present the resulting parameter values for 2009 and 2010, 2011 and 2012 respectively.

Table 13: Non-fuel resource VOC parameter values, 2009 and 2010 values in 2010 prices

Purpose	*a1* (pence/km)	*b1* (pence/hr)
Work	4.9660	135.9460
Non-work	3.8460	0

Source: Table 15, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

Table 14: Non-fuel resource VOC parameter values, 2011 values in 2010 prices

Purpose	*a1* (pence/km)	*b1* (pence/hr)
Work	4.9648	135.9460
Non-work	3.8450	0

Source: Interpolated from 2010 and 2015 values presented in Table 16, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, October 2012.

Table 15: Non-fuel resource VOC parameter values, 2012 values in 2010 prices

Purpose	*a1* (pence/km)	*b1* (pence/hr)
Work	4.9636	135.9460
Non-work	3.8440	0

Source: Interpolated from 2010 and 2015 values presented in Table 16, WebTAG Unit 3.5.6, Values of Time and Vehicle Operating Costs, June 2012 (in draft).

Consistent with the approach used to implement the fuel or energy cost formula given in Equation 3.1, the average speeds used for the VOC formula are calculated separately for each OD pair using highway LOS for the chosen time period. This approach takes account of variation in travel speeds and congestion levels both across the network and between the four model time periods.

Price adjustment

The fuel or energy and other VOC formulae allow costs to be calculated for travel in 2009, 2010, 2011 and 2012 in 2010 prices. To convert these costs into 2011 prices, values from the CHAW all-items Retail Prices Index (RPI) have been used. The CHAW index was used because it covers all items to provide a representative measure of inflation. The RPI values used are summarised in Table 16.

Table 16: CHAW RPI indices for car operating costs

Year	CHAW Index
2010	223.6
2011	235.2

Source: Table 20, Annual Average Consumer Price Indices, May 2012, Office for National Statistics. Downloaded from: http://www.ons.gov.uk/ons/index.html, June 2012.

3.1.3 Parking costs

Parking cost data

Parking cost data for zones in the city centres of each of the seven districts in the West Midlands Metropolitan Area were supplied by Mott MacDonald. Car parks for the centres were identified using Google Maps, and then parking cost data were assembled from the online Parkopedia database. Mott MacDonald judged this to be the best approach for assembling the data short of contacting car park operators directly, which would have added time and cost to the data assembly effort. On-street parking is included in Parkopedia and has been included in the information assembled. However, no information on private non-residential parking was collected.

It is emphasised that the parking cost data are for city centres only, for all other locations it is assumed that parking is free.

The parking cost information details the 2012 parking costs for stays of different durations, assumed to apply for the whole period of the HI. Some model zones contain more than one car park, and so to allow representative parking costs to be calculated, information on the total number of spaces in each car park was obtained. Average costs for each zone were then calculated as a weighted average over the car parks in that zone. The calculation of the average parking costs by zone was made by RAND Europe using the data supplied for each individual car park by Mott MacDonald. The final values for the parking costs used in the model estimations are detailed in Table 125 presented Appendix

B. This table gives the average parking cost in pence for stays of different durations for those model zones where parking costs are defined.

For most zones, non-zero parking costs are defined for stays of any duration. In model estimation, the activity duration at the PD (for HB tours) or the SD (for NHB detours and PD-based tours) is used to calculate the appropriate parking cost.

For some zones, highlighted in red in Table 125 (Appendix B), parking costs are zero for stays of certain durations. For zones where no parking cost information is available for stays of up to 1 hour (zones 1531 and 2213), it is assumed that parking is free for stays of up to 1 hour. However, for zones where parking cost information is only available for stays of up to 3 hours (zones 3043 and 3081), the car parks are for short stay parking only. For these zones, it is assumed that parking is free for stays of *all durations* for mandatory travel purposes (commute, business and education) where average stays are longer than 3 hours. This is to avoid inconsistencies whereby a tour with a longer duration of stay receives zero parking cost, and a short-stay tour receives a parking cost. If individuals are travelling by car to these zones for mandatory travel purposes, they must be staying in another parking location and in the absence of other information we assume that parking at this other location is free. For discretionary travel purposes (shopping, escort, other) where mean activity durations are shorter, the short-stay parking cost information is used in estimation, and to avoid individuals with activity durations of 3 hours and above receiving zero parking costs for this zone, the parking cost for stays of 2–3 hours is assumed for longer stays.

The proportion of individuals who have to pay for parking

The information provided in Table 125 (in Appendix B) defines parking costs for individuals parking in the centres. However, not all individuals parking in these zones pay for parking. For example, some individuals commuting by car driver to these central zones will have free parking provided by their employer, or in other cases individuals may park for free in another zone and then walk to their final destination. To take account of this, the proportions of individuals paying for parking who were making HB car driver tours in the HI sample were analysed. There were not sufficient data to undertake this analysis for each individual zone, and so the data were segmented into the zones in the centres for which parking cost information was provided and all other zones where in the absence of other information it is assumed parking is free. The analysis was undertaken using the samples of car driver tours where the individual had provided a response when asked whether they had to pay for parking at their destination. Table 17 summarises the results obtained.

Table 17: Car driver tours where individuals report that they pay for parking

	Zones with parking cost information			Other zones		
	Did not pay	Paid	% who pay	Did not pay	Paid	% who pay
Work	563	36	6.0%	1962	18	0.9%
Empl. business	55	6	9.8%	292	7	2.3%
Education	32	5	13.5%	64	4	5.9%
Shopping	155	41	20.9%	442	17	3.7%
Escort	127	2	1.6%	646	5	0.8%
Other	163	20	10.9%	796	22	2.7%
Total	1095	110	9.1%	4202	73	1.7%

For all purposes, the percentages of individuals who report that they pay for parking are significantly higher in the zones for which parking cost information has been provided, and for the other zones the assumption of zero parking costs is reasonable given that only 1.7% of these drivers report that they pay for parking. For zones with parking cost information, the purpose with the highest fraction of people who pay for parking is shopping, but even here only one-fifth of drivers report that they have to pay to park. For commute, just 6% of car drivers who travel to zones with parking cost information report that they have to pay for parking, and so most car drivers who travel to these destinations must use free workplace parking, or some other source of free parking.

For tours to zones with parking cost information, the proportions from Table 17 have been applied to calculate parking costs for an average individual. As the proportions of drivers that pay for parking are relatively low, the average parking costs represented in model estimation are significantly lower than the values presented in Table 125 (Appendix B). In model application, the same proportions are applied to discount the full parking costs in city centre zones. These proportions are specified as a user input so that the impact of future changes in these proportions on the model forecasts can be assessed.

A potential model improvement would be to include a model that represents the probability than an individual pays for parking. This probability could be predicted as a function of employment status, work status, tour purposes etc.

Price adjustment

The parking cost data were assembled during August 2012 and incorporated into the model estimation procedure during September 2012, and at that point a Consumer Price Index (CPI) figure for August 2012 was not available. Therefore the most recently available CPI figure was used (for May 2012) to deflate the 2012 parking costs to 2011 prices. Table 18 summarises the CPI measures used.

Table 18: CHAW CPI indices for parking costs

Year	CHAW Index
2011	235.2
May 2012	242.4

Source: Table 20, Annual Average Consumer Price Indices, May 2012, Office for National Statistics. Downloaded from: http://www.ons.gov.uk/ons/index.html, June 2012.

3.2 Public transport level of service

3.2.1 Network level of service

Public transport LOS information for estimation of the model parameters was supplied by Mott MacDonald. This LOS was generated by assigning 2006 base matrices to 2006 networks defined in the original PRISM zoning system, and then converting the LOS into the new zoning system used for the current work. The procedure that was followed to generate the LOS was documented in Section 2 of Mott MacDonald (2012).

Three sets of PT network LOS were supplied by Mott MacDonald for estimation of the models:

- train LOS, generated from a PT network with train, metro and bus PT modes represented
- metro LOS, generated from a PT network with metro and bus PT modes represented
- bus LOS, generated from a PT network with only the bus PT mode represented

This approach retains the hierarchy of West Midlands PT modes used in the original version of PRISM and in the tour building analysis: train at the top with metro and bus forming possible access modes, followed by metro with bus forming a possible access mode, and by bus as the lowest PT mode in the hierarchy.

The following information was supplied in the PT LOS:

- train in–vehicle-time (IVT) (not for metro and bus LOS)
- metro IVT (not for bus LOS)
- bus IVT
- access time (time to walk from the origin to the first stop or station)
- egress time (time to walk from the final stop or station to the destination)
- walk time at transfer locations
- first wait time (wait time for first PT service)
- transfer wait time (wait time at transfer locations)
- number of transfers
- train distance (not for metro and bus LOS)
- metro distance (not for bus LOS)
- bus distance
- total PT distance

Separate LOS was supplied for the AM peak and inter-peak periods defined in Section 2.5. Currently there are no PM peak or off-peak PT networks defined in PRISM. To model the PM peak, the transpose of the AM peak LOS has been taken. This approach assumes that any ‘tidal’ variation in service provision in the AM peak is reversed in the PM peak, so for example if in the AM peak bus frequencies are higher for services arriving in Birmingham city centre than for services departing from Birmingham city centre, then the assumption is that in the PM peak the pattern will be reversed, and the same higher frequency of service will be provided for bus services departing and the lower frequency of service provided for services arriving.

To model the off-peak period, it has been assumed that the inter-peak LOS can be used without adjustment; this is probably reasonable for the evening and early morning, when most off-peak travel takes place, but of course it would not apply during the night.

It is noted that in contrast to the highway assignments, there is no segmentation between different journey purposes in the PRISM PT assignments. Moreover, the PRISM PT assignment models used to supply data for this project do not incorporate the impact of fares, and so there is no need to take account of differences in values of time between different travel purposes when making the PT assignments.

No LOS was supplied for intrazonal movements and therefore PT modes have been modelled as unavailable for intrazonal tours. No intrazonal train or metro tours were observed in the 2009–2012 HI data, and just 1.8% of bus tours were intrazonals. By contrast, the proportions of intrazonal tours were much higher for non-PT modes, where intrazonal tours are modelled, ranging from 5.3% of tours for car driver up to 43.1% of tours for walk.

3.2.2 Fares data

Centro fare matrices

The 2006-based PRISM PT networks that have been used to generate the network LOS did not include PT fares, and therefore it was necessary to obtain these separately from Centro's PT assignment model. The Centro model uses a 2005 base, and represents AM peak and inter-peak periods. The fares are calculated as flow weighted averages in order to convert from the detailed Centro zoning system to the more aggregate PRISM zoning system. For example, if at the origin end two Centro zones map to a single PRISM zone, and at the destination end there is a one-to-one mapping between the Centro and PRISM zone systems, and the flows from the two origin Centro zones to the destination zone are 10 and 20 trips respectively, then the fares from the two origin zones are weighted by one-third and two-thirds respectively to arrive at a single fare for the OD pair defined in the PRISM zone system. It was necessary to average at both the origin and destination ends for some OD pairs and to do this the same logic was applied.

For the AM peak and inter-peak periods, fare matrices have been generated for the three PT modes represented in the model:

- Train, where fares are calculated as the average fare in a network where train, metro and bus are available.
- Metro, where fares are calculated as the average fare in a network where metro and bus are available.
- Bus, where fares are calculated as the average fare in a network where only bus is available.

The Centro fare matrices reflect full cash fares with no pass discounts, which are calculated as a flat fare plus the sum of all traversed fare points. The flat fares and fare points have been coded for each PT service and were calibrated to 2005 fares. The 2009–2012 HI data collected information on pass ownership which has been used to make adjustments to the full cash fares. The approach used to apply these pass ownership discounts is discussed further in Section 3.2.3.

The Centro fare model covers only the West Midlands Metropolitan Area excluding Coventry. To model fares from zones outside of this area, fare regressions were developed to allow PT fares to be predicted as a function of distance on the highway network. These regressions are documented in the following sub-section.

It should be noted that because the Centro fare matrices have been developed using a different PT assignment model from the PT LOS documented in Section 3.2.1, there is no guarantee that within the area covered by the Centro model the LOS and fare skims will be non-zero for the same set of OD pairs. To account for this issue, if a PT mode is available according to the PT network LOS documented in Section 3.2.1 and the OD pair lies within the Centro model area, a check is made to determine whether the fare matrix is non-zero. For OD pairs where the PT mode is available but the fare matrix is zero, the fare regressions documented in the following sub-section are used to predict the fare.

Consistent with the approach used for the rest of the PT LOS, the transpose of the AM peak fares is used to model the PM peak, and the inter-peak fares are used without adjustment to model the off-peak fares.

Fare regressions

For predicting the PT fares for trips with one or more ends in Coventry, the PRISM intermediate area and the PRISM external area, simple linear regressions with fare as the dependent variable and off-peak car distance as the independent variable were developed. The regressions were run separately for the AM-peak and inter-peak periods, as well as for an 'all-day' time period by including the observations from both the AM peak and inter-peak periods.

$$Fare = Constant + \beta_{Distance} * Distance \qquad (3.3)$$

where: *Fare* is the fare in pence

Distance is the distance in km

Constant and the $\beta_{Distance}$ are the parameters to be estimated

Table 19, Table 20 and Table 21 below show the fare regression results for bus, metro and train respectively.

Table 19: Bus fare regression results (fares in 2005 pence)

	AM peak	Inter-peak	All day
Observations	367,842	361,802	729,644
R-Squared	0.381	0.402	0.391
Constant	179.4	183.7	181.5
$\beta_{Distance}$	4.7	4.7	4.7

Table 20: Metro fare regression results (fares in 2005 pence)

	AM peak	Inter-peak	All day
Observations	367,842	361,802	729,644
R-Squared	0.485	0.404	0.445
Constant	167.6	184.6	176.0
$\beta_{Distance}$	5.9	4.8	5.3

Table 21: Train fare regression results (fares in 2005 pence)

	AM peak	Inter-peak	All day
Observations	367,842	361,802	729,644
R-Squared	0.360	0.389	0.373
Constant	184.1	185.8	185.0
$\beta_{Distance}$	4.5	4.6	4.6

For bus and train, we observe that the fares are slightly higher in the inter-peak period than the AM peak indicated by a higher constant and distance parameter in the inter-peak period than the AM peak. When investigating further, Mott MacDonald found that the number of bus boardings per passenger in the off-peak (1.26) is higher than in the AM peak (1.22). As the fare matrices represent full cash fares, and there is a fare to be paid per boarding, the higher mean number of boardings in the inter-peak period, perhaps connected with a less centre-oriented pattern of demand, is consistent with the higher mean fares indicated by the regression results for that time period.

For all three of the PT modes, the differences between the AM peak and inter-peak fares are small. This is very different from the fare regressions results obtained during the original PRISM development work (RAND Europe, 2004, section 3.2.2), where substantially higher fares were observed in the peak period. Given the relatively small differences between the AM peak and inter-peak fare regression results the all-day regressions have been used to predict fares for all of the four model time periods.

It is strange that the distance effect is slightly smaller for train than for bus, and in general the distance variation in these regressions is weak. For example, the all-day train fare regression predicts a one-way fare for a 100-kilometre trip of £1.85 + £4.60 = £6.45. This may be explained by the fact that the 2005 Centro model only represents local rail trips in detail. The impact of the weak distance effect is that fares for longer train tours to external destinations are under-predicted by the regressions.

Accounting for increases in fares between 2005 and 2011

The fares from the Centro model are in 2005 values. To convert the PT fares into 2011 values for use in the model estimation procedure, the percentage increase in the average cash fare from 2005 to 2011 provided by Centro was used. These increases are summarised in Table 22.

Table 22: PT fare change from 2005-2011

Mode	Increase in nominal values between 2005 and 2011
bus	64 %
metro	81 %
train	31 % (RPI +1 %)

Note that these increases are calculated by comparing 2005 fares in 2005 prices and 2011 fares in 2011 prices. Therefore there was no need to apply any further inflation adjustment.

Day Ranger pass

For train trips that depart after 09:00 made within the West Midlands Metropolitan Area, a Day Ranger pass is available that offers unlimited rail travel for £21.60 (in 2012 prices). Therefore in the model estimation process, rail fares for trips departing after 09:30 (the division between the AM peak and inter-peak periods) made within the West Midlands Metropolitan Area have been capped to £20.90 (which is £21.60 converted into 2011 prices).

Treatment of fares in implementation

When the new 2011 base PRISM demand models come to be used in implementation, both LOS and fare information will be available from the unified 2011 PT model. The unified PT model will provide both LOS and fare information throughout the core and intermediate areas for the AM peak, inter-peak and PM peak periods. Thus there will be no need to use the fare regressions developed for model estimation at the model implementation stage.

The treatment of fares at the implementation stage is discussed in more detail in the model implementation report.

3.2.3 Pass ownership

The PT fare information supplied by Centro was for full cash fares. To calculate representative PT fares in the model estimation procedure, analysis has been undertaken to examine the pass ownership information observed in the HI so that the PT costs used in model estimation take account of the discounts that pass ownership offers over the full fares.

Pass ownership levels observed in the HI data

Table 23 shows the distribution of HB tours by purpose and pass ownership for each of the three PT modes and for all other modes that are modelled. Note that this table excludes observations for motorcycle, taxi and other modes which are not incorporated in the model and therefore the total number of tours is lower than in Table 2.

Table 23: Tours by mode, purpose and pass holding

			No Pass	Pass	Total
Bus	Commute	tours	190	398	588
		percent	32.3%	67.7%	100.0%
	Empl. bus.	tours	14	29	43
		percent	32.6%	67.4%	100.0%
	Education	tours	215	385	600
		percent	35.8%	64.2%	100.0%

			No Pass	Pass	Total
	Shop	tours	126	279	405
		percent	31.1%	68.9%	100.0%
	Other	tours	132	254	386
		percent	34.2%	65.8%	100.0%
	Escort	tours	27	39	66
		percent	40.9%	59.1%	100.0%
	Total	tours	704	1,384	2,088
		percent	33.7%	66.3%	100.0%
Train	Commute	tours	45	82	127
		percent	35.4%	64.6%	100.0%
	Empl. bus.	tours	6	7	13
		percent	46.2%	53.9%	100.0%
	Education	tours	10	30	40
		percent	25.0%	75.0%	100.0%
	Shop	tours	5	17	22
		percent	22.7%	77.3%	100.0%
	Other	tours	22	24	46
		percent	47.8%	52.2%	100.0%
	Total	tours	88	160	248
		percent	35.5%	64.5%	100.0%
Metro	Commute	tours	7	14	21
		percent	33.3%	66.7%	100.0%
	Empl. bus.	tours	0	1	1
		percent	0.0%	100.0%	100.0%
	Education	tours	1	6	7
		percent	14.3%	85.7%	100.0%
	Shop	tours	3	3	6
		percent	50.0%	50.0%	100.0%
	Other	tours	5	3	8
		percent	62.5%	37.5%	100.0%
	Total	tours	16	27	43
		percent	37.2%	62.8%	100.0%
Non-PT Modes	Commute	tours	3,160	246	3,406
		percent	92. 8%	7.2%	100.0%
	Empl. bus.	tours	389	46	435
		percent	89.4%	10.6%	100.0%
	Education	tours	2,118	114	2,232
		percent	94.9%	5.1%	100.0%
	Shop	tours	920	495	1,415
		percent	65.0%	35.0%	100.0%
	Other	tours	1,440	726	2,166
		percent	66.5%	33.5%	100.0%
	Escort	tours	1,553	155	1,708
		percent	90.9%	9.1%	100.0%
	Total	tours	9,580	1,782	11,362
		percent	84.3%	15.7%	100.0%
Total	Commute	tours	3,402	740	4,142
		percent	82.1%	17.9%	100.0%
	Empl. bus.	tours	409	83	492
		percent	83.1%	16.9%	100.0%
	Education	tours	2,344	535	2,879
		percent	81.4%	18.6%	100.0%
	Shop	tours	1,054	794	1,848
		percent	57.0%	43.0%	100.0%
	Other	tours	1,599	1,007	2,606
		percent	61.4%	38.6%	100.0%
	Escort	tours	1,580	194	1,774
		percent	89.1%	10.9%	100.0%

			No Pass	Pass	Total
	Total	tours	10,388	3,353	13,741
		percent	75.6%	24.4%	100.0%

From the all-purpose totals rows in Table 23, tours made by individuals with some form of pass holding comprise:

- 66% of bus tours
- 65% of train tours
- 63% of metro tours
- 16% of tours made by other modes

Two key findings emerge from this analysis. First, around two-thirds of PT users use a pass of some type, and so it is important to represent the impact of pass ownership on PT costs in the estimation of the models. Second, as would be expected PT pass ownership is much lower for individuals who do not choose a PT mode and so it is also important to consider the differences in pass ownership between PT users and users of other modes in model estimation.

Discounts offered by pass type

In order to work out the fares for individuals owning passes, information has been assembled on the discount each pass type observed in the HI data offers over the full cash fare. A discount of 100% means that journeys by eligible PT modes can be undertaken for zero marginal cost. This information is presented in Table 24. There are a total of 49 pass type categories representing various combinations of the pass entitlements in the data – i.e. combinations representing joint holding of two or more passes.[7]

Table 24: Summary of pass entitlements

Pass	Modes	Benefits	Valid	Discount relative to single cash fare
nBus	bus	unlimited bus travel for fixed cost in the PRISM core area	all day	100%
nBus with metro add on	bus and Metro	unlimited bus and metro travel for fixed cost in the PRISM core area	all day	100%
nMetro	metro	unlimited bus travel for fixed cost in the PRISM core area	all day	100%
nTrain	train	unlimited train travel for fixed cost in the PRISM core area	all day	100%
nNetwork	bus, train & metro	unlimited bus travel for fixed cost in the PRISM core area	all day	100%
Centro Concessionary Pass	bus, train & metro	free bus travel all over England; free metro and train travel in the PRISM core area	after 09:30 AM only; for older and disabled people only	free after 9:30
Young Person	train	1/3 discount on standard and	all day	33.3%

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[7] There are only three pass combinations which represent more than two types of pass holding. For the individuals with more than two types of pass combinations only first two passes were taken into account when calculating the pass entitlements.

Pass	Modes	Benefits	Valid	Discount relative to single cash fare
Rail card		first class fares		
Regional Travel Card	bus	unlimited bus travel for fixed cost in the PRISM core area	all day	100%
Regional Travel Card with Metro add on	bus and metro	unlimited bus travel for fixed cost in the PRISM core area	all day	100%
Regional Travel off peak card	bus	unlimited bus travel for fixed cost in the PRISM core area	after 09:30 AM only	100%
Black Country Faresaver	bus	unlimited bus travel for fixed cost in the Black Country region	all day	100%
Student Faresaver	bus	unlimited bus travel for fixed cost in the PRISM core area	all day	100%

In addition to the pass types listed in Table 24, an 'other pass type' category is recorded, which includes a variety of different pass types including disabled and child concession passes. For these pass types a discount of 35% relative to the full cash fare has been assumed.

In applying these discounts in the estimation of the models, a maximum of two pass entitlements per individual has been represented. For example, if a traveller owns two passes, a regional travel card and nTrain card, then for all the bus journeys the traveller gets the discount offered by the regional travel card and for the train journeys the discount offered by the nTrain card.

If a traveller has a pass that is only valid on a certain PT mode, but makes a PT trip that involves travel on more than one PT mode, then the pass discount should only be applied for the proportion of the journey that is made by the PT mode for which the pass is valid. The PT skims break out the distance travelled on each of the three PT modes for each OD pair, and so this distance information has been used to calculate the proportion of the total fare for which the pass discount can be applied. For example, if a traveller has a train-only pass but uses bus to access train, then the train pass discount is only applied to the fraction of the total PT journey distance that is made by train.

Treatment of pass discounts for individuals who do not currently choose a PT mode

For individuals who currently travel by PT, their observed pass ownership can be used to determine any pass discount that applies to the full cash fare. The question then is whether it is valid to use observed pass ownership for individuals who do not currently choose PT as, on average, pass ownership levels are much lower for these individuals and therefore the modelled PT costs would be higher on average. Different assumptions have significant impacts on the modelled costs for PT modes, which in turn impacts on the cost parameter estimates, the implied VoTs and the model elasticities.

It was decided that for commute and education travel, which typically involve regular travel to the same location, most individuals would acquire passes if they switched to a PT mode, and therefore an average discount equivalent to that observed for individuals who were observed to choose one of the PT modes would be represented. This approach ensures that *average* PT costs are the same irrespective of whether individuals currently choose PT.

For purposes other than commute and education, journeys are probably not as frequency and therefore it is unlikely individuals would acquire a pass if they decided to choose a PT mode for a particular journey. Therefore, observed pass ownership levels were used directly for all individuals, i.e. the calculations of PT costs was made in the same way for individuals who chose a PT mode and for individuals who chose one of the non-PT modes. Table 25 summarises the approach used for each HB purpose.

Table 25: Pass discounts applied by home-based purpose

Purpose	Individuals who choose one of the PT modes	Individuals who choose one of the non-PT modes
commute	discounting by observed pass ownership	same average discount as those who chose PT
employer's bus.	discounting by observed pass ownership	discounting by observed pass ownership
education	discounting by observed pass ownership	same average discount as those who chose PT
shopping	discounting by observed pass ownership	discounting by observed pass ownership
escort	discounting by observed pass ownership	discounting by observed pass ownership
other travel	discounting by observed pass ownership	discounting by observed pass ownership

For commute and education, analysis was undertaken from the samples of PT tours to determine the average discounts to apply to the full cash fares for these modes for individuals who do not choose one of the PT modes. These average discounts are summarised in Table 26.

Table 26: Average discounts relative to the full cash fare

Purpose	Bus	Metro	Train
commute	47.9 %	64.0 %	68.3 %
primary education	23.2 %	n/a	0.0 %
secondary education	23.3 %	33.3 %	0.0 %
tertiary education	33.7 %	50.0 %	30.9 %

The average discounts for education travel are lower than for commuting, as a higher fraction of PT users for education pay the full fare. No tours by metro are observed for primary education. For primary and secondary education, all of the observed train tours were made by individuals without a pass and therefore the average discounts are zero.

Treatment of pass ownership in implementation

In implementation two pass ownership segments are used, 'no fare' to represent pass types where no cash fare is paid, and 'full fare' for individuals who pay the full cash fare. Separate PT LOS skims for these two segments are provided from the unified PT model. The 2009–2012 HI data will be analysed to determine average proportions to split individuals between no fare and full fare segments. This analysis is reported in the demand model implementation report.

The current version of PRISM implements a pass ownership model, with five or six pass ownership segments represented per purpose. The implications of moving from the approach of implementing a pass ownership model to allocating to no fare and full fare segments using average proportions by purpose are discussed in more detail in the model implementation report.

CHAPTER 4 Model specification

4.1 Model alternatives

4.1.1 Mode alternatives

Main modes

The 2011 base PRISM models represent seven mode alternatives:

- car driver
- car passenger
- train
- metro
- bus
- cycle
- walk

As discussed in Section 2.4, taxi and motorcycle tours are not modelled, nor are tours made by large vans or lorries.

Car driver is not modelled for primary and secondary education travel, and train, metro and cycle are not modelled for escort and for some of the NHB purposes. Table 27 summarises the main modes that are represented in the models for each travel purpose. For each purpose the cells in grey indicate those modes that are not represented because there is a lack of observed data.

Table 27: Main modes represented by travel purpose

Purpose	Car driver	Car pass.	Train	Metro	Bus	Walk	Cycle
commute	✓	✓	✓	✓	✓	✓	✓
home–business	✓	✓	✓	✓	✓	✓	✓
home–primary education	✓	✓	✓	✓	✓	✓	✓
home–secondary education	✓	✓	✓	✓	✓	✓	✓
home–tertiary education	✓	✓	✓	✓	✓	✓	✓
home–shopping	✓	✓	✓	✓	✓	✓	✓
home–escort	✓	✓			✓	✓	
home–other travel	✓	✓	✓	✓	✓	✓	✓
PD-based tours, work-related PD to work-related SD	✓	✓	✓		✓	✓	
PD-based tours, work-related PD to other SD	✓	✓			✓	✓	
PD-based tours, other PD to other SD	✓	✓			✓	✓	
detours during work-related tours to work-related SDs	✓	✓	✓		✓	✓	
detours during work-related tours to other SDs	✓	✓	✓	✓	✓	✓	
detours during other tours to other SDs	✓	✓	✓	✓	✓	✓	✓

Modes are specified as being available to travellers in the models if the following conditions are met:

- Car driver is available if the traveller holds a driving licence and if there is at least one car in the household.
- Car passenger is available to all travellers. It is assumed that persons in households without a car can still travel as a car passenger with a person from outside their household. Of the 2,040 car passenger tours observed in the 2009–2012 HI, 213 (10.4%) were made by individuals from households without a car.
- Train is available to travellers if a train service exists for their journey, i.e. the train LOS gives a non-zero train IVT for both the outward and return legs of the tour. Note that for some purposes, train access mode choice is represented, and the access station zone may be different from the home zone. The availability conditions used where train access mode choice is modelled are detailed below.
- Metro is available to travellers if a metro service exists for their journey, i.e. the metro LOS gives a non-zero metro IVT for both the outward and return legs of the tour. Metro LOS is not defined for the external area and therefore metro is unavailable for travel to external destinations. This is reasonable as the current metro route does not pass through the external area. Note that for some purposes, metro access mode choice is represented, and the access station zone may be different from the home zone. The availability conditions used where metro access mode choice is modelled are detailed below.
- Bus is available to travellers if a bus service exists for their journey, i.e. the bus-only LOS gives a non-zero bus IVT for both the outward and return legs of the tour. Bus LOS is not defined for the external area and therefore bus is unavailable for travel to external destinations. Further, bus can form an access mode to train and metro but LOS for bus access is not defined in the external area.

- Cycle is available to all travellers provided that the round trip is less than 60 km in length. The 60km limit was determined by plotting tour length distributions for the observed cycle tours. The 60km limit is high, but the mode-destination models contain distance parameters which ensure that the few cycle tours of this length are predicted, and mean predicted cycle tour distances are in line with the observed values.
- Walk is available to all travellers provided that the round trip is less than 30km in length for commute, shopping and other travel tours, and less than 15km for education tours. The 30km and 15km limits were determined during the original PRISM development work by plotting tour length distributions for the observed walk tours. These limits are high, but the mode-destination models contain distance parameters which ensure that the few walk tours of these lengths are predicted, and mean predicted walk tour distances are in line with the observed values.

Access modes to train and metro

In the commuting, shopping and other travel models, two versions of the models have been developed. In the first, car driver and car passenger access to train and metro is modelled as well as access by bus and walk using models of access mode and station choice. Access by bus and walk is represented together as the ‘other’ access mode. The introduction of access mode and station choice into the model structure results in additional model run time, and therefore version of these models have also been developed that do not incorporate car driver and car passenger access, and instead assume all access to train and metro is by bus and walk. In model application, these simplified versions of the models give quicker run times but do not represent the congestion impacts of car access trips around stations, and cannot be used to forecast demand for P&R spaces.

The incorporation of the access mode and station choice models for train and metro travel into the overall model structures is discussed in more detail in Section 4.4. This section includes an analysis of access mode shares by journey purpose which highlights the proportions of train and metro tours that use P&R.

When the three access modes to train are represented in the models, their availability conditions are specified as follows:

- The car driver access mode is available if the train LOS gives a non-zero train IVT for the train journey from the station to the final destination, the traveller holds a licence and if there is at least one car in the household. Note that while up to three station alternatives are considered in the modelling for a given OD pair, LOS only has to exist for one station alternative for car driver access to be available.
- The car passenger access mode is available if the train LOS gives a non-zero train IVT for the train journey from the station to the final destination. Note that while three station alternatives are considered in the modelling for a given origin and destination pair, LOS only has to exist for one station alternative for car passenger to be available.
- The ‘other’ access mode is available to travellers if a train service exists for their journey, i.e. the LOS gives a non-zero train IVT for both the outward and return

legs of the tour (this is the same condition as given on the previous page for train main mode).

The same set of availability conditions are applied to the access modes to metro.

4.1.2 Destination alternatives

There are a total of 994 zones in the 2011 base version of PRISM, which are comprised of:

- 697 core area zones, covering the West Midlands Metropolitan Area
- 254 intermediate area zones, covering all of Warwickshire and Telford & Wrekin, and parts of Staffordshire, Shropshire and Worcestershire
- 43 external area zones, 20 of which cover the part of the West Midlands region not covered by the core and intermediate area zones, and 23 of which cover the rest of Great Britain

In all of the mode and destination choice models, only HB tours that start from homes in the core areas have been modelled, because this is the area covered by the HI surveys. When the models are used in application, they are applied using population forecasts generated from the core and intermediate areas only. In theory all possible destinations, including those in the external area, should be modelled for tours originating in the core and intermediate areas.

However for the education purposes it was not possible to include all external destinations in the models because education enrolment data were available only for zones in the West Midlands Region (zone numbers over 1000) i.e. no enrolment data were available for external zones outside the West Midlands Region. As most education tours are short distance the omission of destinations outside the West Midlands Region from the education models is likely to have a minimal effect.

Destination alternatives are available in the models if a non-zero attraction variable is defined for the zone in question. For example in the commute model, destination zones without employment are set to be unavailable. The attraction variables used for each model purpose are described in Section 4.3.1.

4.2 Treatment of cost

4.2.1 Cost damping

An important consideration during the model development was how travel costs entered into the utilities. During the estimation work for the original version of PRISM, log-cost specifications were used for most of the travel purposes. Consistent with other studies, logarithmic cost was found to give a significant improvement in model fit relative to linear cost, and the implied values of time were judged reasonable for the mean observed costs.

However, a feature of the log-cost specification is that in elasticity tests, destination choice is inelastic to cost changes, because a uniform increase in costs across all destinations becomes a constant change in utility across all destinations once it has been transformed by the logarithm. This means that the only response to cost changes is some mode shifting, and low kilometrage elasticities are observed.

When the 2006 base version of PRISM was validated against the guidance elasticity values in WebTAG, the fuel cost elasticities were observed to be lower than values recommended in WebTAG. As a result, in 2009 the PRISM mode-destination models were re-estimated with both log and linear cost terms in the utility specifications. For most model purposes, a combined log and linear cost specification resulted in an improvement in model fit, plausible values of time, and higher and more plausible fuel cost elasticities, and therefore the models with both linear and log cost terms were incorporated into the 2006 base version of PRISM. However, for other travel, the linear cost term was not significant with this formulation, and the log-cost only formulation remained too inelastic to changes in fuel cost. Therefore a procedure was used to impose a mixture of linear and log cost into the model which allowed a log-linear mixture to be introduced into the model as a single term. This procedure was termed the 'gamma formulation', and used the following functional form:

$$\beta_{\cos t}\left\{\gamma.\mathrm{cost}+(1-\gamma)\log(\mathrm{cost}).\frac{\mathrm{E(cost)}}{\mathrm{E(\log(cost))}}\right\} \tag{4.1}$$

where: γ controls the relative contribution of linear and logarithmic cost

E(cost) is the mean cost

E(log(cost)) is the mean logarithmic cost

the ratio E(cost)/E(log(cost)) ensures linear and logarithmic cost use the same scale

The development of mixed linear and log cost formulations in 2009 was discussed in detail in Fox, Daly and Patruni (2009).

The estimation strategy for the cost specifications in this work was to start with separate linear and logarithmic cost terms and to test whether both terms were negative, significant, and yielded models with acceptable VoTs and elasticities. If it was not possible to estimate models that satisfied all of these criteria, then tests were made using the gamma formulation given in Equation (4.1).

The gamma formulation was used in preference to importing VoTs from WebTAG because it allows estimation of a cost function that is calibrated to the choices made in the 2009–2012 West Midlands HI data, and the distribution of travel costs observed for each mode. Another possibility would have been to import the VoT functions from the previous version of PRISM, however these were calibrated to choice and cost data that is now more than a decade old.

4.2.2 The influence of income on cost sensitivity

A significant shortcoming of the 2001 Household Interview data was the omission of household income information in the survey. The lack of income data meant that in the original mode-destination models it was not possible to examine cost sensitivity by household income. Income segmentation was later introduced into PRISM by importing variation in cost sensitivity by income band using national data, and applying adjustments so that the overall sensitivity to cost changes was consistent with the original model. Thus while cost sensitivity was segmented by income band, the variation in cost sensitivity by income used national rather than West Midlands evidence.

The 2009–2012 HI data collected household income data across 25 different bands:

1. < £1,000
2. £1,000-1,999
3. £2,000-2,999
4. £3,000-3,999
5. £4,000-4,999
6. £5,000-5,999
7. £6,000-6,999
8. £7,000-7,999
9. £8,000-8,999
10. £9,000-9,999
11. £10,000-12,499
12. £12,500-14,499
13. £15,000-17,499
14. £17,500-19,999
15. £20.000-24,999
16. £25,000-29,999
17. £30,000-34,999
18. £35,000-39,999
19. £40,000-49,999
20. £50,000-59,999
21. £60,000-69,999
22. £70.000-74,999
23. £75,000 plus
24. don't know
25. rather not say

These detailed bands correspond to the bands used to record incomes in the National Travel Survey, but imply that rather small numbers are observed in the lowest income bands.

To investigate variation in cost sensitivity with income in the mode-destination models, these 25 bands were first aggregated into 11 bands for individuals with known incomes, and one band for individuals who did not state their income:

1. < £10,000
2. £10,000-19,999
3. £20.000-24,999
4. £25,000-29,999
5. £30,000-34,999
6. £35,000-39,999
7. £40,000-49,999
8. £50,000-59,999
9. £60,000-69,999
10. £70.000-74,999

11. £75,000 plus
12. not stated ('don't know' and 'rather not say' responses)

For each purpose, an initial test was made with separate cost parameters for each of these 12 income bands, and then the cost terms were merged over income bands to try to identify a set of cost terms that gave statistically significant differences in cost sensitivity between income bands. For those purposes where income segmented cost terms have been identified, the final specifications have two to four income bands plus the band for income levels that were 'not stated'.

Of the 5,030 households in the final sample, 1,770 (35%) did not state their income. In model application, the 'not stated' income terms can be dropped, but it was better to retain these individuals in the model estimation procedure because they accounted for around almost one-third of the total tours observed in the HI data.

4.2.3 Cost sharing between drivers and passengers

When the original PRISM mode-destination models were re-estimated in 2009 to incorporate linear and log cost terms, a number of other improvements were made to the treatment of costs, including the use of a cost sharing relationship to allocate car costs between drivers and passengers. This cost sharing specification has been retained in the new PRISM model estimations.

The cost sharing is achieved by specifying cost components for the car driver and car passenger utility functions as specified in Equations (4.2) and (4.3):

$$V(Cost)_{CD} = \beta_{Cost} CarCost_{OD} \left[1 - \frac{S(O_{CD} - 1)}{O_{CD}} \right] \tag{4.2}$$

$$V(Cost)_{CP} = \beta_{Cost} CarCost_{OD} \left(\frac{S}{O_{CP}} \right) \tag{4.3}$$

where:

β_{Cost} is the cost parameter, estimated across all modes in the model

$CarCost_{OD}$ is the car cost, including parking costs at the destination

S is the cost sharing factor

O_{CD} is the mean occupancy for car driver observations in the HI (by purpose)

O_{CP} is the mean occupancy for car passenger observations in the HI (by purpose)

If S takes a value of 0, there is no cost sharing and the driver pays the full cost. If S takes the value of 1, there is equal sharing, i.e. drivers and passengers pay an equal share.[8] Intermediate values of S imply both drivers and passengers contribute towards the total cost, but the driver pays a greater share. The value of S which gives the best fit to the observed data is determined by testing different values iteratively.

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[8] Strictly this is only true if $O_{CD} = O_{CP}$, whereas in reality $O_{CP} > O_{CD}$. If observed occupancies were used equal sharing would occur, the problem is for non-car observations it is not known what the occupancy would have been and so mean occupancies have to be used instead.

Mean occupancies were used rather than observed values because the occupancy was not known for PT and slow mode observations. The mean occupancy values vary with purpose and are summarised in Table 28. The car driver values are the mean car occupancies when car driver is the chosen mode. Similarly the car passenger values are the mean car occupancies when car passenger is the chosen mode. For car passenger, the minimum possible value for the mean occupancy is two because there must always be a driver in the car.

Table 28: Mean occupancy values (source: HI Data)

Purpose	Car driver	Car passenger
commuting	1.045	2.049
home–tertiary education	1.150	2.120
home–shopping	1.300	2.340
home–escort	1.511	2.448
home–other travel	1.235	2.260
work-related PD to work-related SD tours	1.000	2.000
work-related PD to other SD tours	1.053	2.000
other PD to other SD tours	1.187	2.291

Car driver is not represented in the primary and secondary education models and so no cost sharing tests have been made. For home–tertiary education travel, there are substantial numbers of both car driver and car passenger observations and therefore cost sharing tests have been made.

For business travel, it was assumed that it is the driver, rather than any passengers, who reclaims the costs of their travel from their employer, and therefore cost sharing between drivers and passengers was not modelled.

For the three detour models, and the detour model for detours made during work-related PD-based tours to work-related SDs, the samples of car tours were too small to allow cost sharing to be tested and so it was assumed that all of the car costs were paid by the drivers.

4.3 Explanatory variables in the models

4.3.1 Attraction variables

Attraction terms describe the attractiveness of each destination alternative. The attraction variables tested for each purpose were based on the variables identified during the original PRISM estimation work. For education, enrolment data are used as the attraction variable in preference to education employment data as investigations during the original PRISM development work, as well as the development of mode-destination models for Sydney (Australia), have demonstrated that enrolments better explain the choice of destination zone for education tours. Table 29 summarises the attraction variables that have been tested for each purpose.

Table 29: Attraction variables tested by purpose

Purpose	Attractions
commuting	total employment
home–business	total employment
home–primary education	primary education enrolments
home–secondary education	secondary education enrolments
home–tertiary education	tertiary enrolments + further education enrolments total employment
home–shopping	retail employment
home–escort	population total employment primary education enrolments secondary education enrolments
home–other travel	population total employment service employment retail employment
PD-based tours, work-related PD to work-related SD	total employment
PD-based tours, work-related PD to other SD	population total employment service employment retail employment
PD-based tours, other PD to other SD	population total employment service employment retail employment
detours during work-related tours to work-related SDs	total employment
detours during work-related tours to other SDs	population total employment service employment retail employment
detours during other tours to other SDs	population total employment service employment retail employment

Employment data for the core region were sourced by Mott MacDonald from the Inter-Departmental Business Register (IDBR).[9] The IDBR survey covers businesses in all parts of the economy, with the exception of some small businesses and some non-profit making organisations.

As the IDBR data were only purchased for the core region, for intermediate and external areas data from the Business Register and Employment Survey (BRES) was used. The BRES is a new Office for National Statistics (ONS) survey, the aim of which is to maintain the Inter-Departmental Business Register (IDBR) and provide the basis for annual estimates of employment.[10] Analysis revealed that there are some discrepancies between the IDBR data and the BRES data for the core region, the region where both datasets were available, with total employment 5.8% higher in the BRES data compared to

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[9] http://www.ons.gov.uk/ons/about-ons/who-we-are/services/unpublished-data/business-data/idbr/index.html, accessed 4 March 2013.

[10] http://www.nomisweb.co.uk/articles/526.aspx, accessed 4 March 2013.

the IDBR data. Employment totals are lower in the IBDR data because the data only includes information from employers who use Pay As You Earn (PAYE). However, the advice from Mott MacDonald is that the IBDR data gives a better indication of the *distribution* of employment between individual zones in the core region.

To combine the IDBR data and the BRES data, the following approach has been used:

- the BRES data are used without adjustment for zones in the intermediate and external areas
- the IDBR data are used for the core areas, but with adjustment factors applied so that the total employment at the Local Authority level matches control totals from the BRES data
- for the single core area zone missing from the IDBR data (zone 1531, North West Sutton New Hall in Birmingham), data from the BRES data is used without adjustment.

The scaling factors that have been applied to the IDBR data for the seven local authorities in the core area are summarised in Table 30.

Table 30: Employment scaling factors by Local Authority

Local Authority	IDBR total employment control total	BRES total employment, unscaled	Scale factor
Birmingham	481,955	449,029	1.073335
Coventry	141,918	138,223	1.026732
Dudley	115,487	113,197	1.020230
Sandwell	119,421	114,586	1.042195
Solihull	98,962	93,788	1.055167
Walsall	93,052	90,386	1.029496
Wolverhampton	112,954	101,270	1.115375
Total	1,163,749	1,100,479	1.057493

The final specifications for the attraction variables are detailed in Section 5.4.

4.3.2 Level of service terms

The level of service (LOS) information is documented in Chapter 3. Table 31 summarises the initial LOS specification that was tested in the models. The cell entries give the name of the LOS parameter that enters the utility function for that LOS component.

Table 31: Base LOS specification

	Car driver	Car pass.	Train	Metro	Bus	Cycle	Walk
driving cost	Cost	Cost					
toll cost	Cost	Cost					
parking cost	Cost	Cost					
train fare[11]			Cost				
metro fare[12]				Cost			
bus fare					Cost		
total car time	CarTime	CarTime					
train time			TrainTime				
metro time			MetroTime	MetroTime			
bus time			BusTime	BusTime	BusTime		
access/egress time			AcEgTime	AcEgTime	AcEgTime		
interchange walk time			AcEgTime	AcEgTime	AcEgTime		
initial wait time			WaitTime	WaitTime	WaitTime		
other wait time			WaitTime	WaitTime	WaitTime		
transfers			Transfers	Transfers	Transfers		
distance		CarPDist				CycleDist	WalkDist

It is noted that the total car time skim is the total travel time from the highway assignment including any congestion.

As discussed in Section 4.2.3, it is assumed that all car costs are borne by drivers in the employer's business model, and the three PD-based tour models, and therefore there are no cost terms applied to the car passenger alternative for these model purposes.

4.3.3 Socio-economic terms

The starting point for the development of the socio-economic terms was to re-test the terms identified during the original PRISM model estimation, and then to drop terms that no longer had a significant impact on the travel choices made. Model predictions were then compared to the observed choices across a range of socio-economic dimensions to test whether additional socio-economic terms could be added that would improve the fit of the model in a transparent manner.

The following segmentations were investigated in the search for additional socio-economic terms:

- car availability, determined from a combination of household car ownership and personal and household licence holding, with segments including:
    - zero cars
    - no individual licence, but car in the household
    - licence, car competition (more licence holders than cars)
    - licence free car use (licence holders less than or equal to number of cars);

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[11] Including any metro and bus fare payable for the route.

[12] Including any bus fare payable for the route.

- household income;
- gender;
- age band;
- adult status (collected for persons aged 17 and above);
- level of education (highest qualification held);
- household size.

4.3.4 Destination constants

For the commute and business models, Central Business District (CBD) constants have been tested to investigate whether CBD zones have an increased attractiveness over and above that indicated by the attraction variables. Both all-modes effects and mode-specific effects have been tested. Consistent with the original PRISM estimations, the CBD zones have been defined as the set of city centre zones for which non-zero parking cost information has been defined.

