RAND EUROPE

Sydney Strategic Model Re-estimation

Licence, Car Ownership and Frequency Models

Flavia Tsang, Andrew Daly, James Fox, Bhanu Patruni

For more information on this publication, visit www.rand.org/t/RR1130

Original date of publication December 2010

Published by the RAND Corporation, Santa Monica, Calif., and Cambridge, UK

RAND Europe is an independent, not-for-profit policy research organisation that aims to improve policy and decisionmaking in the public interest through research and analysis. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

Preface

RAND Europe were commissioned by the Transport Data Centre (TDC) (now known as the Bureau of Transport Statistics) of the New South Wales Ministry of Transport (now known as Transport NSW) to re-estimate the travel demand model components of the Sydney Strategic Transport Model (STM).

The STM was designed by Hague Consulting Group (1997). In Stage 1 of model development (1999–2000), Hague Consulting Group developed mode-destination and frequency models for commuting travel, as well as models of licence ownership and car ownership, and a forecasting system was developed incorporating these components. In Stage 2 of model development (2001-02), RAND Europe, incorporating Hague Consulting Group, developed mode and destination and frequency models for the remaining home-based purposes, as well as for non-home-based business travel. Then, during 2003–2004, RAND Europe undertook a detailed validation of the performance of the Stage 1 and 2 models. Finally, Halcrow undertook Phase 3 of model development (2007), in which they re-estimated the home–work mode-destination models, and at the same time developed models of access mode choice to train for home–work travel.

By 2009, some model parameters were nearly ten years old, raising concerns that the model may no longer reflect with sufficient accuracy the current behaviour of residents of Sydney. Furthermore, changes to the zone structure of the model occurred with the number of zones approximately trebling in number, and the area of coverage increased to include Newcastle and Wollongong. Therefore TDC decided to commission this study to re-estimate the STM models.

In this stage of model development, the models estimated during Stages 1 to 3 have been re-estimated to use more recent Household Travel Survey data in order to reflect travel conditions for a new 2006 base year. The disaggregate licence holding and car ownership models have been-estimated to reflect the 2006 base year, and the model specifications have been updated. The cohort licence projection procedure has also been updated to reflect the 2006 base year, and now projects forwards to 2041.

Two reports have been produced by RAND Europe during the course of this study:

a) This licence, car ownership and frequency modelling report

b) A separate mode-destination modelling report.

RAND Europe is an independent not-for-profit policy research organisation that serves the public interest by improving policymaking and informing public debate. Clients are governments, institutions and firms with a need for rigorous, impartial, multidisciplinary analysis of the hardest problems they face. This report has been peer-reviewed in accordance with RAND's quality assurance standards (see http://www.rand.org/about/standards/) and therefore may be represented as a RAND Europe product.

For more information about RAND Europe or this document, please contact James Fox at:

RAND Europe
Westbrook Centre
Milton Road
Cambridge
CB4 1YG
+44 (0)1223 353 329
jfox@rand.org

Contents

Table of Figures

Table of Tables

CHAPTER 1 Introduction

This report documents the re-estimation of the licence holding, car ownership and frequency model components. The re-estimation of the mode-destination models is documented separately (Fox et al. 2010).

Chapter 2 describes analysis of licence holding and car ownership in greater Sydney observed in the 1999–2008 Household Travel Survey (HTS) data. A number of conclusions drawn from this analysis for the model estimation phase are detailed.

Chapter 3 then describes the re-estimation of the licence holding models. Two sets of models have been updated: first, the cohort model that predicts aggregate changes in licence holding by age-gender cohort over time; and second the disaggregate models that predict cross-sectional variation in licence across the Sydney population.

Chapter 4 documents the re-estimation of the car ownership models. Both the company car ownership model and the total car ownership model have been re-estimated.

In Chapter 5 the re-estimation of the frequency models is documented.

Finally, Chapter 6 presents a summary of the re-estimation procedure and results.

CHAPTER 2 Licence and Car Ownership Analysis

This chapter discusses the approach for modelling licence holding and car ownership. The validity of the key modelling assumptions is investigated through analyses of Household Travel Survey (HTS) data.

This chapter is structured into five sections. The first section discusses the data available for the different components of the Sydney Strategic Travel model. The next two sections present the two components of the licence holding model, the cohort model and the disaggregate model, respectively. This is followed by a fourth section examining the car ownership model, with particular attention paid to the categorisation of company cars and household cars. The last section sets out key conclusions for the subsequent estimation work.

2.1 Data

Nine waves of HTS data are used in this analysis, with the first wave carried out between July 1999 and June 2000 and the ninth wave carried out between July 2007 and June 2008. These waves are consistently referred to by the starting year of the home interviews in this chapter.

It is important to note that different data exclusion criteria are used for the various components of the Sydney Strategic Travel Model (Table 1). Data are excluded that are inconsistent, for example, children cannot hold driving licences, or incomplete. One of the main data exclusion filters for incomplete data was the variable indicating whether a respondent was in a 'full response' or a 'part response' household. As the cohort model operates at the level of individuals, issues related to full or part response household do not apply and therefore all data are used. Conversely, for the disaggregate licence holding model and the car ownership model, the number of household members is central to the models; therefore only full response households are used.

Additionally, there is the question about interviews recorded on weekdays versus those recorded on weekends. The Sydney Strategic Travel Model represents weekday travel conditions. Therefore, the frequency model and the mode-destination choice models (Fox et al. 2010) use weekday data only. However, there is no reason why the choice of licence holding and car ownership would be dependent on the day of data collection. Therefore, in order to maximise the number of observations, the licence holding and car ownership models include data collected at weekends as well as weekdays.

Table 1: Data Scope for Model Components

Model Component	Full Response Households Only?	Weekday Only?
cohort licence holding model	no	no
disaggregate licence holding model	yes	no
car ownership models	yes	no
frequency model	no	yes
mode-destination choice models	no	yes

2.2 Licence Holding by Cohort

This section discusses the first of the two main components of the licence holding model, the cohort model. The cohort model predicts licence holding for a given age-sex group at an aggregate level. The main idea underlying the cohort approach for licence holding forecasting is that individuals acquire driving licences only once in their lifetimes and few people ever give up licences, therefore the level of licence holding for a given age-sex cohort changes only marginally over time. Thus, a good forecast of licence holding for a given age-sex cohort can be achieved by taking the licence holding rates in the past, and adjusting these with positive changes to represent new licence acquisition and negative changes to represent losses. Loss of licences is most likely due to medical conditions that impair a person's ability to drive safely, including but not limited to conditions associated with old age. People over 75 are required to undergo annual medical tests and people over 85 must pass driving tests every year.[1] People over 75 can have a restricted licence (e.g. only drive during certain times of day), but this kind of detail is currently not recorded in the HTS. People with restricted licences are probably recorded as holding a regular full licence.

It is important to note that the cohort modelling approach is designed to deal with the resident population; that is, a key assumption is that migration is small and therefore, limited adjustments are sufficient. In the rest of this section, we will first discuss gender and age differences in licence holding, then discuss the treatment of the migrant population.

2.2.1 Licence Holding by Gender and Age

Table 2 shows how licence holding by gender has changed over time. The figures for 1971–1991 are taken from a spreadsheet provided by TDC, and the licence holding rates of recent years, 1997–2007, are based on our own analysis. Both TDC's spreadsheet and our own analysis are based on analysis of home interview surveys. However, we note that there are some definitional differences between the two set of analysis. Firstly, the geographic coverage of data analysed are slightly different. While the previous analysis covers only the Sydney Statistical Division, the new analysis covers the whole of the Greater Metropolitan Area. Secondly, the definition of adult is different. The previous analysis included people who were 15 or older, while the new analysis included people who

---

[1] Information about medical tests for older drivers is available at (accessed 01/05/2015): http://www.rta.nsw.gov.au/licensing/renewingalicence/olderdrivers/index.html

are 17 or older, which is consistent with the age at which individuals can currently acquire driving licences. Furthermore, other data exclusion criteria (e.g. weekends versus all survey days, and full or part response households) may also affect the values. Nonetheless, the TDC spreadsheet is our best available resource for historical data and we judge that it is important that we present these available data to illustrate the changes over time.

Licence holding has increased substantially in the period of 1971–1981 for both men and women, and the increase is particularly high for women (20 percentage points in ten years). In the period 1981–1991, while the licence holding for men grew slowly, by only 1 percentage point, the licence holding rate for women grew by 8 percentage points. In the following period (1997–2007), men's licence holding rate stabilised at around 85–86 per cent in the Sydney area and 88–91 per cent in the Greater Metropolitan Area. The licence holding for women continued to grow and reached 76 per cent in the Sydney area and 78 per cent in the Greater Metropolitan area in 2007.

It is noteworthy that our new analysis shows that the licence holding rates of women have become quite stable since 2000, at between 77 per cent and 80 per cent At the same time, the licence holding rate for men remained between 88 per cent and 91 per cent (i.e. about 11 per cent higher than that of women). It is clear that there are still significant differences between the licence holding rates of males and females, highlighting why it is necessary to develop separate models for each of them.

Table 2: Percentage of Population with Driving Licence, by Gender†

	Analysis based on aggregated data from TDC (Sydney Statistical Division only)		New analysis (Greater Metropolitan Area)	
Year	Male	Female	Male	Female
1971	77	40		
1981	84	60		
1991	85	68		
1997			90	76
1998			90	76
1999	86	72	89	74
2000			91	77
2001			90	79
2002			89	78
2003			90	78
2004			88	78
2005			89	79
2006			89	80
2007	85	76	89	78

† Footnote: All values in this table are based on unweighted values from the surveys

The precise definition of a 'licence holder' is an important consideration. There are three types of car licences in New South Wales: (i) full, (ii) provisional and (iii) learner. While people with provisional or full licences can drive independently, people with learner licences cannot drive a car without the supervision of someone with a full licence; therefore, we cannot assume car driver is a mode available for the learners, especially given that mean car occupancy in Sydney is quite low. Another reason to ignore learner licences is in determining competition for vehicles within the household, which is a key issue for the mode-destination choice model segmentations. Consider a household with two full licences and one learner licence held by members of the household. If the household has two vehicles there will not be competition for vehicles as the learner would have to travel with one of the full licensed members. If the learner were to be considered as a household licence then there would be competition for cars within the household. For these reasons, we judge that learners should be treated as non-licensed. This decision also affects the age cut-off to be used. We recommend using 17+ as the minimum age in the licence holding model, given that one can possess a full or provisional licence starting from the age of 17 (while 16 year-olds can only possess learner licences).

Figure 1: Licence Holding by Type and Age (TDC Analysis)

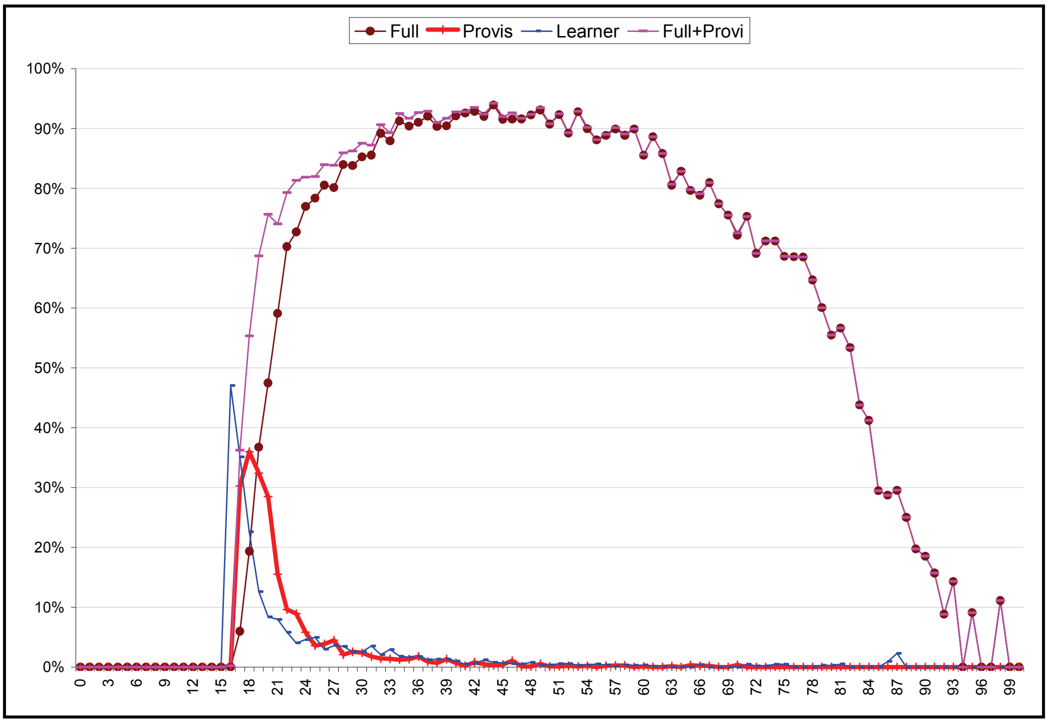


Figure 1 shows an analysis of the level of licence holding by type and age. As expected, the learners are very much concentrated in young people, as are provisional licence holders. The most important curve in this chart is the one representing 'full or provisional', as this is the definition of licence holders in the proposed model.

Importantly, Figure 1 shows the different levels of licence holding across age groups. For young people, licence holding is in a rapid state of flux and acquisition takes place on a large scale. On the other hand, for people of working age, the licence holding rates fluctuate only slightly around high 80s and low 90s per cent. Finally, for older people, the licence-holding rate declines gradually from around age 60 and more steeply from around age 75. Thus, in the licence-holding model, licence-holding rates are predicted separately for three age groups:

1. Young people (17–24);

2. Main working age (25–60)
3. Older people (60+).

2.2.2 Migrant Licence Holding

Additionally, we examined the licence-holding rates of immigrants (Table 3). The countries of origins for immigrants broadly fall into three groups:

- Group (i) consists of Australia, New Zealand, North America and Northern, Western and Eastern Europe, where gender differences in licence holding in the period between 1999 and 2007 are relatively small (24.6 per cent for Eastern Europe is judged to be small given the very high proportion of people over 60).
- Group (ii) consists of Southern Europe and Africa, where gender differences in licence holding are relatively large. While Southern Europe has the highest gender differences among all the geographical groups, 12.9 per cent for Africa is judged to be large given that the proportion of people aged over 60 is small.
- Group (iii) consists of Asia and South America, where gender differences in licence holding are high even though the proportion of people over 60 is low. It is also worth noting that since 1991, Africa and Asia are the two main origins with a change of in-migration; thus, the situations of immigrants from these two continents deserve more detailed investigation.

We reclassify the countries of origin not by geographical location but by cultural or religious characteristics in order to gain further insights into the gender differences in car licence holding. This analysis is presented in Section 3.1.3.

Table 3: Differences in Licence Holding by Country of Origin (Individuals Aged 16+)

Country of origin	1991*			1999–2007		
	Rate Difference (male – female)	Fraction of Population	Proportion over 60	Rate Difference (male – female)	Fraction of Population	Proportion over 60
Australia, New Zealand	13.0%	67.0%	22%	6.7%	67.1%	20.3%
North America	4.9%	0.5%	9%	2.3%	0.9%	12.0%
Northern/Western Europe	20.0%	11.3%	26%	10.7%	8.4%	32.6%
Eastern Europe	31.3%	3.1%	31%	24.6%	1.5%	45.0%
Southern Europe	43.6%	4.0%	30%	31.6%	4.7%	47.8%
Africa	32.9%	0.5%	14%	12.9%	1.9%	18.7%
South America	28.7%	1.0%	8%	22.1%	0.9%	19.9%
Asia	28.8%	11.5%	10%	19.6%	14.6%	12.3%
Total (inc. unknown**)	15.9%	100.0%	n/a	10.6%	100.0%	22.6%

* Footnote 1: Figures for 1991 were taken from Further Estimation Report 9009-3B (HCG, 2000)

** Footnote 2: in 1999–2007, 11.4 per cent of the individuals aged 16+ have missing country of origin data. We note that the adult definition used here, 16+, is slightly different from the recommended adult definition, which is 17+.

2.3 Disaggregate Licence Holding

This section discusses the second of the two main components of the licence-holding model, the disaggregate model. The disaggregate licence-holding model consists of two sub-models. The first sub-model predicts the licence-holding status of the head of household and, if he/she has a partner, the licence-holding status of the partner. The second sub-model applies when there are three or more adults in household and predicts the licence-holding status of each of the remaining adults in the household. This is the approach that was developed during the Stage 1 estimation work. This structure is selected because tests in the development of the previous model had shown that the licence holding of the first two adults was correlated.

The first sub-model predicts the probability of four possible states:

(i) Neither the household head nor their partner has a licence

(ii) Household head has a licence

(iii) Partner of household head has a licence

(iv) Both household head and partner have licences.

The observed choice percentages for single adult and couple households are presented in Table 4. These two groups are distinguished as states (iii) and (iv) are not possible for single adult households.

Table 4: Head and Partner Licence Model Observed Choice Percentages

	Single adult	Couples
Neither have licence	26.7%	3.6%
Head has licence	73.3%	10.9%
Partner has licence		7.1%
Both have licences		78.4%
Total	100.0%	100.0%

The second model applies to each additional adult individually, so it has only two possible states:

(i) Has a licence (71.0 per cent)

(ii) Does not have a licence (29.0 per cent).

2.3.1 Identifying Household Head and Partner

Given the underlying assumption that the licence holding of the household head and his/her partner is determined jointly, the procedure to identify these two people in the household is crucial. In the licence-holding model estimated during the Stage 1 work, the first two records of the household were taken as the household head and partner. There is no strong reason why this approach would identify the true household head and partner, as the HTS survey form simply asks 'Who are the people who usually live here, starting with you?'. Thus, the first record is the person who responded to the survey interviewer, i.e. probably the adult most conveniently available at the time the interviewer called.

An alternative approach, which is more consistent with sociology literature, is to define the household head based on an individual's income, working status, age, and gender. With the available data from the HTS, it is possible to identify the household head based on income. However, the necessary data for identifying the partner is not available, as the HTS data only collect information on individuals' relation to person 1. In fact, the problem of not being able to identify the partner of the household head was the reason why the simple approach was adopted in the Stage 1 model.

In summary, the options available are: (i) use the first two records; and (ii) use Person 1 and partner. These two options were investigated further.

Firstly, we look at how well option (i) performs in terms of capturing the highest earner. In the HTS, income is reported in 10 different income bands (matching Census categories), and the 'highest earner' is defined as the person who is in the highest income band of the household. Sometimes, it is not possible to be unequivocal about which person definitively has the highest income if multiple people from the household are in the same income category and this category is the highest for the household. But, as far as the model is concerned, the approach performs well as long as the highest earner is captured as either the head of household or the partner. Therefore, the issue of having 'ties' (i.e. multiple people from the household are in the same income category and this category is the highest) is only a problem for households with three or more adults. Therefore, our analysis gives particular focus on households with three or more adults. In case of ties, we treat all of them as 'highest earners'. We found that option (i) captures 94.5 per cent of the highest earners in all households and 74.1 per cent of the highest earners in households with three or more adults (Table 5).

Table 5: Highest Earner and Person Number (full response households only)

Person no.	Proportion of highest earner in all households	Proportion of highest earner in 3+ adult households
1	57.0%	36.1%
2	37.5%	38.1%
3	4.0%	19.3%
4	1.1%	5.0%
5	0.2%	1.1%
6	0.1%	0.3%
7	0.0%	0.1%
8	0.0%	0.1%
9	0.0%	0.0%
10	0.0%	0.0%
11	0.0%	0.0%

Secondly, we look at how well option (i) performs in terms of capturing the partner/spouse. For those households where a partner/spouse exists, this person is person number 2 in 98.7 per cent of cases (Table 5). This is true 96.3 per cent of the time even when we consider only households with three or more adults (Table 6). Additionally, we note that about a quarter of the households with three or more adults do not contain any partner or spouse. This is not an issue for option (i), but it is a problem for option (ii) where we need to define a 'partner' for the purposes of the model.

Option (ii) captures the relation between the two selected individuals well by default. Therefore, we look at how well it captures the highest earner (Table 7). The proportion of highest earners recorded as Person 1 and partner is 90.1 per cent overall, but only 67.4 per cent if only households with three or more adults are considered.

Therefore, Option (i) is superior to Option (ii) in terms of capturing income, and at the same time it captures the partnership quite well. Moreover, Option (i) has the advantage of being consistent with the previous model. Thus, Option (i) is the approach that has been adopted in this re-estimation work for identifying the household head and his/her partner.

