RAND EUROPE

STM3 2011 base

Model parameters and overview

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Preface

RAND Europe was commissioned by the Bureau of Transport Statistics (BTS) of Transport for NSW to modify the Sydney Strategic Transport Model (STM) to reflect a 2011 base year. This report presents a summary of the 2011-base models.

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 holding and car ownership. In addition a forecasting system was developed incorporating these components. In Stage 2 of model development (2001–2002), 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 and 2004, RAND Europe undertook a detailed validation of the performance of the Stage 1 and 2 models. Finally, Halcrow undertook Stage 3 of model development (2007), re-estimating the home–work mode-destination models, and at the same time developing models of access mode choice to train for home–work travel.

By 2009, some model parameters dated back to 1999, 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, the BTS commissioned RAND Europe to re-estimate the STM models using more recent information on the travel behaviour of Sydney residents, and implement those updated models. The updated version of the model system is referred to as STM3.

The work to modify STM3 to work with and reflect a 2011-base year was undertaken in the second half of 2014. The work involved updating the frequency, mode-destination and car-ownership models with more recent data so that they reflected a 2011 base year. This report summarises the 2011-base models, the demand that these models collectively predict for the 2011 base year, and an overview of the key differences between the mode-destination models developed for different travel purposes.

This document is intended for a technical audience familiar with transport modelling terminology.

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1. Introduction

The objective of this report is to summarise the final STM3 2011-base model parameters and the base year demand predicted when these models are applied using 2011 population and employment totals. An overview chapter is also included that summarises the key differences between the mode-destination models for the different travel purposes.

Comprehensive documentation of the estimation of the STM3 models is provided in a number of documents. Documentation of the frequency models is provided in *Sydney Strategic Travel Model re-estimation: licence, car ownership and frequency models* (2010). Similarly full documentation of the estimation of the STM3 mode-destination models is provided in *Sydney Strategic Travel Model re-estimation: mode-destination model* (2010) and *Additional estimation of the Sydney Strategic Travel Model* (2013). The implementation of the STM3 frequency and mode-destination models is described in *Application System for Sydney Strategic Travel Model* (2012). The base year for the STM3 estimations was 2006, and all costs are defined in 2006 values. The 2006 zoning system was used for the model estimations.

More recently, BTS transferred the STM3 frequency and mode-destination models into Emme code. In the course of this work a number of issues were identified in the (ALOGIT) estimation and implementation code. The *Revisions to STM3 Code* (2013) note documents the issues and summarises the impact that revisions to the model have had on the model parameters and the base year demand predicted in the implementation.

Since the first version of this note was created in September 2013, there have been a number of further changes to the frequency and mode-destination models. These are summarised as follows:

- In 2014, the frequency and mode-destination models were updated to reflect a 2011 rather than 2006 base year. More recent choice data were used to reflect changes in demand, and the highway and public transport (PT) level-of-service used in the re-estimations reflected changes in supply. Updated attraction data were also used. These models were documented in *STM3 2011-base frequency, mode-destination and car ownership models* (2014). This report presented tables comparing the previous 2006-base and new 2011-base model parameters.
- When BTS implemented the 2011-base parameters and applied the new models for the 2011 base year, they observed a significant decrease in park-and-ride and kiss-and-ride demand for

those travel purposes where these access modes are explicitly modelled,[1] and further investigations identified an error in the estimation setup for highway access legs to rail. Given that correcting this error implied re-estimating the models in question, and that by that point BTS had made some further updates to the 2011 highway network and planning data, it was decided to re-estimate all of the models at the same time, incorporating the correction to highway access with updated 2011 highway skims and updated attraction data. These latest re-estimations were undertaken in October 2014.

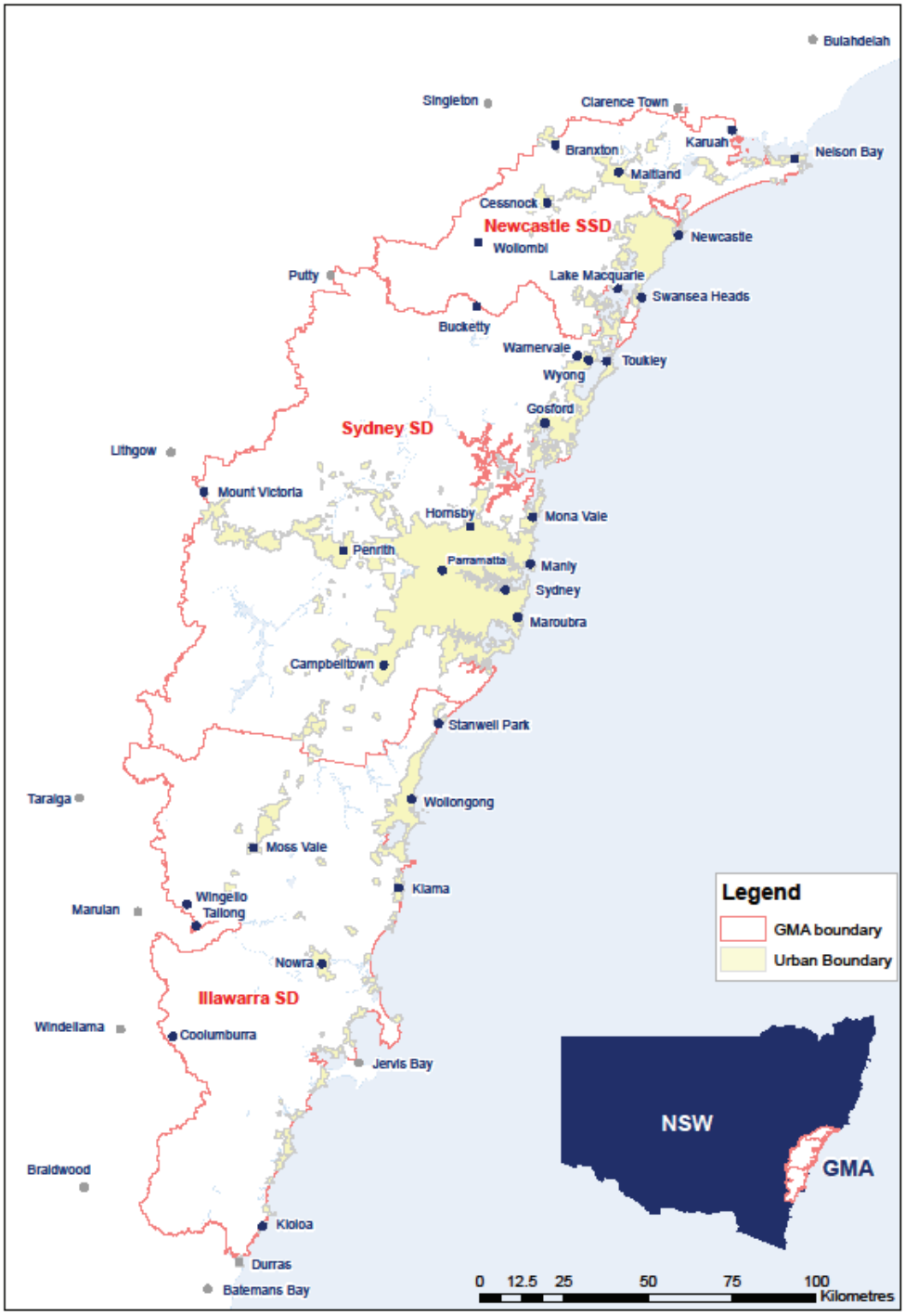
The structure of this report is as follows. The introduction illustrates the model study area, and presents figures showing the overall structure of the STM and the structures of the home-based and non-home-based implementations. Chapters 2, 3 and 4 summarise the final frequency, licence-holding, car-ownership and mode-destination model parameters. Chapter 5 presents validation of the mode-destination models, specifically analysis of the implied values of time and model elasticities. Chapter 6 summarises the segmentations that have been used in application to implement the frequency and mode-destination models. Chapter 7 summarises the base-year levels of demand that they predict and validates these demand levels against expanded Household Travel Survey data. The final overview chapter summarises the key differences between the different model purposes, including differences in model structure.

[1] Namely commute, home–business, home–secondary education, home–tertiary education, home–shopping and home–other travel.

1.1. STM3 study area

Figure 1 shows the model study area. Note that the study area was extended in STM3 to include Newcastle and Illawarra.

