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RAND EUROPE

PRISM 2011 Base

Demand Model Implementation

James Fox, Bhanu Patruni, Andrew Daly

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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 implementation of the new demand models. The implementation comprises three main components: the Population Model, which predicts the future West Midlands population by geographical zone and population segment, the travel demand models, which predict total transport demand for that future population, and distributes that demand over mode, destination and time period alternatives, and the Final Processing Model, which processes the outputs from the travel demand models and applies a pivoting procedure in order to generate trip matrices for assignment to the highway and public transport networks.

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

- the Task 1 report, documenting the development of mode-destination choice models
- the Task 2 report, documenting the development of frequency and car ownership models.

This report is aimed at readers who wish to gain a detailed understanding of how the new PRISM demand models have been implemented. Familiarity with transport demand models is useful in understanding this document.

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Abbreviations

HB:	Home-Based
HI:	Household Interview
NHB:	Non-Home-Based
PD:	Primary Destination
PT:	Public Transport
PRISM:	Policy Responsive Integrated Strategy Model

CHAPTER 1 Introduction

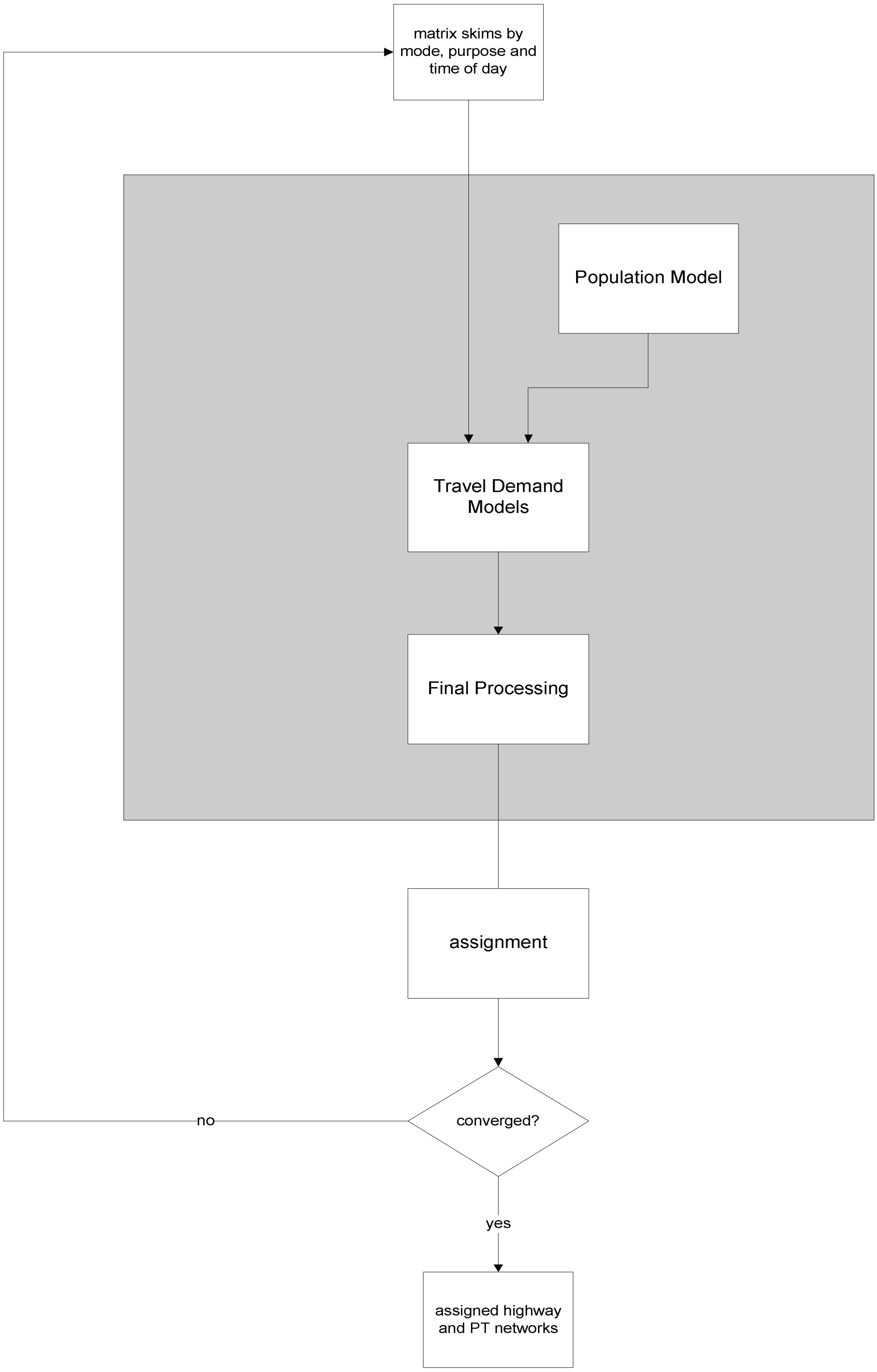
1.1 Structure of the PRISM model

The PRISM travel demand forecasting system comprises three separate components:

1. The Population Model, which contains the prototypical sampling procedure and the car ownership models. This component produces detailed projections of the future West Midlands population, which are not influenced by accessibility.
2. The travel demand models calculate travel accessibility and apply the frequency, mode, destination, PT access mode and station choice, and the time period choice models. In summary, these components predict the future travel choices of the West Midlands population projected by the Population Model.
3. The Final Processing Model takes the predicted trip matrices for each mode, purpose and time period, sums these matrices over travel purposes to reflect the more aggregate segmentations represented in the assignments, and then applies a pivoting procedure to predict changes in demand relative to the base matrices.

The relationship between the three components of the PRISM travel demand forecasting system is summarised in the grey box in Figure 1 overleaf. This figure also illustrates how the system is related to the overall forecasting structure. The components shown outside the grey box are run using the VISUM network modelling software. The overall process is controlled by a Visual Basic application in Microsoft Excel developed and documented by Mott MacDonald. This report only describes the demand model components that lie within the grey box in Figure 1.

Figure 1: PRISM travel demand forecasting system



1.2 Structure of this report

Chapter 2 details the population segments that are represented in the new 2011 base PRISM models. The segments define the key socio-economic effects represented in the frequency and mode-destination models, including car availability and income.

Chapter 3 documents the updates to the Population Model, which uses a base sample of households drawn from the 2009–2012 household interview (HI) data to generate forecasts of the future West Midlands Population by model zone and population segment. The chapter describes the three components of the Population Model, the prototypical sampling procedure, the Car Ownership Model and an accumulation program that accumulates population totals by zone and population segment (the 'ZoneSeg' program).

Chapter 4 describes the implementation of the new travel demand models. Separate sections describe the travel alternatives represented in the models; the travel demand models describe travel for eight home-based (HB) travel purposes, and six non-home-based (NHB) travel purposes.

Chapter 5 documents the Final Processing Module, with descriptions of the procedures used to transpose and add up the trip matrices into the segments used in assignment, and the pivoting procedure, which takes the forecasts of the travel demand models and uses them to predict changes relative to the base matrices.

Finally, Chapter 6 summarises the base year validation of the new 2011 base travel demand models. The models have been validated by comparing predicted travel frequency rates, mode shares and tour lengths to the values observed in the 2009–2012 HI data.

CHAPTER 2 Population segments

This chapter documents the population segments that are represented in the implementation of the new frequency and mode-destination choice models. The segmentations vary between travel purposes, reflecting the different socio-economic factors that influence travel demand for different travel purposes.

In the travel demand models, the frequency models are applied within a loop over the mode-destination segments. Some of the socio-economic parameters in the frequency models can be implemented directly from the mode-destination segments. The frequency segmentations define the *additional* segments required to implement those socio-economic parameters in the frequency models that are not defined by the mode-destination segmentations. A full definition of all of the terms in frequency models is provided in the frequency and car ownership report.

The number of population segments represented in the implementation of the mode-destination models has a significant impact on the run times of the travel demand models, with the run times approximately proportional to the number of segments represented. Therefore some population impacts that have a relative small impact on travel demand, or for which the effect observed in the base year is either not expected to change in the future or cannot be reliably forecast, have not been implemented using separate population segments. Instead, the average effect from the estimation samples, drawn from the 2009–2012 HI data has been used. These average effects are termed 'mean proportions'. For example, in the home–secondary education model the male term on bike has been implemented using mean proportions on the basis that the proportion of males in secondary education is not expected to change over time. Appendix A documents the terms that have been implemented in this way and the mean proportions that have been used.

The segmentations are presented separately for the HB and NHB models. For those travel purposes represented in the 2006 base version of PRISM, a comparison is presented showing the changes to the segment definitions. The number of mode-destination segments has reduced substantially in the new models, because of reductions in the number of pass-ownership segments that follow from the decision not to estimate a pass-ownership model in the 2011 base version of PRISM and other changes, and this will lead to significant reductions in model run times.

The two airport models, which represent the access legs for business and leisure passengers departing from Birmingham International Airport, do not contain any socio-economic segmentation. The airport models assume that all passengers have a car available to make their access trip.

2.1 Home-based segments

2.1.1 Commute

Table 1 summarises the commute mode-destination segmentations represented in the 2006 base and new 2011 base versions of PRISM.

Table 1: Commute mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	no licence, one-plus cars	no licence, one-plus cars
a3	licence, one car, free car use	licence, one car, free car use
a4	licence, one car, car competition	licence, one car, car competition
a5	licence, two-plus cars, free car use	licence, two-plus cars, free car use
a6	licence, two-plus cars, car competition	licence, two-plus cars, car competition
	Worker type b	Worker type b
b1	full-time worker male	other worker male
b2	full-time worker female	other worker female
b3	part-time worker male	part-time worker male
b4	part-time worker female	part-time worker female
	Household income c (2001 prices)	Household income c (2011 prices)
c1	up to £9,999	up to £25,000
c2	£10,000 to £29,999	£25,000 to £34,999
c3	£30,000 to £49,999	£35,000 to £50,000
c4	£50,000 plus	£50,000 plus
	Pass type	Pass segment
p1	Centrocard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	other pass types	
p5	no pass	
	Total segments	Total segments
	480	192

A number of age terms in the commute model have been implemented using mean proportions from the estimation sample of commute tours, rather than adding an additional mode-destination segmentation for age. The mean proportions are for the 17–20, 21–24 and 35–44 age bands, and reflect variations in mode choice between age bands. If future ageing of the population results in later retirement ages, these proportions may decline over the longer term, but in the absence of a mechanism to forecast these changes these age proportions are assumed to remain constant. The mean proportions for these terms are detailed in Appendix A.

The segmentation of tours into pass segments is applied by using the percentage of commute PT tours in the estimation sample: 44.2% of tours are allocated to the no fare segment and 55.8% of tours are allocated to the cash fare segment. There is no variation in these fixed splits between the 96 other segmentation segments.

Table 2 summarises the commute frequency segments represented in the previous 2006 base and new 2011 base versions of PRISM.

Table 2: Additional commute frequency segments

	PRISM 2006 base	PRISM 2011 base
	Occupation type F1	Adult status F1
F1_1	manager/professional, skilled manual/foreman/supervisor, other manual	other worker (b1, b2) part-time worker (b3, b4)
F1_2	other clerical non-manual	full-time worker
F1_3	other occupation types	self-employed
F1_4		full-time student
	Total segments	Total segments
	3	4

There is a single age term in the commute frequency model, which has been implemented using mean proportions from the estimation sample of individuals eligible to make commute tours, specifically adults who are either workers or students. These mean proportions are detailed in Appendix A.

2.1.2 Home–business

In the original version of PRISM, there were insufficient HI data to allow the development of home–business tour models, and so instead road-side interview data were used to develop distribution models for car driver travel only. These models did not contain any socio-economic segmentation and therefore no segments are presented in this section for the 2006 base version of PRISM.

Table 3: Home–business mode-destination segments

	PRISM 2011 base
	Car availability a
a1	no cars in household no licence, one-plus cars
a2	licence, free car use
a3	licence, car competition
	Worker type b
b1	other worker
b2	part-time worker
	Pass segment
p1	no fare
p2	cash fare
	Total segments
	12

No socio-economic terms in the mode-destination model have been implemented using mean proportions.

The segmentation of tours into pass segments is applied by using the percentage of home–business tours observed in the 2009–2012 HI data in the no fare and fare segments. For each of the six possible combinations of the other segments, 14.9% of tours are allocated to the no fare segment and 85.1% of tours are allocated to the cash fare segment. There is no variation in these fixed splits between the six other segmentation segments.

Table 4: Additional home–business frequency segments

	PRISM 2011 base
	Household income F1
F1_1	up to £34,999
F1_2	£35,000-£49,999
F1_3	£50,000 plus
	Adult status F2
F2_1	full-time worker
F2_2	self employed
F2_3	other (PT worker, FT student, PT student)
	Total segments
	9

There are two further terms in the home–business frequency model, which are not defined by these nine segments or the mode-destination segments, a gender term and an age term for persons aged 17–24. Mean proportions from the sample of persons eligible to make business tours have been used to implement these terms; these mean proportions are detailed in Appendix A.

2.1.3 Home–primary education

The mode-destination segments in the 2006 base and 2011 base versions of PRISM are compared in Table 5.

Table 5: Home–primary education mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	one car, free car use	one car
a3	one car, car competition	two-plus cars
a4	two-plus cars, free car use	
a5	two-plus cars, car competition	
	Age b	Not used
b1	5-9, one child in HH aged 0-11	
b2	5-9, two-plus children in HH aged 0-11	
b3	10, one child in HH aged 0-11	
b4	10, two-plus children in HH aged 0-11	
b5	11, one child in HH aged 0-11	
b6	12, two-plus children in HH aged 0-11	
	Household income c (2001 prices)	Not used
c1	up to £9,999	
c2	£10,000 to £29,999	
c3	£30,000 to £49,999	
c4	£50,000 plus	
	Pass type	Pass segment
p1	Centrocard & Scholarcard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	no pass	
	Total segments	Total segments
	480	6

There are no age or household segments in the new model, and this combined with the reduction in the number of car availability and pass segments means that the total number of mode-destination segments has reduced from 480 to just six. All of the socio-economic terms in the home–primary education mode-destination model can be implemented using these six segments.

The segmentation of tours into pass segments is applied by using the percentage of home–primary education tours observed in the 2009–2012 HI data in the no fare and fare segments. For each of the three car availability segments, 3.1% of tours are allocated to the no fare segment and 96.9% of tours are allocated to the cash fare segment. There is no variation in these fixed splits between the three other segmentation segments.

Table 6: Home–primary education additional frequency segments

	PRISM 2006 base	PRISM 2011 base
	Age F1	No segmentation
F1_1	5	
F1_2	6-11	
	Total segments	Total segments
	2	1

In the new home–primary education frequency model, no socio-economic parameters were identified and therefore there are no additional frequency segments in the new 2011 base model. It is noted that in the 2009–2012 HI, ages were collected in bands and a single band was used to cover children aged 5–11. Therefore it was not possible to investigate variation in travel frequency within the 5–11 age band in the new home–primary education frequency model.

2.1.4 Home–secondary education

The mode-destination segments in the 2006 base and 2011 base versions of PRISM are compared in Table 7.

Table 7: Home–secondary education mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	no licence, one car	one car
a3	no licence, two-plus cars	two-plus cars
a4	licence, one-plus cars	
	Age b	Not used
b1	aged 12-15	
b2	aged 16	
b3	aged 17-18	
	Household income c (2001 prices)	Not used
c1	up to £9,999	
c2	£10,000 to £29,999	
c3	£30,000 to £49,999	
c4	£50,000 plus	
	Pass type	Pass segment
p1	Centrocard & Scholarcard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	no pass	
	Total segments	Total segments
	192	6

The number of mode-destination segments is significantly reduced in the new model because no age or income segments have been identified, and the number of car availability and pass segments is reduced. In addition to these six segments, there is a male constant on cycle (reflecting that boys are more likely to cycle to school than girls) that has been implemented using the mean proportion calculated from the estimation sample of home–secondary education tours. This mean proportion value is detailed in Appendix A.

The segmentation of tours into pass segments is applied by using the percentage of home–secondary education tours observed in the 2009–2012 HI data in the no fare and fare segments. For each of the six possible combinations of the other segments, 18.4% of tours are allocated to the no fare segment and 81.6% of tours are allocated to the cash fare segment. There is no variation in these fixed splits between the three other segmentation segments.

Table 8: Home–secondary education additional frequency segments

	PRISM 2006 base	PRISM 2011 base
	Status F1	Status F1
F1_1	full-time student	unemployed
F1_2	part-time worker	other status types
F1_3	other status types	
		Age F2
F2_1		aged 12-16
F2_2		aged 17-18
	Total segments	Total segments
	3	4

Note that older secondary education aged individuals may have already left school and be classified as unemployed. They have lower education tour rates than other individuals and are therefore represented by a different segment.

All of the socio-economic terms in the new home–secondary education frequency model are defined by these four segments.

2.1.5 Home–tertiary education

The mode-destination segments in the 2006 base and 2011 base versions of PRISM are compared in Table 9.

Table 9: Home–tertiary education mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	no licence, one-plus cars	no licence, one-plus cars
a3	licence, one car, free car use	licence, one car, free car use
a4	licence, one-plus cars, car competition	licence, one-plus cars, car competition
a5	licence, two-plus cars, free car use	licence, two-plus cars, free car use
	Status b	Status b
b1	full-time student	full-time student
b2	other status groups	other status groups
	Household income c (2001 prices)	Not used
c1	up to £9,999	
c2	£10,000 to £29,999	
c3	£30,000 to £49,999	
c4	£50,000 plus	
	Pass type	Pass segment
p1	Centrocard & Scholarcard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	other pass types	
p5	no pass	
	Total segments	Total segments
	200	20

The lack of income segments in the new model, combined with the reduction in the number of pass-ownership segments, has resulted in a ten-fold reduction in the number of mode-destination segments.