Intrazonal constants have also been tested, for tours where the origin and destination zones are the same. Intrazonal effects are only tested for car driver, car passenger, walk and cycle modes because intrazonals are unavailable for PT tours. For these modes, an all-modes intrazonal destination constant has been tested, plus additional mode-specific effects relative to the base car driver mode.

4.3.5 Home-based tour mode constants

NHB travel has been modelled as travel that takes place during HB tours, either as detours made during the outward or return legs of PD-based tours, or in the form of PD-based tours. The mode used for the NHB tour would be expected to be the same as the HB tour in many cases. In particular, if an individual uses car driver for a given HB tour, they would be expected to use car driver for any detours and quite likely to use car for any PD-based tours made during that HB tour.

Therefore, in the NHB models constants have been tested for when the HB and NHB tour modes are equal. Only those constants which are significant have been retained in the final model specifications.

4.4 Incorporation of park-and-ride models

In the original PRISM development work, a substantial amount of analysis was undertaken to develop P&R models for train and metro travel. Dedicated P&R survey data was used to develop models representing the choice between three access modes for train and metro:

- car driver (P&R)
- car passenger, covering both kiss-and-ride (K&R), and cases where a passenger arrives with someone who parks
- other access, which includes access by walk, cycle and bus.

In addition to choice of access mode, the choice of access station was modelled for the car driver and car passenger access modes.

Financial and timing constraints meant that a full re-estimation of the access mode and station choice models was not possible in this project. Therefore, to incorporate the access mode and station choice models within the overall mode-destination model structure, parameters for the access mode and station choices have been imported from the original PRISM development work and combined with more recent data on access mode shares to take account of the changes in P&R provision and use since PRISM was first developed.

The reliance on parameters from the original version of PRISM means that access mode and station choice models could only be incorporated for the three home-based purposes where access mode and station models were developed in the original version of PRISM, specifically commute, home–shopping and home–other travel.

The following sub-sections present analysis detailing how access mode shares have been calibrated in the new models, and explain how the P&R parameter estimates from the original PRISM development work have been incorporated into the new model structures.

Access mode share analysis

To calibrate the access mode shares, initial analysis was undertaken to examine the train and metro access mode shares in the 2009–2012 HI data. This analysis is summarised in Table 32 and Table 33 for the three purposes where P&R is modelled.

Table 32: Train access mode shares, 2009–2012 HI data

Purpose	Car driver		Car passenger		Other access		Total	
commuting	25	19.5%	13	10.2%	90	70.3%	128	100.0%
home–shopping	3	13.6%	3	13.6%	16	72.7%	22	100.0%
home–other travel	4	8.7%	3	6.5%	39	84.8%	46	100.0%
Total	32	16.3%	19	9.7%	145	74.0%	196	100.0%

Table 33: Metro access mode shares, 2009–2012 HI data

Purpose	Car driver		Car passenger		Other access		Total	
commuting	3	16.3%	2	9.7%	16	74.0%	21	100.0%
home–shopping	2	33.3%	1	16.7%	3	50.0%	6	100.0%
home–other travel	1	12.5%	1	12.5%	6	75.0%	8	100.0%
Total	6	17.1%	4	11.4%	25	71.4%	35	100.0%

It can be seen from Table 32 and that there is limited information on train access mode shares from the HI, particular for car driver and car passenger access. Table 33 highlights that there is even less information on access mode shares for metro. On the basis of these tabulations, it was concluded that the HI data did not provide sufficiently large sample sizes to allow train and metro access mode shares to be reliably determined, and therefore alternative data sources were sought.

In 2008, a passenger OD survey was undertaken by Centro at 25 different train and metro stations across the Birmingham area. All but one of these stations was a train station. At the single metro station surveyed, no car access tours were observed for shopping or other travel, and only three car access tours for work travel were observed. Rather than calibrate metro access mode shares using this limited sample of data, the train and metro data has been pooled to provide estimates of overall access mode shares. The access mode shares observed in this pooled train and metro data are presented in Table 34. It should be noted that the survey does not distinguish between HB and NHB travel, and therefore it is not possible to restrict the analysis to home-based travel only. Ideally this analysis would be made using HB travel only because the mode-destination models in which the access mode choice models are incorporated represent HB travel only; it would be expected that NHB would form a very small share of P&R travel.

Table 34: Train and metro access mode shares, 2008 Centro data

Purpose	Car driver		Car passenger		Other access		Total	
work	823	38.4%	115	5.4%	1,205	56.2%	2,143	100.0%
shopping	39	20.6%	16	8.5%	134	70.9%	189	100.0%
other travel	40	13.2%	9	3.0%	254	83.8%	303	100.0%
Total	902	34.2%	140	5.3%	1,593	60.5%	2,635	100.0%

The Centro data provides a much larger sample of train and metro tours for estimation of the access mode shares than the 2009–2012 HI data. These access mode shares have been used to calibrate the access mode shares for both train and metro when the access mode choice models were imported into the overall mode-destination structure. This approach assumes, in the absence of a sufficiently large sample size of metro data to prove otherwise, that train and metro access mode shares for each purpose are equal. It is noted that these access mode shares imply higher car driver and lower car passenger shares than the shares observed in the much smaller samples of train and metro tours in the 2009–2012 HI data.

Integrating the original P&R parameter estimates within the model structures

Parameters from the original PRISM models incorporating P&R have been transferred into the new model structure. To account for differences in model scale between the old and new PRISM models, the P&R parameters have been rescaled on the basis of changes in the sensitivity to car time between the original and new models. The sensitivities to those LOS parameters that can be estimated from the 2009–2012 HI data without a P&R structure in place have been used directly. The attraction terms, which are the number of P&R spaces, and constants from the original P&R models have been transferred without adjustment.

The structural parameters governing the relative sensitivity of main mode and access mode choice (θ_{AccMd_MCh}), and the relative sensitivity of access mode and station choice ($\theta_{AccMdStaCh}$), are summarised in Table 35.

Table 35: Structural parameters in access mode and station choice models

Parameter	Commute	Home–shopping	Home–other travel
θ_{AccMd_MCh}	1.00	1.00	1.00
$\theta_{AccMdStaCh}$	0.33	0.40	0.43

These structural parameters imply that the main mode and access mode choices are equally sensitive to changes in utility (θ_{AccMd_MCh} is fixed to one for each purpose), i.e. effectively at the same level in the choice hierarchy, but that station choice is significantly more sensitive to changes in utility than access and main mode choice ($\theta_{AccMdStaCh}$ is significantly less than one for each purpose).

The model structure for the access mode and station choice models is illustrated in Figure 6, which shows main mode choice as the highest level choice, with the access mode and station choice alternatives for train nested below the train main mode. The same structure is used below the metro made mode but is not presented in Figure 6 because of space limitations.

The three station alternatives nested below the car driver and car passenger access modes are the three most attractive alternatives identified by a pre-processing run that loops over all possible station alternatives, and evaluations the cost and LOS associated with both the car access leg and the PT main mode leg of tours using each station alterative.

Figure 6: Main mode, train access mode and station choice model structure

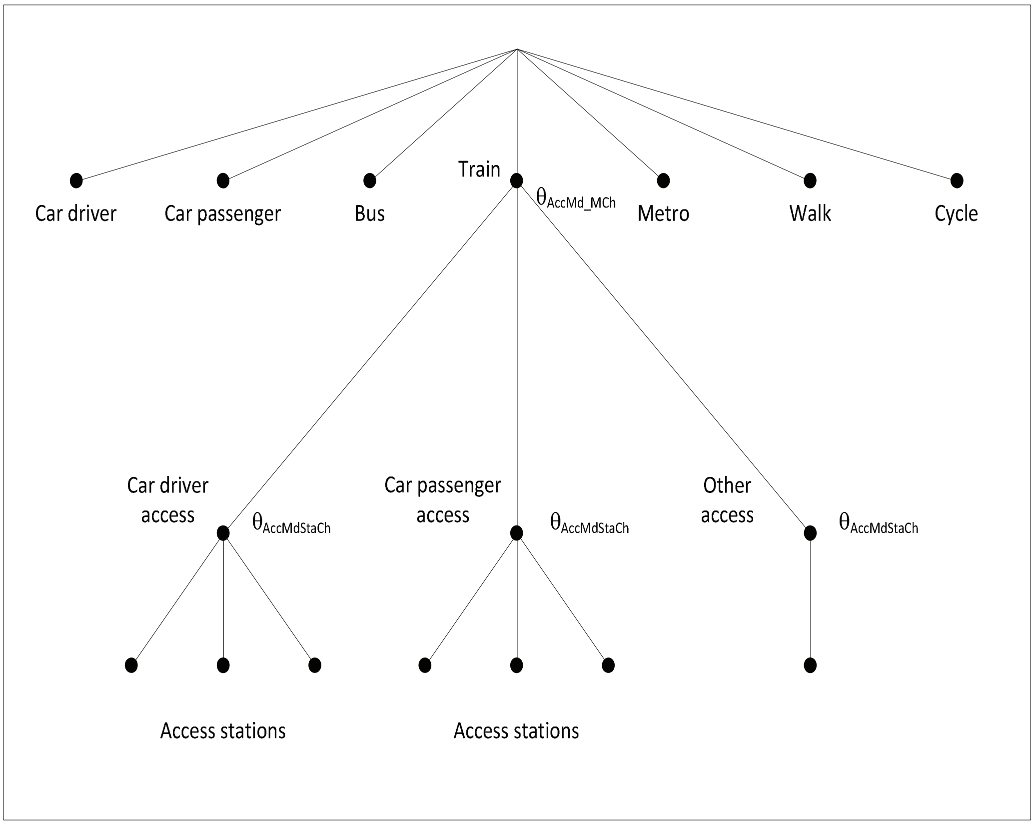


Table 36 summarises the terms included in the utilities for each of the access modes in the commute model, and clarifies which terms have been transferred on the basis of car time (highlighted in green), which have been estimated directly from the 2009–2012 HI data (highlighted in blue), and which parameters have been transferred without adjustment (highlighted in red). Parameter names referenced by ‘(O)’ are the parameters from the original estimations. The parameter names are defined in full in Appendix C.

Table 36: Specification of the access mode utilities for commute

Access Mode	Specification in Original PRISM Estimations	Specification in New PRISM Estimations
CarD	CostAS	Gcost
	LogCostAS	
	CarAccTime	CarTime*(CarAcctime(O)/CarTime(O))
	TrMtTime	PT Gentime
	BusTime	
	WaitTime	
	AcEgTime	
	Transfers	Transfers
	CarDAccMale	CarTime*(CarDAccMale/CarTime(O))
	CarDAc16t19	CarTime*(CarDAcc16t19/CarTime(O))
	CarAc20t24	CarTime*(CarDAc20t24/CarTime(O))
	CarDAcc1Car	CarTime*(CarDAcc1Car/CarTime(O))
	TotSpaces	TotSpaces
	CoreNoPR	CoreNoPR
	InterStat	InterStat
CarP	CostAS	Gcost
	LogCostAS	
	CarAccTime	CarTime*(CarAcctime(O)/CarTime(O))
	TrMtTime	PT Gentime
	BusTime	
	WaitTime	
	AcEgTime	
	Transfers	Transfers
	CarPAccMale	CarTime*(CarPAccMale/CarTime(O))
	CarPAc35t44	CarTime*(CarPAcc35t44/CarTime(O))
	CarPAcc0Car	CarTime*(CarDAcc0Car/CarTime(O))
Other	CostAS	Gcost
	LogCostAS	
	CarAccTime	CarTime*(CarAcctime(O)/CarTime(O))
	TrMtTime	PT Gentime
	BusTime	
	WaitTime	
	AcEgTime	
	Transfers	Transfers
	OthAccRl0n	Pass type variable (no equivalent variable in the current model)

The 'OthAccRlOn' parameter refers to a pass type that was recorded in the 2001 HI data (rail only pass). As this parameter cannot be implemented with the no fare/fare segmentation used in the new model it has been dropped from the model.

The exact specification of the access mode utilities varies slightly for home–shopping and home–other travel, but the same principles have been applied, with the car access time and socio-economic terms transferred using car time, the LOS parameters estimated directly from the 2009–2012 HI data, and the 'TotSpaces', 'CoreNoPR' and 'Interstat' parameters which define the relative attractiveness of different P&R locations transferred directly from the original PRISM models. Full details of these models are reported in RAND Europe (2004a).

4.5 Incorporation of time period choice models for car drivers

Stated preference evidence

In 2003, as part of the original PRISM development work, a Stated Preference (SP) exercise was undertaken through a programme of 555 face-to-face interviews with people who had driven in the West Midlands over the past two weeks. These SP data were analysed to develop models of time period and mode choice (RAND Europe, 2004b).

SP models of time period and mode choice were developed for commute, home–business, non-home–business, and other travel (including shopping) purposes. The models were developed using the four aggregate time periods represented in PRISM (AM peak, interpeak, PM peak, off-peak), with the time period alternatives defined to cover the possible combinations of outward and return time period. To determine the appropriate placement of the time period choice in the overall mode-destination model structure, the time period and mode choice models were estimated using travel time and cost parameters imported from the mode-destination models. This enabled the tests of the relative sensitivity of mode and time period choices to be undertaken in a manner that was as consistent as possible with how the time period choice models were incorporated in the mode-destination models.

For all of the purposes tested, the best structure for time period and mode choice was a multinomial one with time period and mode choice equally sensitive to changes in utility. Therefore to implement time period choice in the re-estimated PRISM models, time period choice for car drivers has been incorporated into the model structure at the same level as main mode choice unless there was clear evidence that an alternative structure gave a better fit to the data. This is consistent with the guidance provided in WebTAG Unit 3.10.3, para. 1.11.17, which states:

"*Less evidence is available about the sensitivity of the macro-time period choice than either main mode or destination choice. Recent research conducted for the Department suggests that the sensitivity of the choice between relatively long time periods, such as three hours or so, should be about the same as that of main mode choice.*"

It is noted that the WebTAG guidance was based on analysis of a number of SP datasets including the 2003 data collected for PRISM (Hess et al., 2007).

Implementing car driver time period choice in the new PRISM models

The time period constants obtained from the SP models are not appropriate for use in the updated PRISM models, because the SP data were collected for a quota-based non-representative data sample, and reflects 2003 conditions. Therefore the time period constants have been estimated using the 2009–2012 HI data.

A total of 13 time period combination alternatives has been specified that define the 13 possible combinations of outward and return time period, noting that the return leg always occurs after the outward leg, and that the off-peak period covers both the start and the end of the day. The time period alternatives represented in the models are defined in Table 37.

Table 37: Time period alternatives

Outward period	Return period				
	Off-peak (early)	AM peak	Inter-peak	PM peak	Off-peak (late)
Off-peak (early)	1_1	1_2	1_3	1_4	1_1
AM peak		2_2	2_3	2_4	2_1
Inter-peak			3_3	3_4	3_1
PM peak				4_4	4_1
Off-peak (late)					1_1

Not all of the 13 possible combinations are observed for each travel purpose. Time period combinations that are not observed in the HI data for a given travel purpose have been set to be unavailable in the model estimation procedure.

The time period choice models reflect the choice between time period combination alternatives on the basis of the difference in travel times and travel costs between each alternative, and the time period alternative constants.

Car driver is not available for home–primary education and home–secondary education travel, and therefore car driver time period choice is not represented for these purposes. For home–tertiary education, the sample of car driver tours is relative low (106 tours), and given that activity times for education travel are typically fixed, so that there is limited scope for time shifting at the macro time period level, time period choice has not been modelled.

For the six NHB travel purposes, the sample sizes of car driver tours are relatively low (particularly for the PD-based tour models), and furthermore implementing models with time period choice would require a complex implementation segmented by the time period of the HB tour during which the NHB travel is made. Therefore time period choice has not been modelled for NHB travel purposes.

For those purposes where time period choice is not modelled, highway LOS for the chosen time periods is used in model estimation. For model application time period distributions have been calculated from the 2009–2012 HI data and calculate weighted average all-day LOS.

Table 38 summarises the treatment of time period choice for car drivers for each of the model purposes.

Table 38: Treatment of car driver time period choice by purpose

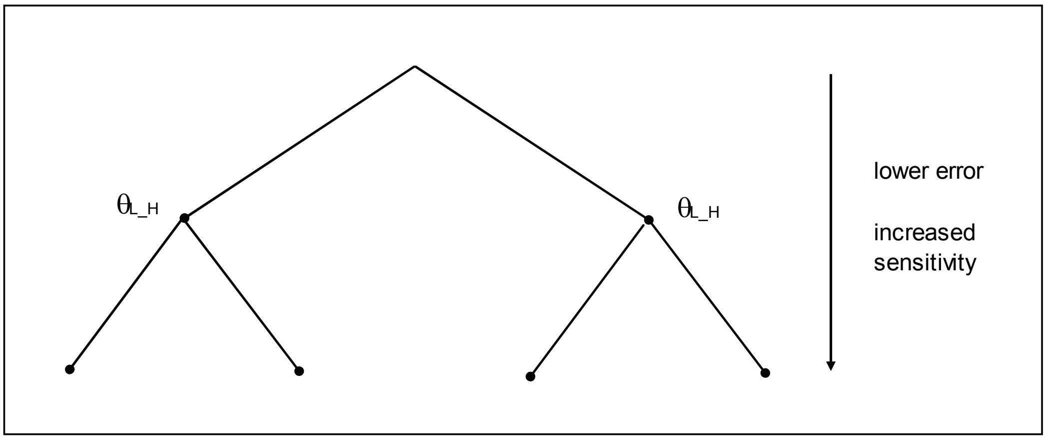
Purpose	Treatment of car driver time period choice
commuting	modelled
home–business	modelled
home–primary education	no car driver
home–secondary education	no car driver
home–tertiary education	assumed fixed
home–shopping	modelled
home–escort	modelled
home–other travel	modelled
PD-based tours, work-related PD to work-related SD	assumed fixed
PD-based tours, work-related PD to other SD	assumed fixed
PD-based tours, other PD to other SD	assumed fixed
detours during work-related tours to work-related SDs	assumed fixed
detours during work-related tours to other SDs	assumed fixed
detours during other tours to other SDs	assumed fixed

4.6 Structural tests

The initial model development included only main mode and destination choices in the model structure. Once the final model specification had been identified, structural tests were carried out that provide insight into the relative sensitivities of the different responses.

To perform the structural tests, nested logit structures were set up with the different choices represented at different levels in the structure, as illustrated in Figure 7.

Figure 7: Nested Structures



Choices lower down in the structure have lower levels of error, and are more sensitive to changes in utility. Less error means that the unobserved component of utility is lower relative to the observed component of utility and therefore the observed component of utility is better able to explain the observed choices. The structural parameter θ_{L_H} defines the relative levels of error in the lower and higher levels of the structure, where L denotes lower level and H denotes higher level, i.e.:

$$\theta_{L\_H} = \frac{\sigma_L}{\sigma_H} \tag{6.3}$$

where: σ_L is the standard deviation of the error in the utilities at the lower level

σ_H is the standard deviation of the error in the utilities at the higher level

For the structure to be valid the condition $\sigma_H \geq \sigma_L$ should hold, which gives the condition $0 < \theta_{L\_H} \leq 1$. If a model was estimated that gave $\theta_{L\_H} > 1$ then the structure was rejected and a structure was tested with the higher and lower levels reversed or the parameter would be constrained to a value of one.

There are up to five different responses represented in each of the PRISM mode-destination models:

- main mode choice
- choice of time period for car drivers
- train and metro access mode choice
- choice of station for car driver and car passenger access modes to train and metro
- destination choice.

Thus up to four different structural parameters were estimated or imported to define the relative sensitivity of these five different choices. These were parameters defining:

- relative sensitivity of main mode and car driver time period choices
- relative sensitivity of main mode and train & metro access mode choices
- relative sensitivity of train & metro access mode and station choices
- relative sensitivity of main mode and destination choices.

The results of the structural tests are reported in Section 5.6.

CHAPTER 5 Model results

This Chapter describes the model estimation results. The detailed parameter results are presented in Appendix C and compared to the mode-destination parameters used in the current version of PRISM which were estimated from 2001 HI data.

5.1 Specification of cost

5.1.1 Cost damping

When analysing the gamma tests documented in this section, models were selected by making a trade-off between the fit to the data, the implied VoTs for car driver, the fuel cost elasticity for car driver and the car time elasticity for car driver.

Loss of fit to the data is measured using log-likelihood, the measure of model fit that is optimised when the models are estimated.

The indicative values for the VoTs are the WebTAG perceived cost values in 2011 prices and values, which are 6.79 £/hr for commute, 30.17 £/hr for employer's business and 6.00 £/hr for other purposes. Evidence suggests that VoTs vary with trip length and with income, and both of these measures vary between regions, therefore the WebTAG values give us an indication of the implied VoTs we would expect. A complication with models that use the gamma formulation is that the VoTs vary with the cost of the tour, and there are different ways of calculating the average cost. It possible to calculate the mean value of 1/cost, or the mean value of cost, and because the distributions of observed costs are not symmetrical these different ways of averaging give different mean costs and hence different implied VoTs. Both values are presented to give an idea of the range of VoTs implied around the mean tour costs for the mode.

For the fuel cost elasticity, the overall target value is −0.25 to −0.35 or slightly higher, as there is a damping effect when the models are run in iteration with supply in application. However, this range reflects an average across all travel and we would expect variation between individual purposes.

For the car time elasticity the WebTAG guidance is less prescriptive – the only guidance is that these should not produce very high values stronger than -2.0.

Commute

For the commute model, it was possible to estimate separate linear and log-cost terms, and both were negative and statistically significant. However, the implied VoTs in these models were too low (£1.10/hr for car at the average observed car cost). Therefore, the gamma formulation defined in Equation 4.1 was adopted, and models were tested for different values of gamma. For each model tested, the loss of fit to the data relative to the model where the linear and log cost contributions were freely estimated was determined, and the impact on the implied values of time and elasticities for car was calculated. Table 39 summarises the results of these tests.

Table 39: Commute model gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms) Car driver	
			E(1/cost)	E(cost)	Fuel cost	Car time
36	0.0352	0	1.08	2.14	-0.217	-0.509
37	0.25	-120.4	2.60	3.75	-0.319	-0.456
38	**0.40**	**-167.1**	**5.76**	**7.33**	**-0.262**	**-0.607**
39	0.50	-183.5	8.06	9.64	-0.237	-0.666

Model 38 was selected on the basis that it gave acceptable elasticity values and VoTs while minimising the loss of fit to the data relative to model 36, where the linear and log cost terms were freely estimated but the VoTs were implausibly low.

Subsequent to running these tests, the treatment of PT fares in the models was revised to maximise consistency with the approach used to implement the models. Specifically, individuals holding passes were assumed to have zero cost for trips where their passes were valid, rather than dividing the cost of the pass by an average number of trips to work out an average cost per trip. This led to changes in the relative magnitude of the cost and IVT parameters, which in turn impacted on the balance between VoTs and elasticities. Therefore additional tests were made to confirm whether the gamma values of 0.4 was still appropriate. The results from these tests are summarised in Table 40.

Table 40: Additional commute model gamma tests

Model	Gamma	Change in fit relative to gamma=0.4 (log-likelihood)	VoTs, top-end estimates at mean costs (2011 £/hr, calculated using E(cost))				Car elasticities (kms) Car driver
			Car	Train	Metro	Bus	Fuel cost
75	0.35	31.9	4.22	3.93	3.80	3.70	-0.389
74	0.40	0	5.25	4.43	4.29	4.61	-0.375
76	**0.45**	**-27.1**	**6.56**	**5.44**	**5.20**	**5.02**	**-0.357**
77	0.50	-49.7	8.24	6.48	6.16	5.92	-0.335

While reducing the value of gamma to 0.35 results in improved fit to the data, the resulting VoTs (which are top-end estimates of the VoT range for the mean costs) are lower than the WebTAG guidance value of 6.79 £/hr for all modes, and the fuel cost elasticity is a little high. Values of gamma greater than 0.4 result in some loss of fit to the data, but gives VoTs closer to the WebTAG values, and while the fuel cost kilometrage elasticity falls with increasing gamma it remains above the WebTAG all-purposes average target value of -0.3. Model 76 with a gamma value of 0.45 was selected to minimise loss of fit to the data while yielding acceptable fuel cost elasticities and VoTs.

Home–business

For the home–business model, a model specification with separate IVT parameters and linear and log cost terms yielded negative cost terms, with a strongly significant log-cost term and an insignificant linear cost term. In this specification the car in-vehicle time parameter was not significantly identified. In a model specification where the linear cost term was dropped, it was possible to identify a significant car time parameter. However, the magnitude of the car time parameter was small and consequently the implied VoTs were unacceptably low (less than 1 £/hr).

As it was not possible to identify a model specification with separate IVT and cost parameters that yielded acceptable VoTs, VoTs were imported from WebTAG which were used to convert monetary costs into generalised time units. Then the sensitivity to generalised time was estimated. The all-modes perceived cost VoT from WebTAG of 30.17 £/hr (2011 values and prices) was used. No guidance exists in WebTAG to specify variation in business VoT with distance. However, the significance of the log-cost term in earlier tests indicated strong evidence for a cost-damping effect, whereby the sensitivity to cost reduces with increasing cost, which gives rise to higher VoTs with increasing cost. Therefore a distance damping effect was tested for VoT. A distance elasticity of 0.36 was imported, based on the value for *commute* travel given in Table A6 of WebTAG Unit 3.12.2. To calculate distance damped VoTs, the following formulation was used:

$$VOT_d = VOT_0 * \left(\frac{D}{D_0} \right)^{\eta} \tag{5.1}$$

where: VoT_d is the VoT at distance d

VoT_0 is the average WebTAG VoT of 30.17 £/hr

D is the one-way tour distance in miles

D_0 is the national average business trip distance of 19.4 miles[13]

η is the distance elasticity of 0.36

This formulation gives the average WebTAG VoT value of 30.17 at the average distance of 19.4 miles. Figure 17 in Section 6.2.2 plots the variation in the implied VoT with distance given by this VoT relationship.

Home–primary education

For the home–primary education model, the car driver mode is not available, and tests revealed that assuming passengers pay a proportion of the car costs resulted in a worse fit to the data. Therefore the only cost information available is from PT modes, most of which is bus travel.

Given that limited cost information was available for primary education, no gamma tests were undertaken and so linear-only and log-cost-only specifications were tested. The log-cost-only specification gave a better fit to the data and therefore has been selected for the final model.

Home–secondary education

As in the home–primary education model, car driver is not available in the home–secondary education model. Furthermore, tests revealed that assuming passengers pay a proportion of the car costs resulted in a worse fit to the data. Therefore the only cost

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[13] National Travel Survey data for 2011 Great Britain, downloaded from Table NTS0405: https://www.gov.uk/government/publications/national-travel-survey-2011, accessed 18 February 2013.

information available for the estimation of the cost terms is from PT modes, mostly bus tours.

In the base model specification with both linear and log cost terms, a negative linear cost term was identified but the log-cost term was positive and significant. As limited cost information was available for secondary education no gamma tests were undertaken and a choice was made between linear-cost-only and log-cost-only specifications. The log-cost-only specification gave a better fit to the data and was therefore selected for the final model specification.

Home–tertiary education

In the base model specification with both linear and log-cost terms, while both terms were negative only the log-cost term was significant. Car driver is an important mode for home–tertiary education travel, with a mode share of 18%, and therefore gamma tests were undertaken to search for a cost specification that gives acceptable fuel cost elasticities, VoTs and model fit. Table 41 summarises the results from tests made using the gamma formulation.

Table 41: Home–tertiary education gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)	
			E(1/cost)	E(cost)
15	0.0387	0	2.09	4.12
16	0.1	-1.5	2.58	4.53
17	**0.25**	**-4.8**	**4.72**	**6.84**
18	0.5	-7.3	8.52	10.25

On the basis of these tests, a gamma value of 0.25 was tentatively selected on the basis that it gave acceptable VoTs for car while minimising loss of fit to the data.

Tests were undertaken later in the model development, following a revision to the treatment of PT fares to ensure maximum consistency with the approach used to implement the models. The revised tests are summarised in Table 42.

Table 42: Additional home–tertiary education gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Fuel cost elasticity (km)
			E(1/cost)	E(cost)	
43	**0.25**	**0**	**5.59**	**7.67**	**-0.297**
44	0.5	-15.5	7.35	8.84	-0.303
45	0.75	-24.4	10.08	10.85	-0.265

On the basis of these tests, it was decided to retain the gamma value of 0.25 as higher values of gamma lead to a loss of fit and an increase in the VoTs above the guidance value from WebTAG.

Home–shopping

In the base model specification with both linear and log-cost terms, the log-cost term was negative and highly significant but the linear cost term was positive and insignificant. A log-cost-only specification would be expected to yield low fuel cost kilometrage elasticities, and therefore gamma tests were made to search for a cost specification with acceptable fuel cost elasticities, implied VoTs and fit to the observed data. Table 43 summarises the results from the gamma tests that have been made.

Table 43: Home–shopping gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Fuel cost km elasticity
			E(1/cost)	E(cost)	
42	-0.0381	0	4.36	9.36	-0.02
43	**0.1**	**-13.3**	**6.69**	**11.55**	**-0.09**
44	0.2	-23.9	8.90	13.70	-0.10
45	0.3	-32.6	10.74	15.10	-0.11
46	0.4	-39.6	12.33	16.09	-0.11

The first run uses the gamma value implied by the freely estimated linear and log cost parameters. The gamma value is negative because the linear cost term was positive.[14] It can be seen that the fuel cost elasticity is very small, and the PT cost elasticity (not presented in Table 43) was actually positive because of the contribution of the positive linear cost term.

It can be seen that increasing gamma to 0.1 and higher results in VoTs above the WebTAG guidance value of 6.00 £/hr, and that the increase in fuel cost elasticity with increasing gamma is very slight, so that even with a gamma value of 0.4 the fuel cost kilometrage elasticity is just -0.11. It was decided that the very marginal increase in fuel cost elasticity with gamma values above 0.1 did not justify the high VoTs and loss of fit to the data, and so a gamma value of 0.1 was selected for the final model specification.

Home–escort

The base model specification with both linear and log-cost terms yielded a significant negative log-cost term, but the linear cost term was positive and significant. Therefore a series of gamma runs were undertaken starting from a model with gamma=0 (pure log-cost). These runs are summarised in Table 44.

Table 44: Home–escort gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms) Car driver	
			E(1/cost)	E(cost)	Fuel cost	Car time
12	0	0	4.12	9.01	-0.078	-1.023
13	0.05	-9.4	4.65	9.25	-0.130	-0.915
14	**0.1**	**-18.3**	**5.75**	**10.54**	**-0.153**	**-0.894**
15	0.2	-31.7	9.15	14.71	-0.158	-0.957
16	0.3	-40.1	13.22	19.17	-0.148	-1.025

A value of gamma of 0.1 gave acceptable VoTs, but the fuel cost elasticity is relatively low at -0.153. Increasing gamma to 0.2 results in a loss of fit to the data and a significant increase in VoT, and yields only a slight increase in the fuel cost elasticity. Higher values of gamma result in even higher VoTs, and reductions in the fuel cost elasticity. Overall it was judged that a gamma value of 0.1 gave the best balance between the three criteria.

The model specification was subsequently revised to drop the car passenger distance term, which was positive and significant due to four long escort tours. Dropping this term had a significant impact upon the cost terms in the model, and so the gamma tests were re-run. The revised tests are summarised in Table 45.

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[14] This model could not be recommended for implementation because of the positive linear cost term.

Table 45: Additional home–escort gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Fuel cost km elasticity
			E(1/cost)	E(cost)	
36	0.1	0	2.96	1.61	-0.262
37	0.2	-21.8	3.32	2.06	-0.320
38	0.3	-40.5	4.50	3.10	-0.319
39	**0.4**	**-53.7**	**6.33**	**4.75**	**-0.296**
40	0.5	-62.7	8.40	6.74	-0.272

A gamma value of 0.4 was used in the final model. The loss of model fit was judged to be acceptable relative to model 36, given than the car VoTs were higher and more consistent with the WebTAG values, and the fuel cost elasticity was also higher and closer to the all-purpose average.

Home–other travel

For the other travel model, when separate linear and log-cost terms were tested the log cost parameter was negative as expected, but the linear cost parameter was positive which is implausible. The next step was to implement the gamma formulation. Table 46 summarises the results from tests with different gamma values.

Table 46: Home–other travel gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms)	
			E(1/cost)	E(cost)	Fuel cost	Car time
22	0.0	0	0.92	2.75	-0.022	-0.712
18	0.1	-81.8	0.68	1.60	-0.253	-0.346
19	0.2	-180.2	2.02	3.96	-0.246	-0.531
20	**0.25**	**-213.7**	**3.53**	**6.42**	**-0.218**	**-0.663**
21	0.3	-237.4	5.28	8.97	-0.198	-0.760

Model 22, with a gamma value of zero (i.e. a pure log-cost model) gave the best fit to the data, but unacceptably low VoTs and fuel cost elasticities. With increasing gamma, the fit to the data worsened, but the VoTs and fuel cost elasticities increased. A gamma value of 0.25 was selected that gave acceptable VoTs and elasticity values while minimising the loss in the fit to the data.

Subsequent to running the initial gamma tests reported in Table 46, a number of changes were made to the home–other model specification, including a revised treatment of PT costs for owners of passes which offer travel for zero marginal cost. The collective impact of these changes was for the VoTs with a gamma values of 0.25 were too high, and so on the basis of the results presented in Table 46 lower gamma values were tested in the expectation that this would both improve the VoTs and improve the fit to the data. The additional gamma tests are summarised in Table 47.

Table 47: Additional home–other travel gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs E(cost)	Car elasticities (kms)	
				Fuel cost	Car time
66	0.25	0	11.02	-0.226	-1.078
72	0.20	15.9	9.20	-0.231	-1.036
74	0.15	36.6	6.35	-0.237	-0.968

Reducing the gamma value to 0.15 gave lower and more plausible VoTs, an improved fit to the data, and a slightly higher fuel cost elasticity. Therefore the gamma value of 0.15 was adopted in the final model specification.

PD-based tour models

For the work–work and work–other models, the sample sizes were too small to allow gamma tests to be run.

For the work–work model, the linear cost term was positive and insignificant, and therefore the final model specification contains a log-cost term only. For the work-other model, the linear cost term was also positive in the base model and so the final model specification also contains a log-cost term only.

Finally, for the other–other model in both linear-cost-only and log-cost-only model specifications, the cost parameter was positive. Therefore a generalised time formulation was used, with costs converted into generalised time units using the WebTAG VoT of £6.00/hr in 2011 prices and values. Both linear and log generalised time terms were tested. The log generalised time was not significant and therefore the final model uses a linear generalised time specification.

Work–work detours

In the base model specification with separate linear and log cost parameters, the linear cost term was not significant but a significant log-cost effect was identified. Therefore tests were undertaken using models with a gamma formulation. Table 48 reports the results from these tests. It is noted that elasticities have not been run for all of these models – gamma was varied until acceptable VoTs were obtained, and elasticities were calculated and their plausibility was assessed.

Table 48: Work–work detour gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms) Car driver	
			E(1/cost)	E(cost)	Fuel cost	Car time
15	0.00	0.0	1.83	6.55	-0.024	-1.085
16	0.10	-1.1	0.92	2.49		
17	0.20	-3.9	0.69	1.51		
18	0.30	-7.0	1.15	2.14		
19	0.50	-11.1	4.06	5.91		
22	**0.55**	**-11.7**	**5.23**	**7.24**	**-0.306**	**-0.559**
20	0.75	-13.3	12.02	14.08	-0.220	-0.721
21	1.00	-14.2	25.51	25.51	-0.156	-0.851

While models with a gamma value of 1.00 gave VoTs in the range that would be expected for employer's business travel (which is the nature of work–work detours), the generalised cost parameter was insignificant in both models 20 and 21. Therefore model 22, the highest values of gamma which yielded a significant cost term, was selected. The VoTs in this model are lower than would be expected for employer's business, whereas the fuel cost elasticity is on the high side. However, work-work detours form a small fraction of total travel and so the impact of these differences on total travel are very slight.

Work–other detours

Consistent with the tests for other travel purposes, in the base model a significant log-cost term was identified, but the separate linear cost term was insignificant. A pure log-cost model gave very low fuel cost kilometrage elasticities for car driver (-0.02) and therefore gamma tests were undertaken to search for a model formulation with acceptable VoTs, elasticities and fit to the data. The results from these tests are summarised in Table 49. It is noted that elasticities have not been calculated for all of these models.

Table 49: Work–other detour gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms) Car driver	
			E(1/cost)	E(cost)	Fuel cost	Car time
23	0.02739	0.0	12.31	25.48	-0.020	-0.995
24	0.00	-0.1	12.51	27.41		
25	0.10	-0.4	12.36	22.53		
26	0.20	-1.5	13.26	21.14	-0.086	-0.897
27	0.30	-2.8	14.78	21.25		
28	**0.50**	**-5.0**	**18.86**	**23.34**	**-0.115**	**-0.865**
29	0.75	-6.8	24.83	27.09	-0.115	-0.874
30	1.00	-8.0	30.82	30.82		

Model 23 uses the gamma values that is implied from the freely estimated linear and log cost parameters. The loss in model fit resulting from using higher values of gamma was only slight. The VoTs in model 23 were high relative to WebTAG values (6.00 £/hr for other), and the VoTs increased further as gamma increased. The fuel cost elasticities were very low for lower values of gamma, and even for higher values of gamma the values were on the low side. In the end a gamma value of 0.5 was selected, as further increases in gamma had no impact upon the fuel cost elasticity values.

Other–other detours

In the base model specification with separate linear-cost and log-cost terms, while the log-cost term was negative and significant, the linear cost term was positive and significantly identified. Therefore gamma tests were run with the objective of identifying a model specification with acceptable VoTs, elasticities and fit to the data. The results from the gamma tests that were made are summarised in Table 50.

Table 50: Other-other gamma tests

Model	Gamma	Change in fit (log-likelihood)	Car VoTs (2011 £/hr)		Car elasticities (kms) Car driver	
			E(1/cost)	E(cost)	Fuel cost	Car time
24	*-0.0653*	0	2.91	6.81		
25	0.0	-2.1	2.40	5.07		
26	0.1	-11.9	2.41	4.45		
27	0.2	-24.2	3.59	5.95	-0.154	-0.621
28	**0.3**	**-33.6**	**6.47**	**9.74**	**-0.142**	**-0.706**
29	0.5	-43.4	15.35	19.85		
30	0.75	-48.8	28.74	32.15		
31	1.0	-51.0	46.46	46.46		

The value of gamma of 0.3 was selected. Lower values of gamma gave VoTs lower than the WebTAG guidance values, and based on the results from the other model purposes would be expected to give low fuel cost elasticities. Higher values of gamma resulted in higher VoTs and a greater loss of fit to the data, and would be expected to give lower fuel cost elasticities as the fuel cost elasticity reduces when gamma is increased from 0.2 to 0.3.

Summary

Table 51 summarises the cost specifications used in the final models for each model purpose.

Table 51: Summary of cost specifications

Purpose	Cost specification
commuting	gamma specification, gamma = 0.45
home–business	VoTs imported from WebTAG with a distance damping
home–primary education	log-cost only
home–secondary education	log-cost only
home–tertiary education	gamma specification, gamma = 0.25
home–shopping	gamma specification, gamma = 0.1
home–escort	gamma specification, gamma = 0.4
home–other travel	gamma specification, gamma = 0.15
PD-based tours, work-related PD to work-related SD	log-cost only
PD-based tours, work-related PD to other SD	log-cost only
PD-based tours, other PD to other SD	VoTs imported from WebTAG, linear generalised time formulation
detours during work-related tours to work-related SDs	gamma specification, gamma = 0.55
detours during work-related tours to other SDs	gamma specification, gamma = 0.5
detours during other tours to other SDs	gamma specification, gamma = 0.3

5.1.2 Income segmentation

For a number of model purposes, cost sensitivity parameters segmented by household income band have been estimated using the local 2009-2012 HI data, and therefore reflect the variation in cost sensitivity observed across West Midlands residents. This represents a significant improvement on the current version of PRISM, where variation in cost sensitivity by income band was imported using national data sources.

The following sub-sections report the results of the income segmentation tests undertaken for each travel purpose. The income segmentation tests were carried out after the tests to determine the appropriate cost damping specification (described above).

Commute

In the final commute model specification, cost sensitivity (specified using the gamma formulation) is segmented into five income bands:

1. < £25k p.a.
2. £25-35k p.a.
3. £35-50k p.a.
4. £50k+ p.a.
5. income not stated ('don't know' and 'rather not say' responses)

This means that five separate cost parameters are estimated, one for each of the income bands. Each cost parameter is multiplied by the mixture of linear and log cost given by the gamma formulation:

$$\beta_{\cos t,inc}\left\{\gamma.\text{cost}+(1-\gamma)\log(\text{cost}).\frac{\text{E(cost)}}{\text{E(log(cost))}}\right\} \tag{5.2}$$

where: $\beta_{cost,inc}$ is the cost parameter specific to the income band

γ is the gamma value, determined from the tests documented in Section 5.1.1

E(cost) is the mean cost

E(log(cost)) is the mean logarithmic cost

the ratio E(cost)/E(log(cost)) ensures linear and logarithmic cost use the same scale

In model application, the model will be applied for individuals with known incomes only so only four income segments will be required.

Home–business

As documented in Section 5.1.1, distance-damped WebTAG VoTs have been used to convert costs into generalised time units. The WebTAG VoTs for business do not vary with income band and so the VoTs are not segmented by income band.

It was possible to identify differences in sensitivity to generalised time by income band from the business data. However, the improvement in model fit was not statistically significant, and furthermore this formulation implies different sensitivities to in–vehicle time by income band, which would be inconsistent with the models for the other travel purposes which assume sensitivity to IVT to be uniform across income bands. Therefore the income segmented generalised time formulation was not adopted.

Thus the final home–business model specification does not incorporate variation in cost sensitivity with income band.

Home–primary education

Income segmentation was tested in the home–primary education model, but it was not possible to identify a model where cost sensitivity reduced with increasing income. Thus the final home–primary education model specification does not incorporate any income segmentation.

Home–secondary education
When income segmentation was tested in the home–secondary education model, a specification was identified where cost sensitivity reduced with increasing income, but the difference in cost sensitivity between the income segmentations was not statistically significant. Therefore the final home–secondary education model specification does not incorporate any income segmentation.

Home–tertiary education
The result of the income segmentation tests for the home–tertiary education model is consistent with that of the tests for home–secondary education – a segmentation where cost sensitivity reduced with increasing segmentation was identified, but the differences in cost sensitivity by income band were not statistically significant and therefore the final home–tertiary education specification does not incorporate any income segmentation.

Home–shopping
The final home–shopping model segments cost sensitivity, specified using the gamma formulation, into three income bands:

1. < £35k p.a.
2. £35k+ p.a.
3. income not stated ('don't know' and 'rather not say' responses)

In model application, the model is applied for individuals with known incomes only and so only two income segments are required.

Home–escort
Income segmentation was tested in the home–escort model, but the differences in cost sensitivity between different household income bands were not statistically significant and therefore the final model specification does not incorporate any income segmentation.

Home–other travel
The final home–other travel model specification segments cost sensitivity, specified using the gamma formulation, into four income bands:

1. < £35k p.a.
2. £35-50k p.a.
3. £50k+ p.a.
4. income not stated ('don't know' and 'rather not say' responses)

In model application, the model is applied for individuals with known incomes only so and therefore only three income segments are required.

PD-based tour models
The sample sizes in the PD-based tour models were too small to allow tests to test segmenting the cost sensitivity parameters by income band, and therefore the final model specifications for these purposes do not contain any income segmentation.

Work–work detours

Tests were undertaken where the cost sensitivity parameters were segmented by household income band. However, the cost segmented models did not give a significant improvement in model fit relative to the unsegmented models, and therefore the final model specification for the work–work detour model does not contain any income segmentation. Given the small sample size of 138 detours, the inability to identify any significant variation in cost sensitivity with income band was not surprising.

Work—other detours

The income segmented models runs did identify a model specification whereby cost sensitivity was segmented into bands for individuals from households with incomes less than and greater than £35k p.a. However, the difference in the cost sensitivities between these two income bands was small, and statistically insignificant. Therefore, the final work-other detour model specification does not contain any income segmentation.

Other–other detours

The final other–other detour model specification segments cost sensitivity, specified using the gamma formulation, into four income bands:

1. < £35k p.a.
2. £35-50k p.a.
3. £50k+ p.a.
4. income not stated ('don't know' and 'rather not say' responses)

In model application, the model is applied for individuals with known incomes only so only three income segments are required.

Summary

Table 52 summarises the income segmentations used for the cost parameters in the final models for each model purpose. Note that the purposes with larger tour samples are generally the ones that where an income segmentation has been identified, suggesting that income effects on cost sensitivity may exist for other travel purposes, but it was not possible to identify these with the household interview sample sizes collected for the study.

Table 52: Summary of income segmentations

Purpose	Household income specification
commuting	four bands plus income not stated
home–business	no segmentation
home–primary education	no segmentation
home–secondary education	no segmentation
home–tertiary education	no segmentation
home–shopping	two bands plus income not stated
home–escort	no segmentation
home–other travel	three bands plus income not stated
PD-based tours, work-related PD to work-related SD	no segmentation
PD-based tours, work-related PD to other SD	no segmentation
PD-based tours, other PD to other SD	no segmentation
detours during work-related tours to work-related SDs	no segmentation
detours during work-related tours to other SDs	no segmentation
detours during other tours to other SDs	three bands plus income not stated

5.1.3 Cost sharing between drivers and passengers

As discussed in Section 4.2.3, cost sharing tests have been run to examine the optimum allocation of car costs between drivers and passengers. Table 53 summarises the results from these tests that have been undertaken using Equations (4.2) and (4.3). A cost share factor of 0 indicates that the driver pays all of the costs, whereas a share of 1 indicates costs are shared equally between drivers and passengers.

For business travel, it is assumed that it is the driver, rather than any passengers, who reclaims the costs of their travel from their employer, and therefore cost sharing between drivers and passengers was not modelled.

As noted in Section 4.2.3 car driver is not represented in the primary and secondary education models and so no cost sharing tests have been made. Tests were made for these two purposes where the full cost for the car tour was included in the car passenger utilities, but these model specifications resulted in a reduction in model fit and therefore the final model specifications do not represent any car costs.

For home–escort, the car passenger mode share is very low (2.3%), as most of the individuals who make escort tours by car are car drivers, and therefore cost sharing has not been tested.

For the three PD-based tour models, and the detour model for detours made during work-related PD-based tours to work-related SDs, the samples of car passenger observations were too small to test cost sharing and so it has been assumed that all car costs are paid by the driver.

Table 53: Cost sharing tests

Purpose	Share
commuting	0.25
home–tertiary education	0.25
home–shopping	0.25
home–other travel	1.00
detours during work-related tours to other SDs	1.00
detours during other tours to other SDs	0.25

For commute, the results imply that drivers pay most of the car costs, whereas for home–other travel, which is discretionary, assuming that costs are shared equally between drivers and passengers gave the best fit to the data. These differences are broadly consistent with our findings in other studies, for example in models for Sydney we obtained a cost sharing factor of 0.5 for commute and home–tertiary education travel, and 1.0 for home–shopping and home–other travel.