Figure 1: STM study area



1.2. STM3 model architecture

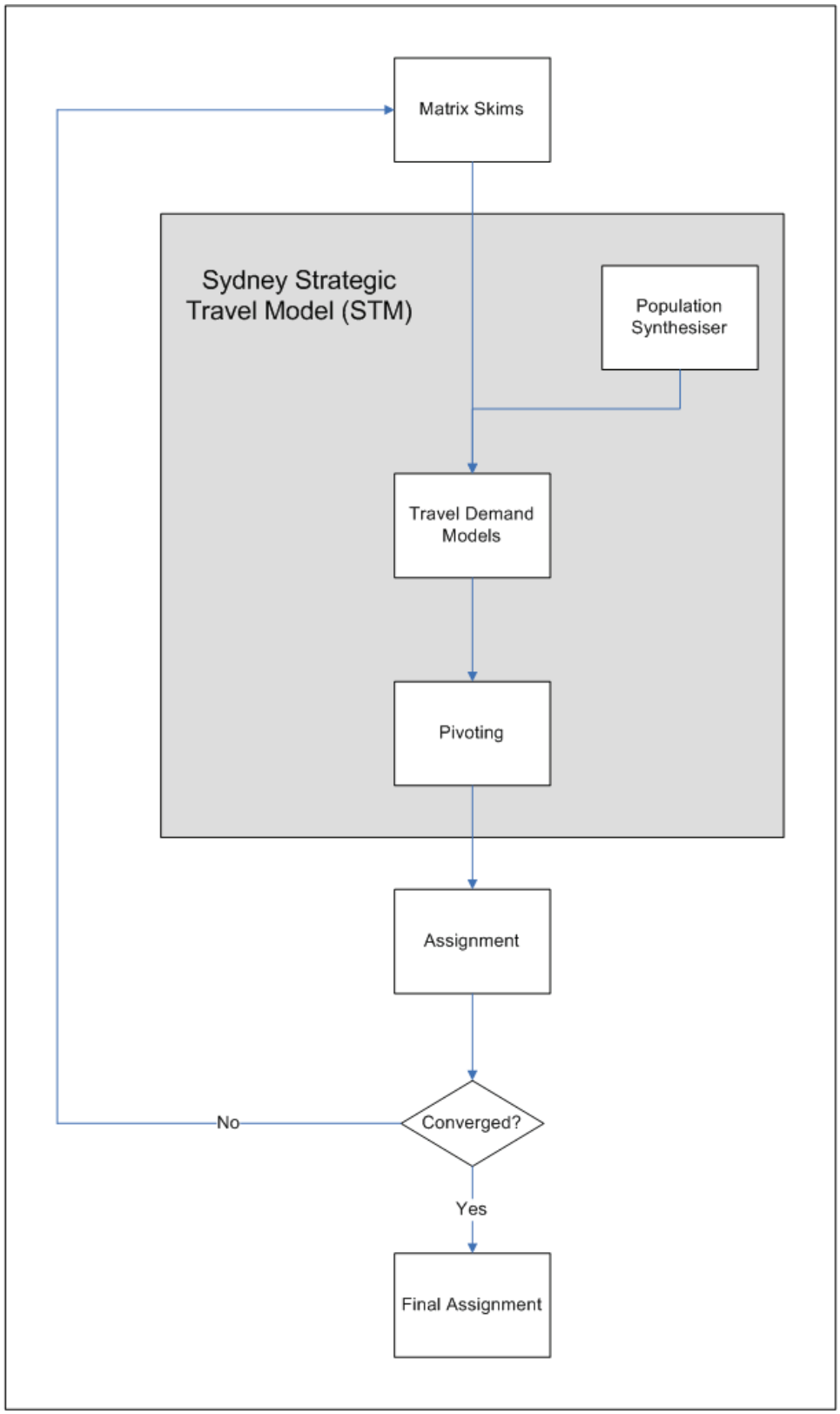
The STM system comprises four main components:

- A Population Synthesiser, which implements the car ownership and licence holding models and predicts the future population by segment.
- The Travel Demand (TravDem) models, which combine the frequency and mode-destination models estimated for each purpose.
- A pivoting procedure, which combines base and future demand model predictions to 'pivot' off the base matrices in order to produce best estimate forecasts of future demand.
- Network assignments, run separately in Emme for highway and PT.

The link between these four components is illustrated in Figure 2.

In a full application the system is run iteratively, in order that an acceptable level of convergence can be achieved between supply (as represented by the Emme network assignments) and demand (represented by the TravDem models). However, sometimes the model system is run without iteration, especially for the early stages of investigation of PT projects. This operation of the model is termed 'single cycle'.

Figure 2: Structure of the Sydney Strategic Travel Model



The structure of the home-based TravDems is illustrated in Figure 3 and the structure of the NHB TravDems in Figure 4. It is noted that the NHB TravDems are run after the home-based TravDems, as

NHB demand is predicted as a function of the number of home–work and home–business tours arriving in each zone. These tour arrivals are termed 'tour ends' in Figure 4. Note also that in the current version of STM only NHB business travel is modelled.

Figure 3: Structure of home-based TravDem models

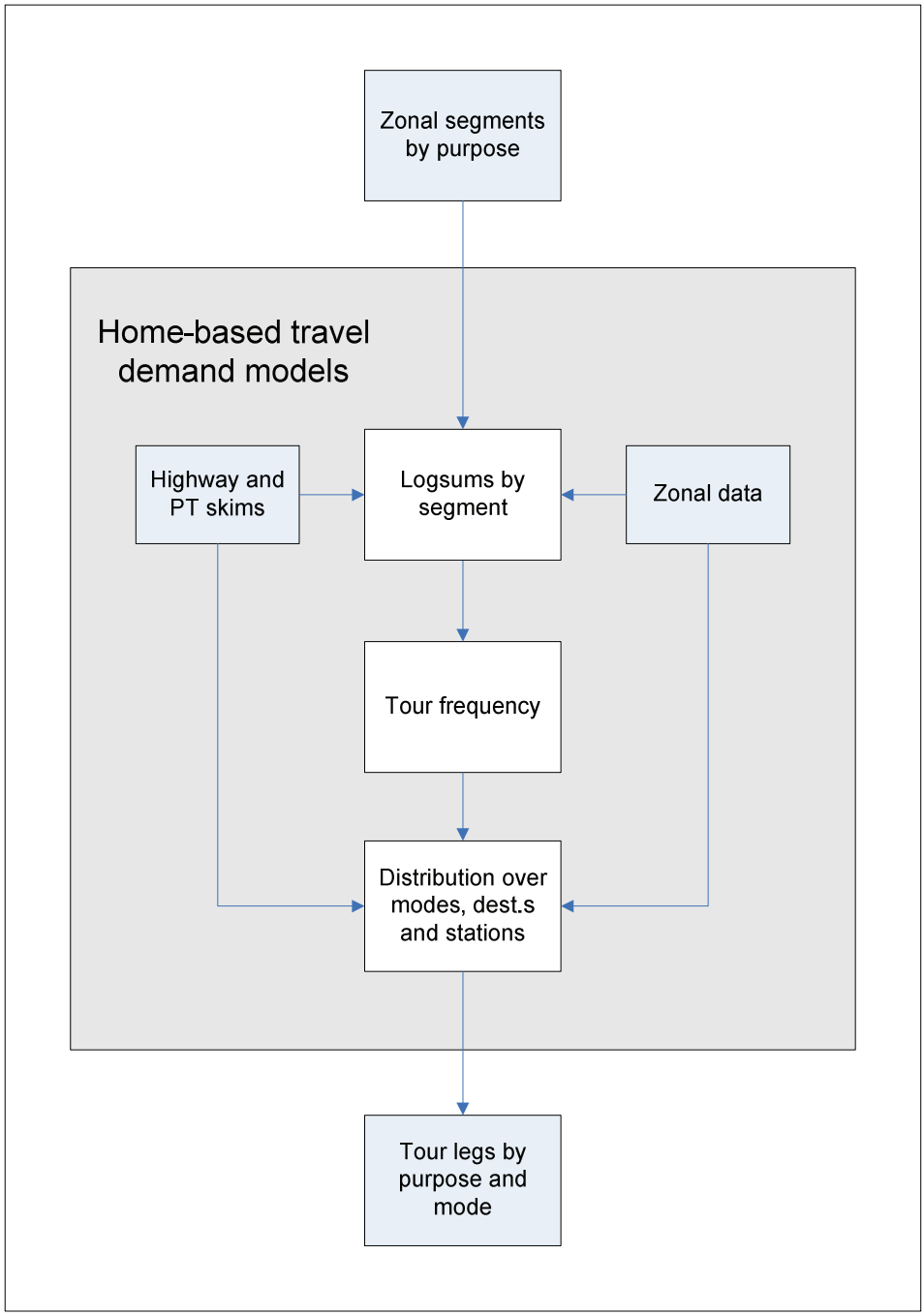
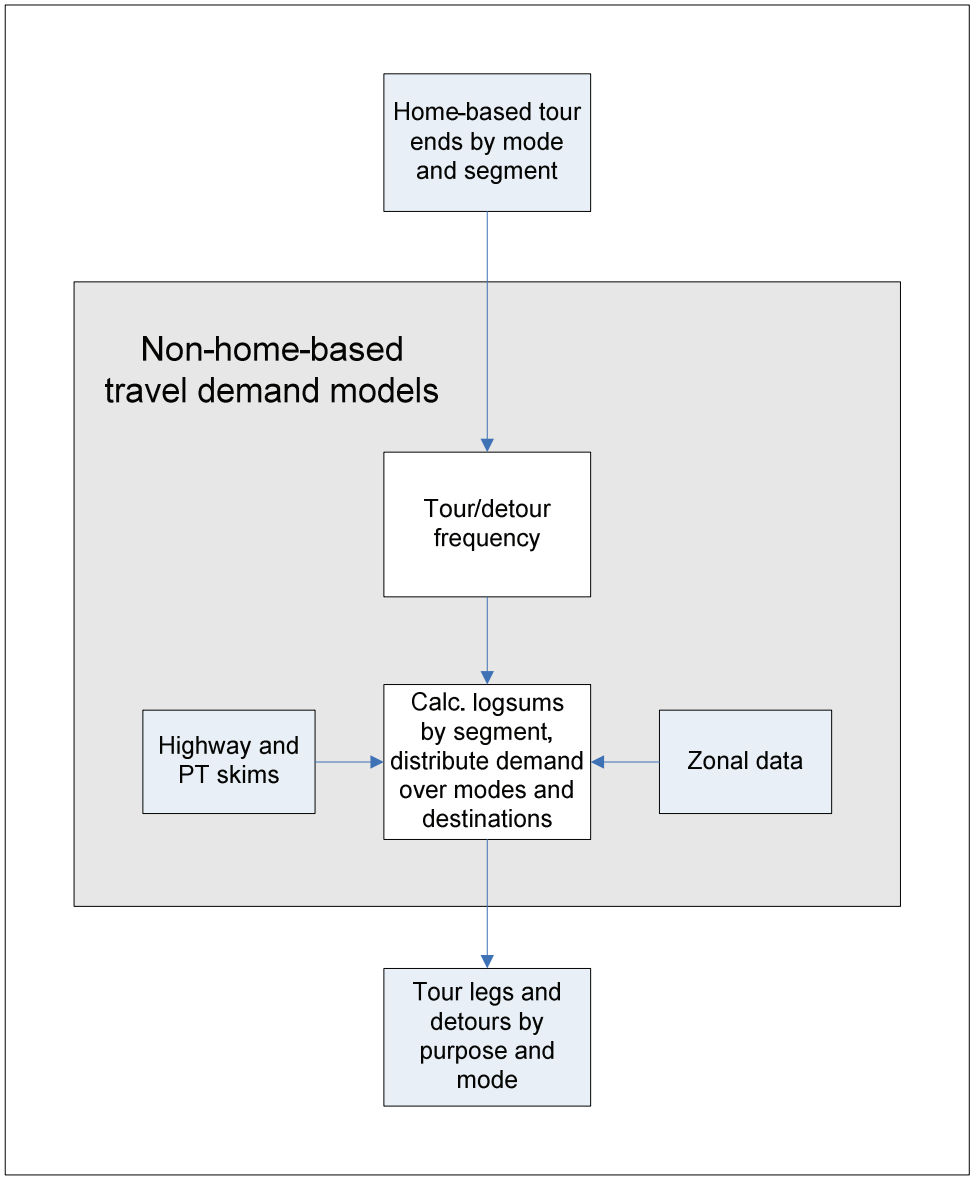