A couple of car ownership segments for individuals from multi-car households have been implemented using mean proportions segmented by car availability a, rather than extending the car availability segmentation to define all possible combinations of the different car availability terms. Furthermore constants on walk for retired persons, and on cycle for travellers from single person households, have also been implemented using mean proportions. These mean proportions are detailed in Appendix A.

Tours are segmented into no fare and cash fare segments using the observed sample of home–tertiary education tours. Applying this percentage means that 44.6% of tours are allocated to no fare and 55.4% to cash fare, for each of the ten other mode-destination segments.

Table 10: Home–tertiary education additional frequency segments

	PRISM 2006 base	PRISM 2011 base
	Status F1	Status F1
F1_1	full-time worker	full-time worker
F1_2	FT stud., PT worker, unemp./sick, retired	part-time student
F1_3	other status types	other status types
	Age F2	Age F2
F2_1	under 40	aged up to 30
F2_2	40-49	31-39
F2_3	50-plus	40-49
F2_4		aged 50 plus
	Total segments	Total segments
	9	12

There is a highest education qualification term in the home–tertiary education frequency segmentation that is not defined by the mode-destination or additional frequency segments. This term has been implemented using a mean proportion from the sample of persons eligible to make tertiary education tours. This mean proportion is detailed in Appendix A.

2.1.6 Home–shopping

The mode-destination segments in the 2006 base and 2011 base versions of PRISM are compared in Table 11.

Table 11: Home–shopping mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	no licence, 1+ cars, free car use, 2 pers. in hhld	no licence, 1+ cars, free car use, 2 pers. in hhld
a3	no licence, 1+ cars, 3+ pers. in hhld	no licence, 1+ cars, 3+ pers. in hhld
a4	licence, 1 car, free car use	licence, 1 car, free car use
a5	licence, 1 car, car competition, 2 pers. in hhld	licence, 1+ cars, car competition, 2 pers. in hhld
a6	licence, 1 car, car competition, 3+ pers. in hhld	licence, 1+ cars, car competition, 3+ pers. in hhld
a7	licence, 2+ cars, free car use, 2 pers. in hhld	licence, 2+ cars, free car use, 2 pers. in hhld
a8	licence, 2+cars, free car use, 3+ pers. in hhld	licence, 2+cars, free car use, 3+ pers. in hhld
a9	licence, 2+ cars, car comp, 3+ pers. in hhld	
	Status b	Status b
b1	full-time student	full-time student
b2	full-time worker	retired
b3	part-time worker	other groups
b4	retired	
b5	unemployed/sick, other	
	Household income c (2001 prices)	Household income c (2011 prices)
c1	up to £9,999	up to £34,999
c2	£10,000 to £29,999	£35,000 plus
c3	£30,000 to £49,999	
c4	£50,000 plus	
	Pass type	Pass segment
p1	Centrocard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	other pass types	
p5	no pass	
	Total segments	Total segments
	900	96

Reductions in the numbers of categories represented for each of the four segmentations has allowed a substantial reduction in the numbers of population segments represented in the models.

Two gender terms, and two terms for persons with a disability, have been implemented using mean proportions rather than introducing additional segmentations. The mean proportions used in implementation are detailed in Appendix A.

The segmentation of tours into the two pass segments is applied using the percentages of shopping tours that fall into each pass segment observed in the estimation sample. For each of the 48 possible combinations of the other mode-destination segments, 41.5% of tours are allocated to the no fare segment and 58.5% of tours are allocated to the cash fare segment.

Table 12: Home–shopping additional frequency segments

	PRISM 2006 base	PRISM 2011 base
	Status F1	Status F1
F1_1	FT stud, FT workers, PT workers, retired, unemp/sick	full-time worker
F1_2	Other	part-time worker
F1_3		self employed
F1_4		disabled
F1_5		look after home
F1_6		FT student / retired / other
	Gender F2	Gender F2
F2_1	male	male
F2_2	female	female
	Total segments	Total segments
	4	10

The number of frequency segments has increased from four to ten; however, as the frequency models run very quickly this will have little impact on model run times.

There is a household size term and four age terms in the frequency model that are not defined by the segments listed in Table 12. These terms have been implemented using mean proportions of these variables observed in the sample of persons eligible to make shopping frequency tours. These mean proportions are detailed in Appendix A.

2.1.7 Home–escort

Home–escort travel was not modelled separately in the 2006 base version of PRISM, and therefore only the segments in the 2011 base version of PRISM model are presented in this section.

Table 13: Home–escort mode-destination segments

	PRISM 2011 base
	Car availability a
a1	no cars in household
a2	no licence, one-plus cars
a3	licence, one car, free car use
a4	licence, one car, car competition
a5	licence, two-plus cars
	Presence of children b
b1	no children/infants
b2	children/infants
	Pass segment
p1	no fare
p2	cash fare
	Total segments
	20

There is a single gender term in the new home–escort model, which has been implemented using mean proportions from the estimation sample of home–escort tours. These mean proportions are detailed in Appendix A.

Population is allocated into the no fare and cash fare segments using the percentage of home–escort tours in these two segments in the estimation sample. This gives an allocation of 9.1% of tours to the no fare segment and 90.9% of tours to the cash fare segment.

There are two separate home–escort frequency models, the first to predict the frequency of home–escort school travel, the second to predict the frequency of home–escort travel for other purposes. Frequency segments have been defined to implement the socio-economic terms in both of these models. These segments are detailed in Table 14.

Table 14: Home–escort additional frequency segments

	PRISM 2011 base
	Adult status F1
F1_1	full-time worker
F1_2	full-time student
F1_3	unemployed
F1_4	retired
F1_5	looking after family
F1_6	other
	Gender F2
F2_1	male
F2_2	female
	Number of children/infants F3
F3_1	no children/infants
F3_2	1 child/infant
F3_3	2 children/infants
F3_4	3 children/infants
F3_5	4-plus children/infants
	Total segments
	60

In addition to socio-economic terms that can be implemented using these 60 segments, there are four age terms in the frequency models, and a household income term, that have been implemented using mean proportions calculated from the sample of persons eligible to make home–escort tours. These mean proportions are detailed in Appendix A.

2.1.8 Home–other travel

The home–other travel mode-destination segments in the 2006 base and 2011 base versions of PRISM are compared in Table 15.

Table 15: Home–other travel mode-destination segments

	PRISM 2006 base	PRISM 2011 base
	Car availability a	Car availability a
a1	no cars in household	no cars in household
a2	no licence, 1+ cars, free car use, 2 pers. in hhld	no licence, 1+ cars, free car use, 2 pers. in hhld
a3	no licence, 1+ cars, 3+ pers. in hhld	no licence, 1+ cars, 3+ pers. in hhld
a4	licence, 1 car, free car use	licence, 1 car, free car use
a5	licence, 1 car, car competition, 2 pers. in hhld	licence, 1+ cars, car competition, 2 pers. in hhld
a6	licence, 1 car, car competition, 3+ pers. in hhld	licence, 1+ cars, car competition, 3+ pers. in hhld
a7	licence, 2+ cars, free car use, 2 pers. in hhld	licence, 2+ cars, free car use, 2 pers. in hhld
a8	licence, 2+ cars, 2+ pers. in household	licence, 2+cars, free car use, 3+ pers. in hhld
	Status b	Status b
b1	full-time worker	unemployed
b2	unemployed/sick	retired
b3	retired	Looking after family
b4	full-time student, part-time worker, other	other
	Household income c (2001 prices)	Household income c (2011 prices)
c1	up to £9,999	up to £34,999
c2	£10,000 to £29,999	£35,000 to £49,999
c3	£30,000 to £49,999	£50,000 plus
c4	£50,000 plus	
	Pass type	Pass segment
p1	Centrocard	no fare
p2	bus-only pass	cash fare
p3	rail-only pass	
p4	other pass types	
p5	no pass	
	Total segments	Total segments
	640	192

Reductions to the number of status, household income and pass segments mean that the total number of segments has reduced from 640 to 192.

In addition to socio-economic terms implemented by these 192 segments, there are five gender, age and disability parameters in the mode-destination model, which have been implemented using mean proportions from the estimation samples of home–other travel tours, rather than through additional segmentations. These mean proportions are detailed in Appendix A.

The no fare/cash fare splits from the home–other travel estimation sample that are used to allocate tours between the two segments are 37.0% no fare and 63.0% cash fare. There is no variation in these fixed splits between the 96 other segmentation segments.

Table 16: Home–other travel additional frequency segments

	PRISM 2006 base	PRISM 2011 base
	Status F1	Status F1
F1_1	FT worker, unemp/sick , retired , FT student	unempl, retired, other groups
F1_2	part-time worker	full-time worker
F1_3	other (incl look after home)	full-time student
F1_3		disabled
	Age F2	Gender F2
F2_1	5-9	male
F2_2	10-14	female
F2_3	15-19	
F2_4	20-plus	
	Household size F3	Household size F3
F3_1	one	one
F3_2	two	two
F3_3	three	three
F3_4	four	four-plus
F3_5	five-plus	
	Occupation type F4	
F4_1	manager/professional	
F4_2	other clerical non-manual	
F4_3	skilled man./foreman/superv.r, other man., non-wkrs	
	Total segments	Total segments
	180	32

All of the socio-economic parameters in the new home–other travel frequency model can be defined using the mode-destination segments and these additional 32 frequency segments.

2.2 Non-home-based segments

The NHB models are applied conditional on the outputs from the HB models, specifically on the numbers of tours predicted to arrive in each primary destination zone. For the NHB detour models, the primary destination zone forms one end of the detour, and then the mode-destination choice model predicts the location of the other end of the detour (termed the secondary destination). For the primary destination based tour models the primary destination always forms the tour origin. This linkage to the HB models means that the segmentations represented in the NHB models must be defined by the mode-destination segmentations used in the related HB models.

Table 17 illustrates the relationship between the HB and NHB model purposes.

Table 17: Relationship between home-based and NHB travel purposes

HB purposes	Related NHB purpose
commute home–business	work–work tours work–other tours work–work detours work–other detours
home–primary education home–secondary education home–tertiary education home–shopping home–escort home–other travel	other–other tours other–other detours

The implication of this mapping is that segments used in the work–work tour, work–other tour, work–work detour and work–other detour models must be defined by the mode-destination segmentations in both the commute *and* home–business models. Similarly, the segments used in the other–other tour and other–other detour models must be defined by the segmentations in *each* of the five HB purposes listed in Table 17. Given that run times for the HB models are critical as they are the main driver of the total demand model run times, and that adding additional HB segments to implement the NHB models would result in increases in HB run times, the need for the NHB segments to be defined by the HB segments restricts the number of segments that can be used in the NHB models considerably.

The NHB models include parameters that depend on the mode used to make the HB tour. These parameters are implemented by tracking the number of HB tours that arrive in each primary destination zone separately by mode.

For the NHB models, a single set of segmentations is specified for each travel purpose that defines the socio-economic parameters in both the mode-destination and frequency models.

2.2.1 Work–work tours

The segmentations represented in the new work–work tour model are summarised in Table 18. For mode-destination segmentations where there is not a one-to-one mapping between the segments represented and those used in the commute (HW, home–work) and home–business (HB) models, the mapping to the segmentations used in those models is given.

Table 18: Work–work tour model segments

	PRISM 2011 base		
	Car availability a	HW segments	HB segments
a1	no car, no licence	a1, a2	a1
a2	other	a3, a4, a5, a6	a2, a3
	Worker type b	HW segments	HB segments
b1	part-time worker	b3, b4	b2
b2	other workers & students	b1, b2	b1
	Pass type p		
p1	no fare		
p2	cash fare		
	Home-based tour mode HB		
HB1	car driver, bus, walk, train, metro		
HB2	car passenger, bus, walk, train, metro		
	Total segments		
	16		

Note that the outputs from the HB models are summed separately by the 16 segments, which allows the pass type segmentation to be defined directly.

There is a constant in the work–work frequency model for males that has been applied using mean proportions segmented by worker type b. These mean proportions are detailed in Appendix A.

2.2.2 Work–other tours

The segments represented in the new work–other tour model are summarised in Table 19. For mode-destination segmentations where there is not a one-to-one mapping between the segments represented and those used in the HW and HB models, the mapping to the segmentations used in those models is given.

Table 19: Work–other tour model segments

	PRISM 2011 base		
	Car availability a	HW segments	HB segments
a1	no car, no licence	1,2	1
a2	other	3,4,5,6	2,3
	Worker type b	HW segments	HB segments
b1	part-time worker	3, 4	2
b2	other workers & students	1, 2	1
	Pass type p		
p1	no fare		
p2	cash fare		
	Total segments		
	8		

There is a constant in the work–other frequency model, which has been implemented using mean proportions segmented by worker type. These mean proportions are detailed in Appendix A.

2.2.3 Other–other tours

The segmentations used in the new other–other model are summarised in Table 20, as are the mappings to the home–primary education (HPE), home–secondary education (HSE), home–tertiary education (HTE), home–shopping (HS), home–escort (HE) and home–other travel (HO) car availability segmentations.

Table 20: Other–other tour model segments

	PRISM 2011 base						
	Car availability a	HPE	HSE	HTE	HS	HE	HO
a1	no car, no licence	a1 to a3	a1 to a3	a1, a2	a1 to a3	a1, a2	a1 to a3
a2	other	n/a	n/a	a3 to a5	a4 to a8	a3 to a5	a4 to a8
	Pass type p						
p1	no fare						
p2	cash fare						
	Home-based tour mode HB						
HB1	car passenger						
HB2	car driver, bus, walk, train, metro						
	Total segments						
	8						

These eight segments define all of the socio-economic terms in the other–other mode-destination and frequency models.

2.2.4 Work–work detours

The segmentations used in the new work–work detour model are summarised in Table 21. This table includes a mapping between the car availability segments used in the model and those used in the HW and HB models.

Table 21: Work–work detour model segments

	PRISM 2011 base		
	Car availability a	HW segments	HB segments
a1	no car, no licence	a1, a2	a1
a2	other	a3 to a6	a2, a3
	Worker type b	HW segments	HB segments
b1	part-time worker	b3, b4	b2
b2	other workers & students	b1, b2	b1
	Pass type p		
p1	no fare		
p2	cash fare		
	Home-based tour mode HB		
HB1	car driver		
HB2	bus		
HB3	car passenger, train, metro, cycle, walk		
	Total segments		
	24		

In addition to the socio-economic terms implemented by these 24 segments, a self-employed worker term in the work–work outward detour frequency model has been implemented using mean proportions by worker type b. These mean proportions are detailed in Appendix A.

2.2.5 Work–other detours

The segmentations used in the new work–other detour model are summarised in Table 22. This table includes a mapping between the car availability segments used in the model and those used in the HW and HB models.

Table 22: Work–other detour model segments

	PRISM 2011 base		
	Car availability a	HW segments	HB segments
a1	no car, no licence	a1, a2	a1
a2	licence, car competition	a4, a6	a3
a3	other	a3, a5	a2
	Worker type b	HW segments	HB segments
b1	part-time worker	b3, b4	b2
b2	other workers & students	b1, b2	b1
	Pass type p		
p1	no fare		
p2	cash fare		
	Home-based tour mode HB		
HB1	car driver		
HB2	car passenger		
HB3	train		
HB4	bus		
HB5	metro, cycle, walk		
	Total segments		
	60		

The work–other detour frequency models include gender and number of infants & children parameters. These terms have been implemented using mean proportions, which are detailed in Appendix A.

2.2.6 Other–other detours

The segmentations used in the new other–other detour model are summarised in Table 23.

Table 23: Other–other detour model segments

	PRISM 2011 base						
	Car availability a	HPE	HSE	HTE	HS	HE	HO
a1	no car	a1	a1	a1	a1	a1	a1
a2	no licence, passenger opportunity	a2, a3	a2, a3	a2	a2, a3	a2	a2, a3
a3	licence, passenger opportunity	n/a	n/a	a4, a5	a5 to a8	a4, a5	a5 to a8
a4	licence, no passenger opport.	n/a	n/a	a3	a4	a3	a4
	Pass type p						
p1	no fare						
p2	cash fare						
	Home-based tour mode HB						
HB1	car driver						
HB2	car passenger						
HB3	train						
HB4	bus						
HB5	walk						
HB6	metro, cycle						
	Total segments						
	48						

The other–other detour frequency models include gender, age and status parameters that have been implemented using mean proportions detailed in Appendix A.

