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RAND EUROPE

PRISM 2011 Base

Frequency and Car Ownership Models

James Fox, Sunil Patil, 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 development of the updated travel frequency and car ownership models. Frequency models have been developed for 14 travel purposes. Travel frequency is predicted by applying two linked sub-models to predict the total amount of travel an individual makes on an average weekday in school term time. The first sub-model predicts whether an individual makes any travel, the second sub-model predicts how much travel will be made given that an individual makes at least some travel.

The original version of PRISM used the car ownership models from the Department for Transport's National Transport Model, recalibrated to local conditions. Because of the lack of income data in the 2001 household interview (HI) data it was not possible to develop local car ownership models. However, the 2009 to 2012 HI data collected for the PRISM Refresh project did collect income data. This has allowed the development of local car ownership models in this project. Car ownership has been modelled using household level models of car ownership, which predict the probability of a household owning zero, one, two or three-plus cars.

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 3 report, documenting the implementation of the new demand models.

This report is aimed at readers who wish to gain an understanding of the frequency and car ownership models implemented in the PRISM model system. It describes the scope of the models and the variables that are used to predict frequency and car ownership choices. Some familiarity with disaggregate choice 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
PRISM:	Policy Responsive Integrated Strategy Model
SD:	Secondary Destination

Acknowledgements

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CHAPTER 1 Introduction

This report documents the re-estimation of the frequency and car ownership model components. The re-estimation of the mode-destination models is documented in a separate report, as is the implementation of the new models.

Frequency models have been developed for 14 travel purposes. Travel frequency is predicted by applying two linked sub-models to predict the total amount of travel an individual makes on an average weekday in school term time. The first sub-model predicts whether an individual makes any travel, the second sub-model predicts how much travel will be made given that an individual makes at least some travel.

The original version of PRISM used the car ownership models from the Department for Transport's National Transport Model, recalibrated to local conditions. Because of the lack of income data in the 2001 HI data it was not possible to develop local car ownership models. However, the 2009 to 2012 HI data collected for the PRISM Refresh project did collect income data. This has allowed the development of local car ownership models in this project. Car ownership has been modelled using household level models of car ownership, which predict the probability of a household owning zero, one, two or three-plus cars.

Chapter 2 describes the specification of the frequency models. It defines the units that are modelled, and then outlines the structure of the models, highlighting the special model structure that has been used to model the home–escort school travel frequency.

Chapter 3 describes the re-estimation of the home-based (HB) tour frequency models. For each HB travel purpose, a table is presented summarising the observed rate of travel frequency making, and then the model results are presented. This chapter also compares the frequency models estimated in the original version of PRISM and the new frequency models.

Chapter 4 describes the estimation of the non-home-based (NHB) frequency models. In the original version of PRISM, NHB frequency was modelled using aggregate generation rates from TEMPro (Trip End Model Presentation Program). The new NHB frequency models predict the frequency of making PD-based tours, and the rate of making of detours during HB tours.

Chapter 5 documents the estimation of car ownership models for the West Midlands. The 2009–2012 HI survey collected income data, and this has allowed local car ownership models to be developed. In the original version of PRISM, the HI data did not collect income data and therefore national car ownership models had to be used instead.

CHAPTER 2 Frequency model specification

This chapter describes the specification of the frequency models. It starts with a brief discussion of the types of travel that are represented in PRISM 2011 base, specifically tours and detours, and the travel purposes represented, before describing the frequency model structures.

2.1 Modelling units and purposes

2.1.1 Home-based travel

HB travel has been modelled using HB tours. A *home-based tour* is a series of linked trips that start and finish at the individual's home. When a traveller makes a direct trip from the home to an out-of-home destination and back home again, determining the purpose of the tour is straightforward; 85% of fully-observed tours are of this type. However, if two or more out-of-home destinations are visited, it is necessary to identify *primary destination* (PD) in order to define the main purpose of the tour.

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

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

If there are ties after applying the purpose hierarchy, then the destination at which the most time was spent is taken as the PD. If there were still ties after the purpose hierarchy and maximum time criteria were applied, then of the tied destinations the destination furthest from the home was taken as the PD; if there were still ties after the purpose hierarchy, maximum time and maximum distance criteria were applied, then the first tied destination visited was taken as the PD (this only happened for a few cases).

Most tours observed in the 2009–2012 HI data are *full tours*, which means that both an outward leg from the home to the PD, and a return leg from the PD back to the home have been recorded in the HI data. An *outward half tour* is where a movement from the home to the PD is recorded, but no corresponding return is observed; for example, an individual who leaves the home on the survey day to visit a friend and stays overnight at their friend's house. Similarly a *return half tour* is a movement from the PD back to home where no corresponding outward leg is recorded; for example, a nightshift worker returning home after their shift.

Over 97% of the HB tour types observed in the 2009–2012 HI data were full tours:

- 13,960 (97.5%) full tours
- 268 (1.9%) outward half tours
- 90 (0.6%) return half tours.

Half tours can occur for two reasons: first, because the full tour cannot be recorded within the survey day, which ran from 03:30 to 03:30 the following day; and second, because of coding errors, where individuals have recorded only partial information about their trip chain.

To develop the mode-destination models, only full tours have been modelled, because it was judged that modelling the small numbers of half tours was not justified given the small number of these and the higher levels of error associated with half tours. However, half tours are more important for frequency modelling, because if they are all excluded the frequency models will slightly under-predict total travel. Therefore the approach that has been used for the frequency models is to include all full tours *and* outward half tours. Each outward half tour is treated as equivalent to a full tour, whereas return half tours are dropped, recognising that coding error is more likely to lead to the omission of return half tours.

Tour frequency models have been developed for eight different HB tour purposes:

- commute
- employer's business
- primary education
- secondary education
- tertiary education
- shopping
- escort
- other travel.

As discussed in Section 2.3 of the mode-destination modelling report (RR-186-MM), the employer's business purpose includes travel to destinations recorded as 'not usual workplace' as well as 'employer's business'.

The modelling of the escort purpose separately from 'other travel' is new in the 2011 model; the introduction of this purpose is also discussed in the mode-destination report. Separate frequency models have been developed for escort school tours, and other escort travel. The analysis that informed the decision to segment escort travel is this way is presented in Section 3.7.1.

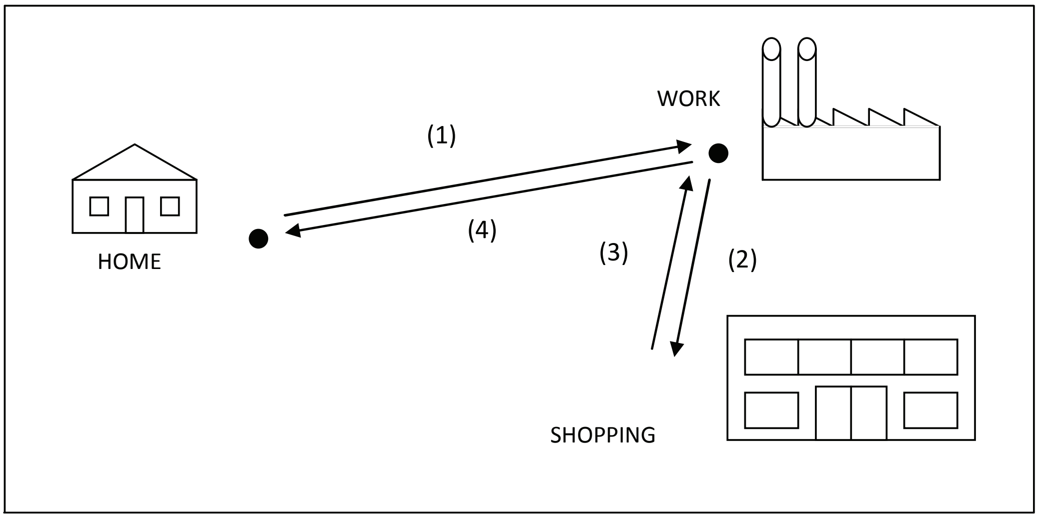
2.1.2 Non-home-based travel

Once the HB tours had been identified, the NHB travel associated with those HB tours was identified. Two types of NHB travel have been represented for travel made during full HB tours only:

- PD-based tours – a series of linked trips starting and finishing at the same PD location; for example, if an individual pops out to the shops at lunchtime during their work day
- NHB detours made during the outward or return legs of HB tours – a single trip to or from the PD, for example, if an individual makes a diversion on their journey back home to pick up a child from school.

These two cases are illustrated by the examples in the following figures. In Figure 1 trips (2) and (3) form the PD-based tour. In Figure 2, trip (2) forms the NHB detour.

Figure 1: PD-based tour example



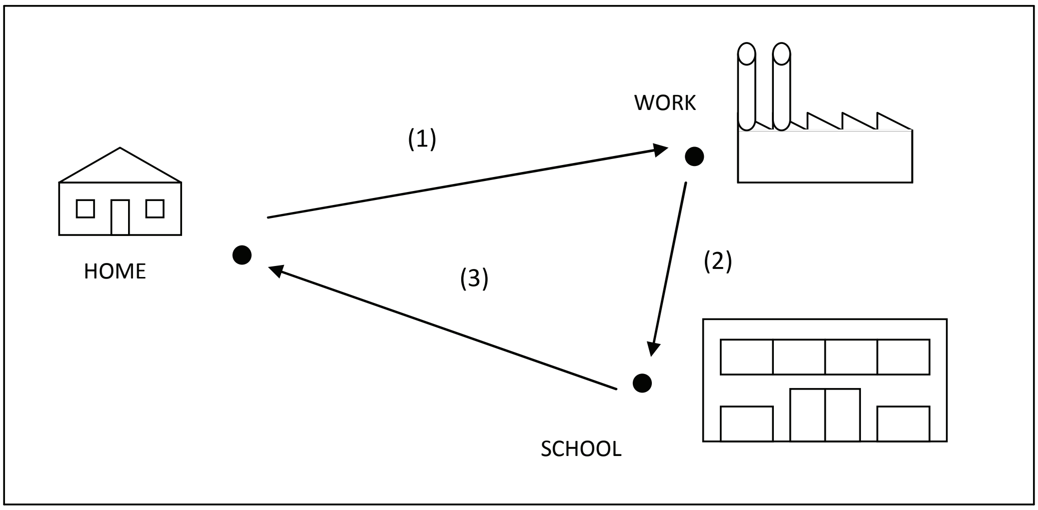


Figure 2: NHB detour example

If multiple destinations are visited during the PD-based tour, a single *secondary destination* (SD) is identified, and a direct return tour between the PD and SD is modelled. Similarly, if an individual detours to more than one destination during an outward or return HB tour leg, a single SD is identified in that direction, and a direct trip between the PD and the SD is modelled. In both cases, the SD is identified using the same set of rules used to determine the PD, with a purpose hierarchy applied first, and then subsequent tie-break rules are applied if required. The number of cases where individuals visit multiple SDs is low, and so the additional complexity that results from modelling multiple SD visits during a single tour separately is not justified.

Only full PD-based tours are modelled, because only NHB travel made within HB travel is modelled. Any PD-based half tours must be coding errors because an individual has to return to the PD before travelling back home again.

Three types of PD-based travel have been modelled, taking advantage of the hierarchy of purposes, which means that work is always the PD when it occurs on a tour:

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

Three further purposes have been defined to model NHB detours:

- detours made during work-related PD tours to work-related SDs
- detours made during work-related PD tours to other purpose SDs
- detours made during other purpose PD tours to other purpose SDs.

2.2 Model structure

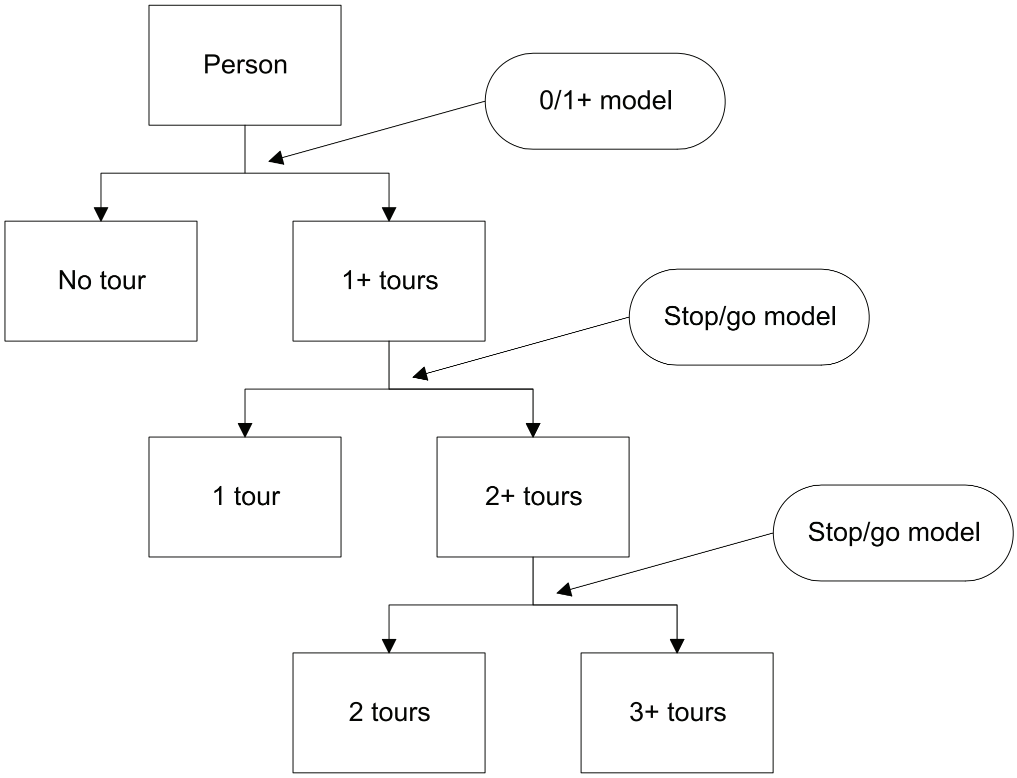
Frequency models have been developed to predict the number of tours and detours made by a traveller on an average weekday in school term time for a given travel purpose.

2.2.1 Tour model structure

This model structure combines a first sub-model to predict whether any tours will be made (zero/one-plus model), and a second sub-model to predict the extent to which additional tours are made, given at least one tour is made (stop/go model). The two sub-models are estimated together in a single model run for efficiency.

This model structure is used for all of the HB tour purposes, except escort to school, and for the three PD-based tour purposes. The structure was not used for escort to school travel because adults are more likely to make two escort school tours per day than one; this issue is explained further in Section 2.2.2. The model structure is illustrated in Figure 3, which would extend to include the rare travellers making four or more tours for a given purpose in a day.

Figure 3: Tour frequency model structure



In the zero/one-plus model, utilities are defined for the 'no tours' alternative and therefore the model terms reflect the increased probability of *not* making a tour. Therefore negative model terms imply an increased probability of making a tour.

In the stop/go model utilities are defined for the stop alternatives (one tour, two tours) and therefore in this model the model terms reflect the probability of *not* making additional tours. This means that negative model terms imply an increased probability of making multiple tours. In the example presented in Figure 3, no more than two tours are observed per individual on a given day. For each model purpose, the structure for the stop/go model is tailored to reflect the maximum number of tours observed.

It is noted that the utility functions are identical on the 1 tour, 2 tour etc. alternatives, as the probability of stopping is assumed to be constant for a given individual.[1] A negative binomial distribution could be used, which would give more control over the tail of the distribution. However, for most purposes the number of individuals making more than one tour per day is low and so the additional effort involved with using a negative binomial distribution was not felt to be justified.