Figure 4: Structure of the NHB travel demand models



2. Licence-holding and car-ownership models

The STM3 explicitly models licence holding and car ownership.

2.1. Licence-holding models

Two licence-holding models have been estimated. The first is the head of household and partner model, which predicts the probability of four possible states:

- Neither the household head nor the partner has a licence
- Household head has a licence
- Partner of household head has a licence
- Both household head and partner have licences.

A multinomial choice between these four alternatives is modelled. The model parameters are defined in Table 1. It is noted that the 'Neither the household head nor the partner has a licence' alternative is the base alternative and as such no utility terms are defined for that alternative. Licence holding is modelled solely as a function of the socio-economic characteristics of the household, with no account taken of the costs of car ownership.

Table 1: Head and partner licence-holding model (model 17) parameters

Parameter	Description	Alternative			Value	t-ratio
		Head	Partner	Both		
Alternative specific constants:						
HeadLic	head of household constant	✓			0.915	13.2
PartLic	partner constant		✓		0.536	6.3
BothLic	head and partner constant			✓	1.762	16.7
Household income terms:						
HdHHInc	household income term for head	✓		✓	0.009	14.2
PtHHInc	household income term for partner		✓	✓	0.008	13.6
Age terms:						
Hd>70yrs	head over 70 (years over 70)	✓		✓	-0.100	-20.3
Pt>70yrs	partner over 70 (years over 70)		✓	✓	-0.147	-19.0
Hd<35yrs	head under 35 (years under 35)	✓		✓	-0.087	-17.5
Pt<35yrs	partner under 35 (years under 35)		✓	✓	-0.101	-19.8
Worker status terms:						
HeadFtTm	head is a full-time worker	✓		✓	1.053	17.3
PartFtTm	partner is a full-time worker		✓	✓	1.094	16.7
HeadPtTm	head is a part-time worker	✓		✓	1.049	12.5
PartPTTm	partner is a part-time worker		✓	✓	1.136	11.2
HdOthWrk	head is a casual or voluntary worker	✓		✓	0.631	8.3
PtOthWrk	partner is a casual or voluntary worker		✓	✓	0.643	6.6
Gender terms:						
FemaleHD	head is female	✓		✓	-0.718	-14.3
FemalePt	partner is female			✓	-1.027	-18.9
FemPtAlt	partner is female		✓		-1.789	-20.2
Migration terms:						
HeadAus	head was born in Australia	✓		✓	0.604	14.7
PartAus	partner was born in Australia		✓	✓	0.884	17.4
Household characteristics terms:						
HdChilds	number of children term	✓		✓	0.213	7.9
PtChilds	number of children term		✓	✓	0.138	4.7
HdAdults	number of adults term	✓		✓	-0.099	-3.5
HdMarried	married couple in household	✓		✓	0.369	7.3
PtMarried	married couple in household		✓	✓	0.640	11.8

The second licence-holding model predicts the probability of owning a licence for other adults in the household, i.e. the third adult, fourth adult, etc., for households with three or more adults. For each of these 'other adults', i.e. adult numbers of three and more, a binary choice model predicts the probability of owning a licence. The model terms, which are all placed on the 'licence' alternative, are defined in Table 2.

Table 2: Other adults licence-holding model (model 17) parameters

Parameter	Description	Value	t-ratio
Alternative specific constant:			
OTAd_lic	adult licence constant	0.005	0.0
Household income terms:			
OTHHinc	household income	0.004	7.1
Age terms:			
OTAge<19	under 19 (years under 19)	-0.600	-8.7
OTAge<25	under 25 (years under 25)	-0.158	-7.7
OT25_29dum	head under 35 (years under 35)	-0.499	-4.0
OTMale>70	males over 70 (years over 70)	-0.189	-7.3
OTFem>50	females over 50 (years over 50)	-0.092	-12.5
Worker status terms:			
OTFtEmp	full-time worker	0.824	9.6
OTnonwrk	non-worker	-0.636	-6.1
Gender terms:			
OTFemale	female	-0.571	-8.3
Migration terms:			
OTAus	born in Australia	0.508	7.2
Household characteristics terms:			
OTChild	number of children term	-0.107	-2.8
Characteristics of first two adults:			
OTHdLic	head has a licence	1.020	10.2
OTPtLic	partner has a licence	0.679	7.3
OTH_PEmpl	head FT worker, partner FT worker	-0.145	-2.7

It is noted that the 'OTH_PEmpl' term is applied separately conditional on whether the head and partner are full-time workers; thus if both the head and partner are full-time workers the term is applied twice.

2.2. Car-ownership models

Car ownership in the STM is predicted using two linked household level models. The first predicts the number of company cars owned; the second predicts the total car ownership of the household conditional on the number of company cars owned.

In the company-car ownership model, the choice between three alternatives is modelled:

- No company cars
- 1 company car
- 2+ company cars.

The zero company cars (CC) alternative is the base alternative and as such no terms are placed on that alternative. The one and two-plus company car alternatives are only available to households that contain at least one worker. The model terms are detailed in Table 3.

Table 3: Company-car ownership model (model 34) parameters

Parameter	Description	Alternative		Value	t-ratio
		1 car	2+ cars		
Alternative specific constants:					
1CCar0508	1 CC constant, 2005/06–2008/09	✓		-2.371	-27.4
2pCCar0508	2+ CC constant, 2005/06–2008/09		✓	-4.522	-19.4
1CpCar	1 CC constant, 2009/10–2012/13	✓		-2.500	-28.3
2pCpCar	2+ CC constant, 2009/10–2012/13		✓	-4.652	-19.9
Age terms:					
D1age35	over 35 (years over 35)	✓		0.012	5.1
D2age35	over 35 (years over 35)		✓	0.029	6.8
Age<29c1	head under 35 (years under 35)	✓		-0.100	-5.4
Age<29c2	partner under 35 (years under 35)		✓	-0.118	-2.9
Workers terms:					
nworkers1	number of workers in household	✓		0.190	5.8
nworkers2	number of workers in household		✓	0.276	3.7
nftwks0_1	no full-time workers in household	✓		-0.925	-8.9
nftwks0_2	no full-time workers in household		✓	-1.109	-4.5
Gender terms:					
FMHdHHCmp	head of household is female	✓	✓	-0.343	-7.6
Migration terms:					
WkAus1	worker 1 or 2 born in Australia	✓		0.246	7.7
WkAus2	worker 1 or 2 born in Australia		✓	0.281	4.7
Household characteristics terms:					
nresident1	number of residents in household	✓		0.202	10.5
nresident2	number of residents in household		✓	0.367	10.1
couples1	married couple in household	✓		0.262	4.7
couples2	married couple in household		✓	0.377	3.4
Parking cost terms:					
PCost	parking cost at the home zone	✓	✓	-0.011	-1.7
Licence holding terms:					
UnlicAdsc1	number of adults with no licence	✓		-0.341	-8.4
UnlicAdsc2	number of adults with no licence		✓	-0.498	-6.4
D2-Lic<Car	less than two workers with licences		✓	-0.651	-4.9

Workers are defined as individuals whose adult status is full-time worker or part-time worker.

The migration terms are applied separately conditional on whether the first and second workers were born in Australia. Thus if there are two people who work in the household, and both of them were born in Australia, the terms are applied twice.

The parking cost parameter is multiplied by the number of company cars owned.

It is noted that company-car ownership is sensitive to taxation policy, which is not included as a variable in the model.

The total car ownership model represents the choice between four alternatives:

- No car
- 1 car
- 2 cars
- 3+ cars.

The availability of these alternatives is conditioned on the number of company cars held, as the total number of cars owned can never be less than the number of company cars owned.