CHAPTER 3 The Population Model

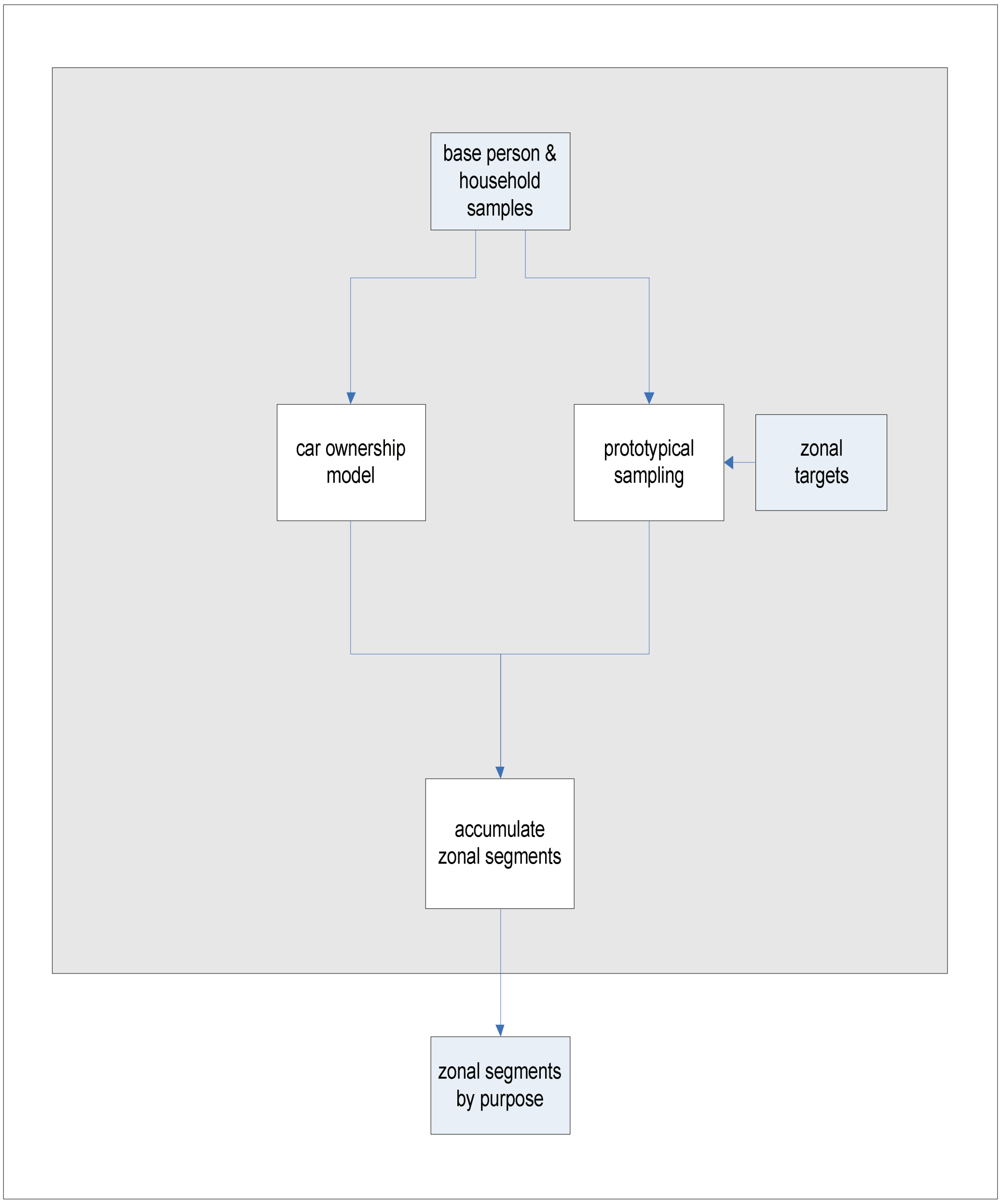
The Population Model comprises three linked components:

- prototypical sampling, where the prototypical sample is expanded to meet zonal targets defined for each model zone
- car ownership, where the car ownership probabilities for each household in the prototypical sample are calculated
- accumulate zonal segments, where the outputs from the prototypical sampling procedure and the car ownership model are combined and the forecast population is accumulated over the socio-economic segmentations represented in the travel demand models.

The linkage between these three components is illustrated in Figure 2 overleaf. The predictions of the Population Model do not depend on accessibility. Therefore the model only needs to be run once for a given future scenario.

The Population Model is run in order to generate forecasts of the numbers of individuals by segment required to feed into the HB travel demand models. Forecasts are not generated for the six NHB purposes, as these models are applied as a function of the predicted HB tours by segment. The airport models are applied using exogenous forecasts of the number of passengers departing from Birmingham International Airport and therefore do not depend on the outputs from the Population Model.

Figure 2: The Population Model structure



3.1 Prototypical sampling

3.1.1 Mathematical formulation

The prototypical sampling procedure expands the base HI sample to best match population targets defined for each zone in the core and intermediate areas. The expansion is undertaken using a quadratic minimisation that is applied for separately for each of the 951 zones in the core and intermediate areas:

For each zone, $\min_{\varphi} F(\varphi)$, subject to $\varphi_i \geq 0$ for all categories i, where

$$F(\varphi)=\sum_t w_t\left(y_t-\sum_c \varphi_c x_{tc}\right)^2+\sum_c\left(\varphi_c-f_c\right)^2 \tag{3.1}$$

where φ_c gives the frequency in the population of household category *c*

f_c gives the base frequency in the same units of household category *c*

w_t gives the weight attached to meeting target *t*

y_t is the target variable for the zone (the zonal target)

x_{tc} is the average quantity of target variable for a household of category *c*

It can be seen that the objective function comprises two elements, the first assessing the fit to the zonal targets, and the second the deviation from the base distribution. The software that implements this quadratic minimisation function is named QUAD.

It is the φ variables that are varied to optimise $F(\varphi)$. Note that all the weights for divergences from base frequencies – the term $\Sigma_c\ (\varphi_c - f_c)^2$ in Equation 3.1 – are assumed to be equal and these are then given the arbitrary value 1: the weights *w* for divergences from the targets are defined relative to this arbitrary scale. Appropriate values for the weights *w* were determined during testing of the Population Model for the 2011 base year.

An important point should be emphasised at this stage. The second term in $F(\varphi)$ seeks to minimise the difference between the zonal expansion and the base distribution over household categories. If there are fundamental differences between the base distribution and the distribution implied by the target variables then the zonal targets will never be achieved exactly. Rather the objective function achieves a balance between meeting the zonal targets and retaining the characteristics of the base sample.

The base sample is drawn from the 2009–2012 HI data used to estimate the new demand models, and contains both person and household information. It is documented in Section 3.1.2. The base sample is processed to create the following sets of inputs:

- *A-priori* fractions which define the base frequencies (number of households) by household category *c*. They are the terms f_c in Equation 3.1.
- Target averages which define the average value of each target variable *t* for each household category *c*. They are the terms x_{tc} in Equation 3.1.

The target information for the 2011 base year has been assembled by Mott MacDonald. The 2011 target data are documented in Section 3.1.2.

3.1.2 The base sample

The base sample has been drawn from the sample of 5,030 HIs collected in the 2009–2012 HI. The prototypical sample contains sufficient person and household information to define all of the socio-economic segmentations represented in the travel demand models defined in Chapter 2, as well as information about the characteristics of the household that is required to specify the re-weighting procedure used in the prototypical sampling, and to implement the car ownership model.

The mode-destination models are only applied to the sample of households with stated incomes so that cost sensitivity terms segmented by income band can be implemented. Furthermore, the car ownership models are also only applied to households with stated incomes. Therefore the base sample has been specified as the 3,226 households from the 2009–2012 HI data with stated incomes.

It is noted that in the commute mode-destination model, the cost sensitivity term estimated for individuals from households that did not state an income term indicates that these individuals have a cost sensitivity in line with the middle income bands. Therefore, it is not believed that omitting individuals from households who did not state an income will result in significant bias.

The re-weighting of the prototypical sample to match zonal targets is performed by defining weights for 46 different household categories. These 46 household categories are defined from considering combinations of four different variables:

- number of adults in the household
- number of workers in the household
- age of the head of the household
- presence of children.

The same four variables were used in the prototypical samples used in the original 2001 base version of PRISM that used 2001 HI data to define the base sample (PRISM v1.0), and the version of PRISM that was revised to include income data and that defined the base sample using 2000–2002 National Travel Survey data (PRISM v1.5).

Table 24 to Table 27 compare the distribution of the new base sample to the base samples used in PRISM v1.0 and PRISM v1.5.

Table 24: Base sample distributions by number of adults

Adults	PRISM v1.0 2001 West Midlands HI data		PRISM v1.5 2000–2002 NTS data (national sample)		PRISM 2011 base 2009–2012 West Midlands HI data	
1	3,219	27.4 %	4,212	34.2 %	709	22.0 %
2	6,223	52.9 %	6,545	53.2 %	1,782	55.2 %
3	1,531	13.0 %	1,133	9.2 %	471	14.6 %
4+	788	6.7 %	411	3.3 %	264	8.2 %
Total	11,761	100.0 %	12,301	100.0 %	3,226	100.0 %

The percentage of households with three or more adults in the new sample is higher in the new sample compared to PRISM v1.5, reflecting the higher fraction of 3+ adult households in the West Midlands. This difference was also observed from the PRISM v1.0 and PRISM v1.5 comparison, though the 3+ adult fraction has also increased between the 2001 HI and 2009–2012 West Midlands samples.

Table 25: Base sample distributions by number of workers

Workers	PRISM v1.0 2001 West Midlands HI data		PRISM v1.5 2000–2002 NTS data (national sample)		PRISM 2011 base 2009–2012 West Midlands HI data	
0	5,326	45.3 %	4,725	38.4 %	841	26.1 %
1	2,968	25.2 %	3,247	26.4 %	1,027	31.8 %
2	2,790	23.7 %	3,567	29.0 %	1,119	34.7 %
3+	677	5.8 %	762	6.2 %	239	7.4 %
Total	11,761	100.0 %	12,301	100.0 %	3,226	100.0 %

Mott MacDonald has reported verbally that the original 2001 HI over-sampled economically inactive households, and this is reflected in the high fraction of zero worker households. In the new base sample, the fraction of zero worker households is much lower than in either of the previous samples and there are also higher fractions of multi-worker households.

Table 26: Base sample distributions by presence of children

Children	PRISM v1.0 2001 West Midlands HI data		PRISM v1.5 2000–2002 NTS data (national sample)		PRISM 2011 base 2009–2012 West Midlands HI data	
No	8,627	73.4 %	9,005	73.2 %	1,927	59.7 %
Yes	3,134	26.6 %	3,296	26.8 %	1,299	40.3 %
Total	11,761	100.0 %	12,301	100.0 %	3,226	100.0 %

The fraction of households with children is much higher in the new base sample compared to the two previous samples, suggesting such households may have been over-sampled in the 2009–2012 HI.

Table 27: Base sample distributions by age of head of household

Age of head	PRISM v1.0 2001 West Midlands HI data		Age of head	PRISM v1.5 2000–2002 NTS data (national sample)		PRISM 2011 base 2009–2012 West Midlands HI data	
< 40	3,259	27.7 %	< 40	3,550	28.9 %	1,118	34.7 %
40–55	3,070	26.1 %	40–64	5,306	43.1 %	1,642	50.9 %
55–70	2,792	23.7 %	65+	3,445	28.0 %	466	14.4 %
70+	2,640	22.4 %					
Total	11,761	100.0 %	Total	12,301	100.0 %	3,226	100.0 %

The original 2001 HI over-sampled economically inactive households, and therefore a high fraction of households had a head aged 70+. In the new sample, the fraction of households with an old head is much lower, suggesting these households may have been under-sampled, consistent with an over-sampling of households with children.

Distribution of the base sample across the 46 household categories used in the prototypical sampling process is given in Table 28.

Table 28: Base sample household category distribution

Adults	Age head	Children?	Workers 0 (+)	1 (0)	2 (0, 1)	3+	Total
1	< 40	No	16	87			103
		Yes	81	55			136
	40–64	No	84	140			224
		Yes	29	44			73
	65+	Either	167	6			173
2	< 40	No	14	52	158		224
		Yes	58	181	234		473
	40–64	No	83	164	226		473
		Yes	28	92	240		360
	65+	Either	201	44	7		252
3 (4+)	< 40	No		40	20	11	71
		Yes		17	12	10	39
	40–64	No		73	74	62	209
		Yes		37	66	19	122
	65+	Either	41				41
4+	< 40	No			30	17	47
		Yes			15	10	25
	40–64	No			42	74	116
		Yes			34	31	65
Total			802	1,032	1,158	234	3,226

3.1.3 Zonal targets

Zonal target information for applying the prototypical sampling procedure for the 2011 base year was supplied by Mott MacDonald. These targets have been derived by making updates the 2001 zonal targets calculated from the 2001 Census data that were developed for the original version of PRISM.

The new model works with eight fewer zonal targets, as the eight licence per adult (LPA) targets are no longer used because growth in LPA is predicted using an alternative approach, documented in Section 5.3.2 of the frequency and car ownership modelling report (Fox et al., 2013b). The new targets are defined in Table 29.

Table 29: Zonal targets

Number	Name	Definition
1	males	males
2	females	females
3	0–19	population aged 0–19
4	20–44	population aged 20–44
5	45–64	population aged 45–64
6	65+	population aged 65+
7	full-time workers	full-time employees aged 16–74+ self-employed people aged 16–74
8	part-time workers	part-time employees aged 16–74 only
9	students	full-time economically active students plus economically inactive students
10	single person households	one person pensioner households plus one person other households
11	lone parent households	lone parent households with both dependent and non-dependent children
12	couple households without children	both married couples and cohabiting couples
13	couple households with children	married and cohabiting couple households with dependent and/or non-dependent children
14	other households	one family households which are all pensioner, all other family types[1]
15	total income	mean household income times number of households / 100,000[2]

Table 30 to Table 32 compare the distributions of the base sample and the 2011 zonal targets across the different target variables. It should be noted that the base sample was only collected from the core area, whereas the targets are defined for both the core and intermediate areas.

Table 30: Base sample and zonal target comparison across age band targets

Age band	Base sample		Zonal targets	
0–20	2,986	31.8 %	1,092,433	25.4 %
21–44	3,334	35.5 %	1,449,560	33.7 %
45–64	2,175	23.2 %	1,060,528	24.6 %
65+	884	9.4 %	703,964	16.3 %
Total persons	9,379	100.0 %	4,306,485	100.0 %

This comparison confirms that persons aged 65+ have been under-sampled in the HI data that forms the base sample, whereas young persons aged 0–20 have been over-sampled.

[1] Other households with dependent children, other households which are all student households, other households which are all pensioner households, 'other' other households.

[2] In PRISM v1.5, incomes were divided by 10,000 rather than 100,000. The weighting was revised downward to improve the performance of the prototypical sampling procedure.

Table 31: Base sample and zonal target comparison across worker and student targets

Status	Base sample		Zonal targets	
full-time worker	3,328	35.5 %	1,507,179	35.0 %
part-time worker	755	8.0 %	373,547	8.7 %
students	523	5.6 %	217,064	5.0 %
other	4,773	50.9 %	2,208,695	51.3 %
Total	9,379	100.0 %	4,306,485	100.0 %

The base sample distribution across worker and student targets matches the zonal target information well.

Table 32: Base sample and zonal target comparison across household type targets

Household type	Base sample		Zonal targets	
single person	500	15.5 %	515,529	29.1 %
lone parent	366	11.3 %	184,907	10.4 %
couples, no children	772	23.9 %	300,763	17.0 %
couples, with children	1,269	39.3 %	504,292	28.4 %
other households	319	9.9 %	267,478	15.1 %
Total households	3,226	100.0 %	1,772,968	100.0 %

There are substantial differences between the base sample distribution and the zonal target distribution across household types. As noted earlier, the base sample has over-sampled couples with children households, whereas single person households are significantly under-sampled.

These significant differences mean that it is difficult for the prototypical sampling procedure to reweight the base sample to match the household type targets.

The mean household income in the base sample is £25,912, whereas the mean income in the zonal targets is £28,267, which is 9.1% higher. However, nearly all of the households in the base sample lie within the core region, whereas the zonal target information includes households in both the core and intermediate areas. The mean household income from the zonal targets for zones in the core area is £25,945, which is very close to the mean value observed in the base sample.

3.1.4 Base year validation

A total of 22 different runs of the QUAD program were made in order to achieve an acceptable match between the expanded sample and the target variables.

The first run used weights of 1 for all of the targets. In this run, the fit to the target variables was relatively poor, and in particular there was a poor match to the worker and student targets, and the household targets. A series of runs were then made with modified weights to improve the fit to these targets, while minimising the loss of fit to the other target variables. Higher weights of 2, 5, 10 and 20 were tested, and furthermore the total income target was divided by 10 so that it received a lower weight relative to all of the other targets.

The final run used the following set of target weights:

- 20 for worker and student targets

- 10 for the household type targets
- 2 for all of the other targets (but with the income target divided by a factor of 10 relative to PRISM v1.5).

Table 33 compares the overall fit to the target variables for the first QUAD run, with all weights 1, and the final run that has been used to give the expansion of the base population (as described above).

Table 33: QUAD run validation

	Target total	Predicted, all weights 1		Predicted, final run	
		Total	Diff.	Total	Diff.
males	2,116,559	2,254,970	6.5 %	2,133,750	0.8 %
females	2,180,139	2,227,572	2.2 %	2,154,473	-1.2 %
aged 0–20	1,091,867	1,137,481	4.2 %	1,135,038	4.0 %
aged 21–44	1,452,310	1,535,653	5.7 %	1,484,962	2.2 %
aged 45–64	1,054,830	1,098,001	4.1 %	1,024,633	-2.9 %
aged 65+	697,706	711,368	2.0 %	643,471	-7.8 %
full-time worker	1,502,704	1,827,835	21.6 %	1,508,458	0.4 %
part-time worker	372,352	502,263	34.9 %	378,134	1.6 %
students	213,433	205,447	-3.7 %	231,154	8.3 %
single person	516,179	675,141	30.8 %	521,205	1.0 %
lone parent	185,611	175,855	-5.3 %	176,340	-5.0 %
couples, no children	298,420	514,044	72.3 %	337,944	13.2 %
couples, with children	502,197	481,778	-4.1 %	509,148	1.4 %
other households	265,625	151,061	-43.1 %	205,595	-22.6 %
total income (£)	4,970,842	4,625,314	-7.0 %	4,004,770	-19.4 %
population	4,296,698	4,482,542	4.3 %	4,288,223	-0.2 %
workers	1,875,056	2,330,098	24.3 %	1,886,592	0.6 %
households	1,768,032	1,997,879	13.0 %	1,750,232	-1.0 %
mean household inc. (£)	28,115	23,151	-17.7 %	22,881	-18.6 %

It can be seen that the final model run achieves a significantly better match to total population, total workers and total households than the first run with all weights equal to 1.