Table 6: Relation to Person 1 by Person Number (full response households only)

Person no.	Absolute values self	Absolute values spouse/ partner	Absolute values Other	Proportion self	Proportion spouse/ partner	Proportion other
1	25,281	0	0	100.0%	0.0%	0.0%
2	0	15,504	3,069	0.0%	98.7%	29.5%
3	0	125	4,641	0.0%	0.8%	44.6%
4	0	48	1,903	0.0%	0.3%	18.3%
5	0	15	555	0.0%	0.1%	5.3%
6	0	7	159	0.0%	0.0%	1.5%
7	0	2	47	0.0%	0.0%	0.5%
8	0	2	16	0.0%	0.0%	0.2%
9	0	0	2	0.0%	0.0%	0.0%
10	0	0	3	0.0%	0.0%	0.0%
11	0	0	1	0.0%	0.0%	0.0%
	25,281	15,703	10,396	100%	100%	100%

Table 7: Relation to Person 1 by Person Number (3+ adults full response households only)

Person no.	Absolute values self	Absolute values spouse/ partner	Absolute values other	Proportion self	Proportion spouse/ partner	Proportion other
1	4,963	0	0	100.0%	0.0%	0.0%
2	0	3,604	1,311	0.0%	96.3%	15.3%
3	0	86	4,610	0.0%	2.3%	53.7%
4	0	30	1,891	0.0%	0.8%	22.0%
5	0	12	552	0.0%	0.3%	6.4%
6	0	6	158	0.0%	0.2%	1.8%
7	0	2	47	0.0%	0.1%	0.5%
8	0	2	16	0.0%	0.1%	0.2%
9	0	0	2	0.0%	0.0%	0.0%
10	0	0	3	0.0%	0.0%	0.0%
11	0	0	1	0.0%	0.0%	0.0%
	4,963	3,742	8,591	100%	100%	100%

Table 8: Proportion of Highest Earners Recorded as Person 1, Partner or Other

	All full response households	All 3+ adults full response households
self	57.0%	36.1%
partner/spouse	33.1%	31.3%
other	9.9%	32.7%

2.4 Car Ownership

The car ownership model consists of two linked models, reflecting household ownership of company cars and total cars respectively. This model structure is a result of a number of tests performed in the Stage 1 model development, which indicated that the number of household cars was dependent on the number of company cars in the household (HCG, 2000). The same model structure is also used in the UK national car ownership model (Whelan, 2001).

The HTS data categorises vehicle ownership into four different classes:

(i) Household

(ii) Company

(iii) Other (e.g. owned by a non-household member, such as an individual's parents)

(iv) Unknown or missing.

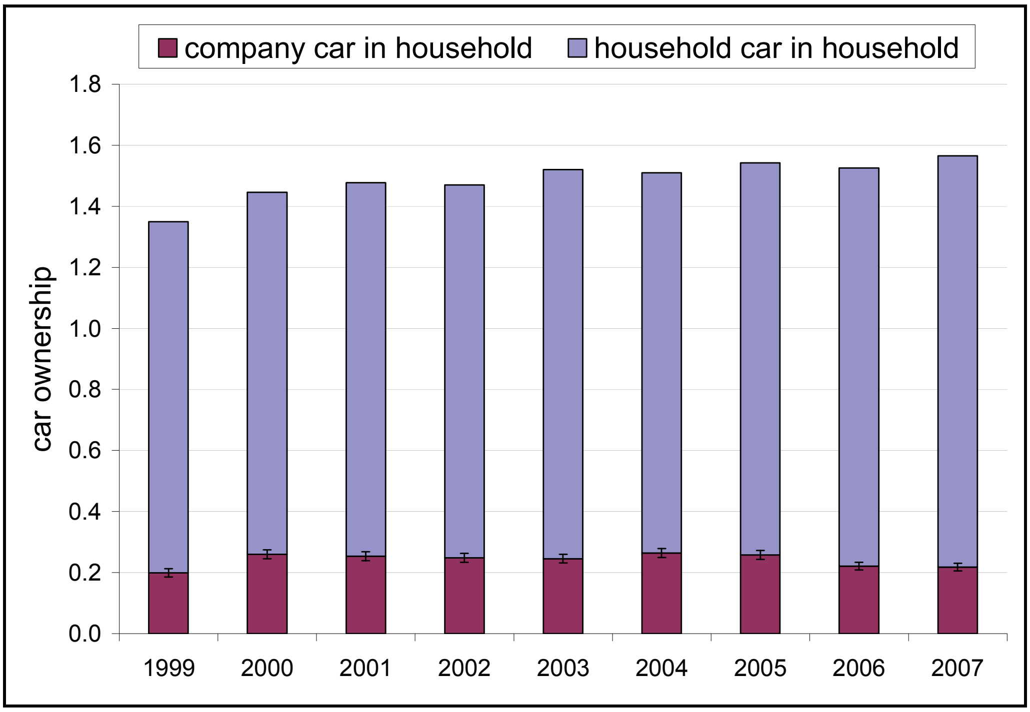
While it is clear that it is necessary to distinguish between household car and company car, the best treatment of 'other', 'unknown' and 'missing' ownership classes are less clear. We propose merging these classes with the 'household" cars in the model, as we judge that the inclusion of these vehicles would provide a better representation of car availability, which is important for the modelling of mode and destination choice in subsequent stages. Additionally, we note that vehicles not garaged at the household[2] have been excluded.

Figure 2 shows the ownership level of company cars and household cars (including those with ownership class as 'other', 'unknown" or 'missing') by household survey wave. The figure illustrates that total ownership has increased steadily over time, from 1.35 cars per household in 1999 to 1.57 cars per household in 2007. This is despite a minor decrease in household size from 2.73 in 1999 to 2.66 in 2008 (TDC, 2009). In the last round of model development in 1999, it was found that changes over time in income and in licence-holding explained a large part of the observed time trend, but 'it could not be established clearly that these two effects accounted for all of the long-term changes in car ownership'. Thus, it was necessary to include a 'trend term' in the model to indicate whether the long-term trend effect has been fully accounted for.

Additionally, we note that there is some fluctuation across time in the ownership level of company cars. Therefore, we also show the confidence limits for the level of company car ownership in Figure 2. The confidence limits are very narrow, around 0.01 cars per household, due to the large size of the sample. This confirms that the fluctuation over time observed is not random. However, the fluctuation is likely to be due to changes in economic activity and tax policies rather than a long-term trend. That is, the trend observed in total car ownership is driven primarily by increases in household cars.

[2] The HTS uses vehicle_no. codes greater than 20 to represent vehicles non-household vehicles that people travel in on the survey day. These are typically work pool cars or those of neighbours and friends.

Figure 2: Average Car Ownership Level by Wave



Note: 'household car' includes those HTS records with ownership status as 'other', 'unknown' or 'missing', as we judge that the inclusion of these vehicles provides a better representation of car availability, which is important for the modelling of mode and destination choice in subsequent stages. The proportion of vehicles in the HTC that has ownership status coded as 'other' is 5 per cent and the proportion that has ownership status coded as 'unknown' or 'missing' is 3 per cent.

2.5 Conclusions from Analysis

A number of conclusions were taken from this analysis.

We first confirmed that our new analysis on licence holding rates is consistent with previous calculations.

We have then clarified the definition of licence holders as including both provisional and full licence holders. As people with learner licences cannot drive a car without the supervision of someone with a full licence, they are considered as non-licensed.

We observe different licence holding rates between men and women, and note that this difference has decreased over time, for both those who are Australian-born and immigrants.

Additionally, we have illustrated that the difference in licence holding between men and women is strongly dependent on their continent of origin.

Further, for the disaggregate licence-holding model, we have explored an alternative approach for identifying the household head and partner and have found that the existing approach performs better. Therefore, we conclude that the definition of head and partner adopted in the Stage 1 work should be retained for this re-estimation work.

Finally, for the car ownership models, we found no clear trends in company car ownership, but noted that the trend in household car ownership and its relation with income growth and other factors, like licence holding, needs to be investigated further.

CHAPTER 3 Licence-Holding Models

The licence-holding model in the STM comprises two components: the cohort projection spreadsheet, which calculates the study-area-wide licence holding levels for 32 age-sex cohorts; and the disaggregate licence-holding models, which predict the probabilities of licence holding for each adult in the household. This chapter discusses the re-estimation of each component in turn.

3.1 Cohort Projection Spreadsheet

The cohort projection spreadsheet was created during Stage 1 of the model development for the Sydney Strategic model (described in HCG (2000)), and was later updated to a 2001 base in Stage 2 (reported in RAND Europe (2004)). The main idea underlying the cohort approach for licence holding is that individuals acquire driving licences only once in their lifetime and few people ever give up licences, therefore the level of licence holding for a given age-sex cohort changes only marginally over time. Thus, the predicted licence-holding rates for a given age-sex cohort can be estimated by taking the licence holding in the past, and adjusting it with a small positive change to represent new licence acquisition and a small negative change to represent loss.

In the current work, while the fundamental equations that drive the spreadsheet are largely unchanged, the source data of the spreadsheet are updated to a 2006 base year. Additionally, detailed changes have been made to some of the formulae, as detailed in this chapter. Specifically, the key updates are:

- The base year of the cohort projection spreadsheet has been changed from 2001 to 2006 and the forecast year is extended to 2041.
- An additional cohort has been added to distinguish between those aged 85-90 and 90+.
- The '2001' data have been updated to include four waves of data in order to increase the statistical reliability of the results.
- The treatment of migrants is revised to reflect more recent thinking and data.

The revised version of the spreadsheet is: lic_proj_2006_base_v9.xls, dated 04/09/2009.

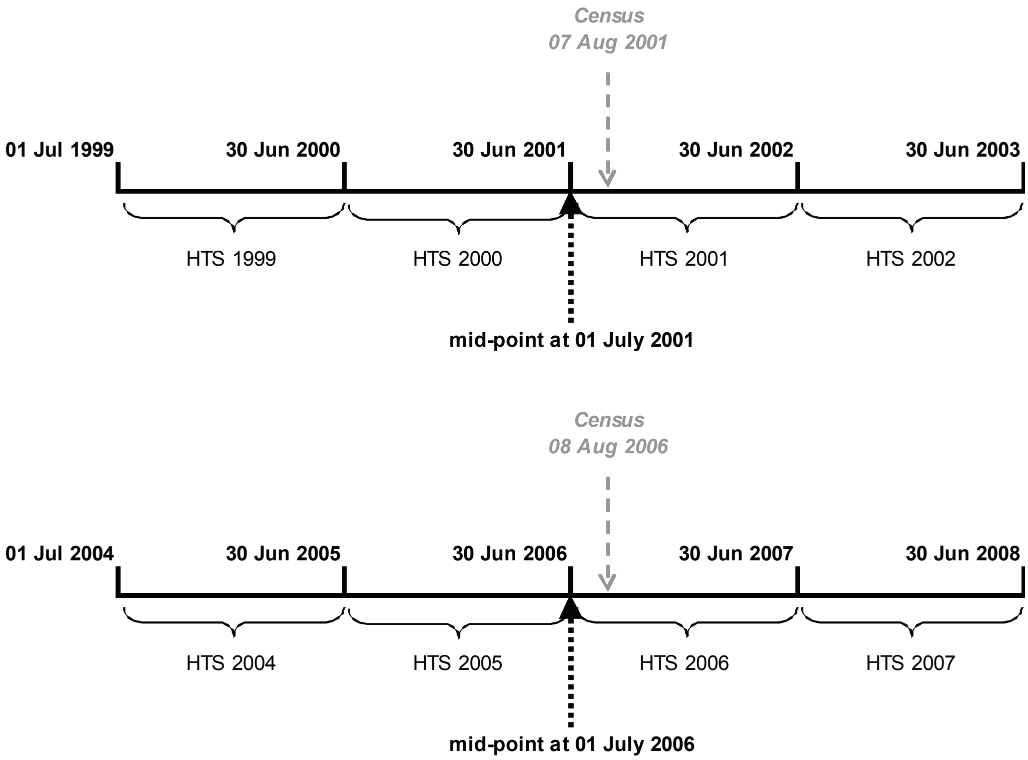
3.1.1 Data

In this work we have used four waves of HTS data, covering the period between the beginning of July 2004 and the end of June 2008, to represent the situation in 2006.

These four waves give a mid-point of June 2006, with two two-year periods either side (Figure 3). A major advantage of including multiple waves of data instead of just a single year is that the sample size is maximised, and therefore the licence-holding rates calculated from the sample are more statistically reliable.

For the same reason, we have also updated the data for the 2001 base using four waves of data, i.e. HTS 1999–2002; only two waves of data were used in the previous analyses.

Figure 3: Four Waves of HTS Data used for each Period



It can be seen in the diagram that the mid-point for each of the two data periods is close to the census date, so that any error in using census data for total population estimates should be small.

3.1.2 The Model

The basic model is that the licence holding for a cohort is equal to the licence holding of the same cohort in the previous time period, plus net acquisitions (acquisitions minus losses) that have happened meanwhile. Because acquisitions are much more common than losses, the rate is expressed as a fraction of the numbers who did not hold licences in the previous period, but could do so. This formulation ensures that licence holding can never exceed the saturation level. As in the previous version of the model the fundamental formula is:

$$P_{c,t} = P_{c,t-1} + A_c\left(S - P_{c,t-1}\right) \qquad (3.1)$$

where $P_{c,t}$ is the licence-holding fraction for cohort (defined by birth date) c at time t, expressed in five-year steps, i.e. if t refers to 2006, then $t-1$ refers to 2001

A_c is the net acquisition rate for cohort c, assumed not to change over time

S is the saturation level, i.e. the maximum possible level of licence holding, given some individuals will never acquire licences.

For older people, currently defined to be those over 60, the number of licences lost is greater than the number acquired, so that the change is more appropriately calculated based on the number of people who currently have licences, rather than those who might still acquire them. This gives a model

$$P_{c,t} = P_{c,t-1}\left(1 + L_c\right) \tag{3.2}$$

where L_c is the net rate of *gain* of licences, i.e. $L_c < 0$

For younger people, those under 25, the assumption is that licence holding will be similar to that of the *previous cohort*, but again may move towards the saturation level. The equation used is

$$P_{c,t} = P_{c-1,t-1} + A_c\left(S - P_{c-1,t-1}\right) \tag{3.3}$$

which may be compared with the standard equation.

However, in recent years it appears that the rate of licence holding is declining among young people. Evidence is not available to predict whether these rates will decline further in the future, and so it is currently assumed that these age groups will have the same licence holding in future as at present. This assumption could be revised if new evidence becomes available.

The model calculates the licence acquisition or loss rates in five-year step by the 32 age-sex-cohorts (Table 9 a and b). The acquisition or loss rates are calculated based on these formulae:

Young people (17–24): $A_c = k/n * (P_{c,t} – P_{c-1,t-1}) / (S – P_{c-1,t-1})$ (3.4)

Main working age people (25-59): $A_c = k/n * (P_{c,t} – P_{c,t-1}) / (S – P_{c,t-1})$ (3.5)

Older people: $L_c = k/n * (P_{c,t} – P_{c,t-1}) / P_{c,t-1}$ (3.6)

where

k represents the age difference of successive cohorts in years, i.e. 5[3]

n represents the time interval in years between two sets of observed data; i.e. for the observations in 2001 and 2006, n = 5

$P_{c,t}$ represents the licence-holding rates, i.e. proportion of the population with a licence, for a particular age-sex cohort (c) at time (t)

[3] For the first two cohorts, the cohort age difference is not relevant, as these values are set for the age group without application of the cohort model. The value k = 5 is nevertheless used for those cohorts so that the rates of change represent those for a standard interval of five years. For the last cohort, the value k = 5 is also used, effectively assuming that those aged over 95 have the same licence holding as those aged 90–95; the small numbers involved justify the simplification.

S represents the saturation level for licence holding, which is assumed to be 0.98

Table 9: Licence Acquisition and Loss Rates, 2001 and 2006

(a) Males

Cohort	Age	% of population with licence		Licence penetration		A_c or L_c	
		2001	2006	2001	2006	weighted by year	Final
1	17–19	61.5%	56.2%	0.0011	-0.1450	-0.1576	0.0000
2	20–24	85.3%	81.3%	-0.2511	-0.3118	-0.2083	0.0000
3	25–29	88.6%	86.4%	0.3628	0.0845	0.2472	0.0966
4	30–34	94.2%	91.5%	0.2658	0.3029	0.2998	0.0966
5	35–39	95.5%	95.0%	0.2795	0.2225	0.2645	0.0966
6	40–44	95.3%	94.7%	0.0217	-0.3316	-0.0644	0.0966
7	45–49	95.2%	95.1%	-0.0771	-0.0703	0.0045	0.0966
8	50–54	95.3%	96.1%	-0.2837	0.3093	0.0382	0.0966
9	55–59	96.2%	94.9%	-0.0909	-0.1435	-0.1277	0.0966
10	60–64	92.9%	94.7%	-0.0101	-0.0156	-0.0137	-0.0137
11	65–69	90.5%	91.6%	-0.0024	-0.0147	-0.0060	-0.0060
12	70–74	88.2%	85.2%	0.0033	-0.0576	-0.0227	-0.0227
13	75–79	82.0%	85.2%	-0.0205	-0.0338	-0.0254	-0.0254
14	80–84	72.1%	77.3%	-0.0518	-0.0579	-0.0563	-0.0563
15	85–90	39.0%	44.4%	-0.2300	-0.3846	-0.2899	-0.2899
16	90+	32.1%	18.9%	-0.2238	-0.5153	-0.3397	-0.3397

(b) Females

Cohort	Age	% of population with licence		Licence penetration		A_c or L_c	
		2001	2006	2001	2006	weighted by year	Final
1	17–19	48.1%	46.2%	-0.0593	-0.0385	-0.0682	0.0000
2	20–24	78.3%	73.4%	-0.0990	-0.2469	-0.0987	0.0000
3	25–29	83.6%	81.6%	0.3296	0.1669	0.2565	0.2565
4	30–34	87.2%	88.7%	0.1658	0.3536	0.2651	0.2651
5	35–39	89.1%	89.7%	0.1881	0.2306	0.2101	0.2101
6	40–44	89.3%	92.7%	0.1231	0.4082	0.2270	0.2270
7	45–49	90.0%	89.4%	0.1516	0.0062	0.0835	0.0835
8	50–54	84.3%	88.3%	-0.0032	-0.2106	-0.0789	-0.0468
9	55–59	79.7%	85.2%	-0.0829	0.0642	-0.0106	-0.0468
10	60–64	72.0%	79.6%	-0.0225	-0.0016	-0.0039	-0.0039
11	65–69	63.4%	69.8%	-0.0146	-0.0301	-0.0186	-0.0186
12	70–74	55.5%	61.5%	-0.0573	-0.0300	-0.0433	-0.0433
13	75–79	48.5%	56.2%	-0.0429	0.0122	-0.0129	-0.0129
14	80–84	31.6%	38.2%	-0.0957	-0.2132	-0.1684	-0.1684
15	85–90	13.9%	20.2%	-0.2646	-0.3612	-0.3316	-0.3316
16	90+	6.0%	5.9%	-0.2770	-0.5747	-0.4220	-0.4220

Information is available about the rates of change of licence holding over a long period, as we have data going back to 1971 (although only 2001 and 2006 are shown in Table 9). The rates of change in licence holding are therefore calculated as a weighted average of the changes that have been observed. The weights used in those calculations represent a judgement of the appropriate balance between the reliability and age of the data and its ability to pick up long-term trends. The weights employed for the observed changes are:

1971 to 1981	0
1981 to 1991	0.5
1991 to 2001	1.0
2001 to 2006	1.0

Using these weighted averages gives quite reliable and stable rates of change. Nevertheless, we observed negative acquisition rates for a few of the middle age cohorts, including 40–44 males, 55–59 males, 50–54 females and 55–59 females (again see Table 9 a and b). A potential explanation to the problem is random fluctuations in the licence-holding rates ($P_{c,t}$). Given the sample size of each of the age-sex cohorts is approximately 1,000, increased to effectively 2,500 by the averaging process, and the percentage of the population with a licence is about 89 per cent; the error is about ½ per cent,[4] implying a potential error margin in the acquisition rate of ±0.045 (=0.005/(1-0.89)). This is not quite enough to explain the fluctuations in acquisition rates that are observed but we have anyway applied a smoothing to the male acquisition rates, setting them equal for all the cohorts for ages 25–60. For the female rates, given that the negative values affect the older part of the working-age population, the negative values were retained, but set equal for the cohorts 50–54 and 55–59 as without this change the younger cohort was losing licences more quickly than the older.

The licence acquisition rates for the older people (60 or over) are expected to be negative, in order to represent loss of licences due to medical conditions that impair a person's ability to drive safely (typically related to old age). The acquisition rates for the older people did not require adjustment.

3.1.3 Migrant Rates

Table 10 shows the rates of licence holding separately for migrants and those born in Australia (labelled as 'Australian-born') for the cohorts aged from 20 to 50 and for the years 1991 and four waves of HTS around 2006. Table 10 shows clearly that licence-holding rates among migrants are lower in both 1991 and 2006, both for men on average and for women in all cohorts, than for those born in Australia in these age groups

The analysis shows substantial differences in licence-holding rates between Australian-born residents and migrants. Additionally, there are substantial changes between 1991 (i.e. the data used for the migration analysis in the previous implementation) and 2006 (i.e. the current implementation based on HTS 2004–2007). The biggest differences are observed in the younger age groups (20–29). This may be explained by the general trend of delaying licence acquisition for young people. For the other male cohorts we also observe a decline in licence-holding rates among immigrants, perhaps caused by migration from different

[4] Based on a confidence level of 95 per cent, the error margin in each direction is calculated as $1.96 * \sqrt{0.89 * (1-0.89)} / 2500 = 0.0054$.

countries, and small declines among Australians. Similarly for females, we observe a decrease in licence-holding rates for younger people (20–29). But for other female cohorts, the HTS 2004–2007 licence-holding rates are higher than the previous rates, for both immigrants and those born in Australia. These results reflect the general increase over time in the licence-holding rates for females aged over 30.