'No car' is the base alternative and therefore no model terms are placed on that alternative except for the accessibility term, which is placed on the 'No car' alternative as well as the car-owning alternatives in order to capture the increase in accessibility offered by the 1 car, 2 car and 3+ cars alternatives relative to owning no cars.

The model parameters are defined in Table 4.

Remaining household income is calculated as gross household income net of an assumed annual cost of car ownership of $12,000. It should be noted that because these costs are calculated in terms of gross income they represent the gross-income-equivalent cost of car ownership. If a marginal tax rate of (say) 30 per cent were used, the $12,000 figure would be equivalent to $8,400 of disposable income.

The log of distance from the central business district (CBD) term in the model is multiplied by the number of cars owned.

The accessibility term is multiplied by a logsum from the commute mode-destination model for an 'average individual', namely a full-time worker with a personal income in the $32,000–$41,600 range. The accessibility term is placed on each of the car ownership alternatives and thus represents the increase in accessibility offered to a household from owning one, two or three-plus cars relative to not owning a car.

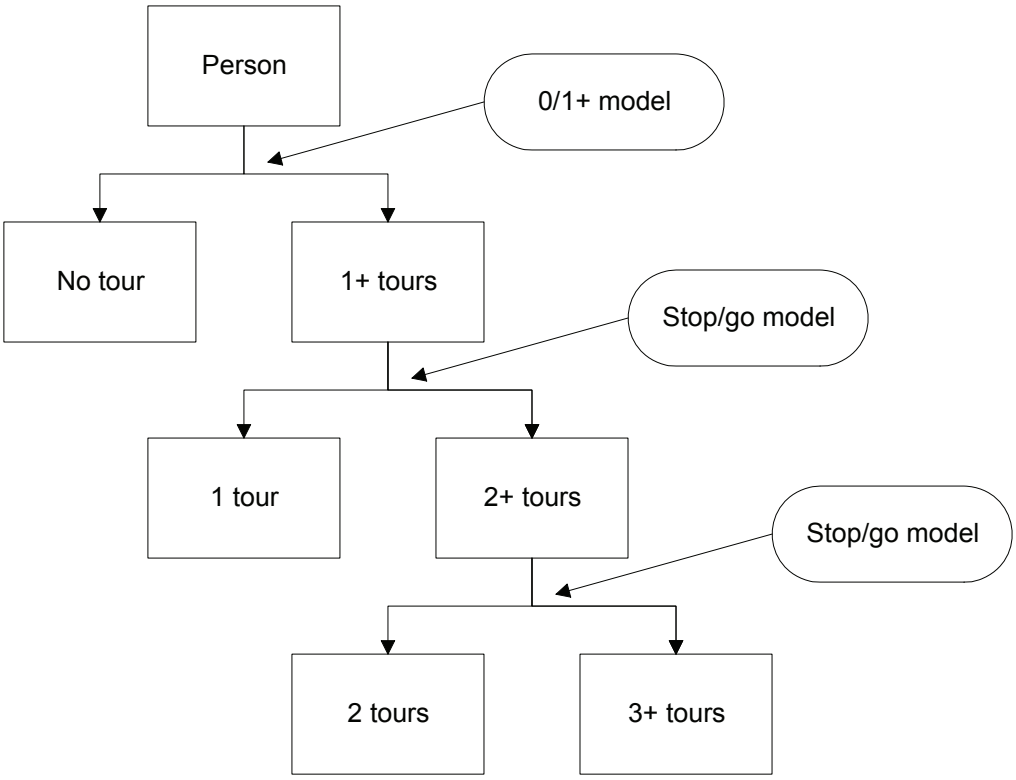
Table 4: Total car-ownership model (model 44) parameters

Parameter	Description	Alternative: 1 car	2 cars	3+ cars	Value	t-ratio
Alternative specific constants:						
1car_0508	1 car constant, 2005/06-2008/09	✓			-3.216	-17.1
2car_0508	2 car constant, 2005/06-2008/09		✓		-8.132	-26.9
3+car_0508	3+ car constant, 2005/06-2008/09			✓	-15.226	-38.2
1CarOwned	1 car constant, 2005/06-2008/09	✓			-3.074	-16.2
2CarOwned	2 car constant, 2005/06-2008/09		✓		-7.861	-25.9
3+CarOwned	3+ car constant, 2005/06-2008/09			✓	-14.903	-37.3
Household income terms:						
HHInc1	log of remaining household income	✓			0.120	5.3
HHInc23	log of remaining household income		✓	✓	0.176	10.8
Age terms:						
D1age35	over 35 (years over 35)	✓			0.031	9.7
D2age35	over 35 (years over 35)		✓		0.065	12.7
D3age35	head under 35 (years under 35)			✓	0.084	15.3
D23age50	aged over 50 (years over 50)		✓	✓	-0.047	-7.4
Workers terms:						
FtTmWrk1	full-time workers in household	✓			0.433	5.2
FtTmWrk2	full-time workers in household		✓		0.789	9.0
FtTmWrk3	full-time workers in household			✓	1.154	12.1
PrTmWrk1	part-time workers in household	✓			0.573	4.3
PrTmWrk2	part-time workers in household		✓		0.913	6.6
PrTmWrk3	part-time workers in household			✓	1.139	7.8
Gender terms:						
FmHdHH2	head of household is female		✓		-0.309	-7.1
FmHdHH3	head of household is female			✓	-0.301	-4.5
Migration terms:						
NAus_1	count of Australian-born in household	✓			0.178	3.5
NAus_2	count of Australian-born in household		✓		0.400	7.5
NAus_3	count of Australian-born in household			✓	0.493	8.9
Household characteristics terms:						
nchildcof	number of children in household	✓	✓	✓	0.432	5.0
couple1	couple only household	✓			0.100	2.1
Distance from CBD term:						
CBDdist	log of distance to CBD	✓	✓	✓	0.590	25.8
Accessiblity term:						
m_d_access	commuter mode-dest. accessibility	✓	✓	✓	0.708	11.7
Licence holding terms:						
NumLics1	number of adults with licences	✓			1.148	10.7
NumLics2	number of adults with licences		✓		2.127	15.4
NumLics3	number of adults with licences			✓	3.072	22.5
D2Lic_Car	licences less than cars		✓		-1.132	-9.5
D3Lic_Car	licences less than cars			✓	-0.534	-4.5
Company car ownership terms:						
CmpCar1_2	1 company car owned		✓		1.098	15.7
CmpCar1_3	1 company car owned			✓	1.680	19.5
CmpCar2_3	2 company cars owned			✓	1.414	15.3

3. Frequency models

Frequency models have been developed to predict the number of full tours made by a traveller on a work day (Monday to Friday excluding public holidays) for a given travel purpose. The frequency model structure is illustrated in Figure 5.

Figure 5: Frequency model structure



The model structure combines a first sub-model to predict whether any tours will be made (0/1+ model), and a second sub-model to predict the extent to which repeat tours are made, given that at least one tour is made (Stop/go model).

The utilities for the first model are applied to the 'No tour' 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, etc., alternatives, and positive parameters imply an individual is *less* likely to make multiple tours. In this example, up to two tours per day are observed, and so the final choice in the tree is

2 and 3+. For other purposes, the number of tours may be lower or higher, in which case the tree would be pruned or extended accordingly.

A key feature of the home-based frequency models is that they incorporate accessibility terms to represent the link between travel frequency and accessibility.

Tables 5–14 document the frequency model parameters for each model purpose.

Table 5: Commute frequency model (model 24) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
Constant	constant to ensure fraction making at least one tour is replicated	-0.637	-3.9
FTed	full-time students less likely to make tours than full-time workers	2.142	20.3
PTed	part-time students less likely to make tours than full-time workers	1.578	10.1
PTwk	part-time workers less likely to make tours than full-time workers	0.711	10.8
caswk	casual workers less likely to make tours than full-time workers	0.894	10.0
volwk	voluntary workers less likely to make tours than full-time workers	1.260	8.0
ageo39	persons over 39 less likely to make tours than those aged up to 39	0.155	3.2
ageo59	persons over 59 less likely to make tours than those aged up to 59	0.277	3.7
carcompet	individuals in households with car competition make fewer tours	-0.087	-1.6
compcar	individuals in households with company cars make more tours	0.595	11.7
males	males less likely to make tours than females	0.555	11.7
manufac	individuals with manufacturing occupations make more tours	-0.604	-7.4
incpu20.8k	individuals with incomes under $20,800 p.a. make fewer tours	0.618	8.6
incge67.6k	individuals with incomes of $67,600 p.a. and above make more tours	-0.162	-2.9
access	individuals with higher accessibility make more tours	-0.069	-2.8
Stop/go model:			
Constant2	constant to observed multiple tour making rate is replicated	3.497	32.7
compcar2	individuals in households with company cars make more multiple tours	-0.563	-3.2
manufac2	individuals with manufacturing occupations make fewer multiple tours	0.340	1.2
inpu20.8k2	*individuals with incomes under $20,800 p.a. make more multiple tours*	*0.000*	*n/a*
inge67.6k2	individuals with incomes of $67,600 p.a. and above make fewer multiple tours	0.506	2.4

The 'inpu20.8k2' term was insignificant when the models were re-estimated using 2011 level-of-service, and was therefore constrained to zero in the final model.