The final run also achieves a much better match to the single person target, and a significantly improved match to the couples no children target, though this target remains over-predicted. The significant difference between the distributions of the base sample and the target variables for the household type distributions (highlighted in Table 32) meant that even with high weights of 10, it was not possible to achieve a better fit for these targets.

The main issue with the final run is that mean household incomes are under-predicted by 19%. As income is a key variable in explaining car ownership, in the car ownership implementation an adjustment factor is applied so that the average income reflects the target income value, and therefore this under-prediction does not introduce a bias. However, the under-prediction of income will have an impact on the distribution of the population over the income segments represented in the commute and home–other travel mode-destination models, which are the two purposes where cost sensitivity is segmented by income.

3.2 Forecasting car ownership

If no person in the household has a licence, it is assumed that the household does not own a car (the probability of owning zero cars is fixed to 1). These households are never predicted to own cars.

For households with licences, the new total car ownership model documented in Fox et al. (2013b) was applied. In summary, the total car ownership model predicts the probability that a household owns zero, one, two and three-plus cars as the function of the following household variables:

- household income
- household licence holding
- number of workers
- number of infants and children
- age, gender and ethnicity of head of household.

The total car ownership model is applied to the base sample separately for each zone in the core and intermediate area. To apply the car ownership model for each model zone, the zonal expansion factors from QUAD are used to expand the car ownership model predictions to the predicted number of households in the zone. Household income is a key variable in the car ownership model, and as illustrated in Table 33 this variable is under-predicted in the base year QUAD expansion. As discussed in Section 3.1, to avoid an under-prediction of car ownership as a result of the under-prediction of income, an income adjustment is applied in the car ownership implementation so that the mean income matches the target mean income for the model zone.

A procedure is used to adjust household licence holding to take account of future growth in licence holding for older persons due to cohort effects. This procedure is documented in Section 5.3 of Fox et al. (2013b).

To validate the performance of the new car ownership model, the total number of predicted households by ownership category was calculated and compared to the 2009–2012 HI data used to estimate the models, and the predictions of the car ownership model implemented in TEMPRO. This comparison is presented in Table 34.

Table 34: Car ownership model validation, core zones only

Household cars	2009–2012 HI data		TEMPRO		Car ownership model forecasts	
0	752	23.3 %	293,004	26.9 %	333,180	30.9 %
1	1,390	43.1 %	515,640	47.4 %	450,494	41.8 %
2	811	25.1 %	228,244	21.0 %	219,973	20.4 %
3+	273	8.5 %	52,105	4.8 %	73,092	6.8 %
Total households	3,226	100.0 %	1,088,993	100.0 %	1,076,740	100.0 %

The car ownership model predicts a significantly higher fraction of zero car households than observed in the estimation sample, and a higher fraction than is predicted in TEMPRO. Thus the new model over-predicts zero car households somewhat, and, in the absence of other differences, this would be expected to result in some under-prediction of car driver travel. However, the detailed validation results presented in Appendix B demonstrate that while for home–shopping, home–escort and home–other travel car driver tours are under-predicted, for home–work, home–business and home–tertiary education car driver tours are over-predicted. The predicted proportion of households with three-plus cars is higher than in TEMPRO, but the fraction of three-plus car households observed in the estimation sample is much higher than the fraction predicted by TEMPRO.

3.3 Zone segment files

Zone segment files are calculated by combining the prototypical sample expansion and the predictions of the car ownership model, and then for each zone in the core and intermediate areas accumulating the population across the mode-destination and additional frequency segmentations detailed in Chapter 3.

The zone segment files are created by a FORTRAN application named zoneseg.exe. Separate zone segment files are created for each of the eight HB model purposes and specify the population by origin zone and segment. The zone segment files are summarised in Table 35.

Table 35: Zone segment files

File Name	HB purpose	Population included
COM_FREQ.DAT	commuting	all adults (17+) in status groups 1–5
BUS_FREQ.DAT	business	all adults (17+) in status groups 1–5
PRIM_FREQ.DAT	primary education	all persons aged 5–11
SEC_FREQ.DAT	secondary education	all persons aged 12–16
TER_FREQ.DAT	tertiary education	all adults aged 17+
SHOP_FREQ.DAT	shopping	all persons aged 5+
ESC_FREQ.DAT	escort	all adults aged 17+
OTH_FREQ.DAT	other travel	all persons aged 5+

To validate the population distributions predicted by the population model, comparisons have been made between the segment distributions in the unweighted 2009–2012 HI data, and the segment distributions predicted by the Population Model for 2011. As noted earlier, the Population Model predictions represent an expansion of the base sample to match the target distributions, and so we would expect some differences between the distributions. For example, as Section 3.1 demonstrated, the percentage of single person households is lower in the base sample than in the target distributions, and so the predicted population is expected to have a higher fraction of single person households. Nonetheless, the distribution comparisons are useful in validating that the predicted distributions have been calculated correctly, and in confirming that where differences do exist they are consistent with differences between the base and target distributions.

The following sub-sections present the validations separately for each of the eight HB purposes. For each purpose, validations are presented across each of the mode-destination segmentations represented for that purpose.

3.3.1 Commute

Table 36: Commute car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars in household	12.5 %	15.1 %	2.6%
2	no licence, 1+ cars	13.8 %	12.4 %	-1.4%
3	licence, one car, free car use	13.9 %	15.8 %	1.9%
4	licence, one car, car competition	15.8 %	13.3 %	-2.6%
5	licence, 2+ cars, free car use	36.4 %	34.1 %	-2.3%
6	licence, 2+ cars, car competition	7.6 %	9.3 %	1.7%
Total		100.0%	100.0 %	0.0 %

The proportion of persons in zero car households is over-predicted relative to the 2009–2012 HI data, which is consistent with the over-prediction of zero car households by the car ownership model. Otherwise the predicted distribution matches the unweighted distribution in the 2009–2012 HI data reasonably well (Table 36).

Table 37: Commute worker type validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	other worker male	49.8 %	48.9 %	-0.9%
2	other worker female	33.9 %	33.1 %	-0.8%
3	part-time worker male	3.7 %	4.8 %	1.2%
4	part-time worker female	12.7 %	13.2 %	0.5%
Total		100.0%	100.0 %	0.0 %

For commute worker type validation, higher fractions of part-time workers are predicted relative to the 2009–2012 HI data, but that is consistent with the higher part-time worker fraction in the target data relative to the HI data (Table 31).

Table 38: Commute income segmentation validation

c	Description	2009–2012 HI data	2011 predicted	% diff.
1	< £25,000	39.4 %	43.9 %	4.5%
2	£25,000–34,999	21.9 %	21.8 %	0.0%
3	£35,000–50,000	20.5 %	18.0 %	-2.5%
4	£50,000+	18.2 %	16.3 %	-1.9%
Total		100.0%	100.0 %	0.0 %

The predicted distribution for commute income segmentation validation has a higher fraction of individuals in the lowest band, and a lower fraction of individuals in the top band, consistent with the overall under-prediction of average household incomes (Table 38).

3.3.2 Home–business

Table 39: Home–business car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars in household, & no licence, 1+ cars	26.3 %	27.5 %	1.3%
2	licence, 1+ car, free car use	50.3 %	49.9 %	-0.4%
3	licence, 1+ car, car competition	23.4 %	22.5 %	-0.9%
Total		100.0%	100.0 %	0.0 %

Across the more aggregate car availability segments used in the home–business car availability validation model there is a good match between the two distributions (Table 39).

Table 40: Home–business car availability validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	other worker	83.7 %	82.0 %	-1.7%
2	part-time worker	16.3 %	18.0 %	1.7%
Total		100.0%	100.0 %	0.0 %

The part-time worker fraction is slightly higher in the predicted distribution for home–business car availability validation, reflecting the higher part-time worker fraction in the 2011 zonal targets relative to the unweighted 2009–2012 HI data (Table 40).

3.3.3 Home–primary education

Table 41: Home–primary education car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars	20.7 %	21.9 %	1.3%
2	1 car	46.7 %	44.2 %	-2.5%
3	2+ cars	32.7 %	33.8 %	1.2%
Total		100.0%	100.0 %	

Table 41 shows that the two distributions for home–primary education car availability validation match fairly closely.

3.3.4 Home–secondary education

Table 42: Home–secondary education car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars	16.3 %	18.4 %	2.1%
2	1 car	43.1 %	41.0 %	-2.1%
3	2+ cars	40.7 %	40.7 %	0.0%
Total		100.0%	100.0 %	

The zero car household fraction is over-predicted slightly relative to the 2009–2012 HI data for home–secondary education car availability validation (Table 42).

3.3.5 Home–tertiary education

Table 43: Home–tertiary education car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars in household	19.4 %	23.4 %	4.0%
2	no licence, 1+ cars	17.0 %	15.2 %	-1.7%
3	licence, one car, free car use	13.3 %	15.5 %	2.3%
4	licence, 1+ cars, car competition	22.0 %	19.9 %	-2.1%
5	licence, 2+ cars, free car use	28.4 %	26.0 %	-2.4%
Total		100.0%	100.0 %	

As per the other purposes, the zero car fraction is over-predicted relative to the 2009–2012 HI data for home–tertiary education car availability validation; otherwise the predicted distribution matches the 2009–2012 HI data reasonably well (Table 43).

Table 44: Home–tertiary education status validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	full-time student	7.1 %	6.3 %	-0.8 %
2	other status groups	92.9 %	93.7 %	0.8 %
Total		100.0%	100.0 %	

The fraction of full-time students is lower in the predicted population for home–tertiary education status validation, which is consistent with the lower student fraction in the zonal targets relative to the unweighted 2009–2012 HI data (Table 44).

3.3.6 Home–shopping

Table 45: Home–shopping car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars in household	19.3 %	22.8 %	3.6 %
2	no licence, 1+ cars, free car use, 2 persons in hhld	3.6 %	3.5 %	-0.2 %
3	no licence, 1+ cars, 3+ persons in hhld	25.7 %	22.9 %	-2.8 %
4	licence, 1 car, free car use	10.9 %	13.5 %	2.6 %
5	licence, 1+ cars, car competition, 2 persons in hhld	5.0 %	4.1 %	-0.8 %
6	licence, 1+ cars, car competition, 3+ persons in hhld	12.8 %	12.3 %	-0.4 %
7	licence, 2+ cars, free car use, 2 persons in hhld	7.0 %	5.8 %	-1.2 %
8	licence, 2+cars, free car use, 3+ persons in hhld	15.8 %	15.1 %	-0.7 %
Total		100.0 %	100.0 %	

Once again the no car in household fraction is over-predicted relative to the 2009–2012 HI data for home–shopping car availability validation; otherwise the match across segments is fairly good (Table 45).

Table 46: Home–shopping status validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	full-time student	24.6 %	22.1 %	-2.5 %
2	Retired	11.8 %	14.8 %	3.0 %
3	other groups	63.6 %	63.1 %	-0.5 %
Total		100.0 %	100.0 %	

The fraction of full-time students is lower in the predicted distribution for home–shopping status validation, which is consistent with the lower student fraction in the targets (Table 46).

Table 47: Home–shopping income validation

c	Description	2009–2012 HI data	2011 predicted	% diff.
1	< £34,999	70.8 %	74.8 %	4.0 %
2	£35,000+	29.2 %	25.2 %	-4.0 %
Total		100.0 %	100.0 %	

A higher fraction of individuals are predicted in the lower income band for home–shopping income validation, consistent with the under-prediction of mean household incomes in the 2011 expansion (Table 47).

3.3.7 Home–escort

Table 48: Home–escort car availability validation

a	Description	2009–2012 HI data	2011 predicted	% diff.
1	no cars in household	19.4 %	23.4 %	4.0 %
2	no licence, 1+ cars	17.0 %	15.2 %	-1.7 %
3	licence, one car, free car use	13.3 %	15.5 %	2.3 %
4	licence, one car, car competition	15.8 %	12.7 %	-3.0 %
5	licence, 2+ cars	34.6 %	33.2 %	-1.4 %
Total		100.0 %	100.0 %	

The biggest discrepancy in home–escort car availability validation is the over-prediction of the no car in household population (Table 48).

Table 49: Home–escort presence of children validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	no children/infants	59.5 %	67.2 %	7.6 %
2	children/infants	40.5 %	32.8 %	-7.6 %
Total		100.0 %	100.0 %	

The predicted population for home–escort presence of children validation has a lower fraction of population in households with children/infants, which is consistent with the lower fraction of couple with children households in the target distributions relative to the 2009–2012 HI data (Table 49).

3.3.8 Home–other travel

The home–other travel model uses the same car availability segmentation as home–shopping and so an identical distribution across car availability segments was observed.

Table 50: Home–other travel status validation

b	Description	2009–2012 HI data	2011 predicted	% diff.
1	unemployed	6.3 %	6.8 %	0.6 %
2	retired	11.8 %	14.8 %	3.0 %
3	looking after family	5.9 %	5.4 %	-0.5 %
4	other	76.0 %	72.9 %	-3.1 %
Total		100.0 %	100.0 %	

The retired fraction is higher in the predicted population, consistent with the higher fraction of 65+ person in the target age distribution (Table 50).

Table 51: Home–other travel income validation

c	Description	2009–2012 HI data	2011 predicted	% diff.
1	< £34,999	70.8 %	74.8 %	4.1 %
2	£35,000–49,999	16.1 %	13.8 %	-2.3 %
3	£50,000+	13.1 %	11.4 %	-1.7 %
Total		100.0 %	100.0 %	

The fraction of population in the lowest income band is higher in the predicted population, consistent with the under-prediction of mean incomes in the 2011 expansion (Table 51).

CHAPTER 4 Travel demand models

The travel demand (TravDem) models read in the zonal population by segment, calculate the total travel demand by applying the tour frequency models, and then distribute the total demand over the available modes, destinations and any other alternatives represented.

Separate TravDem models are run for each of the eight HB travel purposes:

- home–work (commuting)
- home–business
- home–primary education
- home–secondary education
- home–tertiary education
- home–shopping
- home–escort
- home–other travel.

There are also separate TravDems for each of the six NHB travel purposes:

- work–work tours
- work–other tours
- other–other tours
- work–work detours
- work–other detours
- other–other detours.

Finally, there are two separate TravDems for air passengers departing from Birmingham International Airport.

The model alternatives represented in the TravDems are discussed next in Section 4.1. Then the HB TravDems are discussed further in Section 4.2, and the NHB TravDems are discussed in Section 4.3. Finally, Section 4.4 describes the destination sampling procedure that is used to speed up applications of the home–work, home–shopping and home–other travel models.

4.1 Model alternatives

4.1.1 Modes

Up to seven main modes represented in the HB TravDems:

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

Car driver is not available to primary and secondary education pupils, and so is not included in the home–primary and home–secondary education models which represent choice between the other six modes. The other HB TravDems represent all seven of these modes.

For some of the NHB models, where the estimation samples were smaller than those for the HB models, not all of these seven modes are represented. Table 52 summarises the modes included in each of the NHB TravDems.

Table 52: NHB TravDem main modes

Mode	Work–work tours	Work–other tours	Other–other tours	Work–work detours	Work–other detours	Other–other detours
car driver	✓	✓	✓	✓	✓	✓
car passenger	✓	✓	✓	✓	✓	✓
train	✓	✓	✓	✓		
metro		✓	✓			
bus	✓	✓	✓	✓	✓	✓
cycle			✓			
walk	✓	✓	✓	✓	✓	✓

For the commute, home–shopping and home–other travel models, there are two versions of the TravDems, with different treatment of access modes to train and metro:

- the 'S=0' version of the models, which assume all access is by other public transport modes and walk
- the 'S=3' version of the models, which model the choice between three access modes: car driver, car passenger and other, and the choice between three access stations for car driver and car passenger access ('S=3' denotes three access stations); the 'other' access mode is access by other public transport modes and walk.

The predicted demand for the car driver access alternatives to train and metro allow predictions of demand for park-and-ride (P&R) stations to be calculated.

The airport access models represent a different set of modes, reflecting the modes that are important for airport access:

- car driver
- car passenger, dropped at airport
- car passenger, arrive together with a driver
- train
- bus
- coach
- taxi.

4.1.2 Destinations

The models represent the choice between the 994 model zones that cover the core, intermediate and external areas in the PRISM model. Destination alternatives are only available if a non-zero attraction variable is defined for the destination zone, e.g. work tours can only be made to zones where employment exists.

Education enrolment data have been supplied for the West Midlands region only. Thus the education model only predicts education travel to destination zones in the West Midlands region. For the other models, the attraction variables are defined for all model zones and therefore travel is predicted to all zones in Great Britain.

4.1.3 Time periods

For some model purposes, time period choice for travel by car driver is modelled, representing the choice between the four model time periods:

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

Table 53 summarises the purposes where car driver time period choice is modelled.