Additionally, it is important to note that there is another factor, the change in study area, which may impact licence-holding rates. In the current work, the study area is broadened to cover more rural and longer established areas, in which the average licence-holding rate is higher than the urban areas covered by the 1991 data. Statistics for the wider area are not available to us for analysis for 1991.

Table 10: Migrant and Non-Migrant Licence-Holding Rates

(a) Males

Age	1991		2006		Difference	
	Migrants	Australian-born	Migrants	Australian-born	Migrants	Australian-born
20–24	0.831	0.914	0.702	0.851	-13%	-6%
25–29	0.872	0.946	0.776	0.906	-10%	-4%
30–34	0.935	0.963	0.877	0.935	-6%	-3%
35–39	0.952	0.959	0.934	0.96	-2%	0%
40–44	0.964	0.963	0.935	0.955	-3%	-1%
45–49	0.976	0.956	0.958	0.947	-2%	-1%

(b) Females

Age	1991		2006		Difference	
	Migrants	Australian-born	Migrants	Australian-born	Migrants	Australian-born
20–24	0.643	0.870	0.571	0.792	-7%	-8%
25–29	0.692	0.904	0.678	0.885	-1%	-2%
30–34	0.764	0.921	0.801	0.933	4%	1%
35–39	0.777	0.920	0.833	0.935	6%	2%
40–44	0.730	0.920	0.868	0.965	14%	4%
45–49	0.680	0.917	0.818	0.945	14%	3%

With regard to the licence-holding for migrants, a brief analysis was made of the country of birth of Asian migrants to see whether any cultural or religious trends could be determined that might affect licence holding and in particular the difference between male and female licence holding. We subdivided the 60 Asian countries into two groups, (i) where Islam is the primary religion (28 countries) and (ii) countries with other primary religions. However, despite a detailed study, no significant effects were found. For both country groups, the differences between male and female licence holding are 20 per cent.

Another possible subdivision of migrants would be to compare those from Western countries (New Zealand, Western Europe, North America) with other migrants. However, the differences in licence holding between those groups of countries are confounded with the age of the people concerned, western European migrants often being older than other migrants, while the numbers are quite small in some cases.

It was concluded that any subdivision of migrants would be of limited value, while an amendment to the model and the spreadsheet implementation would be costly. Therefore treatment of migrants as a single group, as per the Stage 1 analysis, was maintained.

While the HTS tells us that about 36 per cent of the population are migrants from outside Australia, it does not indicate how long people have been in Australia. Therefore, information is required on migration *rates*. Specifically, for any five-year period in the forecasting period, we need to know how many new migrants there will be and how these are distributed over the cohorts. We focus on the age groups from 25 to 50, as these are the key migration ages, while young people up to 25 can be assumed to adapt very quickly to Australian patterns.

Migration rates are taken from a report from the Australian Bureau of Statistics[5] (ABS) mainly focusing on 2006–2007 migration, which was the largest volume ever recorded and amounted to 0.9 per cent of the current population for both Australia as a whole and for New South Wales. It seems reasonable to use the NSW rates as applicable to the Sydney area.

What we require for the licence model is the migration rates, as a fraction of the resident population, separately for men and women and separately for each of the five cohorts from 25 to 50. These cohorts comprise about 45 per cent of total net migration, while around 2.5 per cent only are older people and more than half are younger, including many students. The ABS report indicates (Table 4.2) that the sex ratio of migrants to NSW was 100.0 men per 100 women, so we shall assume that the rates are equal for men and women (the resident population is also roughly equally divided between men and women in those age groups).

Figure 4.1 in the ABS report (referenced in footnote 5) gives the age distribution for 2006–2007 migration, while Figure 3.2 gives the same information for 2005–2006 migration. These are presented in Table 11, using readings taken from the figure made by eye. These are figures for Australia, not just the greater Sydney area. In the absence of better data, we assume the age distribution in the greater Sydney area to be similar to Australia. Table 11 shows the proportion of migrants in each age group, derived from the report. This is compared with the proportion of the population in the cohorts, taken from HTS. We can then calculate the migration rate specific to the cohort per five-year period.

Table 11: Migration Rates

Age group	Prop. of migrants	Prop. of population	Migration rate per 5 years
25–29	15.7%	7.8%	8.0%
30–34	11.7%	9.7%	4.8%
35–39	8.5%	11.0%	3.1%
40–44	6.3%	10.9%	2.3%
45–49	2.5%	10.0%	1.0%
Total	44.7%	49.4%	4.0%

These rates are applied for all forecast periods for both men and women.

[5] Report 3142.0, *Migration*, 26 March 2008, Australian Bureau of Statistics, Canberra.

3.1.4 Licence Projections

To demonstrate the operation of the cohort model, licence projections have been calculated to 2041 and compared to the 2004–2007 HTS data that represents the 2006 base year. These comparisons are presented in Figure 4 and Figure 5.

Figure 4: Male Licence Holding by Cohort

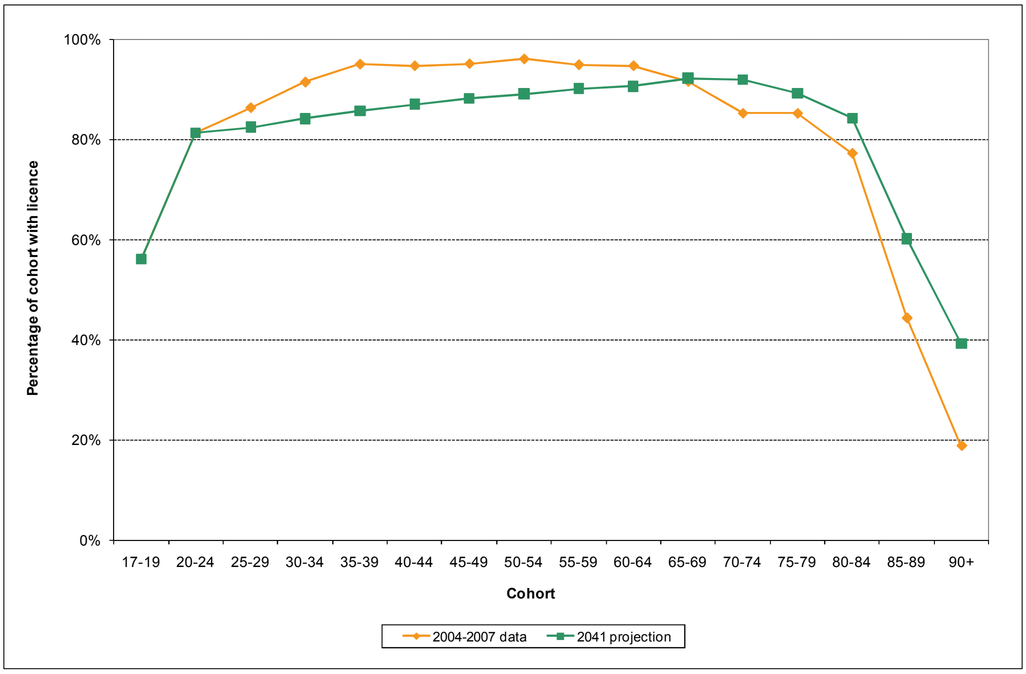
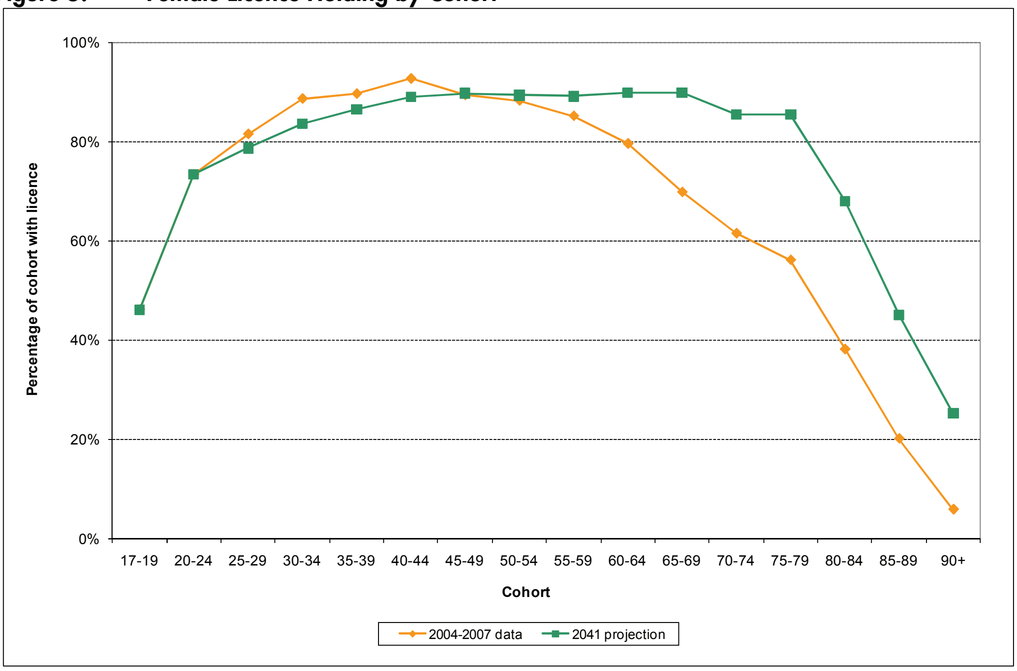


Figure 5: Female Licence Holding by Cohort



Comparing the 2004–2007 data and the 2041 projections for males, we see that up to cohort 10 (age 60–64) licence-holding rates are projected to be lower than at present. This is due to a combination of the recent trend for individuals in the early year cohorts to acquire licences more slowly, and also the higher fraction of migrants in the 2041 population combined with the lower licence-holding rates of migrants. The recent trend for individuals aged under 35 to delay licence acquisition is discussed further in Raimond and Milthorpe (2010). For persons aged 65+, higher licence holding is projected due to the cohort effect of individuals retaining licences well into retirement. Licence holding falls off rapidly at cohort 15 (aged 85+), presumably as individuals give up licences due to deteriorating health.

For females, we also observe the effect of slower licence acquisition in the early cohorts in the 2041 projections, but the differences are not as large as observed for males. For cohort 7 and above (aged 45+) female licence holding is projected to be higher than in 2004–2007, and in particular the overall shape of the licence-holding curve is much closer to that for males as females maintain high levels of licence holding into old age.

3.2 Disaggregate Licence-Holding Model

This section discusses the second of the two main components of the licence-holding model: the disaggregate choice model. The disaggregate licence-holding model consists of two sub-models. The first sub-model predicts the licence holding of the head of household, who is defined to be the first adult contacted[6] and, if he/she has a partner, the licence holding of the partner, who is assumed to be the second adult recorded in the survey form. The second sub-model applies when there are three or more adults in a household and predicts the licence holding of each of the remaining adults in the household after the head and partner.

Our approach to this new round of re-estimation work was to first re-estimate the model with the new waves of data (1999–2007) using the existing model specification. We then investigated different model specifications in order to arrive at a recommended model. The estimation results are presented and discussed below. Prices in the recommended model are in 2006 prices.

3.2.1 Head of Household and Partner Model

The first sub-model predicts the probability of four possible states:

(i) Neither the household head or the partner has a licence

(ii) Household head has a licence

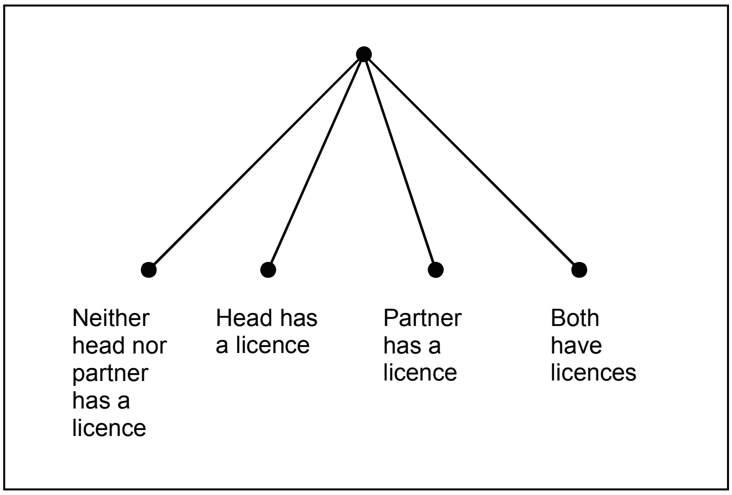
(iii) Partner of household head has a licence

(iv) Both household head and partner have licences.

The model structure is illustrated in Figure 6.

[6] The head of household and partner are defined as set out in the previous chapter.

Figure 6: Choice Structure of Head and Partner Model



There are a total number of 25 parameters in the recommended model. A concise summary of the model parameters is presented in Table 12, including the parameter sign, and whether the variable is newly identified, or was present in the original Stage 1 model. A number of parameters identified in the Stage 1 model were dropped, as they were no longer significant. These are discussed in the text below the tables.

Table 12: Parameters in the Recommended Head and Partner Licence Model

Term	Sign	New?	Definition	Which alternative?		
				head	partner	both
Headlic	+		head of household only alternative specific constants (ASC)[7]	x		
Partlic	+		partner only ASC		x	
Bothlic	+		both head & partner ASC			x
HdHHInc	+		household income term for head of household	x		x
PtHHInc	+		household income term for partner		x	x
Hd>70yrs	–		head of household over 70 (as a continuous variable multiplied by years over 70)	x		x
Pt>70yrs	–		partner over 70 (as a continuous variable multiplied by years over 70)		x	x
Hd<35yrs	–	New	head of household under 35 (as a continuous variable multiplied by years under 35)	x		x
Pt<35yrs	–	New	partner under 35 (as a continuous variable multiplied by years under 35)		x	x
HeadFtTm	+		full-time workers term for head of household	x		x
PartFtTm	+		full-time workers term for partner		x	x

[7] The base for the constants is neither head nor partner has a licence.

Term	Sign	New?	Definition	Which alternative?		
				head	partner	both
HeadPtTm	+		part time workers term for head of household	x		x
PartPtTm	+		part time workers term for partner		x	x
HdOthwrk	+	New	other workers term for head of household	x		x
PtOthwrk	+	New	other workers term for partner		x	x
FemaleHD	–		female head of the household term	x		x
FemalePt	–		female partner term			x
FemPtAlt	–	New	Female partner term applied to the 'only the partner has a licence' alternative		x	
HdChilds	+		number of children term applied to head of household	x		x
PtChilds	+		number of children term applied to partner		x	x
HdAdults	–		number of adults term applied to head of household	x		x
Hdmarried	+	New	married couple in household term applied to head of household	x		x
Ptmarried	+	New	married couple in household term applied to partner		x	x
HeadAus	+	New	head of household was born in Australia	x		x
PartAus	+	New	partner was born in Australia		x	x

Further, Table 13 below shows the parameters values, and associated t-ratios, for the model developed in Stage 1 (hereafter referred to as the 'Stage 1 model'), the re-estimation of the Stage 1 model specification with new data (the 're-estimated model') and the new model with an improved specification (the 'recommended model').

Table 13: Head and Partner Licence Model Parameters (detailed)

	Stage I model	Re-estimated model	Recommended Model	% difference from Stage 1	
				Re-estimated model	Recomm-ended Model
File	HPPR15V7	HPPR_2006 base_V4	HPPR_2006 base_V17		
Obs	13904	25098	25098		
Final log (L)	-9146.1	-14354.6	-13755.2		
D.O.F.	22	20	25		
Rho²(c)	0.278	0.334	0.362		
Estimated	14-Dec-99	04-Nov-09	11-Nov-09		
Constants					
Headlic	1.638 (16.4)	1.515 (24.8)	0.9155 (13.2)	-8%	-44%
Partlic	1.666 (11.8)	1.260 (11.0)	0.5365 (6.3)	-24%	-68%
Bothlic	4.175 (25.7)	3.578 (29.2)	1.762 (16.7)	-14%	-58%
Income					
HdHHInc	0.01339 (9.6)	0.00938 (15.0)	0.00895 (14.2)	-30%	-33%
PtHHInc	0.01857 (15.9)	0.00841 (14.1)	0.00794 (13.6)	-55%	-57%
Age-related					
Hd<25yrs	-0.1857 (-6.8)	-0.2558 (-14.7)		38%	n/a
Pt<25yrs	-0.1662 (-9.1)	-0.2776 (-18.1)		67%	n/a
Pt>50yrs	-0.02715 (-5.6)	0.00927 (2.1)		-134%	n/a
Hd>70yrs	-0.1272 (-16.4)	-0.08772 (-18.6)	-0.1003 (-20.3)	-31%	-21%
Pt>70yrs	-0.07828 (-4.6)	-0.1408 (-12.5)	-0.1470 (-19.0)	80%	88%
Hd<35yrs			-0.08672 (-17.5)		n/a
Pt<35yrs			-0.1015 (-19.8)		n/a
Work status					
HeadFtTm	1.042 (13.6)	0.8852 (15.1)	1.053 (17.3)	-15%	1%
PartFtTm	0.5076 (6.8)	0.9447 (14.3)	1.094 (16.7)	86%	116%
HeadPtTm	0.8327 (6.2)	0.9589 (11.6)	1.049 (12.5)	15%	26%
PartPtTm	0.8156 (7.7)	1.142 (11.4)	1.136 (11.2)	40%	39%
HdOthwrk			0.6305 (8.3)		
PtOthwrk			0.6430 (6.6)		
Gender					
FemaleHd	-1.212 (-20.6)	-0.9333 (-21.2)	-0.7182 (-14.3)	-23%	-41%
FemalePt	-1.021 (-13.1)	-1.157 (-22.0)	-1.027 (-18.9)	13%	1%
FemPtAlt			-1.789 (-20.2)		
Household characteristics					
HdChilds	0.2010 (6.4)	0.1961 (7.6)	0.2130 (7.9)	-2%	6%
HdAdults	-0.2563 (-6.7)	-0.1778 (-6.3)	-0.0989 (-3.5)	-31%	-61%
PtChilds	0.1300 (4.7)	0.2048 (6.7)	0.1382 (4.7)	58%	6%
PtAdults	-0.4579 (-12.3)	-0.1910 (-5.9)		-58%	n/a
Hdmarried			0.3689 (7.3)		n/a
Ptmarried			0.6396 (11.8)		n/a

	Stage I model	Re-estimated model	Recommended Model	% difference from Stage 1	
				Re-estimated model	Recomm-ended Model
Migrant status					
HeadAus			0.6040 (14.7)		n/a
PartAus			0.8835 (17.4)		n/a
Dataset-specific					
HISHead	-0.1793 (-2.9)			n/a	n/a
HISPart	-0.2550 (-3.8)			n/a	n/a

* Note: new parameters are highlighted in grey.

There are a few significant changes between the Stage 1 model and the two new models. Notably, the magnitudes of the income parameters, *HdHHInc* and *PtHHInc*, have decreased by 33 per cent for the head of household and 57 per cent for the partner, comparing the recommended model and the Stage 1 model. Similar decreases in magnitude are also observed for the re-estimated model. A large part of this decrease can be explained by the difference in price year between the Stage 1 model and the new model (1996 in the former and 2006 in the latter). Consumer prices have increased 29 per cent during this time period (OECD, 2009). A further part of the decrease can be attributed to the decreasing importance of income over time as a differentiating factor for possessing a licence.

Additionally, there are some significant changes in the age-related parameters. For individuals between 17 and 25, the parameters estimated are negative, meaning that younger people are less likely to possess a licence. This effect has become stronger in the re-estimated model compared with the Stage 1 model, as indicated by the increased magnitude of the parameters. However, in the recommended model, the term for ages between 17 and 25 becomes statistically insignificant when a new term for 17 to 35 is introduced (see terms in grey). This means that the probability of licence holding continues to be lower after age 25 until age 35.

Similarly, for individuals older than 70 years old, the parameters estimated are negative, meaning that the older the person is, the less likely that the person possesses a licence. However, looking at how the parameter has changed between the Stage 1 model and the two new models, the results are mixed. The effect of age for people over 70 seems to have become less strong for the household head but stronger for the partner. Additionally, we note that the term for partner older than 50 has become insignificant and is excluded in the recommended model. These findings are consistent with what we have observed in the cohort model, specifically that licence holding for older women is on the rise because of cohort effects.

In terms of work status, the model indicates that the effect of the full-time work status of the partner has become much stronger, so that the full-time and part-time parameters are all now approximately equal.