Table 6: Home–business frequency model (model 20) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour replicated	20.060	2.3
zerocrs0	individuals in zero car households make fewer tours	0.356	19.3
carcomp0	individuals in households with car competition make fewer tours	0.226	27.1
cmpcar0	individuals in households with company cars make more tours	-0.962	-19.4
manual0	individuals with manual occupations make many more tours than non-workers	-17.993	6.7
nonmanual0	individuals with non-manual occupations make many more tours than non-workers	-16.656	6.6
manu0	individuals with manufacturing occupations make fewer tours	1.240	16.8
FTst_pens0	full-time students and pensioners make fewer tours	1.107	-14.8
male0	males more likely to make tours than females	-0.919	-19.9
age<24_0	individuals aged up to 24 make fewer tours	0.450	-11.5
lsm0	individuals with higher accessibility make more tours	-0.099	-4.4
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	2.488	3.0
cmpcarpl	individuals in households with company cars make more multiple tours	-0.523	-4.6
age<24pl	individuals aged up to 24 make fewer multiple tours	0.868	-4.0
incu31.2	individuals with incomes under $31,200 p.a. make more multiple tours	-0.516	3.0

Table 7: Home–primary education frequency model (model 17) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour replicated	-0.546	-1.0
spec0	children attending special schools make fewer tours	0.601	0.9
hinc<25k0	individuals from households with incomes under $25,000 p.a. make fewer tours	0.284	2.0
lsm0	individuals with higher accessibility make more tours	-0.181	-2.9
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	5.421	20.2

Table 8: Home–secondary education frequency model (model 19) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour replicated	-1.802	-27.4
age>15_0	persons aged over 15 make fewer tours	0.568	5.5
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	8.931	2.7
lsmpl	individuals with higher accessibility make more multiple tours	-0.380	-1.2

Table 9: Home–tertiary education frequency model (model 28) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour replicated	4.979	16.4
FlTmSt_0	full-time students make more tours than other adult categories	-4.262	-22.6
FlTmWk_0	full-time workers make more tours than other adult categories	0.000	n/a
Uni_0	university students make fewer tours than other education types	-0.165	-1.0
PInc>15.6k	individuals with personal incomes over $15,600 p.a. make fewer tours	0.764	4.9
age1518_0	individuals aged 15–18 make more tours than older individuals	-0.231	-1.2
lsm0	individuals with higher accessibility make more tours	-0.062	-1.2
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	3.454	12.7
lsmpl	*individuals with higher accessibility make more multiple tours*	*0.000*	*n/a*

The 'lsmpl' term was insignificant when the frequency models were re-estimated using school day data only (t = 0.6) and so was constrained to zero.

Table 10: Home–shopping frequency model (model 22) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour is replicated	1.784	26.5
FTstu_0	full-time students make fewer tours	0.639	7.9
PTstu_0	part-time students make fewer tours	0.319	2.9
FTwkr_0	full-time workers make substantially fewer tours	1.005	20.8
unempl_0	unemployed persons make more tours	-0.343	-3.9
lookhm_0	people looking after the home make more tours	-0.417	-8.9
lic_0	licence holders make more tours	-0.261	-5.0
0_1cars_0	individuals in households with zero or one tour make more tours	-0.145	-4.1
compcr_0	individuals in households with car competition make fewer tours	0.147	3.6
age<10_0	children under 10 make fewer tours	1.569	7.8
age<15_0	children under 15 make fewer tours	1.683	12.6
age>29_0	individuals over 29 make more tours	-0.481	-9.1
PerInc>26k	individuals with incomes of $26,000 p.a. and above make fewer tours	0.194	4.4
male_0	males make fewer tours	0.036	1.1
lsm0	individuals with higher accessibility make more tours	-0.120	-7.2
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	2.320	34.5
lsmpl	individuals with higher accessibility make more multiple tours	-0.137	-3.1

Table 11: Home–other travel frequency model (model 22) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour is replicated	0.738	14.7
FlTmSt_0	full-time students make fewer tours	0.422	9.1
FlTmWk_0	full-time workers make substantially fewer tours	1.108	30.1
PtTmWk_0	part-time workers make fewer tours	0.212	4.5
unempl_0	unemployed persons make more tours	-0.536	-6.4
lookhm_0	people looking after the home make more tours	-0.381	-8.1
retired_0	retired persons make more tours	-0.206	-4.6
lic_0	licence holders make more tours	-0.409	-11.3
free1lic_0	individuals in households with one licence holder and free car use make more tours	-0.147	-3.8
2pcars_0	individuals in households with two or more cars make more tours	-0.082	-3.2
hinc>104k0	individuals with incomes of $104,000 p.a. and above make more tours	-0.108	-4.3
0kids_0	individuals in households with no children make fewer tours	0.390	13.1
1kid_0	individuals in households with one child make fewer tours	0.141	4.2
lsm0	individuals with higher accessibility make more tours	-0.228	-13.0
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	1.586	22.5
FlTmStPl	full-time students make fewer multiple tours	0.423	5.9
FlTmWkPl	full-time workers make fewer multiple tours	0.620	15.5
licpl	licence holders make more multiple tours	-0.758	-18.4
hinc>104kp	individuals with incomes of $104,000 p.a. and above make more multiple tours	-0.108	-3.4
0kidspl	individuals from households without children make fewer multiple tours	0.474	13.7
3plkidspl	individuals from households with three or more children make more multiple tours	-0.280	-6.4
lsmpl	individuals with higher accessibility make more multiple tours	-0.185	-7.3

Table 12: Work-based business frequency model (model 12) parameters

Parameter	Description	Value	t-ratio
Zero/1+ model:			
noneASC	constant to ensure fraction making at least one tour replicated	4.326	28.2
compcar_0	individuals from households with company cars make more tours	-0.570	-6.3
FTwk_0	full-time workers make more tours	-0.379	-2.7
PI>41.6k_0	individuals with incomes of $41,600 p.a. and above make more tours	-0.465	-4.4
HB_CarD_0	individuals who drive to work are more likely to make tours	-0.677	-5.7
male_0	males make more tours	-0.390	-4.3
CBD_0	tours are more likely to be made from workplaces in the CBD	-0.638	-4.7
Stop/go model:			
stopASC	constant to observed multiple tour making rate is replicated	1.820	8.1
HB_CarD_pl	individuals who drive to work are more likely to make multiple tours	-0.466	-1.9

The frequency of detours is modelled as a binary choice between no detour and detour alternatives. The parameters are placed on the no detour alternative, and therefore a positive model parameter indicates a lower probability of making a detour.

Table 13: Business detours in the course of home–work tours frequency model parameters (outward model 9, return model 9)

Parameter	Description	Value	t-ratio
Outward detours:			
noneASC_OW	constant to ensure outward detour rate is replicated	5.092	25.7
compcar_OW	individuals from households with company cars make more outward detours	-1.139	-7.9
PI>67.6kOW	individuals with personal incomes of $67,600 p.a. and above make more outward detours	-0.494	-3.3
HB_CarD_OW	individuals who drive to work PD make more outward detours	-0.643	-3.3
male_OW	males make more outward detours	-0.516	-3.3
Return detours:			
noneASC_RW	constant to ensure return detour rate is replicated	4.682	27.7
compcar_RW	individuals from households with company cars make more return detours	-0.781	-6.2
PI>67.6kRW	individuals with personal incomes of $67,600 and above make more return detours	-0.613	-4.8
HB_CarD_RW	individuals who drive to work make more return detours	-0.771	-4.7
male_RW	males make more return detours	-0.374	-2.9

Table 14: Business detours in the course of home–business tours frequency model parameters (outward model 11, return model 7)

Parameter	Description	Value	t-ratio
Outward detours:			
noneASC_OB	constant to ensure observed outward detour rate is replicated	1.900	11.7
PI<31.2kOB	individuals with personal incomes under $31,200 p.a. make fewer outward detours	0.347	3.2
HB_CarD_OB	individuals who drive to their business PD make more outward detours	-0.561	-4.0
male_OB	males make more outward detours	-0.310	-2.6
Return detours:			
noneASC_RB	constant to ensure observed return detour rate is replicated	1.872	12.9
compcar_RB	individuals from households with company cars make more return detours	-0.437	-4.9
HB_CarD_RB	individuals who drive to their business PD make more return detours	-0.408	-3.0
male_RB	males make more return detours	-0.223	-2.1

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4. Mode-destination models

Up to eight main modes are represented in the mode-destination models, which are abbreviated as follows in Tables 15–23:

- Car driver CD
- Car passenger CP
- Train and ferry TR
- Bus BS
- School bus SB
- Bike BK
- Walk WK
- Taxi TX.

Train in this context includes heavy rail, light rail and Sydney Harbour ferry services.

For commute, home–business, home–shopping and home–other travel, separate toll and no-toll alternatives are represented for the car driver:

- Car driver toll CD TL
- Car driver no toll CD NT.

For commute, home–business, home–secondary education, home–tertiary education, home–shopping and home–other travel, separate train access mode alternatives are represented:

- Train, park-and-ride access TR P&R
- Train, kiss-and-ride access TR K&R
- Train, bus access TR BS
- Train, walk access TR WK
- Train, other access (bus and/or walk) TR OT.

Park-and-ride (P&R) is defined as car access where the car is parked at the access station, and therefore can include both drivers and passengers. Kiss-and-ride (K&R) is defined as car access where car passengers are dropped by a car that is driven away.

Tables 15–23 present the mode-destination model parameters and the modes to which they are applied. The t-ratios are expressed to test the difference of the parameter value from zero, except for the structural parameters, where the t-ratio is expressed to test the difference from 1. The gamma cost specification is defined in Section 7.1.1 of *Sydney Strategic Travel Model re-estimation: mode-destination model* (2015).