A further discussion of the possible model forms is provided in Daly and Miller (2006). Daly and Miller concluded in this paper that the probability of making one or more trips should be modelled separately from the probabilities of making multiple trips, and that the

1 P(1|1+) = P(2|2+) = P(3|3+) etc.

accessibility linkage should be achieved using a logsum to ensure consistency with a utility maximisation framework. Both of these features are incorporated in the frequency models presented in this report.

In addition to constant terms, which ensure that the tour rates observed in the 2009–2012 HI data are reproduced, socio-economic terms were tested to represent differences in tour rates according to the personal and household level characteristics of individuals. These have been identified using the frequency specifications from the original PRISM models as the starting point, and then tailoring the model specifications as necessary. It was important in the model development to test the impact of accessibility on travel frequency. Accessibility is measured using logsums from the mode-destination models, which capture differences in accessibility between different home zones and for different socio-economic segments, in particular by car availability. Daly (1997) provides a discussion of the arguments for incorporating accessibility into travel frequency models.

2.2.2 Escort school model structure

For the escort school frequency model, analysis of the number of tours made per adult demonstrated that the standard frequency model structure presented in Figure 3 was not appropriate because the observed frequencies of making two tours was higher than for one tour. This is illustrated in Table 1.

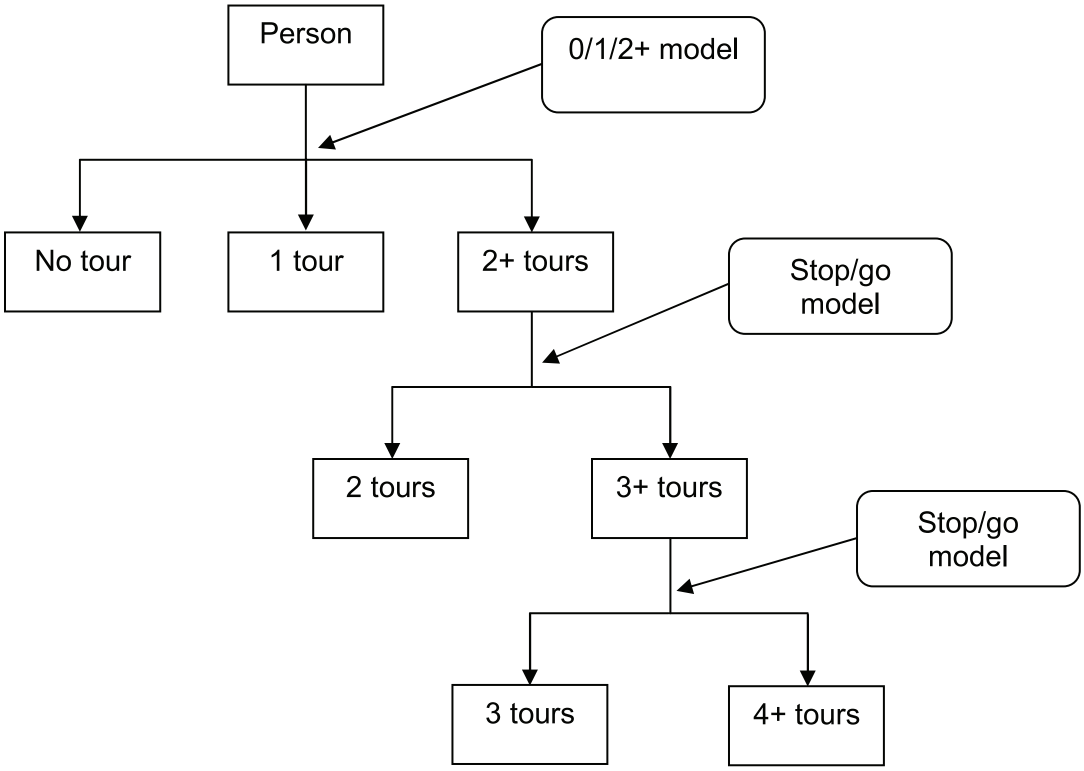
Table 1: Escort school tours made per weekday for adults

Number of tours	Frequency	Percent
0	3,512	80.3 %
1	345	7.9 %
2	460	10.5 %
3	49	1.1 %
4	8	0.2 %
Total	4,374	100.0 %

Two tours are more frequently observed than one because if a parent drops their child at school in the morning, then in many cases the same parent picks them up again in the afternoon. If parents have more than one child, and the school times for their children vary, then one parent may make more than two escort school tours, although the incidence of these is relatively small.

To represent the pattern in the observed data, a revised model structure was used, illustrated in Figure 4.

Figure 4: Escort school model structure



Note that Figure 4 omits the 4 tours versus 5+ tours choice for clarity.

In the modified model structure, a multinomial logit model is used to model the choice between the no tour, 1 tour and 2+ tour alternatives, with utility terms placed on the no tour and 1 tour alternatives. Then a stop/go model is used to predict the probability of making two or more tours.

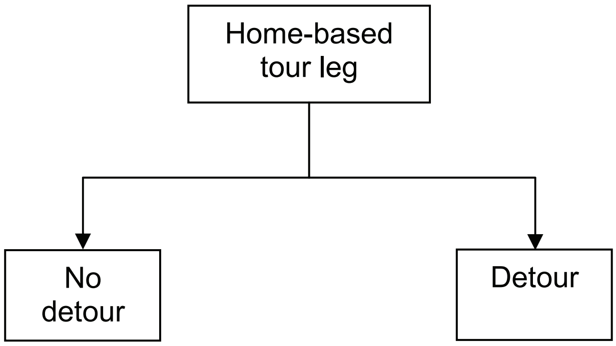
2.2.3 Detour model structure

The detour models predict the binary choice between 'no detour' and 'detour' alternatives. The utilities terms are placed on the 'no detour' alternative and therefore a negative model term indicates that an individual is more likely to make a detour.

Separate detour models have been estimated for detours made during the outward and return legs of HB tours. Separate models have been estimated because we observe that individuals are more likely to make detours during the return legs. The higher detour rate during return legs reflects travel patterns such as individuals visiting the supermarket on the way home from work, or participating in evening social activities near their workplace before returning home.

Figure 5 illustrates the detour frequency model structure. As discussed in Section 2.1.2, only one detour per tour leg is modelled.

Figure 5: Detour frequency model structure



CHAPTER 3 Home-based frequency models

This chapter presents the models for each of the eight HB purposes represented in the new version of PRISM. For home–escort travel, analysis is presented that demonstrates that the observed frequencies of escort school and escort other travel making were different, and therefore separate frequency models have been developed for these two sub-purposes.

For those HB purposes where tour frequency models were developed in the original version of PRISM, a comparison is presented between the final frequency model identified in the original version of the PRISM and the new models. The development of the tour frequency models in the original version of PRISM was documented in full in RAND Europe (2004a).

When presenting the ALOGIT model results for the tour frequency models, two sets of values are presented:

- model summary statistics
- model coefficient values and their associated t-ratios.

The model summary statistics which are presented are defined in Table 2.

Table 2: Model summary statistics

Statistic	Definition
file	This defines the name of the model run.
converged	This indicates whether the model run converged at optimum values for the coefficients.
observations	The number of observations included in the model estimation.
final log (L)	This indicates the value of the log-likelihood at convergence. The log-likelihood is defined as the sum of the log of the probabilities of the chosen alternatives, and is the function that is maximised in model estimation. The value of log-likelihood for a single model has no obvious meaning. However comparing the log-likelihood of two models with different specifications allows the statistical significance of new model coefficients to be assessed properly.
D.O.F.	Degrees of freedom, i.e. the number of coefficients estimated in this model. Note that if a coefficient is constrained to a fixed value (indicated by(*) instead of a t-ratio) then it is not a degree of freedom.
$rho^2(c)$	If the model log-likelihood (LL(final)) value is compared to the log-likelihood from a model with constants only (LL(c)) then: $rho^2(c) = 1 - LL(final)/LL(c)$ Again a higher value indicates a better fitting model.

The coefficient values are then presented. If a coefficient is positive it has a positive impact of utility and so reflects a higher probability of choosing the alternatives to which it is applied. Conversely if a coefficient is negative it has a negative impact on utility and so reflects a lower probability of choosing the alternative to which it is applied.

The value shown in brackets after the coefficient value is the t-ratio, which indicates the significance of the coefficient estimate. A higher t-ratio indicates a more significant estimate. A coefficient should have an absolute t-value greater than 1.96 to be significantly different from zero (at a 95% confidence level). The 95% confidence interval was applied consistently in model development to determine which coefficients to retain in the model; any exceptions to this rule are explicitly documented in the text. If the coefficient is constrained to a fixed value then an asterisk is reported instead of the t-ratio.

3.1 Commute

3.1.1 Estimation sample

To determine the appropriate definition of the estimation sample for the commute frequency model, the number of tours made by adults was cross-tabulated with the employment status of the individual. The resulting cross-tabulation is presented in Table 3.

Table 3: Commute tours made by status, adults aged 17-plus

			Commute tours				Total
			.00	1.00	2.00	3.00	
EmpStatus	FT-Employment	Count	1325	3315	50	2	4692
		% within EmpStatus	28.2%	70.7%	1.1%	.0%	100.0%
	PT-Employment	Count	463	601	15	1	1080
		% within EmpStatus	42.9%	55.6%	1.4%	.1%	100.0%
	Self-Employed	Count	328	140	8	1	477
		% within EmpStatus	68.8%	29.4%	1.7%	.2%	100.0%
	FT-Student	Count	749	52	1	0	802
		% within EmpStatus	93.4%	6.5%	.1%	.0%	100.0%
	PT-Student	Count	47	8	0	0	55
		% within EmpStatus	85.5%	14.5%	.0%	.0%	100.0%
	Unemployed	Count	877	13	1	0	891
		% within EmpStatus	98.4%	1.5%	.1%	.0%	100.0%
	Retired	Count	1692	15	0	0	1707
		% within EmpStatus	99.1%	.9%	.0%	.0%	100.0%
	Disabled	Count	333	2	0	0	335
		% within EmpStatus	99.4%	.6%	.0%	.0%	100.0%
	Looking after the family	Count	764	10	0	0	774
		% within EmpStatus	98.7%	1.3%	.0%	.0%	100.0%
Total		Count	6578	4156	75	4	10813
		% within EmpStatus	60.8%	38.4%	.7%	.0%	100.0%

Nearly all (98%) of work tours are made by persons who are either in full-time employment, part-time employment or self-employed. It is also observed that 6.6% and 14.5% of the individuals within full-time education and part-time education make at least one work tour per day, respectively. Thus significant numbers of commuting tours are made by full- and part-time students, and so these status groups have been included within the commute frequency model.

Among those who are unemployed, retired from paid work, disabled or long-term sick, or looking after family groups, 98.9% of individuals made no commute tours on the survey day. Therefore these groups, highlighted in red in Table 3, have been excluded from the commute tour frequency model. However, to avoid underestimating the total volume of travel, these tours have been reclassified as home–other travel and included in the frequency model estimated for that purpose.

The final commute estimation sample is summarised in Table 4. Employment status groups 1 to 5 include full-time workers, part-time workers, the self-employed, full-time students and part-time students.

Table 4: Commute tours made per weekday for adults in employment status groups 1 to 5

Number of tours	Frequency	Percent
0	2,912	41.0 %
1	4,116	57.9 %
2	74	1.0 %
3	4	0.1 %
Total	7,106	100.0 %

It can be seen that just 1.1% of adults in employment status groups 1 to 5 make two or more commute tours per day, and therefore there are limited data available to estimate parameters for the stop/go model. The average tour frequency rate is 0.602 commute tours per weekday in school term time. It may be noted that travel to workplaces other than the usual workplace is modelled with employer's business and these figures therefore reflect travel to the usual workplace only.

3.1.2 Model results

The starting point for the model development was the final frequency model estimated for the current version of PRISM, which was last re-estimated in 2009.[2] Table 5 compares three models:

- WK_FREQ_32: final model, original PRISM (2001 HI data)
- WK_FREQ_21: final S=0 model, PRISM 2011 (2009–2012 HI data)
- WK_FREQ_23: final S=3 model, PRISM 2011 (2009–2012 HI data).

The commute frequency model specification incorporates a logsum accessibility parameter, reflecting higher commute tour frequency rates for individuals living in more accessible home zones. Accessibility is measured using a logsum from the commute mode-destination models. Zones that offer higher accessibility have higher accessibility measures, and the accessibility measures also vary according to the individual's mode-destination segment, and in particular their car availability. As there are new commute mode-destination models both without park-and-ride represented (S=0) and with park-and-ride represented (S=3),[3] two separate frequency models have been estimated using logsums from the two versions of the commute mode-destination model. Estimating separate frequency models ensures that

[2] The frequency model was re-estimated in 2009 to use updated logsums from the version of the commute mode-destination model estimated in 2009 with linear and log cost terms.

[3] S indicates the number of potential park-and-ride stations considered.

in model application frequency models are applied using logsums that are consistent with those used in estimation.

Table 5: Commute frequency model results

File	WK_FREQ_32.F12		WK_FREQ_21.F12		WK_FREQ_23.F12	
Converged	True		True		True	
Observations	10654		7106		7106	
Final log (L)	-7521.8		-4443.2		-4443.2	
D.O.F.	6		8		8	
Rho^2(c)	0.019		0.148		0.148	
Estimated	23 Apr 09		5 Apr 13		23 Apr 13	
Scaling	1.0000		1.0000		1.0000	
Zero/one-plus model:						
zero	0.5557	(6.4)	1.996	(3.8)	2.007	(3.7)
zero_FTwkr	-0.6855	(-13.5)	-2.540	(-6.6)	-2.540	(-6.6)
zero_PTwkr			-1.927	(-4.9)	-1.928	(-4.9)
zero_selfE			-0.7918	(-2.0)	-0.7913	(-2.0)
zero_FTstu			0.8174	(2.0)	0.8174	(2.0)
zero_1724			0.2795	(3.3)	0.2793	(3.3)
zero_lsum	-0.02673	(-6.2)	-0.03320	(-1.1)	-0.03284	(-1.1)
zero_othnm	-0.1312	(-2.6)				
zero_other	0.6224	(5.7)				
Stop/go model:						
stop	4.055	(42.9)	3.935	(35.3)	3.935	(35.3)

The accessibility parameter in the zero/one-plus model is not statistically significant in models 21 and 23, with a t-ratio of just 1.1 (1.96 is the threshold value for significance at a 95% level). However, the magnitude of the term is plausible, in line with the significant term identified in the original PRISM frequency model, and therefore the term has been retained so that predicted levels of commute travel are responsive to future changes in accessibility.

Just 1.1% of individuals made two or more tours, and therefore there are not many data to identify socio-economic effects in the stop/go model. Unsurprisingly no significant socio-economic effects were identified, and therefore the stop/go model has only a constant that ensures the overall tour frequency rate observed in the data is replicated.

The parameters in the new commute frequency models are summarised in Table 6.