A number of new variables are added to improve the model:

- Age: the variables, *Hd<35yrs* and *Pt<35yrs*, are introduced to represent those who are younger than 35. The parameters are estimated to be negative, indicating a lower probability of licence holding when compared with other age groups (i.e. aged 35–70). As discussed earlier, the introduction of these two new parameters causes the existing parameters *Hd<25yrs* and *Pt<25yrs*, which represent individuals younger than 25, to become statistically insignificant. The identification of these terms with a 35 year cut-off is consistent with the recent trend to delay licence acquisition for persons aged under 35, an issue that is discussed further in Raimond and Milthorpe (2010).
- Work status: the variables, *HdOthwrk* and *PtOthwrk*, are introduced to represent individuals who are involved in 'other work', i.e. who are not in permanent paid employment but are involved in casual work or unpaid voluntary work. The parameters are positive, indicating that those who are involved in other work have a higher probability of holding a licence (relative to those who do not work).
- Household characteristics: the variables, *Hdmarried* and *Ptmarried*, are introduced to represent individuals who are living in households where there is a married couple as reported in the HTS (this variable does not necessarily mean that the household head and the partner are married). The parameters are estimated to be positive, indicating a higher probability of holding a licence.
- Migrant status: the variables, *HeadAus* and *PartAus*, are introduced to represent whether the individual was born in Australia. The parameters are estimated to be positive, indicating that the probability of licence holding is higher for those who were born in Australia than those who migrated to Australia.
- Gender: a gender term, FemPtAlt, is added to the 'only the partner holds a licence' alternative. The resulting term is negative, indicating that female partners are less likely than male partners to have a licence if the head of the household does not have a licence. The inclusion of this parameter has greatly improved the model fit, although there is no strong theoretical reason why this should be the case.

We also report here the parameters that have become insignificant in the recommended model:

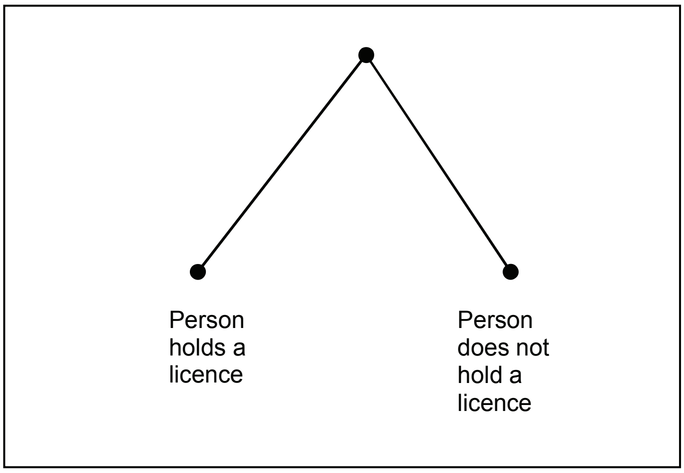
- Age-related variables: the variables *Hd<25yrs* and *Pt<25yrs,* which represent individuals younger than 25, have become insignificant due to the introduction of the variables Hd<35yrs and Pt<35yrs, which represent those who are younger than 35.
- Age-related variables: the variable Pt>50yrs, which represents partners older than 50, has become insignificant. We note that the parameter for household heads older than 50 was found to be insignificant even in Stage 1, which implies there is no strong indication in the data that people over 50 are less likely to possess a driver's licence compared with other age groups. Therefore, it is not surprising that the parameter for partners older than 50 is found to be statistically insignificant.

- Household characteristics: the variable PtAdults, which represents the number of adults in a household on the partner's licence-holding alternative, has become statistically insignificant. We note that the equivalent parameter for the household head is found to be significant, so it is not clear why this is the case. The parameter is excluded in the model purely on the basis of model fit.
- Datasets-related: the two datasets-related parameters, *HISHead* and *HISPart*, are no longer applicable in the current work, as the new model is estimated from HTS data only.

3.2.2 Other Adults Model

The second sub-model applies to cases where there are three or more adults in the household. For each of these adults, a simple binary model is developed, predicting the probability of owning a licence. Figure 7 illustrates the choice structure.

Figure 7: Structure of Other Adults Choice Model



There are a total number of 15 parameters in the recommended model. A concise summary of the model parameters is presented next (Table 14). All the terms apply to the 'person holds a licence' alternative. Prices in the recommended model are in 2006 prices.

Table 14: Parameters in the Recommended Other Adults Licence Model

Term	Sign	New?	Definition
OTAd_lic			adult licence ASC
OTHHinc	+		household income term
OTFtEmp	+		full-time employment term for adult
OTH&Pempl	–		employment term applied separately for both head of household and partner
OTnonwrk	–	new	unemployment term for adult
OTFemale	–		female adult term
OTAge<19	–	new	adult under 19 term (multiplied by age under 19)
OTAge<25	–		adult under 25 term (multiplied by age under 25)
OT25-29dum	–	new	this is a binary term, applies if the adult is aged between 25-29
OTMale>70	–		males over 70 term (multiplied by age over 70)
OTFem>50	–		females over 50 term (multiplied by age over 50)
OTHdLic	+		this term applies if head has a licence
OTPtLic	+		this term applies if partner has a licence
OTChild	–		number of children term
OTAus	+	new	this term applies if the adult was born in Australia

The table below shows the model parameters of the other adults model developed in the Stage 1 model, the re-estimation of the Stage 1 model specification with new data (the 're-estimated model') and the new model with improved specification (the 'recommended model').

Table 15: Other Adults Licence Model Parameters (detailed)

	Stage 1 model	Re-estimated model	Recommended Model	% difference from Stage 1	
				Re-est. model	Rec. Model
File	OTPR12V7	OTPR_2006 base_V1	OTPR_2006 base_V15		
Observations	4459	6576	6576		
Final log (L)	-2140	-3064.6	-2966.8		
D.O.F.	14	13	15		
Rho²(c)	0.201	0.226	0.251		
Estimated	14-Dec-99	03-Nov-09	16-Nov-09		
Constant					
OTAd_lic	-0.1033 (-0.7)	-0.2755 (-2.3)	0.00479 (0.0)	167%	-105%
Income					
OTHHInc	0.00697 (6.4)	0.00460 (8.2)	0.00407 (7.1)	-34%	-42%
Work status					
OTFtEmp	1.092 (12.5)	1.120 (14.1)	0.8236 (9.6)	3%	-25%
OTPtEmp	0.6206 (2.9)	0.4057 (3.2)		-35%	n/a
OTH&Pempl	-0.2489 (-4.1)	-0.1866 (-3.6)	-0.1450 (-2.7)	-25%	-42%
OTnonwrk			-0.6356 (-6.1)	n/a	n/a
Gender					
OTFemale	-0.4183 (-5.3)	-0.5067 (-7.6)	-0.5706 (-8.3)	21%	36%
Age-related					
OTage<19			-0.6000 (-8.7)	n/a	n/a
OTAge<25	-0.1316 (-9.3)	-0.1940 (-16.0)	-0.1582 (-7.7)	47%	20%
OT25-29dum			-0.4991 (-4.0)	n/a	n/a
Age and gender related					
OTMale>70	-0.2111 (-4.6)	-0.2189 (-8.4)	-0.1886 (-7.3)	4%	-11%
OTFem>70	-0.1650 (-1.9)	0.01079 (0.3)		-107%	n/a
OTFem>50	-0.1044 (-7.6)	-0.1124 (-10.3)	-0.09237 (-12.5)	8%	-12%
Household characteristics					
OTHdLic	0.6417 (5.4)	1.104 (11.1)	1.020 (10.2)	72%	59%
OTPtLic	0.7755 (8.4)	0.8111 (8.8)	0.6794 (7.3)	5%	-12%
OTChild	-0.1910 (-5.1)	-0.1929 (-5.1)	-0.1073 (-2.8)	1%	-44%
Migrant status					
OTAus			0.5082 (7.2)	n/a	n/a
Dataset-specific					
HISOther	0.1714 (1.9)			n/a	n/a

* Note: new parameters are highlighted in grey.

There are a few significant changes between the Stage 1 model and the two new models. Again, the magnitude of the income term *OTHHInc* has decreased, by 42 per cent. This magnitude of change is similar to what is observed for the household head and partner model, as discussed earlier in this chapter.

The magnitude of the term *OTH&Pempl*, which applies when the head of household and/or the partner is employed, has decreased by 25 per cent in the re-estimated model. It is further decreased by 17 per cent (i.e. a total of 42 per cent) when the new term *OTnonwrk* is added. This indicates a decrease in the influence of the employment of the household head and partner on the licence holding of other adults in household.

The magnitude of the term *OTFemale*, which applies when the adult is a female, has become more negative (by 36 per cent) compared with Stage 1, indicating that female adults are less likely to have licences. This is contrary to what we have observed in household head and partner model, in which the influence of gender has decreased for the household head compared with Stage 1.

However, the interactions between the licence holding of the household head and that of other adults in the household have increased, as indicated by the 59 per cent increase in magnitude in the term *OTHdLic* (between the Stage 1 model and the recommended model). Conversely, the interactions between the licence holding of the partner of the household head and that of other adults in the household have decreased slightly (by 12 per cent). As a result, while the licence holding of the partner has a slightly stronger influence on the licence holding of other adults in the Stage 1 model, this situation has reversed in the recommended model. That is, the influence of the household head's licence holding has a stronger influence on other adults' licence holding.

Additionally, a number of new variables are added to improve model fit:

- Work status related: the term *OTnonwrk*, which applies when the adult is unemployed, is introduced to the model. This term is negative, indicating a decreased probability in licence holding if the adult is unemployed. It provides a significant improvement in model fit.
- Age related: the term *OTage<19*, which enters the model as a continuous variable multiplied by years of age younger than 19, is added. This term is negative, indicating a decreased probability in licence holding for younger adults before 19. This term provides a significant improvement in model fit, and at the same time causes the adult part-time employment term *OTPtEmp* to become statistically insignificant.
- Age related: the term *OT25-29dum* applies when the adult is aged between 25 and 29, which indicates a reduced likelihood of having a licence for those aged between 25 and 29. During model development, we have tested this variable as a continuous variable multiplied by age younger than 29, but it was found to be insignificant. However, when the term is introduced to the model as a constant, it provides significant improvement in model fit.
- Migrant status: the term *OTAus* is introduced to represent whether the adult was born in Australia. The term has a positive sign, indicating that the probability of licence holding is higher for those who were born in Australia relative to those who immigrated to Australia.

We also report here the parameters that have become insignificant in the recommended model:

- Age and gender related: the term *OTFem>70*, which enters the model as a continuous variable multiplying years of age over 70 for females, has become statistically insignificant when the new data (HTS 1999–2007) was incorporated. Therefore, it is excluded from the recommended model.

- Work status: the term OTPtEmp, which applies when the adult is in part-time employment, is no longer statistically significant when the term representing adult under 19 (*OTAge<19*) is introduced.
- Datasets-related: the term *HISOther* is no longer applicable in the current work.

CHAPTER 4 Car Ownership Models

The car ownership model consists of two linked models, reflecting the ownership at the household level of company and total cars respectively. This model structure is a result of a number of tests performed in the Stage 1 model development work, which concluded that the number of household cars can be predicted dependent on the number of company cars in the household (HCG, 2000). The same model structure is also used in the UK national car ownership model (Whelan, 2001). This chapter discusses each component in turn.

HTS data from 1999–2007 were used for model development. Weekend records are used to maximise sample size, but part response households are excluded because the models include variables that are calculated by summing over the person records in the household.

4.1 Company Car Ownership Model

The company car model predicts the probability of three possible states of company car ownership at the household level for households with at least one worker:

(i) No company car

(ii) 1 company car

(iii) 2+ company cars.

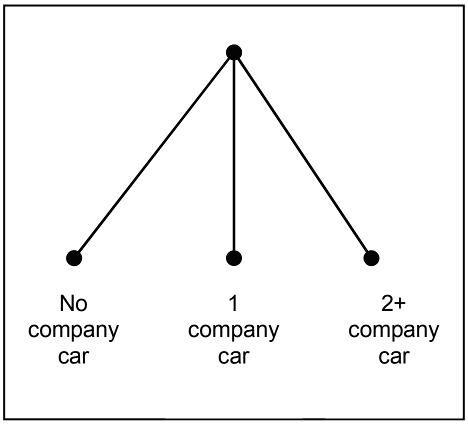
The choice proportions depend on the number of workers in the household, in particular few single worker households have 2+ company cars. The choice proportions are defined for households with given numbers of workers in Table 16.

Table 16: Company Car Choice Proportions by Number of Workers

	1 worker	2+ workers
0 comp. cars	78.5%	64.0%
1 comp. car	19.2%	27.7%
2+ comp. cars	2.3%	8.3%
Total	100.0%	100.0%

The choice structure is illustrated in Figure 8.

Figure 8: Company Car Ownership Model Choice Structure



There are a total number of 25 parameters in the recommended model. A summary of the model parameters is presented next (Table 17). Prices in the recommended model are in 2006 prices.

Table 17: Parameters in the Recommended Company Car Model

Term	Sign	New?	Definition	Which alternative?	
				1	2+
1cpcar			1 company car ASC	x	
2pcpcar			2+ company cars ASC		x
HHInc1	+		household income term for the 1 company car alternative (logarithmic)	x	
HHInc2	+		household income term for the 2+ company cars alternative (logarithmic)		x
FMHdHHCmp	–		female head of household term	x	x
D1age35	+		head of household age term for the 1 company car alternative (multiplied by [age – 35] when age > 35)	x	
D2age35	+		head of household age term for the 2+ company cars alternative (multiplied by [age – 35] when age > 35)		x
Age<29c1	–		head of household age term for the 1 company car alternative (multiplied by [29 – age] when age < 29)	x	
Age<29c2	–		head of household age term for the 2+ company cars alternative (multiplied by [29 – age] when age < 29)		x
nresident1	+	New	number of residents in household term for the 1 company car alternative	x	
nresident2	+	New	number of residents in household term for the 2+ company car alternative		x

Term	Sign	New?	Definition	Which alternative?	
				1	2+
nworkers1	+	New	number of workers in household term for the 1 company car alternative	x	
nworkers2	+	New	number of workers in household term for the 2+ company car alternative		x
nftwks=0_1	–	New	constant if household has no full time worker for the 1 company car alternative	x	
nftwks=0_2	–	New	constant if household has no full time worker for the 2+ company car alternative		x
couples1	+	New	constant if a married couple lives in the household for the 1 company car alternative	x	
couples2	+	New	constant if a married couple lives in the household for the 2+ company car alternative		x
Pcost	–		parking cost at the home zone variable	x	x
UnlicAdsc1	–		number of adults with no licence for 1 company car alt.	x	
UnlicAdsc2	–		number of adults with no licence for 2+ company car alt.		x
D2-LIC<CAR	–		fewer than two workers with licences term applied to 2+ company car alternative		x
wkaus1	+	New	constant when worker 1 or worker 2 in household was born in Australia, for the 1 company car alternative (apply twice if both worker 1 and worker 2 were born in Australia)	x	
wkaus2	+	New	constant when worker 1 or worker 2 in household was born in Australia, for the 2+ company car alternative (apply twice if both worker 1 and worker 2 were born in Australia)		x
wav06-07_1	–	New	constant which applies when the data is from 2006 or 2007 HTS, for the 1 company car alternative	x	
wav06-07_2	–	New	constant which applies when the data is from 2006 or 2007 HTS, for the 2+ company car alternative		x

Table 18 below shows the estimated parameters of the model developed in Stage 1, the re-estimation of the Stage 1 model with new data (the 're-estimated model') and the new model with improved specification (the 'recommended model').

Table 18: Company Car Model Parameters (detailed)

	Stage 1 model	Re-estimated model	Recommended model	% difference from Stage 1	
				Re-estimated model	Recomm-ended Model
File	CM40_L0K	cm_2006base_v2	cm_2006base_v24		
Observations	9133	16730	16730		
Final log (L)	-5854.4	-11913.8	-11700.8		
D.O.F.	17	15	25		
Rho²(c)	0.078	0.045	0.062		
Estimated	12-Nov-99	10-Nov-09	17-Nov-09		
Constants					
1cpcar	-4.583 (-20.4)	-3.303 (-22.6)	-3.096 (-19.5)	-28%	-32%
2pcpcar	-6.979 (-13.1)	-4.600 (-13.9)	-5.527 (-15.4)	-34%	-21%
Income					
HHInc1	0.8700 (16.9)	0.5307 (17.0)	0.2950 (8.1)	-39%	-66%
HHInc2	1.077 (9.3)	0.5443 (8.1)	0.3429 (4.8)	-50%	-68%
Gender					
FmHdHHCmp	-0.7726 (-10.5)	-0.5265 (-12.8)	-0.4105 (-9.6)	-32%	-47%
Age-related					
D1age35	0.00780 (1.5)	0.01150 (3.0)	0.00880 (3.9)	48%	13%
D2age35	0.02565 (2.4)	0.02315 (3.2)	0.03308 (7.9)	-10%	29%
Age<29c1	-0.1525 (-6.8)	-0.05729 (-3.8)	-0.06436 (-4.3)	-62%	-58%
Age<29c2	-0.1771 (-3.3)	-0.06660 (-2.1)	-0.05980 (-1.9)	-62%	-66%
D1age50	-0.03196 (-2.6)	-0.02621 (-3.2)		-18%	0%
D2age50	-0.02557 (-1.1)	0.00164 (0.1)		-106%	0%
Household characteristics					
UnlicAdsc1	-0.5805 (-9.9)	-0.1990 (-5.8)	-0.2963 (-8.1)	-66%	-49%
UnlicAdsc2	-0.6103 (-4.7)	-0.1798 (-2.7)	-0.4583 (-6.4)	-71%	-25%
D2-LIC<CAR	-0.8442 (-6.5)	-1.259 (-13.8)	-0.7723 (-6.4)	49%	-9%
nresident1			0.1711 (9.8)	n/a	n/a
nresident2			0.3044 (8.7)	n/a	n/a
nworkers1			0.09801 (3.0)	n/a	n/a
nworkers2			0.2455 (3.5)	n/a	n/a
nftwks=0_1			-1.001 (-9.2)	n/a	n/a
nftwks=0_2			-0.7719 (-3.4)	n/a	n/a
couples1			0.2938 (5.7)	n/a	n/a
couples2			0.3318 (3.2)	n/a	n/a
Parking cost					
Pcost	-0.01953 (-2.1)	-0.02085 (-3.3)	-0.01707 (-2.7)	7%	-13%
Migrant status					
wkaus1			0.1704 (6.3)	n/a	n/a
wkaus2			0.1974 (4.1)	n/a	n/a
Dataset or year specific					
D1-1991	0.2072 (3.5)				

	Stage 1 model	Re-estimated model	Recommended model	% difference from Stage 1	
				Re-estimated model	Recomm-ended Model
D2+-1991	0.2046 (1.7)				
wav06-07_1			-0.2463 (-5.4)	n/a	n/a
wav06-07_2			-0.2880 (-3.3)	n/a	n/a

Footnote: new parameters are highlighted in grey.

There are a few substantial changes between the Stage 1 model and the two new models.

The magnitudes of the household income parameters, *HHInc1* for 1 company car alternative and *HHInc2* for the 2+ company car alternative, have decreased (by up to 68 per cent) between the recommended model and the Stage 1 model. Part of this decrease can be explained by the difference in 'price year' between the Stage 1 model and the new model (1996 in the former and 2006 in the latter). Consumer prices have increased 29 per cent during this time period, meaning that a dollar in 2006 can buy 29 per cent less consumer goods than a dollar in 1996 (OECD, 2009). Additionally, part of the decrease can be attributed to the decreasing importance of income over time as a differentiating factor for owning a company car. In both cases, a log cost formulation for household income was found to give a better model fit than the linear income formulation.

There are also big changes in the magnitudes of the age-related parameters. For households with a young person (i.e. 29 or younger) as the highest earner, the influence of age has decreased. For households with a person in their main working age (35–50) as the highest earner, the influence of age has increased.

The influence of the number of adults with no licence (*UnlicAdsc1* for the one company car alternative and *UnlicAdsc2* for the two or more company car alternative) has decreased, as indicated by the large decrease (49 per cent and 25 per cent) in the magnitude of the parameters.

The influence of parking cost becomes slightly stronger in the re-estimated model (only by 7 per cent) but becomes weaker (by 13 per cent) in the recommended model in which other new terms are introduced. In any case, there is no big change in the influence of parking cost.

A number of new parameters are added to improve model fit. Many of the new parameters are household characteristics:

- The parameters that represent number of residents (*nresident1* for the 1 company car alternative, and *nresident2* for the 2+ company cars alternative) is positive and statistically significant. This is in agreement with our *a priori* expectation that the probability of owning company cars increases as the number of household residents increases.
- The parameters that represent number of workers (*nworker1* for the 1 company car alternative, and *nworker2* for the 2+ company cars alternative) are positive and

statistically significant. This is in agreement with our *a priori* expectation that the probability of owning company cars increases as the number of workers increases.