Table 15: Commute mode-destination model (model 196) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
LogCost	logarithm of cost in cents	CD, CP, TR, BS, TX	-0.468	-4.7
Cost13	cost (cents), personal income < $20,800 p.a.	CD, CP, TR, BS, TX	-0.0020	-6.4
Cost4	cost (cents), personal income $20,000-$31,199 p.a.	CD, CP, TR, BS, TX	-0.0017	-6.6
Cost5	cost (cents), personal income $31,200-$41,599 p.a.	CD, CP, TR, BS, TX	-0.0014	-6.6
Cost67	cost (cents), personal income $41,600-$67,599 p.a.	CD, CP, TR, BS, TX	-0.0012	-6.8
Cost810	cost (cents), personal income $67,600+ p.a.	CD, CP, TR, BS, TX	-0.0010	-6.7
Cost	cost (cents), personal income missing	CD, CP, TR, BS, TX	-0.0024	-3.3
CarTime	car in-vehicle time (mins)	CD, CP, TX	-0.049	-7.3
RlTime	rail and ferry in-vehicle time (mins)	TR	-0.031	-6.7
BusTime	bus in-vehicle time (mins)	TR, BS	-0.034	-6.6
FWaitTm	first wait time (mins)	TR, BS	-0.079	-5.2
OWaitTm	other wait time (mins)	TR, BS	-0.062	-5.9
AcEgTm	access & egress time (mins)	TR, BS	-0.084	-7.0
CrAcEgTm	car access & egress time to P&R and K&R (mins)	TR P&R, TR K&R	-0.159	-6.4
CarPDist	car passenger distance (km)	CP	-0.056	-5.6
BikeDist	bike distance (km)	BK	-0.237	-6.0
WalkDist	walk distance (km)	WK	-1.169	-7.0
Toll choice terms:				
TollBonus	constant on car driver toll alternative	CD TL	-0.558	-3.1
CarTDist	car toll distance (km)	CD TL	0.013	4.6
Train access mode distance fit terms:				
OrigGW	Gosford-Wyong origin constant for train P&R	TR P&R	1.372	2.1
OrigSWS	Outer South Western Sydney constant for train P&R	TR P&R	0.959	1.7
TrnOthG75	constant for train tours > 75 km for non-car access	TR BS, TR WK	-1.712	-3.9
Car availability terms:				
CarComp	car competition term (licence holders > cars)	CD	-4.013	-6.7
CmpCrDr	company car term	CD	1.468	4.5
PassOpts	passenger opportunity term	CP	3.686	4.9
PRCarComp	car competition term (licence holders > cars)	TR P&R	-1.960	-3.6
PRFr2pCar	free car use, 2+ cars term	TR P&R	0.444	1.1
PRLicence	licence holder term	TR P&R	2.729	4.4
KRPassOpts	passenger opportunity term	TR K&R	1.735	2.3
Other socio-economic terms:				
MaleCrDr	male term on car driver	CD	0.694	3.4
MaleBike	male term on bike	BK	4.940	4.3
FTWrkDist	full-time worker distance term (km)	all	0.013	5.0
Mode constants:				
CarP	car passenger (relative to car driver no toll)	CP	-11.266	-6.6
Train	train (relative to car driver no toll)	TR	-1.442	-3.0
TrainPR	train P&R (relative to train bus access)	TR P&R	-5.724	-6.0
TrainKR	train K&R (relative to train bus access)	TR K&R	-6.011	-5.4
Bus	bus (relative to car driver no toll)	BS	-2.200	-4.8
Bike	bike (relative to car driver no toll)	BK	-16.974	-6.5

Parameter	Description	Modes	Value	t-ratio
Walk	walk (relative to car driver no toll)	WK	-2.391	-3.2
Taxi	taxi (relative to car driver no toll)	TX	-12.299	-5.8
Destination constants:				
Pmatta	Parramatta centre	all	0.985	4.8
Cwood	Chatswood centre	all	1.379	4.6
SLC	St Leonards Crows Nest centre	all	1.090	4.4
NSyd	North Sydney centre	all	1.795	6.0
ISyd	Inner Sydney area	all	0.748	5.5
ESub	Eastern Sydney area	all	0.822	4.1
NBeach	Northern Beaches area	all	0.620	3.0
Walk distance from workplace and workplace location terms:				
LWdistCBD	walk log-distance of CBD from workplace (km)	WK	-0.985	-5.4
WWng	walk, workplace in Wollongong	WK	-2.282	-2.3
WNcast	walk, workplace in Newcastle	WK	-3.450	-3.6
Intrazonal constants:				
CrDNoTlIIZ	car driver no toll	CD TL	-0.709	-2.1
CarPIZ	car passenger	CP	-0.369	-0.6
BikeIZ	bike	BK	-1.129	-0.6
WalkIZ	walk	WK	1.547	3.9
Attraction term:				
TotEmp	total employment in destination zone	all	1.000	n/a
Structural parameters:				
Theta_MD	relative sensitivity of main modes and destinations	n/a	0.707	7.8
Theta_PT	relative sensitivity of destinations and PT modes	n/a	1.000	n/a
Theta_AcMd	relative sensitivity of PT modes and train access modes	n/a	1.000	n/a
sta_ch	relative sensitivity of train access modes and stations	n/a	1.000	n/a
Theta_toll	relative sensitivity of stations and toll choice	n/a	0.545	6.3

Table 16: Business mode-destination model (model 58) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
GCost14	gamma cost, personal income < $31,200 p.a.	CD, TR, BS, TX	-0.0045	-6.4
GCost56	gamma cost, personal income $31,200-$51,999 p.a.	CD, TR, BS, TX	-0.0032	-6.3
GCost710	gamma cost, personal income $52,000+ p.a.	CD, TR, BS, TX	-0.0022	-5.9
GCostX	gamma cost, personal income missing	CD, TR, BS, TX	-0.0055	-5.3
CarTime	car in-vehicle time (mins)	CD, CP, TX	-0.033	-7.8
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.016	-4.0
BusTime	bus in-vehicle time (mins)	TR, BS	-0.032	-4.8
WaitTm	first and other wait time (mins)	TR, BS	-0.077	-5.1
AcEgTm	access & egress time (mins)	TR, BS	-0.066	-4.3
CarAccTime	car access & egress time to K&R (mins)	TR P&R, TR K&R	-0.117	-4.6
CarPDist	car passenger distance (km)	CP	-0.009	-2.3
BikeDist	bike distance (km)	BK	-0.284	-3.8
WalkDist	walk distance (km)	WK	-1.183	-5.7
Toll choice terms:				
TollBonus	constant on car driver toll alternative	CD TL	-0.430	-2.3
CarTDist	car toll distance (km)	CD TL	0.010	6.3

Parameter	Description	Modes	Value	t-ratio
Train access mode distance fit terms:				
OrigGW	Gosford-Wyong origin constant for train P&R	TR P&R	1.656	1.7
TrnOthG100	constant for train tours >100 km for non-car access	TR OT	-0.424	-0.6
Car availability terms:				
CarComp	car competition term (licence holders > cars)	CD	-3.588	-4.5
CmpCrDr	company car term	CD	2.465	3.9
PassOpts	passenger opportunity term	CP	2.273	2.5
PRCarComp	car competition term (licence holders > cars)	TR P&R	-1.365	-2.0
Other socio-economic terms:				
CarPu25	under-25 term on car passenger	CP	2.501	3.0
TrnManProf	managerial & professional occupation types	TR	2.064	4.1
Mode constants:				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-17.529	-5.7
Train	train, 2009/10 to 2012/13 waves	TR	-5.026	-3.5
Bus	bus, 2009/10 to 2012/13 waves	BS	-5.018	-3.6
Bike	bike, 2009/10 to 2012/13 waves	BK	-20.063	-5.1
Walk	walk, 2009/10 to 2012/13 waves	WK	-8.671	-4.3
Taxi	taxi, 2009/10 to 2002/13 waves	TX	-15.513	-4.5
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-17.165	-5.7
Train_0508	train, 2005/06 to 2008/09 waves	TR	-4.798	-3.5
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-4.463	-3.5
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	-17.255	-5.2
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	-9.381	-4.4
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	-14.570	-4.6
TrainPR	train P&R (relative to train other access)	TR P&R	-4.271	-5.0
TrainKR	train K&R (relative to train other access)	TR K&R	-6.046	-5.5
Destination constants:				
CBDRail	CBD destination constant on rail	RL	0.809	2.6
Intrazonal constants:				
CrDNoTllIZ	car driver no toll	CD TL	0.761	3.1
CarPIZ	car passenger	CP	2.978	3.4
BikeIZ	bike	BK	4.245	3.3
WalkIZ	walk	WK	0.946	1.7
Attraction term:				
TotEmp	total employment in destination zone	all	1.000	n/a
Structural parameters:				
Theta_M_P	relative sensitivity of main modes and PT modes	n/a	0.518	7.6
Theta_P_A	relative sensitivity of PT modes and train access modes	n/a	1.000	n/a
Theta_A_D	relative sensitivity of train access modes and destinations	n/a	1.000	n/a
Theta_D_S	relative sensitivity of destinations and stations	n/a	1.000	n/a
Theta_S_T	relative sensitivity of stations and toll choice	n/a	0.601	4.7