5.2 Level of service terms

Initial model tests were undertaken estimating separate weightings for PT IVTs by train, metro and bus mode, and with separate weightings for PT out-of–vehicle components. However, in all of the final models, the PT IVT parameters and the out-of–vehicle time components have been combined to allow estimation of a single generalised PT time parameter, because the individual valuations of the terms were either insignificant, or implied relative valuations for PT out-of–vehicle time components that were lower than PT in–vehicle time which is counter-intuitive.

To combine PT out-of–vehicle components with in–vehicle time components, two tests were made:

- tests where out-of–vehicle components received a weight of 2, a more usual weighting for access and egress time and wait time components
- tests where the out-of–vehicle time components received a weight of 1

WebTAG Unit 3.10.2, Variable Demand Modelling – Key Processes, paragraph 1.10.10 states that '*based on IHT's Guidelines on Developing Urban Transport Strategies (May 1996) and ITS and John Bates's review of value of time savings in the UK in 2003, the following ranges can be used for the relative valuations of these components*:

- *value of walk time = 1.5 to 2.0 times in–vehicle time; and*
- *value of wait time = 1.5 to 2.5 times in–vehicle time.*'

On the basis of these ranges, the tests where both access and egress time and wait time components received a weight of 2 were specified.

The results from the PT out-of–vehicle (OVT) time weight tests for all are summarised in Table 54. The t-ratios for the PTGenTime and CarTime parameters are given in brackets.

Table 54: PT-out-of–vehicle time weighting tests

Purpose	OVT weight	Model fit		PTGenTime	CarTime
		Log-likelihood	Change in fit		
commuting	1	-24,683.6		-0.0221 (13.9)	-0.0330 (15.8)
	2	-24,707.2	-23.6	-0.0166 (13.0)	-0.0325 (15.5)
business	1	-3,160.8		-0.0179 (25.6)	-0.0179 (25.6)
	2	-3,165.1	-4.3	-0.0174 (25.9)	-0.0174 (25.9)
primary education	1	-4,145.8		-0.0309 (6.7)	-0.1116 (3.2)
	2	-4,152.8	-7.0	-0.0234 (5.8)	-0.1128 (3.3)
secondary education	1	-3,004.5		-0.0334 (10.0)	-0.0711 (2.0)
	2	-3,022.6	-18.1	-0.0235 (8.6)	-0.0718 (2.0)
tertiary education	1	-2,812.1		-0.0177 (12.2)	-0.0162 (3.5)
	2	-2,824.3	-12.2	-0.0142 (11.4)	-0.0151 (3.3)
shopping	1	-8,022.2		-0.0487 (17.2)	-0.0883 (17.5)
	2	-8,043.5	-21.3	-0.0395 (16.6)	-0.0864 (17.1)
escort	1	-6,278.3		-0.0399 (9.3)	-0.0979 (15.5)
	2	-6,284.0	-5.7	-0.0330 (9.2)	-0.0969 (15.4)
other travel	1	-15,038.1		-0.0291 (12.0)	-0.0452 (16.8)
	2	-15,043.4	-5.3	-0.0263 (11.6)	-0.0424 (16.7)
work-work detour	1	-851.7		-0.0444 (4.6)	-0.0358 (2.5)
	2	-851.6	-0.1	-0.0382 (4.6)	-0.0344 (2.4)
work-other detour	1	-4,983.90		-0.0572 (9.4)	-0.0848 (8.1)
	2	-4,983.94	-0.04	-0.0502 (9.4)	-0.0851 (8.2)
other-other detour	1	-5,604.1		-0.0691 (10.1)	-0.1524 (13.3)
	2	-5,602.4	-0.3	-0.0598 (10.2)	-0.1534 (13.4)

It can be seen that using out-of–vehicle time weights of two consistently leads to a loss of fit to the data, and further suppresses the PTGenTime parameter estimates, which results in low VoTs for PT modes for some purposes, and low PT IVT elasticities. Therefore we have decided to use out-of–vehicle time weights of 1 to preserve the quality of the models, although the weights are lower than the range of values indicated in WebTAG Unit 3.10.2.

The tests for the HB purposes, and the three NHB detour purposes, all indicated that combining out-of–vehicle components into a single PTGenTime parameter with a weight of 1 gave better quality models. Therefore the weight of 1 was adopted for the three PD-based tour purposes without running additional tests with a weight of 2.

It is believed that the use of LOS relating to a 2006 base year, rather than the 2009–2012 period covered in the HI data, and the need to convert LOS between the old and new PRISM zoning systems, mean that the access and egress times and wait times from the skims provide a less good representation of those actually faced by travellers than might be expected. It is also noted that in the original PRISM estimations, where separate valuations were estimated for access and egress time and wait time components, the relative valuations of out-of–vehicle time components were similar to those for PT IVT, so implied weights closer to 1 than 2 (RAND Europe, 2004a). So difficulties in identifying access and egress and wait time valuations with valuations higher than IVTs were also encountered when the original 2001 PRISM PT network model were used to explain 2001 travel choices.

It is recommended that once the new 2011 base PT networks are ready, the final model specifications are re-tested. Ideally, a higher weight would be found, more consistent with the guidance values set out in WebTAG, so that changes in access and egress time and wait times have a greater impact on predicted PT demands.

Error! Not a valid bookmark self-reference. summarises the final specifications for the PT in–vehicle and out-of–vehicle components for commute, shopping, home–other travel and detours during HB other tours to other PD locations.

Table 55: Final PT LOS specification, commute, home–shopping, home–other travel and other-other detour model

Component	Train	Metro	Bus
train time	PTGenTime		
metro time	PTGenTime	PTGenTime	
bus time	PTGenTime	PTGenTime	PTGenTime
access/egress time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
interchange walk time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	
initial wait time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
other wait time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
transfers	Transfers	Transfers	Transfers

For the remaining HB purposes and all of the NHB travel purposes, it was not possible to estimate significant parameters for the number of PT transfers. Therefore transfers were incorporated into the generalised PT time term with a weight of 10 minutes per transfer. This valuation is sourced from WebTAG Unit 3.10.2 para. 1.10.1, which quotes penalties of between 5 and 10 minutes per interchange. In the original PRISM estimations, it was possible to estimate separate transfer parameters for all purposes, and on average these gave relative valuations closer to 10 minutes than 5 minutes of IVT. Table 56 summarises the final PT LOS specification for these purposes.

Table 56: Final PT LOS specification, other home-based and NHB travel purposes

Component	Train	Metro	Bus
train time	PTGenTime		
metro time	PTGenTime	PTGenTime	
bus time	PTGenTime	PTGenTime	PTGenTime
access/egress time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
interchange walk time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	
initial wait time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
other wait time	PTGenTime (weight = 1)	PTGenTime (weight = 1)	PTGenTime (weight = 1)
transfers	PTGenTime (weight = 10)	PTGenTime (weight = 10)	PTGenTime (weight = 10)

5.3 Socio-economic terms

Travel behaviour varies across different socio-economic groups, and adding such effects to the models improves the fit of the models to the base data, and enables us to take account of the impact of changes in the distribution of the population across the segments in forecasting. For example, if car ownership increases in the future, the population will shift towards segments with higher car availability and this will impact on the future car driver and car passenger mode shares.

The starting points for the identification of the socio-economic terms in the final models were the socio-economic specifications identified in the original PRISM development work (RAND Europe, 2004a). Most terms remained significant when re-estimated with the new data, but some effects were no longer significant and were therefore dropped from the specifications. An important factor was that the total number of HIs available for model estimation was less than half that used in the original estimations, and therefore there were less data available to identify effects, particularly those terms that were not strongly significant in the original estimations.

The final stage was to compare the observed and predicted mode shares by socio-economic segment, and add additional terms to capture any new effects.

Nearly all of the socio-economic terms represented in the final model specifications, both old and new, are mode choice effects. However, there are a few distance terms, which are applied to all modes for specific socio-economic groups.

The following tables summarise the socio-economic effects identified for each of the travel purposes, and clarify which of the terms are new effects identified for the first time. A positive sign (+ve) indicates that the term increases the probability of the mode being chosen.

These tables include a number of car availability terms. The term ‘free car use’ is used to indicate persons from households where the number of licence holders is less than or equal to the number of cars, so each licence holder can drive if they wish. Conversely, 'car competition' indicates that the number of licence holders exceeds the number of cars so that competition exists for the cars in the household. Finally, the term 'passenger opportunity' is applied to car passenger if there is a car and at least one other licence holder in the household – at least one other person in the household able to offer a lift.

Table 57: Commuting socio-economic terms

Parameter name	Mode	Sign	Description	New term?
PTworkdist	all	−ve	part-time workers make shorter tours than other status groups	no
FreeCarUse	car driver	+ve	individuals in households with free car use are more likely to travel as a car driver	no
OneCarComp	car driver	−ve	individuals in single car households where there is competition for the car are less likely to travel as a car driver	no
PassOpt	car pass.	+ve	individuals in households were another household member can offer them a lift are more likely to travel as a car passenger	no
FreeUseCrP	car pass.	−ve	individuals in households where there is free car use are less likely to travel as a car passenger because they are more likely to drive	no
CarPMale	car pass.	−ve	males less likely to travel as a car passenger	no
TrnIncGt50k	train	+ve	individuals from households with incomes of over £50k p.a. are more likely to travel by train	yes
Trn_0cars	train	−ve	individuals from zero car households are less likely to travel by train	yes
Bus_0cars	bus	+ve	individuals from zero car households more likely to travel by bus	yes
BusMale	bus	−ve	males are less likely to travel by bus	no
Bus_17_24	bus	+ve	males aged 17-24 are less likely to travel by bus	no[15]
CycleMale	cycle	+ve	males are more likely to cycle	no
WalkMale	walk	−ve	males are less likely to walk	no

Two additional terms have been added to reflect that households with no cars, are less likely to use train and more likely to travel by bus. The pattern indicated by these terms is plausible, i.e. that lower income households with lower car ownership levels are more likely to use bus, and are less likely to travel by train. In addition, a constant has been placed on train to reflect higher use of train for individuals from households with higher incomes (£50k p.a. and above).

In addition to the socio-economic terms estimated to improve the mode choice and tour distance predictions, a number of socio-economic terms to better explain access mode choice for train and metro have been imported into the model from the original PRISM estimations. These terms are summarised in Table 58.

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[15] In the original version of PRISM, this term was applied to persons aged 16 to 24.

Table 58: **Commuting socio-economic terms, train and metro access mode choice**

Parameter name	Access mode	Sign	Description	New term?
CrDAccMale	car driver	−ve	males less likely to access by car as a driver than females	no
CrDAc16t19	car driver	−ve	individuals aged 16 to 19 less likely to access by car as a driver than persons aged 25-plus	no
CrDAc20t24	car driver	−ve	individuals aged 20 to 24 less likely to access by car as driver than persons aged 25-plus	no
CrDAcc1Car	car driver	−ve	individuals from households with one car are less likely to access by car as a driver than those in two-plus car households	no
CrPAccMale	car pass.	−ve	males are less likely to access by car as a passenger than females	no
CrPAc35t44	car pass.	−ve	persons aged 35 to 44 are less likely to access by car as a passenger than younger and older persons	no
CrPAcc0Car	car pass.	−ve	persons in zero car households are less likely to access by car as a passenger than from households with one or more cars	no

It is noted that the first two age terms cannot be implemented exactly in the new models, because the age bands in the 2009–2012 HI data do not align exactly with the age bands used in the train survey data used to estimate the train and metro access mode choice models. It has been assumed that the 16-19 term can be applied to 17-20 age band, and that the 20-24 term can be applied to the 21-24 age band.

Table 59: **Home–business socio-economic terms**

Parameter name	Mode	Sign	Description
PTWorkDist	all	−ve	part-time workers make shorter tours on average than other adult status groups
OneCarComp	car driver	−ve	individuals in single car households where there is competition for the car are less likely to travel by car as a driver

It is noted that in the original PRISM development work, car-driver-only distribution models were developed for home–business travel from road side interview data, and these models did not incorporate any socio-economic segmentation.

Table 60: **Home–primary education socio-economic terms**

Parameter name	Mode	Sign	Description	New term?
PassOpt	car pass.	+ve	students in households where another household member can offer them a lift are more likely to travel as a car passenger	no
CrP2PlCars	car pass.	+ve	students in households with two or more cars are more likely to travel as a car passenger	no
BsNoCars	bus	+ve	students in households with no cars are more likely to travel by bus	yes

An additional term has been added to the model specification to capture the fact that students in zero-car households are more likely to travel by bus.

Table 61: Home–secondary education socio-economic terms

Parameter name	Mode	Sign	Description	New term?
PassOpt	car pass.	+ve	students in households where another household member can offer them a lift are more likely to travel as a car passenger	no
CarPOneCar	car pass.	−ve	students in households with one car are less likely to travel as a car passenger than students from zero car or multi-car households	no
CyMale	cycle	+ve	males are more likely to cycle than females	yes

The car availability terms identified were present in the original model specifications, but an additional cycle term for men has been added to reflect the higher propensity of men to cycle.

Table 62: Home–tertiary education socio-economic terms

Parameter name	Mode	Sign	Description	New term?
CarComp	car driver	−ve	individuals from households where there is competition for the car are less likely to travel by car as a driver	no
PassOpt	car pass.	+ve	individuals in households where another household member can offer them a lift are more likely to travel as a car passenger	no
BusCarsge2	bus	−ve	individuals in households with two or more cars are less likely to choose bus	yes
WkCars2ge2	walk	−ve	individuals in households with two or more cars are less likely to choose to walk	yes
WkRet	walk	+ve	retired persons are more likely to walk	yes
CyHsize1	cycle	+ve	individuals from single person households are more likely to cycle	yes

Two new terms have been added to reflect the lower use of bus and walk in households with two or more cars. Additional terms have also been added reflect higher use of walk by retired persons, and greater cycle use by single person households.

Table 63: Home–shopping socio-economic terms

Parameter name	Mode	Sign	Description	New term?
OneCarFree	car driver	+ve	individuals in households with one car and free car use are more likely to travel as a car driver	no
2PlCarFree	car driver	+ve	individuals in households with two-plus cars and free car use are more likely to travel as a car driver	no
PassOp2Hh	car pass.	+ve	individuals in two person households where the other household member can offer them a lift are more likely to travel as a car passenger	no
PassOp3PHh	car pass.	+ve	individuals in three-plus person households where another household member can offer them a lift are more likely to travel as a car passenger	no
CarPFTstu	car pass.	+ve	full-time students are more likely to travel as a car passenger	no
CarPRetir	car pass.	+ve	retired persons are more likely to travel as a car passenger	no
CarPMale	car pass.	−ve	males less likely to travel as a car passenger	no
CarPDisab	car pass.	+ve	disabled persons more likely to travel as a car passenger	no

BusMale	bus	−ve	males less likely to travel by bus	no
BusNoCar	bus	+ve	persons in zero car households more likely to travel by bus	yes
SlowDisab	cycle & walk	−ve	disabled persons are less likely to choose to cycle or walk	no

An additional socio-economic term has been identified in the new home–shopping model to account for higher bus use by persons in zero car households.

The detailed specification of the car availability terms has been identified again from the new data. The free car use effect is stronger in two-plus car households. However, the passenger opportunity term is stronger in two person households than three-plus person households, as in three-plus persons households several people may be competing for a lift from a given driver.

In addition to the mode choice effects described in Table 63, a single socio-economic parameter on the car driver access mode to train and metro, 'CarD1Car', has been imported from the original PRISM estimations. This term reflects the fact that the car driver access mode to train and metro is less likely to be chosen by persons in single car households than by persons in households with two or more cars.

The socio-economic parameters in the new home–escort model are summarised in Table 64.

Table 64: Home–escort socio-economic terms

Parameter name	Mode	Sign	Description
OneCarComp	car driver	−ve	individuals in single car households where there is competition for the car are less likely to travel by car as a driver
PassOpt	car pass.	+ve	individuals in households where another household member can offer them a lift are more likely to travel as a car passenger
BusNoCar	bus	+ve	individuals in households with no cars are more likely to choose bus
BusFemale	bus	+ve	females are more likely to choose bus
HHchild	walk	+ve	persons from households with children are more likely to choose walk

It is noted that escort travel was not recorded as a separate travel purpose in the 2001 HI data used to develop the original version of PRISM, and so there is no existing socio-economic segmentation to compare to. It is also emphasised that the mode that is modelled in the home–escort model is the mode chosen by the individual who is doing the escorting. So if the escort purpose is car driver, the individual being escorted is a car passenger.

Table 65: Other travel socio-economic terms

Parameter name	Mode	Sign	Description	New term?
LAFdist	all	−ve	persons whose status is looking after the family make shorter tours on average	yes
FreeCarUse	car driver	+ve	individuals in households with free car use are more likely to travel by car as a driver	no
PassOp2Hh	car pass.	+ve	individuals in two person households where the other household member can offer them a lift are more likely to travel as a car passenger	no
PassOp3PHh	car pass.	+ve	individuals in three-plus person households where another household member can offer them a lift are more likely to travel as a car passenger	no
CarP5t11	car pass.	+ve	individuals aged 5 to 11 more likely to travel as a car passenger	no[16]
CarPRet	car pass.	+ve	retired persons are more likely to travel as a car passenger	no
CarPMale	car pass.	−ve	males are less likely to travel as a car passenger	no
BusUemp	bus	+ve	unemployed persons are more likely to travel by bus	no
BusFemale	bus	+ve	females are more likely to travel by bus	yes
BusNoCar	bus	+ve	individuals from zero car households are more likely to travel by bus	yes
BikeMale	cycle	+ve	males are more likely to cycle	yes
SlowDisab	cycle & walk	−ve	disabled persons are less likely to choose to cycle or walk	no

A new distance term has been identified in the new model to reflect lower mean tour distances by persons whose status is looking after the family. In the home–other model from the original version of PRISM, a distance term was applied to full-time workers but this effect was not significant in the new model.

Three more socio-economic terms have been added to the model specification. Consistent with the new commuting and shopping models, a term has been identified to reflect higher bus usage by individuals from zero car households. Two additional gender effects have also been identified for the bus (women) and cycle (men) modes.

In addition to the socio-economic parameters for tour distance and main mode choice, a number of socio-economic parameters that explain variations in train and metro access mode choice have been imported from the home–other model developed for the original version of PRISM. These terms are summarised in Table 66.

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[16] In the original version of PRISM this term was applied to persons aged 5 to 12, the definition of the term has been revised to reflect the age bands used in the new 2009-2012 HI survey.

Table 66: Home–other travel socio-economic terms, train and metro access mode choice

Parameter name	Access mode	Sign	Description	New term?
CrDAc16t19	car driver	−ve	individuals aged 16 to 19 are less likely to access by car as a driver than persons aged 25-plus	no
CrDAc20t24	car driver	−ve	individuals aged 20 to 34 are less likely to access by car as a driver than persons aged 25-plus	no
CrDAcc1Car	car driver	−ve	individuals from households with one car are less likely to access by car as a driver than those in two-plus car households	no
CrPAcc0Car	car pass.	−ve	persons in zero car households are less likely to access by car as a passenger than from households with two or more cars	no
CrPAcc1Car	car pass.	−ve	persons in one car households are less likely to access by car as a passenger than from households with two or more cars	no

Note that because the age bands in the 2009–2012 HI data do not align exactly with the age bands used in the train survey data used to estimate the train and metro access mode choice models, it has been assumed that the 16-19 term can be applied to 17-20 age band, and that the 20-24 term can be applied to the 21-24 age band.

The estimation samples in the three PD-based tours models were small, with between 34 and 86 observations per purpose. Therefore it was not possible to identify any significant socio-economic parameters in this model.

No socio-economic parameters were identified in the work–work detour model.

Table 67: Work-other detour socio-economic terms

Parameter name	Mode	Sign	Description
PTworkdist	all	−ve	part time workers make shorter detours on average compared to adults in other status groups
CarComp	car driver	−ve	individuals in households where there is car competition are less likely to choose car driver than individuals from households with free car use

The negative distance parameter for part-time workers is consistent with the terms that have been identified in the commute and home–business models, and so there is a consistent pattern for work-related travel purposes of shorter tour and detour lengths for part-time workers relative to other adult status groups.

Table 68: Other-other detour socio-economic terms

Parameter name	Mode	Sign	Description
PassOpt	car pass.	−ve	individuals in households where another household member can offer them a lift are more likely to travel as a car passenger

Only one socio-economic parameter has been identified in the new other-other detour model, to reflect higher use of car passenger for detours made by individuals in households where another household member is able to offer a lift.

5.4 Attraction variables, destination effects and HB tour mode constants

5.4.1 Attraction variables

For commute and home–other travel, most of the model tests were undertaken using the BRES employment data to define attraction terms for core, intermediate and external destinations because the IDBR employment data only became available towards the end of the model development process. When the final model specifications for these purposes were re-run using the IDBR data to specify the employment attractions for the core area, substantial improvements in model fit were observed, indicating that the IDBR data better explains the observed choices to core destinations. As discussed in Section 4.3.1, for zones in the core region the IDBR and BRES data have been combined by rescaling the IDBR data to match BRES control totals for total employment for each of the seven districts that make up the core West Midlands Metropolitan Area.

For home–tertiary travel, a number of different specifications were tested to determine the best specification for the attraction (size) variables. The final specification selected uses tertiary enrolments[17] as the base size variable, and has additional size terms for total employment, with separate size parameters identified for total employment for full-time students and other adults.

The use of total employment terms reflects the fact that some home–tertiary tours are observed to destinations where there are no tertiary enrolment data. Investigations by Mott MacDonald have revealed these can occur for a number of reasons. There are some education establishments that do not appear in government databases, in other cases there are locations where individuals travel for training that would not appear in government educational databases, for example a St John Ambulance centre. The size variables for total employment are segmented into full-time students and others, because the relative attractiveness of the total employment size term is lower for the full-time students group. This result is expected because these individuals are more likely to travel to the education establishments captured in the government databases.

For home–escort travel, a diverse range of size variables has been included in the final model specification, with total employment, population, primary enrolments and secondary enrolments included. The range of size variables reflects the diverse range of different travel purposes which are being escorted, with total employment representing the attractiveness of zones for escort to work tours, population representing the attractiveness of zones for e.g. escort to friends travel, and primary and secondary enrolments representing the attractiveness of zones for escort to school travel. The size variables for primary and secondary enrolments are applied only if there is at least one infant or child in the household.

Five different specifications were tested to describe the attractiveness of destinations for home–other travel:

1. population and total employment as size variables
2. population, total employment and retail employment as size variables

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[17] Specifically tertiary enrolments plus further education enrolments.

3. population, total employment, retail employment and service employment as size variables
4. population, total employment and service employment as size variables
5. population, retail employment and service employment as size variables

It was clear from the results of models 3 and 4 that the total employment and retail employment information was highly correlated. The fifth specification gave the best overall fit to the data, so has been retained as the final model specification. It is noted that this is also the specification for the size variables that was identified for home–other travel in the original PRISM estimations (RAND Europe, 2004a).

For the two NHB models that represent travel to work-related SDs, total employment has been used as the attraction variable, consistent with the attraction variables used for the commute and home–business models.

For the four NHB models that represent travel to other SDs, size variable specifications have been determined with population specified as the base size variable, plus additional size terms for service employment and retail employment if these gave a significant improvement in fit to the data. These tests were based upon the specifications tested for home–other travel.

The attraction variables identified in the final model specifications are summarised in Table 69.

Table 69: Final attraction variables by purpose

Purpose	Attractions
commuting	total employment
home–business	total employment
home–primary education	primary enrolments
home–secondary education	secondary enrolments
home–tertiary education	tertiary + further education enrolments total employment
home–shopping	retail employment
home–escort	total employment population primary enrolments secondary enrolments
home–other travel	population service employment retail employment
PD-based tours, work-related PD to work-related SD	total employment
PD-based tours, work-related PD to other SD	population retail employment
PD-based tours, other PD to other SD	population service employment
detours during work-related tours to work-related SDs	total employment
detours during work-related tours to other SDs	population service employment retail employment
detours during other tours to other SDs	population service employment

5.4.2 Destination effects

Intrazonal constants

Intrazonal tours are tours that have the same origin and destination zone. For PT modes, there is no level-of-service information for intrazonal trips and therefore intrazonal trips are always set to be unavailable. However, for modes that use highway LOS (car driver, car passenger, cycle and walk) intrazonals are available, using LOS generated using the ‘nearest neighbour’ assumption discussed in Section 3.1.1.

The nearest neighbour assumption provides an approximation of the LOS for intrazonal movements, so this LOS would be expected to have greater uncertainty than the LOS for interzonal movements. Therefore intrazonal destination constants have also been tested, to investigate whether constants are required in the models so that the fractions of intrazonal tours observed in the 2009-2012 HI data are replicated. These constants have been identified by initially estimating an ‘IntraDest’ constant, estimated across the four modes that use the highway LOS, plus mode-specific constants for car passenger, cycle and walk modes that are estimated relative to car driver. However, only some of these effects were significant in magnitude and so not all of the terms have been retained in the final model specifications. Table 70 summarises the intrazonal terms retained in the final model specifications.

Table 70: Final specifications of intrazonal terms

Purpose	All modes constant	Car driver constant	Car pass. constant	Cycle constant	Walk constant
commuting					
home–business	✓				✓
home–primary education	✓				
home–secondary education	✓				✓
home–tertiary education					
home–shopping					✓
home–escort	✓		✓		✓
home–other travel	✓		✓		✓
PD-based tours, work-related PD to work-related SD					
PD-based tours, work-related PD to other SD					
PD-based tours, other PD to other SD					
detours during work-related tours to work-related SDs			✓		
detours during work-related tours to other SDs					
detours during other tours to other SDs	✓	✓			

For commuting, no significant intrazonal terms were identified.

No intrazonal tours were observed for home–tertiary education and therefore no intrazonals terms could be estimated for this purpose.

For the three PD-based tour purposes, where the sample sizes are small, no significant intrazonal terms were identified. No significant intrazonal terms were identified in the work–other detour model either.

Central Business District terms

Consistent with the original version of PRISM, Central Business District (CBD) destination effects have been tested by defining CBD zones as any of the zones listed in Table 125 (Appendix B) with a non-zero parking cost.

For each travel purpose, the following CBD destination terms have been tested:

- an all-modes CBD destination constant
- a train CBD destination constant
- a metro CBD destination constant
- a bus CBD destination constant

Specific terms have been tested for PT modes based on our experience from the original PRISM development work and other modelling studies that positive CBD destination terms are often required for PT modes because the PT mode shares to CBD destinations may be higher than can be explained on the basis of LOS alone. These terms may proxy for effects such as perceived difficulties in using car to access CBD locations, and the fact that many PT services run directly to CBD locations and this increased attractiveness may not be fully represented through the LOS parameters.

Table 71 summarises the CBD destination terms identified in the final model specifications, and indicates whether the effect has a positive or negative impact on the likelihood of a CBD destination being chosen. No CBD destination terms have been tested for primary or secondary education purposes because these activities are not concentrated at CBD locations.

Table 71: Final specifications of CBD terms

Purpose	All modes constant	Train constant	Metro constant	Bus constant
commuting		+ve		
home–business		+ve		
home–tertiary education	−ve	+ve		
home–shopping	−ve			
home–escort	+ve			−ve
home–other travel	−ve	+ve	+ve	+ve

As expected, all of the PT terms except the home–escort term for bus are positive, as PT is more attractive when travelling to CBD zones than indicated by the LOS alone. This result may reflect perceived difficulties in parking in CBD zones, as well as the fact that many PT services directly serve CBD zones. The sign of the all modes constant is less significant, it simply indicates the average effect required to match the observed share of tours that travel to the CBD.

No significant CBD effects have been identified in the NHB models.

5.4.3 HB tour mode constants for NHB travel

Table 72 summarises the significant HB tour mode constants that have been identified in the final NHB model specifications. The HB tour mode constants reflect the higher probability of using the HB tour mode when choosing which mode to use to make the NHB tour or detour. Due to limited sample sizes, not all of the modes are represented in the NHB models: modes which have not been modelled because of lack of data are shaded in grey.

Table 72: Home-based tour mode constants

NHB purpose	Car driver	Car pass.	Train	Metro	Bus	Walk	Cycle
PD-based tours, work-related PD to work-related SD				▨			▨
PD-based tours, work-related PD to other SD			▨	▨			▨
PD-based tours, other PD to other SD		✓	▨	▨			▨
detours during work-related tours to work-related SDs	✓			▨	✓		▨
detours during work-related tours to other SDs	✓	✓	✓		✓		▨
detours during other tours to other SDs	✓	✓	✓		✓	✓	

As would be expected, HB tour mode constants have been identified for the majority of the modes that are available in the three detour models. As these models represent the choice of mode for detours made in the course of a HB tour, the HB mode and detour mode would be expected to be the same in a higher proportion of cases. For PD-based tours, which are made separately from the outward and return legs of the HB tour, the HB tour mode and PD-based tour mode are less likely to be the same, and as a result only one significant HB tour model has been identified across the three PD-based tour models.

5.5 Park-and-ride models

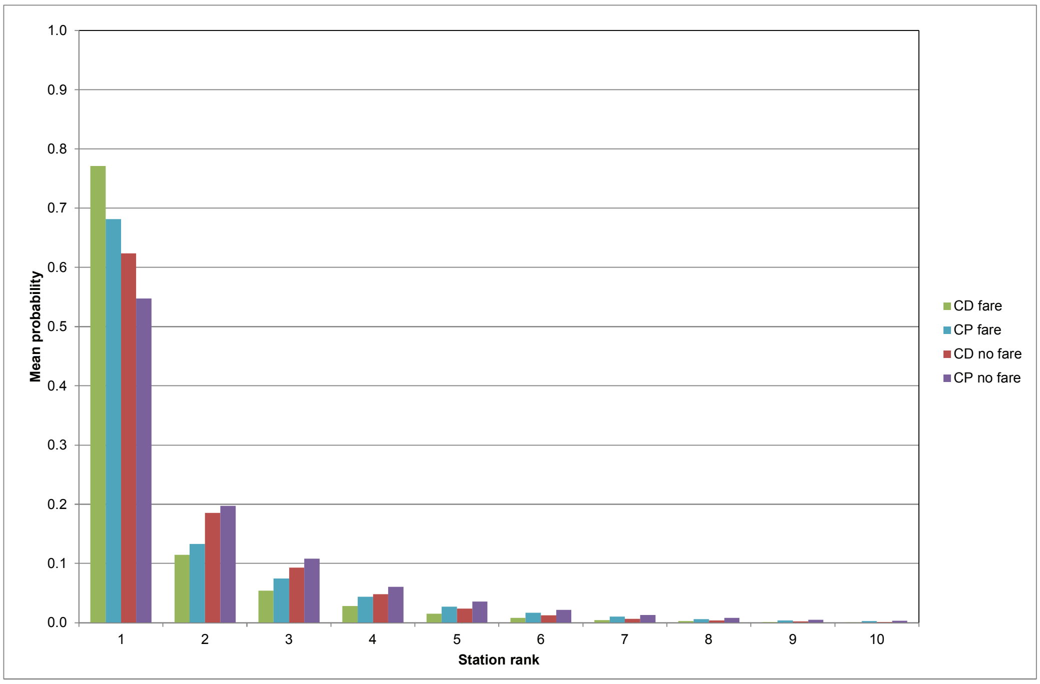
As documented in Section 4.4, the parameters for the P&R models have been imported from the models estimated for the previous version of PRISM and so there are no new parameter estimates to report.

For commute, home–shopping and home–other travel, models with and without the P&R sub-models have been estimated so that in application forecasts for these purposes can be generated with and without the P&R sub-models. The ‘S = 0’ version of these models exclude the P&R sub-model, and so represent all access to train and metro as ‘other access’, which means access by walk, cycle and bus. The S = 0 versions of the model offer faster run times. The ‘S = 3’ version of these models includes the P&R sub-model, and for car access represents the choice between the three most attractive stations for each OD pair.

To validate that the P&R models are working correctly, the probability of the top ten ranked stations for each OD pair has been calculated. For each OD pair, the top ranked stations are identified on the basis of the LOS for the car access and train legs, and for P&R access the number of P&R spaces.

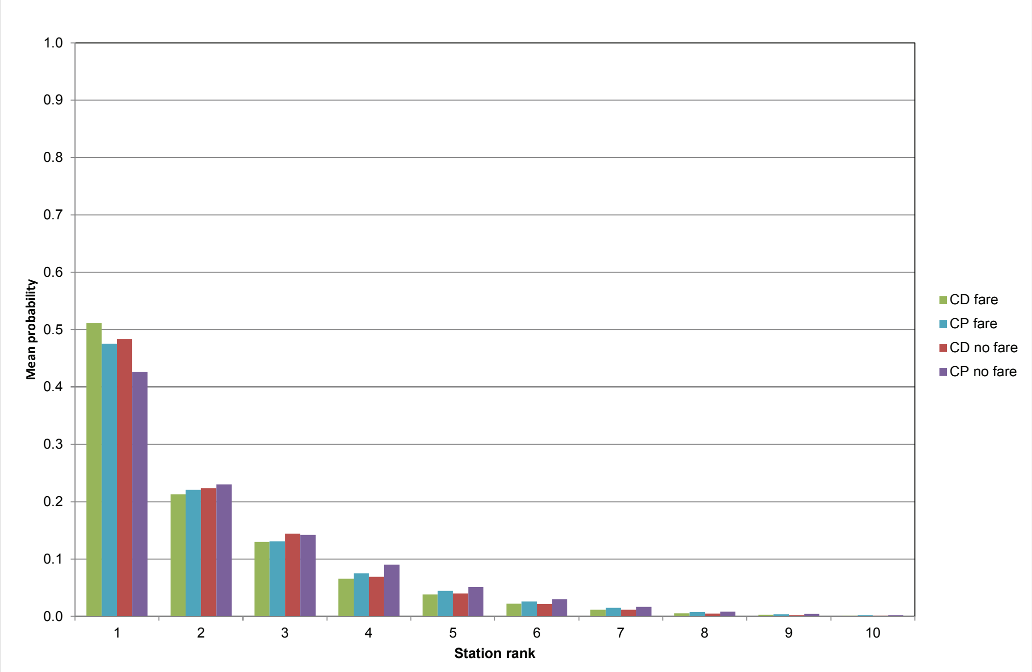
The validation step ensured that the process is correctly ranking the different P&R alternatives for each OD pair, and provided a check that the decision to model the 3 most attractive station options for OD pair, rather than a higher number of station alternatives, remained valid. In each plot, the rankings are presented separate for car driver and car passenger access modes, and for no fare (those with PT passes that offer travel at zero marginal cost) and fare segments. The P&R models are applied separately for the no fare and fare segments because in the no fare segment, travellers are not sensitive to the marginal cost of their PT journey and this impacts upon the stations that they are predicted to use. The station rankings are also generated separate for car driver (CD) and car passenger (CP) access modes. For car driver access, the attractiveness of different station alternatives depends on the number of P&R spaces provided, whereas for car passenger access all stations are equally attractive.

Figure 8: Validation of commute station choice rankings for train



The percentage of demand that is predicted to use the top 3 ranked stations varies between 85% for the car passenger no fare segment to 94% for the car driver no pass segment. This level of concentration of the demand in the top 3 ranked suggestions indicates that the decision to represent the top 3 ranked stations remains valid.

Figure 9: Validation of commute station choice rankings for metro



The average probabilities of station choices are less concentrated at the top ranked station for metro. Nonetheless, the top three ranked stations capture 80-85% of the demand across the top ten ranked stations.

The same set of analysis has been made for home–shopping and home–other travel. For home–shopping, the top three ranked stations capture at least 98% of train demand from the top ten ranked stations, and at least 94% of metro demand from the top 10 ranked stations. For home–other, the top three ranked stations capture at least 84% of train demand from the top ten ranked stations, and at least 77.0% of metro demand from the top 10 ranked stations.

Overall, while the degree to which demand is concentrated at the top three ranked stations varies between purposes, the decision to model the top three ranked stations rather than a higher number was judged to be valid and therefore this number of stations has been retained in the final models. It should be noted that no demand is lost by representing the top three ranked stations for each OD pair, rather than a higher number of station alternatives. Instead, total P&R demand for a given OD pair is allocated over the most three attractive stations, rather than over all possible station alternatives including those with a very low probability of being used.

5.6 Structural tests

The final model structures are presented in the following tables. Choices represented at the highest level in the structure are least sensitive to changes in utility, and then the sensitivity increases working down to the lowest and most sensitive choice. In the tables presented below, the sensitivities are presented relative to the highest level choice, which is main mode choice for all of the models (the least sensitive choice). The tables present the structural parameters which indicate the sensitivity of the choices relative to main mode choice. The t-ratios for the structural parameters are given in brackets and express the significance of the structural parameter estimated relative to a value of one. If the parameter is constrained to a particular value this is indicated by an asterisk in brackets. If the structural parameter for adjacent choices is constrained to a value of one, this means that the choices are effectively at the same level in the choice hierarchy and are equally sensitive to changes in utility (a multinomial structure).

Purposes where train and metro access mode and station choice is modelled

For the three model purposes where train and metro access mode and station choice is modelled, five different choice responses are included and therefore up to four structural parameters can be identified. However, the two structural parameters for the train & metro access mode and station choices were imported from the original PRISM models rather than being re-estimated, and therefore a maximum of two new structural parameters were estimated in the newly estimated models.

Table 73 summarises the final structural parameters for commute and home–shopping.

Table 73: Final model structure, commute and home–shopping

Choice	Commuting	Home–shopping
main mode choice		
car driver time period choice	1.00 (*)	1.00 (*)
train & metro access mode choice	1.00 (*)	1.00 (*)
destination choice	0.78 (4.6)	0.42 (12.7)
train & metro station choice	0.33 (*)	0.40 (*)

For commuting and home–shopping, the main mode, car driver time period and train & metro access mode choices are all at the same level in the choice hierarchy. In both models, it was not possible to simultaneously estimate two structural parameters for the car driver time period choice and destination choices, and there was little difference in fit to the data between restricted models with main modes and time periods at the same level in the hierarchy above destinations, and restricted models with main mode choice above multinomial time periods and destinations. WebTAG 3.10.3, para. 1.11.17, indicates that the sensitivity of the choice between relatively long time periods, such as three hours or so, should be about the same as that of main mode choice. Therefore the models with time period choice constrained to be at the main mode choice level were selected ensuring consistency with that guidance. Destination choice is more sensitive (lower in the structure) than main mode choice; again this is consistent with WebTAG guidance.

The sensitivities of the train & metro station choice relative to train & metro access mode choice have been imported from the original PRISM estimations. It can be seen that these imported values mean that the train & metro station choice is the most sensitive choice in the model structure.

Table 74: Final model structure, home–other travel

Choice	Home–other travel
main mode choice	
car driver time period choice	1.00 (*)
train & metro access mode choice	1.00 (*)
train & metro station choice	0.43 (*)
destination choice	0.27 (23.3)

For home–other travel, destination choice is the lowest level (most sensitive choice), with a sensitivity slightly higher than that for train & metro station choice. Car driver time period choice is at the same level in the choice hierarchy as main mode choice.

As per the commute and home–shopping models, it was not possible to simultaneously estimate structural parameters for the car driver time period choice and destination choices. Therefore time period choice needed to be fixed to either the main mode or destination choice levels in the structure. There was very little difference in model fit between the two model structures and therefore time period choice was constrained to be at the main mode choice level consistent with WebTAG guidance.

Remaining purposes where time period choice is modelled

Table 75 summarises the results of the structural tests for home–business and home–escort purposes.

Table 75: Final model structures, home–business and home–escort

Choice	Home–business	Home–escort
main mode choice car driver time period choice destination choice	 1.00 (*) 0.19 (7.7)	 1.00 (*) 0.47 (7.2)

For both purposes, in the final model structure main mode and car driver time period choices are at the same level in the choice hierarchy, and destination choice is the lowest level (most sensitive choice). For home–business, destination choice is much more sensitive than main mode choice. Both model structures are consistent with WebTAG guidance.

Purposes where only main mode and destination choices are modelled

The final model structures for the three home–education purposes are summarised in Table 113.

Table 76: Final model structures, home–education purposes

Choice	Home–primary education	Home–secondary education	Home–tertiary education
main mode choice destination choice	1.00 (*)	0.58 (5.5)	0.69 (3.3)

In the primary education model, the structure parameter for the relative sensitivity of main mode and destination choice was not significantly different from one, and therefore in the final model specification the parameter has been constrained to a value of one. For both home–secondary and home–tertiary education, the final structure has modes above destinations, consistent with WebTAG guidance.

The final model structures for the NHB models are summarised in Table 77.

Table 77: Final model structures, PD-based tour models

Choice	Work-related PD to work-related SD	Work-related PD to other SD	Other PD to other SD
main mode choice destination choice	1.00 (*)	1.00 (*)	1.00 (*)

For all three of the PD-based tour models, it was not possible to identify a significant structural parameter and therefore the final model structures all have main mode choice and destination choice at the same level in the structure.

Table 78: Final model structures, detour models

Choice	Work-related PD to work-related SD	Work-related PD to other SD	Other PD to other SD
main mode choice destination choice	1.00 (*)	1.00 (*)	0.25 (10.5)

The only model where it was possible to identify a structural parameter this is significantly different from one is the other-other detour model, were the structure is modes above (less sensitive than) destinations.

CHAPTER 6 Model validation

6.1 Elasticity tests

The following elasticity validation tests have been run for four policy tests:

- a 10% increase in fuel cost
- a 10% increase in car time
- a 10% increase in PT fares, including both cash fares and season tickets
- a 10% increase in PT IVT.

The 10% increases are applied uniformly across all origin–destination pairs. The elasticities are then calculated using the constant elasticity formulation:

$$\boxed{E_{m,p} = \frac{\ln\left(\frac{D_{m,p}}{D_{m,b}}\right)}{\ln\left(\frac{110}{100}\right)}} \qquad (6.1)$$

where: $E_{m,p}$ is the elasticity for mode m under policy p

$D_{m,p}$ is the demand for mode m under policy p

$D_{m,b}$ is the demand for mode m in the base case b

It should be emphasised that the elasticities are first order elasticities only; they do not take into account network effects. When the models are applied iteratively, so that changes in demand impact on the supply costs, the fuel cost elasticities would be expected to be slightly lower because of network effects damping the model response. The car time elasticities will be by run for one iteration only, as the guidance in WebTAG Unit 3.10.4.

For those HB tour purposes where time period choice has been incorporated for car driver choices, an additional elasticity test has been run to validate the sensitivity of the time period choice model. In this test, a 10% increase to *outward* travel times in the AM peak has been applied, and the impact on the predicted demand across time period alternatives has been calculated. It is noted that as well as causing switching between time period alternatives, this test results in some demand shifting to other modes and so these mode shifts have also been calculated.

Equation (6.1) was also used to present the elasticities calculated during the gamma cost sensitivity tests presented in Section 5.1.1. The elasticity values presented in this section are calculated from the final model specifications.

6.1.1 Mode and destination elasticities

Table 79 summarises the car time and fuel cost elasticities for car driver for each of the HB purposes. The total elasticity values have been calculated by summing the tours and kilometres over purposes for the base and elasticity runs, and then calculating elasticities from the changes in total demand and kilometres.

Table 79: Fuel cost and car time elasticities by purpose

Purpose	Tours/detours		Kilometres	
	Fuel cost	Car time	Fuel cost	Car time
commuting	-0.061	-0.096	-0.351	-0.640
home–business	-0.002	-0.028	-0.071	-1.326
home–tertiary education	-0.094	-0.162	-0.297	-0.620
home–shopping	-0.040	-0.150	-0.095	-0.933
home–escort	-0.088	-0.168	-0.304	-0.746
home–other travel	-0.040	-0.076	-0.237	-0.968
PD-based work–work tours	-0.053	-0.102	-0.063	-1.313
PD-based work–other tours	-0.182	-0.819	-0.163	-1.630
PD-based other–other tours	-0.150	-0.259	-0.410	-0.654
work–work detours	-0.009	-0.051	-0.142	-0.774
work–other detours	-0.004	-0.032	-0.104	-0.842
other–other detours	-0.005	-0.014	-0.139	-0.704
Total elasticity	-0.051	-0.101	-0.247	-0.858

The total fuel cost kilometrage elasticity is −0.247, at the bottom end of the −0.25 to −0.35 range indicated in WebTAG Unit 3.10.4. Lower elasticity is observed for home–business, as would be expected, but also for home–shopping where despite a number of model tests it was not possible to obtain a model with a higher elasticity value. The fuel cost elasticities for commute lie at the top end of the WebTAG range, whereas those for home–tertiary education and home–escort lie in the middle of the WebTAG range. For home–other travel, the elasticity is slightly lower than the WebTAG all-purpose range.

The overall car time kilometrage elasticity of -0.858 is reasonable; the only guidance in WebTAG Unit 3.10.4 is that the trip elasticities should not exceed -2.0. The difference between the tour/detour and kilometrage elasticities is significant and demonstrates that the main response in the models to increases in fuel cost is destination switching, with only small mode shift responses.

Table 80 summarises the PT fare and IVT elasticities for each of the HB purposes. Total PT demand has been calculated by summing over bus, metro and train demand. The total elasticity values have again been calculated from the changes in total demand kilometres summed over purposes.

Table 80: Public transport fare and in–vehicle time elasticities by purpose

Purpose	Tours		Kilometres	
	PT fare	PT IVT	PT fare	PT IVT
commuting	-0.365	-0.400	-0.617	-0.808
home–business	-0.048	-0.170	-0.115	-0.778
home–primary education	-0.488	-0.928	-0.496	-1.531
home–secondary education	-0.802	-0.493	-1.019	-0.978
home–tertiary education	-0.226	-0.249	-0.369	-0.664
home–shopping	-0.121	-0.347	-0.191	-0.825
home–escort	-0.694	-0.338	-0.642	-0.774
home–other travel	-0.159	-0.246	-0.448	-0.769
PD-based work-work tours	-0.162	-0.479	-0.431	-1.158
PD-based work-other tours	-0.074	-0.958	-0.086	-1.575
PD-based other-other tours	-0.755	-0.764	-0.822	-1.256
work-work detours	-0.128	-0.361	-0.594	-1.046
work-other detours	-0.194	-0.528	-0.425	-1.139
other-other detours	-0.118	-0.120	-0.202	-0.628
Total elasticity	-0.302	-0.357	-0.487	-0.811

WebTAG Unit 3.10.4 states that PT fare elasticities trip should lie in the range −0.2 to −0.9 for changes over a period longer than a year. The overall PT fare tour elasticity lies in this range. The tour elasticities for home–business lie outside of this range, however lower values would be expected for this purpose. The shopping model, which has low sensitivity to cost changes, also has tour elasticities below the −0.2 to −0.9 range, as do five of the six NHB models.

No guidance values are provided in WebTAG Unit 3.10.4 for PT IVT elasticities. On the basis of our experience from other studies the values in Table 80 seem reasonable.