- The parameters that apply when there is no full-time worker in a household (*nftwks=0_1* for the 1 company car alternative, and *nftwks=0_2* for the 2+ company cars alternative) are negative and statistically significant. This is in agreement with our *a priori* expectation that households with no full-time workers have a lower probability of owning company cars.
- The parameters that represent whether a married couple lives in the household (*couples1* for the 1 company car alternative, *couples2* for the 2+ company car alternative) are positive and statistically significant. We do not have an *a priori* expectation for the sign of these parameters, but it is plausible that households with married couples have a higher probability of owning a company car.

Additionally, two migrant status related parameters are added:

- The migrant status related parameters apply when worker 1 or worker 2 in the household was born in Australia (*wkaus1* for the 1 company car alternative and *wkaus2* for the 2+ company car alternative). The parameters are multiplied by two when both worker 1 and 2 were born in Australia. They are estimated to be positive. This is in agreement with our *a priori* expectation that the probability of owning company cars is likely to be higher for Australian born people.

Finally, a year-specific term is added to improve model fit:

- Year-specific: when year-specific terms for 2006 and 2007 (*wav06-07_1* for the 1 company car alternative, and *wav06-07_2* for the 2+ company car alternative) are introduced to the model, there is a significant improvement in model fit. The estimated parameters are negative, indicating a lower probability of owning any company cars in these two years. This may relate to changes in the tax regime for company cars.

We also report here the parameters that have become insignificant in the recommended model:

- Age-related parameter: the parameters, *D1age50* and *D2age50*, which apply when head of household is aged 50 or over, have become statistically insignificant. The former became statistically insignificant when the model specification was improved and the latter became statistically insignificant when the new data (HTS 1999–2007) was applied. Therefore, they are excluded from the recommended model.
- Datasets-related: the two datasets-related parameters *D1-1991* and *D2+-1991* are no longer applicable in the current work, as the HIS data has not been used in the re-estimation work.

4.2 Car Ownership Model

The total car model predicts the probability of four possible states of car ownership at the household level:

(i) No car

(ii) 1 total car

(iii) 2 total cars

(iv) 3 or more total cars.

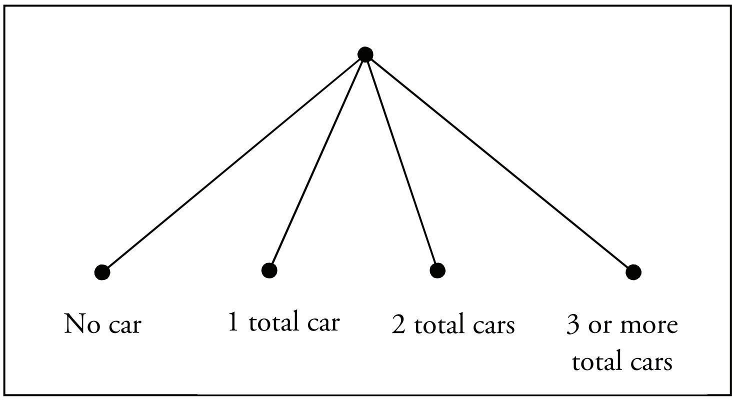
The choice proportions depend on the number of adults in the household. The choice proportions are tabulated by the number of adults in Table 19. The choice proportions are for households with given numbers of adults.

Table 19: Total Car Ownership Choice Proportions by Number of Adults

	1 adult	2 adults	3+ adults
0 cars	12.3%	3.0%	1.6%
1 car	81.8%	42.7%	18.5%
2 cars	5.1%	48.1%	39.4%
3+ cars	0.8%	6.2%	40.6%
Total	100.0%	100.0%	100.0%

Total cars include household and company cars. The choice structure is illustrated in Figure 9.

Figure 9: Total Car Ownership Choice Structure



A total of 32 parameters are in the recommended total car ownership model. A concise summary of the model parameters, along with definitions of the parameters, is presented next in Table 20.

Table 20: Parameters in the Recommended Total Car Ownership Model

Term	Sign	New?	Definition	Which alternative?			
				0	1	2	3+
1carowned			1 car Alternative-specific constant (ASC)		x		
2carowned			2 car ASC			x	
3+carowned			3+ plus cars ASC				x
HHInc1	+	new	household income - car costs (logarithmic)		x		
HHInc23	+	new	household income - car costs (logarithmic)			x	x
FmHdHH2	–		female head of household term for 2 cars alternative			x	
FmHdHH3	–		female head of household term for 3+ cars alternative				x
D1age35	+		head of household age term for 1 car alternative (multiplied by [age – 35] when age > 35)		x		
D2age35	+		head of household age term for 2 cars alternative (multiplied by [age – 35] when age > 35)			x	
D3age35	+		head of household age term for 3+ cars alternative (multiplied by [age – 35] when age > 35)				x
D2_3age50	–		head of household age term for 2 & 3+ cars alternatives (multiplied by [age – 50] when age > 50)			x	x
FtTmWrk1	+		number of full-time workers for 1 car alternative		x		
FtTmWrk2	+		number of full-time workers for 2 cars alternative			x	
FtTmWrk3	+		number of full-time workers for 3+ cars alternative				x
PrTmWrk1	+		number of part-time workers for 1 car alternative		x		
PrTmWrk2	+		number of part-time workers for 2 cars alternative			x	
PrTmWrk3	+		number of part-time workers for 3+ cars alternative				x
NChildCof	+		number of children		x	x	x
Numlics1	+		number of licences for 1 car alternative		x		
Numlics2	+		number of licences for 2 cars alternative			x	

Term	Sign	New?	Definition	Which alternative?			
				0	1	2	3+
Numlics3	+		number of licences for 3+ cars alternative				x
D2-LIC<CAR	–		licences less than cars for 2 cars alternative			x	
D3-LIC<CAR	–		licences less than cars for 3+ car alternative				x
CmpCar1_2	+		1 company car for 2 cars alternative			x	
CmpCar1_3	+		1 company car for 3+ cars alternative				x
CmpCar2_3	+		2+ company cars for 3+ cars alternative				x
Naus_1	+	new	number of Australian-born in household		x		
Naus_2	+	new	number of Australian-born in household			x	
Naus_3	+	new	number of Australian-born in household				x
couple1	+	new	household comprising a married couple only		x		
CBDdist	+	new	multiple by log of distance to CBD		x	x	x
m_d_access	+		multiplied by logsum	x	x	x	x

Table 21 below shows the estimated parameters of the model developed in Stage 1, the re-estimated model with new data (the 're-estimated model'), and the final model ('the recommended model'). The specification of the re-estimated model does not include the accessibility variable, i.e. the logsum term (*m_d_access*), as this variable is dependent upon completion of the home–work mode-destination choice model, and the mode-destination model was not complete when the re-estimated model was run. However, the recommended model specification does include the accessibility term, which was found to be highly significant.

Table 21: Total Car Ownership Model Parameters (detailed)

	Stage 1 model	Re-estimated model	Recommended model	% difference from Stage 1	
				Re-estimated model	Optimised Model
File	J141_L9K.F12	hhcar_2006base_v1.F12	hhcar_2006base_v34.F12		
Converged	TRUE	TRUE	TRUE		
Final log (L)	-8967.6	-16865.2	-15967.9		
D.O.F.	35	31	32		
Rho²(0)	0.45	0.431	0.462		
Estimated	15-Dec-99	10-Nov-09	00-Jan-00		
Constants					
1carowned	-2.313 (-8.8)	-0.4103 (-2.9)	-3.774 (-19.6)	-82%	36%
2carowned	-5.806 (-13.4)	-1.986 (-9.8)	-9.020 (-27.2)	-66%	39%

	Stage 1 model	Re-estimated model	Recommended model	% difference from Stage 1: Re-estimated model	% difference from Stage 1: Optimised Model
3+carowned	-8.500 (-15.8)	-6.273 (-21.7)	-14.87 (-36.2)	-26%	65%
Income					
HHInc	0.1818 (9.8)	0.1666 (9.8)	n/a	-8%	n/a
HHInc1	n/a	n/a	0.1468 (8.5)	n/a	n/a
HhInc23	n/a	n/a	0.2019 (14.8)	n/a	n/a
Gender					
FmHdHH1	-0.2603 (-2.9)	0.05539 (0.8)	n/a	-121%	n/a
FmHdHH2	-0.4337 (-4.1)	-0.2220 (-2.9)	-0.1745 (-4.2)	-49%	-59%
FmHdHH3	-0.5224 (-3.7)	-0.3943 (-4.2)	-0.3003 (-4.3)	-25%	-41%
Work status					
FtTmWrk1	0.3389 (4.1)	0.2272 (3.3)	0.3854 (5.2)	-33%	11%
FtTmWrk2	0.5467 (6.0)	0.4121 (5.4)	0.6346 (8.0)	-25%	15%
FtTmWrk3	0.9179 (9.0)	0.6411 (7.6)	0.8727 (9.9)	-30%	-4%
PrTmWrk1	0.2104 (1.3)	0.3228 (2.8)	0.4544 (3.9)	53%	109%
PrTmWrk2	0.6389 (3.9)	0.6397 (5.4)	0.7311 (6.0)	0%	13%
PrTmWrk3	0.9008 (5.0)	0.8587 (6.7)	0.9114 (6.9)	-5%	2%
Age-related					
D1age35	0.06336 (6.4)	0.04588 (6.3)	0.03131 (10.9)	-28%	-49%
D2age35	0.08946 (8.3)	0.08167 (10.4)	0.07205 (15.4)	-9%	-19%
D3age35	0.1012 (8.8)	0.09305 (11.4)	0.08441 (16.1)	-8%	-16%
D1age50	-0.05211 (-3.5)	-0.01314 (-1.2)	n/a	-75%	n/a
D2_3age50	-0.1174 (-6.9)	-0.08368 (-7.0)	-0.06341 (-10.1)	-29%	-47%
Age<25	-0.1337 (-3.3)	-0.02376 (-0.7)	n/a	-82%	n/a
Household characteristics					
NChildCof	0.3779 (6.6)	0.5929 (10.0)	0.3195 (5.0)	57%	1%
Numlics1	1.576 (12.7)	0.9099 (10.0)	1.476 (14.1)	-42%	-16%
Numlics2	2.802 (16.4)	1.717 (15.1)	2.628 (18.4)	-39%	-15%
Numlics3	3.186 (17.8)	3.024 (24.6)	3.365 (23.8)	-5%	1%
UnlicAds1	-0.3081 (-4.6)	-0.07350 (-1.3)	n/a	-76%	n/a
UnlicAds2	-0.2421 (-3.0)	0.05044 (0.8)	n/a	-121%	n/a
D2-LIC<CAR	-0.7851 (-4.7)	-2.066 (-22.9)	-0.8181 (-6.2)	163%	34%
D3-LIC<CAR	-1.187 (-7.6)	-1.027 (-9.0)	-0.8776 (-7.3)	-13%	-21%
CmpCar1_2	1.536 (19.6)	1.297 (23.3)	1.191 (20.2)	-16%	-24%
CmpCar1_3	1.866 (16.6)	1.827 (24.3)	1.649 (20.6)	-2%	-14%
CmpCar2_3	1.247 (8.6)	1.492 (16.9)	1.445 (15.9)	20%	16%
couple1	n/a	n/a	0.1498 (3.4)	n/a	n/a
CBDdist	n/a	n/a	0.5429 (24.9)	n/a	n/a
Migrant status					
Naus_1	n/a	n/a	0.09819 (2.4)	n/a	n/a
Naus_2	n/a	n/a	0.2755 (6.4)	n/a	n/a
Naus_3	n/a	n/a	0.3505 (7.7)	n/a	n/a
Cost					
Pcost	-0.03136 (-4.4)	-0.03522 (-9.3)	n/a	12%	n/a
Accessibility					
m_d_access	0.9667 (12.5)	n/a	0.6885 (12.3)	n/a	-29%
Dataset or year specific					
D1-1991	-0.1793 (-1.9)	n/a	n/a	n/a	n/a

	Stage 1 model	Re-estimated model	Recommended model	% difference from Stage 1	
				Re-estimated model	Optimised Model
D2-1991	-0.3772 (-3.5)	n/a	n/a	n/a	n/a
D3-1991	-0.5373 (-4.1)	n/a	n/a	n/a	n/a

There are a few significant changes between the Stage 1 model and the two new models.

On the effect of income, we observe a small decrease (only -8 per cent) in the magnitude of the income term in the re-estimated model. This is quite different from what we have observed in the company car model and the licence-holding models, in which the income terms have decreased by 30–60 per cent in magnitude. The small decrease of 8 per cent is less than the 30 per cent change in consumer prices, suggesting that income has become a stronger differentiating factor for total car ownership.

In the recommended model, we introduce income parameters by car ownership level, HHInc1 and HHInc23, to improve model fit. Income parameters by car ownership level mean that income is less important in the purchase of the first vehicle, but more important in purchasing subsequent vehicles. The income parameters are applied to a term representing log of net income, i.e. household income subtracted by the average car operating cost.[8]

Additionally, the distance to CBD term is introduced to the model. The term is introduced to represent lower car ownership in central areas due to difficulties in parking, better accessibility and lifestyle choice. It enters the model as a term multiplying the log of distance to CBD (measured from zone 71), up to a maximum distance of 35 km. Taking the log allows the model to represent a strong effect in the vicinity of the CBD and a diminishing effect in outer areas. The maximum distance is determined by empirical testing. We have tested a maximum distance of 30, 35, 40, 45 km and found that 35 km gives the best fitting model (Figure 10). The term has substantially improved model fit. With the inclusion of the distance to CBD term, the accessibility term *m_d_access* is still highly significant. However, the parking cost term (*Pcost*) has become insignificant.

[8] The average car operating cost is empirically tested to be 12K. This value is also equivalent to a 30 per cent consumer prices increase in the car operating cost of 9K in the Stage I model.

Figure 10: Tests of Maximum Distance for Distance to CBD Term

A few other new parameters are added to improve model fit. Many of the new parameters are household characteristics:

- The parameter *couples1* for the 1 car alternative applies to households comprising married couples only. It is positive and statistically significant, indicating that households with married couples have a higher probability of sharing one car (as opposed to not owning a car at all, or each household member owning one or more cars).
- The migrant status parameters, *Naus_1, Naus_2 and Naus_3*, enter the model by multiplying the number of Australian-born in household. The parameters are positive, with higher magnitudes at higher car ownership levels. This is in agreement with our *a priori* expectation that the probability of owning cars is likely to be higher for Australian-born people.

We summarise here the parameters that have become insignificant in the recommended model:

- Age-related: the term *Age<25* which applies when the household head is younger than 25 becomes statistically insignificant. *D1age50* which applies to the one car alternative when the household head is older than 50 also become statistically insignificant, although the household head older than 50 terms still applies to the two car and three plus car alternative. *Age<25* and *D1age50* are excluded from the recommended model.
- Licence-related: the number of unlicensed adults terms, *UnlicAds1* and *UnlicAds2*, become insignificant and are dropped from the model. This does not mean that licence holding is not important, as there are other terms in the model, *Numlics1, Numlics2 and Numlics3*, which capture the licence-holding effect.

- The female household head term for one car, *FmHdHH1*, becomes insignificant and is dropped from the recommended model.
- The parking cost term becomes insignificant, as discussed in the paragraph about the inclusion of distance to CBD term.
- Datasets-related: the three datasets-related parameters, *D1-1991*, *D2-1991 and D2-1991,* are no longer applicable in the current work, as the HIS data has not been used in the re-estimation work.

CHAPTER 5 Frequency Models

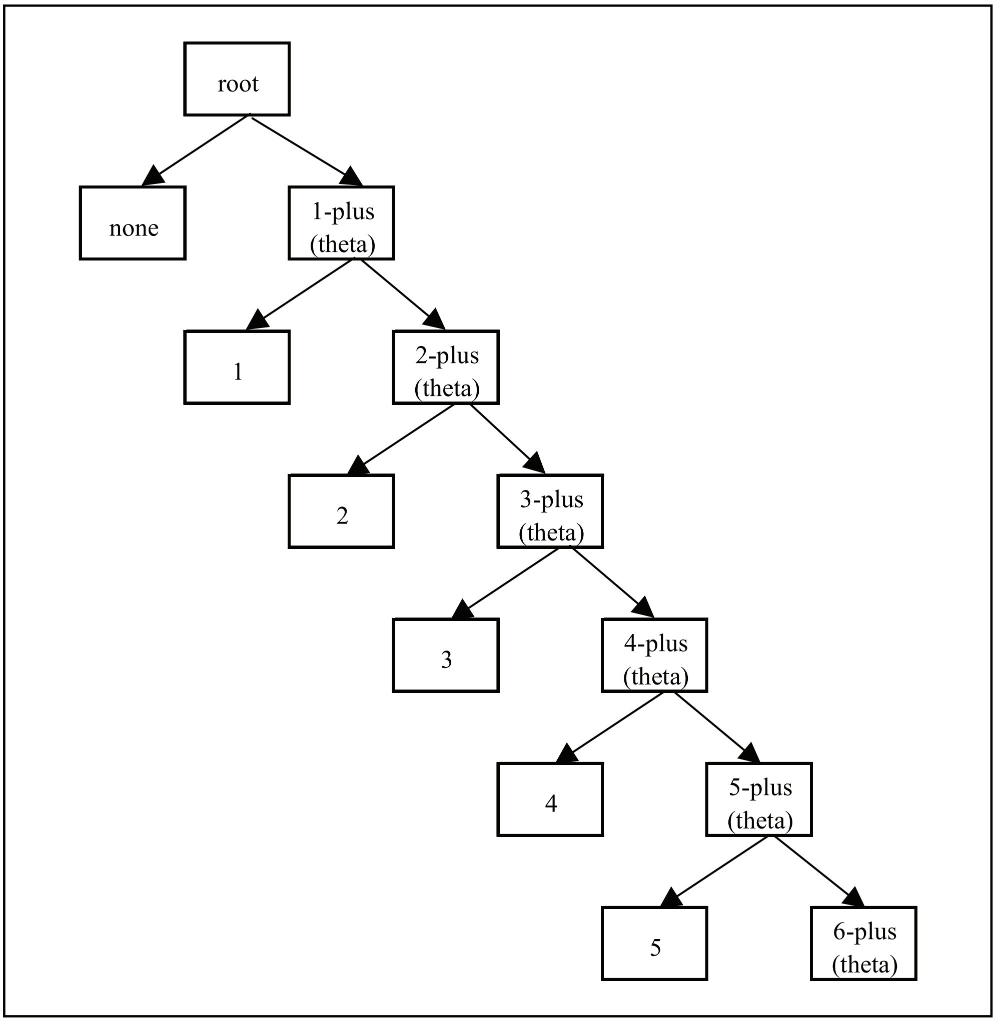
5.1 Model Structure

Frequency models have been developed to predict the number of full tours made by a traveller on a workday (Monday to Friday excluding public holidays) for a given travel purpose. To ensure that the models reproduce the total volumes of travel observed in the HTS data, both full tours and outward half tours have been included in the tour counts. The logic of including outward half tours, rather than including both outward and return half tours with weights of 0.5, is that return half tours are more likely to be affected by coding errors and therefore the outward half tour data has been judged to be more reliable.

HTS data from 1999–2008 were available for model estimation. For most home-based purposes, all these data have been used to maximise sample sizes. However, the home–work and home–tertiary education estimation samples were restricted to 2004–2008 because earlier waves of data had noticeably higher tour rates that would have biased the main tour rate upwards, given the new model has a 2006 base year. The non-home-based models are linked to the home–work models in application, and therefore have also been estimated from 2004–2008 data only to ensure consistency with the home–work model.

The frequency model structure is consistent with that used in the Stage 2 models and is illustrated in Figure 11.

Figure 11: Frequency Model Structure



The 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 repeat 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. Full details of the procedure were presented in Appendix A of report 0032-6C.

The utilities for the first model are applied to the 'none' alternative, thus a positive parameter implies that an individual is *less* likely to make at least one tour. Similarly, the utilities for the second model are applied to the 1, 2, 3, etc. alternatives and therefore positive parameters imply an individual is less likely to make multiple tours. In this example, up to five tours per day are observed, and therefore the final choice in the tree is five and six-plus. For other purposes, the number of tours may be lower or higher, and then the tree would be pruned or extended accordingly.

It is noted that the utility functions are identical on the 1, 2, 3, etc. alternatives, as the probability of stopping is assumed to be constant for a given individual[9]. 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 (1.7 per cent for commuting) 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 had to be modelled separately from the probabilities of making multiple trips, and that the 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 chapter.

In addition to constant terms, which ensure that the tour rates observed in the HTS data are reproduced, socio-economic terms are added to represent differences in tour rates according to the personal and household level characteristics of individuals. These have been identified using the Stage 1 specifications as the starting point, and then tailoring the model specifications as necessary. An important test in the model development is to test the impact of accessibility on travel frequency. Accessibility is measured using logsums from the mode-destination models.