Table 17: Home–primary education mode-destination model (model 20) parameters

Parameter	Description	Modes	Value	t-ratio
Level of service terms:				
CarTime	car in-vehicle time (mins)	CP, TX	-0.136	-54.7
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.065	-4.1
BusTime	bus in-vehicle time (mins)	TR, BS	-0.057	-7.9
ScBusTime	school bus in-vehicle time (mins)	SB	-0.065	-3.9
WaitTm	first and other wait time (mins)	TR, BS	-0.032	-3.1
AcEgTm	access & egress time (mins)	TR, BS	-0.014	-3.9
SBusDist	school bus distance (km)	SB	-0.053	-2.0
BikeDist	bike distance (km)	BK	-0.660	-4.9
WalkDist	walk distance (km)	WK	-0.862	-20.1
Car availability terms:				
PassOpts	passenger opportunity term	CP	8.070	6.9
CarP_CCar	company car(s) in household term	CP	0.485	3.1
Other socio-economic terms:				
CarP<8	under-8 term on car passenger	CP	0.793	4.0
Bike_Male	male term	BK	1.006	1.3
Mode constants:				
Train	train, 2009/10 to 2012/13 waves	TR	2.356	2.0
Bus	bus, 2009/10 to 2012/13 waves	BS	2.686	3.6
ScBus	school bus, 2009/10 to 2012/13 waves	SB	3.056	4.1
Bike	bike, 2009/10 to 2012/13 waves	BK	1.019	1.0
Walk	walk, 2009/10 to 2012/13 waves	WK	7.714	8.0
Taxi	taxi, 2009/10 to 2002/13 waves	TX	-2.018	-1.8
Train_0508	train, 2005/06 to 2008/09 waves	TR	1.486	0.9
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	3.555	4.7
ScBus_0508	school bus, 2005/06 to 2008/09 waves	SB	2.691	3.8
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	0.609	0.6
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	7.650	7.9
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	0.000	n/a
Destination constants:				
SCB_NC	Newcastle destination constant for school bus	SB	-0.621	-0.6
Intrazonal constants:				
CarPIZ	car passenger	CP	0.466	5.9
BikeIZ	bike	BK	1.192	1.8
WalkIZ	walk	WK	0.794	5.3
Attraction term:				
TotEnrol	primary enrolments in destination zone	all	1.000	n/a
Structural parameters:				
Theta_M_P	relative sensitivity of main modes and PT modes	n/a	0.693	1.1
Theta_P_D	relative sensitivity of PT modes and destinations	n/a	0.760	0.8

Table 18: Home–secondary education mode-destination model (model 41) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
LogCost	log of costs in cents	CD, TR, BS, TX	-0.522	-6.0
Cost	cost (cents)	CD, TR, BS, TX	0.0000	n/a
CarTime	car in-vehicle time (mins)	CD, CP, TX	-0.051	-9.7
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.032	-12.6
BusTime	bus in-vehicle time (mins)	TR, BS	-0.034	-15.0
SBusTime	school bus in-vehicle time (mins)	SB	-0.063	-7.6
WaitTm	first and other wait time (mins)	TR, BS	-0.017	-4.9
AcEgTm	access & egress time (mins)	TR, BS	-0.010	-5.5
CarAccTime	car access & egress time to P&R and K&R (mins)	TR K&R	-0.068	-8.0
CrP_dist	car passenger distance (km)	CP	-0.076	-8.0
SBus_dist	school bus distance (km)	SB	-0.016	-1.4
BikeDist	bike distance (km)	BK	-0.455	-5.7
WalkDist	walk distance (km)	WK	-0.798	-16.3
Train access mode distance fit terms:				
OCWS	Central Western Sydney origins	TR OT	0.090	0.2
OIWS	Inner Western Sydney origins	TR OT	0.866	1.9
OCantB	Canterbury Bankstown origins	TR OT	0.227	0.6
TrnOthGt30	constant for train tours >100 km for non-car access	TR OT	-1.081	-4.4
Car availability terms:				
PassOpts	passenger opportunity term	CP	3.642	5.2
Mode constants:				
Train	train, 2009/10 to 2012/13 waves	TR	5.626	8.1
Bus	bus, 2009/10 to 2012/13 waves	BS	5.692	8.4
ScBs	school bus, 2009/10 to 2012/13 waves	SB	1.665	2.4
Bike	bike, 2009/10 to 2012/13 waves	BK	-0.020	0.0
Walk	walk, 2009/10 to 2012/13 waves	WK	5.000	7.1
Taxi	taxi, 2009/10 to 2002/13 waves	TX	0.863	1.0
Train_0508	train, 2005/06 to 2008/09 waves	TR	5.240	7.6
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	5.474	8.1
ScBs_0508	school bus, 2005/06 to 2008/09 waves	SB	1.572	2.3
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	1.763	2.2
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	5.312	7.4
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	0.000	n/a
TrainKR	train K&R (relative to train other access)	TR K&R	-0.926	-3.0
Destination constants:				
ScB_OutRng	Sydney outer ring destinations	SB	0.201	1.2
ScB_New	Newcastle destinations	SB	1.391	5.3
ScB_Wng	Wollongong destinations	SB	1.060	3.7
Intrazonal constants:				
CarPIZ	car passenger	CP	-0.278	-1.3
BikeIZ	bike	BK	-1.708	-1.4
WalkIZ	walk	WK	-0.199	-1.0
Attraction term:				
TotEnrol	secondary enrolments in destination zone	all	1.000	n/a
Structural parameters:				
Theta_M_P	relative sensitivity of main modes and PT modes	n/a	1.000	n/a
Theta_P_A	relative sensitivity of PT modes and train access modes	n/a	1.000	n/a
Theta_A_D	relative sensitivity of train access modes and destinations	n/a	0.831	2.9

Parameter	Description	Modes	Value	t-ratio
Theta_D_S	relative sensitivity of destinations and stations	n/a	1.000	n/a

Table 19: Home–tertiary education mode-destination model (model 51) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
LogCost	log of costs in cents	CD, CP, TR, BS, TX	-0.398	-4.3
CarTime	car in-vehicle time and car access time (mins)	CD, CP, TR P&R, TR K&R, TX	-0.029	-12.6
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.011	-6.7
BusTime	bus in-vehicle time (mins)	TR, BS	-0.018	-8.5
WaitTm	first and other wait time (mins)	TR, BS	-0.029	-6.4
AcEgTm	access & egress time (mins)	TR, BS	-0.002	-1.3
CarPDist	car passenger distance (km)	CP	-0.012	-1.6
BikeDist	bike distance (km)	BK	-0.198	-4.0
WalkDist	walk distance (km)	WK	-0.682	-11.4
Train access mode distance fit terms:				
OrigGW	Gosford-Wyong origins	TR K&R	0.122	0.2
TrnOthG50	constant for train tours >100 km for non-car access	TR OT	-0.825	-3.8
Car availability terms:				
CarComp	car competition term (licence holders > cars)	CD	-1.315	-6.5
CmpCrDr	company car(s) in household term	CD	-0.104	-0.4
PassOpts	passenger opportunity term	CP	2.038	3.4
Mode constants:				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-5.240	-8.0
Train	train, 2009/10 to 2012/13 waves	TR	-0.897	-3.2
Bus	bus, 2009/10 to 2012/13 waves	BS	-1.001	-3.8
Bike	bike, 2009/10 to 2012/13 waves	BK	-5.595	-6.7
Walk	walk, 2009/10 to 2012/13 waves	WK	-0.719	-1.2
Taxi	taxi, 2009/10 to 2012/13 waves	TX	-18.561	0.0
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-5.088	-7.8
Train_0508	train, 2005/06 to 2008/09 waves	TR	-1.211	-4.1
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-1.320	-4.7
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	-5.409	-6.7
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	-1.062	-1.7
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	-6.108	-6.0
TrainKR	train K&R (relative to train other access)	TR K&R	-1.989	-8.1
Destination constants:				
PT_UNSW	PT to University of New South Wales destination zone	TR, BS	0.591	3.8
Intrazonal constants:				
CrDNoTllIZ	car driver	CD	-1.605	-2.2
BikeIZ	bike	BK	0.000	n/a
WalkIZ	walk	WK	-1.227	-2.8
Attraction term:				
TotEmp	tertiary employment in destination zone	all	1.000	n/a