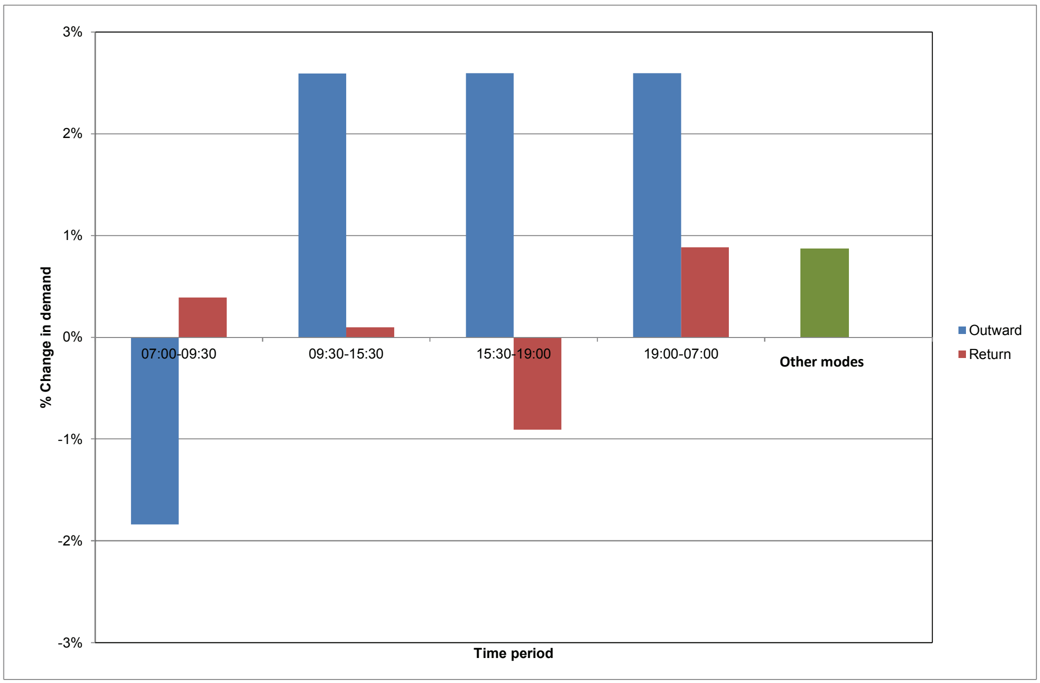
6.1.2 Car driver time period elasticities

These tests have only been made for those models that model car driver time period choice, specifically commute, home–business, home–shopping, home–escort and home–other travel. For the remaining HB purposes, and all of the NHB purposes, fixed time period factors are used.

The time period choice elasticities tests are run by making 10% increases to the travel times for AM peak outward tour leg travel times, simulating the impact of increases in AM peak congestion, and calculating the resulting shifts in car driver demand for each outward and return time period, and the amount of demand that shifts to other modes.

Figure 10 plots the impact of a 10% change to outward travel times in the AM peak period for commute.

Figure 10: Commute time period choice model, AM peak outward period elasticity test results



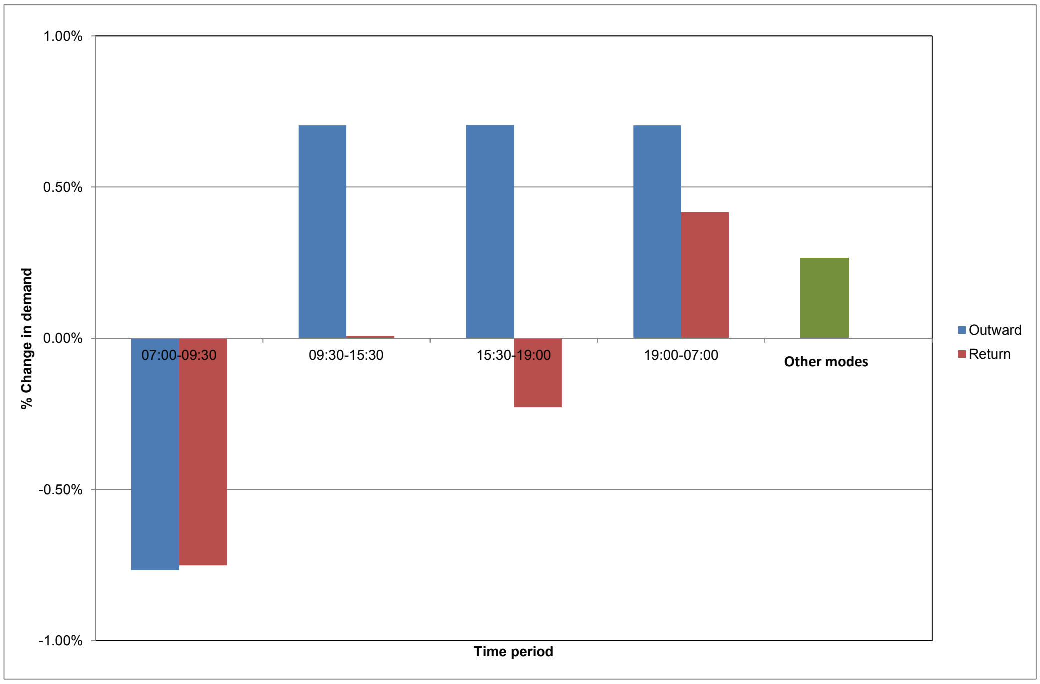
The 10% increase in outward AM peak travel time results in a 1.84% decrease in demand travelling out in the AM peak, giving a direct elasticity of -0.195. As the choice between time period combination alternatives is multinomial, equal percentage increases in demand of 2.59% are observed in the other three outward time periods.

The percentage of tours returning in the PM peak decreases because demand for the AM peak out PM peak return combination has decreased, whereas the numbers of tours returning in the inter-peak and off-peak periods increases because more tours are departing in the off-peak and the inter-peak periods. These changes indicate that the time period choice model is responding plausibly to increase congestion in the AM peak.

Demand for other modes increases by 0.87% in this test, which is equivalent to a cross-elasticity of 0.091.

Figure 11 plots the impact of a 10% change to outward travel times in the AM peak for home–business travel.

Figure 11: Home–business time period choice model, AM peak outward period elasticity test results



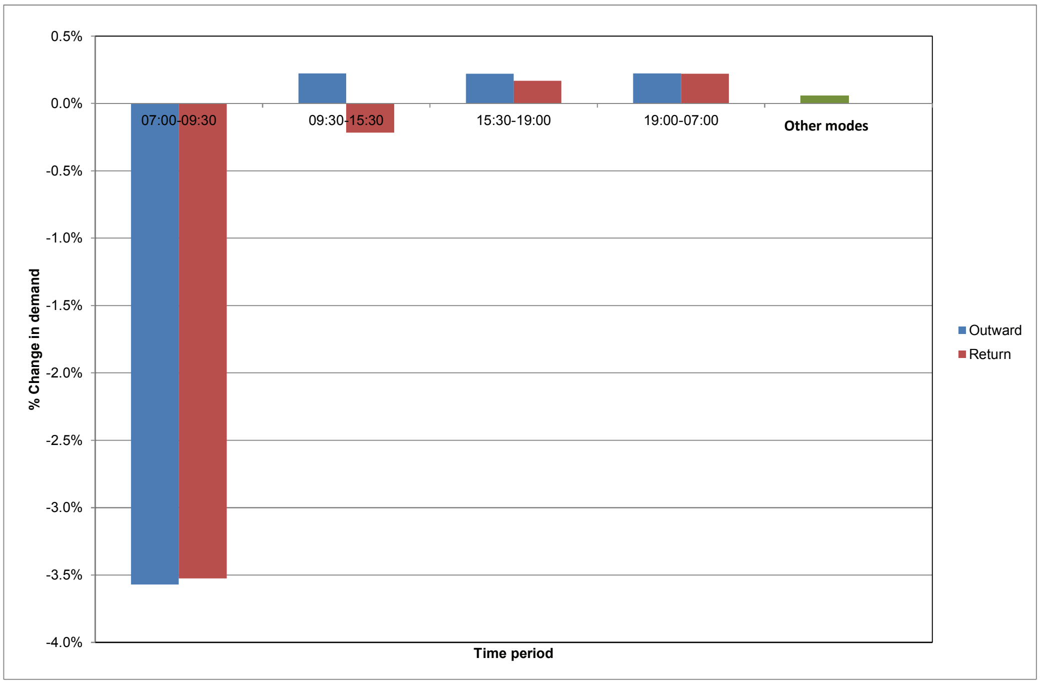
The 10% increase in outward travel times in the AM peak leads to a 0.77% reduction in demand for travel in that outward time period, giving a direct elasticity of just -0.081. As was observed for commute, uniform increases in the percentage of demand departing in other outward time periods are observed because the choice between time-period combination alternatives is multinomial.

More than three quarters (76 %) of business tours that depart in the AM peak return in the PM peak, and so the increase in outward AM peak travel times leads to a reduction in the number of tours that return in the PM peak. The only business tours in the estimation sample that return in the AM peak also depart in the AM peak, and therefore the largest percentage reduction in the return distribution is observed for the AM peak period. The key response to the test is an increase in the number of tours that return in the off-peak, and a 0.27% increase in demand for other models, equivalent to a cross-elasticity of 0.028.

Overall car driver time period choice in the home–business model is relatively insensitive to changes in travel times.

Figure 12 plots the impact of a 10% increase in outward AM peak time travel times for the home–shopping model.

Figure 12: Home–shopping time period choice model, AM peak outward period elasticity test results



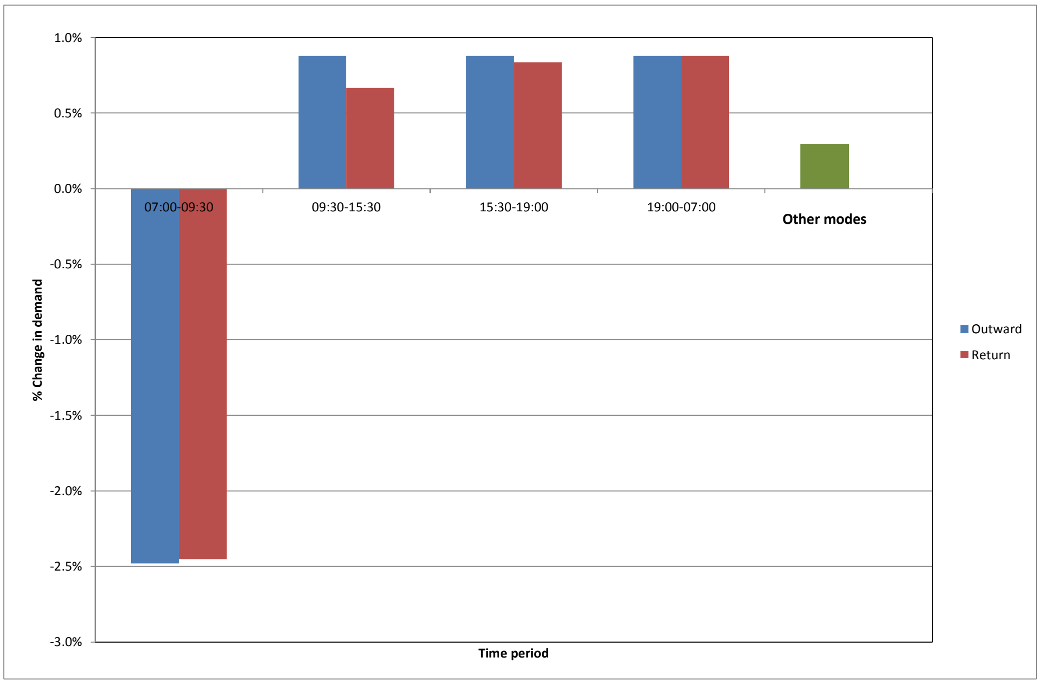
For home–shopping, the proportion of outward tours that depart in the AM peak is much lower than form home–work and home–business, and therefore the impact of the elasticity test on outward AM peak demand is higher than in the equivalent tests for the commuting and home–business models. The 3.57% reduction in outward AM peak demand is equivalent to an elasticity of -0.381.

For the return time period distribution, while the biggest response in percentage terms is for tours in the AM peak (because all of the shopping tours in the estimation sample that return in the AM peak also depart in the AM peak), the period with the largest reduction in demand is the inter-peak period.

Demand for other modes increases by 0.06% in this test, equivalent to a cross-elasticity of just 0.006. This cross-elasticity is lower than the commute values because main mode choice is less sensitive than time period choice in the shopping model.

Figure 13 plots the impact of a 10% increase in outward AM peak time travel times for the home–escort model.

Figure 13: Home–escort time period choice model, AM peak outward period elasticity test results

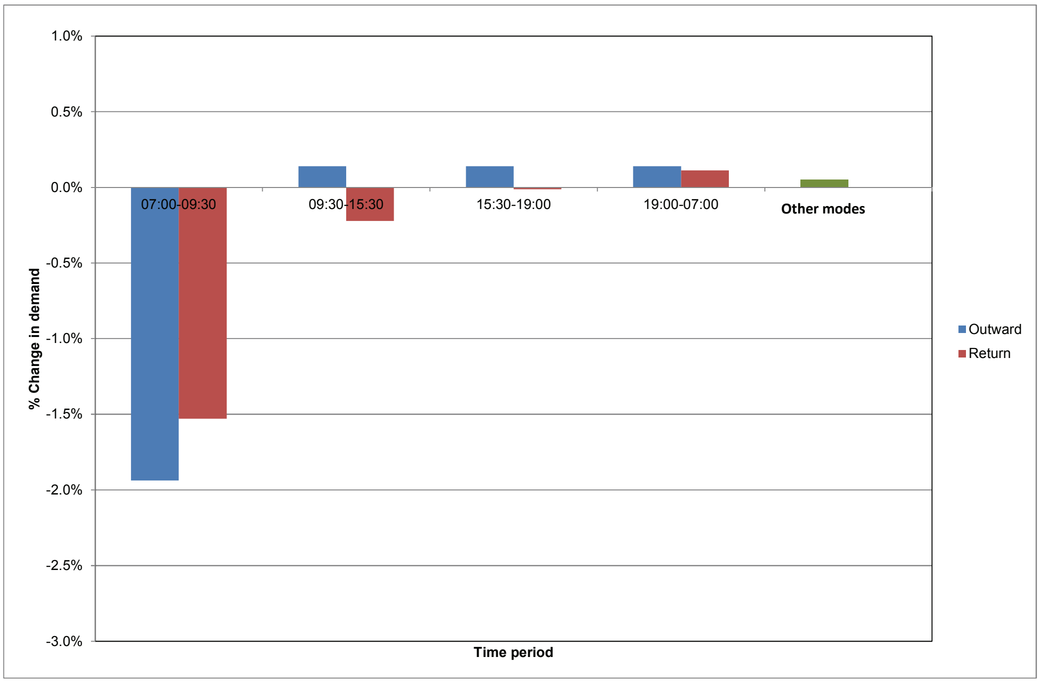


Demand in the AM peak outward period decreases by 2.43% in this test, giving a direct elasticity of −0.263. Demand for all other outward time periods increases by the same percentage as expected.

Most escort tours are short in duration, and so the outward and return time periods are equal. As a result, the changes in the outward and return time period distributions are similar.

Figure 14 plots the impact of a 10% increase in outward AM peak time travel times for the home–other travel model.

Figure 14: **Home–other travel time period choice model, AM peak outward period elasticity test results**



For home–other travel, the percentage of base demand travel that travels out in the AM peak is low at just 6.7%, and so in the impact of the increase in AM peak travel times is relatively large in percentage terms. The reduction in outward AM peak demand of 1.94% is equivalent to a direct elasticity of -0.205, similar to the value observed for home–shopping.

For the return time period distribution, whilst the biggest response in percentage terms is for tours returning in the PM peak, s the largest change is the reduction in demand in the inter-peak period. The only return time period where the number of trips increases in this test is the off-peak period.

Demand for other modes increases by just 0.05% as a result of this test, equivalent to a cross-elasticity of 0.005.

In summary, while the impact of the elasticity test varies between travel purposes as a function of the base distribution of demand across time period combination alternatives, the tests indicate that the models respond plausibly to changes in outward AM peak travel times. There's no evidence of high sensitivity to travel times changes, which is consistent with the placement of time period choice at the highest (least sensitive) level in the model hierarchy for all of the travel purposes where time period choice is modelled. For commute and home–business, the impact of the 10% increase in outward AM peak travel times is lower in terms of change in AM peak demand because a much higher fraction of outward travel is made in the AM peak compared to the other purposes.

6.2 Values of time

In the commute and home–other travel mode-destination models, the cost contribution to utility is specified using a 'gamma' formulation, which calculates a mixture of linear and log cost contributions. The gamma formulation was used as given in Equation (4.1) above.

Separate cost sensitivity parameters have been estimated for different household income bands, and therefore the VoTs vary between these different income bands. For commuting, there are four income bands, plus a term for 'don't know' and 'prefer not to say' responses. For other travel, there are three income bands, plus a term for 'don't know' and 'prefer not to say' responses.

The implied VoTs for each mode can be calculated from Equation (6.1). It can be seen from this formula that the implied VoTs vary with the cost of the tour, and as the cost of the tour increases, the implied VoTs also increase.

$$VOT = \frac{\partial U / \partial \mathrm{time}}{\partial U / \partial \mathrm{cost}} = \frac{\beta_{time}}{\beta_{\cos t}\left\{\gamma + \frac{(1-\gamma)}{\mathrm{cost}} \cdot \frac{\mathrm{E(cost)}}{\mathrm{E(log(cost))}}\right\}} \qquad (6.1)$$

where: β_{time} is the IVT parameter for the mode

β_{cost} is the cost parameter, which varies by income band

γ controls the relative contribution of linear and logarithmic cost

E(cost) is the mean cost

E(log(cost)) is the mean logarithmic cost

the ratio E(cost)/E(log(cost)) ensures linear and logarithmic cost use the same scale

It is noted that for both the commuting and other travel models, a single generalised PT time parameter has been estimated, which is applied for train, metro and bus modes. It was not possible to estimate significantly different IVT parameters for the separate PT modes; an important consideration is that the majority of PT records in the HI are bus trips, and the low fractions of train and metro tours make it difficult to identify separate terms for these modes. Therefore the VoTs for a given cost are the same for the three PT modes.

It is emphasised that because the β_{cost} parameters vary between income bands, the implied VoTs also vary with income band. The β_{time} and β_{cost} parameters also vary by purpose and therefore the VoTs also vary by purpose.

As discussed in Section 5.1.1, for a number of the models a gamma specification has been used to represent cost sensitivity. The gamma value, which controls the shape of the cost sensitivity function, impacts on the implied VoTs. The gamma values were selected by balancing fit to the data, model elasticity and implied VoTs. VoTs higher than the guidance values given in WebTAG are observed for some purposes as a result of these trade-offs.

6.2.1 Commuting

The commuting VoTs for car and PT are summarised in the following figures, which plot the variation in the VoTs by cost for each household income band.

Figure 15: Commute implied VoTs for car driver (2011 prices)

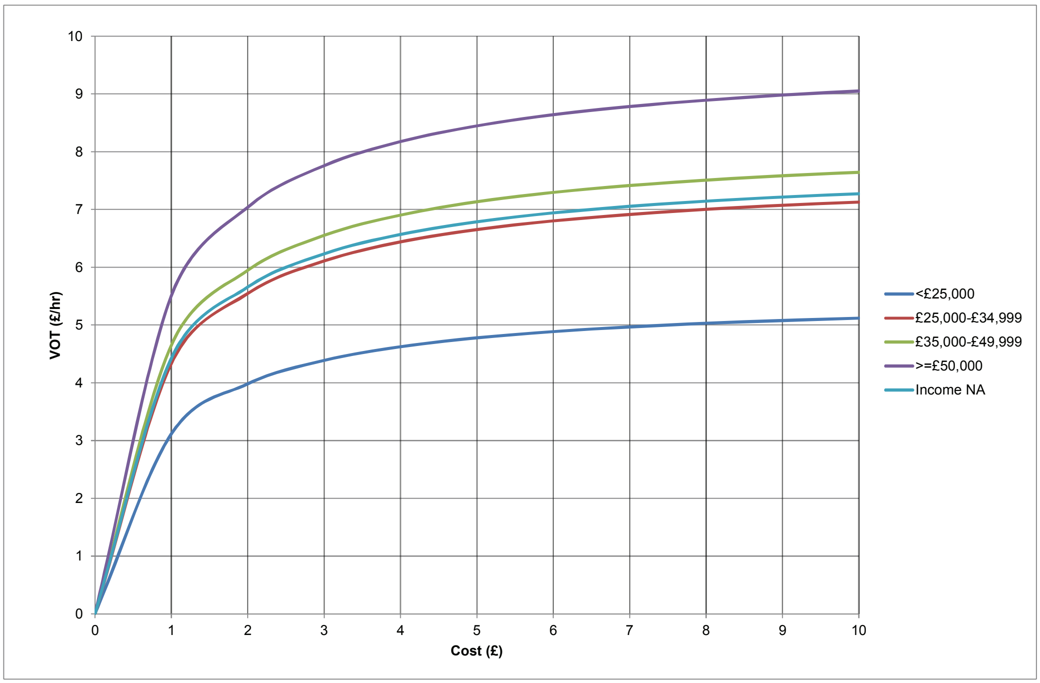
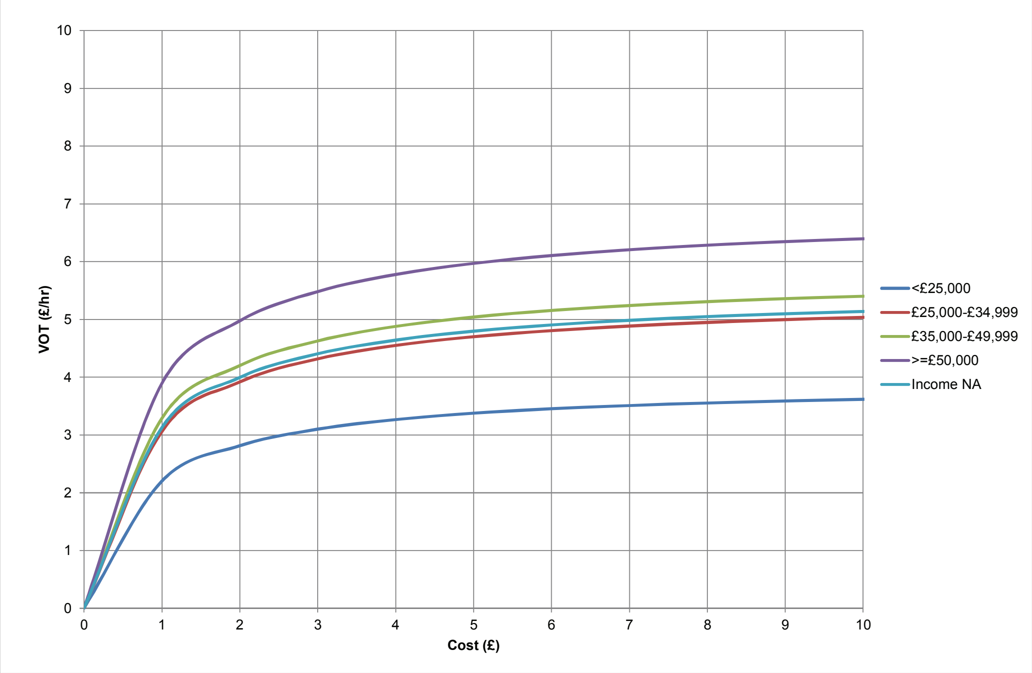


Figure 16: Commute implied VoTs for public transport modes (2011 prices)



Comparison of Figure 15 and Figure 16 illustrates that the PT VoTs are lower than the car VoTs for journeys of the same cost, which is because the PT IVT parameter is smaller than the car time parameter. However, as demonstrated in Table 81 to Table 84, the mean costs for PT tours are higher than those for car tours because PT modes cost more per kilometre than car, so this counterbalances the impact of the smaller IVT parameter to a small extent.

The 'Income NA' lines plot the VoTs for individuals who did not state their incomes. These individuals have implied VoTs that lie between the two middle income bands, implying that the average incomes for individuals who did not state their income are in line with the average incomes for individuals who did state their income.

Average VoT values by mode and income band have been calculated from the mean costs by mode and income band. Average VoTs by mode have then been calculated as a weighted average across income bands. These values are presented in the following tables.

Table 81: Commute car driver values of time (2549 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£25k	19.5 %	2.28	4.12
£25k-£35k	15.7 %	3.21	6.19
£35k-£50k	15.7 %	3.35	6.69
>£50k	16.6 %	3.47	7.98
not stated	32.6 %	3.17	6.30
Weighted average	100.0 %	3.08	6.20

Table 82: Commute train values of time (114 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£25k	19.4 %	3.87	3.25
£25k-£35k	12.6 %	7.32	4.91
£35k-£50k	14.6 %	4.42	4.95
>£50k	24.3 %	6.18	6.13
not stated	29.1 %	6.24	4.93
Weighted average	100.0 %	5.64	4.89

Table 83: Commute metro values of time (20 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£25k	36.1 %	6.07	3.46
£25k-£35k	8.3 %	5.09	4.71
£35k-£50k	0.0 %	0.00	n/a
>£50k	36.1 %	4.18	5.82
not stated	19.4 %	5.60	4.87
Weighted average	100.0 %	5.22	4.69

Table 84: Commute bus values of time (567 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£25k	32.1 %	5.81	3.44
£25k-£35k	12.0 %	5.19	4.72
£35k-£50k	14.7 %	6.13	5.17
>£50k	4.8 %	5.62	6.06
Not stated	36.5 %	5.97	4.90
Weighted average	100.0 %	5.83	4.51

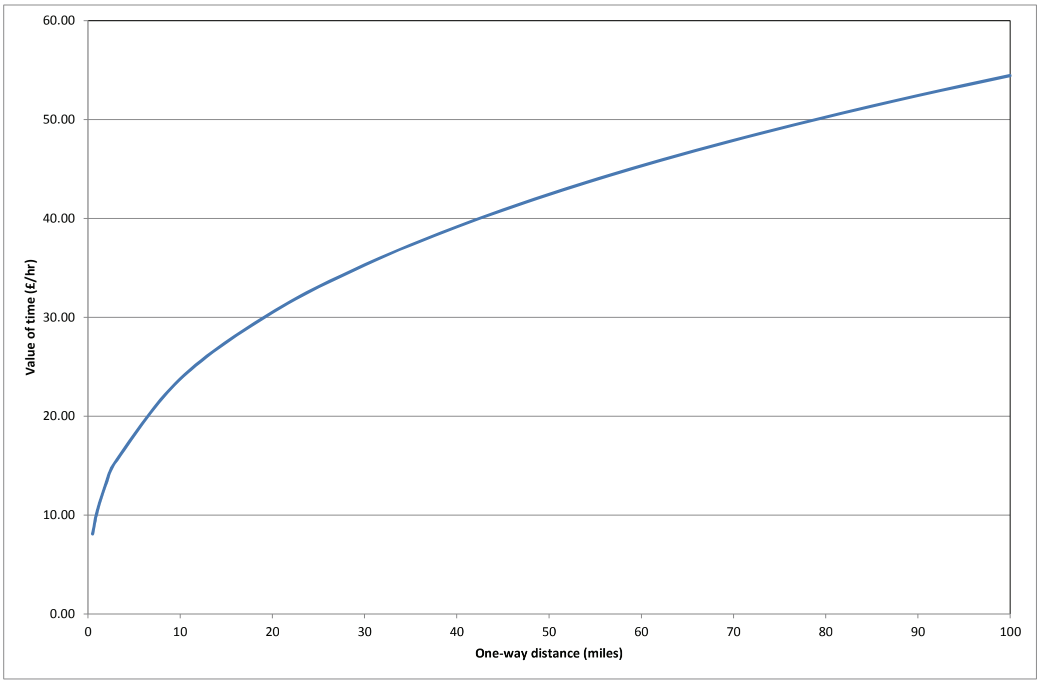
WebTAG Unit 3.5.6 (October 2012) quotes an all-modes average 2010 VoT for commute travel of 6.46 £/hr. Converting to 2011 prices, and accounting for real growth in GDP between 2010 and 2011, gives a value of 6.79 £/hr in 2011 values and prices. It can be seen that the average car driver values are consistent with this value, at 6.20 £/hr. For the three PT modes, the weighted average VoTs are slightly lower than the all-modes average values quoted in WebTAG. Comparing the different PT modes, it can be seen that persons from higher income households (> £50k p.a.) are more likely to use train and metro than bus, and this contributes to the higher implied VoTs for train and metro compared with bus.

6.2.2 Home–employer's business

As documented in Section 5.1.1, for employer's business VoTs were imported from WebTAG using a distance elasticity of 0.36. The VoTs were used to convert monetary costs into generalised time minutes, and then the sensitivity to generalised time minutes was estimated.

Figure 17 plots the shape of the VoT relationship used in the home–employer's business model.

Figure 17: Variation in employer's business VoT with distance (£/hr in 2011 prices)

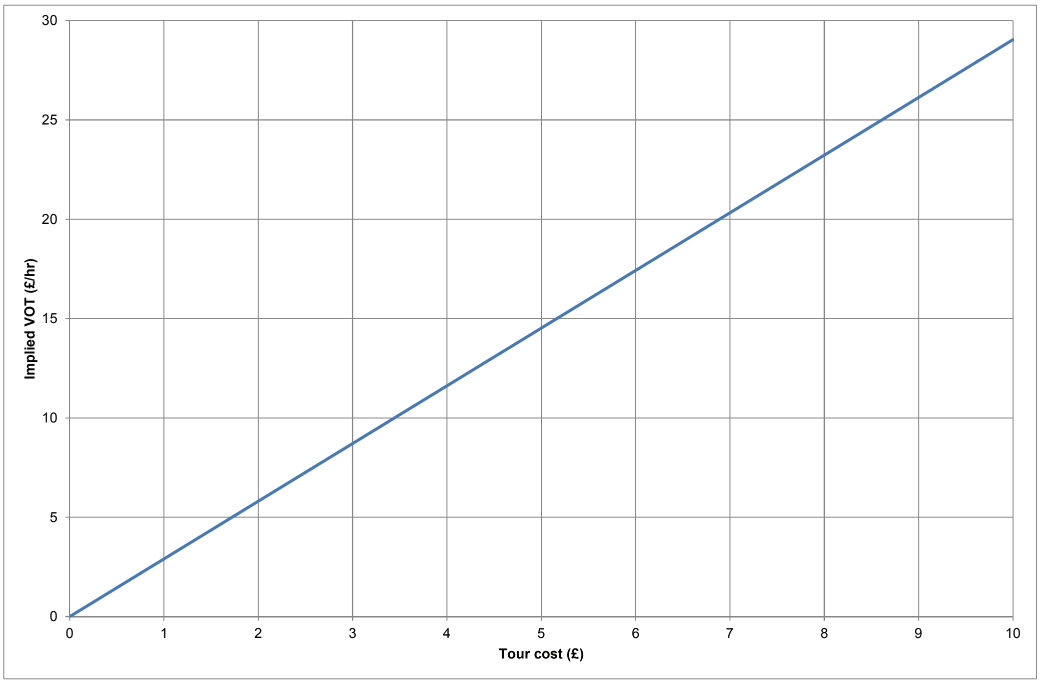


The average one-way tour distance in miles observed in the sample of home–employer's business tours was 21.4 miles. At this mean distance, the VoT from this relationship is 31.25 £/hr.

6.2.3 Home–primary education

The variation in the implied PT VoTs for home–primary education with tour cost is plotted in Figure 18. Car driver is not modelled for home–primary education, and for car passenger it is assumed that all car costs are paid by the driver. Therefore cost does not enter into the utility for the car passenger alternative.

Figure 18: Home–primary education VoTs



With a pure log-cost formulation, the VoTs are directly proportional to the tour costs and consequently for long tours with high costs, the implied VoTs are high. As noted in Section 5.1, there is limited cost information for primary education and therefore cost sensitivity tests with the preferred gamma formulation were not run. It is noted that the alternative linear cost formulation also resulted in high VoTs.

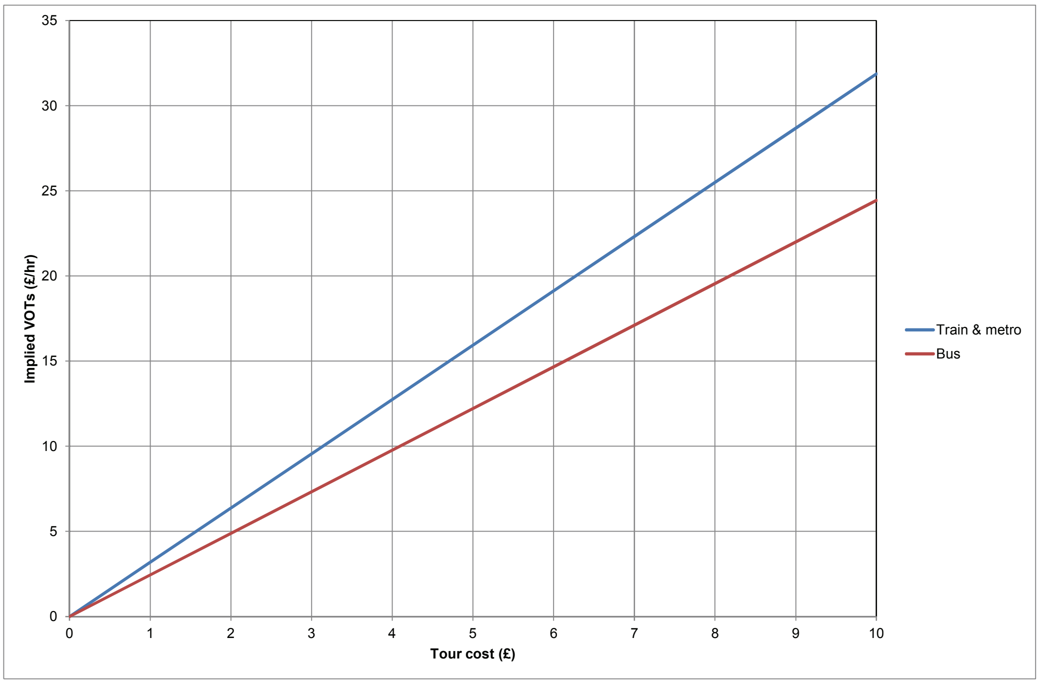
Nearly all PT tours for home–primary education are made by bus. The mean cost for chosen bus tours is £5.99, which gives an implied VoT of 17.39 £/hr. These VoTs are high relative to WebTAG values. However, a linear cost only model also had VoTs that were high relative to WebTAG guidance, with VoTs of 10.50 £/hr for tours of all costs, and the log-cost formulation gave a significantly better fit to the data.

Overall, it was judged to be better to retain the log-cost term in the home–primary education model, despite the high implied VoTs, so that in application the model predictions were sensitive to changes in PT fares.

6.2.4 Home–secondary education

The variation in the PT VoTs for home–secondary education with tour cost is plotted in Figure 19. Separate generalised time parameters have been estimated for train & metro, and for bus, and so separate VoT relationships are plotted for these two modes.

Figure 19: Home–secondary education VoTs

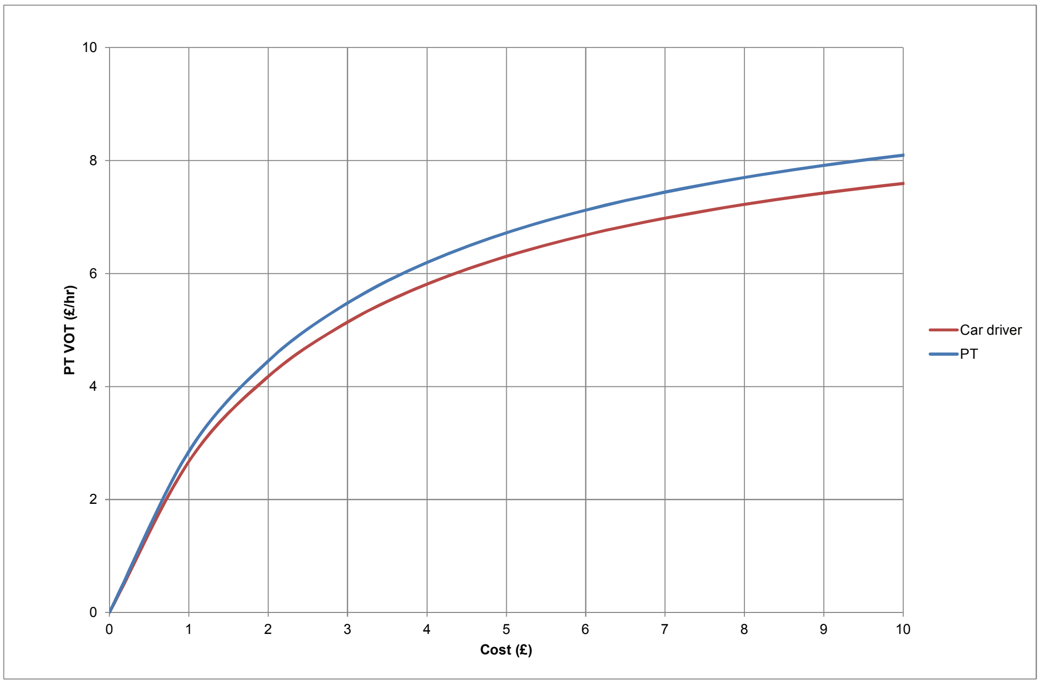


The mean tour costs for chosen train, metro and bus tours are £5.71, £7.07 and £6.13 respectively. These costs give implied VoTs in the 15-22 £/hr range. These VoTs are high relative to the WebTAG guidance values, but overall it was judged better to retain a log-cost term in the home–secondary model so that the model predictions are sensitive to changes in PT fares. It is noted that the alternative linear cost formulation also resulted in high VoTs.

6.2.5 Home–tertiary education

The VoTs for home–tertiary education are plotted in Figure 20.

Figure 20: Home–tertiary education VoTs



For tours of the same cost, the VoTs for PT are slightly higher than those for car driver because the generalised PT time parameter is large in magnitude than the car time parameter.

The average car cost is £4.02 giving an implied VoT of 5.82 £/hr, in line with the WebTAG guidance value of 6.00 £/hr. The average tour costs for train, metro and bus are £9.18, £6.82 and £5.92. The implied VoTs at these average tours costs are 7.09, 7.39 and 7.95 £/hr respectively, 1-2 £/hr higher than the WebTAG guidance values.

6.2.6 Home–shopping

The home–shopping VoTs for car and PT are summarised in the following figures, which plot the variation in VoTs by cost and by household income band.

Figure 21: Home–shopping implied VoTs for car driver (2011 prices)

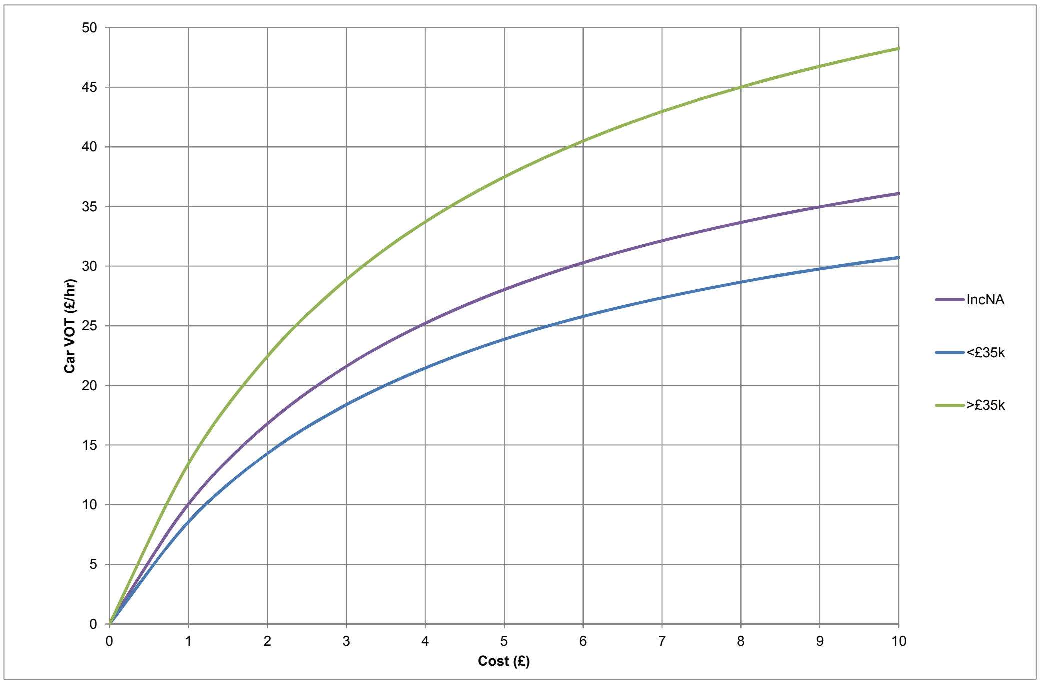
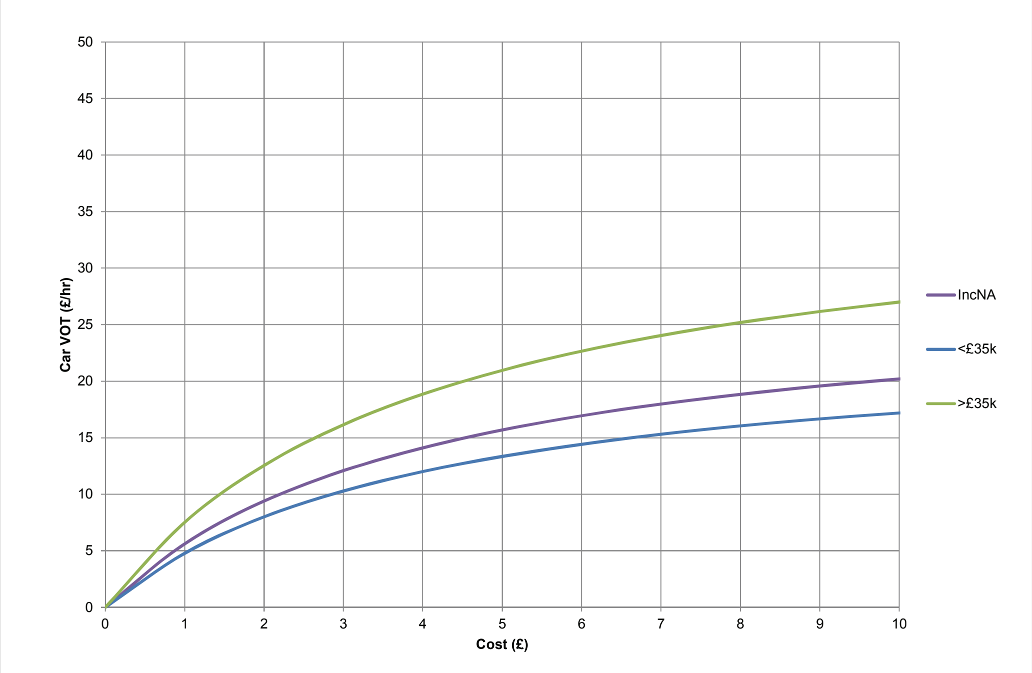


Figure 22: Home–shopping implied VoTs for public transport (2011 prices)



The PT VoTs are lower than the car VoTs for a given tour cost, however mean tours costs for public transport modes are significantly higher than those for car.

Average VoT values by mode and income band have been calculated from the mean costs by mode and income band. Average VoTs by mode have then been calculated as a weighted average across income bands. These values are presented in the following tables.

Table 85: Home–shopping car driver values of time (656 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£35k	51.5 %	1.47	11.53
>£35k	15.5 %	1.68	19.90
not stated	32.9 %	1.47	13.53
Weighted average	100.0 %	1.51	13.49

Table 86: Home–shopping train values of time (19 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£35k	38.6 %	4.74	13.03
>£35k	0.0 %	0.00	0.00
not stated	61.4 %	6.85	17.83
Weighted average	100.0 %	6.04	15.98

Table 87: Home–shopping metro values of time (6 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£35k	100.0%	5.57	13.99
>£35k	0.0%	0.00	n/a
not stated	0.0%	0.00	0.00
Weighted average	100.0%	5.57	13.99

Table 88: Home–shopping bus values of time (400 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
<£35k	57.2 %	4.92	13.25
>£35k	7.4 %	4.46	19.88
not stated	35.4 %	4.91	15.56
Weighted average	100.0 %	4.88	14.56

The average values VoTs for home–shopping are high, 2.25 to 2.67 times the WebTAG guidance values of 6.00 £/hr in 2011 prices and values. When higher values of gamma were tested during the cost specification, even higher VoTs were observed. As the final model had a low gamma value of 0.1, there was no scope for reducing gamma to increase the VoTs without further lowering the fuel cost elasticity, which is low for this purpose.

6.2.7 Home–escort

The cost parameters in the final home–escort model are not segmented by household income band, so there is no variation in the implied VoTs with household income.

Figure 23 plots the variation in the car driver and bus VoTs with the cost of the tour. Note that train and metro are not modelled for home–escort travel.

Figure 23: Home–escort implied VoTs (2011 prices)

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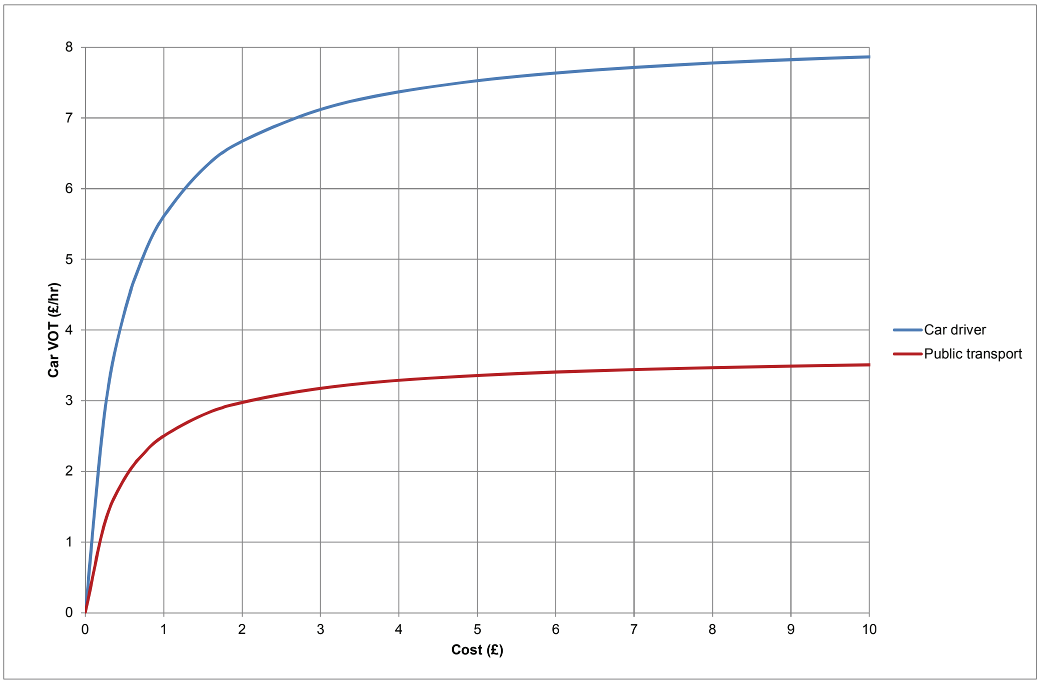


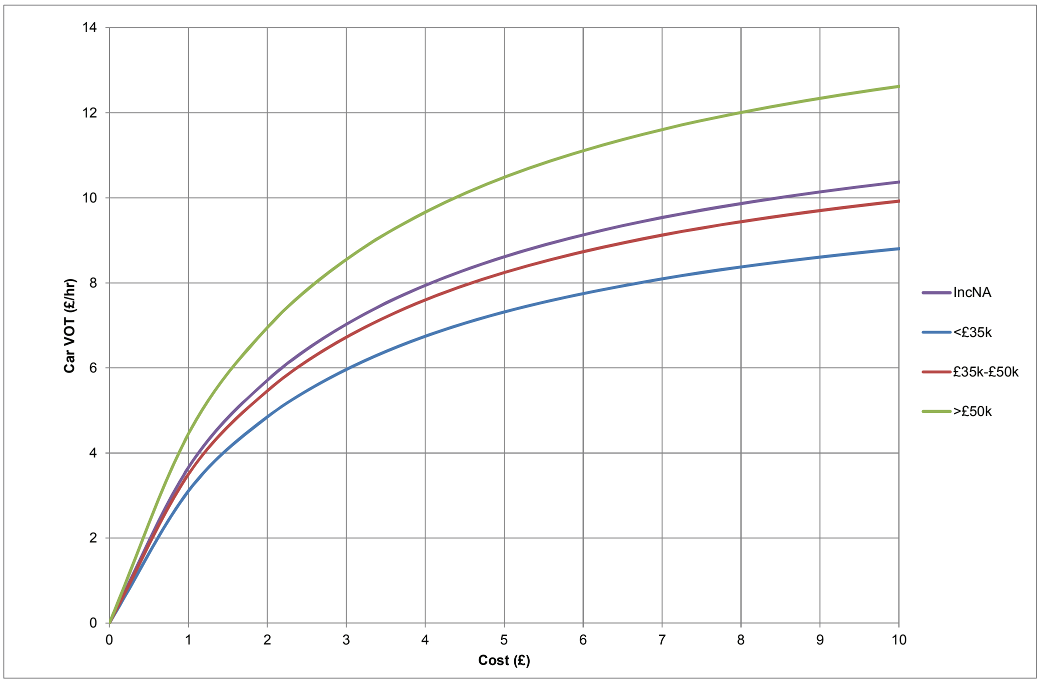
The bus VoTs are noticeably lower than those of car driver for tours of the same cost because the PT generalised time parameter is lower in magnitude than the car time parameter.