Table 6: Commute frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making at least one tour is replicated
zero_FTwkr	–	full-time workers are more likely to make tours than part-time students
zero_PTwkr	–	part-time workers are more likely to make tours than part-time students, but less likely than full-time workers
zero_selfE	–	self-employed workers are more likely to make tours than part-time students, but less likely than full- and part-time workers
zero_FTstu	+	full-time students are less likely to make tours than part-time students
zero_1724	+	individuals aged 17–24 are less likely to make tours than those aged 25 and above
zero_lsum	–	individuals resident in more accessible home zones, and from car availability, income and gender segmentations which result in higher accessibility, are more likely to make tours
stop	+	constant to ensure observed rate of multiple tour making is replicated

3.2 Home–business

3.2.1 Estimation sample

A cross-tabulation of employment status and number of (employer's) business tours made by adults aged 17+ was generated to determine the appropriate definition of the business model estimation sample (Table 7).

Table 7: Business tours made by status, adults aged 17-plus

			Business tours				Total
			0	1	2	3	
Status	FT-employment	Count	4,361	316	13	2	4,692
		Percent	92.9 %	6.7 %	.3 %	.0 %	100.0 %
	PT-employment	Count	1,043	34	3	0	1,080
		Percent	96.6 %	3.1 %	.3 %	.0 %	100.0 %
	Self-employed	Count	344	123	10	0	477
		Percent	72.1 %	25.8 %	2.1 %	.0 %	100.0 %
	FT-student	Count	789	13	0	0	802
		Percent	98.4 %	1.6 %	.0 %	.0 %	100.0 %
	PT-student	Count	53	2	0	0	55
		Percent	96.4 %	3.6 %	.0 %	.0 %	100.0 %
	Unemployed	Count	*888*	*3*	*0*	*0*	*891*
		Percent	*99.7 %*	*.3 %*	*.0 %*	*.0 %*	*100.0 %*
	Retired	Count	*1,704*	*3*	*0*	*0*	*1,707*
		Percent	*99.8 %*	*.2 %*	*.0 %*	*.0 %*	*100.0 %*
	Disabled	Count	*334*	*1*	*0*	*0*	*335*
		Percent	*99.7 %*	*.3 %*	*.0 %*	*.0 %*	*100.0 %*
	Looking after the family	Count	*774*	*0*	*0*	*0*	*774*
		Percent	*100.0 %*	*.0 %*	*.0 %*	*.0 %*	*100.0 %*
Total		Count	10,290	495	26	2	10,813
		Percent	95.2 %	4.6 %	.2 %	.0 %	100.0 %

In total, 553 business tours are observed in the sample, and just seven of these (1.3%) were made by individuals whose status was unemployed, retired, disabled or looking after the family. Therefore these groups, highlighted in red italics in Table 7, were excluded from the estimation sample. However, to avoid underestimating the total volume of travel, these tours have been reclassified as home–other travel and included in the frequency model estimated for that purpose.

The final business estimation sample is summarised in Table 8.

Table 8: Business tours made per weekday for adults in employment status groups 1 to 5

Number of tours	Frequency	Percent
0	6,590	92.7 %
1	488	6.9 %
2	26	0.4 %
3	2	0.0 %
Total	7,106	100.0 %

Over 90% of individuals made no business tours on the survey day, and just 0.4% of people in the survey made two tours. The average tour frequency rate is 0.077 business tours per weekday in school term time, far lower than the commute tour frequency rate of 0.602.

3.2.2 Model results

In the original version of PRISM, there were insufficient numbers of business tours to allow tour-based models to be estimated for business travel and so no comparable tour frequency model exists.

Table 9 presents the results from the final specification of the new business tour frequency model.

Table 9: Business frequency model results

```
File                EB_FREQ_15.F12
Converged                     True
Observations                  7106
Final log (L)              -1801.0
D.O.F.                           9
Rho²(c)                      0.084
Estimated                 5 Apr 13

Zero/one-plus model:
zero                 4.323  (16.0)
zero_FTwkr         -0.6242  (-3.8)
zero_selfE          -2.153 (-11.4)
Zero_l35k           0.2367   (2.2)
zero_g50k          -0.2195  (-1.6)
zero_male          -0.5863  (-5.5)
Zero_1724           0.3250   (1.9)
zero_lsum          -0.1635  (-3.6)

Stop/go model:
stop                 2.845  (15.1)
```

It is noted that the highest tour frequency rates are predicted for self-employed persons, who include plumbers, electricians and so on who make multiple tours on a given day.

The income terms in the zero/one-plus model illustrate that as household income increases, the probability of making at least one employer's business tour increases. The 'zero_g50k' term is insignificant at a 95% confidence level, but is significant at a 90% confidence level. As the magnitude of the term is reasonable, and it picks up a plausible pattern of increasing tour frequency with increasing income, the term has been retained in the final model specification.

The logsum term on the zero tours alternative is significant and has a plausible magnitude. This term reflects higher tour frequency rates for individuals with higher mode-destination accessibility. In model application, future improvements in accessibility lead to increases in the frequency of making home–business tours.

Just 0.4% of individuals were observed to make more than one business tour, and therefore there are few data to identify socio-economic terms for the stop/go model. As a result, the only term retained in this model is a constant to ensure the observed tour rate is replicated.

The parameters in the new business frequency model are summarised in Table 10.

Table 10: Business frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making at least one tour is replicated
zero_FTwkr	–	full-time workers are more likely to make tours than part-time workers and students
zero_selfE	–	self-employed workers are much more likely to make tours than part-time workers and students
zero_l35k	+	individuals from households with incomes less than £35k p.a. are less likely to make business tours than those with incomes between £35k and £50k p.a.
zero_g50k	–	individuals from households with incomes greater than £50k p.a. are more likely to make business tours than those with incomes between £35k and £50k p.a.
zero_male	–	males are more likely to make business tours than females
zero_1724	+	individuals aged 17–24 are less likely to make business tours than those aged 25 and above
zero_lsum	–	individuals living in zones with higher accessibility, and whose socio-economic segment gives higher accessibility, are more likely to make business tours
stop	+	constant to ensure observed rate of multiple tour making is replicated

3.3 Home–primary education

3.3.1 Estimation sample

The primary education frequency model has been estimated from the sample of children in the 5–11 age band. Table 11 summarises the observed numbers of primary education tours made per child on an average weekday.

Table 11: Primary education tours made per child aged 5–11 per weekday

Number of tours	Frequency	Percent
0	108	7.8 %
1	1,249	90.3 %
2	26	1.9 %
Total	1,383	100.0 %

As the 2009–2012 HI data were collected in school term time, over 90% of primary-aged children were observed to make at least one school tour on the survey day. Just 1.9% of children made more than one primary school tour, so clearly few pupils return home for lunch during the school day in the West Midlands. The overall tour frequency rate is 0.941 primary education tours per weekday in school term time.

3.3.2 Model results

Table 12 compares model results from the final model specification from the current version of PRISM (PR_FREQ_6) estimated from 2001 HI data to the new model specification estimated from the 2009–2012 HI data.

Table 12: Primary education model results

```
File                 PR_FREQ_6.F12   PRIM_FREQ_2.F12
Converged                     True              True
Observations                  2292              1383
Final log (L)              -1472.6            -506.5
D.O.F.                           4                 2
Rho²(c)                      0.007            -0.001
Estimated                 7 Dec 06         26 Feb 13

Zero/one-plus model:
zero               0.7726   (1.0)     -2.468 (-24.6)
zero_5             0.3845   (2.8)
zero_11           -0.3013  (-2.3)
zero_lsum         -0.2235  (-1.9)

Stop/go model:
stop                                   3.893  (19.6)
```

It is noted that in the 2001 HI data used to estimate the original version of PRISM, ages were recorded in years, which allowed model terms to be identified for individuals aged 5 and 11. However, in the 2009–2012 HI data ages were recorded in bands, and a single band was used to record ages in the 5–11 range. Therefore it was not possible to re-test terms for 5 and 11 year olds with the new 2009–2012 HI data.

In the new model no socio-economic parameters could be identified, and when a logsum term was tested on the zero tours alternative the parameter was positive. A positive accessibility parameter would lead to counter-intuitive results in model application, because increases in accessibility would lead to a *reduction* in tour frequency.

A significant logsum parameter was identified on the stop alternative, however the magnitude of this term was high (−2.196) and in application this model would have predicted large increases in multiple tour making in response to changes in accessibility. Such a high responsiveness was judged to be implausible for primary education travel, and therefore the final model specification omitted the logsum term from the stop/go model.

The final model specification is a constants-only model and will therefore predict the same average tour frequency rate in the base year and all future scenarios.

The parameters in the final primary education tour frequency model are defined in Table 13.

Table 13: Primary education tour frequency model parameters

Parameter	Sign	Definition
zero	–	constant to ensure overall fraction of individuals making at least one tour is replicated
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

3.4 Home–secondary education

3.4.1 Estimation sample

The secondary education frequency model has been estimated from the sample of children in the 12–14 and 15–16 age bands. Table 14 summarises the observed numbers of secondary education tours made per weekday in school term time.

Table 14: Secondary education tours made per child aged 12–16 per weekday

Number of tours	Frequency	Percent
0	177	15.1 %
1	981	83.5 %
2	17	1.4 %
Total	1,175	100.0 %

The average secondary education tour frequency rate is 0.864 secondary education tours per weekday in school term time. The percentage of individuals making zero tours is nearly double that observed for primary education. However, some individuals aged 16 will have left school and will not be in education and therefore a higher percentage of no tour individuals is expected.

3.4.2 Model results

Table 15 compares model results from the final model from the current version of PRISM (SE_FREQ_12) to the new model results (SEC_FREQ_4).

Table 15: Secondary education model results

```
File               SE_FREQ_12.F12     SEC_FREQ_4.F12
Converged                    True               True
Observations                 2764               1175
Final log (L)             -1569.6             -549.1
D.O.F.                          7                  4
Rho²(c)                     0.186              0.060
Estimated               22 Jan 07          26 Feb 13

Zero/one-plus model:
zero                4.400  (10.3)     -1.363 (-12.1)
zero_unemp                             2.973   (4.6)
zero_1214                            -0.9037  (-5.2)
zero_PTwkr         -1.693  (-2.7)
zero_FTstu         -4.031 (-11.6)
zero_16            0.4812   (3.7)
zero_17_18         0.6866   (6.0)
zero_lsum         -0.3233  (-5.0)

Stop/go model:
stop                5.197  (15.5)      4.073  (16.7)
```

The (negative) constant in the model for 12–14 years olds means that higher tour rates are predicted for this age group relative to 15 and 16 year olds, which is plausible as some 16 year olds will have left school; the effect was also found in the previous model. The unemployed term on zero tours (defined in Table 16) also accounts for the fact that some 16 years olds will have left school. It is noted that three education tours were made by persons in this age group who were classified as unemployed.

A logsum term was tested in the new model but the parameter was insignificant with a t-ratio of just 0.6. It was therefore dropped from the final model specification.

As per the primary education frequency model, only a few individuals make more than one tour and therefore the only significant parameter that has been identified in the stop/go model is the constant to ensure that the observed tour frequency rate is replicated by the model.

The parameters in the new secondary education tour frequency model are summarised in Table 16.

Table 16: Secondary education tour frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making at least one tour is replicated
zero_unemp	+	individuals who are unemployed are less likely to make secondary education tours than those in other status groups (full-time workers, part-time workers, full-time students, part-time students, disabled and looking after the family)
zero_1214	–	individuals aged 12 to 14 are more likely to make secondary education tours than those aged 15–16
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

3.5 Home–tertiary education

3.5.1 Estimation sample

To determine the appropriate population for tertiary education travel, a cross-tabulation was made of the number of tertiary education tours made and the status of the individual (Table 17).

Table 17: Tertiary education tours by status, adults aged 17+

		Education tours			Total
		0	1	2	
Status	FT-employment	4,665	26	1	4,692
	PT-employment	1,063	17	0	1,080
	self-employed	473	4	0	477
	FT-student	318	482	2	802
	PT-student	35	20	0	55
	unemployed	870	21	0	891
	retired	1,702	5	0	1,707
	disabled	330	5	0	335
	looking after the family	756	18	0	774
Total		10,212	598	3	10,813

Most tertiary education tours are made by full-time students. However, tertiary education tours are also made by all other status groups and so it was decided to estimate the tertiary education frequency model for all adults aged 17+, and then include terms in the model to account for differences in tour frequency between different status groups.

The final tertiary education estimation sample is summarised in Table 18.

Table 18: Tertiary education tours made per weekday for adults

Number of tours	Frequency	Percent
0	10,212	94.4 %
1	598	5.5 %
2	3	0.0 %
Total	10,813	100.0 %

The average tour frequency rate is just 0.056 tertiary education tours per adult per weekday in school term time. However, for full-time students the rate is over ten times higher, 0.606 tours per weekday in school term time. Only three adults made two tertiary education tours on the survey day and therefore there were very few data available to identify socio-economic terms for the stop/go model.

3.5.2 Model results

Table 19 compares model results from the final model from the current version of PRISM (TE_FREQ_22) to the new model results (TER_FREQ_12).

Table 19: Tertiary education model results

File	TE_FREQ_22.F12		TER_FREQ_12.F12	
Converged	True		True	
Observations	22068		10813	
Final log (L)	-2644.1		-1094.7	
D.O.F.	12		10	
Rho^2(c)	0.255		0.532	
Estimated	22 Jan 07		5 Apr 13	
Zero/one-plus model:				
zero	3.149	(14.0)	4.328	(5.3)
zero_FTwkr	1.452	(10.5)	1.108	(4.7)
zero_FTstu	-2.569	(-21.2)	-3.982	(-21.6)
zero_PTstu			-3.059	(-9.5)
zero_31_39			0.6716	(3.1)
zero_40_49	0.5833	(4.8)	0.7744	(3.2)
zero_50pl	2.264	(15.5)	2.211	(7.0)
zero_mGSCE			-0.4323	(-3.3)
zero_male	0.3895	(4.0)	0	(*)
zero_othst	-0.7223	(-6.0)		
zero_free	-0.4093	(-2.7)		
zero_lsum	-0.1250	(-1.6)	-0.1141	(-0.9)
Stop/go model:				
stop	1.262	(10.0)	5.300	(9.2)
stop_FTstu	4.333	(4.3)	0	(*)
stop_othst	-0.7271	(-4.0)		

The status terms in the new model are plausible, reflecting the fact that students are more likely to make tertiary education tours that other groups, and that full-time workers have the lowest overall tour rates. The age terms also have a sensible pattern, reflecting the fact that the likelihood of participating in tertiary education decreases with increasing age.

The parameter 'zero_mGCSE' reflects higher tertiary education tour frequency rates for individuals who have either no qualifications at all, or whose highest level of educational qualification is GCSEs, relative to those whose highest level of qualifications is A-levels or higher. Thus individuals without tertiary educational qualifications are more likely to participate in tertiary education than individuals who already have higher level qualifications.

The 'zero_lsum' term is not significant, with a t-ratio of just 0.9. However, the magnitude of the term is plausible, and in line with the term identified in the original version of PRISM. Therefore the parameter was been retained so that predicted tertiary education tour making is sensitive to changes in accessibility.

The parameters in the new tertiary education model are described in Table 20.