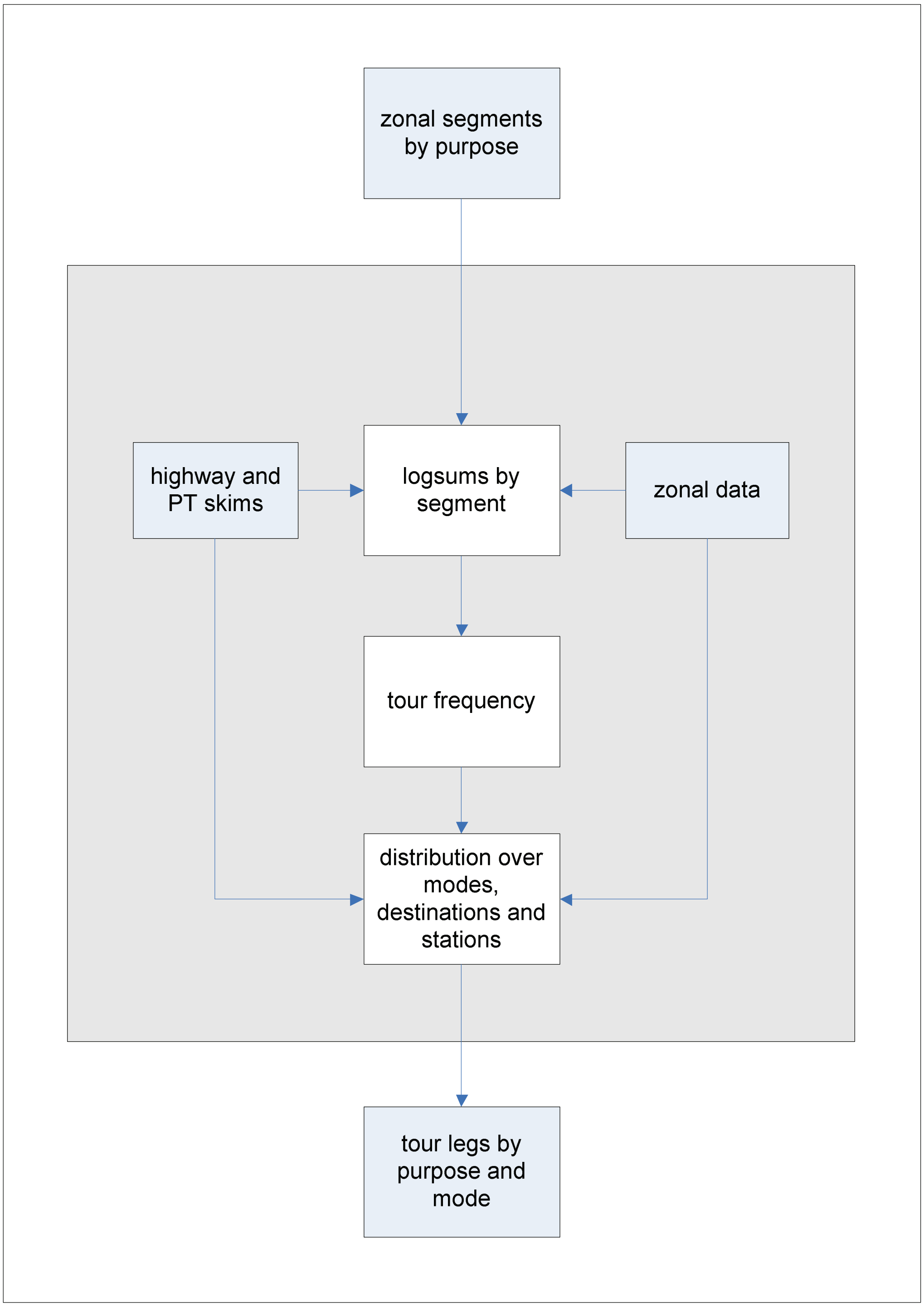
Table 53: Treatment of car driver time period choice by purpose

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, wore-related PD to wore-related SD	assumed fixed
PD–based tours, wore-related PD to other SD	assumed fixed
PD–based tours, other PD to other SD	assumed fixed
detours during wore-related tours to wore-related SDs	assumed fixed
detours during wore-related tours to other SDs	assumed fixed
detours during other tours to other SDs	assumed fixed
airport business	assumed fixed
airport leisure	assumed fixed

4.2 Home-based purposes

The architecture of the HB TravDems is illustrated in Figure 3.

Figure 3: Home-based TravDem architecture



4.2.1 Zonal segments by purpose

Separate input files are defined for each HB travel purpose, from the zonal accumulation procedure described earlier, which gives the number of persons in each model zone for each of the travel segments relevant for that travel purpose.

The segmentations are defined in Chapter 2. The zone segment files are generated by the Population Model, which is described in Chapter 3.

4.2.2 Highway and PT skims

Level-of-service skims from the VISUM highway and PT networks provide input to the TravDems. Highway skims are generated for four time periods:

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

The following information from the highway skims is used in the TravDems:

- congested travel time (minutes)
- distance (kilometres)
- toll cost (2011 pence).

For PT, only AM-peak and inter-peak networks are modelled. To model the PM-peak, AM-peak level of service (LOS) has been transposed. 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, the inter-peak LOS is used without adjustment.

4.2.3 Zonal data

The zonal data read in by the TravDems comprise the attraction variables and parking cost data. The attraction variables specify the 'attractiveness' of destinations. The data to describe these, for each journey purpose, are summarised in Table 54.

Table 54: Attraction variables for HB travel purposes

Purpose	Attractions
commuting	total employment
home–business	total employment
home–primary education	primary enrolments
home–secondary education	secondary enrolments
home–tertiary education	tertiary plus 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

4.2.4 Computing logsums

A key component of the implementation system is the calculation of logsums, which are used to compute the choice probabilities across different levels of the nesting structure.

The calculation of the logsums varies somewhat by travel purpose, as the car driver time period choice is only represented for some travel purposes, and for three of the HB purposes there are two versions of the TravDems, with and without access mode and station choice for train and metro represented. To illustrate the logsum calculations, the structure from the HB models including car driver time period choice, but omitting the train and metro access mode and station choice structure, has been used. In this structure, three choices are represented:

- main modes m
- time periods t
- destinations d.

The logsums are calculated from the following equations, which work up from the bottom of the structure:

$$V_{mt} = \theta_{td} \log \sum_{d'} \exp V_{mtd'} \quad (4.1)$$

$$V_m = \theta_{mt} \log \sum_{t'} \exp V_{mt'} \quad (4.2)$$

$$V = \log \sum_{m'} \exp V_{m'} \quad (4.3)$$

where:

V_{mtd} is the utility at the lowest level, for a specific m, t, d alternative

θ_{td} defines the relative sensitivity of time period and destination choices

V_{mt} is the utility for a mode and time period combination

θ_{mt} defines the relative sensitivity of mode and time period choices

V_m is the utility for a mode

V is the overall logsum over all alternatives.

For the S=3 versions of the commute, home–shopping and home–other models, Equation 4.1 to Equation 4.3 are extended to cover the additional access mode and station choices, maintaining the principle of calculating the logsums by working from the bottom of the structure up.

4.2.5 Tour frequency

The tour frequency models are documented in full in the frequency and car ownership modelling report (Fox et al., 2013b). Chapter 2 of that report presents the structure used for the estimation of the frequency models. In summary, two sub-models are used:

- a zero/one-plus model, which predicts the probability of an individual making at least one tour for a specific journey purpose on a given work-day
- a stop/go model, which predicts the conditional probability of making additional tours for that specific journey purpose (e.g. the probability of making two or more shopping tours, given at least one shopping tour has been made).

For home–escort, two frequency models are used, one for escort school tours, the other for escort other tours. The escort school model uses a modified structure to reflect the different structure of the estimation sample, with a zero/one/two-plus model, and then a stop/go model predicting probability of making three of more escort school tours.

In application, these models can be combined to predict the total number of tours F originating in home zone h and in segment s:

$$F_{hs} = \frac{P_{1+|hs}}{\left(1 - P_{go|hs}\right)} N_{hs} \tag{4.4}$$

where:

$P_{1+|hs}$ is the probability of making at least one tour for an individual from segment s living in zone h

$P_{go|hs}$ is the conditional probability of making n+ tours, given at least (n−1) tours have been made, for an individual in segment s living in zone h

N_{hs} is the number of individuals in segment s living in zone h.

A modified version of this formula is used for the home–escort school frequency model because of the different structure of that model.

For those purposes where a significant relationship between tour frequency and accessibility (across modes and destinations) has been identified, the calculation of P_{1+} and/or P_{go} depends on the mode-destination logsum discussed in the previous section.

4.2.6 Distribution over modes, time periods and destinations

This component of the TravDem takes the demand predicted by the frequency model, and distributes that demand over available main mode, car driver time period, and destination alternatives. For the S=3 versions of the commute, home–shopping and home–other travel models, for train and metro main modes demand is also distributed over access mode and access station alternatives.

Considering the model structures without train and metro access mode and access station choices represented, for an individual from home zone *h* in segment *s*, the demand by mode *m*, time period *t* and destination *d* can be calculated as:

$$T_{hsmtd} = F_{hs}.P_{mtd|hs} \quad (4.5)$$

where:

T_{hsmtd} is the number of tours from zone *h* by mode *m* in time period *t* and destination alternative *d* for segment *s*

F_{hs} is the number of tours from zone *h* for segment *s* (from Equation 4.4)

$P_{mdt|hs}$ is the probability of choosing *mdt* for *hs*, calculated from Equation 4.6 to Equation 4.8 below.

The probability calculations are set out in Equation 4.6 to Equation 4.9, which use the utilities calculated in Equation 4.1 to Equation 4.3 above. The home zone and segment subscripts *h* and *s* have been dropped for presentation clarity. Opposite to the logsums, the choice probabilities are computed by working from the top to the bottom of the tree structure.

$$P_m = \frac{\exp V_m}{\sum_{m'} \exp V_{m'}} \quad (4.6)$$

$$P_{t|m} = \frac{\exp V_{t|m}}{\sum_{t'} \exp V_{t'|m}} \quad (4.7)$$

$$P_{d|mt} = \frac{\exp V_{d|mt}}{\sum_{d'} \exp V_{d'|mt}} \quad (4.8)$$

$$P_{mtd} = P_m P_{t|m} P_{d|mt} \quad (4.9)$$

It is noted that for main modes other than car driver there is no time period nest and therefore Equation 4.7 reduces to $P_{t|m}$=1.

These calculations are extended to incorporate the train and metro access mode and station alternatives for the S=3 versions of the commute, home–shopping and home–other travel models.

4.2.7 Tour legs by mode, purpose and time period

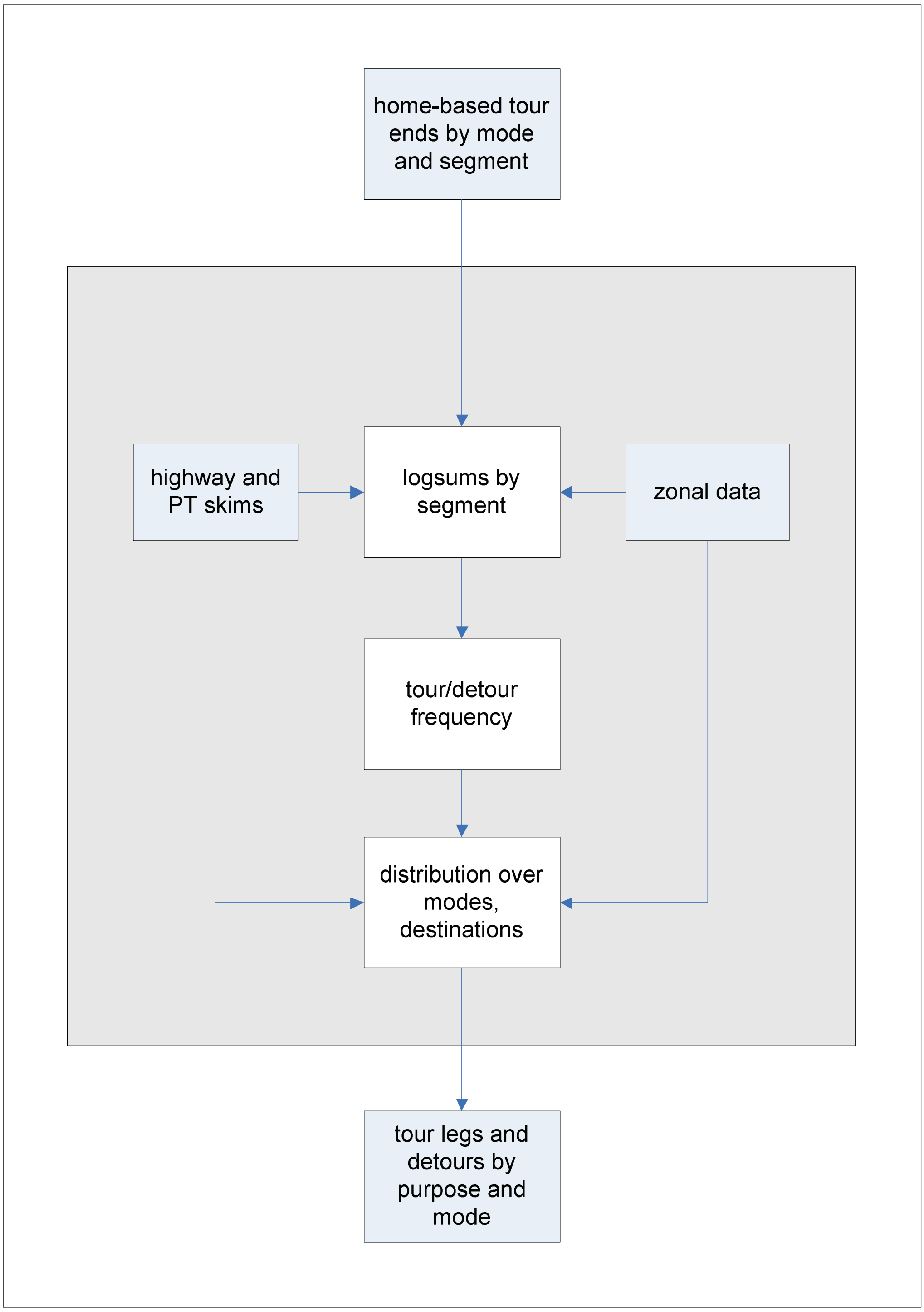
The outputs from the HB tour models are tour matrices by time period which are in Production–Attraction (P→A) format.

These tour matrices feed into the third and final stage of the PRISM system, the final processing step, which includes the pivoting process. Pivoting is the process which takes the tour matrices created for base and future applications of the TravDem models, and combines these matrices in order to forecast changes relative to an observed base matrix.

4.3 Non-home-based purposes

The architecture of the NHB TravDems is illustrated in Figure 4.

Figure 4: The NHB TravDem architecture



4.3.1 Home-based tour ends by mode and segment

The inputs for the NHB TravDems are the outputs from the HB TravDem models. Specifically, for the work–work tour, work–other tour, work–work detour and work–other detour models the inputs are the numbers of commute and home–business tours arriving in each primary destination zone split by mode and segment. For the other–other tour and other–other detour models the inputs are the numbers of home–primary education, home–secondary education, home–tertiary education, home–shopping, home–escort and home–other travel tours arriving at each primary destination zone split by mode and segment.

4.3.2 Highway and public transport skims

The treatment of the highway and PT skims in the NHB TravDems is identical to the treatment in the HB TravDems, as documented in Section 4.2.2.

4.3.3 Zonal data

The attraction variables used in the NHB TravDems are listed in Table 55.

Table 55: NHB TravDem attraction variables

Purpose	Attractions
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 wore-related tours to wore-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

Parking cost data are also read in.

4.3.4 Logsums by segment

The calculation of logsums by segment follows the same approach as that used for the HB purposes, as detailed in Section 4.2.4, though the NHB models do not include the car driver time period choice alternatives. The following alternatives are represented in the NHB models:

- main modes
- destinations.

4.3.5 Tour/detour frequency

The tour/detour frequency models follow similar principles to the frequency models used for the HB purposes (Section 4.2.5). However, an important difference is that the frequency of NHB tour/detour making depends on the mode used for the HB tour. Specifically, NHB tour/detour rates for some purposes are higher if the HB tour mode is car driver.

For the work–work, work–other and other–other tour models, the total number of tours F can be calculated as:

$$F_{zms} = \frac{P_{1+|zms}}{\left(1 - P_{go|zms}\right)} HB_{zms} \qquad (4.10)$$

where:

$P_{1+|zms}$ is the probability of making at least one tour from PD zone z for an individual with HB tour mode m from segment s

$P_{go|zms}$ is the conditional probability of making n+ tours, given at least (n-1) tours have been made (n > 1), for an individual with HB tour mode m from segment s

HB_{zms} is the number of HB tours arriving in PD zone z by mode m and segment s (work-related or other, depending on the purpose).

The detour model is a simple binary model with alternatives 'detour' and 'no detour'. However, a complication is that separate detour models are applied for detours made on the outward and return legs of HB tours, because detour rates on return legs are higher.

Equation 4.11 shows how the number of detours is calculated for the work–work, work–other and other–other detour models:

$$F_{zmsr} = P_{1|zmsr} HB_{zms} \qquad (4.11)$$

where:

r distinguishes between outward and return detours

$P_{1|zmsr}$ is the probability of making at least one tour from PD zone z for an individual with HB tour mode m from segment s given r

HB_{zms} is the number of HB tours arriving in PD zone z by mode m and segment s (either work-related or other).

4.3.6 Distribution over modes, destinations

This component of the TravDem takes the demand predicted by the frequency model, and distributes that demand over available mode and destination alternatives.

The modes represented in the TravDems were listed in Section 4.1.1.