At the mean car cost of £1.16, the implied VoTs are 5.86 £/hr, just under the WebTAG guidance value of 6.00 £/hr. At the mean bus cost of £6.20, the implied VoT is 3.41 £/hr, which is 57% of the WebTAG value. Thus the bus VoTs are low in the home–escort model because of the low magnitude of the PT generalised time term. It is noted that just 1.44% of the escort tours in the estimation sample used bus, so limited data are available to estimate the sensitivity to generalised PT time.

6.2.8 Home–other travel

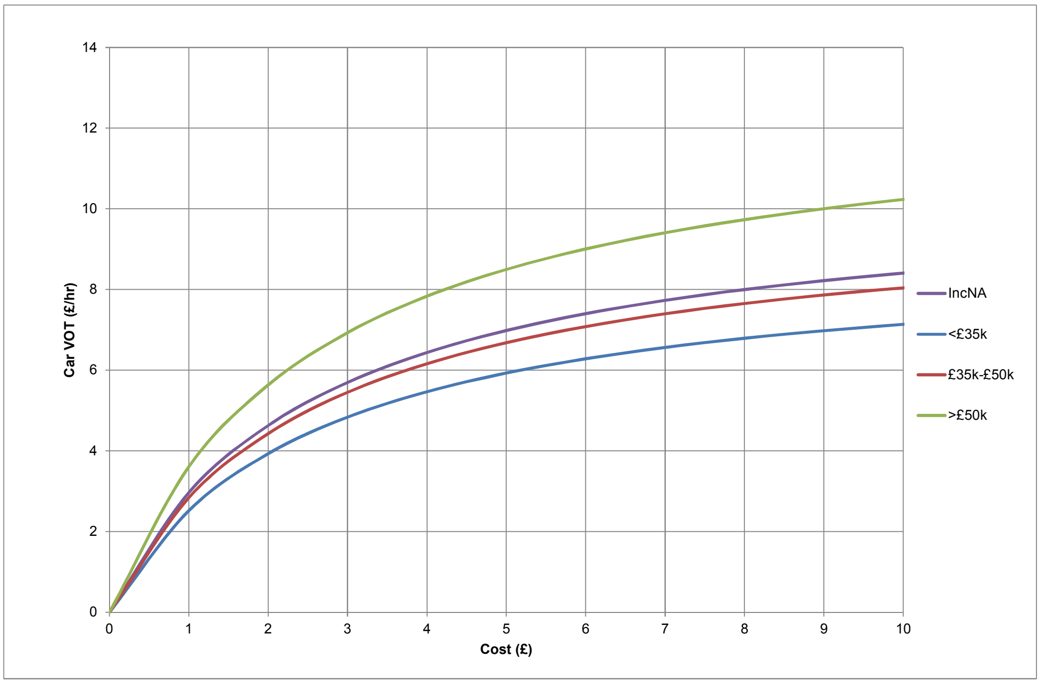
The home–other travel VoTs for car and PT are summarised in the following figures, which plot the variation in the VoTs by cost for each household income band.

Figure 24: Home–other travel implied VoTs for car driver (2011 prices)



It is noted that the curve for the 'IncNA' band is plotted directly beneath the curve for the '£35-50k' band because the cost sensitivities of these two groups are very similar.

Figure 25: Home–other travel implied VoTs for public transport (2011 prices)



Again, it is noted that the curve for the 'IncNA' band is plotted directly beneath the curve for the '£35-50k' band because the cost sensitivities of these two groups are very similar.

For journeys of a given cost, the PT VoTs are lower than the car VoTs because the PT IVT parameter is smaller than the car time parameter. However, the average costs associated with PT tours are higher.

Average VoT values by mode and income band have been calculated from the mean costs by mode and income band. Average VoTs by mode have then been calculated as a weighted average across income bands. These values are presented in the following tables.

Table 89: Home–other travel car driver values of time (1006 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
< £35 k	47.3 %	2.35	5.29
£35-50 k	12.6 %	2.89	6.60
£>=50 k	10.2 %	3.65	9.31
not stated	29.8 %	2.90	6.91
Weighted average	100.0 %	2.71	6.35

Table 90: Home–other travel train values of time (45 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
< £35 k	46.3 %	12.45	7.44
£35-50 k	20.7 %	6.21	7.15
£>=50 k	3.3 %	32.43	11.91
not stated	29.8 %	8.31	8.07
Weighted average	100.0 %	10.59	7.71

Table 91: Home–other travel metro values of time (8 observations) (2011 prices)

Household income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
< £35 k	81.8 %	7.95	6.78
£35-50 k	0.0 %	0.00	0.00
£>=50 k	0.0 %	0.00	n/a
not stated	18.2 %	5.30	7.12
Weighted average	100.0 %	7.47	6.84

Table 92: Home–other travel bus values of time (367 observations) (2011 prices)

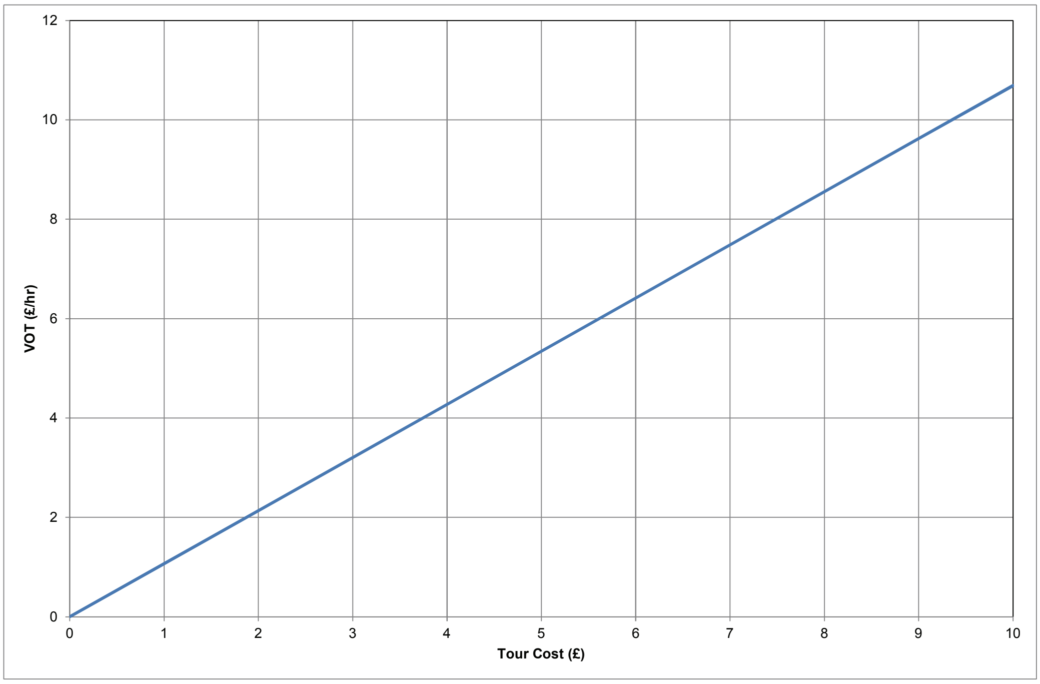
HH. Income band	Percentage of data	Mean cost (£)	Implied VoTs (£/hr)
< £35 k	52.8 %	5.39	6.07
£35-50 k	6.6 %	6.18	7.14
£>=50 k	2.9 %	6.72	9.31
Not stated	37.7 %	5.83	7.34
Weighted average	100.0 %	5.65	6.72

The WebTAG VoTs for other travel are 6.00 £/hr in 2011 prices and values. The average values for car driver, metro and train, which were calculated using the E(cost) formulation and so are upper-bound estimates of the VoTs are average modal costs, are only slightly higher than the WebTAG values. Consistent with the commuting analysis, fewer car driver and train users are in the lowest income band and this is reflected in the higher average VoTs.

6.2.9 PD-based work–work tours

The PD-based work–work tour model uses log-cost formulation, and so the implied VoT varies linearly with the cost of the tour. A generalised time parameter is used in the model, which is shared between car driver and PT modes, and so the implied VoTs at a given tour cost are equal for these two modes. The variation in implied VoT with tour cost is plotted in Figure 26.

Figure 26: Work-work tour VoTs (2011 prices)

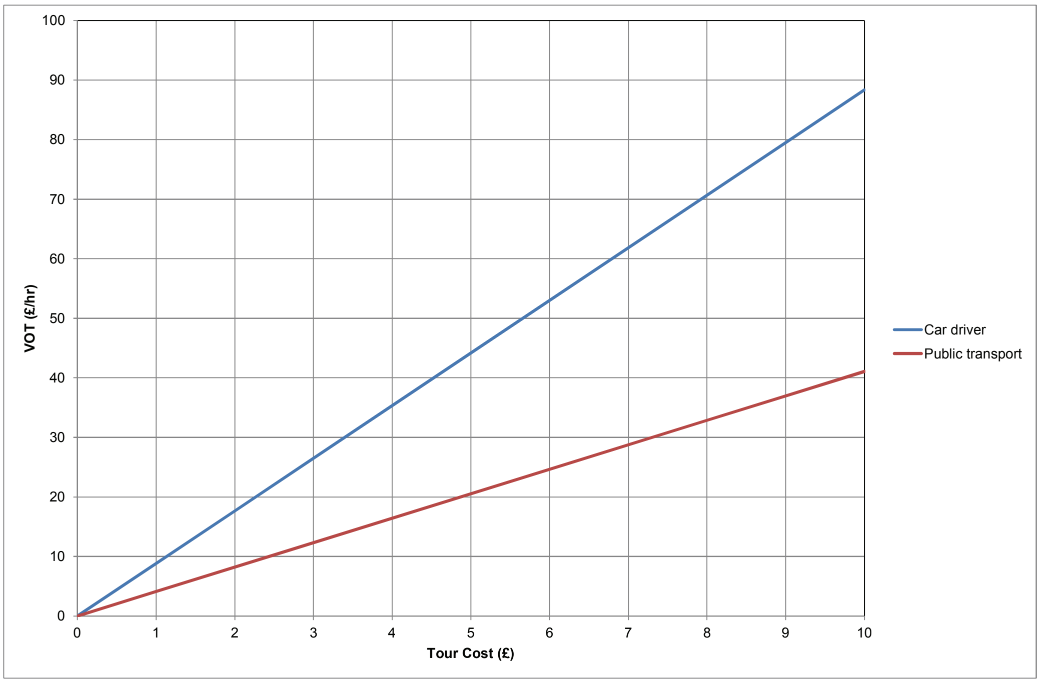


The implied VoTs at the mean tour costs vary from 7.90 £/hr for car driver to 38.02 £/hr for train, where the mean tour cost is much higher. These compare to the all-modes WebTAG guidance value for employer's business travel of 30.17 £/hr. There were only two bus tours in the estimation sample, and for both of these tours the individual held a pass offering bus travel at zero marginal cost. Therefore the mean bus cost for these observations was zero. Consequently VoTs are the mean cost value cannot be calculated for bus.

6.2.10 PD-based work–other tours

The PD-based work–other tour model also used a log-cost formulation, and has a single generalised time parameter that is used for both car driver and PT modes. The variation in the implied VoT with tour cost is plotted in Figure 26.

Figure 27: Work-other tour VoTs (2011 prices)



The VoTs for the PD-based work-other model are high, with values at the mean tour cost of 17.10 £/hr for car, and 32.38 £/hr for bus, compared with the WebTAG all-modes values of 6.00 £/hr for other travel. There are just 86 observations in the estimation sample, and the log-cost parameter is not strongly estimated (t-ratio of just 2.0). It is the small magnitude of the cost parameter that leads to the high VoTs, rather than a high sensitivity to travel time.

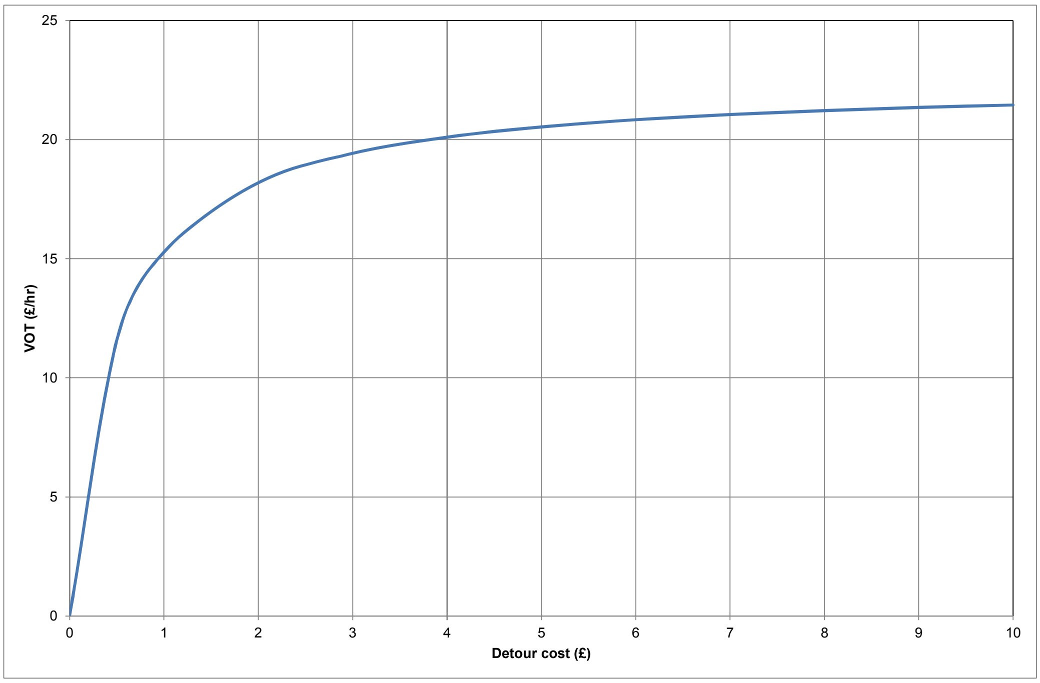
6.2.11 PD-based other–other tours

In the PD-based other–other model, it was not possible to estimate separate significant cost and time parameters, and therefore the all modes VoT of 6.00 £/hr was imported from WebTAG.

6.2.12 Work-work detours

The work-work detour model uses a gamma cost formulation, which means that the implied VoTs vary with the cost of the detour. Car driver and PT modes share the same generalised time parameter in this model. Figure 28 plots the variation in the implied VoTs with detour cost.

Figure 28: Work-work detour VoTs (2011 prices)

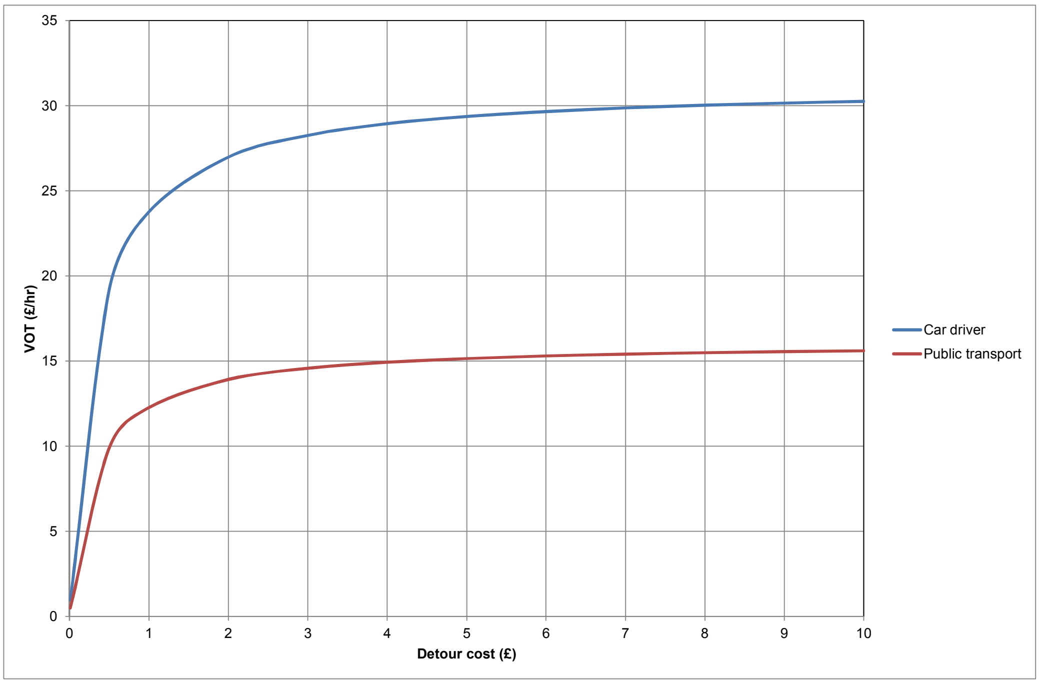


The implied VoTs at the mean tour costs are 19.36 £/hr for car driver, 20.88 £/hr for train and 19.30 £/hr for bus. These are somewhat lower than the all-modes values for employer's business travel from WebTAG of 30.17 £hr. However, detours are relatively short and so lower than average VoTs are expected.

6.2.13 Work–other detours

The work–other detour model uses a gamma-formulation for cost sensitivity, and separate parameters are used for car time and PT generalised time. The implied VoTs for the work–other detour model are plotted in Figure 29.

Figure 29: Work–other detour VoTs (2011 prices)

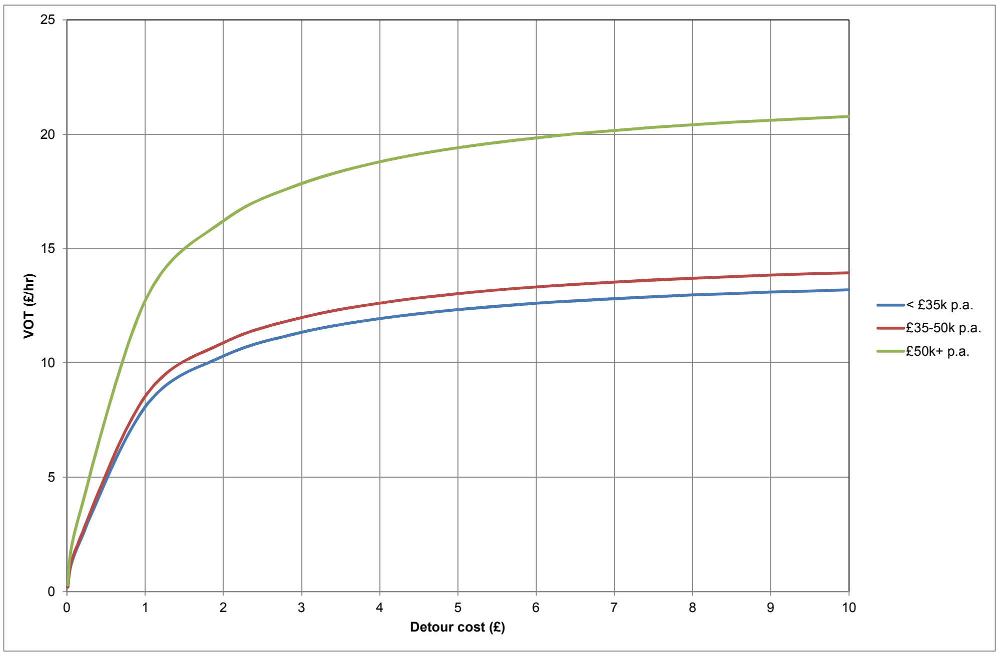


The implied VoTs for work–other travel are higher than would be expected for other travel, and are closer to the values observed in the work–work detour model. At the mean detour costs, the implied VoTs for car driver are 24.98 £/hr, whereas those for train and bus are 14.91 £/hr and 14.55 £/hr. Although work–other detours are made to non-work-related detour locations, they are made in the course of work-related tours and this may explain the relatively high VoT values.

6.2.14 Other–other detours

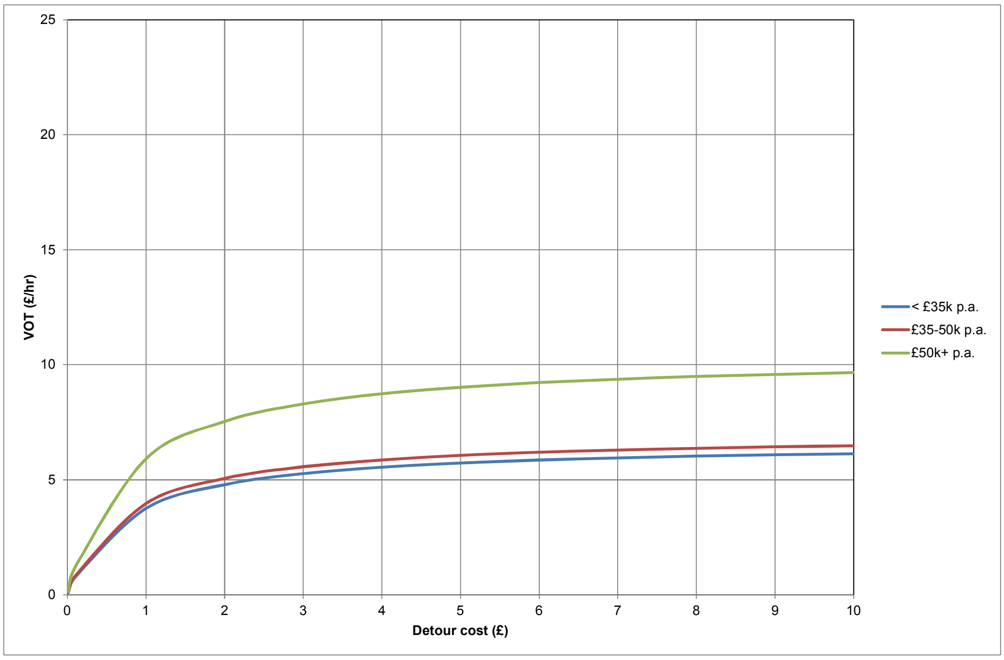
The other–other detour model uses a gamma formulation for cost sensitivity, and also incorporates variation in cost sensitivity with income band. Furthermore, separate IVT parameters are used for car and PT modes. Figure 30 plots the variation in implied VoT with cost and income band for car driver.

Figure 30: Other–other detour VoTs for car driver (2011 prices)



The VoTs are noticeably higher for the top income band. At the mean car cost, the VoTs range from 7.73 £/hr in the < £35k income band to 12.16 £/hr in the £50k+ in the £50k+ income band.

Figure 31: Other–other detour VoTs for public transport (2011 prices)



The PT VoTs are noticeably lower than the car values for detours of the same cost because the PT generalised cost parameter is less than half the magnitude of the car time parameter. At the mean chosen PT costs, the VoTs range from 5.04 £/hr to 8.29 £/hr.

This the PT VoTs are in line with the WebTAG guidance value of 6.00 £/hr, whereas the car driver values are somewhat higher.

6.2.15 Summary

The implied VoTs for each purpose are summarised in Table 93, and compared to the WebTAG guidance values. Values are not presented for home–business and other-other tours because VoTs are imported from WebTAG for these purposes.

Table 93: Summary of VoT implied values by purpose (2011 £/hr)

Purpose	Car driver	Train	Metro	Bus	WebTAG
commuting	6.20	4.89	4.69	4.51	6.79
home–primary education	n/a	-	-	17.39	6.00
home–secondary education	n/a	5.71	7.07	6.13	6.00
home–tertiary education	5.82	7.09	7.39	7.95	6.00
home–shopping	13.49	15.98	13.99	14.56	6.00
home–escort	5.86	n/a	n/a	3.41	6.00
home–other travel	6.35	7.71	6.84	6.72	6.00
work–work tours	7.90	38.02	n/a	-	30.17
work–other tours	17.10	n/a	n/a	32.38	6.00
work–work detours	19.36	20.88	n/a	19.30	30.17
work–other detours	24.98	14.91	n/a	14.55	6.00
other–other detours	8.10	5.32	5.60	5.57	6.00

6.3 Tour and detour lengths

Observed and predicted tour and detour lengths by mode are presented in this section. The observed tour lengths are the mean tour lengths observed in the 2009–2012 household interview data. The observed tour lengths are presented together with the sample sizes as for some mode-purpose combinations the sample sizes are small. The predicted tour lengths are the mean tour lengths predicted when the models are applied to the estimation samples. Tour lengths are the distances for the return tour, i.e. out and return.

The tour and detour length distributions for car driver have also been validated, these are presented in Appendix D. It is noted that for the tour models, the distances presented are for the return tour, i.e. the outward distance plus the return distance.

6.3.1 Commute

Table 94 compares observed and predicted tour lengths for the final commute model specification without train and metro access mode and station choice (model v85).

Table 94: **Commute tour length validation (kms)**

Mode	Observed		Predicted model v85	Difference
	Tours	kms		
car driver	2,549	25.6	24.3	-4.9 %
car passenger	315	22.7	22.7	-0.1 %
train	114	48.7	52.8	8.4 %
metro	20	32.6	33.6	3.0 %
bus	567	16.5	21.4	29.6 %
PT	701	22.2	26.9	20.9 %
cycle	67	11.5	11.6	0.8 %
walk	385	5.0	5.0	-0.4 %
Total	4,017	22.6	22.6	0.1 %

Overall tour lengths are predicted accurately, and tour lengths for car passenger, cycle and walk modes are also predicted accurately because of the distance parameters estimated for these modes.

Car driver tour lengths are under-predicted by 5%. The tour length distribution plotted in Appendix D suggests that this is due to an under-prediction of long commute tours, greater than 75 km in length.

PT tour lengths are over-predicted by just over 20% overall, with the largest over-prediction for bus, which accounts for 81% of the observed PT tours.

6.3.2 Home–business

Table 95 compares observed and predicted tour lengths for the final home–business model specification.

Table 95: **Home–business tour length validation (kms)**

Mode	Observed		Predicted model v60	Difference
	Tours	kms		
car driver	354	71.1	73.9	3.9 %
car passenger	45	71.3	71.7	0.5 %
train	12	259.0	182.9	-29.4 %
metro	1	21.2	47.3	123.4 %
bus	38	16.6	30.2	81.8 %
PT	51	73.7	66.5	-9.9 %
cycle	1	10.9	13.6	24.9 %
walk	21	3.7	3.5	-3.6 %
Total	472	68.3	69.6	2.0 %

Total tour lengths are over-predicted by just 2%.

Tour distances for car passenger and walk are predicted well because of the distance terms used for these modes. For cycle, there is only a single observation in the data and so the distance term is insignificant.

Tour distances are predicted to within 4% for car driver, which accounts for 75% of the estimation sample, though the fit to the observed tour length distribution, which is plotted in Appendix D, is less good. There are only ten train tours, and a single metro tour, in the estimation sample and therefore the observed tour lengths are based on small samples. For bus, where there are 38 tours, tour lengths are over-predicted by 82%.

6.3.3 Home–primary education

Table 96 compares observed and predicted tour lengths for the final home–primary education model specification.

Table 96: **Home–primary education tour length validation (kms)**

Mode	Observed		Predicted model v21	Difference
	Tours	kms		
car passenger	458	6.5	6.5	0.1 %
train	2	31.9	28.8	-9.7 %
metro	0	0.0	26.8	n/a
bus	73	12.1	14.5	20.2 %
PT	75	12.6	14.9	18.1 %
cycle	7	4.7	4.7	0.0 %
walk	676	3.4	3.4	0.0 %
Total	1,216	5.2	5.3	2.8 %

Most primary education travel is by car passenger and walk, and tour lengths for these two modes are predicted accurately.

There are no metro tours in the estimation sample and therefore no observed tour length is available for metro.

6.3.4 Home–secondary education

Table 97 compares observed and predicted tour lengths for the final home–secondary education model specification.

Table 97: **Home–secondary education tour length validation (kms)**

Mode	Observed		Predicted model v22	Difference
	Tours	kms		
car passenger	176	9.8	10.2	4.0 %
train	6	20.2	27.0	33.7 %
metro	3	26.1	30.2	15.6 %
bus	219	13.2	15.7	19.1 %
PT	228	13.6	16.2	19.4 %
cycle	11	5.8	5.9	1.3 %
walk	413	4.5	4.5	-0.5 %
Total	828	8.1	8.9	9.8 %

Total tour lengths are over-predicted by 10% due to an over-prediction of PT tour lengths.

Almost half of the secondary pupils in the estimation sample walked to school, and the tour lengths for these individuals are predicted accurately as a result of the distance term. The next most important modes are car passenger and bus, which together account for 48% of the tours in the estimation sample. Car passenger tour lengths are predicted accurately, but tour lengths for bus are over-predicted by one-fifth.

6.3.5 Home–tertiary education

Table 98 compares observed and predicted tour lengths for the final home–tertiary education model specification.

Table 98: Home–tertiary education tour length validation (kms)

Mode	Observed		Predicted model v45	Difference
	Tours	kms		
car driver	106	31.8	29.4	-7.6 %
car passenger	56	12.8	13.0	1.5 %
train	29	77.3	45.7	-40.8 %
metro	4	42.0	38.0	-9.6 %
bus	255	16.0	21.0	31.2 %
PT	288	22.5	23.7	5.2 %
cycle	13	9.6	10.5	8.8 %
walk	112	5.9	5.9	0.2 %
Total	575	19.8	19.9	0.9 %

Total tour lengths are predicted accurately.

There is a 7.6% under-prediction of car driver tours lengths, which the trip length distribution plotted in Appendix D demonstrates is due to an under-prediction of the longest tours in the 75+ km band. Car passenger distances are predicted more accurately because of the car passenger distance parameter.

For public transport, train distances are under-predicted, whereas bus distances are over-predicted. Distances for cycle and walk are predicted well due to the distance terms included in the utilities for these modes.

6.3.6 Home–shopping

Table 99 compares observed and predicted tour lengths for the final home–shopping specification without train and metro access mode and station choice.

Table 99: Home–shopping tour length validation (kms)

Mode	Observed		Predicted model v67	Difference
	Tours	kms		
car driver	656	12.0	11.0	-8.1 %
car passenger	294	11.8	11.9	0.6 %
train	19	53.5	34.7	-35.1 %
metro	6	24.0	28.1	17.1 %
bus	400	11.1	12.4	11.8 %
PT	425	13.1	13.6	3.4 %
cycle	4	9.7	10.3	6.6 %
walk	444	4.1	4.1	0.1 %
Total	1,823	10.3	10.1	-2.3 %

Total home–shopping tour lengths are predicted accurately. There is a slight under-prediction of car-driver tours lengths, which the tour length distribution plot in Appendix D shows is because there are a few long shopping tours in the 75km+ band which the model under-predicts. For the PT modes, train tour lengths are under-predicted, whereas metro and bus tour lengths are over-predicted somewhat, so that overall PT tour lengths are predicted quite well.

There are only four cycle tours in the estimation sample, and mean tour lengths are predicted reasonably well for these. Walk tours lengths are predicted precisely.

6.3.7 Home–escort

Table 100 compares observed and predicted tour lengths for the final home–escort model. It is noted that train, metro and cycle are not modelled in the home–escort model.

Table 100: Home–escort tour length validation (kms)

Mode	Observed		Predicted model v41	Difference
	Tours	kms		
car driver	762	9.7	9.6	-0.9 %
car passenger	39	40.2	13.6	-66.2 %
bus	58	10.2	14.1	37.8 %
walk	838	3.5	3.5	0.3 %
Total	1,697	7.3	6.8	-7.0 %

For car driver, which accounts for 45% of home–escort tours, tour lengths are predicted accurately. The car driver tour length distribution, plotted in Appendix D, shows a reasonably good correspondence between the observed and predicted distributions. Walk accounts for 49% of home–escort tours, and for this mode there is a distance term in the utilities which ensures that the observed and predicted tour lengths match closely.

Car-passenger tour lengths are substantially under-predicted, however the observed tour length is skewed by four long escort tours, and the predicted tour length is comparable with the observed car passenger tour lengths for home–shopping and home–other travel tours. Consistent with the pattern seen in a number of other model purposes, bus tour distances are over-predicted.

6.3.8 Home–other travel

Table 101 compares observed and predicted tour lengths for the home–other travel model.

Table 101: Home–other travel tour length validation (kms)

Mode	Observed		Predicted model v74	Difference
	Tours	kms		
car driver	1,006	22.8	20.1	-12.0 %
car passenger	539	21.5	21.3	-0.8 %
train	45	93.7	59.8	-36.2 %
metro	8	30.6	35.8	17.0 %
bus	367	14.2	17.4	22.2 %
PT	420	23.0	22.3	-3.4 %
cycle	36	8.6	8.8	1.9 %
walk	568	4.3	4.3	0.0 %
Total	2,569	18.3	17.1	-6.8 %

Tour lengths for car passenger, cycle and walk are predicted accurately due to the distance parameters included in the utility functions for these modes.

There is some under-prediction of mean tour lengths for car driver. For PT, the pattern is consistent with a number of other purposes, with an under-prediction of train tour lengths balanced by an over-prediction of bus tour lengths, so that overall PT tour lengths are predicted quite well.

6.3.9 Work–work tours

Table 102 compares observed and predicted tour lengths for the work–work PD-based tour model.

Table 102: Work–work PD-based tour length validation (kms)

Mode	Observed		Predicted model v13	Difference
	Tours	kms		
car driver	27	52.3	58.4	11.6 %
car passenger	3	15.9	15.9	0.4 %
train	1	512.5	112.5	-78.0 %
bus	2	22.4	28.9	28.9 %
PT	3	185.8	56.8	-69.4 %
walk	1	7.4	7.4	-0.1 %
Total	34	59.6	53.0	-11.0 %

Tour lengths for car passenger and walk are predicted accurately due to the distance parameters used for these modes.

For car driver, where there are 27 tours in the estimation sample, tour lengths are over-predicted by 12%. Train distances are significantly under-predicted, however there is just one train tour in the estimation sample and that tour is unusually long. For bus, where there are just two tours in the estimation sample, distances are over-predicted by 29%. Overall PT tour distances are significantly under-predicted but the observed value is biased by the long train tour.

Overall, given the sample sizes available to estimate this model the tour length validation is reasonable.

6.3.10 Work–other tours

Table 103 compares observed and predicted tour lengths for the work-other PD-based tour model.

Table 103: PD-based work–other tour length validation (kms)

Mode	Observed		Predicted model v19	Difference
	Tours	kms		
car driver	23	16.1	15.1	-6.4 %
car passenger	5	10.8	10.5	-3.0 %
bus	3	10.0	14.0	40.1 %
walk	55	3.3	3.3	0.0 %
Total	86	7.4	7.3	-2.1 %

Overall tour lengths are predicted accurately, as are the tour lengths for car passenger and walk where distance parameters are used.

Car driver tour lengths are under-predicted slightly, whereas bus tour lengths are over-predicted by 40%. However, there are just three observed bus tours from which the observed mean tour length has been calculated.

6.3.11 Other–other tours

Table 104 compares observed and predicted tour lengths for the other–other PD-based tour model.

Table 104: PD-based other–other tour length validation (kms)

Mode	Observed		Predicted model v28	Difference
	Tours	kms		
car driver	13	12.6	21.5	71.1 %
car passenger	8	7.8	7.8	0.0 %
bus	5	16.0	14.4	-9.7 %
walk	18	3.8	3.8	0.0 %
Total	44	8.5	10.9	29.1 %

Tour lengths for car driver are over-predicted by 71%, and as a result overall tour lengths are over-predicted by almost 30%. The match for car passenger and walk is excellent due to the distance terms included in the utilities for these modes. Bus tour lengths are underpredicted by 10%, however there are just four observed bus tours and therefore this level of fit is reasonable.

6.3.12 Work–work detours

Table 105 compares observed and predicted detour lengths for the work-work detour model.

Table 105: Work–work detour length validation (kms)

Mode	Observed		Predicted model v32	Difference
	Tours	kms		
car driver	110	19.8	19.3	-2.6 %
car passenger	5	11.4	11.3	-1.4 %
train	3	80.2	37.4	-53.4 %
bus	15	8.2	8.5	3.6 %
PT	18	20.2	13.3	-34.1 %
walk	5	2.4	2.4	0.0 %
Total	138	18.9	17.6	-6.9 %

The observed mean detour length for train is long, and this is underpredicted by the model which has a single IVT parameter for train and bus. As a result, PT tour lengths are underpredicted by one-third and this contributes to the overall 7% under-prediction of detour lengths.

However, tour distances for car driver, car passenger, bus and walk modes are predicted accurately, to within ±4% of the observed values.

6.3.13 Work-other detours

Table 106 compares observed and predicted detour lengths for the work-work detour model.

Table 106: Work-other detour length validation (kms)

Mode	Observed		Predicted model v38	Difference
	Tours	kms		
car driver	642	10.2	10.2	-0.2 %
car passenger	49	9.6	9.5	-1.1 %
train	11	38.2	21.1	-44.8 %
metro	3	25.9	12.8	-50.8 %
bus	57	7.4	8.7	17.8 %
PT	71	13.0	10.8	-16.5 %
walk	57	3.5	3.5	0.0 %
Total	819	9.5	9.4	-2.0 %

For car driver, car passenger and walk modes, which account for 92% of the observed tours, detour distances are predicted accurately and consequently total detour lengths are also predicted accurately.

PT detour distances are predicted less well, and consistent with the pattern observed for a number of the other purposes train distances are under-predicted whereas bus distances are over-predicted.

6.3.14 Other-other detours

Table 107 compares observed and predicted detour lengths for the other-other detour model.

Table 107: Other-other detour length validation (kms)

Mode	Observed		Predicted model v39	Difference
	Tours	kms		
car driver	440	7.2	6.8	-5.6 %
car passenger	234	6.7	6.6	-1.4 %
train	7	38.7	23.5	-39.3 %
metro	5	11.7	14.8	26.6 %
bus	152	6.8	7.2	5.2 %
PT	164	8.3	8.1	-2.7 %
walk	8	4.8	5.0	2.6 %
Total	262	2.6	2.6	1.6 %

For car driver, car passenger, cycle and walk the predicted detour lengths match the observed data well. These modes account for 85% of the observed detours, and so the overall tour length is also predicted accurately.

For train and metro where the sample sizes are small, the match between observed and predicted detour lengths is less good. An under-prediction of observed train distances is balanced by over-predictions for metro and bus so that the overall PT tour lengths are predicted closely.

CHAPTER 7 Summary

This section summarises the model results, and the findings from the model validation.

Model results

Cost specification

The model development commenced with a search for the appropriate specification for the cost term. Initial tests investigated separate linear and log cost terms, but it was not possible for any of the purposes to identify these effects separately. The final model specifications use either a 'gamma' cost formulation, where a mixture of linear and log costs effects is imposed, a log-cost-only formulation, or import VoTs directly from WebTAG in order to convert monetary costs into generalised time units.

Variation in sensitivity to cost with household income was tested in the new models. Significant variations in cost sensitivity with household income were identified for the commute, home–shopping, home–other travel and other–other detour models. Two to four income segments are represented for each purpose.

Tests have been made to investigate whether car costs should be shared between drivers and passengers. In the final commute, home–tertiary education, home–shopping, home–other travel, work–other detour and other–other detour models it is assumed that passengers pay a proportion of the car costs.

Cost sensitivity for home–shopping is relatively low, resulting in high VoTs and low cost elasticities. It is believed that this result relates to the weak distance relationship in the PT fare information which makes it difficult to estimate the cost sensitivity parameter. Low cost sensitivity and elasticities are also observed for home–other travel.

Level-of-service terms

Tests were made where PT out-of–vehicle time components were estimated separately from PT IVT components. However, in many of these tests the parameters for access and egress time and wait times were smaller in magnitude than PT IVT. Therefore models were estimated where PT IVTs and out-of–vehicle times were combined into PT generalised time units. Tests were made weighting out-of–vehicle time components by 1 and 2. A weighting of 2 would be consistent with the range of values indicated in WebTAG, however for all model purposes using this weighting resulted in a worse fit to the data than a weight of 1, and furthermore the sensitivity to changes in PT IVT are lower with a weight of 2 which would damp the elasticities to IVT changes. Therefore to preserve the quality of the models weights of 1 were used, despite the inconsistency this raises with WebTAG guidance. If the models are re-estimated using LOS from the new 2011 unified PT model, then it is recommended that these tests are re-run.

For the commute, home–shopping, home–other and other–other detour models, where sample sizes are larger, parameters for the number of transfers have been estimated separately from the PT generalised time term. For all other purposes transfers has been combined with PT generalised time using a weighting of 10 minutes per transfer.

Socio-economic terms

The majority of the socio-economic effects identified in the original PRISM estimations remain significant when tested with the new data, and so have been retained in the models.

A number of additional socio-economic effects have been added to the model specifications. In particular, terms reflecting the higher use of bus by persons from zero car households have been identified for a number of the different travel purposes, and a number of additional gender effects have been identified. In the home–other travel model, a new distance effect has been added to take account of lower tour distances by persons who are looking after their family.

Destination effects

No PT LOS exists for intrazonals, and therefore no PT intrazonal tours are incorporated in the model (PT is unavailable for intrazonal tours). For car driver, car passenger, walk and cycle modes, intrazonal constants have been incorporated for a number of the model purposes so the models replicate the observed fractions of intrazonal tours, either at the all modes level, and/or for particular modes.

CBD constants have been added for some purposes, either as an all-modes constant picking up differences in the attractiveness of CBD destinations relative to other destinations, or to pick up mode specific effects. The main pattern these terms reveal is higher use of train to access CBD destinations than can be explained on the basis of differences in LOS and fare between train and other modes.

Park-and-ride models

The P&R models developed for the original version of PRISM have been imported into the model structures for commute, home–shopping and home–other travel. The P&R models predict the choice of access mode for train and metro, with car driver, car passenger and other access modes (metro, bus and walk or cycle) represented. For car driver and car passenger access modes, the choice of access station is also represented.

Validation of the station choice model component has demonstrated that the station ranking process is operating correctly, and that the distribution of demand across stations validates the original decision to model the top three ranked stations.

The P&R models result in higher run times in model application, because of the need to loop over the three station alternatives for each OD pair. Therefore, separate versions of the commute, home–shopping and home–other models have been developed with and without the P&R models. The models without P&R are named ‘S=0’, the models with P&R are termed ‘S = 3’, with S indicating the number of P&R stations represented for each OD pair. In the S = 0 versions of the models, it is assumed that all access to train and metro is by another PT mode and/or walk.

Car driver time period choice models

For the commute, home–business, home–shopping, home–escort and home–other travel models, the choice of time period has been modelled for car driver. Time period choice is modelled by representing 13 time period combination alternatives defined from possible combinations of four outward and four return time periods.

The choice between time period combination alternatives is predicted on the basis of differences in travel time and cost between each time period combination, and constants which have been estimated to replicate the distributions over time period combination alternatives observed in the 2009–2012 HI data.

For home–tertiary education travel, and for the six non-home-based purposes, time period choice is fixed to the proportions from the 2009–2012 HI data.

Model structure

The model structures have been determined by identifying the sensitivity of the various choices relative to main mode choice.

The final model structure for commuting and home–other travel has main mode choice, car driver time period choice and train & metro access mode choice all at the same level in the structure as the highest (least sensitive) choices. Destination choice lies beneath main mode choice, and then train & metro station choices is the lowest (most sensitive choice).

For home–other travel, the highest level choice is the same, with main mode choice, car driver time period choice and train and metro access mode choice all at the same level. However, train and metro station choice is the next level in the structure, and then destination choice is the lowest (most sensitive) choice.

For home–business and home–escort, there are no P&R models. These models both have a structure with main mode and car-driver time period choice at the same level as the highest (least sensitive) choices, and destination choice at the lowest level (more sensitive) choice.

For the three education models, only main mode and destination choices are modelled. For home–primary education, it was not possible to identify a significant nesting parameter and therefore the final model structure is multinomial with modes and destinations equally sensitive to changes in utility. For home–secondary and home–tertiary education, the final structure has destination choice beneath mode choice.

For the six NHB purposes, only main mode and destinations choices are modelled. For the other–other detour model, a significant nesting parameter was identified for a destinations beneath modes structure. For the other five NHB purposes, where sample sizes are small, it was not possible to identify significant values for the structural parameters and therefore the final model structures are multinomial with modes and destinations equally sensitive to changes in utility.

WebTAG guidance in Unit 3.10.3 is that for relatively long time periods, such as those represented in PRISM, the sensitivity of main mode and time period choices should be similar. The new models that include car driver time period choice all represent main mode and time period choices with equal sensitivity and are therefore consistent with this guidance. WebTAG Unit 3.10.3 indicates a default hierarchy of destination choice following main mode choice, and all of the HB models except primary education are consistent with this default hierarchy.

Model validation

Elasticity tests

The total fuel cost kilometrage elasticity is –0.247, at the lower end of the –0.25 to –0.35 range indicated in WebTAG Unit 3.10.4. The overall car time kilometrage elasticity is –0.858 which is reasonable; the car time trip elasticity of -0.101 is much lower, indicating that the main response of the models to changes in car time is redistribution over destinations, and that mode shifting is relatively limited.