Table 20: Tertiary education tour frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making at least one tour is replicated
zero_FTwkr	+	full-time workers are less likely to make tours than other status groups (part-time workers, unemployed, retired, disabled, looking after family)
zero_FTstu	−	full-time students are more likely to make tours than other status groups (part-time workers, unemployed, retired, disabled, looking after family)
zero_PTstu	−	part-time students are more likely to make tours than other status groups (part-time workers, unemployed, retired, disabled, looking after family), but less likely that full-time students
zero_31_39	+	adults aged 31–39 are less likely to make tours than those aged under 30, but more likely than those aged 40 and above
zero_40_49	+	adults aged 40–49 are less likely to make tours than those aged under 40, but more likely than those aged 50 and above
zero_50pl	+	adults aged 50 and above are less likely to make tours than those aged under 50
zero_mGCSE	−	individuals whose highest level of educational qualification is either GCSEs or no qualifications at all are more likely to make tours than those whose highest level of educational qualification is A-levels or higher
zero_lsum	−	individuals resident in more accessible home zones, and from car availability and status groups which result in higher accessibility are more likely to make tours
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

3.6 Home–shopping

3.6.1 Estimation sample

Table 21 presents a cross-tabulation of the number of shopping tours made by age.

Table 21: Number of shopping tours made by age

			Shopping tours				Total
			0	1	2	3	
Age	<5	count	*1,178*	*0*	*0*	*0*	*1,178*
		percent	*100.0 %*	*.0 %*	*.0 %*	*.0 %*	*100.0 %*
	5–11	count	1,357	23	0	0	1,380
		percent	98.3 %	1.7 %	.0 %	.0 %	100.0 %
	12–14	count	663	8	0	0	671
		percent	98.8 %	1.2 %	.0 %	.0 %	100.0 %
	15–16	count	490	14	0	0	504
		percent	97.2 %	2.8 %	.0 %	.0 %	100.0 %
	17–20	count	765	61	2	0	828
		percent	92.4 %	7.4 %	.2 %	.0 %	100.0 %
	21–24	count	747	75	1	0	823
		percent	90.8 %	9.1 %	.1 %	.0 %	100.0 %
	25–30	count	1,134	119	2	0	1,255
		percent	90.4 %	9.5 %	.2 %	.0 %	100.0 %
	31–34	count	735	96	3	0	834
		percent	88.1 %	11.5 %	.4 %	.0 %	100.0 %
	35–39	count	949	134	5	0	1,088
		percent	87.2 %	12.3 %	.5 %	.0 %	100.0 %
	40–44	count	1,086	137	9	1	1,233
		percent	88.1 %	11.1 %	.7 %	.1 %	100.0 %
	45–49	count	856	117	8	0	981
		percent	87.3 %	11.9 %	.8 %	.0 %	100.0 %
	50–54	count	760	126	7	0	893
		percent	85.1 %	14.1 %	.8 %	.0 %	100.0 %
	55–59	count	550	109	6	0	665
		percent	82.7 %	16.4 %	.9 %	.0 %	100.0 %
	60–64	count	537	197	6	0	740
		percent	72.6 %	26.6 %	.8 %	.0 %	100.0 %
	65+	count	928	527	17	1	1,473
		percent	63.0 %	35.8 %	1.2 %	.1 %	100.0 %
Total		count	12,735	1,743	66	2	14,546
		percent	87.5%	12.0 %	.5 %	.0 %	100.0 %

All age groups except infants (aged under 5, highlighted in red italics in Table 21) are observed to make shopping tours, and therefore the shopping frequency model has been estimated from the sample of persons aged 5 and above.

Table 22 summarises the final shopping frequency estimation sample.

Table 22: Shopping tours made per weekday for persons aged 5 and above

Number of tours	Frequency	Percent
0	11,557	86.5 %
1	1,743	13.0 %
2	66	0.5 %
3	2	0.0 %
Total	13,368	100.0 %

The average shopping tour frequency rate is 0.141 tours per average weekday in school term time.

3.6.2 Model results

Table 23 compares results from the frequency model estimated for the original version of PRISM (SH_FREQ_35) to results from the new models. The new models are SHP_FREQ_16, for use with the S=0 version of the mode-destination model in implementation, and SHP_FREQ_18, for use with the S=3 version of the mode-destination model in implementation. Two different versions of the new frequency model have been implemented because the base year accessibility measures used to estimate the models vary between the S=0 and S=3 versions of the mode-destination models.

Table 23: Shopping model results

File	SH_FREQ_34.F12		SHP_FREQ_16.F12		SHP_FREQ_18.F12	
Converged	True		True		True	
Observations	27431		13368		13368	
Final log (L)	-10456.7		-4679.8		-4679.9	
D.O.F.	15		17		17	
Rho²(c)	0.139		0.165		0.165	
Estimated	22 Jan 07		7 Apr 13		23 Apr 13	
Zero/one-plus model:						
zero	0.5118	(11.3)	1.861	(4.8)	1.830	(4.9)
zero_FTwst			1.510	(15.7)	1.510	(15.7)
zero_PTwkr	0.8843	(12.2)	0.8929	(7.3)	0.8932	(7.3)
zero_selfE			1.245	(6.8)	1.245	(6.8)
zero_ret			-0.3003	(-2.7)	-0.3009	(-2.8)
zero_dis			0.3789	(2.4)	0.3790	(2.4)
zero_Lfam			-0.2193	(-1.9)	-0.2194	(-1.9)
zero_5_14	1.299	(6.8)	1.606	(7.9)	1.605	(7.9)
zero_15_30			0.5512	(5.7)	0.5508	(5.7)
zero_31_39			0.2813	(2.8)	0.2810	(2.8)
zero_40_49			0.1890	(2.0)	0.1889	(2.0)
zero_nocar			-0.5913	(-7.1)	-0.5919	(-7.1)
zero_1free	-0.2213	(-4.0)	-0.4554	(-5.4)	-0.4576	(-5.4)
zero_male	0.2384	(5.9)	0.3100	(5.1)	0.3098	(5.1)
zero_hh4pl	0.2316	(4.7)	0.3000	(4.5)	0.3001	(4.5)
zero_lsum			-0.1986	(-2.9)	-0.1939	(-2.9)
zero_FTstu	1.611	(12.5)				
zero_FTwkr	1.821	(30.1)				
zero_unemp	0.2183	(3.4)				
zero_15_29	0.3910	(5.4)				
zero_30_39	0.1255	(2.0)				
zero_nolic	0.2752	(6.3)	0	(*)	0	(*)
zero_NoPss	0.06576	(4.5)				
Stop/go model:						
stop	3.972	(13.7)	3.253	(26.7)	3.253	(26.7)
stop_lsum	-0.2119	(-2.0)	0	(*)	0	(*)

A large number of model parameters has been identified in the shopping frequency model, representing the significant variation in shopping tour frequency across status, age band, car availability, gender and household size segmentations.

It is believed that households without cars have higher tour frequency rates because they need to make more, but presumably smaller, shopping trips for groceries and so on than households with a car.

The 'zero_1free' term is only applied if the individual has a licence and there is free car use in the household. For this term to apply, this individual can be the only person in the household able to drive the car, and therefore higher shopping tour frequency rates are expected for these individuals relative to other individuals in households with a car.

The parameters in the new shopping frequency model are described in Table 24.

Table 24: Shopping frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making at least one tour is replicated
zero_FTwst	+	full-time workers and full-time students are less likely to make tours than all other status groups
zero_PTwkr	+	part-time workers are more likely than full-time workers, full-time students and the self-employed, but less likely than all other status groups
zero_selfE	+	self-employed workers are more likely to make tours than full-time workers and full-time students, but less likely than all other status groups
zero_ret	–	retired persons are more likely to make tours than any other status group
zero_dis	–	disabled persons are less likely to make tours than all other groups except full-time workers, full-time students and the self-employed
zero_Lfam	–	people looking after the family are more likely to make tours than all other status groups except retired persons
zero_5_14	+	individuals aged 5–14 make fewer shopping tours than all other age groups
zero_15_30	+	individuals aged 15–30 make more shopping tours than those aged under 15, but fewer than those aged over 30
zero_31_39	+	individuals aged 31–39 make more shopping tours than those aged under 31, but fewer than those aged over 39
zero_40_49	+	individuals aged 40–49 make more shopping tours than those aged under 40, but fewer than those aged over 49
zero_nocar	–	individuals from households with no cars make more shopping tours than those from households with one or more cars
zero_1free	–	individuals from households where there is one car and where the individuals has free car use make more shopping tours that other individuals
zero_male	+	males make fewer shopping tours than females
zero_hh4pl	+	individuals from households with four or more people make fewer tours than smaller households
zero_lsum	–	individuals resident in more accessible home zones, and from car availability, status and household income segments which result in higher accessibility are more likely to make tours
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

In the original version of PRISM, no significant accessibility term could be identified for the zero/one-plus model, but it was possible to identify an accessibility term in the stop/go model to account for a pattern of higher multiple tour making by individuals with higher accessibility. In the new models, a significant accessibility term has been identified in the zero/one-plus model, but no significant effect could be identified in the stop/go model.[4]

3.7 Home–escort travel

3.7.1 Estimation sample

In the 2009–2012 HI data two separate travel escort purposes were recorded: escort to school, and escort for other purposes. Escort for other purposes includes escorting people to work, and escorting people to social activities, for example dropping or picking up a child from their friend's house. Analysis was undertaken to investigate who made escort tours for each of these two purposes, and whether a single escort frequency model should be developed, or whether the two purposes should be represented separately. Mode-destination choice for both purposes is represented by the same model.

Table 25 presents a cross-tabulation of the number of escort tours made by age.

Table 25: Escort tours made by age

Age band	School escort		Other escort	
6–11	10	0.7 %	2	0.7 %
12–14	1	0.1 %	0	0.0 %
15–16	1	0.1 %	2	0.7 %
17–20	24	1.6 %	6	2.0 %
21–24	38	2.5 %	5	1.6 %
25–30	282	18.8 %	21	6.8 %
31–34	242	16.2 %	7	2.3 %
35–39	372	24.8 %	27	8.8 %
40–44	296	19.8 %	60	19.5 %
45–49	126	8.4 %	41	13.4 %
50–54	48	3.2 %	33	10.7 %
55–59	19	1.3 %	30	9.8 %
60–64	15	1.0 %	25	8.1 %
65+	23	1.5 %	48	15.6 %
Total	1,497	100.0 %	307	100.0 %

The vast majority (99.2%) of the escort tours are made by individuals aged 17 and over; 80% of the school escort tours are made by individuals in the age band 25–44. Individuals aged 16 years or under (highlighted in red in Table 25) account for just 0.8% of the escort tours and therefore these have been dropped from the escort frequency and mode-destination models.

Table 26 shows the distribution of the home–escort school tours made by persons aged 17+ with the number of children in the household as well as the number of children and infants in the household. Children are defined as those aged between 5 and 17 inclusive, infants as those aged under 5.

[4] The accessibility parameter in the stop/go model had a t-ratio of just 0.4.

Table 26: Escort school tours made by number of children/infants in the household

	Children		Children/infants	
0	248	16.7 %	41	2.8 %
1	449	30.2 %	273	18.4 %
2	499	33.6 %	598	40.3 %
3	208	14.0 %	365	24.6 %
4	66	4.4 %	146	9.8 %
5	11	0.7 %	48	3.2 %
6	4	0.3 %	10	0.7 %
7	0	0.0 %	4	0.3 %
Total	1,485	100.0 %	1,485	100.0 %

By definition, we would expect that school tours are only available for households with children, but a significant proportion of escort school tours (17%) are made by individuals from households without children. However, if infants are also added, the number of tours from zero children/infant households reduces to just 2.8% (highlighted in red in Table 26), which suggests that a proportion of the escort school tours are escorting infants to nursery, kindergarten and so on.

On the basis of this analysis it was decided to only model the 1,444 escort school tours made by individuals from households with at least one child or infant.

Table 27 tabulates the number of escort other tours made by persons aged 17+ with the number of children and children/infants in the household.

Table 27: Escort other tours made by number of children/infants in the household

	Children		Children/infants	
0	178	58.7 %	160	52.8 %
1	48	15.8 %	45	14.9 %
2	55	18.2 %	67	22.1 %
3	13	4.3 %	21	6.9 %
4	4	1.3 %	2	0.7 %
5	5	1.7 %	8	2.6 %
Total	303	100.0 %	303	100.0 %

Individuals from households without children or infants make over half of other escort tours, and therefore the other escort model was estimated from the sample of all persons aged 17 and above.

The separate estimation samples for the escort school and escort other frequency models are summarised in Table 28 and Table 29.

Table 28: Escort school tours made per weekday by persons aged 17+ in households with at least one infant or child

Number of tours	Frequency	Percent
0	3,512	80.3 %
1	345	7.9 %
2	460	10.5 %
3	49	1.1 %
4	8	0.2 %
Total	4,374	100.0 %

Table 29: Escort other tours made per weekday by persons aged 17+

Number of tours	Frequency	Percent
0	10,570	97.8 %
1	191	1.8 %
2	45	0.4 %
3	6	0.1 %
4	1	0.0 %
Total	10,813	100.0 %

The mean escort school tour frequency rate for persons aged 17+ in households with at least one infant or child is 0.330 escort school tours per weekday in school term time. Over 80% of adults make zero escort school tours. It should be noted that these tour rates are the rates per adult in the household; in a multi-adult household typically only one adult makes the escort tours. Furthermore, children are aged 5 to 16 and many children aged 11 and above travel to school alone.

The mean escort other tour frequency rate for persons aged 17+ is 0.028 escort school tours per weekday in school term time.

The distribution of the number of escort school tours made per day tabulated in Table 28 is distinct from all of the other purposes modelled, with more individuals observed to make two tours per day than one. Therefore, as discussed in Section 2.2.2, a modified model structure has been used for escort school travel, with separate models for the 0/1/2+ tours choices, and a stop/go model applied for the 2/3+, 3/4+ and 4/5+ choices.

3.7.2 Escort school model results

No escort frequency models were developed in the original 2001 base version of PRISM, as escort travel was not recorded separately in the 2001 HI data. Table 30 presents the results from the new escort school tour frequency model.

Table 30: Escort school tour frequency model results

```
File                SCH_ESC_FREQ_21.F12
Converged                          True
Observations                       4374
Final log (L)                   -2442.6
D.O.F.                               21
Rho²(c)                           0.173
Estimated                      5 Apr 13

Zero/one/two-plus model:
zero                    5.796   (7.9)
zero_FTwkr              1.438   (9.3)
zero_unemp            -0.6713  (-4.7)
zero_ret                1.147   (3.1)
zero_lfam             -0.9291  (-6.9)
zero_Fem              -0.7614  (-7.3)
zero_2ch              -0.9732  (-9.1)
zero_3ch               -1.456 (-11.4)
zero_4pch              -1.691 (-10.2)
zero_lt25k            -0.3947  (-4.3)
zero_lsum             -0.3514  (-3.9)
one                   -0.3152  (-3.1)
one_FTwkr              0.6909   (3.7)
one_lfam              -0.7293  (-4.4)

Stop/go model:
stop                    9.520   (4.3)
stop_2ch               -2.389  (-2.3)
stop_3ch               -2.671  (-2.6)
stop_4pch              -3.283  (-3.2)
zero_3039             -0.2214  (-2.4)
zero_1724               1.576   (8.5)
stop_lsum             -0.6389  (-2.5)
```

The parameters in the escort school tour frequency model are summarised in Table 31. In this term the table 'children' refers to both infants aged 0 to 4 and children aged 5 to 16.