The NHB models only represent main mode and destination alternative, and therefore the formulae set out in Equation 4.6 to Equation 4.8 of Section 4.2.6 are applied after removing the car driver time period choice. The final probability calculation is as follows:

$$P_{md} = P_m P_{d|m} \qquad (4.12)$$

4.3.7 Tour legs and detours by purpose, mode and time period

The outputs from the work–work, work–other and other–other models are tour matrices by time period in Production–Attraction (P→A) format. Demand is allocated into time periods using fixed time period proportions observed in the 2009–2012 HI data.

The outputs from each of the detour models are two detour matrices for each time period, the first containing detours on the outward (P→A) leg of HB work and business tours, the second containing detours on the return (A→P) leg of HB work and business tours.

4.4 Destination sampling

4.4.1 Model run times

For future year runs, the demand and assignment models are run iteratively until supply and demand have converged to equilibrium. Therefore demand model run times are important in determining overall model run times.

To understand the contribution of different model purposes to the overall demand model run times the run times by purpose were tabulated. The results are tabulated in Table 56 and were generated using a machine with two Intel Xeon 2.8 GHz processors and 16 GB of RAM.

Table 56: Demand model run times

Purpose	Segments	Run time (minutes)	
home–work	192	S=0: 226	S=3: 250
home–business	12	13	
home–primary education	6	4	
home–secondary education	6	4	
home–tertiary education	20	10	
home–shopping	96	S=0: 76	S=3: 110
home–escort	20	20	
home–other travel	192	S=0: 192	S=3: 219
work–work tours	6	5	
work–other tours	4	3	
other–other tours	4	3	
work–work detours	12	7	
work–other detours	12	16	
other–other detours	72	42	
airport models	1 per model	0.5	

In application the six HB models are run first, in parallel, and then the six NHB models and the two airport models are run second, again in parallel. The maximum run time for the HB models is 226/250 minutes (S=0/S=3) whereas for the NHB models the maximum run time is 42 minutes. Thus the HB model run times are critical in determining the total time required to run the entire demand model.

Therefore destination sampling has been implemented for the three purposes that have the greatest impact on the HB run times, specifically the S=3 versions of the home–work, home–shopping and home–other travel models. The destination sampling approach is used to reduce model run times in model application. It is based on the observation that for a given origin zone most demand will be concentrated in a small number of nearby, large and attractive zones. Destination sampling involves identifying a limited sample of destination zones for each origin, taking advantage of this concentration in demand.

4.4.2 Destination sampling procedure

The procedure developed for PRISM in 2007 to compensate for the increase in model run times associated with the introduction of income segmentation, and was documented in

Miller et al. (2007). The procedure described in full in Miller et al. (2007) has been implemented without modification in the 2011 base version of PRISM, and is summarised here.

To select the destination sample for a given purpose, a two-step procedure is followed for each origin zone:

1. For each mode m identify the destination d with the highest concentration of demand in the base year b, i.e. $max\{S^b_{m,d}\}$, and then add the intrazonal destination to the sample if it has not been sampled already so that intrazonals are always included in the sample. Mode in this context includes each of the access modes to train and metro in the S=3 models.
2. Identify the remaining destinations by importance sampling where the probability of destination d being sampled $P(d)$ is proportional to the base year synthetic demand, i.e. $P(d) \propto S^b_d$ where S^b_d is summed over all modes.

A sample has been identified that satisfies the overall condition:

$$\sum_{\in o} \sum_{\in d} \frac{S^b_0}{S^b} \geq 0.9 \qquad (4.13)$$

Thus destination samples have been identified that capture at least 90 % of total synthetic demand in the base year summed over all origins and destinations.

Once the destination sample has been identified, adjustments to the attraction variables for the sampled destinations are calculated to take account of the attractiveness of the unsampled destinations. If, for a given purpose, origin and mode, a sampled destination D_0 is chosen to represent unsampled destinations $D_1 ... D_n$, and the attraction variables in base and forecast years are A^b and A^f respectively, then for each destination expected future demand can be calculated as:

$$S^f_i = S^b_i \frac{A^f_i}{A^b_i} \qquad (4.14)$$

In the absence of information about future LOS, future year demand would be expected to be distributed over sampled and unsampled destinations in the ratio $S^f_0 : S^f_1 : ... : S^f_n$. The attractiveness of the *sampled* destination in the future year is therefore given by:

$$A^f_0 = \frac{A^b_0}{S^b_0} \left(S^b_0 \frac{A^f_0}{A^b_0} + S^b_1 \frac{A^f_1}{A^b_1} + ... + S^b_n \frac{A^f_n}{A^b_n} \right) \qquad (4.15)$$

The TravDems are then run for the sampled destinations using the modified attraction variables. Once demand for the sampled destinations has been calculated, it is redistributed over both sampled and unsampled destinations by dividing it by the ratio:

$$S^f_0 : S^f_1 : ... : S^f_n \qquad (4.16)$$

A more detailed explanation of the process is provided in Miller et al. (2007).

4.4.3 Destination sampling tests

To set up the destination sampling process for the new 2011 base version of the model, a series of runs was made testing different sized destination samples. The objective was to identify the minimum sample size necessary to achieve the required level of performance, specifically a set of destinations that capture 90 % of the total (unsampled) demand. The results of these tests are summarised Table 57 to Table 59.

Table 57: Home–work destination sample tests

Destinations		percentage of demand captured
number	percentage of total	
300	30.2	89.5
350	**35.2**	**91.6**
400	40.2	93.9
500	50.3	96.5

A sample of 350 destinations was used in order to capture over 90 % of total demand.

Table 58: Home–shopping destination sample tests

Destinations		percentage of demand captured
number	percentage of total	
80	**8.0**	**92.4**
100	10.1	94.3
120	12.1	95.6

Home–shopping tours are shorter than home–work tours, and concentrated at fewer destinations. Consequently a much smaller sample of 80 destinations is required to achieve the 90 % of total demand threshold.

Table 59: Home–other travel destination sample tests

Destinations		percentage of demand captured
number	percentage of total	
250	**25.2**	**90.0**
300	30.2	92.4
350	35.2	94.2

Home–other tours are longer than home–shopping tours (18.4 km on average compared with 10.3 km for home–shopping), and demand is also distributed over a wider range of destinations relative to home–shopping. Consequently a larger sample of 250 destinations is required to meet the 90 % demand captured threshold.

The run times resulting from destination sampling are summarised in Table 60.

Table 60: Impact of destination sampling on model run times (minutes)

Purpose	Unsampled		Sampled		Percentage	
	Zones	Run time	Zones	Run time	Zones	Run time
Home–work	994	250	350	96	35.2	38.4
Home–shopping	994	110	80	16	8.0	14.5
Home–other travel	994	219	250	62	25.2	28.3

It can be seen that the run time saving is more or less proportional to the reduction in the number of destinations modelled. Thus destination sampling yields significant run time reductions.

Validation statistics for models with and without destination sampling are presented in Sections 6.2 to 6.4.

CHAPTER 5 Final processing

5.1 Transpose and add up

For the eight HB models, and for the three PD-based tour models, matrices of outward and return tour legs are output split by the four model time periods. Outward tour leg matrices, which represent travel from the home to the PD, are equivalent to trip matrices and so can be used directly. However return tour leg matrices, which represent travel from the PD back to the home, need to be transposed before they can be treated as trip matrices. The matrices are transposed using ALOGIT code.

The next step is to add up the matrices across purposes to reflect the segmentations used in the VISUM assignments. For PT modes, there is no purpose segmentation and so the matrices are summed across all purposes. For the two airport purposes, predicted coach demand is *not* added to the bus matrices because coach movements are not represented in the bus base matrices, and predicted taxi demand is *not* added to the highway matrices because taxi movements are not represented in the car base matrices. For car, four purposes are distinguished in the highway assignments. Table 61 shows the mapping between the 16 purposes in the PRISM demand model and the two highway assignment purposes.

Table 61: Highway assignment purpose mapping

Demand model purpose	Highway assignment purpose
commute	other
home–business	business
home–primary education	other
home–secondary education	other
home–tertiary education	other
home–shopping	other
home–escort	other
home–other travel	other
work–work tours	business
work–other tours	other
other–other tours	other
work–work detours	business
work–other detours	other
other–other detours	other
airport business	business
airport leisure	other

5.2 Pivoting

The pivoting procedure makes best-estimate forecasts by predicting changes relative to a known base situation, defined by the base matrices.

The pivoting is carried out at matrix cell level. For a specific origin, destination, mode, time of day and – for car driver only – purpose, adjustments are made relative to the corresponding cell in a base matrix.

The procedures set out below are based on RAND Europe experience with a number of pivot–point models, experience which is described in more detail in Daly et al. (2011). Some of these models have special procedures to adjust the calculation when the growth in a specific cell is considered to be 'extreme'.

The preferred approach to pivot-point forecasting is to apply the ratio of model outputs for base and forecast situations as a growth factor to the base matrix – in a given cell the predicted number of trips P is given by

$$P = B \cdot \frac{Sf}{Sb} \qquad (5.1)$$

where:

B is the base matrix

Sb is the base year synthetic trips

Sf is the future year synthetic trips.

However, two considerations make it not possible to apply this calculation as simply as stated.

First, any combination of the three components on the right hand side of this equation may be zero (or very small) making the calculation impossible or meaningless. Eight possible cases arise (combinations of zero values) and these are dealt with separately below.

Second, particularly when there is a land-use change affecting the whole of a zone, the change may be quite extreme and strict application of the formula above can lead to an 'explosion' in the number of trips. In these cases it is better to 'pivot' by applying an absolute growth – (Sf – Sb) – to the base matrix, rather than a factor as shown above. In the recommendations below, this absolute growth is applied to all cases when Sb is zero and to other cases when Sf / Sb exceeds a specified factor (including 'infinity' when Sb=0 and Sf is non-zero).

The eight possible cases and the recommended treatments are set out in Table 62.

Table 62: Eight pivoting cases

Case	Base (B)	Synthetic base (Sb)	Synthetic future (Sf)	Predicted (P)	
1	0	0	0	0	
2	0	0	>0	*Sf*	
3	0	>0	0	0	
4	0	>0	>0	Normal growth, ($Sf < X_1$)	0
				Extreme growth ($Sf > X_1$)	$Sf - X_1$
5	>0	0	0	*B*	
6	>0	0	>0	$B + S_f$	
7	>0	>0	0	0	
8	>0	>0	>0	Normal growth ($Sf < X_2$)	$B.Sf / Sb$
				Extreme growth ($Sf > X_2$)	$B.X_2 / Sb + (Sf - X_2)$

where:

$$X_1 = X_2 = 5Sb \tag{5.2}$$

Once the pivoting rules have been applied at the cell level, a row normalisation factor is applied so that the predicted growth in trips at the origin level is equal to the growth predicted between the synthetic future and base. This gives the condition:

$$\sum_{x \in O} P_x' = \sum_{x \in O} B_x \frac{\sum_{x \in O} Sf_x}{\sum_{x \in O} Sb_x} \tag{5.3}$$

To implement this condition the following formula is applied:

$$P_x' = P_x \left(\frac{\sum_{x \in O} B_x \sum_{x \in O} Sf_x}{\sum_{x \in O} P_x \sum_{x \in O} Sb_x} \right) \tag{5.4}$$

where:

P_x' is the pivoted trips after row normalisation

P_x is the pivoted trips before row normalisation.

5.3 Output for assignment

The final stage is to convert the pivoted matrices into a format suitable for reading into VISUM ready for assignment. This step is implemented using ALOGIT code, which outputs the matrices in the required *.fma format.

A total of 20 matrices are output:

- CAR_BUS_**.fma: car business trips
- CAR_OTH_**.fma: car other trips
- TRAIN_**.fma: train trips
- METRO_**.fma: metro trips
- BUS_**.fma: bus trips

where: ** is the time period (AM, IP, PM or OP).

CHAPTER 6 Base year validation

Four sets of tests have been made to verify and validate the performance of the TravDem models for the 2011 base year:

- replication of the mode-destination logsums obtained with the estimation set-ups
- comparison of observed and predicted tour rates
- comparison of observed and predicted mode shares
- comparison of observed and predicted mean tour lengths.

These four validation tests are documented in Sections 6.1 to 6.4, which present summary results for each of the model purposes. For the home–work, home–shopping and home–other travel purposes the validation statistics are presented in Section 6.2 to Section 6.4 for:

- the S=0 versions of the models which do not model P&R
- the S=3 P&R versions of the models
- the S=3 P&R versions of the models using destination sampling.

Detailed validation results for the three versions of the models are presented in Appendix B.

6.1 Logsums

The mode-destination model includes main mode, car driver time period and destination choices. For a given home zone and model segment combination, a mode-destination logsum can be calculated over each of these choices (as per Equation 4.3).

For the eight HB purposes, mode-destination logsums were created during the model estimation phase to enable the impact of mode-destination accessibility to be tested in the tour frequency models. As a result, for the HB TravDems, it is possible to verify that the base year application of the TravDem exactly replicates the logsums obtained from the estimation set-ups.

Verifying the mode-destination model obtained at the implementation stage against the values obtained at the estimation stage is a rigorous check that the mode-destination model has been implemented correctly, because it can only be satisfied if the mode and destination utilities, the availability of each mode-destination alternative, and the model structures match exactly between the estimation and application set-ups.

The mode-destination logsums have been validated exactly against the estimation values for the eight HB purposes. For the two NHB purposes, this check is not possible because logsums were not extracted at the estimation phase, and so the validation for these purposes relies on the validation tests reported in Section 6.2 to Section 6.4.

6.2 Tour and detour rates

The tour and detour rates have been validated by comparing the predicting tour rates to the tour rates observed in the 2009–2012 HI data used to estimate the models.

The results from the tour frequency rate checks for the eight HB purposes are presented in Table 63.

Table 63: Tour frequency rate validation, HB purposes

Purpose	2009–2012 HI data	TravDem 2011 base rate	Difference
commute, S=0	0.602	0.603	0.2 %
commute, S=3	0.602	0.593	-1.5 %
commute, S=3, destination sampling	0.602	0.593	-1.5 %
home–business	0.077	0.073	-4.6 %
home–primary	0.941	0.923	-1.9 %
home–secondary	0.864	0.862	-0.2 %
home–tertiary	0.056	0.047	-15.4 %
home–shopping, S=0	0.141	0.147	4.6 %
home–shopping, S=3	0.141	0.147	4.7 %
home–shopping, S=3, dest. sampling	0.141	0.147	4.7 %
home–escort	0.162	0.123	-23.9 %
home–other travel, S=0	0.208	0.215	3.3 %
home–other travel, S=3	0.208	0.212	1.7 %
home–other travel, S=0 dest. samp.	0.208	0.212	1.7 %

For home–work, home–business home–primary, home–secondary, home–shopping and home–other travel purposes the predicted tour rates are within 5 % of those observed in the estimation samples.

The home–tertiary education tour rate is significantly lower in the 2011 base TravDem than in the unweighted 2009–2012 HI data. Tour rates are much higher for full-time students than for other status groups, and the proportion of full-time students in the predicted 2011 population is significantly lower than the proportion observed in the 2009–2012 HI data (see Table 44).

The predicted home–escort tour rate is also significantly lower than the rate observed in the 2009–2012 HI data. Frequency for home–escort travel is predicted by two separate models, the first for school escort travel, the second for other escort travel. The predictions of the escort school travel model vary strongly with the number of children in the household. As shown by Table 49, the fraction of households without children is higher in the 2011 predicted population than in the 2009–2012 HI data, and as a result the predicted tour rate for school escort travel is 10 % lower than the rate observed in the HI data. For the home–escort other model, the predicted tour rate is lower than the observed tour rate as mean proportions were used to implement the strongly identified age terms in the model.

Comparing the S=0 and S=3 results in Table 63, some differences in tour rate are observed arising from differences between the S=0 and S=3 mode-destination logsums that feed into the frequency models. It is noted that separate frequency models are used in the S=0 and S=3 models, but these models were estimated using logsums calculated from the 2006 LOS used for the mode-destination model estimation rather than the 2011 LOS used for the base year implementation.

The results in Table 63 demonstrate that the use of accessibility logsums from the S=3 models with destination sampling demonstrates introduces no bias to the tour rates.

The tour and detour frequency rate validation for NHB purposes is presented in Table 64. For the three detour purposes, outward and return detours have been summed together.

Table 64: Tour and detour frequency rate validation, NHB purposes

Purpose	2009–2012 HI data	TravDem 2011 base rate	Difference
work–work tours	0.011	0.010	-14.7 %
work–other tours	0.019	0.019	-1.6 %
other–other tours	0.005	0.005	1.5 %
work–work detours	0.035	0.034	-2.4 %
work–other detours	0.195	0.165	-15.4 %
other–other detours	0.128	0.124	-2.9 %

For work–work tours and work–other detours the significant differences between the predicted tour and detour rates and those observed in the 2009–2012 HI data arise from the use of mean proportions in the frequency models to implement gender and number of children terms. For the remaining NHB purposes predicted tour and detour rates are within 5 % of the observed values.

The idea behind using mean proportions is that they preserve the quality of the estimations by allowing important effects to be retained without adding to the complexity of the implementations. However, it is clear from this analysis that the terms have led to some differences between predicted and observed tour rates and therefore if the PRISM models are re-estimated in the future we suggest that either the models are re-estimated with these effects dropped or additional frequency segments are added.

6.3 Mode shares

To calculate a summary measure of the replication of mode share to observed HI data, a root-mean-square (RMS) measure has been used, defined as follows:

$$RMS(M) = \sqrt{\frac{\sum_m \left(HI_m - TD_m\right)^2}{M}} \quad (6.1)$$

where: m are the modes, with M modes in total

HI_m are the mode shares from the 2009–2012 HI data

TD_m are the mode shares predicted by the TravDems.