The total PT fare elasticity is –0.302, at the lower end of the –0.2 to –0.9 range indicated in WebTAG Unit 3.10.4. The PT fare information outside of the core area is predicted by fare regressions which have a low sensitivity to fare with distance, and will therefore underestimate the costs associated with very long PT trips. If the models were to be re-estimated using fares from the new 2011 unified PT models, and provided the fare matrices in these models give greater variation in fare with distance, then a higher sensitivity to PT fare changes would be expected. The assumption of zero PT costs for holders of passes will also contribute to the relative low PT fare elasticities, because all of these individuals are insensitive to changes in the modelled PT fares.

Overall, the new model is less sensitive to cost changes than the average values given in WebTAG. This result is consistent with the cost sensitivities observed for the 2006 base version of PRISM.

For those purposes where car-driver time period choice models have been estimated, sensitivity tests have been run making changes to travel times in the AM peak for outward journeys only. These tests demonstrate that the time period choice models respond plausibly to journey time changes, and that the overall sensitivity of car driver time period choice is moderate, which is expected given that it is represented at the highest (least sensitive) level of the choice hierarchy.

Implied VoTs

The implied VoTs for commute, home–tertiary and home–escort travel are in line with the values in WebTAG Unit 3.5.6 for car driver, and slightly lower than WebTAG Unit 3.5.6 for PT modes. The implied VoTs for home–other travel and in line the WebTAG values for car driver, bus and metro, and somewhat higher than the WebTAG values for train because of the higher incomes of train travellers and the higher mean costs for the sample of train tours.

For home–primary education and home–secondary education, the implied VoTs are high, up to 3.8 times the WebTAG values. However, there is limited cost information for these purposes because there is no car driver data, and it was judged to be better to accept these high VoT values, rather than drop cost from the models altogether, so that the models are sensitive to PT fare changes. These purposes represent a small fraction (13%) of total PT tours and so the impact of these purposes on total PT demand is relatively small.

The implied VoTs are also on the high side for the home–shopping model. The home–shopping model proved problematic in the model estimations, the gamma value which determines the log-linear mixture is already low at 0.1 and so there is no scope for lowering the gamma value to increase the VoTs.

For home–business, VoTs have been imported from WebTAG.

For the NHB models where the sample sizes are low, the work–work PD-based tour model has low VoTs, and the work-other PD-based tour and work–work detour models have high VoTs, relative to WebTAG guidance values. For the other–other PD-based tour model, VoTs have been imported from WebTAG.

Tour and detour lengths

The tour and detour lengths predicted when the models are applied to the estimation samples have been compared with the tour and detour lengths observed in the estimation samples (the 2009–2012 HI data).

For most purposes the models predict the total tour and detour lengths observed in the 2009–2012 HI data accurately, and for all of the home-based models the predicted tour length is within ±10% of the observed.

Car passenger, cycle and walk tour and detour lengths are predicted accurately because specific distance terms are included in the utility functions for these modes.

Car driver tour lengths are predicted to within ±10% of the observed for all HB purposes except home–other travel, and the predicted tour length distributions match the observed reasonably well for both HB and NHB purposes.

The correspondence between observed and predicted tour and detour lengths for the PT modes is more disappointing. There is a consistent pattern of under-prediction of train tour distances, and over-prediction of bus tour distances across purposes. It is hoped that if the models were recalibrated using the new 2011 unified PT model that revised models would better replicate the observed PT tour lengths. In particular, with the current fare regressions the distance effect is weak and therefore the costs of very long tours are under-predicted.

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APPENDICES

Appendix A: Tour building analysis

Introduction

This Appendix documents the analysis that has been undertaken to 'build' tours[18] from the 2011 HI PRISM data. The tours have then been analysed to help in determining a number of issues concerning the scope of the modelling. The headline points from the tour building analysis are:

- in terms of the HB tour purposes to be represented:
    - there is sufficient employer's business data to develop a mode-destination model if 'work, not usual workplace' destinations are included – this assumption is justified by analysis of mode share, activity duration and distance from the home
    - an additional escort purpose should be modelled using multiple attraction variables in the mode-destination choice model to reflect the range of destination activities that give rise to escort travel, and with escort frequency predicted as a function of household characteristics such as size and the presence of children
    - there is sufficient data to retain the other existing purposes, namely commute, home–primary education, home–secondary education, home–tertiary education, home–shopping and home–other travel
- in terms of the modes to be represented for home-based (HB) tours[19]:
    - only 68 school bus tours are observed, as in the current version of PRISM so these are merged with bus
    - only 16 motorcycle tours are observed, and therefore as in the current version of PRISM these are dropped
    - taxi has a mode share of less than 1% for all purposes except other – given the difficulties in assembling appropriate taxi cost information and the lack of current policy interest in taxi, taxi tours are dropped from the modelling
    - the modelled main modes are therefore car driver[20], car passenger, train, metro, bus, cycle and walk

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[18] A tour is a series of linked trips starting and finishing at the same location. The next section of this Appendix begins with a full definition of the home-based tours used for this analysis.

[19] If more than one mode is used during a tour, hierarchies are applied to determine the main and (where relevant) access modes. These mode hierarchies are given in Table 111 presented later in the Appendix.

  - mode symmetry is high for outward and return journeys, so assuming that a single mode can be used to represent the entire tour remains a valid assumption
  - volumes of train and metro park-and-ride (P&R) data are low, and therefore we rely on previous analysis to provide parameters for the park-and-ride (P&R) and kiss-and-ride model components
  - for bus, just (1.4%) of tours use car access (mainly car passenger) and therefore we retain the approach used in the current version of PRISM where bus access is assumed to be by walk
- in terms of the non-home-based (NHB) modelling:
  - there is sufficient data to develop NHB models from the HI data – in the original PRISM development there was insufficient NHB data in the 2001 HI, despite an overall sample size that was more than two times higher, because NHB travel was significantly under-reported
  - we model detours made during home-based tours, and tours made from the primary destination, separately
  - modelling NHB detours enables us to more accurately reflect the travel patterns observed in the 2011 HI data, by modelling NHB travel conditional on HB travel – this represents a significant improvement on the approach used in the original version of PRISM, where NHB travel was predicted independently from HB travel
  - we model three different NHB purposes that distinguish work-related and other travel: work-related NHB travel made in the course of work-related HB tours, other NHB travel made in the course of work-based HB tours, and other NHB travel made in the course of other HB tours
  - for tours made from the primary destination, the volumes of data are low and therefore model parameters are imported
  - the NHB mode is modelled separately from the home-based mode, but constants will be included in the models to represent the linkage between home-based and NHB modes, particularly for detours.

In addition to the tour building analysis documented in this Appendix, tabulations have been run summarising the socio-economic characteristics of individuals observed to make tours for each of the home-based journey purposes. Cross-tabulations of purpose with age, employment status, household income band and gender show plausible distributions and provide reassurance that the socio-economic information collected is sensible. The analysis to build home-based tours from the trip data recorded in the HI is documented in the next section of this Appendix. The analysis of NHB travel is documented in the final section of this Appendix.

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[20] The car driver mode includes light vans with an unladen weight of 1.5 tonnes or less. Heavier vans are recorded together with lorries, and are therefore excluded from the definition of car driver.

Building home-based tours

The travel data recorded in the HI data is recorded as trips, defined as movements between two different activity locations. An individual trip can include movements by more than one mode, and up to four modes are recorded for each trip in the HI data.

A full home-based tour is a series of linked trips starting and finishing at the individual's home. The purpose of a home-based tour is determined by identifying the *Primary Destination* (PD) of the tour. Most tours (85%) comprise a direct trip to the PD and a direct return home, such as home–work-home. For these tours, the PD is simply the destination travelled to on the first trip of the tour. However, for some tours more complex chains of trips are observed, such as home–education-work-home. To determine the PD for home-based tours comprising three or more trips, the following rules have been used:

1. apply the following purpose hierarchy (where a is highest):
    a. work, usual workplace
    b. work, not usual workplace
    c. employer's business
    d. education
    e. all other purposes
2. if after step 1 there are still ties, take the PD as the tied destination at which the most time was spent
3. if after step 2 there are still ties, take the PD as the tied destination most distant from the home
4. if after step 3 there are still ties, define the PD as the first tied destination visited

Once the PD has been determined, we can define the outward tour leg as the journey from the home to the PD, and the return tour leg as the journey from the PD back to the home.

It is possible to observe *half tours*, which can occur in two ways:

- chains of trips where the *origin* purpose for the first trip recorded on the survey day[21] is not the home – these are return half tours, observed at the start of the survey day, e.g. a nightshift worker returning home; and
- chains of trips which depart from the home but do not return to the home on the survey day – these are outward half tours, for example an individual who leaves the home on the survey day to visit a friend and stays overnight at their friend's house, or a nightshift worker leaving for work.

Some half tours may be coding errors, where individuals have only recorded partial information about their trip chains. In the 2011 HI the outbound leg is recorded more often than the return leg.

There are a total of 31,521 trip records in the HI data available for tour building. The destination purpose of these trip records is tabulated in Table 108.

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[21] The survey day runs from 03:30 in the morning to 03:30 on the following day.

Table 108: Trip records, destination purposes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Home	14,217	45.1	45.1	45.1
	Work, usual workplace	4,432	14.1	14.1	59.2
	Employer's business	255	.8	.8	60.0
	Education	2,991	9.5	9.5	69.5
	Shopping	2,414	7.7	7.7	77.1
	Other	3,759	11.9	11.9	89.0
	Escort	2,858	9.1	9.1	98.1
	Work, not usual work place	594	1.9	1.9	100.0
	Total	31,521	100.0	100.0	

The volume of trips with destination purpose coded as employer's business is low (less than 1% of the data). However, there are more than twice as many trips to workplace locations recorded as 'not usual workplace'. Modelling these trips as employer's business would substantially boost the volume of employer's business data.

A significant proportion of trips are escort trips.

The 31,521 trips have been processed into HB tours. Once this process is complete, each trip record can be classified into one of ten categories:

- the outward leg of a Simple Tour (ST)[22]
- the return leg of a Simple Tour (ST)
- the outward leg of a Complex Tour (CT)[23]
- the return leg of a Complex Tour (CT)
- half tours (HT), outward leg
- half tours (HT), return leg
- NHB trips, full tour – NHB trips associated with complex full-tours
- NHB trips, outward HT – NHB trips associated with outward half tours
- NHB trips, return HT – NHB trips associated with return half tours
- NHB trips, SA – standalone (SA) chains of trips that cannot be associated with a home-based tour

Table 109 presents the frequency distribution of trips across these ten categories.

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[22] A simple tour has two trips, the first (the outward leg) from the home to the primary destination, the second (the return leg) from the primary destination back to the home.

[23] A complex tour has three or more trips. Complex tours include at least one NHB trip.

Table 109: Trips by trip type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	ST Outward Leg	11872	37.7	37.7	37.7
	ST Return Leg	11872	37.7	37.7	75.3
	CT Outward Leg	2088	6.6	6.6	82.0
	CT Return Leg	2088	6.6	6.6	88.6
	HT - Outward only Leg	268	.9	.9	89.4
	HT - Return only Leg	90	.3	.3	89.7
	NHB Trips - Full tour	3105	9.9	9.9	99.6
	NHB Trips - Out HT	108	.3	.3	99.9
	NHB Trips - Ret HT	28	.1	.1	100.0
	NHB Trips - SA	2	.0	.0	100.0
	Total	31521	100.0	100.0	

Three-quarters (75.3%) of trips are associated with simple return tours, and a further 13.2% are associated with complex full tours comprising three or more trips. Almost 10% of trips are NHB trips associated with full tours, and it should be possible to develop a model NHB travel from these 3,105 trip records. There are only two standalone trips which cannot be associated with a home-based tour.

From Table 109 the following distributions of tour types can be defined:

- 13,960 (97.5%) full tours
- 268 (1.9%) outward half tours
- 90 (0.6%) return half tours

The most frequently observed purpose for outward half tours is work, typically corresponding to nightshift workers, followed by ‘other’, typically including individuals who visit friends or travel to a nightclub and do not return by the end of the survey day. *Outward* half tours are included in the frequency models to ensure that the total volume of travel is modelled correctly, but *all* half tours are dropped from the mode-destination choice modelling as the samples are relatively small and they can only be included if a number of assumptions are made, for example the timing of the tour leg that has not been recorded.

Tour purpose

The remainder of the tables presented in this section include the sample of 13,960 full tours that are included in the mode-destination modelling. Note that Table 108 and Table 109 present numbers of trips, not numbers of tours. The 13,690 full tours comprise the 11,872 simple tours and the 2,088 complex tours from Table 109. Table 110 presents an analysis of the tour purpose, and is comparable to the sample sizes available from the 2001 household interview data used to develop the original version of PRISM. The current tour building has been undertaken with the sample of 5,030 households available for analysis. The sample size in the 2001 HI data was 11,765 households, i.e. 2.6 times higher, although the data was of lower quality in a number of ways.

Table 110: Tour purpose, full tours

PD purpose	Full tours 2011 HI data	Full tours 2001 HI data	2011 sample as a % of 2001 sample
usual work place	4,215	7,736	54.5 %
employer's business	152	141	380.8 %
not usual work place	385		
education	2,903	4,650	62.4 %
shopping	1,865	5,177	36.0 %
other	2,661	4,054	109.5 %
escort	1,779		
Total	13,960	21,758	62.9 %

The samples of full commute, education, shopping, other and escort tours are sufficient to allow the estimation of home-based tour models. There are significant numbers of escort tours, and additional analysis is required to determine whether these should be merged with the 'other' purpose category (the approach used in the current version of PRISM) or whether these tours should be modelled separately.

There are just 152 full employer's business tours, too small a sample to allow the estimation of a separate employer's business tour model. However, there are 385 tours to 'not usual' workplaces and if these were combined with tours where the purpose is recorded as employer's business there would be a total of 537 employer's business tours, sufficient for the estimation of an employer's business tour model. Additional analysis is presented in Section 2.3.1 of the main text to compare the characteristics of tours to non-usual workplaces to those for work and employer's business tours to investigate the validity of assuming these tours to be employer's business tours.

Comparing the sample sizes to those observed in the 2001 HI data, if we include not usual workplace tours there is a significant increase in the number of employer's business tours available for estimation, despite the much smaller overall sample size, and therefore the issue of under-reporting of employer's business travel in the 2001 HI has been overcome. The large number of escort tours observed in the 2011 HI data means that the total number of other purpose and escort tours is slightly higher than observed in the 2001 HI data, despite the significant reduction in the number of households interviewed. Our proposed treatment of escort travel is discussed later on in this section. The number of shopping tours as a proportion of the total is lower in the 2011 HI data.

Tour mode

Next, the main and access modes used for the outward and return tour legs have been analysed. For each trip, up to 4 different modes are recorded, and a tour leg may comprise more than one trip. To determine the main and access modes, the following mode hierarchies have been applied to all of the modes recorded for all of the trips on the tour leg.

Table 111: Main mode hierarchies

	Main mode
1	train, park-and-ride
2	train
3	metro
4	bus / coach
5	school bus
6	car driver
7	motorcycle
8	car passenger
9	taxi
10	cycle
11	walk

Table 112: Access mode hierarchies

	Access mode
1	car driver
2	motorcycle
3	car passenger
4	taxi
5	bus / coach
6	school bus
7	metro
8	train
9	train, park-and-ride
10	cycle
11	walk

These mode hierarchies are chosen to maximise the volume of PT tours, and further to maximise the number of park-and-ride tours.

In the current version of PRISM, it is assumed that the mode chosen for the outward tour leg can be used to model both the outward and return legs of the tour. To review the validity of this assumption we cross-tabulate the outward and return tour modes for the sample of 13,960 full tours from the 2011 HI data (see Table 113 below). Cells on the main diagonal where the outward and main modes are identical are highlighted in grey.

Table 113: Outward and return tour mode cross-tabulation, full tours only

		ret_mode												
		PRRail	Train	Metro	Bus/Coach/ WorkBus/PR Bus	School Bus	Car-Driver	Motorcycle	Car-Passenger	Taxi	Cycle	Walk	Other/none/do not know	Total
out_mode	PRRail	1	0	0	0	0	0	0	0	0	0	0	0	1
	Train	0	220	0	10	0	1	0	9	3	1	3	1	248
	Metro	0	0	40	3	0	0	0	0	0	0	0	0	43
	Bus/Coach/WorkBus/PR Bus	0	12	1	1829	7	2	0	116	24	0	35	2	2028
	School Bus	0	0	0	8	54	0	0	5	0	0	1	0	68
	Car-Driver	0	6	0	1	0	5493	0	28	2	0	9	6	5545
	Motorcycle	0	0	0	0	0	0	16	0	0	0	0	0	16
	Car-Passenger	0	5	2	95	3	24	0	1768	9	1	132	1	2040
	Taxi	0	1	0	8	0	0	0	10	71	0	6	0	96
	Cycle	0	0	0	0	0	0	0	1	0	146	0	0	147
	Walk	0	0	0	36	2	12	0	121	24	0	3426	0	3621
	Other/none/do not know	0	0	0	0	0	1	0	3	0	0	0	104	107
Total		1	244	43	1990	66	5533	16	2061	133	148	3612	113	13960

For 13,168 out of 13,960 tours (94.3%) the outward and return main modes are identical. Furthermore, the numbers of tours off the main diagonal tend to balance out, so that using the outward mode to define the mode for the tour as a whole would not introduce an overall bias. For example, a significant number of cases where the outward main mode is car passenger have a different return main mode (2,040-1,768=272, 13% of the total). However, the total numbers of tours where car passenger is the main outward and return mode are very similar (2,040 and 2,061, so only different by 21 tours, 1% of the total) and so the cases off the main diagonal more or less balance. An important exception to this is taxi, which is more frequently used as a mode of travel for the return leg of a tour than on the outward leg, and therefore using the outward mode would underestimate the overall mode share. However, as taxi tours comprise less than 1% of the total the impact of the symmetry assumption would be minimal.[24]

The car driver mode includes light vans with an unladen weight of 1.5 tonnes or less. Large vans are recorded together with lorries in the 2011 HI data, and have therefore been excluded from the definition of the car driver mode – instead they form part of the 'other/none/do not know' cells in Table 113. Any tours in these cells have been excluded from the estimations.

The volume of school bus tours is relatively low (68 tours) and therefore, as in the current version of PRISM, these are modelled together with bus as a main mode.

Just 16 motorcycle tours are observed, and therefore these are dropped from the modelling, as in the current version of PRISM.

The main and access modes for the outward tour leg are cross-tabulated in Table 114.

Table 114: Outward main mode (out_mode) and access mode (out_accmode) cross-tabulation, full tours only

			out_accmode										
			Car-Driver	Car-Passenger	Taxi	Bus/Coach/WorkBus/PR Bus	School Bus	Metro	Cycle	Walk	Other/none/do not know	No access mode	Total
out_mode	PRRail	Count	1	0	0	0	0	0	0	0	0	0	1
		% within out_mode	100.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%
	Train	Count	35	21	3	46	0	4	5	112	0	22	248
		% within out_mode	14.1%	8.5%	1.2%	18.5%	.0%	1.6%	2.0%	45.2%	.0%	8.9%	100.0%
	Metro	Count	6	4	0	14	1	0	0	16	0	2	43
		% within out_mode	14.0%	9.3%	.0%	32.6%	2.3%	.0%	.0%	37.2%	.0%	4.7%	100.0%
	Bus/Coach/WorkBus/PR Bus	Count	5	24	2	0	1	0	2	1587	0	407	2028
		% within out_mode	.2%	1.2%	.1%	.0%	.0%	.0%	.1%	78.3%	.0%	20.1%	100.0%
	School Bus	Count	0	1	0	0	0	0	0	15	0	52	68
		% within out_mode	.0%	1.5%	.0%	.0%	.0%	.0%	.0%	22.1%	.0%	76.5%	100.0%
	Car-Driver	Count	0	11	1	0	0	0	1	309	2	5221	5545
		% within out_mode	.0%	.2%	.0%	.0%	.0%	.0%	.0%	5.6%	.0%	94.2%	100.0%
	Motorcycle	Count	0	0	0	0	0	0	0	1	0	15	16
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	6.3%	.0%	93.8%	100.0%
	Car-Passenger	Count	0	0	0	0	0	0	0	106	1	1933	2040
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	5.2%	.0%	94.8%	100.0%
	Taxi	Count	0	0	0	0	0	0	0	6	0	90	96
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	6.3%	.0%	93.8%	100.0%
	Cycle	Count	0	0	0	0	0	0	0	2	0	145	147
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	1.4%	.0%	98.6%	100.0%
	Walk	Count	0	0	0	0	0	0	0	0	1	3620	3621
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
	Other/none/do not know	Count	0	0	0	0	0	0	0	0	0	107	107
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
Total		Count	47	61	6	60	2	4	8	2154	4	11614	13960
		% within out_mode	.3%	.4%	.0%	.4%	.0%	.0%	.1%	15.4%	.0%	83.2%	100.0%

There is only a single tour record where the main mode has been recorded as 'park-and-ride rail', and for that record car driver is the access mode as would be expected. Of the 248 train tours, 35 (14.1%) have access by car driver, and 21 (8.5%) have access by car passenger. For metro, there are just 43 tours, of which 6 (14.0%) have car driver access,

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[24] Because of their low volume, taxi tours have been dropped from the model as described below.

and 4 (9.3%) have car passenger access. It is clear that there is insufficient information on park-and-ride (P&R) and kiss-and-ride (K&R) travel in the HI data to allow separate P&R and K&R access mode and station choice models to be estimated from the HI data. Therefore information from earlier datasets has been used to import P&R and K&R into the model structure for train and metro.

For bus, just 5 (0.2%) of tours use car driver as the access mode, and just 24 (1.2%) use car passenger as the access mode; therefore we retain the approach used in the existing version of PRISM, where all bus access is assumed to be by walk.

After dropping the 16 motorcycle and 107 tours with mode other/unknown which will not be included in the modelling, the mode shares by purpose were tabulated.

Table 115: Mode shares by tour purpose tabulation, full tours only

			PD_Purp							
			Usual work place	Employers Business	Education	Shopping	Other	Escort	Not usual work place	Total
out_mode	PRRail	Count	1	0	0	0	0	0	0	1
		% within PD_Purp	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%
	Train	Count	127	5	40	22	46	0	8	248
		% within PD_Purp	3.1%	3.6%	1.4%	1.2%	1.7%	.0%	2.3%	1.8%
	Metro	Count	21	0	7	6	8	0	1	43
		% within PD_Purp	.5%	.0%	.2%	.3%	.3%	.0%	.3%	.3%
	Bus/Coach/WorkBus/PR Bus	Count	587	16	543	405	384	66	27	2028
		% within PD_Purp	14.1%	11.7%	18.8%	21.7%	14.5%	3.7%	7.6%	14.7%
	School Bus	Count	1	0	59	5	3	0	0	68
		% within PD_Purp	.0%	.0%	2.0%	.3%	.1%	.0%	.0%	.5%
	Car-Driver	Count	2600	101	107	664	1018	792	263	5545
		% within PD_Purp	62.5%	73.7%	3.7%	35.6%	38.4%	44.5%	74.3%	40.1%
	Car-Passenger	Count	329	8	778	294	541	52	38	2040
		% within PD_Purp	7.9%	5.8%	26.9%	15.8%	20.4%	2.9%	10.7%	14.7%
	Taxi	Count	20	0	12	14	46	4	0	96
		% within PD_Purp	.5%	.0%	.4%	.8%	1.7%	.2%	.0%	.7%
	Cycle	Count	67	0	34	4	36	4	2	147
		% within PD_Purp	1.6%	.0%	1.2%	.2%	1.4%	.2%	.6%	1.1%
	Walk	Count	409	7	1311	449	570	860	15	3621
		% within PD_Purp	9.8%	5.1%	45.3%	24.1%	21.5%	48.4%	4.2%	26.2%
Total		Count	4162	137	2891	1863	2652	1778	354	13837
		% within PD_Purp	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Taxi has a mode share of less than 1% for all purposes except other, and given the difficulties in assembling appropriate taxi cost information, and the lack of current policy interest in taxi, taxi has been dropped as a mode from the modelling. Dropping taxi tours is preferred to merging them with car driver because taxi tours are unusual in characteristics, and so merging them with car driver may introduce bias to the car driver model parameters. Note that this step leads to a change relative to the current version of PRISM, where a separate taxi mode is modelled. Taxi tours are not assigned in the current version of PRISM, and so dropping taxi as modelled mode does not impact on the predicted car matrices.

Cycle also has a low mode share, with the highest share of 1.6% observed for work tours. However, no cost information is required to model cycle tours and retaining the ability to model policies aimed at encouraging cycling would be a useful feature. Therefore cycle is retained as a mode for those purposes where there is sufficient data, specifically work (usual workplace), education, other and shopping.

Analysis of NHB travel

Linked trips which are made during the course of a home-based (HB) tour but do not depart from or arrive at home are defined as NHB trips. The travel associated with these trips can be modelled within the tour-based approach in the following two ways:

1. Primary destination based (PD-based) tours, i.e. a series of linked trips starting and finishing at the same primary destination location, e.g. if an individual makes a lunchtime journey to the shops during their work day.
2. NHB detours made during the outward or return legs of home-based tours, i.e. a single trip to or from the PD, e.g. if an individual makes a diversion on their journey back home to pick up a child from school.

These two cases are illustrated by the examples in the following figures. In Figure 32 trips (2) and (3) form the PD-based tour. In Figure 33, trip (2) forms the NHB detour.

Figure 32: PD-based tour example

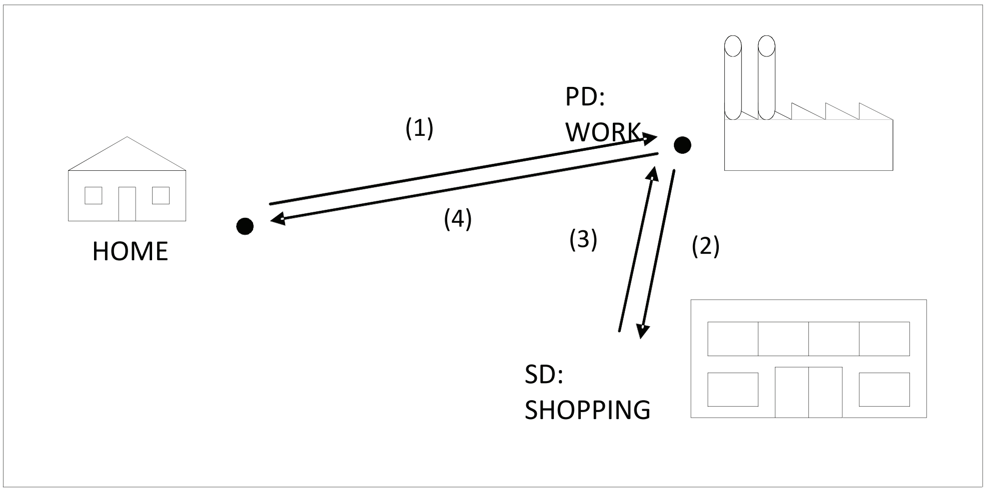
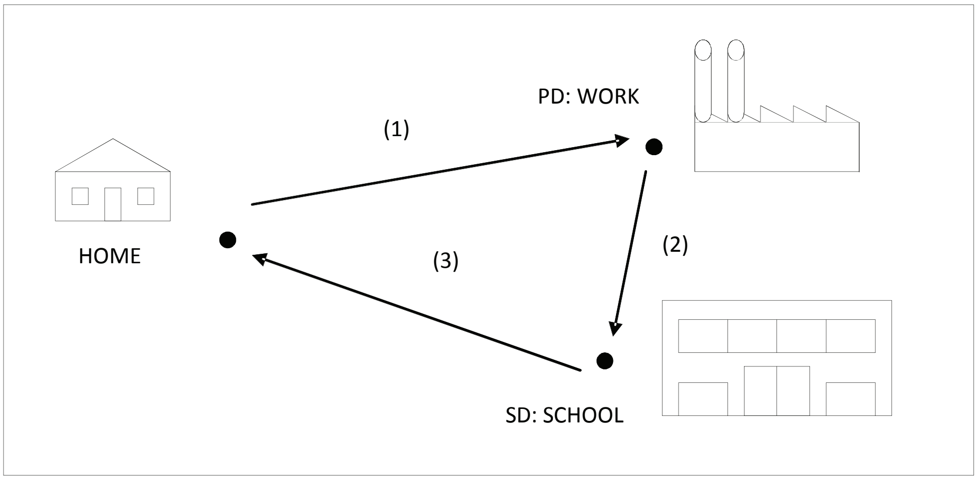


Figure 33: NHB detour example



In case 1, the purpose of the PD based tours is determined by identifying a *Secondary Destination* (SD). Most PD based tours comprise a direct return to the PD travel such as PD-EB[25]-PD for which the SD is readily determined. These are referred to as 'simple PD-based tours'. However, for some cases chains of three or more trips are observed, such as PD-other-EB-PD. For these cases the SD is identified based on the same rules which have been used for identifying the PD. These are referred to as 'complex PD-based tours'.

The purpose for detours (case 2) is also determined by identifying the purpose at the SD. Most NHB detours comprise a direct trip to or from PD, such as home–escort-PD or PD-escort-home for which SD is readily determined. For cases where more complex chains of trips are observed, such as home–escort-shop-PD, the SD is again identified based on the same rules which have been used for identifying the PD.

From Table 109, we observe that 10.3% of the trips can be associated with NHB travel of which 9.9% are associated with a full HB tour. For this analysis and in the modelling only NHB trips associated with full HB full tours are used.

Table 116 below shows the classification of the NHB-trips associated with HB full tours into detours and PD based tours. Table 109 demonstrates that 3,105 NHB trips have been identified from the tour building; however one of these trips has been dropped from the analysis due to missing purpose information. Of the remaining 3,104 NHB trips, 2,706 trips (87%) are associated with detours and 398 trips (13%) are associated with PD-based tours.

Of the NHB-trips associated with detours, 72.7% of the trips can be directly identified as a simple outward or simple return detour (cases where an individual makes only one detour on the tour leg). To reduce the complexity of the modelling task, it is assumed that only one detour is made per tour leg. Thus, while 27.3% of the trips form complex chains of trips, only 10.6% of trips are associated with an outward or a return detour, and the rest of the trips are not modelled (given that we are only modelling one detour per tour leg) and are therefore labelled as 'drop' in Table 116. Summing across simple and complex detours, we observe more return detours (47.3%) than outward detours (36.0%).

Of the NHB-trips associated with PD-based tours, 86.4% of the trips can be directly identified as a simple outward leg or simple return leg of a PD-based tour. 13.6% of the trips form complex chain of trips from which only 8.0% can be associated with an outward leg or a return leg of a PD-based tour. The rest of the trips (5.5%) need to be dropped as they cannot be modelled within the tour-based approach (and they are therefore labelled as 'drop' in Table 116). This is because to model complex tours we assume a direct return tour between the PD and the SD rather than model each individual NHB trip in the chain separately.

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[25] EB denotes employer's business.

Table 116: **NHB detours by trip type**

		Frequency	Percent	Valid percent	Cumulative percent
Valid	drop	450	16.6	16.6	16.6
	simple outward detour	877	32.4	32.4	49.0
	simple return detour	1091	40.3	40.3	89.4
	complex outward detour	98	3.6	3.6	93.0
	complex return detour	190	7.0	7.0	100.0
	Total	2,706	100.0	100.0	

Table 117: **PD-based tours by type**

		Frequency	Percent	Valid percent	Cumulative percent
Valid	drop	22	5.5	5.5	5.5
	ST Outward Leg	172	43.2	43.2	48.7
	ST Return Leg	172	43.2	43.2	92.0
	CT Outward Leg	16	4.0	4.0	96.0
	CT Return Leg	16	4.0	4.0	100.0
	Total	398	100.0	100.0	

Table 118 and Table 119 below show cross-tabulations between HB-tour purpose and NHB detour purpose across outward detours and return detours respectively. The majority of the outward and return detours are either escort tours, or other tours. Employer's business and not usual work place account for only 5.6% of outward detours and 7.0% of return detours.

Table 118: Home-based tour purpose (PD purpose) and NHB tour purpose: outward detours

			NHB Purpose							
			Work	Employers Business	Education	Shopping	Other	Escort	Not usual work place	Total
PD purpose	Work	Count	14	9	6	9	58	284	14	394
		% within PDpurpose	3.60%	2.30%	1.50%	2.30%	14.70%	72.10%	3.60%	100.00%
	Employers Business	Count	0	7	0	1	2	3	0	13
		% within PDpurpose	0.00%	53.80%	0.00%	7.70%	15.40%	23.10%	0.00%	100.00%
	Education	Count	0	0	12	3	21	39	0	75
		% within PDpurpose	0.00%	0.00%	16.00%	4.00%	28.00%	52.00%	0.00%	100.00%
	Shopping	Count	0	0	0	35	50	65	0	150
		% within PDpurpose	0.00%	0.00%	0.00%	23.30%	33.30%	43.30%	0.00%	100.00%
	Other	Count	0	0	0	62	114	60	0	236
		% within PDpurpose	0.00%	0.00%	0.00%	26.30%	48.30%	25.40%	0.00%	100.00%
	Escort	Count	0	0	0	5	10	51	0	66
		% within PDpurpose	0.00%	0.00%	0.00%	7.60%	15.20%	77.30%	0.00%	100.00%
	Not usual work place	Count	0	0	0	1	4	11	25	41
		% within PDpurpose	0.00%	0.00%	0.00%	2.40%	9.80%	26.80%	61.00%	100.00%
Total		Count	14	16	18	116	259	513	39	975
		% within PDpurpose	1.40%	1.60%	1.80%	11.90%	26.60%	52.60%	4.00%	100.00%

Table 119: Home-based tour purpose (PD purpose) and NHB tour purpose: return detours

			NHB Purpose							
			Work	Employers Business	Education	Shopping	Other	Escort	Not usual work place	Total
PD purpose	Work	Count	8	12	9	109	180	195	42	555
		% within PDpurpose	1.40%	2.20%	1.60%	19.60%	32.40%	35.10%	7.60%	100.00%
	Employers Business	Count	0	9	1	1	6	1	0	18
		% within PDpurpose	0.00%	50.00%	5.60%	5.60%	33.30%	5.60%	0.00%	100.00%
	Education	Count	0	0	14	37	133	39	0	223
		% within PDpurpose	0.00%	0.00%	6.30%	16.60%	59.60%	17.50%	0.00%	100.00%
	Shopping	Count	0	0	0	60	46	21	0	127
		% within PDpurpose	0.00%	0.00%	0.00%	47.20%	36.20%	16.50%	0.00%	100.00%
	Other	Count	0	0	0	76	107	49	0	232
		% within PDpurpose	0.00%	0.00%	0.00%	32.80%	46.10%	21.10%	0.00%	100.00%
	Escort	Count	0	0	0	9	8	50	0	67
		% within PDpurpose	0.00%	0.00%	0.00%	13.40%	11.90%	74.60%	0.00%	100.00%
	Not usual work place	Count	0	6	0	7	16	9	21	59
		% within PDpurpose	0.00%	10.20%	0.00%	11.90%	27.10%	15.30%	35.60%	100.00%
Total		Count	8	27	24	299	496	364	63	1281
		% within PDpurpose	0.60%	2.10%	1.90%	23.30%	38.70%	28.40%	4.90%	100.00%

Representing each possible combination of PD purpose and SD purpose in the NHB detour modelling would result in an unreasonably large number of purpose combinations given the volumes of detours available for model estimation. Therefore the detour modelling is simplified to reflect work-related travel (work usual workplace, work not usual workplace and employer's business) and all other purposes. Then separate sets of detour mode-destination models will be developed for the following three cases:

1. detours made during work-related PD tours to work-related SDs;
2. detours made during work-related PD tours to other purpose SDs; and
3. detours made during other purpose PD tours to other purpose SDs.[26]

For the detour frequency modelling, the models will be further segmented by whether the traveller makes tours on their outward or return journey, as the detour rates are different by direction. Table 120 below shows the classification of the detours into the above three cases.

Table 120: Detours by simplified purpose

				SD Purpose		Total
NHB				Work Related	Other	
Outward detour	PD Purpose	Work Related	Count	69	379	448
			% within PD Purpose	15.4%	84.6%	100.0%
		Other	Count	0	527	527
			% within PD Purpose	.0%	100.0%	100.0%
	Total		Count	69	906	975
			% within PD Purpose	7.1%	92.9%	100.0%
Return detour	PD Purpose	Work Related	Count	98	534	632
			% within PD Purpose	15.5%	84.5%	100.0%
		Other	Count	0	649	649
			% within PD Purpose	.0%	100.0%	100.0%
	Total		Count	98	1183	1281
			% within PD Purpose	7.7%	92.3%	100.0%

Only 7.1% of the outward and 77% of the return detours are case 1, 38.9% of the outward and 41.7% of return the detours are case 2, and 54.0% of the outward and 50.7% of return detours are case 3.

Table 120 cross-tabulates the outward main mode with the detour mode across the outward and the return detours. Cells on the main diagonal where the outward and the detour mode are identical are highlighted in grey.

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[26] Note that because of the purpose hierarchies employed, it is not possible to make a detour from an other PD to a work-related SD.

Table 121: Outward main mode and detour main mode cross-tabulation

				Det_mode											
				Train	Metro	Bus/Coach /WorkBus/ PRBus	School Bus	Car-Driver	Motorcycle	Car-Passenger	Taxi	Cycle	Walk	Other/none /do not know	Total
Outward detour	out_mode	Train	Count	10	1	1		4		1	0	1	3	0	21
			% within out_mode	47.6%	4.8%	4.8%		19.0%		4.8%	.0%	4.8%	14.3%	.0%	100.0%
		Metro	Count	0	1	0		1		1	0	0	2	0	5
			% within out_mode	.0%	20.0%	.0%		20.0%		20.0%	.0%	.0%	40.0%	.0%	100.0%
		Bus/Coach/Work Bus/PRBus	Count	0	0	90		3		8	1	0	37	0	139
			% within out_mode	.0%	.0%	64.7%		2.2%		5.8%	.7%	.0%	26.6%	.0%	100.0%
		School Bus	Count	0	0	0		0		1	0	0	0	0	1
			% within out_mode	.0%	.0%	.0%		.0%		100.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Driver	Count	0	0	0		577		2	0	0	3	0	582
			% within out_mode	.0%	.0%	.0%		99.1%		.3%	.0%	.0%	.5%	.0%	100.0%
		Car-Passenger	Count	0	0	0		0		104	0	0	8	0	112
			% within out_mode	.0%	.0%	.0%		.0%		92.9%	.0%	.0%	7.1%	.0%	100.0%
		Taxi	Count	0	0	0		0		0	4	0	1	0	5
			% within out_mode	.0%	.0%	.0%		.0%		.0%	80.0%	.0%	20.0%	.0%	100.0%
		Cycle	Count	0	0	0		0		0	0	1	0	0	1
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	100.0%	.0%	.0%	100.0%
		Walk	Count	0	0	0		0		0	0	0	106	0	106
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	.0%	100.0%	.0%	100.0%
		Other/none/do not know	Count	0	0	0		0		0	0	0	0	3	3
			% within out_mode	.0%	.0%	.0%		.0%		.0%	.0%	.0%	.0%	100.0%	100.0%
	Total		Count	10	2	91		585		117	5	2	160	3	975
			% within out_mode	1.0%	.2%	9.3%		60.0%		12.0%	.5%	.2%	16.4%	.3%	100.0%

				Det_mode											
				Train	Metro	Bus/Coach /WorkBus/ PRBus	School Bus	Car-Driver	Motorcycle	Car-Passenger	Taxi	Cycle	Walk	Other/none /do not know	Total
Return detour	out_mode	Train	Count	16	0	2	0	0	0	2	0	0	5	0	25
			% within out_mode	64.0%	.0%	8.0%	.0%	.0%	.0%	8.0%	.0%	.0%	20.0%	.0%	100.0%
		Metro	Count	0	6	1	0	0	0	0	0	0	0	0	7
			% within out_mode	.0%	85.7%	14.3%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		Bus/Coach/Work Bus/PRBus	Count	5	0	126	1	1	0	15	0	0	53	2	203
			% within out_mode	2.5%	.0%	62.1%	.5%	.5%	.0%	7.4%	.0%	.0%	26.1%	1.0%	100.0%
		School Bus	Count	0	0	0	1	0	0	1	0	0	0	0	2
			% within out_mode	.0%	.0%	.0%	50.0%	.0%	.0%	50.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Driver	Count	4	0	0	0	650	0	5	2	0	21	3	685
			% within out_mode	.6%	.0%	.0%	.0%	94.9%	.0%	.7%	.3%	.0%	3.1%	.4%	100.0%
		Motorcycle	Count	0	0	0	0	0	3	0	0	0	0	0	3
			% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	.0%	.0%	.0%	.0%	100.0%
		Car-Passenger	Count	0	1	9	1	4	0	135	1	1	23	1	176
			% within out_mode	.0%	.6%	5.1%	.6%	2.3%	.0%	76.7%	.6%	.6%	13.1%	.6%	100.0%
		Taxi	Count	0	0	0	0	0	0	0	1	0	1	0	2
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	50.0%	.0%	50.0%	.0%	100.0%
		Cycle	Count	0	0	0	0	0	0	0	0	6	0	0	6
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	.0%	100.0%
		Walk	Count	0	0	13	2	3	0	19	0	0	126	0	163
			% within out_mode	.0%	.0%	8.0%	1.2%	1.8%	.0%	11.7%	.0%	.0%	77.3%	.0%	100.0%
		Other/none/do not know	Count	0	0	0	0	0	0	0	0	0	0	9	9
			% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
	Total		Count	25	7	151	5	658	3	177	4	7	229	15	1281
			% within out_mode	2.0%	.5%	11.8%	.4%	51.4%	.2%	13.8%	.3%	.5%	17.9%	1.2%	100.0%

Of the 975 outward detours the outward main mode and detour mode are identical for 859 (91.8%) records. Walk, car driver and car passenger are more strongly correlated when compared to other modes and together with bus account for 97% of the outward detours.

There are no outward detour records associated with school bus or motorcycle as the detour mode. Of the 1,281 return detours the outward main mode and detour mode are identical for 1,079 (84.2%) records. The closest association is seen for car driver (94.9%), which is also the dominant mode with a mode share of 51.4%. Car driver, car passenger, walk and bus modes account for 95% of the return detours.

Given the strong relationship between the detour mode and the main tour mode we use the detour mode for assigning the mode choice in the detour models and estimate a constant for the corresponding outward main mode. There are 3 and 15 outward and return detours respectively for which the detour mode is unknown and these have been dropped from the modelling.

Table 122 shows the cross-tabulation between HB-tour purpose and PD based tour purpose. The majority of PD based tours are for other purposes. Employer's business and not usual work place purposes together account for 24.7% of all the PD based tours.

Table 122: Cross-tabulation of PD and SD purposes for PD-based tours

			SD Purpose							
			Work	Employers Business	Education	Shopping	Other	Escort	Not ususal work place	Total
PD purpose	Work	Count	1	25		26	54	1	24	131
		% within PDpurpose	0.80%	19.10%		19.80%	41.20%	0.80%	18.30%	100.00%
	Employers Business	Count	0	2		0	0	0	0	2
		% within PDpurpose	0.00%	100.00%		0.00%	0.00%	0.00%	0.00%	100.00%
	Education	Count	0	0		5	19	0	0	24
		% within PDpurpose	0.00%	0.00%		20.80%	79.20%	0.00%	0.00%	100.00%
	Shopping	Count	0	0		1	0	0	0	1
		% within PDpurpose	0.00%	0.00%		100.00%	0.00%	0.00%	0.00%	100.00%
	Other	Count	0	0		6	6	7	0	19
		% within PDpurpose	0.00%	0.00%		31.60%	31.60%	36.80%	0.00%	100.00%
	Escort	Count	0	0		1	1	2	0	4
		% within PDpurpose	0.00%	0.00%		25.00%	25.00%	50.00%	0.00%	100.00%
	Not usual work place	Count	0	1		1	5	0	0	7
		% within PDpurpose	0.00%	14.30%		14.30%	71.40%	0.00%	0.00%	100.00%
Total		Count	1	28		40	85	10	24	188
		% within PDpurpose	0.50%	14.90%		21.30%	45.20%	5.30%	12.80%	100.00%

Given the volumes of PD-based tours available for estimation, the PD and SD purposes are simplified to reflect the same cases identified for the detour modelling presented earlier in this section. Table 123 below shows the classification of PD-based tours in the three cases: cases 1, 2 and 3 account for 28.2%, 46.3% and 25.5% of the PD-based tours respectively.

Table 123: PD-based tours by simplified purpose

				SD Purpose		Total
				Work Related	Other	
PD based tour	PD Purpose	Work Related	Count	53	87	140
			% within PD Purpose	37.9%	62.1%	100.0%
		Other	Count	0	48	48
			% within PD Purpose	.0%	100.0%	100.0%
	Total		Count	53	135	188
			% within PD Purpose	28.2%	71.8%	100.0%

The sample sizes of PD-based tours by aggregated purpose remain low.

Table 124 below shows a cross-tabulation between the outward main modes and the PD-based tour mode. Cells on the main diagonal where the outward and the PD-based mode are identical are highlighted in grey.

Table 124: Mode shares for work-based tours

			SD Mode							
			Train	Metro	Bus/Coach /WorkBus/ PRBus	Car-Driver	Car-Passenger	Walk	Other/none /do not know	Total
PD_Mode	Train	Count	0	0	0	0	0	5	0	5
		% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	Metro	Count	0	0	0	0	0	2	0	2
		% within out_mode	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	Bus/Coach /WorkBus/ PRBus	Count	1	8	0	0	2	25	0	36
		% within out_mode	2.8%	22.2%	.0%	.0%	5.6%	69.4%	.0%	100.0%
	Car-Driver	Count	0	0	0	66	6	30	12	114
		% within out_mode	.0%	.0%	.0%	57.9%	5.3%	26.3%	10.5%	100.0%
	Car-Passenger	Count	0	0	0	0	7	5	1	13
		% within out_mode	.0%	.0%	.0%	.0%	53.8%	38.5%	7.7%	100.0%
	Cycle	Count	0	0	0	0	0	0	1	1
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
	Walk	Count	0	1	1	1	2	11	0	16
		% within out_mode	.0%	6.3%	6.3%	6.3%	12.5%	68.8%	.0%	100.0%
	Other/none /do not know	Count	0	0	0	0	0	0	1	1
		% within out_mode	.0%	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%
Total		Count	1	9	1	67	17	78	15	188
		% within out_mode	.5%	4.8%	.5%	35.6%	9.0%	41.5%	8.0%	100.0%

For 85 tours out of 188 tours (45.2%) the outward main mode and the PD-based tour mode are identical, a much lower level of association than was observed for detours made in the course of home-based tours. Car driver and walk modes account for 70% (136) of PD-based tours. We use the PD-based tour mode for assigning the mode choice in the modelling and estimate a constant for the corresponding outward main mode. Also, 8% (15) of tours where the mode is unknown are excluded from the modelling.