5.2 Commute

The commute frequency model is estimated from the sample of adults (persons aged 15-plus) in adult status groups 1 to 6, which correspond to:

- Full-time students
- Part-time students
- Full-time workers
- Part-time workers
- Casual workers
- Unpaid voluntary workers.

Individuals with adult status codes 7 and higher are excluded from the commute frequency model. This restriction to adult status codes 1 to 6 is taken from analysis undertaken during the Stage 1 estimation work, which demonstrated that these were the adult status categories observed to make work tours. It is noted that the classifications used in the HTS data for this variable have not changed between the Stage 1 estimation work and this study.

It should also be noted that the adult status codes listed above are derived from the multi-punch adult category question in the HTS survey, which allows an individual to tick more than one box. For example, an individual may record that they are both a full-time student

[9] P(1|1+) = P(2|2+) = P(3|3+) etc.

and a part-time worker. To convert individuals who tick two or more categories into one of the adult status categories listed above, the following hierarchy is applied:

1. Full-time workers
2. Full-time students
3. Part-time students
4. Part-time workers
5. Casual workers
6. Unpaid voluntary workers
7. Unemployed
8. Looking after the home
9. Aged pensioner
10. Other pensioner[10]
11. Retired[11]
12. Other.

Therefore, in the example cited above, the individual would be classified as a full-time student in the adult status variable.

The terms in the final commute frequency model are summarised in Table 22 for the zero/one-plus model and Table 23 for the stop/go model. As well as defining the model terms, the tables detail whether the terms were present in the Stage 1 specification.

[10] People who are in receipt of government pensions such as Invalid Pension, Single-Parent Benefits, Widows or Service Pension, Sickness Benefits, etc.

[11] Refers to those who have stopped work and never intend to work again. The exception is people who have stopped working to marry or raise a family: these are *not* retired.

Table 22: Commute Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 1?
Constant	-	constant to ensure overall fraction of individuals making at least one tour is replicated	Yes
Fted	+	full-time students less likely to make tours than full-time workers	Yes
pted	+	part-time students less likely to make tours than full-time workers	Yes
ptwk	+	part-time workers less likely to make tours than full-time workers	Yes
caswk	+	casual workers less likely to make tours than full-time workers	Yes
volwk	+	voluntary workers less likely to make tours than full-time workers	Yes
ageo39	+	persons aged over 39 less likely to make tours than those aged 39 and less	Yes
ageo59	+	persons aged over 59 less likely to make tours than those aged 59 and less (term is applied in addition to the ageo39 term)	Yes
nolic	-	individuals without licences more likely to make tours than those with licences	Yes
carcompet	-	individuals in households with car competition are more likely to make tours	Yes
compcar	-	individuals in households with company cars are less likely to make tours	Yes
males	+	males are less likely to make tours than females	Yes
manuf	-	individuals with manufacturing occupation types are more likely to make tours than others	Yes
incpu20.8k	+	persons with low incomes make fewer tours	Yes[12]
incge67.6k	-	persons with high incomes make more tours	Yes
access	-	individuals with higher accessibility to commute mode-destination alternatives make more tours	Yes

In general the parameter signs are plausible.

One notable exception is the car availability parameters (nolic, carcompet, compcar), which imply lower tour frequency rates for individuals with higher car availability. It was suggested in report 9009-3B that this effect, which was also observed in the Stage 1 model, is due to an interaction of this model with travel for employer's business. It is noteworthy that the business tour frequency model predicts *higher* tour frequency rates for individuals with higher car availability.

The sign of the male dummy was contrary to expectation. Investigations revealed that, while there are fewer females in the estimation sample (adult status groups 1 to 6, who are observed to make work tours) the mean tour rate for those females in the sample is slightly higher than for males in the sample (0.551 tours per day, compared with 0.529 for males).

[12] The definition of the income bands was different in the Stage 1 models, but the terms represented the same pattern of commute tour frequency increasing with personal income.

Table 23: Commute Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 1?
Constant2	-	constant to ensure observed multiple tour making rate is replicated	Yes
compcar2	-	individuals from households with company cars are more likely to make multiple tours	Yes
manuf	+	individuals with manufacturing occupation types are less likely to make multiple tours than others	Yes
incpu20.8k	+	low income persons are less likely to make multiple tours	No
incge67.6k	-	high income persons are less likely to make multiple tours	No

The terms are plausible, and consistent in sign with the Stage 1 model. The income effects, which again show a pattern of increasing tour frequency with income, were not present in the Stage 1 stop/go model.

Two parameters from the Stage 1 specification were dropped: a car competition term and an accessibility term. It is noteworthy that neither of these terms was significant at a 95 per cent confidence level in the Stage 1 model.

The final parameter values (COMFR_v10) are compared with the model parameters from Stage 1 (MAIN25 and STOPGO12) in Table 24. It should be noted that the Stage 1 models were specified differently, and this means that the signs of the parameters have reverse meanings. In the Stage 1 models, positive parameters indicated higher rates of tour making, whereas in the re-estimated models positive parameters indicate *lower* rates of tour making.

Table 24: Commute Frequency Parameters

File	MAIN25.F12		STOPGO12.F12		COMFR_v10.F12	
Converged	True		True		True	
Observations	14663		7561		11788	
Final log (L)	-8535.3		-1133.4		-8259.6	
D.O.F.	18		5		21	
Rho²(c)	0.160		0.012		0.092	
Estimated	4 Jan 00		4 Jan 00		13 Oct 10	
Scaling	1.0000		1.0000		1.0000	
Zero/One-Plus Model:						
Constant	0.02109	(0.1)			-0.09138	(-0.6)
fted	-2.439	(-21.4)			1.630	(15.6)
pted	-1.704	(-11.8)			1.406	(9.9)
ptwk	-0.7741	(-11.9)			0.7043	(11.3)
caswk	-0.9692	(-11.6)			0.9197	(11.1)
volwk	-1.101	(-7.0)			1.745	(10.4)
ageo39	-0.09227	(-2.3)			0.1575	(3.6)
ageo59	-0.3271	(-3.6)			0.3229	(4.1)
nolic	0.3350	(4.9)			-0.1941	(-2.7)
manufac	0.5922	(10.8)			-0.6947	(-9.6)
males	-0.5144	(-12.2)			0.5226	(11.9)
compcar	-0.2285	(-5.3)			0.6715	(14.6)
carcompet	0.2943	(6.8)			-0.2706	(-5.3)
incpu2k	-1.156	(-9.6)				
incpu15.6k	-0.3884	(-5.7)				
incpu26k	0.1019	(2.2)				
incge52k	0.2122	(3.3)				
incge67.6k					-0.1282	(-2.4)
incpu20.8k					0.3964	(6.1)
access	0.07369	(4.0)			-0.1239	(-6.5)

```
Stop/Go Model:

Constant2                              -4.380  (-6.4)     3.394  (33.9)
compcar2                               0.4357   (3.2)   -0.4903  (-3.3)
manufac2                              -0.7165  (-3.5)    0.5266   (2.0)
carcompet2                             0.2115   (1.5)
access2                               0.08811   (1.4)
inpu20.8k2                                              -0.3637  (-2.0)
inge67.6k2                                               0.4894   (2.5)
```

The accessibility parameter 'access' in the zero/one-plus model is more significant and has a stronger effect (i.e. is larger in magnitude) in the re-estimated model. As noted above, the parameters change sign due to the models being specified differently in Stage 1.

5.3 Home–Business

The home–business model is estimated from all adults in the HTS data, as analysis of the HTS data during the Stage 2 estimations observed individuals from all adult status groups made business tours.

The terms in the final business frequency model are summarised in Table 25 for the zero/one-plus model and Table 26 for the stop/go model. As well as defining the model terms, the tables detail whether the terms were present in the Stage 2 specification.

Table 25: Business Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
zerocars0	+	individuals in zero car households make fewer business tours	Yes
carcomp0	+	individuals in households where car competition exists make fewer business tours	Yes
cmpcar0	-	individuals in households with company cars make more business tours	Yes
manual0	-	individuals with manual occupations make far more business tours than those without an occupation, i.e. non-workers	Yes
nonmanual0	-	individuals with non-manual occupations make far more business tours than those without an occupation, i.e. non-workers, but fewer business tours than manual workers	Yes
manu0	+	individuals in manufacturing employment make fewer business tours than other individuals	Yes
FTst_pens0	+	fulltime students and pensioners make fewer business tours than other adults	Yes
male0	-	males make more business tours than females	Yes
age<24_0	+	individuals aged under 25 are less likely to make business tours	Yes
lsm0	-	individuals with higher accessibility to business mode-destination alternatives make more tours	Yes

A term for 3-plus cars was dropped from the specification used in Stage 1 as it was no longer significant, as was an income term for incomes up to \$26k p.a.

The parameter signs are consistent with *a priori* expectations; in particular, the car availability terms show the expected pattern of increasing tour frequency with increasing levels of car availability.

Table 26: Business Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
cmpcarpl	-	individuals in households with a company car are more likely to make multiple tours	Yes
age<24pl	+	individuals aged under 25 are less likely to make multiple tours	Yes
incu31.2	-	individuals with incomes less than $31.2k p.a. are more likely to make multiple tours	No

The term that predicts higher multiple tour making for those with incomes less than $31.2k p.a. may capture door-to-door salesmen, gardeners, etc. who make relatively high numbers of business tours on a given day.

The parameter values (BUSFR_v10) are compared with the Stage 2 parameter values (BUSFR30) in Table 27.

Table 27: Business Frequency Parameters

```
File                  BUSFR30.F12     BUSFR_v10.F12
Converged                    True              True
Observations                25952             34941
Final log (L)             -6437.6          -10172.3
D.O.F.                         16                15
Rho²(c)                     0.217             0.222
Estimated               18 Mar 02         10 Sep 10
Scaling                    1.0000            1.0000
theta                     0      (*)       0      (*)

Zero/One-Plus Model:

noneASC             5.791  (19.1)     7.556  (17.4)
zerocrs0           0.5494   (3.8)    0.3875   (2.9)
3plcars0          -0.2667  (-4.3)
carcomp0           0.2326   (3.8)    0.1900   (3.5)
cmpcar0           -0.6177 (-11.1)   -0.9289 (-20.1)
nonmanual0         -2.670 (-13.9)    -4.330 (-10.5)
manual0            -3.867 (-20.1)    -5.714 (-13.8)
manu0               1.107  (13.5)     1.245  (16.8)
FTst_pens0          1.457   (6.4)     1.015   (7.2)
male0             -0.9308 (-14.7)   -0.9182 (-19.7)
age<24_0           0.4825   (5.8)    0.5047   (7.5)
lsm0             -0.03808  (-1.4)  -0.06388  (-2.1)

Stop/Go Model:

stopASC             2.081  (24.0)     2.518  (26.7)
cmpcarpl          -0.2985  (-2.4)   -0.4504  (-4.1)
age<24pl           0.3985   (1.7)    0.9457   (3.9)
inc<26k            0.1374   (2.3)
incu31.2                            -0.4304  (-3.6)
```

5.4 Home–Primary Education

The primary education model is estimated from the sample of 'primary persons', who are defined as:

- Children with child category 'kindergarten/infant/primary school'
- Children with child category 'special school' aged up to 11.

This definition is taken from analysis of the HTS data during the Stage 2 estimation work.

The terms in the final primary education frequency model are summarised in the following tables, which also detail whether the terms were identified in the Stage 2 estimations.

Table 28: Primary Education Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
spec0	+	children attending special schools make fewer tours	Yes
hinc<25k	+	individuals from households with incomes in the range $1-25k p.a. make fewer tours	No
lsm0	-	individuals with higher accessibility to primary mode-destination alternatives make more tours	No

Two terms from the Stage 2 specification were dropped as they were no longer significant. First, a zero and one car term, which may no longer be significant due to the presence of the logsum term (the logsums are segmented by car availability). Second, a higher income term on zero tours.

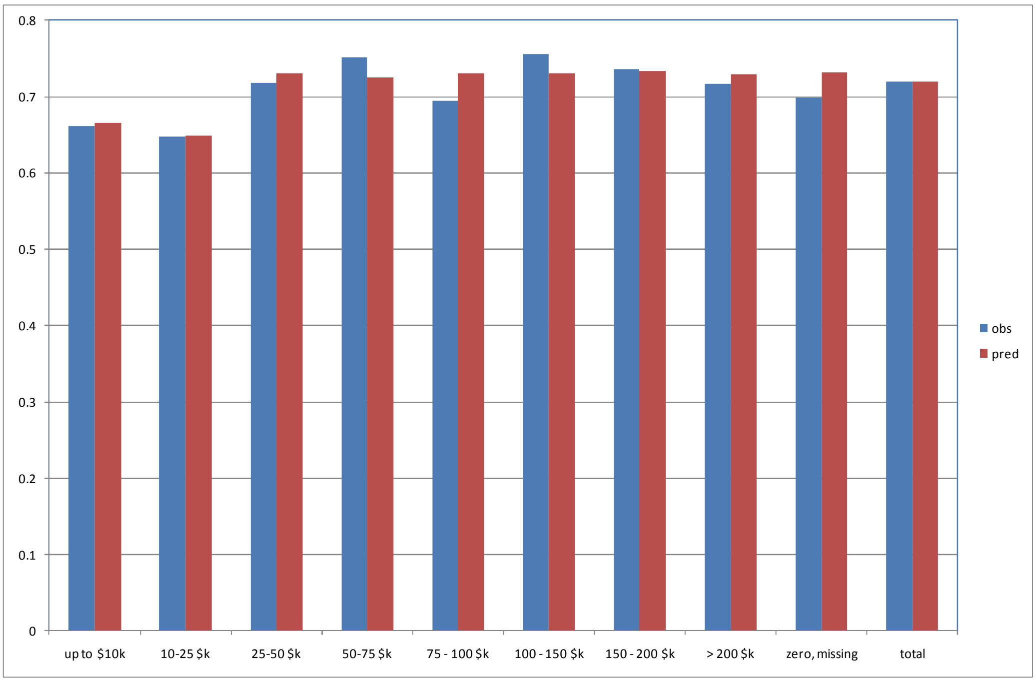
Table 29: Primary Education Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes

In the Stage 2 model, an accessibility term was used in the stop/go model to predict higher multiple tour making for individuals with higher accessibility. In the new estimation dataset, there are just 19 individuals who make multiple primary education tours, whereas the logsum term that has been identified for the zero/one-plus model is based on 1466 zero tour, and 3670 one tour, observations.

Investigations were undertaken to investigate the variation in primary education tour rates with income band, in particular to investigate whether children who attend private schools attend school less frequently on average due to longer school holidays. Figure 12 compares observed and predicted primary tour rates by income band.

Figure 12: Primary Education Tour Rates by Household Income Band



The lower tour rates for individuals with incomes less than $25k p.a. are predicted by the model. There is no evidence of lower than average tour rates for the highest household income bands, who are most likely to use private schools.

The parameter values (PRIFR_v9) are compared to the Stage 2 values (PriFr14) in Table 30.

Table 30: Primary Education Frequency Parameters

File	PriFr14.F12		PRIFR_v9.F12	
Converged	True		True	
Observations	3588		5155	
Final log (L)	-2270.8		-3179.0	
D.O.F.	6		5	
Rho²(c)	0.003		0.006	
Estimated	8 Jun 01		4 Aug 10	
Scaling	1.0000		1.0000	
theta	0	(*)	0	(*)
Zero/One-Plus Model:				
noneASC	-1.130	(-15.9)	-0.2343	(-0.8)
zero1crs0	0.2541	(3.2)		
spec0	0.7338	(1.5)	1.244	(3.4)
hinc>52k0	0.1393	(1.8)		
hinc<25k0			0.3517	(4.0)
lsm0			-0.1255	(-2.7)
Stop/Go Model:				
stopASC	6.191	(4.8)	5.269	(22.9)
lsmpl	-0.2546	(-1.3)		

5.5 Home–Secondary Education

The secondary education model is estimated from the sample of 'secondary persons', who are defined as:

- Children with child category 'secondary school'
- Children with child category 'special school' aged 12 to 14
- Adults with 'secondary_uni' code 'secondary school'
- Adults with 'secondary_uni' code 'other' aged 15 to 17.

This definition is taken from analysis of the HTS data during the Stage 2 estimation work.

The terms in the final secondary education frequency model are summarised in the following tables, which also detail whether the terms were identified in the Stage 2 estimation works.

Table 31: Secondary Education Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
age>15_0	+	persons aged over 15 are more likely to make zero tours	Yes

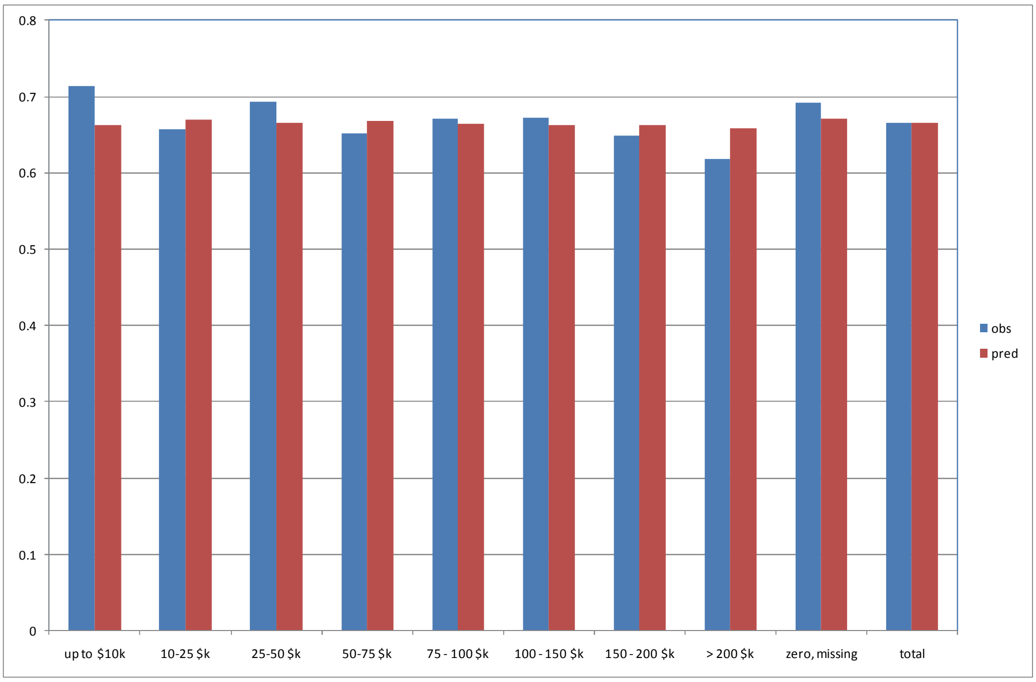
Four terms have been dropped from the Stage 2 specification. Two were income terms, defined for household incomes < 4 $k/p.a. and > 36 $k/p.a. No systematic pattern of variation in secondary tour frequency with income was observed in the re-estimation dataset. The other two terms that were dropped were for zero and three-plus cars.

Table 32: Secondary Education Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
lsmpl	-	persons with higher accessibility are more likely to make multiple tours	Yes

Overall, little variation in the secondary education tour rate with socio-economic characteristics has been identified. As per the primary education model, investigations were undertaken to investigate the variation in the tour frequency rate with household income, the hypothesis being that because private schools have longer holidays the mean tour rate for pupils from higher income households may be lower. Figure 13 compares observed and predicted tour rates for the final model.

Figure 13: Secondary Education Tour Rates by Household Income Band



At the low-income end, tour rates are higher than average for the first band, but the volume of data is relatively small and so this may be noise in the observed data. At the higher income end, tour rates are lower for the > $200k p.a. band. However, the volume of data here is also low, and when a dummy parameter was tested it was not statistically significant. Overall, there is no strong pattern of variation in secondary education tour rates with household income.

The final parameter values (SecFr_v13) are summarised in Table 33. Also presented are the Stage 2 parameter values (SecFr25).

Table 33: Secondary Education Frequency Parameters

File	SecFr25.F12		SecFr_v13.F12	
Converged	True		True	
Observations	2723		3820	
Final log (L)	-1878.7		-2573.2	
D.O.F.	8		4	
Rho²(c)	0.010		0.004	
Estimated	30 May 02		22 Sep 10	
Scaling	1.0000		1.0000	
Zero/One-Plus Model:				
noneASC	-0.9831	(-11.0)	-0.7558	(-18.3)
0cars_0	0.3705	(2.1)		
3plcars_0	0.2618	(2.3)		
hhinc<4k	0.9842	(2.9)		
hhinc>36k	0.3019	(3.1)		
age>15_0	0.2871	(3.3)	0.3178	(4.3)
Stop/Go Model:				
stopASC	5.332	(3.6)	6.127	(2.7)
lsmpl	-0.1203	(-0.7)	-0.1603	(-0.6)

It is noted that the accessibility term 'lsmpl' is insignificant. However, the magnitude of the term is plausible and therefore the term has been retained so that future predictions of secondary education travel are responsive to changes in accessibility.