Table 31: Escort school tour frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making zero tours is replicated
zero_FTwkr	+	full-time workers make fewer escort school tours than any other status group
zero_unemp	–	unemployed persons make more escort school tours than any other status group except people looking after the family
zero_ret	+	retired persons make fewer escort school tours than any other status group except full-time workers
zero_lfam	–	people looking after the family make more escort school tours than any other status group
zero_fem	–	females make more escort school tours than males
zero_2ch	–	individuals in households with two children make more escort tours than those in households with one child
zero_3ch	–	individuals in households with three children make more escort tours than those in households with less than three children
zero_4pch	–	individuals in households with four-plus children make more escort tours than those in households with less than four children
zero_1724	+	individuals aged 17–24 make fewer escort school tours than those aged 25 and above
zero_3039	–	individuals aged 30–39 make more escort school tours than those aged 25–29 and 40-plus

Parameter	Sign	Definition
zero_lt25k	–	individuals from households with incomes under £25k p.a. make more escort school tours than individuals from households with incomes of £25k p.a. and above
zero_lsum	–	individuals resident in more accessible home zones, and from car availability and presence of children segments which result in higher accessibility, are more likely to make tours
one	–	constant to ensure overall fraction of people making one tour is replicated
one_FTwkr	+	full-time workers are more likely to make one escort school tour than other status groups
one_lfam	–	individuals who are looking after the family are less likely to make one escort school tour than other status groups
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated
stop_2ch	–	individuals in households with 2 children are more likely to make 3 or more tours than households with 1 child
stop_3ch	–	individuals in households with 3 children are more likely to make 3 or more tours than households with 1 or 2 children
stop_4pch	–	individuals in households with 4+ children are more likely to make 3 or more tours than households with fewer than 4 children
stop_lsum	–	individuals resident in more accessible home zones, and from car availability and presence of children segments which result in higher accessibility, are more likely to make multiple tours

The parameters on zero tours pick up plausible effects, with full-time workers and retired persons least likely to make escort school tours, and unemployed and persons looking after the family most likely to make escort school tours. Females are also observed to be more likely to make school escort trips. As would be expected, the probability of making at least one escort school tour increases as the household size increases, and is highest for those in the 30–39 age band who are presumably more likely to have young children who need escorting than persons in other age bands.

The two socio-economic parameters on the one tour alternative pick up interesting effects. While full-time workers are the group most likely to make no escort tours at all, they are more likely to make one escort tour than other status groups. This is consistent with a pattern where they escort the child either in the morning or the afternoon, but another individual in the household makes the escort tour in the other direction, or the child is escorted in one direction but travels unaccompanied in the other direction.

Individuals whose adult status is looking after the family are least likely to make one escort school tour, and as they are also the group least likely to make zero escort school tours this means that they are the group most likely to make two or more escort school tours, which is a plausible pattern.

The socio-economic terms on the stop alternative in the stop/go model reflect the pattern of higher multiple tours making (three or more) tours as the number of children increases. This is highly plausible, as the larger the number of children, the more likely it is that more than two escort school tours need to be made because of staggered school times, and/or the need to escort children to multiple pre-school or school locations.

Significant accessibility effects have been identified in both the zero/one/two-plus and stop/go models. Both terms reflect that parents with higher accessibility are more likely to make escort school tours.

3.7.3 Escort other model results

No escort frequency models were developed in the original 2001 base version of PRISM. The results from the new escort other frequency model are presented in Table 32.

Table 32: Escort other tour frequency model results

File	OTH_ESC_FREQ_13.F12	
Converged	True	
Observations	10813	
Final log (L)	-1242.9	
D.O.F.	9	
Rho²(c)	0.053	
Estimated	5 Apr 13	
Zero/one-plus model:		
zero1	6.912	(13.4)
zero_4049	-0.9590	(-5.3)
zero_50pl	-1.117	(-6.3)
zero_FTst1	1.328	(1.8)
zero_lfam1	-0.8365	(-3.5)
zero_fem1	0.6497	(4.4)
zero_lsum1	-0.3891	(-5.9)
Stop/go model:		
stop1	2.783	(2.4)
stop_lsum1	-0.1910	(-1.2)

The escort other tour frequency model predictions were compared to observed data across household size and number of children dimensions, but no significant differences between observed and predicted data were identified.

The full-time student parameter on zero tours is not significant at a 95% confidence level. However, the parameter is significant at a 90% confidence level and it was decided to retain the term in the final model because the escort other tour rate for full-time students is significantly lower than the tour rate for other status groups.

The accessibility parameter in the stop/go model is not significant, however the magnitude of the term was judged to be reasonable, indicating a lower sensitivity to accessibility than for the escort school model, and therefore the parameter was retained in the final model.

The parameters in the escort other model are defined in Table 33.

Table 33: Escort other tour frequency model parameters

Parameter	Sign	Definition
zero1	+	constant to ensure overall fraction of individuals making zero tours is replicated
zero_4049	–	individuals aged 40 to 49 make more escort other tours than individuals aged under 40
zero_50p	–	individuals aged 50 and above make more escort other tours than individuals aged under 50
zero_FTst1	+	full-time students make fewer escort other tours than other status groups
zero_lfam1	–	individuals who are looking after the family make more escort other tours than other status groups
zero_fem1	+	females make fewer escort other tours than males
zero_lsum1	–	individuals with from home zones and car availability and presence of children segments that give higher accessibility are more likely to make escort other tours
stop1	+	constant to ensure overall fraction of individuals making multiple tours is replicated
stop_lsum1	–	individuals with from home zones and car availability and presence of children segments that give higher accessibility are more likely to make multiple escort other tours

Note: some of the parameter names end with '1' so that none of the parameter names clash with those of the final escort school tour frequency model. Parameter name clashes need to be avoided because in implementation these two frequency models are implemented in a single ALOGIT model run.

The difference in the patterns for the age terms on zero tours between this model and the escort education model are interesting. For escort other, the highest tour frequency rates are observed for the 50-plus age group, whereas for escort education the highest tour frequency rates were observed for the 30–39 age group. It may be that individuals aged 50-plus have more time available than other household members, as a fraction of them will be fully or semi-retired, and are therefore more likely to make escort other tours. They may also be escorting elderly relatives.

It is also interesting to note that females make fewer escort other tours than males, but more escort school tours.

Individuals looking after the family have the highest escort other tour frequency rates, as would be expected. FT students are least likely to make escort other tours; this result is plausible as it is likely that these are the individuals who are being escorted in many cases.

3.8 Home–other travel

3.8.1 Estimation sample

Table 34 presents a cross-tabulation of the number of home–other travel tours made by age band. The home–other travel purpose covers travel to PDs where the purpose is not work, business, education, shopping or escort. In addition to the home–other travel tours identified from the tour building process, small numbers of commute and employer's business tours made by individuals whose status code is unemployed, retired, disabled and looking after the family have been added to the tour counts for the home–other estimation sample.

Table 34: Other travel tours made by age

			Other travel tours						Total
			0	1	2	3	4	5	
Age	< =5	count	*1,178*	*0*	*0*	*0*	*0*	*0*	*1,178*
		percent	*100.0 %*	*.0 %*	*.0 %*	*.0 %*	*.0 %*	*.0 %*	*100.0 %*
	6–11	count	1,311	67	2	0	0	0	1,380
		percent	95.0 %	4.9 %	.1 %	.0 %	.0 %	.0 %	100.0 %
	12–14	count	624	44	2	1	0	0	671
		percent	93.0 %	6.6 %	.3 %	.1 %	.0 %	.0 %	100.0 %
	15–16	count	443	59	2	0	0	0	504
		percent	87.9 %	11.7 %	.4 %	.0 %	.0 %	.0 %	100.0 %
	17–20	count	693	127	7	1	0	0	828
		percent	83.7 %	15.3 %	.8 %	.1 %	.0 %	.0 %	100.0 %
	21–24	count	654	159	9	1	0	0	823
		percent	79.5 %	19.3 %	1.1 %	.1 %	.0 %	.0 %	100.0 %
	25–30	count	1030	206	18	1	0	0	1255
		percent	82.1 %	16.4 %	1.4 %	.1 %	.0 %	.0 %	100.0 %
	31–34	count	691	140	3	0	0	0	834
		percent	82.9 %	16.8 %	.4 %	.0 %	.0 %	.0 %	100.0 %
	35–39	count	898	168	19	3	0	0	1,088
		percent	82.5 %	15.4 %	1.7 %	.3 %	.0 %	.0 %	100.0 %
	40–44	count	1,018	197	17	1	0	0	1,233
		percent	82.6 %	16.0 %	1.4 %	.1 %	.0 %	.0 %	100.0 %
	45–49	count	815	144	16	5	1	0	981
		percent	83.1 %	14.7 %	1.6 %	.5 %	.1 %	.0 %	100.0 %
	50–54	count	730	154	8	0	0	1	893
		percent	81.7 %	17.2 %	.9 %	.0 %	.0 %	.1 %	100.0 %
	55–59	count	523	132	10	0	0	0	665
		percent	78.6 %	19.8 %	1.5 %	.0 %	.0 %	.0 %	100.0 %
	60–64	count	526	183	30	1	0	0	740
		percent	71.1 %	24.7 %	4.1 %	.1 %	.0 %	.0 %	100.0 %
	65+	count	924	487	57	3	2	0	1,473
		percent	62.7 %	33.1 %	3.9 %	.2 %	.1 %	.0 %	100.0 %
Total		count	12,058	2,267	200	17	3	1	14,546
		percent	82.9%	15.6 %	1.4 %	.1 %	.0 %	.0 %	100.0 %

Other travel tours are observed by all age groups except infants (persons aged under 5, highlighted in red in Table 34). Therefore the other travel tour frequency model has been estimated from the sample of 13,368 persons aged 5 and above.

Table 35 summarises the final other travel frequency estimation sample.

Table 35: Other travel tours made per weekday for persons aged 5 and above

Number of tours	Frequency	Percent
0	10,835	81.1 %
1	2,308	17.3 %
2	204	1.5 %
3	17	0.1 %
4	3	0.0 %
5	1	0.0 %
Total	13,368	100.0 %

The average other travel tour frequency rate is 0.208 tours per average weekday in school term time. The percentage of the population making two or more tours (1.7%) is higher than all of the other HB purposes except escort school, and therefore there are more data available for the identification of socio-economic effects in the stop/go model.

3.8.2 Model results

In the original and current versions of PRISM, separate frequency models were estimated for personal business, visiting friends and recreation & leisure sub-purposes. However, in the 2009–2012 HI data these purposes were not recorded separately. Thus it is not possible to make a direct comparison between the other travel frequency models in the original version of PRISM and the new other travel frequency models.

The final specifications for the new home–other travel frequency models contain accessibility terms, with accessibility measured using a logsum from the home–other travel mode-destination model. Separate mode-destination models have been estimated with and without sub-models for access mode and station choice for train and metro, with 'S=0' models estimated without the access mode and station choice sub-model, and 'S=3' models estimated with the access mode and station choice sub-model. Separate frequency models have been estimated using logsums from the S=0 (OTH_FREQ_17) and S=3 (OTH_FREQ_19) models so that in application fully consistent frequency models can be applied for the two model versions. The parameter results from these models are presented in Table 36.

Table 36: Other travel frequency model results

File	OTH_FREQ_17.F12		OTH_FREQ_19.F12	
Converged	True		True	
Observations	13368		13368	
Final log (L)	-6794.4		-6793.0	
D.O.F.	13		13	
Rho²(c)	0.073		0.073	
Estimated	7 Apr 13		26 Apr 13	
Zero/one-plus model:				
zero	3.491	(11.7)	3.367	(12.3)
zero_FTwkr	0.7258	(10.5)	0.7272	(10.5)
zero_FTstu	0.7284	(8.5)	0.7217	(8.4)
zero_ret	-0.6627	(-8.6)	-0.6647	(-8.7)
zero_dis	-0.4404	(-3.3)	-0.4453	(-3.4)
zero_male	-0.2304	(-4.8)	-0.2302	(-4.8)
zero_1hh	-0.5570	(-5.5)	-0.5600	(-5.6)
zero_2hh	-0.3085	(-4.6)	-0.3078	(-4.6)
zero_4phh	0.1796	(2.8)	0.1798	(2.8)
zero_lsum	-0.3903	(-7.2)	-0.3969	(-7.4)
Stop/go model:				
stop	4.248	(5.7)	4.143	(6.1)
stop_lsum	-0.3612	(-2.6)	-0.3694	(-2.7)

There are small differences between the parameter values in the two models, reflecting small differences in the impact of the accessibility effects between the two models. The model considering park-and-ride more fully gives a slightly better explanation of the data, as would be expected.

The status parameters show that full-time workers and full-time students make fewer other travel tours than other status groups, whereas the unemployed, the retired and persons with a disability make more other travel tours than other status groups. These differences seem plausible given that these models are predicting tour rates on an average weekday in school term time, and that these groups have more time available to make other travel tours.

The household size parameters pick up a consistent pattern of decreasing frequency of other travel tour making with increasing household size. A possible explanation is that people who live alone need to make tours in order to interact with other people (unless they host visitors), whereas in larger households individuals can interact with one another without leaving the home.

Significant accessibility effects have been identified in both the zero/one-plus and stop/go models, and therefore in future applications the models will predict increased other travel frequency rates in response to improvements in accessibility. Accessibility improvements can come about both because of network improvements, and through shifts in the distribution of population across different mode-destination segments, and in particular shifts towards segments with higher car availability which will have higher accessibility.

Despite the relatively high number of multiple tours that are observed in the estimation sample for the home–other travel purpose, no significant terms were identified in the stop/go model other than the constant and the accessibility parameter.

The model parameters are defined in Table 37.

Table 37: Other travel frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making zero tours is replicated
zero_FTwkr	+	full-time workers make fewer other travel tours than the base group (part-time workers, self-employed, part-time students and persons looking after the family)
zero_FTstu	+	full-time students make fewer other travel tours than any other status groups
zero_unemp	−	unemployed persons make more other travel tours than any other status group
zero_ret	−	retired persons make more other travel tours relative to the base group (part-time workers, self-employed, part-time students and persons looking after the family)
zero_dis	−	disabled persons make more other travel tours relative to the base group (part-time workers, self-employed, part-time students and persons looking after the family)
zero_male	−	males make more other travel tours than females
zero_1hh	−	single person households make more other travel tours than those in larger households
zero_2hh	−	individuals in two-person households make more other travel tours than persons in three-plus person households, but fewer other travel tours than single person households
zero_4phh	+	individuals in four-plus person households make fewer other travel tours than individuals in households with less than four persons
zero_lsum	−	individuals resident in more accessible home zones, and from car availability, status and household income segments which result in higher accessibility, are more likely to make tours
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated
stop_lsum	−	individuals resident in more accessible home zones, and from car availability, status and household income segments which result in higher accessibility, are more likely to make multiple tours

CHAPTER 4 Non-home-based frequency models

This chapter presents the frequency models for the six NHB purposes represented in the new version of PRISM. In the original and current versions of PRISM, disaggregate frequency models were not developed for NHB travel, because insufficient NHB travel was recorded in the 2001 home interview survey; instead travel frequency was predicted using production rates taken from TEMPRO.

As detailed in Section 2.1.2, NHB travel is identified once the HB tours have been identified. In model application, NHB travel is forecast as a function of HB travel. Therefore the NHB frequency models have been estimated from the samples of HB tours during which the NHB travel can occur.

In future year model runs, improvements in accessibility result in the generation of additional HB tours through the mode-destination logsum terms represented in the HB tour frequency models. As NHB travel will be forecast as a function of HB travel, this means that the predicted volumes of NHB travel will increase as a result of accessibility improvements. No further accessibility effects have been tested in the NHB generation models as in the judgement of the study team adding such terms in addition to the HB accessibility effects would over-estimate the overall impact of accessibility on NHB generation.