Table 65 summarises the measures obtained for each of the HB travel purposes. Detailed comparisons of mode share for each travel purpose are presented in Appendix B.

Table 65: Mode share validation, HB TravDems

Purpose	RMS(M)
commute, S=0	1.6 %
commute, S=3	1.6 %
commute, S=3, destination sampling	1.6 %
home–business	1.3 %
home–primary	8.2 %
home–secondary	2.7 %
home–tertiary	2.7 %
home–shopping, S=0	3.3 %
home–shopping, S=3	3.2 %
home–shopping, S=3, dest. sampling	3.3 %
home–escort	2.1 %
home–other travel, S=0	3.6 %
home–other travel, S=3	3.6 %
home–other travel, S=0 dest. samp.	3.6 %

Overall, mode shares are predicted well, with RMS errors of no more than 4 % for most purposes. There is a tendency to under-predict the bus shares observed in the 2009–2012 HI data, however nearly all of the HIs were undertaken in the core region, whereas the base model is applied for both core and intermediate areas, and bus mode shares would be expected to be higher in the core region.

For primary education, the RMS is significantly higher than for other purposes. The high RMS value comes about because the predicted car passenger shares are higher than those observed in the 2009–2012 HI data, whereas the walk shares are lower. Car passenger shares would be expected to be higher in the intermediate area where car ownership is higher, and mean tour distances are also higher.

Comparison of the S=0 and S=3 versions of the models demonstrates that extending the models to represent access mode choice to train and metro does not result in a reduction in the overall fit to the observed mode shares.

Similarly the S=3 results with and without destination sampling demonstrate that the process has no impact on the fit to the observed mode shares.

Table 66: Mode share validation, NHB TravDems

Purpose	RMS(M)
work–work tours	3.7 %
work–other tours	5.3 %
other–other tours	4.1 %
work–work detours	3.3 %
work–other detours	0.8 %
other–other detours	2.4 %

For the three PD-based tour TravDems, the mode shares validate less well than most of the HB TravDems. For work–work there is a substantial difference between the observed and predicted train shares, whereas for work–other there is a large difference between the observed and predicted bus shares. The number of PT tours in the estimations samples are very low, and this makes it difficult for the models to replicate the observed shares in application.

6.4 Tour and detour lengths

The means tour lengths predicted for each HB purpose are compared to those observed in the 2009–2012 HI data in Table 67.

Table 67: Total tour length validation, HB purposes (km)

Purpose	2009–2012 HI data	TravDem 2011	Difference
commute, S=0	22.6	25.7	13.7 %
commute, S=3	22.5	25.8	14.3 %
commute, S=3, destination sampling	22.5	25.8	14.3 %
home–business	68.3	93.7	37.3 %
home–primary	5.2	5.7	11.0 %
home–secondary	8.1	9.9	21.7 %
home–tertiary	19.8	22.1	11.6 %
home–shopping, S=0	10.3	10.4	0.9 %
home–shopping, S=3	10.3	10.5	1.3 %
home–shopping, S=3, dest. sampling	10.3	10.4	1.1 %
home–escort	7.3	7.1	-3.4 %
home–other travel, S=0	18.3	18.2	-0.5 %
home–other travel, S=3	18.4	18.1	-1.8 %
home–other travel, S=0 dest. samp.	18.4	18.1	-1.5 %

There is a general pattern of over-prediction of tour lengths relative to the 2009–2012 HI data. The 2009–2012 HI data were collected in the core region, whereas the TravDem predictions are for both the core and intermediate areas, and longer tour lengths would be expected in the intermediate area. For home–primary and home–secondary, where the differences between observed and predicted tour lengths are largest, predicted bus tour lengths are significantly higher than those observed in the 2009–2012 HI data.

Using destination sampling in the S=3 models has only a slight impact on the predicted total tour lengths.

Table 68: Total tour and detour length validation, NHB purposes (km)

Purpose	2009–2012 HI data	TravDem 2011	Difference
work–work tours	59.6	53.0	-11.1 %
work–other tours	7.4	7.3	-1.9 %
other–other tours	8.5	10.9	29.1 %
work–work detours	18.9	17.6	-6.9 %
work–other detours	9.5	9.4	-2.0 %
other–other detours	6.2	6.0	-3.3 %

Consistent with the HB purposes, the predicted NHB tour and detour lengths are generally higher than those observed in the 2009–2012 HI data. Particularly marked differences are observed for work–other tours and other–other tours. For work–other tours, predicted bus tour lengths are much higher than those observed in the 2009–2012 HI data. For other–other tours, the main cause was that predicted car driver tours lengths are much higher than those observed in the 2009–2012 HI data.

To look at the fit to observed tour lengths are the modal level an RMS measure has been used:

$$RMS(T) = \sqrt{\sum_m S_m \left(\frac{P_m - O_m}{O_m} \right)^2} \qquad (6.2)$$

where: S_m is the observed mode share (noting these sum to 1 over the modes)

O_m is the observed tour length for mode *m*

P_m is the predicted tour length for mode *m*.

The RMS tour length measures calculated for the HB purposes are presented in Table 69. RMS measures have been calculated across all modes, and across all non-PT modes. Detailed validation of tour lengths by mode is presented in Appendix B.

Table 69: Tour length RMS measures, HB purposes

Purpose	RMS(T)	RMS(T) excluding PT modes
commute, S=0	18.9 %	18.3 %
commute, S=3	18.6 %	18.2 %
commute, S=3, destination sampling	18.6 %	18.2 %
home–business	53.9 %	48.9 %
home–primary	6.9 %	6.3 %
home–secondary	32.9 %	30.7 %
home–tertiary	20.0 %	16.6 %
home–shopping, S=0	12.5 %	14.1 %
home–shopping, S=3	14.2 %	14.2 %
home–shopping, S=3, dest. sampling	13.5 %	14.2 %
home–escort	10.4 %	10.1 %
home–other travel, S=0	14.5 %	14.7 %
home–other travel, S=3	13.0 %	12.8 %
home–other travel, S=0 dest. samp.	13.0 %	12.8 %

The RMS measures illustrate that on average there is a relatively large difference between predicted tour lengths and those observed in the 2009–2012 HI data. Larger differences are observed for PT modes, with a tendency to under-predict observed train distances, and over-predict observed metro and bus distances. Thus when PT modes are excluded from the RMS calculations, the average error is lower for all purposes.

The pattern of under-prediction of train distances and over-prediction of metro and bus distances was observed when the models were validated using the estimation samples (Fox et al. 2013a). As noted in that report, if the models were re-estimated using LOS from the new 2011 unified PT model then the models would be expected to better replicate the observed PT tour lengths.

The other factor that contributes to the relatively high RMS measures in Table 69 is that the model is applied to both the core and intermediate areas, whereas nearly all of the 2009–2012 HI data were collected in the core area, and longer tour lengths would be expected for tours originating in the intermediate area.

Table 70: Tour length RMS measures, NHB purposes

Purpose	RMS(T)	RMS(T) excluding PT modes
work–work tours	74.4 %	76.4 %
work–other tours	20.3 %	19.6 %
other–other tours	51.0 %	53.8 %
work–work detours	28.1 %	28.7 %
work–other detours	25.2 %	25.8 %
other–other detours	7.0 %	4.8 %

As per the HB models, discrepancies between observed and predicted tour lengths for PT modes play a role in the relatively high overall RMS figures. For both work–work and other–other tours, predicted car driver tour lengths are significantly higher than those observed in the 2009–2012 HI data and as a result the RMS measure remains high when PT modes are excluded.

CHAPTER 7 Summary

The segmentations used to implement the PRISM models have been revised in light of the new 2011 base frequency and mode-destination models. For all of the HB purposes, the numbers of mode-destination segments has been reduced because there is no pass-ownership model in the 2011 base model.

The Population Model is used to predict the future West Midlands population by zone and segment. It has been updated to reflect the revised population segments and to implement the new local car ownership model, which has been developed using the 2009–2012 HI data.

The travel demand (TravDem) models have been updated to implement the new models. This required the coding of a TravDem for home–escort travel, and six new TravDems to implement the NHB models. For the home–work, home–shopping and home–other versions of the TravDems incorporating P&R, a destination sampling procedure has been implemented which delivers significant reductions in model run time.

The final process module takes the output from the TravDems, aggregates over purposes to reflect the segmentation used in the assignments, and applies the pivoting procedure to predict changes relative to the base matrices. The procedure has been updated to work with the new TravDems and the revised highway assignment purpose segmentation used in the 2011 base version of PRISM.

The HB TravDems have been validated for the 2011 base year by comparing mode-destination logsums to values calculated from the estimation set-ups. This provides a rigorous check that the estimation and application set-ups are exactly consistent.

All of the TravDems have been validated by comparing against the 2009–2012 HI data.

For tour and detour rates, there is a generally a good match to the HI data for most HB purposes. However, for home–tertiary education, the application tour rate is significantly lower than the rate observed in the 2009–2012 HI data. This difference is caused by the lower fraction of full-time students in the predicted 2011 population compared with the HI data. For home–escort, the application tour rate is also significantly lower than the rate observed in the HI; this difference is caused by a higher fraction of individuals in no child households in the predicted 2011 population compared with the HI data. Four of the six NHB models validated well, for two significant differences between the predicted and observed rates were observed due to the use of mean proportions to implement some of the frequency model terms. If the PRISM models are re-estimated in the future it is suggested that either the frequency models are modified to drop terms implemented using mean proportions, or additional frequency segments are added.

In most cases mode share is predicted well, though for primary education the validation is less good because of the higher car passenger shares in application. The models were estimated from data collected in the core area, but are applied to both the core and intermediate areas. Higher use of car passenger would be expected in the intermediate area where car ownership and mean tour lengths are higher. The mode share fit in the S=3 versions of the models with P&R is similar to that in the S=0 versions without P&R, and there is no deterioration in the destination sampling versions of the travel demand models. Overall the mode share fit in the NHB models is slightly worse than the HB models; these differences result from difficulties in accurately replicating the very low observed PT shares in application.

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APPENDICES

Appendix A: Mean proportions

The mean proportions used to implement those socio-economic parameters in the mode-destination models not defined by the segments defined in Chapter 2 have been calculated from the tour estimation samples for the mode-destination model terms. Mean proportions are also required to implement the parking cost information, as described below.

In estimation, parking costs in city centre zones are calculated as a function of the activity duration at the primary destination. For implementation, the observed distributions of activity duration by parking cost length of stay band have been calculated to allow mean parking costs to be calculated. For some model purposes, these distributions have been calculated separately for different model segments, for example for commute the distributions are calculated separately for part-time workers who on average have shorter working days than other workers.

Mean proportions have also been calculated for those socio-economic parameters in the frequency models that are not defined by the mode-destination and additional frequency segmentations. The following sections detail the mean proportions that have been calculated for each model purpose.

Commute

To implement the age terms in the mode-destination model, mean proportions were extracted segmented according into part-time workers and other groups.

	Worker type b	17–20	21–24	35–44
b3, b4	part-time worker	0.005	0.008	0.045
b1, b2	other	0.032	0.064	0.239

To calculate mean parking costs for city centre zones where parking costs are defined, mean proportions of tours by activity duration category were extracted segmented by part-time workers and other groups.

Activity duration (hours)	Part-time worker (b3, b4)	Other groups (b1, b2)	Total
< 1	0.031	0.025	0.026
1–2	0.038	0.008	0.012
2–3	0.049	0.013	0.018
3–4	0.100	0.020	0.032
4–6	0.260	0.059	0.089
6–8	0.304	0.234	0.245
8–12	0.207	0.610	0.549
> 12	0.010	0.032	0.029
Total	1.000	1.000	1.000

To implement the aged 17–24 parameter in the frequency model, mean proportions segmented by frequency segmentation F1 have been used.

	Status F1	Aged 17–24
F11_1	full-time worker	0.111
F11_2	part-time worker	0.124
F11_3	self-employed	0.040
F11_4	full-time student	0.830
F11_5	part-time student	0.636

Home–business

To implement the parking cost calculations, mean activity durations have been calculated. In contrast to commute, these calculations have not been segmented by worker type because the smaller sample size does not allow the worker split to be reliably applied.

Activity duration (hours)	Proportion of tours
< 1	0.072
1–2	0.066
2–3	0.072
3–4	0.061
4–6	0.144
6–8	0.199
8–12	0.373
> 12	0.013
Total	1.000

To implement the male and aged 17–24 parameters in the frequency model, mean proportions segmented by frequency segmentation F2 have been used.

	Status F2	Male	Aged 17–24
F2_1	full-time worker	0.594	0.111
F2_2	self-employed	0.790	0.040
F2_3	other	0.359	0.431

Home–primary education

No mean proportions were required to implement the socio-economic parameters in the home–primary education model.

Home–secondary education

To implement the male parameters in the mode-destination choice model, the overall fraction of males observed in the estimation sample of 0.519 was used.

Home–tertiary education

To implement the two-plus cars and single person household terms, mean proportions by car availability segmentation a were extracted.

	Car availability a	2+ cars	Single person household
a1	no cars in household	0.000	0.051
a2	no licence, 1+ cars	0.383	0.000
a3	licence, one car, free car use	0.000	0.208
a4	licence, 1+ cars, car competition	0.539	0.000
a5	licence, 2+ cars, free car use	1.000	0.000

To implement the retired term in the mode-destination choice model, the mean proportion of 0.044 persons in status group b=2 was used. Status group b=1 is full-time students and therefore the retired term is never applied for this segment.

To implement the parking cost calculations, mean proportions by activity duration were extracted segmented by status segment b.

Activity duration (hours)	Full-time student b=1	Other status groups b=2
< 1	0.011	0.044
1–2	0.028	0.080
2–3	0.039	0.159
3–4	0.067	0.115
4–6	0.197	0.239
6–8	0.465	0.292
8–12	0.184	0.071
> 12	0.009	0.000
Total	1.000	1.000

To implement the proportion of persons whose highest educational qualifications are at GSCE level or who have no educational qualifications at all, mean proportions segmented by frequency segmentation F1 have been used.

	Status F1	GCSE or no qualifications
F1_1	full-time worker	0.387
F1_2	part-time student	0.400
F1_3 (b=1)	full-time student	0.299
F1_3 (b=2)	other	0.709

Home–shopping

To implement the one car constant in the train & metro access mode choice model, mean proportions by car availability segmentation a were extracted.

	Car availability segmentation a	One car in hh
a1	no cars in household	0.000
a2	no licence, 1+ cars, free car use, 2 persons in hhld	0.950
a3	no licence, 1+ cars, 3+ persons in hhld	0.772
a4	licence, 1 car, free car use	0.986
a5	licence, 1+ cars, car competition, 2 persons in hhld	1.000
a6	licence, 1+ cars, car competition, 3+ persons in hhld	0.608
a7	licence, 2+ cars, free car use, 2 persons in hhld	0.000
a8	licence, 2+cars, free car use, 3+ persons in hhld	0.000

Mean proportions for male and disabled parameters in the mode-destination choice model have been implemented using mean proportions segmented by status segment b.

	Status b	male	disabled
b1	full-time student	0.477	0.000
b2	retired	0.451	0.000
b3	other groups	0.358	0.075

To implement the parking cost calculations, the proportions of tours by activity duration was extracted. As most shopping tours were short, the observed data did not justify segmenting these proportions according by the mode-destination status segmentation b.

Activity duration (hours)	Proportion of tours
< 1	0.509
1–2	0.309
2–3	0.107
3–4	0.041
4–6	0.024
6–8	0.008
8–12	0.003
> 12	0.000
Total	1.000

To implement the frequency parameter for persons from households with four-plus persons, mean proportions by car availability segmentation a have been used. These are detailed in the following table.

	Car availability a	4+ person households
a1	no cars in household	0.382
a2	no licence, 1+ cars, free car use, 2 persons in hhld	0.000
a3	no licence, 1+ cars, 3+ persons in hhld	0.780
a4	licence, 1 car, free car use	0.228
a5	licence, 1+ cars, car competition, 2 persons in hhld	0.000
a6	licence, 1+ cars, car competition, 3+ persons in hhld	0.628
a7	licence, 2+ cars, free car use, 2 persons in hhld	0.000
a8	licence, 2+cars, free car use, 3+ persons in hhld	0.632

To implement the four age-band terms in the frequency model, mean proportions by status segment b have been used.

	Status b	Aged 5–14	Aged 15–30	Aged 31–39	Aged 40–49
b1	full-time student	0.616	0.373	0.008	0.002
b2	retired	0.000	0.004	0.001	0.002
b3	other groups	0.002	0.260	0.226	0.264

Home–escort

To implement the gender parameter on bus in the mode-destination choice model, mean gender proportions have been calculated by presence of children segment b.

	Presence of children b	Aged 5–14
b1	no children/infants	0.303
b2	children/infants	0.697

To implement the parking cost calculations, the proportions of home–escort tours by activity duration have been extracted. As would be expected, for most home–escort tours that duration of stay is less than one hour.

Activity duration (hours)	Proportion of tours
< 1	0.960
1–2	0.021
2–3	0.006
3–4	0.003
4–6	0.004
6–8	0.004
8–12	0.002
> 12	0.000
Total	1.000

To implement the age and income parameters in the two home–escort frequency models, mean proportions by frequency segmentation F1 have been used.