5.6 Home–Tertiary Education

In the Stage 2 models, the home–tertiary model was estimated for all adults, except those who are classified as 'secondary persons' according to the definition given in Section 5.5. This definition allowed the possibility of including tours made by someone who (for example) attends evening classes, but has not stated that they are in education.

However, in the re-estimation work no tertiary education tours were observed by persons who had stated that they were in tertiary education according to the 'secondary_uni' variable. Therefore, the definition of 'tertiary persons' was revised to only include:

- Adults with 'secondary_uni' code 'TAFE'[13]
- Adults with 'secondary_uni' code 'university'
- Adults with 'secondary_uni' code 'other' aged 18+

The terms in the final tertiary education frequency model are summarised in the following tables, which also detail whether the terms were identified in the Stage 2 estimations.

Table 34: Tertiary Education Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
fltmst_0	-	full-time students make more tours than other adult categories	Yes
fltmwk_0	+	full-time workers make fewer tours than other adult categories	Yes
Uni_0	+	university students make fewer tours than those with 'TAFE' or 'other' tertiary education types	Yes
PInc>15.6k	+	students with personal incomes over $15.6k p.a. make fewer tours	Yes
age1518_0	-	students aged 15 to 18 make more tours than older students	No
lsm_0	-	students with higher accessibility make more tours	Yes

Two terms were dropped from the Stage 2 model for 'TAFE' and 'other' tertiary education types. However, due to the revised definition of 'tertiary persons' at most only one of these terms would be required, and analysis has shown that the mean tour rates for these two groups are similar and therefore no term is required. It should be noted that the mean observed tour rate for university students is *higher* than for the other two tertiary education types. This is consistent with the model terms in Table 34 because university students are more likely to be full-time students than the other two groups, and the negative full-time student term has a stronger effect than the positive university term.

[13] TAFE stands for Technical and Further Education. The acronym is typically used without definition in New South Wales.

The new age1518_0 term applies only to those in TAFE education. Discussions with BTS suggest this term is plausible, as this category will include students who enter TAFE directly from high school, and would be expected to attend TAFE more frequently than older persons.

Table 35: Tertiary Education Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
lsmpl	-	students with higher accessibility are more likely to make multiple tours	Yes

The parameter values (TERFR_v17) are given in Table 36, as are the Stage 2 parameters (TERFR13).

Table 36: Tertiary Education Frequency Parameters

File	TERFR13.F12		TERFR_v17.F12	
Converged	True		True	
Observations	24581		1679	
Final log (L)	-1246.4		-873.5	
D.O.F.	10		9	
Rho²(c)	0.604		0.119	
Estimated	19 Mar 02		20 Sep 10	
Scaling	1.0000		1.0000	
Zero/One-Plus Model:				
noneASC	11.15	(9.9)	1.499	(4.4)
fltmwk_0	0.8565	(4.7)	1.067	(4.4)
fltmst_0	-1.011	(-7.2)	-0.7406	(-4.5)
Uni_0	-8.318	(-8.3)	0.2388	(1.8)
TAFE_0	-8.832	(-8.8)		
OthEd_0	-8.833	(-8.6)		
PInc>15.6k	0.2876	(2.0)	0.6757	(4.6)
age1518_0			-0.4093	(-2.3)
lsm0	-0.1381	(-3.1)	-0.09314	(-1.6)
Stop/Go Model:				
stopASC	7.036	(2.4)	8.883	(3.5)
lsmpl	-0.2974	(-1.2)	-0.8536	(-2.1)

The term on university students and the logsum term on zero tours are not significant at a 95 per cent confidence interval, but both are retained as the magnitudes of the effects they represent are plausible.

5.7 Home–Shopping

As per the Stage 2 models, the home–shopping model has been estimated from all persons (both adults and children) in the HTS data.

The terms in the final shopping model are summarised in the following tables, which also detail whether the terms were identified in the Stage 2 estimations.

Table 37: Shopping Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
FTstu_0	+	full-time students make fewer tours than casual & voluntary workers, the retired and children	Yes[14]
PTstu_0	+	part-time students make fewer tours than casual & voluntary workers, the retired and children	No
FTwkr_0	+	full-time workers make substantially fewer tours than casual & voluntary workers, the retired and children	Yes
PTtmwk_0	+	part-time workers make fewer tours than casual & voluntary workers, the retired and children	Yes
unempl_0	-	unemployed persons make more tours than casual & voluntary workers, the retired and children	No
lookhm_0	-	people looking after the home make more tours than casual & voluntary workers, the retired and children	No
lic_0	-	licence holders make more tours	Yes
0_1cars_0	-	individuals in households with zero or one cars make more tours	Yes
compcr_0	+	individuals in households with car competition make fewer tours	Yes
age<10_0	+	children aged under 10 make fewer tours	Yes
age<15_0	+	children aged under 15 make fewer tours (this term is applied to children aged under 10 in addition to the age<10_0 term)	Yes
age>29_0	-	persons aged over 29 make more tours	Yes
PerInc>26k	+	individuals with incomes > $26k p.a. make fewer tours	Yes
male_0	+	males make fewer tours	No
lsm0	-	individuals with higher accessibility make more tours	Yes

The higher tour frequency associated with lower car ownership (0_1_cars_0) is believed to reflect the fact that higher car ownership levels allow fewer larger shopping tours to be made.

A low personal income term (<$4k p.a.) present in the Stage 2 specification was dropped from the model. This effect may be captured by the additional adult category variables that have been added to the model.

Table 38: Shopping Frequency Terms, Stop/Go Model

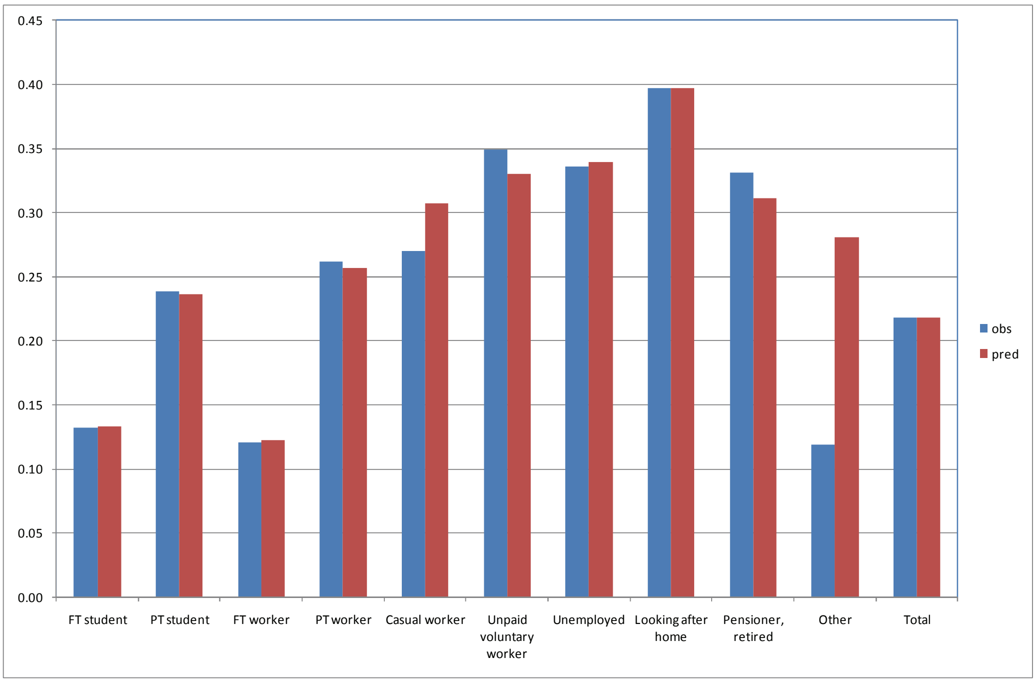
Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
lsmpl	-	students with higher accessibility are more likely to make multiple tours	Yes

A number of additional terms have been added to the shopping frequency model to reflect variation in tour frequency rate with adult category. Figure 14 compares observed and

[14] A single term was used for full-time students and full-time workers combined.

predicted tour rates by adult category for the final model specification. Children are omitted from this analysis.

Figure 14: Shopping Tour Rates by Adult Category



The figure demonstrates the significant variation in shopping frequency across adult categories, and these patterns are largely predicted by the model. The number of adults in the 'other' category is small and therefore no parameter has been added for this category.

The final parameter values (Shop_v13) are detailed in Table 39, which presents the parameters alongside the final Stage 2 model (ShopFr26).

Table 39: Shopping Frequency Parameters

File	ShopFr26.F12		Shop_v13.F12	
Converged	True		True	
Observations	33565		50421	
Final log (L)	-16033.2		-22436.8	
D.O.F.	14		18	
Rho²(c)	0.091		0.103	
Estimated	18 Mar 02		22 Sep 10	
Scaling	1.0000		1.0000	
theta	0	(*)	0	(*)
Zero/One-Plus Model:				
noneASC	1.455	(19.6)	1.429	(22.4)
FTpers_0	1.088	(25.0)		
FTstu_0			0.5751	(8.6)
FTwkr_0			1.109	(23.9)
PTstu_0			0.3241	(3.5)
PTtmwk_0	0.4193	(6.9)	0.3369	(6.8)
unempl_0			-0.2734	(-3.5)
lookhm_0			-0.3062	(-7.7)
lic_0	-0.2852	(-5.2)	-0.3712	(-8.3)
0_1cars_0	-0.1950	(-5.4)	-0.1665	(-5.7)
compcr_0	0.06497	(1.7)	0.1517	(4.5)
age<10_0	0.8691	(7.5)	1.377	(10.9)
age<15_0	1.573	(16.5)	1.282	(13.7)
age>29_0	-0.2635	(-6.2)	-0.3378	(-8.1)
PerInc<4k	-0.2085	(-4.9)		
PerInc>26k	0.2071	(4.5)	0.08744	(2.2)
male_0			0.1509	(5.3)
lsm0	-0.07055	(-2.5)	-0.1190	(-6.4)
Stop/Go Model:				
stopASC	2.585	(18.9)	2.031	(52.1)
lsmpl	-0.1897	(-3.6)	-0.2314	(-5.2)

5.8 Home–Other Travel

As per the Stage 2 models, the home–other travel model has been estimated from all persons (both adults and children) in the HTS data.

The terms in the final model are summarised in the following tables, which also detail whether the terms were identified in the Stage 2 estimations.

Table 40: Other Travel Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
fltmst_0	+	full-time students make fewer tours	Yes
fltmwk_0	+	full-time workers make far fewer tours	Yes
pttmwk_0	+	part-time workers make fewer tours	No
unempl_0	-	unemployed persons make more tours	Yes[15]
lookhm_0	-	persons looking after the home make more tours	No
retired_0	-	retired persons make more tours	Yes
lic_0	-	licence holders make more tours	Yes
free1lic_0	-	individuals in households with free car use and a single licence holder make more tours	No
2pcars_0	-	individuals in households with two or more cars make more tours	No[16]
agelt5_0	-	individuals aged under 5 make more tours	No
age6t15_0	+	individuals aged 6 to 15 make fewer tours	No
age25t34_0	+	individuals aged 25 to 34 make fewer tours	No
hinc>104k0	+	individuals from high income households make fewer tours	Yes
0kids_0	+	individuals in households with no children make fewer tours	Yes
1kid_0	+	individuals in households with one child make fewer tours, but not as few as those without children	Yes
lsm0	-	individuals with higher accessibility make more tours	Yes

A number of parameters were dropped from the model specification used in Stage 2. One was a low household income term (< $8k p.a.); another was a low personal income term (<$4k p.a.). An age < 10 term was dropped, but other age terms have been introduced that cover that age range. A term for 3-plus car households been replaced by a term for 2-plus car households.

Table 41: Other Travel Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
fltmstpl	+	full-time students less likely to make multiple tours	Yes
fltmwkpl	+	full-time workers less likely to make multiple tours	Yes
licpl	-	licence holders more likely to make multiple tours	Yes
hinc>104kp	-	individuals from high income households more likely to make multiple tours	Yes
0kidspl	+	individuals from households without children less likely to make multiple tours	Yes
3plkidspl	-	individuals from households with three or more children more likely to make multiple tours	Yes
agelt5_pl	-	individuals under 5 make more tours	No
lsmpl	-	students with higher accessibility are more likely to make multiple tours	Yes

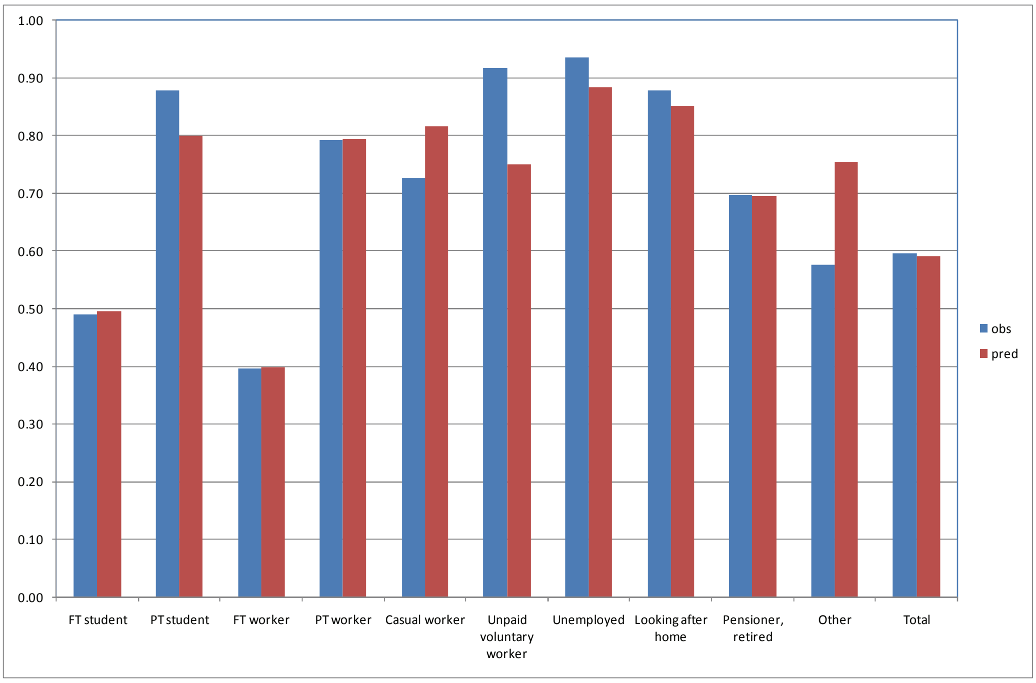
15 A single term was used for unemployed and retired persons combined.

16 A term on three-plus cars was present, however.

The terms for the under-fives will reflect the fact that this group will make a lot of other tours where they accompany their parents or guardians.

A number of additional adult status parameters have been added to the home–other frequency model. Figure 15 compares predicted and observed tour rates for the final model specification.

Figure 15: Other Travel Tour Rates by Adult Category



The fit across adult categories is generally good, and in particular the most frequently observed categories (full-time students, full-time workers, part-time workers, looking after home, pensioner/retired) are predicted accurately.

The final model parameters (OthFr_v13) are detailed in Table 42 alongside the Stage 2 estimates (OthFr42).

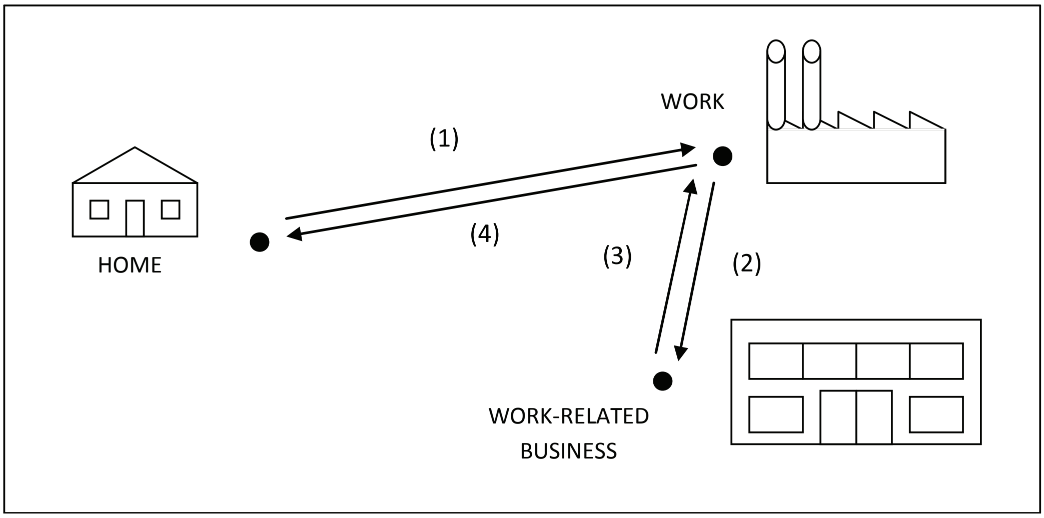
Table 42: Other Travel Frequency Model Parameters

File	OthFr42.F12		OthFr_v13.F12	
Converged	True		True	
Observations	13782		50421	
Final log (L)	-13521.9		-50954.3	
D.O.F.	21		26	
Rho²(c)	0.043		0.046	
Estimated	18 Mar 02		14 Sep 10	
Scaling	1.0000		1.0000	
theta	0	(*)	0	(*)
Zero/One-Plus Model:				
noneASC	0.6325	(9.7)	0.3770	(7.4)
fltmst_0	0.3600	(4.7)	0.2993	(6.9)
fltmwk_0	1.012	(19.4)	1.042	(29.5)
pttmwk_0			0.2440	(5.4)
lookhm_0			-0.2454	(-5.9)
pens_unem0	-0.2735	(-4.2)		
unempl_0			-0.4436	(-6.0)
retired_0			-0.09737	(-2.3)
lic_0	-0.6475	(-8.8)	-0.3744	(-10.7)
free1lic_0			-0.1850	(-5.7)
2pcars_0			-0.07953	(-3.7)
3plcars_0	0.2052	(3.8)		
age<10_0	-0.3770	(-5.1)		
agelt5_0			-0.6308	(-11.9)
age6t15_0			0.3714	(8.4)
age25t34_0			0.1586	(5.3)
pinc<4k_0	-0.09455	(-1.6)		
hinc<8k0	0.2175	(2.5)		
hinc>104k0	-0.1859	(-3.6)	-0.08814	(-4.0)
0kids_0	0.3480	(7.2)	0.4172	(15.8)
1kid_0	0.1493	(2.8)	0.1571	(5.5)
lsm0	-0.1854	(-4.3)	-0.1462	(-8.6)
Stop/Go Model:				
stopASC	1.230	(16.3)	1.482	(25.6)
fltmstpl	0.4079	(3.4)	0.2314	(3.9)
fltmwkpl	0.4920	(7.5)	0.5917	(17.3)
licpl	-0.5561	(-7.5)	-0.8621	(-20.2)
agelt5_pl			-0.3669	(-7.4)
hinc>104kp	-0.1510	(-2.3)	-0.1215	(-4.3)
0kidspl	0.5962	(10.0)	0.4686	(15.8)
3plkidspl	-0.2492	(-3.8)	-0.2703	(-7.3)
lsmpl	-0.2105	(-3.7)	-0.1073	(-4.3)

5.9 Work-Based Business

A work-based business tour is a series of linked journeys to a business destination that starts and finishes at the individual's main workplace. Figure 16 illustrates how a work-based business tour can be made. Trips (2) and (3) form the work-based business tour.

Figure 16: Work-Based Business Tour Example



The work-based frequency models predict the number of full work-based business tours per home–work tour. The link to the home–work tour means that in model application, the number of work-based business tours is predicted conditional on the predicted home–work tours. This in turn means that the parameters in the work-based business frequency model must be defined by the home–work segmentation in order for them to be applied directly. Alternatively terms can be defined using mean observed proportions.

The work-based business model has been estimated by summing the number of full work-based business tours made for each full home-based work tour in the 2004–2008 HTS data. The restriction to 2004–2008 ensures consistency with the data used for the estimation of the home–work mode-destination and frequency models.

The predictions of the home–work frequency model depend on the home–work accessibility, and therefore there is an indirect link between the home–work accessibility, and the work-based business tour frequency. No accessibility effects have been tested in the work-based business model, as the appropriate accessibility measure would be difficult to calculate, and the volume of work-based business travel is relatively low. However, tests have been made to investigate variations in work-based business tour making between workplaces located in centres, including the main Sydney CBD, and other areas. The rationale is that the type of jobs located in these areas, particularly in the main Sydney CBD, are more likely to result in work-based business tours.

Bearing in mind this restriction on the possible model specifications, the parameters identified in the final model are summarised in the following table.

Table 43: Work-Based Business Frequency Terms, Zero/One-Plus Model

Parameter	Sign	Definition	Stage 2?
noneASC	+	constant to ensure observed proportion making at least one tour is replicated	Yes
compcar_0	-	individuals from households with company cars make more tours	Yes
FTwk_0	-	full-time workers make more tours	Yes
PT>41.6k_0	-	higher income persons make more tours	Yes[17]
HB_CarD_0	-	individuals who drive to work are more likely to make tours	Yes
male_0	-	males are more likely to make tours	Yes
CBD_0	-	tours are more likely to be made from workplaces in the CBD	No

A term reflecting lower tour rates for those employed in manufacturing industries was dropped because manufacturing/non-manufacturing is no longer used as a segmentation in the home–work model.