Appendix B: Parking cost data

Table 125 presents the average parking costs by zone and length of stay that have been calculated. Mott MacDonald supplied detailed information which gives the parking costs by parking duration for each individual car park in these zones. For zones containing more than one car park, weighted average parking costs have been calculated by weighting by the number of spaces in each car park.

Table 125: Average parking costs by PRISM zone (pence, 2012 prices)

Zone	0-1 hr	1-2 hrs	2-3 hrs	3-4 hrs	4-6 hrs	6-8hrs	8-12 hrs	12+ hrs
1022	76.42	96.07	129.41	180.35	247.21	326.72	351.31	375.90
1033	260.00	380.00	390.00	450.00	580.00	640.00	1280.00	1290.00
1043	51.51	61.94	76.83	91.73	263.81	284.68	284.68	284.68
1062	227.60	329.81	340.78	396.89	521.04	583.97	1143.58	1152.61
1083	10.25	23.05	30.74	38.42	58.92	84.53	84.53	84.53
1152	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1163	53.76	103.76	129.83	151.97	299.30	464.54	872.75	310.43
1165	16.50	37.12	53.62	61.86	123.73	123.73	136.10	136.10
1181	200.00	300.00	400.00	400.00	500.00	500.00	500.00	500.00
1193	3.67	9.18	12.86	16.53	29.39	45.92	45.92	45.92
1201	203.75	341.25	1029.58	1029.58	1535.42	2039.58	2545.42	3069.33
1207	400.00	670.91	1068.18	1068.18	1436.36	1622.73	2036.36	2036.36
1208	20.00	50.00	70.00	90.00	160.00	250.00	250.00	250.00
1233	40.00	90.00	120.00	150.00	230.00	330.00	330.00	330.00
1234	40.00	90.00	120.00	150.00	230.00	330.00	330.00	330.00
1283	20.00	50.00	70.00	90.00	160.00	250.00	250.00	250.00
1284	33.56	67.29	94.17	120.40	192.11	286.11	310.40	730.40
1285	20.00	50.00	70.00	90.00	160.00	250.00	250.00	250.00
1291	143.72	194.42	245.12	343.02	395.81	451.40	590.93	1149.07
1293	110.00	210.00	300.00	380.00	820.00	820.00	820.00	820.00
1294	294.39	381.91	555.38	643.63	860.89	1051.37	1287.67	1608.90
1296	146.62	265.00	310.61	397.98	505.27	531.72	650.38	899.03
1297	425.46	456.63	484.25	508.94	821.54	827.77	961.08	1038.14
1312	20.00	50.00	70.00	90.00	160.00	250.00	250.00	250.00
1376	79.53	98.68	145.57	189.04	373.51	581.04	581.04	581.04
1392	40.00	90.00	130.00	170.00	230.00	330.00	330.00	330.00
1501	30.00	60.00	80.00	100.00	170.00	270.00	270.00	810.00
1502	30.00	60.00	80.00	100.00	170.00	270.00	270.00	810.00
1503	100.00	190.00	280.00	350.00	400.00	500.00	500.00	500.00
1504	303.20	303.20	360.80	360.80	411.20	461.60	461.60	461.60
1508	200.00	400.00	500.00	500.00	600.00	800.00	1000.00	2000.00
1509	15.22	28.26	43.48	56.52	164.35	296.52	366.96	366.96
1510	163.79	327.59	362.07	560.34	560.34	646.55	732.76	905.17
1511	60.00	110.00	170.00	220.00	340.00	410.00	820.00	1230.00
1513	202.15	207.40	327.01	652.36	655.68	655.68	793.36	793.36
1514	120.00	310.00	460.00	570.00	860.00	860.00	1030.00	1430.00
1515	89.46	154.45	208.32	273.32	336.07	393.87	405.73	524.35

Zone	0-1 hr	1-2 hrs	2-3 hrs	3-4 hrs	4-6 hrs	6-8hrs	8-12 hrs	12+ hrs
1516	50.00	100.00	150.00	200.00	300.00	400.00	500.00	800.00
1517	110.00	220.00	330.00	450.00	700.00	1050.00	1050.00	1050.00
1519	110.00	220.00	330.00	450.00	970.00	970.00	970.00	970.00
1520	628.31	697.72	1271.69	1445.21	2315.07	2315.07	3248.86	4680.37
1521	284.29	528.13	837.90	866.93	1109.23	1736.50	1835.35	1842.27
1523	417.65	655.88	1002.94	1002.94	1561.76	1626.47	2064.71	1900.00
1525	123.85	300.47	390.90	496.41	656.64	959.09	1210.84	1210.84
1526	70.00	140.00	200.00	200.00	300.00	300.00	300.00	300.00
1527	70.00	140.00	200.00	300.00	400.00	400.00	400.00	500.00
1531	0.00	50.00	100.00	110.00	160.00	160.00	160.00	160.00
2121	100.00	180.00	230.00	300.00	800.00	1000.00	1000.00	1000.00
2206	100.00	180.00	230.00	300.00	800.00	1000.00	1000.00	1000.00
2207	300.00	400.00	450.00	500.00	800.00	800.00	800.00	800.00
2208	300.00	400.00	450.00	500.00	800.00	800.00	800.00	800.00
2209	181.68	272.57	349.80	626.73	854.46	1000.00	1000.00	1000.00
2210	300.00	400.00	450.00	500.00	800.00	800.00	800.00	800.00
2212	117.76	192.36	257.71	344.45	567.92	851.16	929.27	1163.61
2213	0.00	180.00	250.00	350.00	700.00	700.00	700.00	700.00
3021	41.36	82.73	124.09	148.03	148.03	148.03	148.03	250.00
3043	50.00	100.00	150.00	0.00	0.00	0.00	0.00	0.00
3051	217.70	268.84	268.84	328.05	328.05	328.05	328.05	328.05
3081	50.00	100.00	150.00	0.00	0.00	0.00	0.00	0.00
3082	38.82	77.65	116.47	120.21	120.21	120.21	120.21	120.21
3123	4.42	8.84	13.26	22.09	22.09	22.09	22.09	22.09
3132	50.00	100.00	150.00	250.00	250.00	250.00	250.00	250.00
3152	10.92	21.84	32.76	30.09	30.09	30.09	30.09	30.09
3191	53.25	73.38	93.51	158.94	158.94	158.94	158.94	158.94
3212	50.00	100.00	150.00	250.00	250.00	250.00	250.00	250.00
3231	57.08	103.54	153.54	254.75	264.24	264.24	264.24	264.24
3301	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3312	50.00	100.00	150.00	250.00	250.00	250.00	250.00	250.00
4182	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4183	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4202	40.00	80.00	120.00	160.00	200.00	200.00	200.00	200.00
4203	40.00	80.00	120.00	160.00	200.00	200.00	200.00	200.00
4304	40.00	80.00	120.00	160.00	200.00	200.00	200.00	200.00
4306	40.00	80.00	120.00	160.00	200.00	200.00	200.00	200.00
4307	40.00	80.00	120.00	160.00	200.00	200.00	200.00	200.00
5132	231.30	231.30	231.30	231.30	231.30	289.12	289.12	289.12
5172	200.00	300.00	400.00	400.00	500.00	500.00	500.00	500.00
5202	147.53	230.00	310.00	400.00	553.49	836.02	918.81	1084.39
6061	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6081	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6092	91.24	98.42	189.67	256.89	188.10	216.67	273.81	116.22
6094	140.00	140.00	280.00	380.00	500.00	500.00	500.00	500.00
6301	280.00	280.00	390.00	390.00	500.00	500.00	650.00	650.00
6306	201.38	308.44	469.88	557.44	679.96	679.96	679.96	679.96
6307	140.00	140.00	380.00	380.00	500.00	500.00	500.00	500.00
7172	98.31	195.79	247.89	304.21	783.14	783.14	791.57	791.57
7174	250.00	250.00	250.00	250.00	450.00	450.00	450.00	450.00
7307	174.80	174.80	258.80	384.80	746.00	872.00	872.00	872.00
7308	250.00	250.00	250.00	250.00	450.00	450.00	450.00	450.00
7309	94.20	116.58	200.00	344.74	1076.28	1434.23	1793.39	2868.47
7310	264.20	457.48	773.23	777.07	932.42	932.42	932.42	932.42
7311	227.55	255.35	310.97	422.19	644.65	644.65	644.65	644.65
7312	111.74	211.74	311.74	400.00	600.00	600.00	600.00	600.00
7313	350.00	350.00	490.00	490.00	800.00	800.00	800.00	800.00

Appendix C: Model results

This first section of this Appendix presents the new model parameters.

The second section of this Appendix presents a comparison, for purposes where a tour-based model was estimated in the current version of PRISM, of the current and new model parameters.

New model parameters

Table 126: New commute model parameters

Coefficient	Description	Model v85 S=0 model		Model v95 S=3 model	
		Value	t-ratio	Value	t-ratio
Cost parameters:					
GcostNA	Gamma cost parameter, income not stated	-0.0047	-13.0	-0.0046	-13.0
Gcost123	Gamma cost parameter, HH inc < £25k p.a.	-0.0066	-15.7	-0.0064	-15.5
Gcost45	Gamma cost parameter, HH inc £25-35k p.a.	-0.0048	-10.9	-0.0046	-10.8
Gcost67	Gamma cost parameter, HH inc £35-50k p.a.	-0.0044	-10.3	-0.0043	-10.2
Gcost811	Gamma cost parameter, HH inc > £50k p.a.	-0.0037	-8.9	-0.0038	-8.9
Level of service parameters:					
CarTime	Car in-vehicle time	-0.0273	-14.7	-0.0278	-15.0
CarPDist	Car passenger distance	-0.0218	-6.7	-0.0215	-6.6
PTGenTme	PT generalised time (both in and out vehicle)	-0.0193	-13.3	-0.0201	-13.4
Transfers	Public transport transfers	-0.2894	-5.8	-0.2801	-5.4
CycleDist	Cycle distance	-0.1680	-9.4	-0.1683	-9.4
WalkDist	Walk distance	-0.4832	-28.6	-0.4816	-28.6
CarAccTime	Car access time to train and metro			-0.0609	n/a
Socio-economic parameters:					
PTworkdist	Part-time worker distance	-0.0516	-11.2	-0.0518	-11.3
FreeCarUse	Free car use term on car driver	1.6201	6.9	1.5105	6.9
OneCarComp	Car competition for one HH car, car driver	-0.9414	-4.5	-0.9533	-4.8
PassOpt	Passenger opportunity term, car passenger	1.2597	5.0	1.2002	5.0
FreeUseCrP	Free car use term, car passenger	-0.6298	-2.2	-0.5508	-2.1
CarPMale	Male car passenger constant	-0.3926	-2.1	-0.3873	-2.2
TrIncGt50k	Train high income term (HH inc > £50k p.a.)	0.8045	2.0	0.8061	2.2
Trn_0cars	Zero cars term on train	-1.3460	-3.0	-0.8334	-2.0
Bus_0cars	Zero cars term on bus	0.5059	2.6	0.4553	2.5
BusMale	Male bus constant	-0.7299	-4.3	-0.7115	-4.4
Bus_17_24	Constant for persons aged 17-24 on bus	0.7463	3.7	0.6974	3.7
CycleMale	Male cycle constant	2.5648	4.7	2.4116	4.7
WalkMale	Male walk constant	-0.6648	-3.6	-0.6354	-3.6
Access mode socio-economic parameters:					
CrDAccMale	Male constant on car driver access			-0.7854	n/a
CrDAc16t19	Car driver contant for persons aged 16-19			-2.8411	n/a
CrDAc20t24	Car constant for persons aged 20-24			-0.7756	n/a
CrDAcc1Car	Constant for persons from 1 car households			-1.8215	n/a
CrPAccMale	Male constant on car passenger access			-0.9924	n/a
CrPAc35t44	Contants for persons aged 35-44			-0.6684	n/a
CrPAcc0Car	Constant for persons from zero car housholds			-3.5293	n/a
Mode constants:					
CarP	Car passenger (relative to car driver)	1.0893	2.9	0.9727	10.9
Train	Train (relative to car driver)	1.8448	5.3	0.2189	1.1
Metro	Metro (relative to car driver)	1.6019	3.8	0.0606	0.1
Bus	Bus (relative to car driver)	4.0889	11.7	3.9200	48.2
Cycle	Cycle (relative to car driver)	-1.3250	-2.2	-1.2372	-7.4
Walk	Walk (relative to car driver)	5.5606	16.2	5.3799	62.4
Access mode constants:					
TrainCP	Train, car passenger (relative to car driver)			-2.5786	-4.8
TrainOth	Train, other access (relative to car driver)			0.7011	2.8
MetroCP	Metro, car passenger (relative to car driver)			-3.1474	-2.4
MetroOth	Metro, other access (relative to car driver)			0.8370	1.4
Time period constants:					
TP_11	Out AM peak, return AM peak	-2.6874	-4.4	-2.5252	-4.4
TP_12	Out AM peak, return inter-peak	2.3053	9.2	2.1884	9.3
TP_13	Out AM peak, return PM peak	4.7243	13.6	4.4754	14.0
TP_14	Out AM peak, return off-peak	1.3167	5.5	1.2509	5.5
TP_22	Out inter-peak, return inter-peak	-0.0286	-0.1	-0.0190	-0.1
TP_23	Out inter-peak, return PM peak	1.5179	6.3	1.4441	6.4
TP_24	Out inter-peak, return off-peak	0.9717	4.0	0.9219	4.0
TP_33	Out PM peak, return PM peak	-2.0089	-4.1	-1.8851	-4.1
TP_34	Out PM peak, return off-peak	0.2124	0.8	0.2065	0.8
TP_41	Out off-peak, return AM peak	-2.7883	-4.5	-2.6273	-4.5
TP_42	Out off-peak, return inter-peak	1.5215	6.3	1.4412	6.4
TP_43	Out off-peak, return PM peak	2.1123	8.5	2.0017	8.6
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a	0.0000	n/a
Destination constants:					
CBDTrain	CBD zones term on train	0.9596	4.8	1.1274	5.9
ExtDest	External destinations term	1.4838	8.5	1.4847	8.6
TrExtDest	External destinations by train term	-2.8882	-5.4	-2.5126	-4.7
Attraction variable:					
TotEmp	Total employment attraction variable	1.0000	n/a	1.0000	n/a
Structural parameters:					
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.7373	5.6	0.7807	4.6

Table 127: New business model parameters

Model v60			
Coefficient	**Description**	**Value**	**t-ratio**
Level of service parameters:			
GenTime	Generalised time	-0.0171	-25.7
Walk	Car passenger distance	0.5726	0.2
CarPDist	Cycle distance	-0.0111	-6.1
CycleDist	Walk distance	-0.1007	-1.0
Socio-economic parameters:			
PTworkdist	Part-time worker distance	-0.0214	-3.0
FreeCaruse	Car competition for one HH car, car driver	0.0000	n/a
Mode constants:			
TotEmp	Car passenger (relative to car driver)	1.0000	n/a
CarP	Train (relative to car driver)	-1.7497	-0.8
Train	Metro (relative to car driver)	-7.4148	-3.0
Metro	Bus (relative to car driver)	-18.1772	-3.3
Bus	Cycle (relative to car driver)	-0.9102	-0.4
Cycle	Walk (relative to car driver)	-19.8823	-3.5
Time period constants:			
TP_12	Out AM peak, return AM peak	5.4776	3.1
TP_13	Out AM peak, return inter-peak	13.3015	8.5
TP_14	Out AM peak, return PM peak	-0.8437	-0.4
TP_22	Out AM peak, return off-peak	4.5716	2.5
TP_23	Out inter-peak, return inter-peak	8.0447	4.8
TP_24	Out inter-peak, return PM peak	0.8737	0.4
TP_33	Out inter-peak, return off-peak	-4.3848	-1.6
TP_34	Out PM peak, return PM peak	1.6151	0.8
TP_41	Out PM peak, return off-peak	0.0000	n/a
TP_42	Out off-peak, return AM peak (never chosen)	-1.4390	-0.6
TP_43	Out off-peak, return inter-peak	3.9469	2.1
TP_44	Out off-peak, return PM peak	0.0000	n/a
CBDDest	Out off-peak, return off-peak (base combination)	0.0000	n/a
Destination constants:			
CarPIZ	Intrazonal destinations	0.0000	n/a
TP_11	Walk intrazonal constant	-9.1776	-2.3
Attraction variable:			
IntraDest	Total employment attraction variable	2.4730	8.3
Structural parameters:			
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.1908	15.1

The out off-peak return AM peak time period combination is never chosen, and was therefore set to be unavailable in the model estimations.

Table 128: New home–primary education model parameters

Model v21			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
LogCost		-0.6758	-6.8
Level of service parameters:			
CarTime	Car time	-0.0865	-2.7
PTGenTime	Public transport generalised time	-0.0327	-11.3
CarPDist	Car passenger distance	-0.1665	-2.9
CycleDist	Cycle distance	-0.4307	-3.9
WalkDist	Walk distance	-0.5651	-28.5
Socio-economic parameters:			
PassOpt	Passenger opportunity	2.8710	8.2
CrP2PlCars	Two-plus cars term on car passenger	0.6542	4.8
BsNocars	Zero cars constant on bus	0.8010	2.9
Mode constants:			
TrainMetro	Train and metro (relative to car passenger)	1.1630	1.1
Bus	Bus (relative to car passenger)	3.7421	5.2
Cycle	Cycle (relative to car passenger)	-0.8207	-1.1
Walk	Walk (relative to car passenger)	4.2868	12.2
Destination constants:			
IntraDest	Intrazonal destinations	0.5260	5.6
Attraction variable:			
PEnrols	Primary enrolments attraction variable	1.0000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

There are no observed metro tours in the estimation sample. Rather than set metro to be unavailable, metro was retained as a mode in the model and a combined train and metro constants was estimated.

Table 129: New home–secondary education model parameters

Model v22			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
LogCost	Log of cost	-0.7525	-6.6
Level of service parameters:			
CarTime	Car time	-0.1293	-18.4
TMGenTime	Train and metro generalised time	-0.0400	-3.8
BsGenTime	Bus generalised time	-0.0306	-18.3
CycleDist	Cycle distance	-0.3949	-4.8
WalkDist	Walk distance	-0.5322	-27.1
Socio-economic parameters:			
PassOpt	Passenger opportunity	3.4902	4.2
CarPOneCar	One car constant on car passenger	-0.9606	-2.9
CyMale	Male constant on cycle	3.8742	2.1
Mode constants:			
TrainMetro	Train and metro (relative to car passenger)	2.8254	2.2
Bus	Bus (relative to car passenger)	7.1386	6.1
Cycle	Cycle (relative to car passenger)	-3.7061	-1.8
Walk	Walk (relative to car passenger)	6.1258	6.9
Attraction variable:			
SecEnrol	Secondary enrolments attraction variable	1.0000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	0.5808	5.5

Table 130: New home–tertiary education model parameters

Model v45			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
GCost	Gamma cost parameter	-0.0048	-6.7
Level of service parameters:			
CarTime	Car time	-0.0189	-4.1
CarPDist	Car passenger distance	-0.0917	-5.3
PTGenTime	Public transport generalised time	-0.0202	-14.3
CycleDist	Cycle distance	-0.1805	-3.7
WalkDist	Walk distance	-0.4136	-13.8
Socio-economic parameters:			
CarComp	Competition for cars in HH	-2.8284	-4.4
PassOpt	Passenger opportunity term	1.8929	2.7
BusCarsge2	Two-plus HH cars term on bus	-1.2061	-3.2
Wkcarsge2	Two-plus HH cars term on walk	-1.9498	-3.5
WkRet	Retired persons term on walk	4.9319	2.6
CyHSizeq1	Single person HH term on cycle	4.5862	3.6
Mode constants:			
CarP	Car passenger (relative to car driver)	-5.6179	-4.8
Train	Train (relative to car driver)	-4.1465	-4.7
Metro	Metro (relative to car driver)	-4.8356	-3.7
Bus	Bus (relative to car driver)	-0.7972	-1.4
Cycle	Cycle (relative to car driver)	-6.8262	-4.9
Walk	Walk (relative to car driver)	-1.1102	-1.5
Size variables:			
SizeMult	Base size term, tertiary enrolments	1.0000	n/a
TotEmpFTS	Total employment term, FT students	0.0382	-22.5
TotEmpOth	Total employment term, other status groups	0.0943	-9.4
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	0.6936	3.3

Table 131: New home–shopping model parameters

Coefficient	Description	Model v67 S=0 model		Model v76 S=3 model	
		Value	t-ratio	Value	t-ratio
Cost parameters:					
GCostNA	Gamma cost parameter, income not stated	-0.0109	-7.6	-0.0110	-7.6
GCost1t5	Gamma cost parameter, HH inc < £35k p.a.	-0.0128	-9.2	-0.0128	-9.2
GCost611	Gamma cost parameter, HH inc > £35k p.a.	-0.0081	-4.2	-0.0080	-4.1
Level of service parameters:					
CarTime	Car in-vehicle time	-0.0916	-21.5	-0.0915	-21.3
PTGenTme	PT generalised time (both in and out vehicle)	-0.0513	-17.5	-0.0519	-17.4
Transfers	Public transport transfers	-0.2908	-3.4	-0.2704	-3.1
CycleDist	Cycle distance	-0.2081	-2.3	-0.2079	-2.3
WalkDist	Walk distance	-0.5578	-22.1	-0.5578	-22.1
CarAccTime	Car access time to train and metro			-0.3719	n/a
Socio-economic parameters:					
OneCarFree	Free car use term on car driver, 1 car in HH	1.3503	3.0	1.3672	3.0
2PlCarFree	Free car use term on car driver, 2+ cars in HH	1.7822	4.1	1.8412	4.1
PassOp2Hh	Passenger opportunity term, car pass., 2 person HH	4.5775	6.4	4.6467	6.4
PassOp3PHh	Passenger opportunity term, car pass., 3+ person HH	3.9069	6.1	3.9724	6.1
CarPFTstu	Full-time student car passenger constant	1.9685	2.9	1.9697	2.9
CarPRetir	Retired persons car passenger constant	1.4627	3.3	1.4611	3.3
CarPMale	Male car passenger constant	-1.5158	-3.6	-1.5282	-3.6
CarPDisab	Persons with a disability constant on car passenger	2.2932	2.7	2.2988	2.7
BusMale	Male bus constant	-0.8314	-2.4	-0.8461	-2.4
BusNoCar	Zero car constant on bus	1.9176	4.8	1.9036	4.8
SlowDisab	Persons with a disability constant on cycle & walk	-1.7178	-2.0	-1.7536	-2.0
Access mode socio-economic parameters:					
CarD1Car	1 car constant on car driver access			-7.2334	n/a
Mode constants:					
CarP	Car passenger (relative to car driver)	-1.5744	-2.5	-1.6079	-7.9
Train	Train (relative to car driver)	-2.0539	-2.6	-5.8861	-5.0
Metro	Metro (relative to car driver)	-2.2763	-1.8	-5.5259	-2.6
Bus	Bus (relative to car driver)	3.1502	5.4	3.1886	15.2
Cycle	Cycle (relative to car driver)	-9.3785	-5.0	-9.4811	-7.8
Walk	Walk (relative to car driver)	3.9109	7.1	3.9159	20.7
Access mode constants:					
TrainCP	Train, car passenger (relative to car driver)			-5.2586	-2.4
TrainOth	Train, other access (relative to car driver)			3.0891	2.3
MetroCP	Metro, car passenger (relative to car driver)			-5.8167	-1.5
MetroOth	Metro, other access (relative to car driver)			2.3666	1.0
Time period constants:					
TP_11	Out AM peak, return AM peak	-5.6300	-4.0	-5.6861	-4.0
TP_12	Out AM peak, return inter-peak	0.3334	0.7	0.3340	0.7
TP_13	Out AM peak, return PM peak	-7.2645	-3.8	-7.3361	-3.8
TP_14	Out AM peak, return off-peak	0.0000	n/a	0.0000	n/a
TP_22	Out inter-peak, return inter-peak	5.0962	7.8	5.1425	7.8
TP_23	Out inter-peak, return PM peak	0.8662	1.9	0.8721	1.9
TP_24	Out inter-peak, return off-peak	0.0000	n/a	0.0000	n/a
TP_33	Out PM peak, return PM peak	1.2054	2.7	1.2142	2.6
TP_34	Out PM peak, return off-peak	-0.7035	-1.3	-0.7115	-1.3
TP_41	Out off-peak, return AM peak	0.0000	n/a	0.0000	n/a
TP_42	Out off-peak, return inter-peak	-9.1038	-3.5	-9.1908	-3.5
TP_43	Out off-peak, return PM peak	0.0000	n/a	0.0000	n/a
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a	0.0000	n/a
Destination constants:					
WalkIZ	Walk intrazonal constant	0.9410	5.9	0.9427	5.9
CBDDest	CBD destination term	-0.1495	-2.3	-0.1455	-2.2
CBDBus	CBD bus term	0.3970	3.1	0.3992	3.1
Attraction variable:					
TotEmp	Retail employment attraction variable	1.0000	n/a	1.0000	n/a
Structural parameters:					
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.4211	12.4	0.4172	12.7

Table 132: New home–escort model parameters

Coefficient	Description	Modes	Value	t-ratio
Cost parameters:				
GCost	Gamma cost parameter	CD, BS	-0.014	-8.0
Level of service parameters:				
CarTime	Car time	CD, CP	-0.076	-10.4
BsGTime	Generalised bus time	BS	-0.034	-7.7
WalkDist	Walk distance	WK	-0.515	-26.4
Socio-economic parameters:				
OneCarComp	Competition for car, 1 car in HH	CD	-1.833	-4.4
PassOpt	Passenger opportunity term	CP	1.527	1.8
BusNoCar	No car constant on bus	BS	3.501	3.9
BusFemale	Female constant on bus	BS	2.891	2.7
HHchild	Constant on walk for HHs with children	WK	5.276	4.6
Mode constants:				
CarP	Car passenger (relative to car driver)	CP	-6.400	-5.5
Bus	Bus (relative to car driver)	BS	-4.018	-3.0
Walk	Walk (relative to car driver)	WK	-1.114	-1.2
Time period constants for car driver:				
TP_11	Out AM peak, return AM peak	CD	3.456	5.9
TP_12	Out AM peak, return inter-peak	CD	-3.357	-3.7
TP_13	Out AM peak, return PM peak	CD	-6.085	-3.8
TP_14	Out AM peak, return off-peak	CD	0.000	n/a
TP_22	Out inter-peak, return inter-peak	CD	2.355	5.0
TP_23	Out inter-peak, return PM peak	CD	1.456	3.6
TP_24	Out inter-peak, return off-peak	CD	-6.221	-3.9
TP_33	Out PM peak, return PM peak	CD	1.809	4.3
TP_34	Out PM peak, return off-peak	CD	-2.279	-3.4
TP_41	Out off-peak, return AM peak	CD	-7.044	-3.7
TP_42	Out off-peak, return inter-peak (never chosen)	CD	0.000	n/a
TP_43	Out off-peak, return PM peak (never chosen)	CD	0.000	n/a
TP_44	Out off-peak, return off-peak (base combin.)	CD	0.000	n/a
Destination constants:				
CarPIZ	Car passenger intrazonal constant	CP	2.205	5.1
WalkIZ	Walk intrazonal constant	WK	0.915	8.2
CBDDest	CBD destination constant	all	0.188	2.1
CBDBus	CBD bus constant	BS	-0.869	-2.1
Attraction variable:				
L_S_M	Log-size multiplier	all	1.000	n/a
Size_Pop	Population size parameter	all	0.255	n/a
Size_Prim	Primary enrolments size parameter	all	29.639	n/a
Size_Sec	Secondary enrolments size parameter	all	7.121	n/a
Structural parameters:				
TR_M_TP	Relative sensitivity of modes and time periods	n/a	1.000	n/a
TR_TP_D	Relative sensitivity of time periods and dest.s	n/a	0.471	7.1

Table 133: New home–other travel model parameters

Coefficient	Description	Model v74 S=0 model		Model 82 S=3 model	
		Value	t-ratio	Value	t-ratio
Cost parameters:					
Cycle	Gamma cost parameter, income not stated	-10.5806	-5.7	-11.9608	-5.8
Gcost1t5	Gamma cost parameter, HH inc < £35k p.a.	-0.0111	-11.3	-0.0125	-11.7
Gcost67	Gamma cost parameter, HH inc £35-50k p.a.	-0.0098	-7.7	-0.0109	-8.1
Gcost811	Gamma cost parameter, HH inc > £50k p.a.	-0.0077	-6.4	-0.0086	-6.6
Level of service parameters:					
CarTime	Car in-vehicle time	-0.0408	-13.5	-0.0370	-11.4
CarPDist	Car passenger distance	-0.0025	-1.1	-0.0029	-1.2
PTGenTme	PT generalised time (both in and out vehicle)	-0.0330	-13.5	-0.0334	-13.3
Transfers	Public transport transfers	-0.3409	-4.4	-0.3081	-3.9
CycleDist	Cycle distance	-0.2409	-7.8	-0.2426	-7.8
WalkDist	Walk distance	-0.4415	-24.0	-0.4415	-24.0
CarAccTime	Car access time to train and metro			-0.1216	n/a
Socio-economic parameters:					
LAFdist	Looking after family distance term	-0.0312	-3.5	-0.0309	-3.4
FreeCarUse	Free car use term on car driver	1.7816	4.2	1.9944	4.3
PassOp2Hh	Passenger opportunity term, car pass., 2 pers HH	4.8330	6.3	5.4180	6.3
PassOp3Hh	Passenger opportunity term, car pass., 3+ pers HH	3.5098	5.6	3.9349	5.6
CarP5t11	Car passenger term, aged 5-11	4.5180	4.2	4.9859	4.2
CarPRet	Retired constant on car passenger	0.7328	1.7	0.8128	1.7
CarPMale	Male constant on car passenger	-1.8467	-4.4	-2.0499	-4.4
BusUemp	Unemployed persons constant on bus	1.6256	2.8	1.8274	2.8
BusFemale	Female constant on bus	1.0113	2.3	1.1119	2.3
BusNoCar	No car constant on bus	2.2214	4.3	2.4037	4.2
BikeMale	Male constant on cycle	4.0499	2.7	4.5059	2.7
SlowDisb	Disabled persons constant on cycle and walk	-2.4122	-2.5	-2.7070	-2.5
Access mode socio-economic parameters:					
CrDAc16t19	Car driver contant for persons aged 16-19			-4.8033	n/a
CrDAc20t24	Car driver constant for persons aged 20-24			-5.6176	n/a
CrDAcc1Car	Car driver constant for 1 car households			-3.6840	n/a
CrPAcc0Car	Car passenger constant for 0 car households			-10.3976	n/a
CrPAcc1Car	Car passenger constant for 1 car households			-2.9974	n/a
Mode constants:					
CarP	Car passenger (relative to car driver)	-0.9642	-1.6	-1.1347	-4.9
Train	Train (relative to car driver)	-4.9357	-5.3	-18.3417	-12.1
Metro	Metro (relative to car driver)	-9.1181	-4.7	-22.1170	-6.2
Bus	Bus (relative to car driver)	-0.3635	-0.7	-0.4734	-1.7
Cycle	Cycle (relative to car driver)	-10.5806	-5.7	-11.9619	-18.7
Walk	Walk (relative to car driver)	2.3940	5.4	2.3296	10.1
Access mode constants:					
TrainCP	Train, car passenger (relative to car driver)			-6.3433	-1.8
TrainOth	Train, other access (relative to car driver)			12.0499	7.4
MetroCP	Metro, car passenger (relative to car driver)			-6.4825	-0.8
MetroOth	Metro, other access (relative to car driver)			10.8684	2.8
Time period constants:					
TP_11	Out AM peak, return AM peak	-6.7387	-6.1	-7.5359	-6.1
TP_12	Out AM peak, return inter-peak	-3.5661	-5.4	-4.0004	-5.4
TP_13	Out AM peak, return PM peak	-7.0520	-6.1	-7.8846	-6.1
TP_14	Out AM peak, return off-peak	-11.7332	-5.8	-13.0750	-5.8
TP_22	Out inter-peak, return inter-peak	1.4828	4.2	1.6250	4.1
TP_23	Out inter-peak, return PM peak	-0.3704	-1.0	-0.4432	-1.1
TP_24	Out inter-peak, return off-peak	-8.1518	-6.3	-9.0815	-6.2
TP_33	Out PM peak, return PM peak	-1.9547	-4.0	-2.2107	-4.0
TP_34	Out PM peak, return off-peak	0.0218	0.1	0.0058	0.0
TP_41	Out off-peak, return AM peak	-11.7491	-5.8	-13.0902	-5.8
TP_42	Out off-peak, return inter-peak	-11.1822	-5.9	-12.4529	-5.9
TP_43	Out off-peak, return PM peak	-17.0690	-4.4	-19.0090	-4.4
TP_44	Out off-peak, return off-peak (base combination)	0.0000	n/a	0.0000	n/a
Destination constants:					
CBDDest	CBD destination term	-0.0576	-0.9	-0.0533	-0.8
CBDTrain	CBD zones term on train	0.7323	2.3	0.8970	2.7
CBDMetro	CBD zones term on metro	2.0624	2.3	2.3177	2.6
CBDBus	CBD zones term on bus	0.4095	3.3	0.4015	3.2
IntraDest	Intrazonal destination term	0.3518	2.8	0.2827	2.2
Attraction variable:					
L_S_M	Log-size multiplier	1.0000	n/a	1.0000	n/a
Size_Ser	Size term on service employment	3.5987	n/a	3.6219	n/a
Size_Ret	Size term on retail employment	4.9522	n/a	4.9257	n/a
Structural parameters:					
TR_M_TP	Relative sensitivity of modes and time periods	1.0000	n/a	1.0000	n/a
TR_TP_D	Relative sensitivity of time periods and destinations	0.3023	20.0	0.2718	23.0

Table 134: New work-work PD-based tour model parameters

Model v13			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameter:			
LogCost	Log of cost	-0.7522	-3.5
Level of service parameters:			
GenTime	Generalised time	-0.0134	-3.3
CarPDist	Car passenger distance	-0.0732	-1.5
WalkDist	Walk distance	-0.2265	-1.2
Mode constants:			
CarP	Car passenger (relative to car driver)	-4.7321	-3.2
Train	Train (relative to car driver)	-2.7679	-2.3
Bus	Bus (relative to car driver)	-3.9625	-2.6
Walk	Walk (relative to car driver)	-4.4887	-2.2
Attraction variable:			
TotEmp	Total employment attraction variable	1.0000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Table 135: New work-other PD-based tour model parameters

Model v19			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameter:			
LogCost	Log of cost	-0.4685	-2.0
Level of service parameters:			
CarTime	Car in-vehicle time	-0.0690	-4.2
PTGenTime	PT generalised time	-0.0321	-2.1
CarPDist	Car passenger distance	-0.0730	-1.2
WalkDist	Walk distance	-0.5814	-9.1
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.1504	-2.6
Bus	Bus (relative to car driver)	-2.4253	-1.8
Walk	Walk (relative to car driver)	1.3120	1.3
Attraction variables:			
SizeMult	Log-size multiplier	1.0000	n/a
Size_Ret	Size term on retail employment	31.4997	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Table 136: New other-other PD-based tour model parameters

Model v29			
Coefficient	**Description**	**Value**	**t-ratio**
Level of service parameters:			
GTime	Generalised time (including monetary costs)	-0.0316	-5.1
CarPDist	Car passenger distance	-0.2025	-2.9
WalkDist	Walk distance	-0.5577	-5.6
Home-based tour mode constants:			
HBMCarP	Home-based & NHB mode car passenger	3.8785	3.0
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.7881	-0.8
Bus	Bus (relative to car driver)	-0.3446	-0.5
Walk	Walk (relative to car driver)	2.2253	2.9
Attraction variables:			
SizeMult	Log-size multiplier	1.0000	n/a
Size_Ser	Size term on retail employment	5.2065	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Table 137: New work-work detour model parameters

Model v32			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
Gcost	Gamma cost parameter	-0.0024	-2.2
Level of service parameters:			
GenTime	Generalised time	-0.0490	-5.6
CarPDist	Car passenger distance	-0.0470	-1.0
WalkDist	Walk distance	-0.8323	-2.9
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	3.2647	2.5
HBMBus	Both home-based and NHB mode car driver	2.7110	2.7
Mode constants:			
CarP	Car passenger (relative to car driver)	-1.3752	-0.9
Train	Train (relative to car driver)	0.3105	0.2
Bus	Bus (relative to car driver)	0.5195	0.4
Walk	Walk (relative to car driver)	2.1601	1.5
Destination constants:			
CarPIZ	Car passenger intrazonal destinations	3.0157	2.4
Attraction variable:			
TotEmp	Total employment attraction variable	1.0000	n/a
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Table 138: New work-other detour model parameters

Model v38			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
Gcost	Gamma cost parameter	-0.0038	-3.5
Level of service parameters:			
CarTime	Car in-vehicle time	-0.1001	-13.9
PTGenTime	PT generalised time	-0.0516	-9.5
CarPDist	Car passenger distance	-0.0244	-1.2
WalkDist	Walk distance	-0.5830	-14.1
Socio-economic parameters:			
PTworkdist	Part-time worker distance	-0.0242	-2.1
CarComp	Car competition	-1.1833	-2.2
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	6.4985	10.7
HBMCarP	Both home-based and NHB mode car passenger	3.6269	6.9
HBMTrn	Both home-based and NHB mode train	3.7833	4.4
HBMBus	Both home-based and NHB mode car driver	2.9743	5.3
Mode constants:			
CarP	Car passenger (relative to car driver)	-0.0234	0.0
Train	Train (relative to car driver)	-0.8351	-0.9
Bus	Bus (relative to car driver)	0.1167	0.1
Walk	Walk (relative to car driver)	3.5143	6.0
Attraction variable:			
SizeMult	Log-size multiplier	1.0000	n/a
Size_Ret	Retail employment size term	4.9078	9.4
Size_Ser	Service employment size term	0.5825	-2.8
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	1.0000	n/a

Table 139: New other-other detour model parameters

Model v39			
Coefficient	**Description**	**Value**	**t-ratio**
Cost parameters:			
GCost1t5	Gamma cost parameter, HH inc <£35k p.a.	-0.0183	-5.7
GCost67	Gamma cost parameter, HH inc £35-50k p.a.	-0.0173	-3.6
GCost811	Gamma cost parameter, HH inc £50k+ p.a.	-0.0116	-2.1
GCostNA	Gamma cost parameter, income not stated	-0.0099	-3.3
Level of service parameters:			
CarTime	Car in-vehicle time	-0.1300	-9.5
PTGenTime	PT generalised time	-0.0605	-8.8
Transfers	PT transfers	-0.6058	-2.6
CarPDist	Car passenger distance	-0.0343	-2.1
CycleDist	Cycle distance	-0.3818	-3.5
WalkDist	Walk distance	-0.7522	-19.2
Socio-economic parameters:			
PassOpt	Passenger opportunity term, car passenger	3.2547	2.1
Home-based tour mode constants:			
HBMCarD	Both home-based and NHB mode car driver	19.8548	3.4
HBMCarP	Both home-based and NHB mode car passenger	11.5222	3.3
HBMTrn	Both home-based and NHB mode train	16.0945	2.7
HBMBus	Both home-based and NHB mode bus	9.3027	3.1
HBMWLK	Both home-based and NHB mode walk	6.0153	3.0
Mode constants:			
CarP	Car passenger (relative to car driver)	-3.1291	-1.7
Train	Train (relative to car driver)	-10.6332	-2.3
Bus	Bus (relative to car driver)	-0.3685	-0.2
Cycle	Cycle (relative to car driver)	-8.1374	-2.7
Walk	Walk (relative to car driver)	4.4882	2.4
Destination constants			
IntraDest	Intrazonal destinations	0.6113	4.3
CarDIZ	Intrazonal destinations, car driver	-1.0522	-4.0
Attraction variable:			
SizeMult	Log-size multiplier	1.0000	n/a
Size_Ret	Retail employment size term	7.6888	15.2
Size_Ser	Service employment size term	0.8435	-1.0
Structural parameters:			
TR_M_D	Relative sensitivity of modes and destinations	0.2507	10.6

Parameter comparison

The following tables present a comparison of the final model parameters from the current version of PRISM to the new model parameters. The development of the models in the current version of PRISM was documented in full in RAND Europe (2004).

For the three purposes where access mode and station choice is modelled for train and metro, specifically commute, home–shopping and home–other travel, two versions of the new models are presented in the tables. The central model presented in the 'S=0' model, which does not incorporate the access mode and station choice model component, and then the model presented on the right is the 'S=3' model which does incorporate the access mode and station choice models for train and metro.