		School escort			Other escort	
	Status F1	Aged 17–24	Aged 30–39	Less than £25k p.a.	Aged 40–49	Aged 50+
F1_1	full-time worker	0.224	0.319	0.206	0.280	0.223
F1_2	full-time student	0.359	0.058	0.272	0.007	0.002
F1_3	unemployed	0.028	0.254	0.509	0.237	0.207
F1_4	retired	0.072	0.010	0.320	0.002	0.993
F1_5	looking after family	0.070	0.406	0.476	0.236	0.173
F1_6	other	0.273	0.311	0.360	0.255	0.364

Home–other travel

The mode-destination model contains gender terms on car passenger, bus and cycle, aged 5–11 terms on car passenger, and disability parameters on walk and cycle, which have been implemented using proportions segmented by status segment b.

	Status b	Male	Aged 5–11	Disabled
b1	unemployed	0.656	0.000	0.000
b2	retired	0.528	0.000	0.000
b3	looking after family	0.042	0.000	0.000
b4	other	0.557	0.049	0.070

To implement the parking cost calculations, the proportions of other travel tours by activity duration have been extracted for each status segment b.

Activity duration (hours)	Proportion of tours
< 1	0.329
1–2	0.274
2–3	0.168
3–4	0.106
4–6	0.078
6–8	0.031
8–12	0.014
> 12	0.001

Work–work tours

The male term in the work–work tour frequency model has been implementing using mean proportions segmented by worker type b.

	Worker type b	Male
b1	part-time worker	0.230
b2	other worker	0.605

Work–other tours

The male term in the work–other tour frequency model has been implementing using mean proportions segmented by worker type b.

	Worker type b	Male
b1	part-time worker	0.230
b2	other worker	0.605

Other–other tours

No mean proportions were used to implement this model.

Work–work detours

The self-employed term in the work–work outward detour frequency model has been implemented using mean proportions segmented by worker type b.

	Worker type b	Self-employed
b1	part-time worker	0.000
b2	other worker	0.066

Work–other detours

The gender and number of children terms in the work–other detour frequency models have been implemented using mean proportions segmented by worker type b.

	Worker type b	Male	1 child	2 children
b1	part-time worker	0.230	0.242	0.285
b2	other worker	0.605	0.201	0.225

Other–other detours

The other–other detour mode-destination contains an income segmentation which has been implemented using mean proportions. These mean proportions are used to factor the total other tours are read into the model into income segments.

	Income band	Proportion
inc1	< £35k p.a.	0.811
inc2	£35–50k p.a.	0.118
inc3	£50k+ p.a.	0.071

The gender, age and status parameters in the other–other detour frequency models have been implemented using mean proportions segmented by car availability segmentation a.

	Car availability a	Male	Age less than 24	Looking after family	Full-time worker
a1	0 cars	0.429	0.370	0.133	0.065
a2	cars, no licence	0.430	0.770	0.082	0.026
a3	cars, licence, passopt	0.447	0.101	0.122	0.295
a4	cars, licence, no passopt	0.589	0.034	0.103	0.270

Appendix B: Detailed TravDem validation

This appendix presents validation of mode shares and tour lengths against the 2009–2012 HI data for each model purpose. For commute, home–shopping and home–other travel validation results are presented for both the S=0 and S=3 versions of the models.

Commute

Mode shares

S=0 model, no access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	852,019	64.0 %	63.5 %	0.6 %
car passenger	127,864	9.6 %	7.8 %	1.8 %
train	9,271	0.7 %	2.8 %	-2.1 %
metro	2,419	0.2 %	0.5 %	-0.3 %
bus	147,321	11.1 %	14.1 %	-3.0 %
cycle	25,585	1.9 %	1.7 %	0.3 %
walk	165,824	12.5 %	9.6 %	2.9 %
Total	1,330,303	100.0 %	100.0 %	0.0 %

S=3 model, access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	847,813	63.7 %	63.4 %	0.4 %
car passenger	128,185	9.6 %	7.8 %	1.8 %
train, car driver	7,928	0.6 %	1.1 %	-0.5 %
train, car passenger	1,162	0.1 %	0.2 %	-0.1 %
train, other	5,249	0.4 %	1.7 %	-1.3 %
metro, car driver	1,550	0.1 %	0.2 %	-0.1 %
metro, car passenger	199	0.0 %	0.0 %	0.0 %
metro, other	1,323	0.1 %	0.3 %	-0.2 %
bus	145,570	10.9 %	14.1 %	-3.2 %
cycle	25,373	1.9 %	1.7 %	0.2 %
walk	165,899	12.5 %	9.6 %	2.9 %
Total	1,330,252	100.0 %	100.0 %	0.0 %

Tour lengths

S=0 model, no access mode choice for train:

Mode	TravDem	HI	Difference
car driver	30.0	25.6	4.5
car passenger	30.1	22.7	7.4
train	53.5	48.7	4.8
metro	37.8	32.6	5.2
bus	20.4	16.5	3.9
cycle	11.2	11.5	-0.4
walk	4.9	5.0	-0.1
Total	25.7	22.6	3.1

S=3 model, access mode choice for train:

Mode	TravDem	HI	Difference
car driver	30.2	25.8	4.4
car passenger	30.3	22.7	7.6
train, car driver	46.1	35.2	10.9
train, car passenger	46.7	42.7	4.0
train, other	53.1	49.3	3.8
metro, car driver	32.3	41.7	-9.4
metro, car passenger	36.5	30.3	6.2
metro, other	37.1	31.1	6.0
bus	19.9	16.5	3.4
cycle	11.1	11.5	-0.4
walk	4.8	5.0	-0.2
Total	25.8	22.5	3.2

Home–business

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	123,644	76.4 %	75.0 %	1.4 %
car passenger	15,610	9.6 %	9.5 %	0.1 %
train	3,091	1.9 %	2.5 %	-0.6 %
metro	211	0.1 %	0.2 %	-0.1 %
bus	11,725	7.2 %	8.1 %	-0.8 %
cycle	365	0.2 %	0.2 %	0.0 %
walk	7,152	4.4 %	4.4 %	0.0 %
Total	161,798	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	108.5	71.1	37.3
car passenger	52.5	71.3	-18.8
train	168.3	259.0	-90.7
metro	62.0	21.2	40.8
bus	31.6	16.6	15.0
cycle	13.2	10.9	2.3
walk	3.7	3.7	0.1
Total	93.7	68.3	25.4

Home–primary education

Mode shares

Mode	Tours	Share	HI share	% difference
car passenger	181,680	46.4 %	37.7 %	8.7 %
train	149	0.0 %	0.1 %	-0.1 %
metro	42	0.0 %	0.0 %	0.0 %
bus	22,302	5.7 %	6.0 %	-0.3 %
cycle	1,971	0.5 %	0.6 %	-0.1 %
walk	185,437	47.4 %	55.6 %	-8.2 %
Total	391,582	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car passenger	6.9	6.5	0.4
train	51.8	31.9	19.9
metro	30.4	n/a	n/a
bus	13.3	12.1	1.2
cycle	4.8	4.7	0.2
walk	3.7	3.4	0.2
Total	5.7	5.2	0.6

Home–secondary education

Mode shares

Mode	Tours	Share	HI share	% difference
car passenger	66,187	21.3 %	24.5 %	3.3 %
train	929	0.9 %	0.3 %	-0.5 %
metro	325	0.2 %	0.1 %	-0.1 %
bus	74,163	26.4 %	27.5 %	1.1 %
cycle	2,052	1.3 %	0.8 %	-0.6 %
walk	125,998	49.9 %	46.7 %	-3.2 %
Total	269,655	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car passenger	14.1	9.8	4.3
train	50.2	20.2	30.0
metro	32.2	26.1	6.1
bus	14.4	13.2	1.2
cycle	6.0	5.8	0.2
walk	4.8	4.5	0.3
Total	9.9	8.1	1.8

Home–tertiary education

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	39,245	18.4 %	23.8 %	5.4 %
car passenger	15,282	9.7 %	9.3 %	-0.5 %
train	3,602	5.0 %	2.2 %	-2.9 %
metro	572	0.7 %	0.3 %	-0.3 %
bus	70,231	44.3 %	42.6 %	-1.7 %
cycle	3,126	2.3 %	1.9 %	-0.4 %
walk	32,796	19.5 %	19.9 %	0.4 %
Total	164,853	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	40.0	31.8	8.2
car passenger	14.2	12.8	1.3
train	60.9	77.3	-16.4
metro	42.4	42.0	0.4
bus	19.7	16.0	3.7
cycle	10.9	9.6	1.3
walk	5.7	5.9	-0.1
Total	22.1	19.8	2.3

Home–shopping

Mode shares

S=0 model, no access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	211,776	34.1 %	36.0 %	-1.9 %
car passenger	96,282	15.5 %	16.1 %	-0.6 %
train	2,430	0.4 %	1.0 %	-0.7 %
metro	944	0.2 %	0.3 %	-0.2 %
bus	120,914	19.5 %	21.9 %	-2.5 %
cycle	1,563	0.3 %	0.2 %	0.0 %
walk	186,704	30.1 %	24.4 %	5.7 %
Total	620,612	100.0 %	100.0 %	0.0 %

S=3 model, access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	212,168	34.2 %	36.0 %	-1.8 %
car passenger	96,292	15.5 %	16.1 %	-0.6 %
train, car driver	644	0.1 %	0.2 %	-0.1 %
train, car passenger	350	0.1 %	0.1 %	0.0 %
train, other	1,819	0.3 %	0.8 %	-0.5 %
metro, car driver	362	0.1 %	0.1 %	0.0 %
metro, car passenger	170	0.0 %	0.0 %	0.0 %
metro, other	669	0.1 %	0.2 %	-0.1 %
bus	120,545	19.4 %	21.9 %	-2.5 %
cycle	1,564	0.3 %	0.2 %	0.0 %
walk	186,668	30.0 %	24.3 %	5.7 %
Total	621,251	100.0 %	100.0 %	0.0 %

Tour lengths

S=0 model, no access mode choice for train:

Mode	TravDem	HI	Difference
car driver	12.9	12.0	0.9
car passenger	15.1	11.8	3.3
train	45.1	53.5	-8.4
metro	30.3	24.0	6.3
bus	10.9	11.1	-0.2
cycle	10.1	9.7	0.5
walk	4.3	4.1	0.2
Total	10.4	10.3	0.1

S=3 model, access mode choice for train:

Mode	TravDem	HI	Difference
car driver	12.9	12.0	0.9
car passenger	15.1	11.8	3.3
train, car driver	66.2	47.4	18.8
train, car passenger	66.8	24.5	42.3
train, other	45.2	59.3	-14.1
metro, car driver	166.2	33.4	132.8
metro, car passenger	168.6	20.9	147.7
metro, other	30.2	18.7	11.5
bus	10.8	11.1	-0.2
cycle	10.1	9.7	0.5
walk	4.3	4.1	0.2
Total	10.6	10.3	0.3

Home–escort

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	182,162	42.5 %	44.9 %	-2.4 %
car passenger	13,070	3.0 %	2.3 %	0.7 %
bus	429,055	100.0 %	3.4 %	-0.1 %
walk	13,070	3.0 %	49.4 %	1.7 %
Total	14,442	3.4 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	10.0	9.7	0.4
car passenger	17.6	40.2	-22.6
bus	11.9	10.2	1.7
walk	3.7	3.5	0.2
Total	7.1	7.3	-0.2

Home–other travel

Mode shares

S=0 model, no access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	322,220	35.5 %	39.2 %	-3.6 %
car passenger	189,968	20.9 %	21.0 %	0.0 %
train	7,672	0.8 %	1.8 %	-0.9 %
metro	1,322	0.1 %	0.3 %	-0.2 %
bus	118,766	13.1 %	14.3 %	-1.2 %
cycle	12,904	1.4 %	1.4 %	0.0 %
walk	254,339	28.0 %	22.1 %	5.9 %
Total	907,192	100.0 %	100.0 %	0.0 %

S=3 model, access mode choice for train:

Mode	Tours	Share	HI share	% difference
car driver	322,506	35.5 %	39.2 %	-3.6 %
car passenger	188,983	20.8 %	21.0 %	-0.2 %
train, car driver	1,137	0.1 %	0.2 %	-0.1 %
train, car passenger	305	0.0 %	0.1 %	0.0 %
train, other	6,897	0.8 %	1.5 %	-0.7 %
metro, car driver	458	0.1 %	0.0 %	0.0 %
metro, car passenger	122	0.0 %	0.0 %	0.0 %
metro, other	1,158	0.1 %	0.3 %	-0.1 %
bus	119,576	13.2 %	14.3 %	-1.1 %
cycle	12,940	1.4 %	1.4 %	0.0 %
walk	254,432	28.0 %	22.1 %	5.9 %
Total	908,514	100.0 %	100.0 %	0.0 %

Tour lengths

S=0 model, no access mode choice for train:

Mode	TravDem	HI	Difference
car driver	24.4	22.8	1.6
car passenger	27.5	21.5	6.0
train	61.5	93.7	-32.2
metro	38.7	30.6	8.1
bus	15.1	14.2	0.9
cycle	8.2	8.6	-0.4
walk	4.4	4.3	0.1
Total	18.2	18.3	-0.1

S=3 model, access mode choice for train:

Mode	TravDem	HI	Difference
car driver	23.8	22.8	0.9
car passenger	26.9	21.5	5.4
train, car driver	123.3	239.8	-116.5
train, car passenger	126.0	75.2	50.8
train, other	59.1	79.7	-20.6
metro, car driver	221.6	48.0	173.6
metro, car passenger	221.7	44.2	177.5
metro, other	39.6	25.4	14.2
bus	15.0	14.2	0.8
cycle	8.3	8.6	-0.3
walk	4.4	4.3	0.1
Total	18.2	18.4	-0.2

Work–work tours

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	10,100	70.4 %	79.4 %	-4.0 %
car passenger	1,324	9.6 %	8.8 %	1.1 %
train	819	12.7 %	2.9 %	3.2 %
bus	747	4.4 %	5.9 %	-0.3 %
walk	412	2.9 %	2.9 %	0.1 %
Total	13,402	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	95.1	52.3	42.8
car passenger	18.2	15.9	2.3
train	78.7	512.5	-433.8
metro	24.3	n/a	1.9
bus	7.2	22.4	-0.2
cycle	79.8	n/a	20.2
walk	95.1	7.4	42.8
Total	18.2	59.6	2.3

Work–other tours

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	7,949	30.4 %	30.5 %	3.7 %
car passenger	1,819	7.2 %	7.0 %	1.2 %
bus	1,245	7.9 %	4.8 %	1.3 %
walk	15,065	54.5 %	57.8 %	-6.2 %
Total	26,079	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	20.8	16.1	4.7
car passenger	12.3	10.8	1.5
bus	10.0	10.0	2.6
walk	12.3	3.3	1.5
Total	13.5	7.4	3.5

Other–other tours

Mode shares

Mode	Tours	Share	HI share	% difference
car driver	3,876	27.4 %	29.5 %	-2.1 %
car passenger	3,722	26.3 %	18.2 %	8.2 %
bus	1,018	7.2 %	11.4 %	-4.2 %
walk	5,511	39.0 %	40.9 %	-1.9 %
Total	14,125	100.0 %	100.0 %	0.0 %

Tour lengths

Mode	TravDem	HI	Difference
car driver	24.3	12.6	11.7
car passenger	8.1	7.8	0.4
bus	13.3	16.0	-2.6
walk	3.8	3.8	0.1
Total	11.2	8.5	2.8

Work–work detours

Mode shares

Mode	Detours	Share	HI share	% difference
car driver	39,196	83.0 %	79.7 %	3.3 %
car passenger	2,649	5.6 %	3.6 %	2.0 %
train	404	0.9 %	2.2 %	-1.3 %
bus	3,150	6.7 %	10.9 %	-4.2 %
walk	1,801	3.8 %	3.6 %	0.2 %
Total	47,201	100.0 %	100.0 %	0.0 %

Detour lengths

Mode	TravDem	HI	Difference
car driver	25.7	19.8	5.9
car passenger	11.2	11.4	-0.3
train	34.0	80.2	-46.2
bus	8.4	8.2	0.2
walk	2.1	2.4	-0.2
Total	22.9	18.9	4.0

Work–other detours

Mode shares

Mode	Detours	Share	HI share	% difference
car driver	168,842	73.3 %	73.6 %	-0.5 %
car passenger	18,261	7.9 %	5.6 %	2.4 %
train	537	0.2 %	1.3 %	-0.2 %
metro	481	0.2 %	0.3 %	0.0 %
bus	11,219	4.9 %	6.5 %	-2.1 %
walk	0	0.0 %	12.6 %	0.4 %
Total	31,045	13.5 %	100.0 %	0.0 %

Detour lengths

Mode	TravDem	HI	Difference
car driver	13.1	10.2	2.9
car passenger	11.7	9.6	2.1
train	25.3	38.2	-12.9
metro	14.8	25.9	-11.1
bus	7.6	7.4	0.2
walk	3.2	3.5	-0.3
Total	11.4	9.5	1.8

Other–other detours

Mode shares

Mode	Detours	Share	HI share	% difference
car driver	128,509	38.2 %	39.7 %	-1.6 %
car passenger	76,033	22.6 %	21.1 %	1.5 %
train	753	0.2 %	0.6 %	-0.4 %
metro	849	0.3 %	0.5 %	-0.2 %
bus	36,017	10.7 %	13.7 %	-3.0 %
cycle	2,479	0.7 %	0.7 %	0.0 %
walk	92,206	27.4 %	23.6 %	3.7 %
Total	336,846	100.0 %	100.0 %	0.0 %

Detour lengths

Mode	TravDem	HI	Difference
car driver	6.8	7.2	-0.4
car passenger	6.9	6.7	0.2
train	21.9	38.7	-16.8
metro	18.2	11.7	6.5
bus	6.5	6.8	-0.3
cycle	4.5	4.8	-0.3
walk	2.5	2.6	-0.1
Total	5.7	6.2	-0.5