The change to the definition of the income parameter was made to ensure consistency with the new home–work income segmentation.

As per the Stage 2 model, the male constant can be implemented using mean proportions.

Following on from the discussion above, a new term has been identified to reflect higher rates of tour making from workplaces located in the CBD. Variations in tour making rates across other centres were investigated, but the relatively small samples of work-based tours originating in these other centres meant that reliably identifying any additional effects was not possible. A combined term for all other centres was tested, but the term was not significant, and therefore it was concluded that the main effect associated with the CBD has been captured.

Table 44: Work-Based Tour Frequency Terms, Stop/Go Model

Parameter	Sign	Definition	Stage 2?
stopASC	+	constant to ensure observed multiple tour making rate is replicated	Yes
HB_CarD_pl	-	individuals who drive to work are more likely to make multiple tours	No

The term for multiple tour making by car drivers is not significant at a 95 per cent confidence level, but has been retained as the effect is plausible.

The model parameter values are given in Table 45 (WkBsFr_v5). The Stage 2 model parameters (WkBsFr65) are also presented.

[17] The cut-off in the Stage 2 specification was $36.4k p.a.

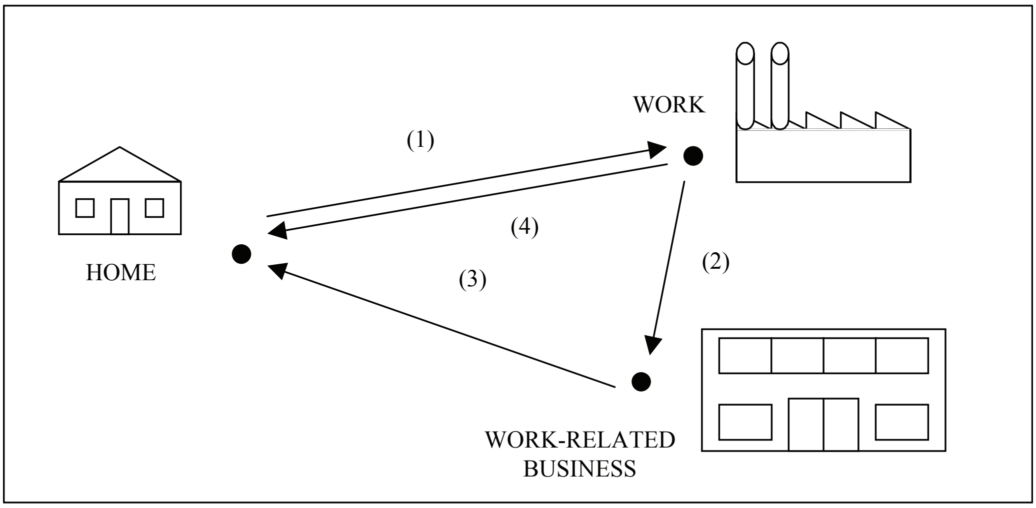
Table 45: Work-Based Business Frequency Parameters

File	WkBsFr65.F12		WkBsFr_v5.F12	
Converged	True		True	
Observations	9679		6220	
Final log (L)	-3312.1		-1914.8	
D.O.F.	8		9	
Rho²(c)	0.039		0.036	
Estimated	18 Mar 02		4 Aug 10	
Scaling	1.0000		1.0000	
theta	0	(*)	0	(*)
Zero/One-Plus Model:				
noneASC	3.632	(27.3)	4.052	(22.8)
compcar_0	-0.7842	(-10.0)	-0.6439	(-6.2)
FTwk_0	-0.5591	(-4.2)	-0.3951	(-3.4)
PI>36.4k_0	-0.3580	(-4.4)		
PI>41.6k_0			-0.4057	(-3.0)
HB_CarD_0	-0.3128	(-3.7)	-0.5873	(-4.4)
male_0	-0.3607	(-4.3)	-0.5128	(-4.8)
manuf_0	0.3536	(3.5)		
CBD_0			-0.4325	(-2.8)
Stop/Go Model:				
stopASC	1.133	(16.2)	1.647	(6.9)
HB_CarD_pl			-0.4022	(-1.5)

5.10 Non-Home-Based Business Detours

Non-home-based business detours may take place during both home–work and home–business tours, and on either the outward or return legs of the home-based tour during which the detour is made. Figure 17 illustrates a non-home-based business detour made on the return leg of a home–work tour. Trip (2) is the non-home-based business detour.

Figure 17: Non-Home-Based Business Detour Example



The actual pattern of trips undertaken by the individual is (1)→(2)→(3). The home-based work model assumes a direct return trip to the workplace, so trip pattern (1)→(4) is represented. The non-home-based business detour modelling represents the additional travel associated with trip (2).

Analysis undertaken during the Stage 2 modelling work revealed two patterns:

- Business detours are much more likely to occur during home-based business tours than during home–work tours.
- Detours are more likely to be made on the return legs of tours than on the outward legs.

These patterns are also apparent in the 2004–2008 HTS data used in this work for these models, as illustrated by Table 46 and Table 47.

Table 46: Outward Detours by Home-Based Purpose

	Purpose				Total	
	Work		Business			
No detour	6,057	97.1%	1,351	75.7%	7,408	92.3%
Detour	181	2.9%	433	24.3%	614	7.7%
Total	6,238	100.0%	1,784	100.0%	8,022	100.0%

Table 47: Return Detours by Home-Based Purpose

	Purpose				Total	
	Work		Business			
No detour	6,034	96.7%	1,282	71.9%	7,316	91.2%
Detour	204	3.3%	502	28.1%	706	8.8%
Total	6,238	100.0%	1,784	100.0%	8,022	100.0%

On this basis, the Stage 2 approach of developing separate models for outward and return detours, and for detours made during home–work and home–business tours, was retained. No more than one detour per tour-leg is represented in the modelling approach, and therefore the detour models predict the binary choice between 'no detour' and 'detour'. For consistency with the other frequency models, the explanatory variables are placed on the 'no detour' alternative and therefore positive parameters indicate a lower probability of making a detour.

No accessibility terms have been tested for the detour models, indeed specifying an accessibility would not be straightforward for a detour, as accessibility at both the home and the detour may have an impact, and there are likely to be significant correlations, for example detours may be more likely on longer tours. However, in model application there will be an indirect link to accessibility, because the detour models make predictions as a function of the predicted home–work and home–business tours, and the frequency models for these purposes do have a link between tour frequency and accessibility.

5.10.1 Detours During Home-Work Tours

The final models for outward and return detours made during home–work tours had the same specification as was developed originally, and the parameters are defined in Table 48. In application, these models are applied after the home–work model, and therefore the possible segments in the model are restricted to those used for the home–work model.

Table 48: Business Detour Frequency Model Terms, PD Work

Parameter	Sign	Definition	Stage 2?
noneASC_*W	+	constant to ensure observed detour rate is replicated	Yes
compcar_*W	-	individuals from households with company cars make more detours	Yes
PI>67.6k*W	-	higher income persons make more detours	Yes[18]
HB_CarD_*W	-	individuals who drive to work are more likely to make detours	Yes
male_*W	-	males are more likely to make detours	No

where: * is O for outward detours, R for return detours

A term for these employed in manufacturing jobs was dropped from the Stage 2 specifications for both outward and return detours because manufacturing/non-manufacturing is no longer used as a segmentation in the home–work model.

A male term has been added to the model. This parameter is not defined by the home–work segmentation but can be implemented by mean proportions segmented by full-time workers and others.

The final model parameter values are given in Table 49.

Table 49: Business Detour Frequency Model Parameters, PD Work

```
File            BsDe_PDwk_O_v4.F12  BsDe_PDwk_R_v4.F12
Converged                     True                True
Observations                  6238                6238
Final log (L)               -773.0              -849.7
D.O.F.                           5                   5
Rho²(c)                      0.056               0.054
Estimated                30 Jul 10           30 Jul 10
Scaling                     1.0000              1.0000

Outward Detour Model:

noneASC_OW          4.941  (22.0)
compcar_OW        -0.8615  (-5.4)
PI>67.6kOW        -0.5165  (-3.3)
HB_CarD_OW        -0.7460  (-3.6)
male_OW           -0.5937  (-3.7)

Return Detour Model:

noneASC_RW                              4.720  (23.0)
compcar_RW                            -0.8846  (-5.9)
PI>67.6kRW                            -0.4675  (-3.2)
HB_CarD_RW                            -0.6310  (-3.3)
male_RW                               -0.6151  (-4.0)
```

Comparison of the two sets of model parameters demonstrates that the company car and male effects are similar across the two models, but that there are differences in the relative impact of personal income and car driver as in the home-based model.

For comparison, the final Stage 2 model parameters are presented in Table 50.

[18] In Stage 2 this parameter used a lower cut-off of 36.4 $k p.a.

Table 50: Stage 2 Business Detour Frequency Model Parameters, PD Work

```
File            BsDe_PDwk_O10.F12  BsDe_PDwk_R10.F12
Converged                    True               True
Observations                 9679               9679
Final log (L)             -1190.8            -1577.6
D.O.F.                          5                  5
Rho²(c)                     0.056              0.055
Estimated                3 Jul 01           3 Jul 01
Scaling                    1.0000             1.0000

Outward Detour Model:

noneASC_OW         4.698  (29.0)
compcar_OW       -0.8606  (-6.8)
PI>36.4kOW       -0.5318  (-4.2)
HB_CarD_OW       -0.9094  (-5.4)
manufac_OW        0.3440   (2.0)

Return Detour Model:

noneASC_RW                             4.103  (32.8)
compcar_RW                           -0.8938  (-8.3)
PI>36.4kRW                           -0.5216  (-4.9)
HB_CarD_RW                           -0.6821  (-5.2)
manufac_RW                            0.5870   (3.7)
```

5.10.2 Detours During Home–Business Tours

The terms in the final frequency models for detours made in the course of home–business tours are detailed in Table 51.

Table 51: Business Detour Frequency Model Terms, PD Business

Parameter	Sign	Definition	Stage 2?
noneASC_*B	+	constant to ensure observed detour rate is replicated	Yes
compcar_RB	-	individuals from households with company cars make more detours (return detour model only)	Yes
PI<31.2kOB	-	lower income persons make fewer detours (outward detour model only)	Yes[19]
HB_CarD_*B	-	individuals who drive for their home-business tour are more likely to make detours	Yes
male_OB	-	males are more likely to make detours (outward detour model only)	No

where: * is O for outward detours, R for return detours

For the outward detour model, a company car term and a term for where the home–business tour mode is walk were dropped. A term for detours where car driver is the home–business tour mode was added, as it was found that the main variation in detour rates with home-based mode was that the rates were higher for car driver; the rates for walk were similar to those for the other non-car driver modes. A term for males was also added to the model.

In contrast to the other three detour frequency models, no income or gender effects were identified in the model for return detours. This meant that two income terms have been dropped relative to the Stage 2 model specification.

[19] In Stage 2 this parameter used a lower cut-off of $15.6k p.a.

The final model parameters are given in the following table.

Table 52: Business Detour Frequency Model Parameters, PD Business

File	BsDe_PDbs_O_v7.F12	BsDe_PDbs_R_v2.F12
Converged	True	True
Observations	1784	1784
Final log (L)	-971.7	-1049.1
D.O.F.	4	3
Rho²(c)	0.017	0.010
Estimated	30 Jul 10	30 Jul 10
Scaling	1.0000	1.0000
Outward Detour Model:		
noneASC_OB	1.979 (9.9)	
PI<31.2kOB	0.3826 (2.2)	
HB_CarD_OB	-0.7135 (-4.1)	
male_OB	-0.3511 (-2.4)	
Return Detour Model:		
noneASC_RB		1.498 (10.1)
compcar_RB		-0.2922 (-2.7)
HB_CarD_RB		-0.4823 (-3.0)

The parameters in the final Stage 2 models are presented for comparison in Table 53.

Table 53: Stage 2 Business Detour Frequency Model Parameters, PD Business

File	BsDe_PDbs_O13.F12	BsDe_PDbs_R14.F12
Converged	True	True
Observations	2516	2516
Final log (L)	-1458.5	-1523.5
D.O.F.	4	5
Rho²(0)	0.164	0.126
Rho²(c)	0.018	0.014
Estimated	3 Jul 01	3 Jul 01
Scaling	1.0000	1.0000
Outward Detour Model:		
noneASC_OB	0.9832 (16.0)	
PI<15.6kOB	0.6522 (3.9)	
compcar_OB	-0.2917 (-3.2)	
HB_Walk_OB	1.959 (3.3)	
Return Detour Model:		
noneASC_RB		1.112 (9.0)
compcar_RB		-0.2183 (-2.4)
PI<15.6kRB		0.5270 (3.4)
15.6_26kRB		0.3193 (2.9)
HB_CarD_RB		-0.3831 (-3.0)

CHAPTER 6 Summary

Licence Cohort Projection Spreadsheet

The licence cohort projection spreadsheet is used to predict changes in licence holding by gender and age cohort over time. The spreadsheet has been updated with new data and some improvements have been made to the calculations.

The base year for the licence projections has been updated from 2001 to 2006, and the forecast period extended to 2041. An additional cohort was added to distinguish those aged 85–90 and 90+, thus improving the treatment of older licence holders. The reliability of the 2001 data used in the projections was improved by using a greater volume of data. Finally, the treatment of migrants has been revised to reflect more recent thinking and data.

Comparing the projected licence holding by gender and age cohort in 2041 to the 2006 base data, two key trends emerge. First is a new tendency to delay licence acquisition in the early years, so that peak licence holding is reached more gradually. Factors such as the high cost of insurance for young drivers, and delaying licence acquisition until after university, are likely to play a role. Second is a substantial increase in licence holding for older female cohorts, as females maintain higher licence holding rates into older age. Continuing high rates of migration depress licence holding, particularly for women.

Disaggregate Licence-Holding Models

The disaggregate licence-holding models are used to predict cross-sectional variation in licence holding across the population. Two separate models are used, the first to predict the licence holding of the head of the household and their partner (if they exist), the second to predict the licence holding of any other adults in the household.

The procedure used for the re-estimation of the models was to estimate the Stage 1 specifications – which were the result of substantial testing – with the 1999–2008 Household Travel Survey (HTS) data and examine the two sets of model parameters before going on to test for revised or additional model terms.

The majority of the socio-economic terms for the head and partner model remained significant, demonstrating the overall transferability of the model specification. The magnitudes of the income parameters decreased, reflecting both differences in price year between the two models, as well as the decreasing importance over time of income as a differentiating factor for possessing a licence.

A noteworthy change in the age-related parameters was that terms for lower licence holding by younger persons, specified for ages 17–25 in the Stage 1 specification, have been re-specified as 17–35. This pattern is consistent with the trend for later licence acquisition for young persons observed in the projections of the cohort model. The changes in the age parameters for older persons were also consistent with changes noted in the cohort model.

A number of additional parameters were added to the head and partner model relating to work status, household characteristics and gender. A notable addition to the model is terms for both the head and partner alternatives indicating higher licence holding for those born in Australia compared with those who have migrated there, all other things being equal.

For the 'other adults' model, most of the parameters identified in the Stage 1 specification were retained. The magnitude of the income parameter was observed to reduce by similar proportions to the reductions observed in the head and partner model, reflecting different price levels and a decline in the importance of income as a differentiating factor for licence holding.

A number of parameters were added to the 'other adults' model defined by work status, age and migrant status. The effect of migrant status was, as in the head and partner model, that licence holding is higher for those born in Australia, all other things being equal.

Car Ownership Models

Two models are used to predict car ownership at the household level. The first predicts the number of company cars owned. The second predicts the total number of cars owned, conditional on the number of company cars owned.

As in the disaggregate licence-holding models, the estimation strategy was to start with the Stage 1 specifications, which were arrived at after substantial testing, and compare the model parameters, before going on to revise or introduce new model terms.

For the company car ownership model, all but two of the Stage 1 model parameters remained significant. Even after accounting for changes in prices, the impact of income on company car ownership has been reduced, although its effect is still strongly significant.

Subsequent optimisation of the model identified ten more parameters to represent the following effects:

- Higher company car ownership for households with more workers
- Higher company car ownership for larger households
- Higher company car ownership when at least one full-time worker lives in the household
- Higher company car ownership for households with married couples
- Higher car ownership for Australian-born workers.

For the total car ownership model, 27 out of 31 of the parameters identified during Stage 1 retained their significance. Interestingly, the changes to the income parameters were much smaller than in the company car or licence-holding models, and therefore there is no evidence of a weakening in the variation in car ownership with income; in fact, after accounting for income changes the effect is estimated to be stronger.

An important effect identified during the Stage 1 estimations, and that remains strongly significant in the re-estimated model, is the accessibility term. This term reflects the increase in accessibility that higher levels of car ownership offers a household. The accessibility gain that car ownership offers will be higher in areas less well served by public transport, such as suburban areas.

A number of new parameters were added to the total car ownership model to represent the following effects:

- Lower car ownership in and close to the CBD, using a log-distance from the CBD formulation capped at 35 km from the CBD – it is noted that the parking cost term identified in Stage 1 specification turned insignificant when the CBD term was added, indicating the CBD term to be the stronger effect.
- Higher probability of married couples owing exactly one car.
- Higher car ownership with increasing numbers of Australian-born persons in the household, over and above other household size terms

Frequency Models

The tour frequency models for the seven home-based tour purposes, and two non-home-based purposes, have been re-estimated. Again, the model specifications identified in the Stage 1 and Stage 2 estimations were used as the starting point.

Following analysis of the variation in tour rate with wave of data, it was decided to re-estimate the home–work and home–tertiary education models from 2004–2008 waves of data only. This was done in order to best represent 2006 conditions, as in both cases earlier waves (1999–2003) had noticeably higher tour rates. For the other home-based purposes, using earlier waves did not have a significant impact on the tour rate and therefore all of the 1999–2008 data were used in order to maximise sample sizes. Both the non-home-based models are linked to the home-based work model, and therefore they were also estimated from 2004–2008 data only for consistency.

The majority of the parameters identified in the Stage 1 and 2 estimations have remained significant, and have therefore been retained. A number of the income parameters have been re-specified, as changes in price levels mean that the definitions of the income terms needed to be revised.

In most models only a couple of additional parameters have been added. In both home–work and home–business, a link between multiple tour making and income has been identified for the first time. For both home–shopping and home–other travel, additional terms have been identified to reflect significant variation in tour making with adult status.

For the primary and secondary education models, variation in tour making with household income was investigated. Pupils from higher income households are more likely to attend private schools, and these tend to have longer holiday periods, which would result in lower education tour frequency rates. However, no significant pattern of variation for children from higher income households was identified, although there was evidence of lower primary education frequency for pupils from low-income households.

In all of the home-based frequency models, a link has again been identified between accessibility and frequency. These terms mean that increases in accessibility will lead to small increases in travel frequency.

In the work-based business and non-home-based business detour frequency models, no accessibility terms have been tested. However, in model application these models are applied to the samples of predicted home–work and home–business tours, and the frequency components of these models do incorporate a link to accessibility. Furthermore, the work-based business frequency model incorporates a parameter that reflects higher work-based tour frequency rates from workplaces located in the CBD.

REFERENCES

Reference List

Australian Bureau of Statistics. 2008. Report 3142.0, *Migration*, 26 March 2008, Australian Bureau of Statistics, Canberra.

Daly, A., S. Miller. 2006. Advances in Modelling Traffic Generation, European Transport Conference Proceedings.

Fox, J., A. Daly and B. Patruni. 2010. Sydney Strategic Model Re-estimation, Report DRR-5270-BTS, RAND Europe, Cambridge, UK.

HCG. 2000. Further Model Estimation (Stage 1 estimation work), a report for the Transport Data Centre of New South Wales Department of Transport (Report 9009-3B).

HCG/RAND Europe. 2001. Further Model Estimation (Stage 2 estimation work), a report for the Transport Data Centre of New South Wales Department of Transport (Report 0032-6).

OECD. 2009. OECD Stats Extracts. As of 6 May 2015: http://stats.oecd.org/.

TDC. 2009. 2007 Household Travel Survey Summary Report 2009 Release. As of 6 May 2015: http://www.transport.nsw.gov.au/sites/default/file/tdc/documents/hts-report-2007.pdf

Raimond, T. and F. Milthorpe. 2010. Why are young people driving less? Trends in licence-holding and travel behaviour, paper presented at 2010 Australasian Transport Research Forum, Canberra, Australia.

RAND Europe. 2004. Sydney Strategic Travel Model: Stage 2 Validation – Population Model (Report 0032-9).

Whelan, G. 2001. Methodological Advances in Modelling and Forecasting Car Ownership in Great Britain, European Transport Conference Proceedings.