The linkage between HB and NHB travel represents a significant improvement relative to the original version of PRISM where HB and NHB travel were modelled independently. A further improvement relative to the original version of PRISM is that all NHB travel is now modelled, rather than only NHB car driver travel.

Table 38 illustrates the relationship between the HB and NHB travel purposes; this follows from the way in which the purpose hierarchies are defined.

Table 38: Relationship between HB 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

Note that home–other travel is defined as all HB travel that is not made for commute, business, education, shopping or escort purposes, whereas for NHB other travel means all travel that is not work-related; thus the definitions differ.

4.1 Work–work

4.1.1 Estimation sample

The work–work tour frequency model predicts the number of full tours made from work-related PDs to work-related SD. Work-related PDs may be either work or employer's business, whereas the SDs can only be employer's business because only one main workplace is considered during the tour building, and if that workplace was visited during a trip chain it would form the PD of the tour.

Thus the estimation sample for the work–work tour frequency model is the sample of full commute and home–business tours. Table 39 summarises the observed frequencies of work–work tour making.

Table 39: Work-related PD-based tours made per full work-related HB tour

Number of tours	Frequency	Percent
0	4,486	98.9 %
1	47	1.0 %
2	2	0.0 %
Total	4,535	100.0 %

The mean tour rate is just 0.011 work-related tours made per work-related HB tour. Only two individuals make more than one PD-based tour in the course of a single HB tour, so there are very few data on multiple tour making.

4.1.2 Model results

The results from the new work–work frequency model are presented in Table 40.

Table 40: Work–work frequency model results

```
File                PDWrkWrk_V5.F12
Converged                      True
Observations                   4535
Final log (L)                -265.7
D.O.F.                            4
Rho²(c)                       0.048
Estimated                 9 Apr 13

Zero/one-plus model:
zero                  6.315  (12.8)
male_O               -1.179  (-3.2)
HBCarD_O             -1.266  (-2.9)

Stop/go model:
stop                  3.199   (4.4)
```

The large positive constants on the zero tours and stop alternatives reflect the fact that most individuals make zero tours, and most of those who do make one tour do not make any further tours.

The model parameters are defined in Table 41.

Table 41: Work–work frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making zero tours is replicated
male_O	–	males make more work-related PD tours tours than females
HBCarD_O	–	individuals who drive on their HB tour are more likely to make PD-based tours
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

4.2 Work–other

4.2.1 Estimation sample

The work–other tour model predicts the number of full tours made from work-related PDs to other (not work-related) SDs. Non-work-related SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the work–other tour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. Table 42 shows the number of other PD-based tours made per full work-related HB tour.

Table 42: Other PD-based tours made per full work-related HB tour

Number of tours	Frequency	Percent
0	4,450	98.1 %
1	84	1.9 %
2	1	0.0 %
Total	4,535	100.0 %

The mean tour frequency rate is just 0.019 other tours per full work-related HB tour. Just one individual makes two work-related tours during a single HB tour, so there are few data on multiple tour making.

4.2.2 Model results

The results from the new work–other model are presented in Table 43.

Table 43: Work–other frequency model results

```
File              PDWrkOth_V3.F12
Converged                    True
Observations                 4535
Final log (L)              -425.6
D.O.F.                          3
Rho²(c)                     0.005
Estimated               9 Apr 13

Zero/one-plus model:
zero                 4.237  (22.7)
male_O             -0.4615  (-2.0)

Stop/go model:
stop                 4.443   (4.4)
```

The model parameters are defined in Table 44.

Table 44: Work–other frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making zero tours is replicated
male_O	−	males make more other PD-based tours than females
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

4.3 Other–other

4.3.1 Estimation sample

The other–other tour model predicts the number of full tours made from other (not work-related) PDs to other (not work-related) SDs. Non-work-related PDs and SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the other–other tour frequency model is the sample of full non-work-related HB tours, which includes home–primary education, home–secondary education, home–tertiary education, home–shopping, home–escort and home–other travel tours (Table 45).

Table 45: Other tours made per full other HB tour

Number of tours	Frequency	Percent
0	8,912	99.5 %
1	44	0.5 %
2	1	0.0 %
Total	8,957	100.0 %

The mean tour frequency rate is just 0.005 other tours per full other HB tour, even lower than the tour rates for work–work and work–other models. Only a single individual is observed to make two other tours during a single home–other tour, and so there are very few data on multiple tour making.

4.3.2 Model results

The results from the new model are presented in Table 46.

Table 46: Other–other frequency model results

```
File              PDOthOth_V1.F12
Converged                    True
Observations                 8957
Final log (L)              -287.9
D.O.F.                          2
Rho²(c)                     0.000
Estimated               4 Apr 13

Zero/one-plus model:
stop                3.807   (3.8)

Stop/go model:
zero                5.288  (35.4)
```

It was not possible to identify any significant socio-economic effects or HB tour mode constants in the other–other model, and therefore the only parameters in the model are the constants.

For completeness the parameters in the new model are defined in Table 44.

Table 47: Other–other frequency model parameters

Parameter	Sign	Definition
zero	+	constant to ensure overall fraction of individuals making zero tours is replicated
stop	+	constant to ensure overall fraction of individuals making multiple tours is replicated

4.4 Work–work detours

4.4.1 Estimation sample

The work–work detour models predict the number of detours made during work-related tours to work-related SDs. Work-related PDs may be either work or employer's business, whereas the SDs can only be employer's business because only one main workplace is considered during the tour building, and if that workplace was visited during a trip chain it would form the PD of the tour.

The estimation sample for the work–work detour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. The number and percentage of work-related detours made per full work-related HB tour is shown in Table 48.

Table 48: Work-related detours made per full work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Frequency	Percent	Frequency	Percent
no detour	4,469	98.5 %	4,444	98.0 %
detour	66	1.5 %	91	2.0 %
Total tours	4,535	100.0 %	4,535	100.0 %

The detour frequency rate on outward tour legs is 0.015 detours per HB tour, whereas on return tour legs the frequency rate is significantly higher at 0.020 detours per HB tour. Given the difference in detour frequency rates separate models have been developed for detours made during the outward and return legs of HB tours. Only one detour per tour leg is considered in the modelling.

Detour frequency rates are relatively low overall, so most individuals make no detours to work-related destinations on the outward or return legs of work-related HB tours.

4.4.2 Model results

The results from the new work–work detour models are presented in Table 49. Model DetWrkWrkO_V7 is the outward detour frequency model, model DetWrkWrkR_V6 is the return detour frequency model.

Table 49: Work–work detour frequency model results

```
File             DetWrkWrkO_V7.F12  DetWrkWrkR_V6.F12
Converged                     True               True
Observations                  4535               4535
Final log (L)               -335.2             -427.2
D.O.F.                           3                  3
Rho²(c)                      0.027              0.042
Estimated                9 Apr 13           9 Apr 13

none_O            4.965  (17.0)
SEwkr_O          -1.127  (-3.3)
HBCarD_O        -0.8653  (-2.7)
none_R                                4.547  (16.9)
PTwrk_R                               2.602   (2.6)
HBCarD_R                             -1.058  (-3.6)
```

The parameters in the new models are defined in Table 50.

Table 50: Work–work detour frequency model parameters

Parameter	Sign	Definition
none_O	+	constant to ensure overall fraction of outward tour legs where no detours are observed is replicated
SEwkr_O	–	self-employed persons are more likely to make work-related detours on outward tour legs than other status groups
HBCarD_O	–	individuals who are using car driver to make their HB tour are more likely to detour on their outward tour leg to a work-related destination
none_R	+	constant to ensure overall fraction of return tour legs where no detours are observed is replicated
PTwrk_R	+	part-time workers are less likely to make work-related detours on return tour legs than other status groups
HBCarD_R	–	individuals who are using car driver to make their HB tour are more likely to detour on their return tour leg to a work-related destination

Outward detour rates for self-employed persons are 0.043, compared with 0.013 for the other employment status groups, and so they are much more likely to make detours. The self-employed group includes plumbers, electricians and so on who visit multiple work-related destinations in the course of a single HB tour.

For return detours, while a high detour rate was observed for self-employed persons, 0.035 compared with 0.019 for other status groups, it was not possible to estimate a significant constant to account for this difference. However, a significant effect was identified for part-time workers, who are much less likely to make return detours than other groups, with a detour rate of 0.002 compared with 0.023 for other status groups.

Outward detour rates for individuals who use car driver to make their HB tour are 0.019, 2.5 times the detour rate of 0.007 for individuals who use other modes for their HB tour. Return detours rates for individuals who use car driver to make their HB tour are 0.026, 3.1 times the detour rate of 0.009 for individuals who use other modes to make their HB tour. The constants for car driver HB mode in the outward and return detours models ensure that in application higher detour rates will be predicted for commute and home–business tours made by car drivers.

4.5 Work–other detours

4.5.1 Estimation sample

The work–other detour models predict the number of detours made during work-related tours to non-work-related SDs. Work-related PDs may be either work or employer's business, whereas non-work-related SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the work–other detour frequency model is the sample of full work-related HB tours, which includes commute and home–business tours. Other detours are detours made for non-work-related purposes, and therefore include escort detours made during the outward or return legs of commute tours. Table 51 shows the number and percentage of non-work-related detours made per full work-related HB tour.

Table 51: Non-work-related detours made per full work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Frequency	Percent	Frequency	Percent
no detour	4,167	91.9 %	4,019	88.6 %
detour	368	8.1 %	516	11.4 %
Total tours	4,535	100.0 %	4,535	100.0 %

The detour frequency rates are 0.081 per outward HB tour leg, and 0.114 per return tour leg. Thus detour rates to other locations are significantly higher than detour rates to work-related locations. Return-leg tour detour rates are significantly higher than outward-leg detour rates, and therefore separate detour frequency models have been estimated for outward and return-leg detours. Only one detour per tour leg is considered in the modelling.

4.5.2 Model results

Results from the new detour models are presented in Table 52. Model DetWrkOthO_V9 is the outward detour frequency model; model DetWrkOthR_V9 is the return detour frequency model.

Table 52: Work–other detour frequency model results

File	DetWrkOthO_V9.F12		DetWrkOthR_V9.F12	
Converged	True		True	
Observations	4535		4535	
Final log (L)	-1082.1		-1533.9	
D.O.F.	6		5	
Rho²(c)	0.153		0.045	
Estimated	9 Apr 13		9 Apr 13	
none_O	3.737	(22.5)		
PTwrk_O	-0.4402	(-3.1)		
male_O	1.053	(8.3)		
1child_O	-1.557	(-9.5)		
2pchild_O	-2.132	(-14.1)		
HBCarD_O	-0.7363	(-5.5)		
none_R			2.492	(21.9)
PTwrk_R			-0.2581	(-2.0)
male_R			0.6938	(6.9)
children_R			-0.7447	(-7.7)
HBCarD_R			-0.5177	(-4.9)

The parameters in the new model are defined in Table 53.

Table 53: Work–other detour frequency model results

Parameter	Sign	Definition
none_O	+	constant to ensure overall fraction of outward tour legs where no detours are observed is replicated
PTwkr_O	–	part-time workers are more likely to make other detours on outward tour legs than other status groups
male_O	+	males are less likely to make other outward-leg detours than females
1child_O	–	individuals in households with 1 child make more outward-leg detours than individuals in households without children
2pchild_O	–	individuals in households with 2+ children make more outward-leg detours than individuals in households without children
HBCarD_O	–	individuals who are using car driver to make their HB tour are more likely to detour on their outward tour leg to a work-related destination
none_R	+	constant to ensure overall fraction of return tour legs where no detours are observed is replicated
PTwrk_R	–	part-time workers are more likely to make work-related detours on return tour legs than other status groups
male_R	+	males are less likely to make other return-leg detours than females
children_R	–	individuals in households with 1 or more children make more return-leg detours than those without children in their household
HBCarD_R	–	individuals who are using car driver to make their HB tour are more likely to detour on their return tour leg to a work-related destination

It is noteworthy that the work–other detour models include parameters that reflect that part-time workers make more detours than other groups during work-related tours, whereas the return detour frequency model for work–work includes a parameter to reflect lower detour rates for the same group. So part-time workers are less likely to detour to work-related locations, but more likely to detour to non-work-related destinations, in the course of commute and home–business tours. These differences seem plausible as individuals who work part-time have more time available for non-work-related activities such as stopping at the shops on their way to or from work.

The terms for the number of children[5] pick up large differences in detour frequency according to whether there are children in the individual's household. For outward tour legs, mean detour rates are 0.026 for zero children in household records, compared with 0.117 and 0.181 in one and two-plus children in household records. For return tour legs, mean detour rates are 0.080, 0.160 and 0.155 for zero, one and two-plus children in household. It is noteworthy that there are large differences between the outward detour rates between one and two-plus children households, whereas for return detours there is little difference in the detour frequency rate between those with one and two children in their household.

Overall, it is clear from these results that most of the work–other detours are to drop off or pick up children from school or other locations.

Detour rates are also higher for HB tours made by car drivers. On outward tour legs, detour rates are 0.097 if car driver is the HB mode, and 0.053 if another mode was used

[5] Children here is all persons aged up to 17 including infants aged 0 to 4.

for the HB tour. The comparable rates for return-leg detours are 0.129 and 0.089. There will be some interaction between the HB tour mode and the number of children in the household. The car ownership model documented in Section 5.2 predicts higher car ownership for households with children, and so individuals in these households will be more likely to choose car driver as the mode for their HB tour.

4.6 Other–other detours

4.6.1 Estimation sample

The other–other detour models predict the number of detours made during non-work-related tours to non-work-related SDs. Non-work-related PDs and SDs may be visited for education, shopping, escort or other travel purposes.

The estimation sample for the work–other detour frequency model is the sample of full non-work-related HB tours (Table 54), which includes home–primary education, home–secondary education, home–tertiary education, home–shopping, home–escort and home–other travel tours.

Table 54: Non-work-related detours made per full non-work-related HB tour

	Outward legs of HB tours		Return legs of HB tours	
	Frequency	Percent	Frequency	Percent
no detour	8,447	94.3 %	8,320	92.9 %
detour	510	5.7 %	637	7.1 %
Total tours	8,957	100.0 %	8,957	100.0 %

Mean detour frequency rates are 0.057 during outward tour legs, and 0.071 during return tour legs. The detour frequency rate is higher on the return tour legs, and therefore once again separate detour frequency models have been developed for outward and return-leg detours. Only one detour per tour leg is considered in the modelling.

4.6.2 Model results

Results from the new detour models are presented in Table 55.

Table 55: Other–other detour frequency model results

```
File            DetOthOthO_V9.F12  DetOthOthR_V6.F12
Converged                    True               True
Observations                 8957               8957
Final log (L)             -1888.6            -2249.2
D.O.F.                          6                  3
Rho²(c)                     0.035              0.021
Estimated                9 Apr 13           9 Apr 13

none_O             2.914  (29.4)
male_O            0.3382   (3.4)
LAF_O            -0.2769  (-2.1)
Agelt24_O         0.5616   (4.6)
HBCarD_O         -0.7774  (-7.2)
HBCarP_O         -0.5176  (-3.9)
none_R                                2.271  (45.9)
FTWork_R                             0.3177   (2.6)
HBWalk_R                             0.9409   (9.0)
```

The parameters in the new model are defined in Table 56.