Table 140: Commute parameter comparison

File	COM_239_AS_C.F12		COM_V85.F12		COM_V95.F12	
Title	PRISM West Midlands		PRISM Refresh		PRISM Refresh	
Converged	True		True		True	
Observations	10707		4017		4024	
Final log (L)	-41840.9		-28433.2		-28577.0	
D.O.F.	2		46		10	
Rho^2(0)	0.445		0.248		0.265	
Rho^2(c)	-1.388		0.022		0.021	
Estimated	30 Apr 09		5 Mar 13		22 Apr 13	
Scaling	1.0000		1.0000		1.0000	
Cost parameters:						
Cost	-2.25e-4	(*)				
LogCost	-0.5837	(*)				
CostAS	-0.00108	(*)				
Gcost123			-0.00661	(-15.7)	-0.00638	(*)
Gcost45			-0.00475	(-10.9)	-0.00463	(*)
Gcost67			-0.00443	(-10.3)	-0.00430	(*)
Gcost811			-0.00374	(-8.9)	-0.00379	(*)
GcostNA			-0.00466	(-13.0)	-0.00458	(*)
Level of service parameters:						
CarTime	-0.03372	(*)	-0.02734	(-14.7)	-0.02779	(*)
CarPDist	-0.01294	(*)	-0.02183	(-6.7)	-0.02154	(*)
TrMtTime	-0.02100	(*)				
BusTime	-0.03033	(*)				
AcEgTime	-0.00148	(*)				
WaitTime	-0.01368	(*)				
PTGenTme			-0.01933	(-13.3)	-0.02006	(*)
Transfers	0	(*)	-0.2894	(-5.8)	-0.2801	(*)
CycleDist	-0.1446	(*)	-0.1680	(-9.4)	-0.1683	(*)
WalkDist	-0.3509	(*)	-0.4832	(-28.6)	-0.4816	(*)
TaxiTime	-0.05032	(*)				
CarAccTime	-0.07526	(*)				
Socio-economic parameters:						
PTwkrdist	-0.03077	(*)				
PTworkdist			-0.05156	(-11.2)	-0.05180	(*)
OneCarComp	-0.6182	(*)	-0.9414	(-4.5)	-0.9533	(*)
FreeCarUse	1.287	(*)	1.620	(6.9)	1.511	(*)
PassOpt	0.7369	(*)	1.260	(5.0)	1.200	(*)
FreeUseCrP	-0.5085	(*)	-0.6298	(-2.2)	-0.5508	(*)
CarPMale	-0.5013	(*)	-0.3926	(-2.1)	-0.3873	(*)
CarPManag	-0.4250	(*)				
Trn_0cars			-1.346	(-3.0)	-0.8334	(*)
TrIncGt50k			0.8045	(2.0)	0.8061	(*)
TrainPass	4.204	(*)				
BusMale	-0.6939	(*)	-0.7299	(-4.3)	-0.7115	(*)
Bus_16_24	0.8697	(*)				
Bus_17_24			0.7463	(3.7)	0.6974	(*)
CycleMale	1.543	(*)	2.565	(4.7)	2.412	(*)
WalkMale	-0.5510	(*)	-0.6648	(-3.6)	-0.6354	(*)

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TaxiMale              -1.277     (*)

Access mode socio-economic parameters:
CrDAccMale           -0.9529     (*)
CrDAc16t19            -3.447     (*)
CrDAc20t24           -0.9410     (*)
CrDAcc1Car            -2.210     (*)
CrPAccMale            -1.204     (*)
CrPAc35t44           -0.8110     (*)
CrPAcc0Car            -4.282     (*)
OthAccRlOn           -0.5214     (*)

Mode constants:
CarP                  -3.634     (*)        1.089   (2.9)       0.9727  (10.9)
Train                 -4.026     (*)        1.845   (5.3)       0.2189   (1.1)
Metro                 -3.436     (*)        1.602   (3.8)      0.06060   (0.1)
Bus                  -0.9430     (*)        4.089  (11.7)        3.920  (48.2)
Cycle                 -6.884     (*)       -1.325  (-2.2)       -1.237  (-7.4)
Walk                  -2.240     (*)        5.561  (16.2)        5.380  (62.4)
Taxi                  -2.398     (*)

Access mode constants:
Oth_AcMd              0.4631  (10.9)
CarP_AcMd            -0.2943  (-5.6)
TrainCP                                                         -2.579  (-4.8)
TrainOth                                                        0.7011   (2.8)
MetroCP                                                         -3.147  (-2.4)
MetroOth                                                        0.8370   (1.4)

Time period constants:
TP_11                                      -2.687  (-4.4)       -2.525     (*)
TP_12                                       2.305   (9.2)        2.188     (*)
TP_13                                       4.724  (13.6)        4.475     (*)
TP_14                                       1.317   (5.5)        1.251     (*)
TP_22                                    -0.02861  (-0.1)     -0.01897     (*)
TP_23                                       1.518   (6.3)        1.444     (*)
TP_24                                      0.9717   (4.0)       0.9219     (*)
TP_33                                      -2.009  (-4.1)       -1.885     (*)
TP_34                                      0.2124   (0.8)       0.2065     (*)
TP_41                                      -2.788  (-4.5)       -2.627     (*)
TP_42                                       1.522   (6.3)        1.441     (*)
TP_43                                       2.112   (8.5)        2.002     (*)
TP_44                                           0     (*)            0     (*)

Destination constants:
IntraDest            -0.4123     (*)
CarPIZ                0.4778     (*)            0     (*)            0     (*)
CycleIZ                1.079     (*)            0     (*)            0     (*)
WalkIZ                 1.029     (*)            0     (*)            0     (*)
CBDDest               0.1883     (*)            0     (*)            0     (*)
CBDCarP              -0.2815     (*)            0     (*)            0     (*)
CBDTrain               1.235     (*)       0.9596   (4.8)        1.127     (*)
BirmDest              0.1023     (*)
WalsDest              0.5037     (*)
ExtDest                                     1.484   (8.5)        1.485     (*)
TrExtDest                                  -2.888  (-5.4)       -2.513     (*)

Attraction terms:
TotEmp                 1.000     (*)        1.000     (*)        1.000     (*)
TotSpaces              1.000     (*)
CoreNoPR               3.477     (*)
InterStat              4.857     (*)

Structural parameters and scaling terms:
ASScale                3.059     (*)
AccMdStaCh            0.3269     (*)
TR_TP_D                                    0.7373  (15.8)       0.7807     (*)
TR_M_TP                                     1.000     (*)        1.000     (*)
Lcoeff                                                           1.000     (*)
```

Table 141: Home–primary education parameter comparison

File	PRIM_44b_T2.F12		PRIM_V21.F12	
Title	PRISM West Midlands		PRISM Refresh	
Converged	True		True	
Observations	1333		1216	
Final log (L)	-4403.8		-3977.1	
D.O.F.	19		14	
Rho^2(0)	0.590		0.588	
Rho^2(c)	-3.025		0.393	
Estimated	24 Jun 09		21 Mar 13	
Scaling	1.0000		1.0000	
Cost parameters:				
Cost	-0.00938	(-5.5)	0	(*)
Logcost	0	(*)	-0.6758	(-6.8)
Level of service parameters:				
CarTime	-0.1224	(-25.5)	-0.08650	(-2.7)
CarPDist			-0.1665	(-2.9)
PTTime	-0.03097	(-6.5)		
Transfers	-0.3232	(-3.0)		
PTGenTime			-0.03270	(-11.3)
SlowDist	-0.5667	(-22.6)		
WalkDist			-0.5651	(-28.5)
CycleDist			-0.4307	(-3.9)
Socio-economic parameters:				
PassOpt	3.180	(4.5)	2.871	(8.2)
CrPCarComp	1.539	(3.9)	0	(*)
CrP2PlCars	2.709	(5.4)	0.6542	(4.8)
CarP1Child	1.881	(4.2)	0	(*)
CarP_10_11	-0.8976	(-3.0)		
Bus_11	2.374	(4.2)		
BusPass	5.126	(4.1)		
BsNocars			0.8010	(2.9)
Mode constants:				
TrainMetro	0	(*)	1.163	(1.1)
Bus	1.863	(3.4)	3.742	(5.2)
Cycle	-5.117	(-2.4)	-0.8207	(-1.1)
Walk	6.747	(6.7)	4.287	(12.2)
Taxi	1.624	(1.1)		
Destination constants:				
IntraDest	1.271	(9.3)	0.5260	(5.6)
WalkIZ	-0.3124	(-1.8)	0	(*)
Attraction terms:				
PrimEnrol	1.000	(*)		
PEnrols			1.000	(*)
Structural parameter:				
TR_M_D	0.5211	(6.9)	1.000	(*)

Table 142: Home–secondary education parameter comparison

```
File                  SEC_42b_T2.F12          SEC_V22.F12
Title            PRISM West Midlands        PRISM Refresh
Converged                       True                 True
Observations                    1282                  828
Final log (L)                -4615.3              -2987.9
D.O.F.                            23                   14
Rho²(0)                        0.511                0.502
Rho²(c)                       -2.720                0.285
Estimated                  24 Jun 09            21 Mar 13
Scaling                       1.0000               1.0000

Cost parameters:
Cost                -7.14e-4  (-1.7)            0     (*)
Logcost                    0     (*)      -0.7525  (-6.6)

Level of service parameters:
CarTime             -0.05295  (-6.1)      -0.1293 (-18.4)
Transfers            -0.1649  (-3.7)
PTTime              -0.01540  (-4.7)
TMGenTime                                -0.03997  (-3.8)
BsGenTime                                -0.03065 (-18.3)
CycleDist            -0.1800  (-2.7)      -0.3949  (-4.8)
WalkDist             -0.4553 (-16.0)      -0.5322 (-27.1)

Socio-economic parameters:
Dist12to15           -0.1076  (-9.3)
Dist16Pl            -0.04093  (-4.1)
PassOpt                3.039   (4.1)        3.490   (4.2)
CarPOneCar           -0.9941  (-2.5)      -0.9606  (-2.9)
BusPass                5.414   (5.6)
TrainPass              7.189   (3.5)
Cymale                                      3.874   (2.1)
Walk_17_18            -1.003  (-2.2)

Mode constants:
CarP                  -5.594  (-4.3)            0     (*)
TrainMetro            -10.51  (-4.6)        2.825   (2.2)
Bus                   -2.706  (-2.9)        7.139   (6.1)
Taxi                  -10.55  (-5.1)
Cycle                 -8.446  (-4.7)       -3.706  (-1.8)
Walk                  0.6003   (0.7)        6.126   (6.9)

Destination constants:
IntraDest            -0.1944  (-0.6)            0     (*)
CycleIZ               0.4515   (0.4)            0     (*)
WalkIZ                0.4585   (1.3)            0     (*)

Attraction term:
SecEnrol               1.000     (*)        1.000     (*)

Structural parameter:
TR_M_D                0.4696   (6.2)       0.5808   (7.6)
```

Note that in the original version of PRISM, the secondary education model included 17 and 18 year olds and therefore the car driver mode was modelled. The new model has been estimated from 12 to 16 year olds and therefore car driver is not modelled. This means that car passenger is the base mode for the mode constants in the new model.

Table 143: Home–tertiary education parameter comparison

File	TER_65b_T2.F12		TER_V45.F12	
Title	PRISM West Midlands		PRISM Refresh	
Converged	True		True	
Observations	852		575	
Final log (L)	-3551.5		-2817.6	
D.O.F.	28		23	
Rho²(0)	0.505		0.410	
Rho²(c)	-3.049		-0.041	
Estimated	26 Jan 09		21 Mar 13	
Scaling	1.0000		1.0000	
Cost parameters:				
Cost	-0.00376	(-3.8)		
LogCost	-0.5568	(-5.7)		
GCost			-0.00476	(-6.7)
Level-of-service parameters:				
CarTime	-0.06528	(-9.7)	-0.01893	(-4.1)
CarPDist			-0.09174	(-5.3)
PTTime	-0.03658	(-11.6)		
PTGenTime			-0.02018	(-14.3)
WalkDist	-0.5790	(-16.6)	-0.4136	(-13.8)
CycleDist	-0.3496	(-2.7)	-0.1805	(-3.7)
TaxiDist	0.1639	(1.6)		
Socio-economic parameters:				
NoCarDist	-0.03926	(-2.9)	0	(*)
FTstuDist	0.03809	(7.5)	0	(*)
CarComp	-3.065	(-5.0)	-2.828	(-4.4)
CarDFTstu	-2.032	(-2.9)	0	(*)
CarPDisab	4.001	(3.3)	0	(*)
PassOpt	1.697	(2.4)	1.893	(2.7)
TrainPass	3.438	(2.6)		
BusFTstu	1.694	(2.6)	0	(*)
BusCarsge2			-1.206	(-3.2)
CyHsizeq1			4.586	(3.6)
WalkFTstu	-3.160	(-4.0)	0	(*)
WalkMale	-1.296	(-2.7)	0	(*)
Wkcarsge2			-1.950	(-3.5)
WkRet			4.932	(2.6)
Mode constants:				
CarP	-10.28	(-6.4)	-5.618	(-4.8)
Train	-10.44	(-5.6)	-4.147	(-4.7)
Metro	-10.73	(-4.5)	-4.836	(-3.7)
Bus	-7.188	(-6.3)	-0.7972	(-1.4)
Cycle	-13.03	(-5.6)	-6.826	(-4.9)
Walk	-3.347	(-4.3)	-1.110	(-1.5)
Taxi	-11.12	(-4.4)		
Destination constants:				
IntraDest	0.1845	(0.8)	0	(*)
WalkIZ	0.8700	(3.1)	0	(*)
CBDDest			-0.2502	(-2.6)
CBDTrain			0.8086	(2.1)
Size terms:				
SizeMult	1.000	(*)	1.000	(*)
EnrolFTstu	2.457	(16.1)		
TotEmpFTS			-3.265	(-22.5)
TotEmpOth			-2.362	(-9.4)
Structural parameter:				
TR_M_D	0.5055	(6.8)	0.6936	(7.5)

Table 144: Home–shopping parameter comparison

File	SHOP_86_AS_T2_cost8_C.F12		SHP_V67.F12		SHP_V76.F12	
Converged	True		True		True	
Observations	4574		1823		1824	
Final log (L)	-17892.7		-8707.6		-8733.6	
D.O.F.	2		37		10	
Rho²(0)	0.508		0.461		0.479	
Rho²(c)	-2.204		0.193		0.191	
Estimated	27 Apr 09		14 Mar 13		22 Apr 13	
Scaling	1.0000		1.0000		1.0000	
Cost parameters:						
Cost	-7.70e-4	(*)				
LogCost	-0.6142	(*)				
GCost1t5			-0.01275	(-9.2)	-0.01284	(*)
GCost611			-0.00812	(-4.2)	-0.00796	(*)
GCostNA			-0.01086	(-7.6)	-0.01098	(*)
Level-of-service parameters:						
CarTime	-0.07262	(*)	-0.09164	(-21.5)	-0.09147	(*)
PTTime	-0.05063	(*)				
AcEgTime	-0.05580	(*)				
WaitTime	-0.02742	(*)				
PTGenTme			-0.05127	(-17.5)	-0.05191	(*)
Transfers	0	(*)	-0.2908	(-3.4)	-0.2704	(*)
CycleDist	-0.2215	(*)	-0.2081	(-2.3)	-0.2079	(*)
WalkDist	-0.3900	(*)	-0.5578	(-22.1)	-0.5578	(*)
TaxiTime	-0.07180	(*)				
CarAccTime	-0.2953	(*)				
Socio-economic parameters:						
OneCarFree	1.228	(*)	1.350	(3.0)	1.367	(*)
2PlCarFree	2.707	(*)	1.782	(4.1)	1.841	(*)
1CrCompCrP	1.089	(*)	0	(*)	0	(*)
2PlCompCrP	2.586	(*)	0	(*)	0	(*)
PassOp2Hh	6.867	(*)	4.577	(6.4)	4.647	(*)
PassOp3PHh	4.690	(*)	3.907	(6.1)	3.972	(*)
CarPMale	-3.151	(*)	-1.516	(-3.6)	-1.528	(*)
CarPFTstu	1.916	(*)	1.969	(2.9)	1.970	(*)
CarPRetir	1.841	(*)	1.463	(3.3)	1.461	(*)
CarPDisab	1.199	(*)	2.293	(2.7)	2.299	(*)
BusMale	-0.8550	(*)	-0.8314	(-2.4)	-0.8461	(*)
BusNoCar			1.918	(4.8)	1.904	(*)
SlowDisab	-1.369	(*)	-1.718	(-2.0)	-1.754	(*)
CycleMale	3.082	(*)				
WalkFTwkr	-2.101	(*)	0	(*)	0	(*)
WalkPTwkr	1.558	(*)	0	(*)	0	(*)
Walk1Hh	1.023	(*)	0	(*)	0	(*)
Mode constants:						
CarP	-10.50	(*)	-1.574	(-2.5)	-1.608	(-7.9)
Train	-12.18	(*)	-2.054	(-2.6)	-5.886	(-5.0)
Metro	-11.25	(*)	-2.276	(-1.8)	-5.526	(-2.6)
Bus	-2.078	(*)	3.150	(5.4)	3.189	(15.2)
Cycle	-17.87	(*)	-9.378	(-5.0)	-9.481	(-7.8)
Walk	-7.145	(*)	3.911	(7.1)	3.916	(20.7)
Taxi	-12.94	(*)				
Access mode constants:						
CarP_AcMd	-5.515	(-11.1)				
Oth_AcMd	0.8828	(2.8)				
TrainCP					-5.259	(-2.4)
TrainOth					3.089	(2.3)
MetroCP					-5.817	(-1.5)
MetroOth					2.367	(1.0)
Access mode socio-economic parameters:						
CarD1Car	-5.743	(*)				

```
Time period constants:
TP_11                                 -5.630  (-4.0)      -5.686     (*)
TP_12                                 0.3334   (0.7)      0.3340     (*)
TP_13                                 -7.264  (-3.8)      -7.336     (*)
TP_14                                      0     (*)           0     (*)
TP_22                                  5.096   (7.8)       5.142     (*)
TP_23                                 0.8662   (1.9)      0.8721     (*)
TP_24                                      0     (*)           0     (*)
TP_33                                  1.205   (2.7)       1.214     (*)
TP_34                                -0.7035  (-1.3)     -0.7115     (*)
TP_41                                      0     (*)           0     (*)
TP_42                                 -9.104  (-3.5)      -9.191     (*)
TP_43                                      0     (*)           0     (*)
TP_44                                      0     (*)           0     (*)

Destination constants:
IntraDest          -0.8750   (*)           0     (*)           0     (*)
CarPIZ              0.2082   (*)           0     (*)           0     (*)
CycleIZ              1.992   (*)
WalkIZ               1.433   (*)      0.9410   (5.9)      0.9427     (*)
DudleyDest          0.6976   (*)
SolihlDest          0.6313   (*)
WalsDest             1.361   (*)
WolverDest          0.7135   (*)
BirmTrain            2.175   (*)
CBDBus                                0.3970   (3.1)      0.3992     (*)
CBDDest                  0   (*)     -0.1495  (-2.3)     -0.1455     (*)

Attraction terms:
RetailEmp            1.000   (*)
TotEmp                                 1.000     (*)       1.000     (*)
TotSpaces            1.000   (*)
CoreNoPR             3.496   (*)
InterStat            4.338   (*)

Structural parameters and scaling terms:
TR_M_D              0.3612   (*)
AccMdStaCh          0.3960   (*)
ASScale             0.9121   (*)
TR_TP_D                               0.4211   (9.0)      0.4172     (*)
TR_M_TP                                1.000     (*)       1.000     (*)
LCoeff                                                     1.000     (*)
```

Table 145: Home–other travel parameter comparison

File	OTH_87_AS_T2_C.F12		OTH_V74.F12		OTH_V82.F12	
Converged	True		True		True	
Observations	4127		2569		2569	
Final log (L)	-18722.7		-16668.8		-16688.1	
D.O.F.	2		50		10	
Rho²(0)	0.408		0.292		0.313	
Rho²(c)	-2.458		0.048		0.048	
Estimated	16 Dec 09		26 Mar 13		22 Apr 13	
Scaling	1.0000		1.0000		1.0000	
Cost parameters:						
Cost	-0.00763	(*)				
Gcost1t5			-0.01105	(-11.3)	-0.01246	(*)
Gcost67			-0.00981	(-7.7)	-0.01094	(*)
Gcost811			-0.00771	(-6.4)	-0.00856	(*)
GcostNA			-0.00939	(-9.8)	-0.01032	(*)
Level-of-service parameters:						
CarTime	-0.05067	(*)	-0.04076	(-13.5)	-0.03697	(*)
CarCgTime	-0.03692	(*)				
CarPDist			-0.00255	(-1.1)	-0.00289	(*)
PTTime	-0.02795	(*)				
AcEgTime	-0.01516	(*)				
FWaitTime	-0.02222	(*)				
Transfers	-0.3678	(*)	-0.3409	(-4.4)	-0.3081	(*)
PTGenTme			-0.03304	(-13.5)	-0.03342	(*)
CycleDist	-0.1376	(*)	-0.2409	(-7.8)	-0.2426	(*)
WalkDist	-0.3946	(*)	-0.4415	(-24.0)	-0.4415	(*)
CarAccTime	-0.1666	(*)				
Socio-economic parameters:						
FTwkrDist	0.007150	(*)				
LAFdist			-0.03120	(-3.5)	-0.03090	(*)
OneCarComp	-1.986	(*)	0	(*)	0	(*)
FreeCarUse			1.782	(4.2)	1.994	(*)
PassOp2Hh	4.759	(*)	4.833	(6.3)	5.418	(*)
PassOp3PHh	3.737	(*)				
PassOp3Hh			3.510	(5.6)	3.935	(*)
CarPMale	-1.981	(*)	-1.847	(-4.4)	-2.050	(*)
CarPRetir	0.8228	(*)				
CarPRet			0.7328	(1.7)	0.8128	(*)
CarPDisab	1.495	(*)				
CarP5to12	4.033	(*)				
CarP5t11			4.518	(4.2)	4.986	(*)
BusOnlyPss	2.892	(*)				
BusUnemp	1.332	(*)				
BusUemp			1.626	(2.8)	1.827	(*)
BusFemale			1.011	(2.3)	1.112	(*)
BusNoCar			2.221	(4.3)	2.404	(*)
SlowDisab	-2.134	(*)				
SlowDisb			-2.412	(-2.5)	-2.707	(*)
WalkFTwkr	-2.286	(*)				
WalkRetir	-1.568	(*)				
BikeMale			4.050	(2.7)	4.506	(*)
Access Mode Socio-economic parameters:						
CrDAcc1Car	-5.049	(*)				
CrDAc16t19	-6.583	(*)				
CrDAc20t24	-7.699	(*)				
CrPAcc0Car	-14.25	(*)				
CrPAcc1Car	-4.108	(*)				
Mode constants:						
CarP	-9.018	(*)	-0.9642	(-1.6)	-1.135	(-4.9)
Train	-12.55	(*)	-4.936	(-5.3)	-18.34	(-12.1)
Metro	-12.39	(*)	-9.118	(-4.7)	-22.12	(-6.2)
Bus	-5.846	(*)	-0.3635	(-0.7)	-0.4734	(-1.7)
Cycle	-14.25	(*)	-10.58	(-5.7)	-11.96	(-18.7)
Walk	-5.221	(*)	2.394	(5.4)	2.330	(10.1)
Taxi	-8.851	(*)				

```
Access mode constants:
CarP_AcMd             1.666   (6.1)
Oth_AcMd              2.084   (8.5)
TrainCP                                                      -6.343  (-1.8)
TrainOth                                                      12.05   (7.4)
MetroCP                                                      -6.483  (-0.8)
MetroOth                                                      10.87   (2.8)

Time period constants:
TP_11                                    -6.739  (-6.1)      -7.536     (*)
TP_12                                    -3.566  (-5.4)      -4.000     (*)
TP_13                                    -7.052  (-6.1)      -7.885     (*)
TP_14                                    -11.73  (-5.8)      -13.08     (*)
TP_22                                     1.483   (4.2)       1.625     (*)
TP_23                                   -0.3704  (-1.0)     -0.4432     (*)
TP_24                                    -8.152  (-6.3)      -9.082     (*)
TP_33                                    -1.955  (-4.0)      -2.211     (*)
TP_34                                   0.02180   (0.1)    0.005776     (*)
TP_41                                    -11.75  (-5.8)      -13.09     (*)
TP_42                                    -11.18  (-5.9)      -12.45     (*)
TP_43                                    -17.07  (-4.4)      -19.01     (*)
TP_44                                         0     (*)           0     (*)

Destination constants:
IntraDest            0.3641     (*)      0.3518   (2.8)      0.2827     (*)
CarPIZ              -0.2163     (*)           0     (*)           0     (*)
BusIZ                -1.416     (*)
CycleIZ              0.9064     (*)
WalkIZ               0.8929     (*)      0.6884   (3.8)      0.7610     (*)
CBDDest                   0     (*)    -0.05757  (-0.9)    -0.05332     (*)
CBDTrain                                 0.7323   (2.3)      0.8970     (*)
CBDMetro                                  2.062   (2.3)       2.318     (*)
CBDBus                                   0.4095   (3.3)      0.4015     (*)
ExtDest                                   2.499  (11.9)       2.338     (*)
InterStat             4.838     (*)
CoreNoPR              4.816     (*)

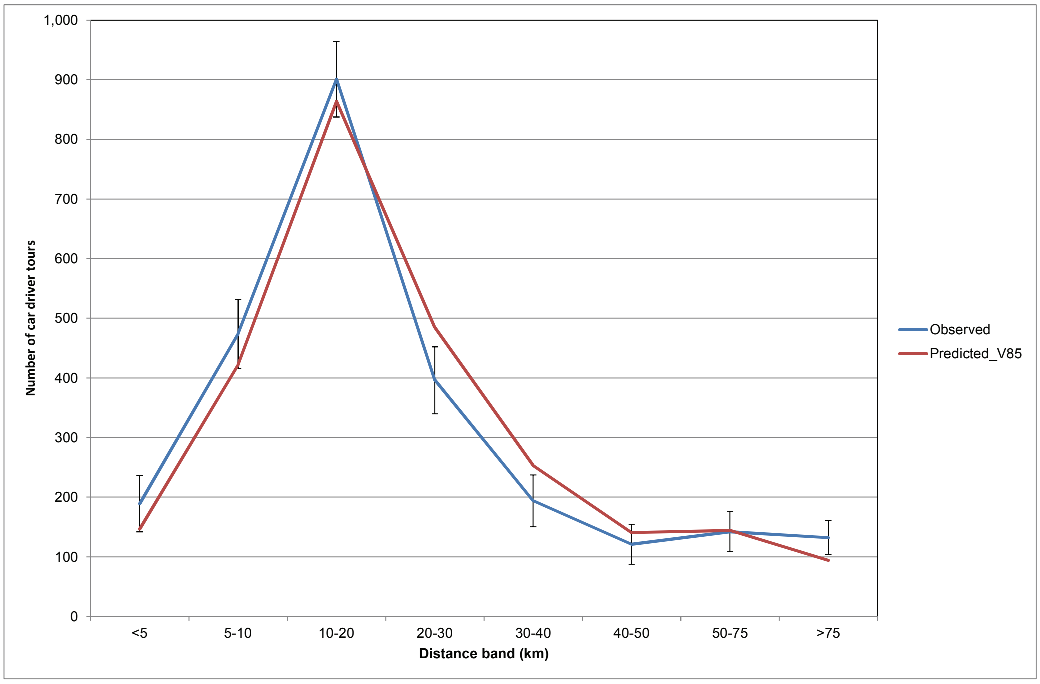
Attraction variables:
SizeMult              1.000     (*)
ServiceEmp            1.216     (*)
RetailEmp             1.854     (*)
L_S_M                                     1.000     (*)       1.000     (*)
Size_Ser                                  1.281  (12.9)       1.287     (*)
Size_Ret                                  1.600   (7.6)       1.594     (*)
TotSpaces             1.000     (*)

Structural parameters and scaling terms:
TR_M_D               0.4187     (*)
ASScale              0.9670     (*)
AccMdStaCh           0.4330     (*)
TR_TP_D                                  0.3023   (8.7)      0.2718     (*)
TR_M_TP                                   1.000     (*)       1.000     (*)
LCoeff                                                        1.000     (*)
```

Appendix D: Car driver tour length distributions

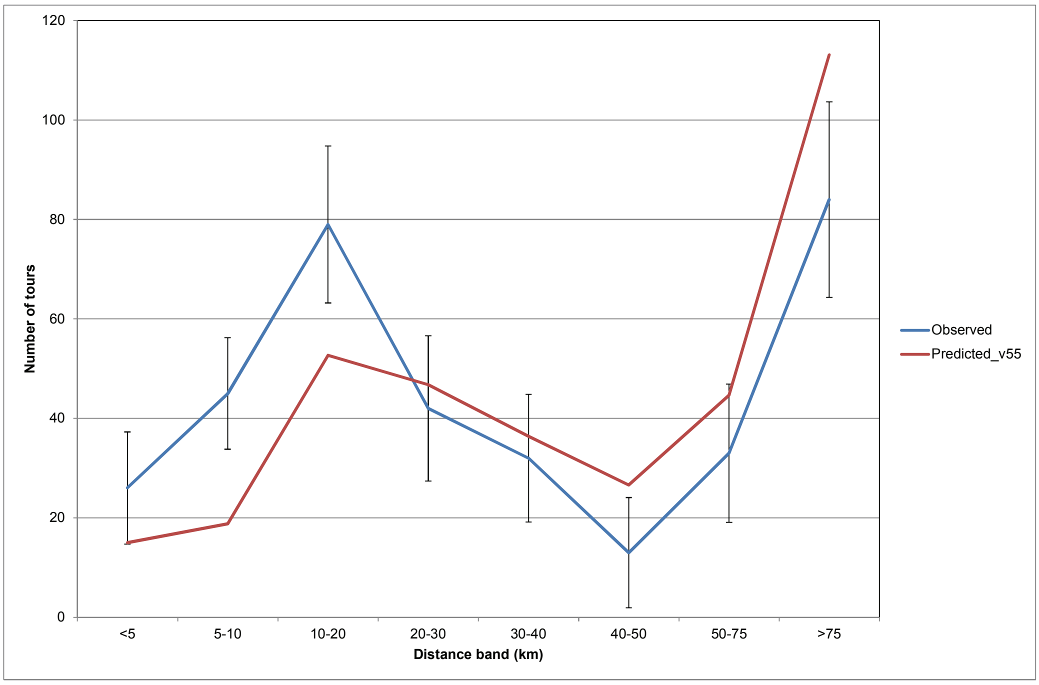
The figures below display the observed distribution of car driver tour lengths and the distribution given by the model in base circumstances.

Figure 34: Commute car driver tour length distribution



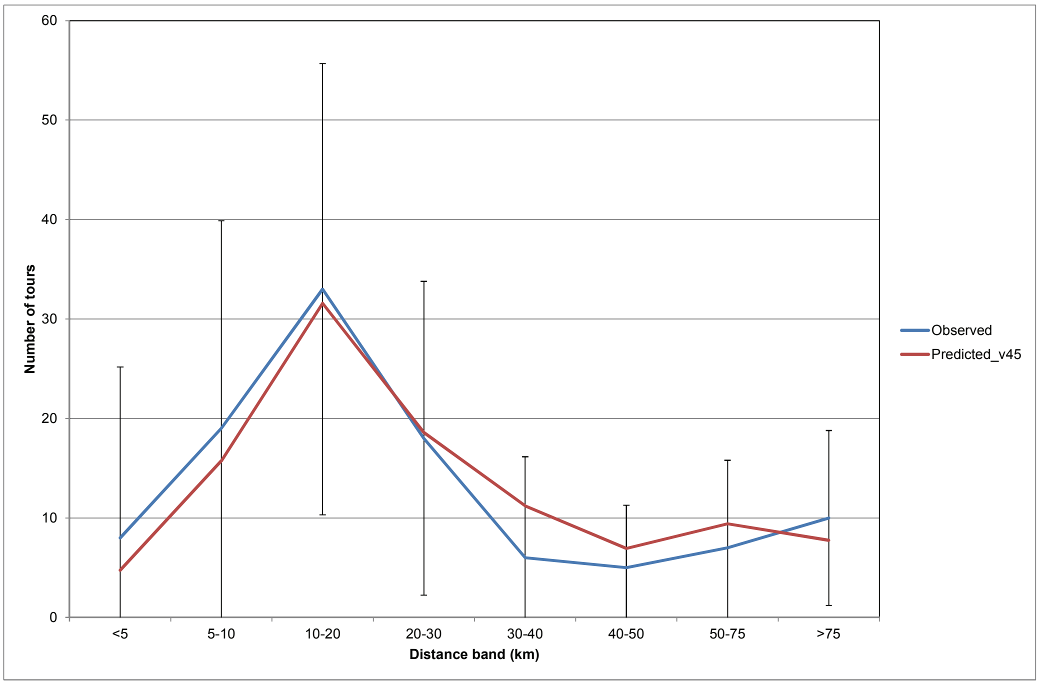
In general observed and predicted tour lengths match well, with the predicted distribution lying within error bars plotted as two times the standard error for the majority of the bands. There is some under-prediction of tours in the 75+ km band and as a result overall mean tours lengths by car driver are under-predicted by 5%.

Figure 35: Home–business car driver tour length distribution



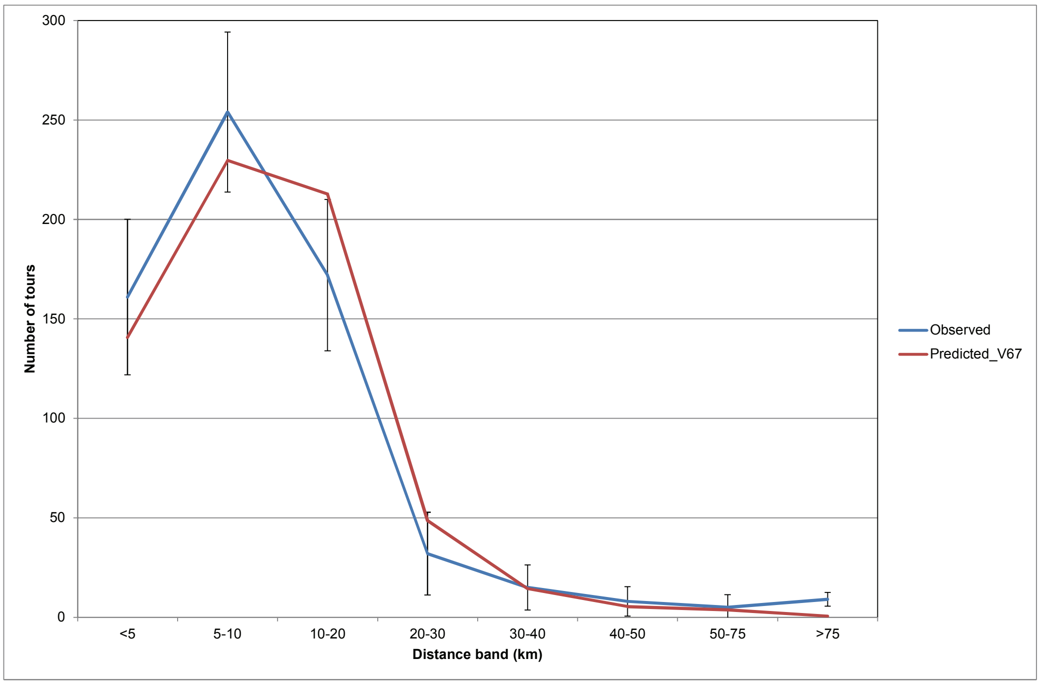
The match between the observed and predicted distributions is reasonable, but there is an under-prediction of the shortest tours, and an over-prediction of the longest tours.

Figure 36: Home–tertiary education car driver tour length distribution



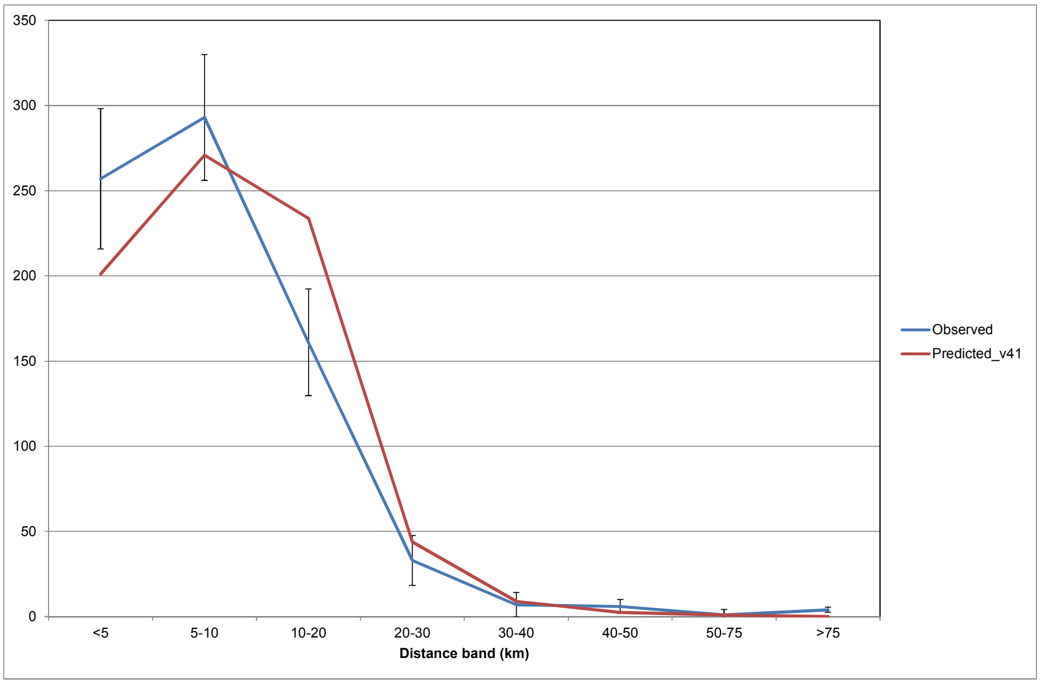
The error bands around the observed distribution are wide due to the low number of tours, with just 106 tertiary education tours in total. Overall, there is a good match between the observed and predicted tour length distributions. However, the longest tours (75km +) are underpredicted and as a result overall car-driver tour lengths are under-predicted by 7.6%.

Figure 37: Home–shopping car driver tour length distribution



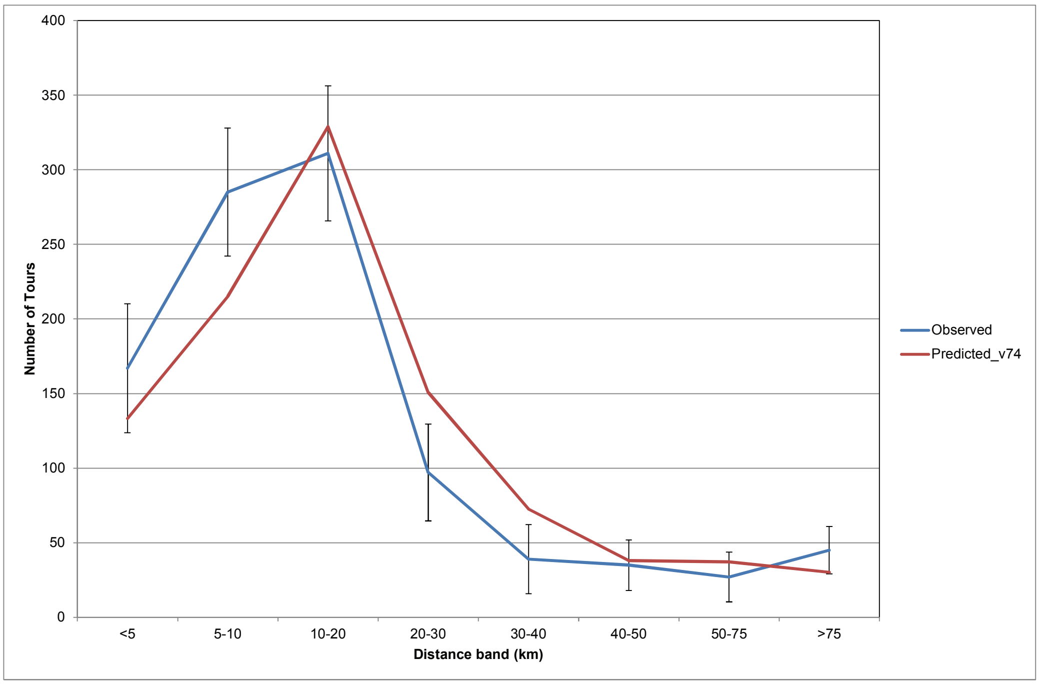
There is a good match between the observed and predicted distributions, with the model predictions lying within the error bands plotted around the observed for all bands except the 75+ km band.

Figure 38: Home–escort car driver tour length distribution



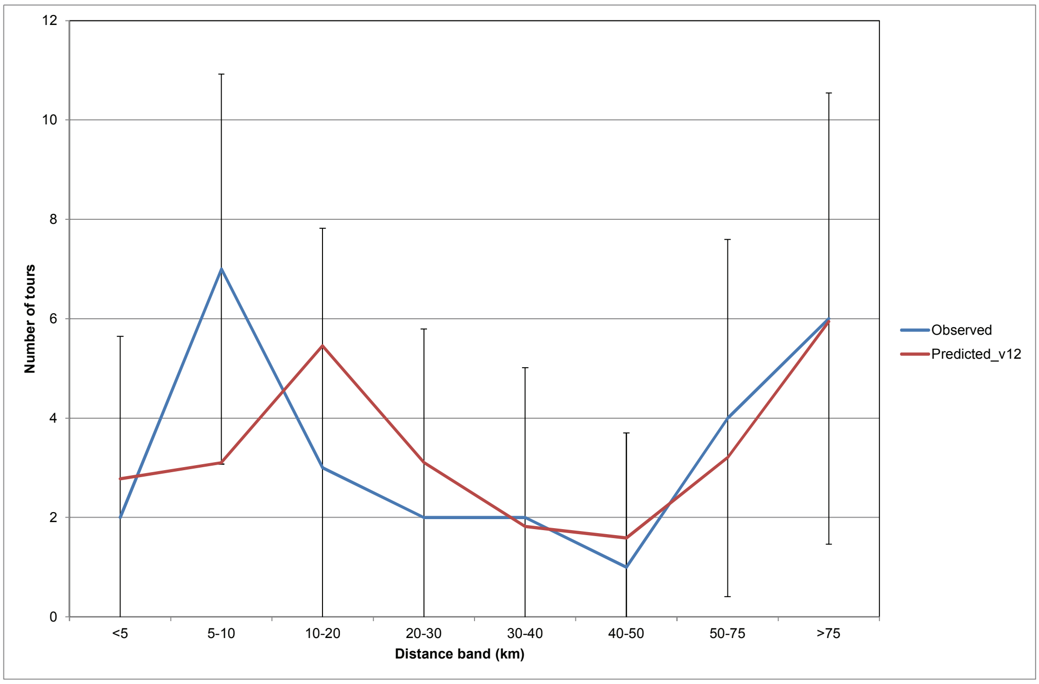
The number of tours in the shortest distance band is under-predicted somewhat, and there's an over-prediction of tours in the 10-20km band, but otherwise the match between the observed and predicted tour length distributions is good.

Figure 39: Home–other travel car driver tour length distribution



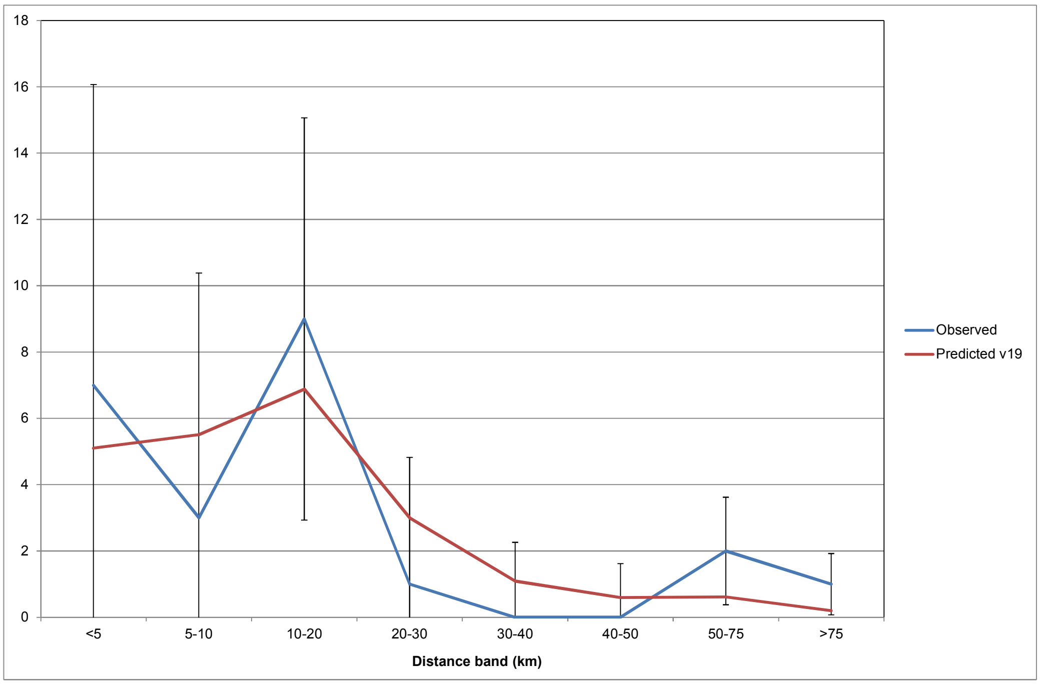
Consistent with most of the other purposes, short tours (up to 10km) and the longest tours (75+km) are under-predicted.

Figure 40: Work-work car driver tour length distribution



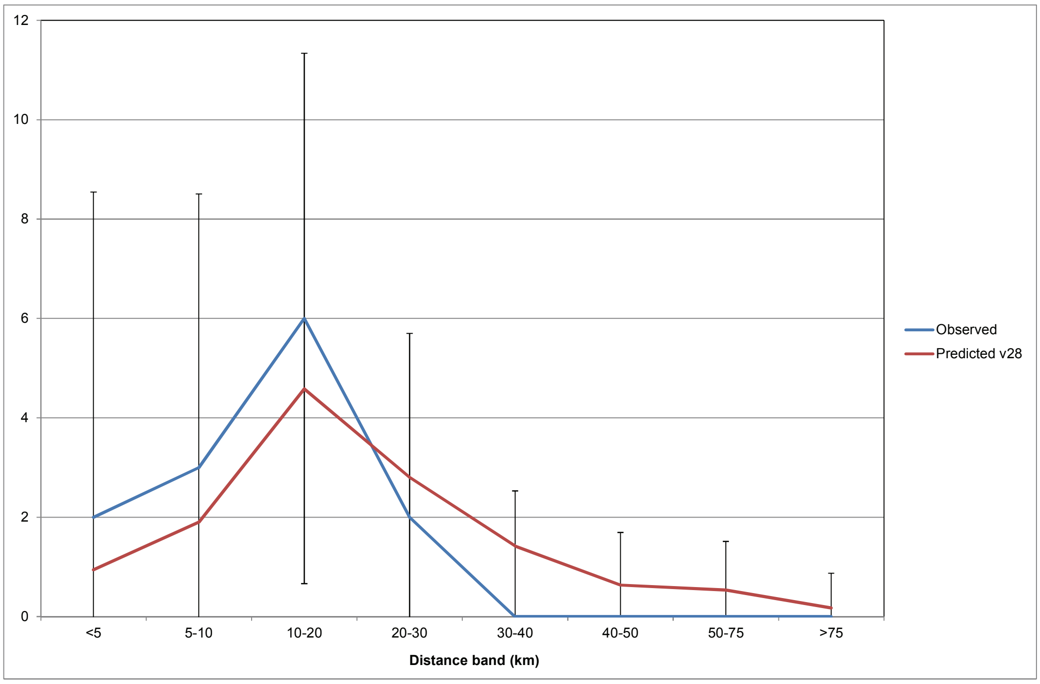
The estimation sample sizes are very small, as demonstrates by the wide error bars plotted around the observed distribution, and for all distance bands the predicted distribution lies within the error margins around the observed data.

Figure 41: Work-other car driver tour length distribution



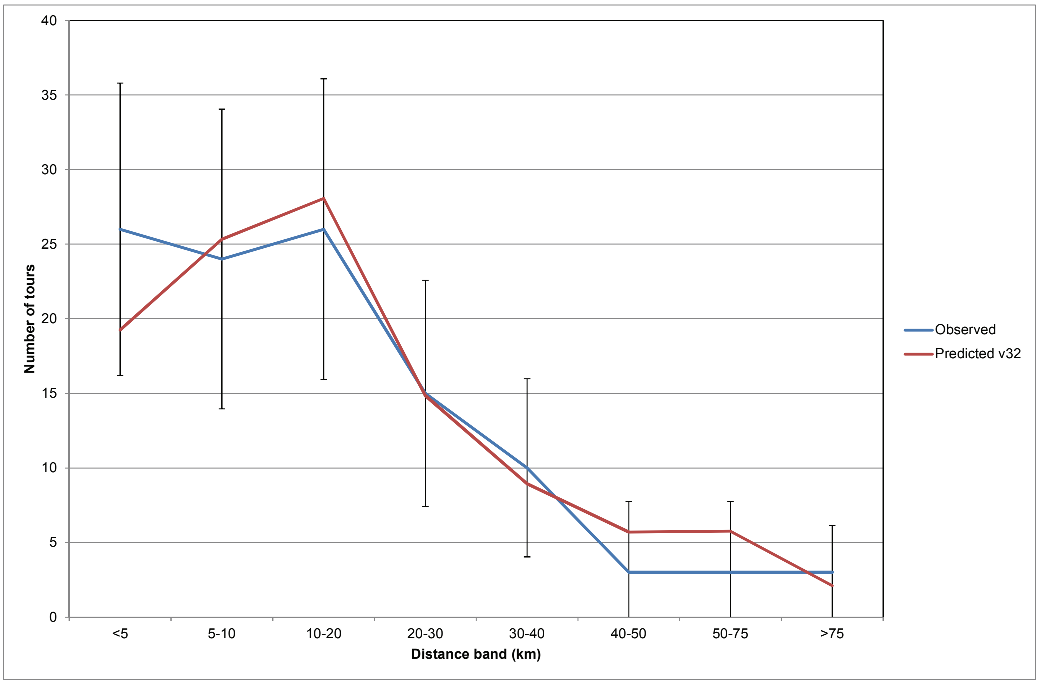
The estimation sample sizes are also very small for work-other, resulting in a lumpy observed distribution, and for all distance bands the predicted distribution lies within the error margins plotted around the observed.

Figure 42: Other-other car driver tour length distribution



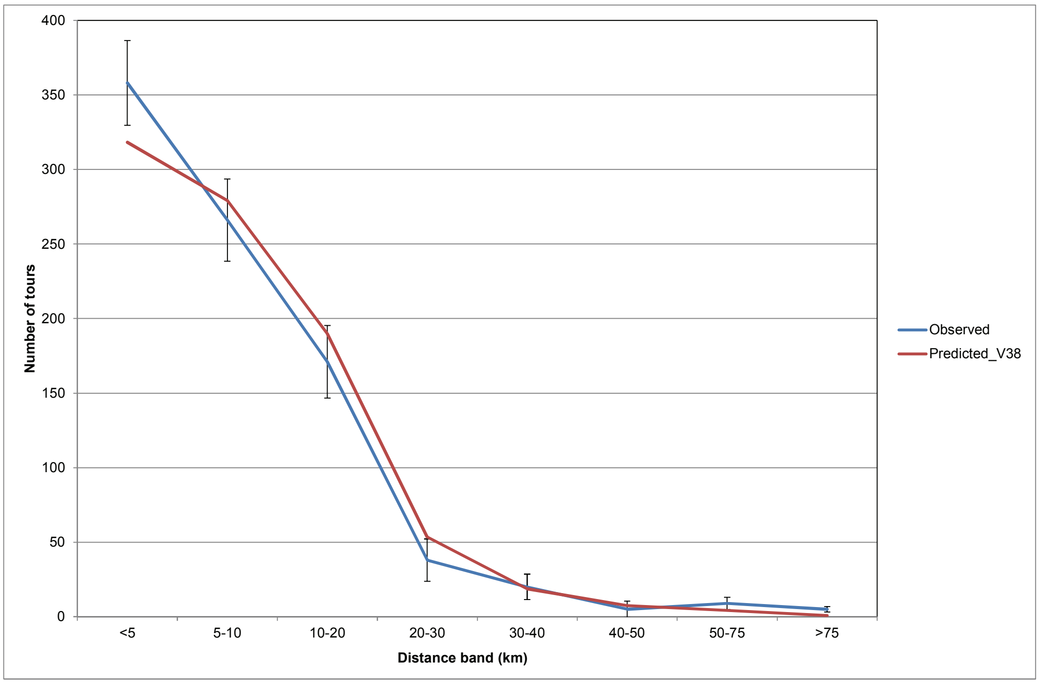
Once again, the lack of data means that the error margins plotted around the observed data are wide, and the predicted distribution lies within the error margins for all bands. No tours are observed for distance bands higher than 30km, and the prediction of tours greater than 30 km in length explains why overall tour lengths for car driver are over-predicted by 70%.

Figure 43: Work-work detour car driver detour length distribution



The predicted distribution replicates the shape of the observed distribution well, and for all distance bands the number of tours is predicted within the error bands plotted around the observed.

Figure 44: Work-other detour car driver detour length distribution



With the exception of an under-prediction of the shortest detours in the <5km band, the predicted detour length distribution matches the observed well.