Table 56: Other–other detour frequency model results

Parameter	Sign	Definition
none_O	+	constant to ensure overall fraction of outward tour legs where no detours are observed is replicated
male_O	+	males are less likely to make other outward-leg detours than females
LAF_O	–	individuals who are looking after the family are more likely to make detours during outward tour legs than other status groups
Agelt24_O	+	individuals who are aged up to 24 are less likely to make detours during outward tour legs than individuals aged 25 and above
HBCarD_O	–	individuals who are using car driver to make their HB tour are more likely to detour on their outward tour leg to a work-related destination than those who use other modes
HBCarP_O	–	individuals who are using car passenger to make their HB tour are more likely to detour on their outward tour leg to a work-related destination than those who use other modes
none_R	+	constant to ensure overall fraction of return tour legs where no detours are observed is replicated
FTwork_R	+	full-time workers are less likely to make a detour during return tour legs than individuals in other status groups
HBWalk_R	+	individuals who are using walk to make their HB tour are less likely to detour on their return tour leg to a work-related destination than those who use other modes

The fit of the models was assessed across number of children in the household categories, but unlike the work–other detour models no significant effects were identified.

The variations in the detour frequency rates across the segments represented in the models were not as strong as the variations observed in the work–work and work–other detour models. The biggest differences were observed across the HB tour mode groups represented. For outward-leg detours, car driver and car passenger detour rates are 0.092 and 0.057 respectively, compared with 0.039 for other modes. For return-leg detours, walk detour rates are 0.038 compared with 0.089 for other modes.

CHAPTER 5 Car ownership models

5.1 Review of car ownership models

To inform the specification of the new PRISM car ownership models, a review was undertaken of the car ownership models incorporated in the previous version of PRISM, and the car ownership models used in the Sydney Strategic Travel Model (STM), a model very similar in structure to PRISM and which has been updated recently. These reviews are summarised in the following sub-sections.

5.1.1 Original PRISM car ownership model

In the absence of disaggregate income data in the 2001 HI data, the National Transport Model (NTM) car ownership models were used in previous versions of PRISM. In the original implementation, the sample derived from 2001 HI data was supplemented with income data defined at the zonal level. The implementation was later modified to use National Travel Survey data in order to provide disaggregate income information to allow income segmented travel demand models to be developed, but the implementation of the NTM car ownership models was retained.

The NTM car ownership models consist of a company car ownership model and a total car ownership model, both of which were implemented in the original version of PRISM. The total car ownership model consists of three sub-models for the number of cars per households: the 0/1+ model, 1/2+ model and 2/3+ model. The utilities in this total car ownership model for a household with household type ‘h’ and area type ‘a’ are defined as:

$U = k_{FES} + t * (LPA) + (b + HH_h + Area_a) * Y + g * CC_{NTS} + e * Emp + p * Pcost + r * Rcost$

The definition of household types ‘h’ is based on number of adults and children in the household:

- one adult, not retired
- one adult, retired
- one adult, with children
- two adults, retired
- two adults, no children
- two adults, with children
- three adults, no children

- three adults, with children.

Five area types are used in the model and are defined as follows:

- Greater London
- metropolitan districts, which applies to the whole PRISM core area
- districts with density greater than 7.9 persons per hectare
- districts with density between 2.22 and 7.9 persons per hectare
- districts with density less than 2.22 persons per hectare.

LPA stands for licences per adult.

The terms used in the total car ownership model are described in Table 57.

Table 57: Terms in the NTM total car ownership model

Term	Definition
k_{FES}	constant
t	time trend coefficient that is attached to LPA
LPA	licences per adult
B	coefficient on the income term
HH_h	a modifying parameter based on household category
$Area_a$	a modifying parameter based on area type definitions
Y	annual household income (1991) prices
G	the coefficient on the company car dummy
CC_{NTS}	company car dummy variable (estimated from National Travel Survey data)
E	coefficient on employment
Emp	number of workers in the household
P	coefficient on purchase cost
Pcost	purchase price index
r	coefficient on running cost
Rcost	running cost index

The company car ownership model is applied first, and then total car ownership is predicted after company car ownership has been predicted.

For more detail on the implementation of the NTM car ownership models in the original version of PRISM, please refer to RAND Europe (2004b).

5.1.2 The Sydney Strategic Model

The total car ownership model in the Sydney STM was originally developed in 1999 from HI data collected in 1991 and 1997–1998. These models were recently re-estimated using 2004–2008 HI data and the model specifications were revised. The re-estimation of the car ownership models is documented in Tsang and Daly (2010).

The total car ownership model in the STM predicts the choice between zero, one, two and three-plus car alternatives. The predictions are made conditional on the number of company cars owned. In model application, a separate model is applied first to predict the number of company cars owned by the household, and then the total car ownership model is applied conditional on the predicted number of company cars. This structure is consistent with the NTM car ownership models discussed in Section 5.1.1.

The terms included in the total car ownership model are summarised in Table 58.

Table 58: Terms in the STM total car ownership model

Term	Definition	Alternative			
		No car	1 car	2 cars	3+ cars
1carowned	1 car alternative-specific constant (ASC)		-		
2carowned	2 car ASC			-	
3+carowned	3+ plus cars ASC				-
HHInc1	household income – car costs (logarithmic)		+		
HHInc23	household income – car costs (logarithmic)			+	+
FmHdHH2	female head of household term for 2 cars alternative			-	
FmHdHH3	female head of household term for 3+ cars alternative				-
D1age35	head of household age term for 1 car alternative (multiplied by [age – 35] when age > 35)		+		
D2age35	head of household age term for 2 cars alternative (multiplied by [age – 35] when age > 35)			+	
D3age35	head of household age term for 3+ cars alternative (multiplied by [age – 35] when age > 35)				+
D2_3age50	head of household age term for 2 & 3+ cars alternatives (multiplied by [age – 50] when age > 50)			-	-
FtTmWrk1	number of full-time workers for 1 car alternative		+		
FtTmWrk2	number of full-time workers for 2 cars alternative			+	
FtTmWrk3	number of full-time workers for 3+ cars alternative				+
PrTmWrk1	number of part-time workers for 1 car alternative		+		
PrTmWrk2	number of part-time workers for 2 cars alternative			+	
PrTmWrk3	number of part-time workers for 3+ cars alternative				+
NChildCof	number of children		+	+	+
Numlics1	number of licences for 1 car alternative		+		
Numlics2	number of licences for 2 cars alternative			+	
Numlics3	number of licences for 3+ cars alternative				+
D2-LIC<CAR	licences less than cars for 2 cars alternative			-	
D3-LIC<CAR	licences less than cars for 3+ car alternative				-
CmpCar1_2	1 company car for 2 cars alternative			+	
CmpCar1_3	1 company car for 3+ cars alternative				+
CmpCar2_3	2+ company cars for 3+ cars alternative				+
Naus_1	number of Australian-born in household		+		
Naus_2	number of Australian-born in household			+	
Naus_3	number of Australian-born in household				+
couple1	household comprising a married couple only		+		
CBDdist	multiple by log of distance to CBD		+	+	+
m_d_access	multiplied by logsum	+	+	+	+

5.1.3 Summary of terms

From the review of these two models, the following variables available from the 2009–2012 HI data were identified for investigation in the new total car ownership model:

- household income
- numbers of workers
- licence holding
- age of the head of household
- ethnicity.

In the development of the NTM models, sensitivity to purchase and running costs was able to be identified, because the observed data were collected at different points over time. However, the new PRISM HI data were collected over a short time scale, 2009–2012, with most data collected in 2010 and 2011. This short time scale does not allow the impact of changes in purchase and running costs to be identified separately from other changes, and purchase and running cost terms have therefore not been included in the new total car ownership model specification. Thus a limitation of the new total car ownership model is that the model predictions are not sensitive to future changes in purchase and running costs.

The 2009–2012 HI data were collected within the West Midlands Metropolitan Area, and all lie within the 'metropolitan districts' area type in the NTM car ownership model classification. Therefore no attempt has been made to investigate differences in car ownership with area type in the new total car ownership model.

Both the STM and the NTM total car ownership models predict total car ownership as a function of the number of company cars owned in the household. When the STM car ownership models were originally developed, tests were undertaken that demonstrated a better fit to the data when company car ownership was predicted first, and then total car ownership was predicted as a function of the number of cars held, rather than a structure where company car ownership is predicted after non-company car ownership.

In the 2009–2012 HI data, company car ownership is relatively low, with just 144 (5.4%) of the 2,675 households in the estimation sample owning one or more company cars. Given this relatively low fraction, and that forecasting changes in company car ownership over time is difficult because changes taxation policy can lead to large changes in company car ownership, it was decided not to forecast company car ownership in the new car ownership models. Therefore no company car ownership model parameters have been included in the new total car ownership model.

5.2 Car ownership models

5.2.1 Estimation sample

The total car ownership models are household level models, and therefore the estimation sample was initially defined as the total number of households observed in the 2009–2012 HI data. However, the sample was subsequently reduced for a number of reasons.

The most important exclusion was dropping households where the household income was not stated, because the household responded 'don't know' or 'prefer not to say' to the household income question. Household income is a key variable in forecasting car ownership. To retain households with missing incomes in the estimations, it would have been necessary to assume a mean income for them, and without developing a sophisticated approach to predict the missing incomes as a function of other household characteristics, using average incomes for those with missing incomes would be likely to understate the impact of household incomes on total car ownership. A further consideration is that a number of the mode-destination models incorporate cost sensitivity parameters that are segmented by household income, and to implement these models it was decided to use only the sample of individuals with stated incomes. Dropping households with missing incomes from the total car ownership model ensured that all of the models in the new forecasting system could be implemented using a consistent sample of households. One-third (35%) of households were dropped from the car ownership estimation sample because they had missing incomes.

In addition, households with zero licences were excluded on the basis that even if these households own cars they cannot drive them. In forecasting, the probability of owning zero cars is always exactly one for zero licence households, and then the total car ownership model is applied to the sample of households with licences to predict their total car ownership.

The total volumes of data dropped for each of these exclusions are detailed in Table 59.

Table 59: Total car ownership model exclusions

Total households	4,985	100.0 %
households that did not state their income	1,755	35.2 %
households with zero licences but cars	4	0.1 %
households with zero licences and zero cars	551	11.1 %
Estimation sample	2,675	53.7 %

As would be expected, very few households (0.7%) that have zero licences own cars. No-one in these households can drive the cars that are owned, and so for the purposes of the modelling it is valid to assume these households have zero cars.

5.2.2 Car ownership alternatives

The following vehicle types were recorded in the 2009–2012 HI data, to facilitate modelling of emissions should that be required:

- four-wheeled cars and 4x4s
- cars adapted for disabled drivers
- other cars and light vans
- large vans and lorries
- minibuses and motorvans
- motorcycles and scooters
- mopeds.

For the PRISM modelling work, the definition of a 'car' includes the following vehicle types:

- four-wheeled cars and 4x4s
- cars adapted for disabled drivers
- other cars and light vans.

Analysis presented in Appendix A of the mode-destination modelling report (Fox *et al.*, 2013) demonstrates that tours made by motorcycles, scooters and mopeds accounted for just 0.1% of the HB tours observed in the 2009–2012 HI data. Therefore it was concluded that it was reasonable to exclude motorcycle, scooter and moped tours from the new 2011 base version of PRISM; it followed that ownership of these vehicles need not be modelled.

Table 60 summarises the distribution of total car ownership in the new estimation sample. As noted in Section 5.2.1, the estimation sample includes only households with stated incomes and with at least one licence holder.

Table 60: Observed car ownership

Cars	Frequency	Percent
0	201	7.5 %
1	1,390	52.0 %
2	811	30.3 %
3	209	7.8 %
4	56	2.1 %
5	6	0.2 %
6	2	0.1 %
Total	2,675	100.0 %

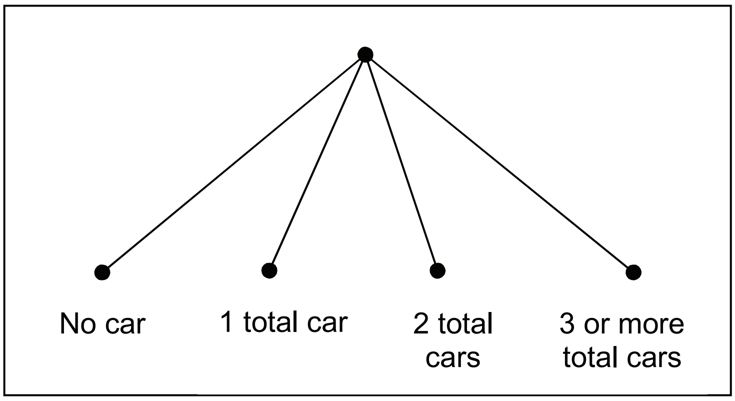
Less than 3% of households in the sample own four or more cars. Therefore it was judged to be reasonable to use a single alternative to represent ownership of three or more cars. The car ownership alternatives in the model are therefore:

- zero cars
- one car
- two cars
- three-plus cars.

The mean number of cars owned by households that own three-plus cars is 3.2711.

A multinomial model is used to represent the choice between these four alternatives, as illustrated in Figure 6.

Figure 6: Total car ownership choice structure



'No car' is the base alternative. The utility of 'no car' is set to be equal to zero, and then all the model parameters are defined on the other three alternatives.

5.2.3 Model results

A number of tests were undertaken to determine the appropriate formulation for the household income terms. Household income is recorded using 23 different bands in the HI data, and has been converted into a continuous variable by using the mid-point for each income band. For the top income band (£75k+ p.a.), different assumptions have been tested for the mean income in the band. Mean income values of £100k, £90k, £85k, £80k and £75k+ were tested. These tests demonstrated that the fit to the observed data improved as the mean income value was reduced, and the best fit was observed with a mean income value of £75k+. This was felt to be implausibly low, and so in the final model specification a mean income of £85k was assumed.

Tests were also undertaken to investigate whether household income should be specified using a linear or logarithmic form. In the Sydney car ownership models a logarithmic formulation was used.[6] These tests found that using a linear form for household income gave a slightly better explanation of the observed car ownership choices, and so household income has been specified using a linear formulation in the final model specification.

The parameters in the final model specification of the new total car ownership model are detailed in Table 61. The t-ratios associated with the parameter estimates are given in brackets.

Table 61: Total car ownership model parameters (and t-ratios)

Parameter	One car		Two cars		Three-plus cars	
alternative specific constant	-0.1147	(-0.4)	-6.1746	(-16.0)	-11.283	(-19.5)
household income	0.000039	(5.1)	0.000078	(9.4)	0.000085	(9.5)
number of full- and part-time workers			0.1564	(2.1)	0.4193	(3.6)
number of self-employed workers			0.6278	(3.8)	1.0613	(4.5)
number of full licence holders	0.6673	(3.7)	2.6134	(12.8)	3.8974	(16.3)
age of head of household under 25					-0.5452	(-2.9)
head of household's ethnicity is 'white, British'	0.4029	(2.4)	1.0292	(5.1)	1.2416	(4.8)
head of the household is male			0.3549	(2.9)	0.5008	(2.4)
number of infants and children in the household	0.2704	(3.3)	0.3375	(3.6)	0.3714	(3.2)

[6] The impact of different assumptions for the average income in the top income band was investigated for the linear and log household income formulations.

The parameters on household income are all positive, as would be expected. The magnitude of the parameters increases with the number of cars owned, so the income effect is stronger for the higher car ownership alternatives.

The numbers of workers terms were only significant on the two cars and three-plus cars alternatives. The parameters indicate that the probabilities of owning two cars and three-plus cars increase as the number of full- and part-time workers in the household increases. The worker effect is stronger for three-plus cars than for two cars, so as the number of workers in the household increases, the probability of owning three-plus cars increases.

The parameters for self-employed workers follow the same pattern as the full- and part-time worker terms, but the parameters are noticeably larger in magnitude indicating that the effect is much stronger. Many self-employed people need a car for their work, and it is noted that the definition of a car in these models includes light vans, so these parameters will capture the impact of self-employed plumbers, builders and so on who own their own van.

As noted in Section 5.2.1 the total car ownership model has been estimated from a sample of households with at least one licence. The probability of owning one or more cars increases with the number of full licences held by household members, and as would be expected the two cars term is stronger than the one car term, and the three-plus cars term is stronger than the two cars term. So households with more than one licence are more likely to own cars, and the probabilities of owning two and three-plus cars increases as the number of licence holders increases. The effects are all plausible.

Only one age of the head of the household effect was identified in the final model, on the three-plus cars alternative. This term is negative, indicating that households are less likely to own three or more cars if the head of the household is aged under 25.

The ethnicity effects are interesting. For each of the car owning alternatives, households are more likely to own cars if the ethnicity of the head of the household is ‘white British’ than where the head has a different ethnicity. Similar terms were recently identified in car ownership models for Sydney, Australia (Tsang and Daly, 2010). Furthermore, the effects increase in magnitude as the number of cars owned increases. Thus households with a white British head have higher car ownership than households whose head has a different ethnicity, all else equal. It is emphasised that these terms pick up differences in car ownership with ethnicity of the household head that exist *after* taking account of the impact of the other model terms, including household income and the number of workers.

Significant parameters for the number of infants (aged 0–4) and children (aged 5–16) have been identified for each of the car owning alternatives. Thus the probability of a household owning at least one car increases with the number of infants and children, and as the number of infants and children increases the probabilities of owning two and three-plus cars increases. Higher car ownership levels would be expected in households with infants and children and so all of these effects are plausible.

A potential improvement to the car ownership model would be to incorporate a mode-destination accessibility term, reflecting the linkage between car ownership and mode-destination accessibility. For example, the car ownership models for Sydney described in

Tsang and Daly (2010) incorporate an accessibility term from the commute mode-destination model.

5.3 Analysis of licence holding

Licence holding is a key variable for forecasting car ownership and the impact of car ownership on travel demand. The car ownership models prohibit car ownership for households without licences and predict higher car ownership levels for households with more licences; furthermore the availability of the car driver mode in the mode-destination models is governed by individual licence holding.

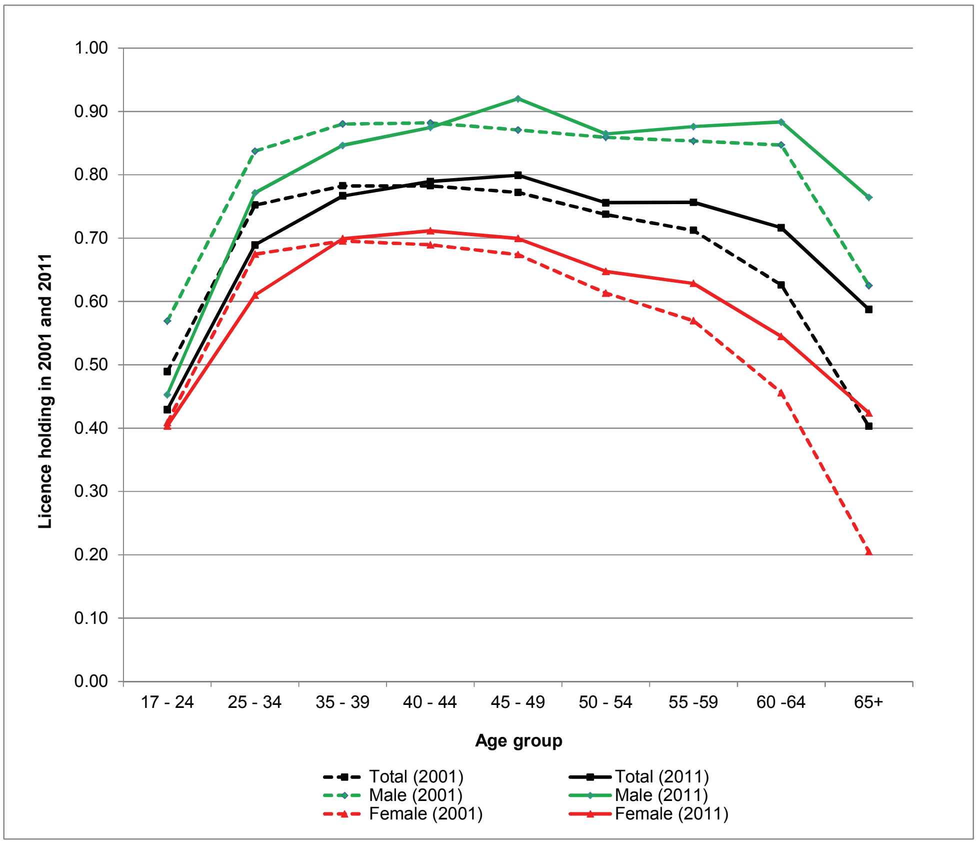
The 2009–2012 HI data provide a detailed cross-sectional picture of licence holding in the 2011 base year, accounting for variations in licence holding by age band and gender. However, cohort effects play an important role in changes on licence holding over time,[7] and these cohort effects cannot be forecast using a single cross-sectional HI survey. Therefore this section presents analysis that investigates how licence holding has changed in the West Midlands over the past decade, and describes an approach that has been devised to forecast how licence holding will change in the future.

5.3.1 Historical changes in licence holding

To examine the changes in West Midlands licence holding over the past decade, licences per adult (LPAs) have been calculated by age band and gender for the 2001 HI used to develop the original version of PRISM, and for the new 2009–2012 HI survey. Figure 7 illustrates the variation in LPAs with age band and gender for each of these two surveys. An LPA value for a given age band of 0 indicates that no adults in that age band hold a licence; an LPA value of 1 indicates that everyone in that age band holds a licence. Licence in this context is full car driving licence.

[7] Cohort effects in this context are effects that are specific to a group of individuals born within a given five- or ten-year period.

Figure 7: LPA by age band and gender



It is clear from Figure 7 that there have been significant changes in West Midlands licence holding over the past decade. The key change has been for older females to retain their licence holding into retirement, so that for the 65+ female group LPA has increased from 0.20 to 0.42 over a decade, and for males in the 65+ age group there has also been a substantial increase in licence holding. Interestingly, for younger age cohorts there is a trend to delay licence acquisition, with the overall level not catching up with the 2001 level until the 35–39 age band for females, and the 40–44 age band for males. This is consistent with the findings of recent national analysis commissioned by the RAC foundation (Le Vine and Jones, 2012).

Total West Midlands licence holding is compared with national data in Table 62.

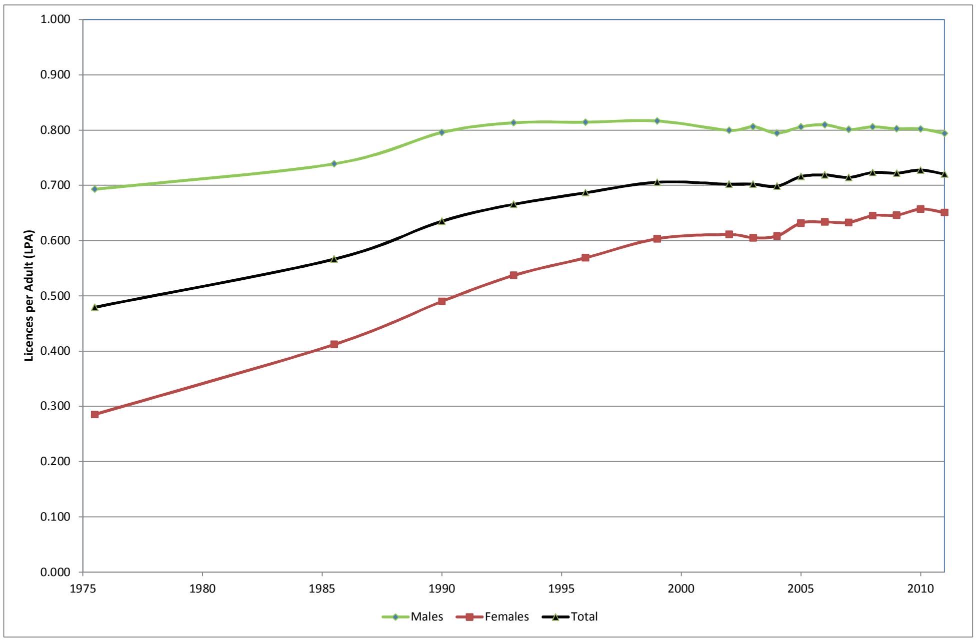
Table 62: Comparison of total licence holding

	2001 HI West Midlands	2009–2012 HI West Midlands	2011 NTS National
male	0.750	0.772	0.79
female	0.391	0.584	0.65
Total	0.583	0.676	0.72

It can be seen that following the rapid increase in female licence holding over the past decade, West Midlands LPA is now not too far below the national values. We would expect the overall average LPA figures in the West Midlands to be below the national averages as a result of below average incomes.

Changes in *national* licence holding over the past 36 years have been analysed using NTS data presented in Transport Statistics Great Britain 2012 (Department of Transport, 2012). These data are summarised in Figure 8.

Figure 8: Changes in national licence holding, 1976 to 2011



It is clear from Figure 8 that overall male LPA has remained essentially constant over the past decade, at around 0.8. Female LPA has increased slightly over the past decade, from 0.6 to 0.65. Some further increase might be expected in the future, although this will depend on the decline in licence acquisition by young people not continuing to still lower rates.

In summary, it seems reasonable to assume that male licence holding observed in the 2009–2012 HI can be assumed to hold constant into the future for age bands up to 65. The argument here is that we do not know whether the pattern of delayed licence acquisition for younger age groups will become even more pronounced in the future. For males aged 65+, an approach to forecast increases in licence holding is required.

For females, while West Midlands licence holding has caught up with the national average over the past decade, it seems some further increase in overall licence holding could be expected as females currently of working age maintain higher licence holding into retirement. Based on the analysis presented in Figure 7, an approach is required to forecast increases in female licence holding for persons aged 50-plus. For females aged up to 50 it seems reasonable to assume licence holding remains constant as we do not know if the pattern of delayed licence acquisition for younger groups will continue into the future.

5.3.2 Predicting future changes in licence holding

To forecast licence holding forward for older age groups, a simple approach has been used, which assumes that licence holding for a given age band can be predicted by taking an average of licence holding for the same cohort a decade back and licence holding for the same age band a decade back. Thus licence holding is predicted as a combination of cohort effects, individuals maintaining their licence holding as they age, and age effects, individuals giving up licences for health reasons. For the 65+ age band, the formula is modified to take an average of the 55–59, 60–64 and 65+ age bands from a decade back.

The approach was validated by using 2001 licence holding to predict the licence holding levels observed in the 2009–2012 HI. Table 63 and Table 64 demonstrate the results of the validation for males and females respectively.

Table 63: Validation of male licence holding predictions, 65+ age band

Age band	2001 HI observed	2011 predicted	2011 observed (2009–2012 HI)	Error
65+	0.625	0.775	0.764	0.011

Table 64: Validation of female licence holding predictions, 50+ age bands

Age band	2001 HI observed	2011 predicted	2011 observed (2009–2012 HI)	Error
50–54	0.613	0.651	0.647	0.004
55–59	0.570	0.622	0.628	-0.007
60–64	0.456	0.535	0.545	-0.010
65+	0.205	0.410	0.424	-0.014

The validation demonstrates that the simple approach, combining cohort and age effects, is able to predict observed increases in licence holding by age band with a good level of accuracy. Therefore the approach has been taken forward to predict future licence holding from the observed 2011 figures.

Table 65 and Table 66 overleaf present the forecasts of licence holding for males and females respectively for 2021, 2031 and 2041. Forecasts for intermediate years can be determined by linear interpolation. Cells in blue are observed data from the 2009–2012 HI data; cells in yellow show age bands where no change in licence holding is assumed, relative to the 2011 values; and cells in green show age bands where future increases in licence holding have been predicted. For females in the 50–54 age band, licence holding in 2031 and 2041 has been restricted to be equal to licence holding in the 45–49 age band because the original projections forecast higher licence holding in the 50–54 age band than in the 45–49 age band.

In implementation, modifications will be made to the licence holding of males aged 65+, and females aged 50+, calculated as the *increase* in licence holding for that age band relative to the 2011 base. These modifications to licence holding are only applied to the fraction of individuals in that age band who do not have a licence in 2011 – if the modifications were applied to all individuals then it would be possible to predict more licences than adults in the household. The modifications are applied as follows:

(change in licence holding for cohort 2011 to 20x1) /

(fraction of cohort without licence in 2011)

Table 65: Forecasts of male licence holding by age group, 2011–2041

Age band	2011	2021	2031	2041
17 - 20	0.360	0.360	0.360	0.360
21 - 24	0.561	0.561	0.561	0.561
25 - 30	0.753	0.753	0.753	0.753
31 - 34	0.772	0.772	0.772	0.772
35 - 39	0.855	0.855	0.855	0.855
40 - 44	0.868	0.868	0.868	0.868
45 - 49	0.917	0.917	0.917	0.917
50 - 54	0.865	0.865	0.865	0.865
55 -59	0.873	0.873	0.873	0.873
60 -64	0.874	0.874	0.874	0.874
65+	0.738	0.828	0.858	0.868

Table 66: Forecasts of female licence holding by age group, 2011–2041

Age band	2011	2021	2031	2041
17 - 20	0.296	0.296	0.296	0.296
21 - 24	0.513	0.513	0.513	0.513
25 - 30	0.594	0.594	0.594	0.594
31 - 34	0.651	0.651	0.651	0.651
35 - 39	0.706	0.706	0.706	0.706
40 - 44	0.723	0.723	0.723	0.723
45 - 49	0.693	0.693	0.693	0.693
50 - 54	0.656	0.690	0.693	0.693
55 -59	0.609	0.651	0.672	0.682
60 -64	0.515	0.586	0.638	0.665
65+	0.374	0.499	0.578	0.629

For males, relatively small increases in licence holding are predicted for the 65+ age band.

For females, larger increases are predicted, particularly for the 65+ age band. However, female licence holding is predicted to remain below male licence holding for all age bands, consistent with the lower holding rates for females in the middle age cohorts in the 2011 data.

5.4 Future improvements

A number of potential improvements to the car ownership models and licence holding forecasting approach have been identified. It was not possible to incorporate these improvements in this phase of the model development given the available budget.

To facilitate modelling of emissions, the car ownership models could be extended to model car type choice. The 2008–2012 HI data deliberately collected road tax class and engine size information that would allow the development of type choice models.

Inclusion of running cost and purchase cost terms in the car ownership model would make the models sensitive to future changes in these costs.

The car ownership model could also be extended to incorporate an accessibility term from the commute mode-destination model. Such terms allow the models to better reflect lower car ownership in areas well served by public transport. However, implementing this linkage introduces additional complexity to the implementation, as there is a need to account for the impact of changes in accessibility on predicted car ownership levels.

Finally, sensitivity tests could be undertaken to investigate different licence holding scenarios, for example scenarios where the recent pattern of delayed licence acquisition for young adults becomes even more pronounced in the future.

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