Table 20: Home–shopping mode-destination model (model 77) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
GCost	gamma cost term	CD, CP, TR, BS, TX	-0.0235	-34.5
CarTime	car in-vehicle time and car access time (mins)	CD, CP, TR P&R, TR K&R, TX	-0.051	-24.2
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.021	-7.6
BusTime	bus in-vehicle time (mins)	TR, BS	-0.027	-10.4
FWaitTm	first wait time (mins)	TR, BS	-0.031	-5.9
OWaitTm	other wait time (mins)	TR, BS	-0.012	-3.8
AcEgTm	access & egress time (mins)	TR, BS	0.019	7.8
Boardings	PT boardings	TR, BS	-0.490	-7.7
CarPDist	car passenger distance (km)	CP	-1.042	-38.6
BikeDist	bike distance (km)	BK	-0.0235	-34.5
WalkDist	walk distance (km)	WK	-0.051	-24.2
Toll choice terms:				
TollBonus	constant on car driver toll alternative	CD TL	-1.335	-2.2
CarTDist	car toll distance (km)	CD TL	0.013	1.1
Train access mode distance fit terms:				
CarADist	car access distance (km)	TR P&R, TR K&R	0.015	1.8
Car availability terms:				
CarComp	car competition term (licence holders > cars)	CD	-1.083	-9.6
CmpCrDr	company car(s) in household term	CD	0.511	3.8
PassOpts	passenger opportunity term	CP	2.743	12.6
Other socio-economic terms:				
CarD<20	under-20 term on car driver	CD	-0.275	-0.8
CarP_Male	male term on car passenger	CP	-1.379	-10.1
CarP<10	under-10 term on car passenger	CP	3.112	6.1
Ret_CarP	retired term on car passenger	CP	0.656	5.5
Bus_Male	male term on bus	BS	-1.080	-5.1
Bus_Pens	pensioner term on bus	BS	0.581	2.9
Bike_Male	male term on bike	BK	2.091	3.6
Bike_10_19	aged 10–19 term on bike	BK	1.237	2.1
Mode constants:				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-6.323	-18.8
Train	train, 2009/10 to 2012/13 waves	TR	-2.708	-6.3
Bus	bus, 2009/10 to 2012/13 waves	BS	-2.383	-6.4
Bike	bike, 2009/10 to 2012/13 waves	BK	-14.212	-16.3
Walk	walk, 2009/10 to 2012/13 waves	WK	-5.590	-20.5
Taxi	taxi, 2009/10 to 2002/13 waves	TX	-5.620	-6.1
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-6.449	-19.0
Train_0508	train, 2005/06 to 2008/09 waves	TR	-3.413	-7.1
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-2.227	-6.2
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	-13.645	-16.7
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	-5.547	-20.7
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	-4.662	-6.6
TrainPR	train P&R (relative to train other access)	TR P&R	-6.128	-5.1
TrainKR	train K&R (relative to train other access)	TR K&R	-6.332	-6.2
Destination constants:				
Dest_CBD	CBD destination constant	all	-0.876	-4.4

Parameter	Description	Modes	Value	t-ratio
CBDRail	CBD rail destination constant	RL	1.454	4.5
CBDBus	CBD bus destination constant	BS	0.970	3.3
Car_MidRng	Sydney middle ring destination constant	CD, CP	0.305	4.6
Car_OutRng	Sydney outer ring destination constant	CD, CP	0.629	8.8
Dest_PopDn	destination population density (persons/ha)	all	0.002	6.0
Regional	regional shopping centres (floor space > 35,000m^2)	all	0.551	14.2
HiQualShps	other shopping centres (floor space < 35,000m^2)	all	0.419	13.3
Intrazonal constants:				
CrDNoTllIZ	car driver no toll	CD TL	-4.726	-28.0
CarPIZ	car passenger	CP	-4.638	-22.2
BikeIZ	bike	BK	0.416	0.8
WalkIZ	walk	WK	0.442	5.3
Attraction term:				
TotEmp	retail employment in destination zone	all	1.000	n/a
Structural parameters:				
Theta_M_P	relative sensitivity of main modes and PT modes	n/a	1.000	n/a
Theta_P_A	relative sensitivity of PT modes and train access modes	n/a	1.000	n/a
Theta_A_D	relative sensitivity of train access modes and destinations	n/a	0.675	9.4
Theta_D_S	relative sensitivity of destinations and stations	n/a	1.000	n/a
Theta_S_T	relative sensitivity of stations and toll choice	n/a	1.000	n/a

Table 21: Home–other travel mode-destination model (model 63) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
GCost	gamma cost term	CD, CP, TR, BS, TX	-0.0147	-64.6
CarTime	car in-vehicle time and car access time (mins)	CD, CP, TR P&R, TR K&R, TX	-0.040	-48.9
RlFrTime	rail and ferry in-vehicle time (mins)	TR	-0.017	-13.3
BusTime	bus in-vehicle time (mins)	TR, BS	-0.022	-15.2
WaitTm	first and other wait time (mins)	TR, BS	-0.033	-7.5
AcEgTm	access & egress time (mins)	TR, BS	-0.013	-5.9
Boardings	PT boardings	TR, BS	-0.134	-3.7
CarPDist	car passenger distance (km)	CP	0.008	9.1
BikeDist	bike distance (km)	BK	-0.232	-16.9
WalkDist	walk distance (km)	WK	-0.748	-65.4
TaxiDist	taxi distance (km)	TX	0.040	4.2
Toll choice terms:				
TollBonus	constant on car driver toll alternative	CD TL	-1.421	-8.8
CarTDist	car toll distance (km)	CD TL	0.023	12.7
Train access mode distance fit terms:				
OrigGW	Gosford-Wyong origins	TR P&R, TR K&R	0.691	1.7
OrigCNS	Central Northern Sydney origins	TR P&R, TR K&R	0.942	3.4
CarADist	car access distance (km)	TR P&R, TR K&R	0.012	5.3

Parameter	Description	Modes	Value	t-ratio
Car availability terms:				
CarComp	car competition term (licence holders > cars)	CD	-1.055	-10.3
CmpCrDr	company car(s) in household term	CD	0.402	4.0
PassOpts	passenger opportunity term	CP	3.681	15.2
Other socio-economic terms:				
CarP_Male	male term on car passenger	CP	-0.905	-9.2
CarP<10	under-10 term on car passenger	CP	2.895	15.9
CarPFTPTW	full- and part-time worker term on car passenger	CP	-1.109	-10.0
Bike_Male	male term on bike	BK	3.087	7.7
Bike_10_19	aged 10–19 term on bike	BK	1.655	5.4
Walk_Male	male term on walk	WK	-0.591	-6.4
Sub-purpose mode terms:				
CarD_DrPu	drop-off pick-up term on car driver	CD	3.054	15.2
CarP_Enter	entertainment term on car passenger	CP	1.537	12.1
PT_Enter	entertainment term on PT	TR, BS	1.993	10.4
Walk_Recr	recreation term on walk	WK	4.217	18.2
Mode constants:				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-6.874	-18.9
Train	train, 2009/10 to 2012/13 waves	TR	-4.452	-10.2
Bus	bus, 2009/10 to 2012/13 waves	BS	-4.855	-11.5
Bike	bike, 2009/10 to 2012/13 waves	BK	-16.961	-21.7
Walk	walk, 2009/10 to 2012/13 waves	WK	-6.355	-25.9
Taxi	taxi, 2009/10 to 2002/13 waves	TX	-8.856	-11.9
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-6.817	-19.0
Train_0508	train, 2005/06 to 2008/09 waves	TR	-4.766	-10.8
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-4.803	-11.4
Bike_0508	bike, 2005/06 to 2008/09 waves	BK	-16.312	-22.1
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	-6.252	-26.3
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	-8.600	-12.1
TrainPR	train P&R (relative to train other access)	TR P&R	-4.678	-16.1
TrainKR	train K&R (relative to train other access)	TR K&R	-4.083	-17.0
Destination constants:				
Car_OutRng	Sydney outer ring destination constant	CD, CP	0.186	5.8
Intrazonal constants:				
CrDNoTllIZ	car driver no toll	CD TL	-4.006	-50.5
CarPIZ	car passenger	CP	-3.797	-46.1
BikeIZ	bike	BK	1.366	7.2
WalkIZ	walk	WK	0.695	16.7
Attraction terms:				
L_S_M	log-size-multiplier	all	1.000	n/a
Retail	retail employment	all	3.073	19.1
Pop	population	all	0.408	27.6
Structural parameters:				
Theta_M_P	relative sensitivity of main modes and PT modes	n/a	0.478	20.8
Theta_P_A	relative sensitivity of PT modes and train access modes	n/a	1.000	n/a
Theta_A_D	relative sensitivity of train access modes and destinations	n/a	1.000	n/a
Theta_D_S	relative sensitivity of destinations and stations	n/a	1.000	n/a
Theta_S_T	relative sensitivity of stations and toll choice	n/a	1.000	n/a

Table 22: Work–business mode-destination model (model 16) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
LogCost	log of cost in cents	CD, TR, BS, TX	-0.771	-15.0
CarTime	car in-vehicle time (mins)	CD, CP, TX	-0.029	-15.1
GenPTTime	generalised PT time (mins)	TR, BS	-0.019	-5.2
WalkDist	walk distance (km)	WK	-0.759	-12.5
Home–based tour mode constants:				
CarDCarD	home–based and NHB modes car driver	CD	1.902	6.7
Socio-economic terms:				
WalkMale	male term on walk	WK	-0.602	-2.9
Mode constants				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-6.026	-12.5
Train	train, 2009/10 to 2012/13 waves	TR	0.609	0.7
Bus	bus, 2009/10 to 2012/13 waves	BS	-0.588	-0.8
Walk	walk, 2009/10 to 2012/13 waves	WK	-0.746	-1.7
Taxi	taxi, 2009/10 to 2002/13 waves	TX	0.633	1.6
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-6.048	-13.4
Train_0508	train, 2005/06 to 2008/09 waves	TR	0.604	0.8
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-1.272	-1.6
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	-0.912	-2.1
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	0.570	1.7
Intrazonal constants:				
CrDIZ	car driver	CD	-0.590	-3.1
WalkIZ	walk	WK	0.547	2.8
Attraction term:				
TotEmp	total employment	all	1.000	n/a
Structural parameters:				
Theta_M_PT	relative sensitivity of main modes and PT modes	n/a	1.000	n/a
Theta_PT_D	relative sensitivity of PT modes and destinations	n/a	0.965	0.6

Table 23: Business detour mode-destination model (model 24) parameters

Parameter	Description	Modes	Value	t-ratio
Cost and level of service terms:				
LogCost	log of cost in cents	CD, TR, BS, TX	-1.020	-19.4
CarTime	car in-vehicle time (mins)	CD, CP, TX	-0.072	-20.0
GenPTTime	generalised PT time (mins)	TR, BS	-0.037	-5.4
CarPDist	car passenger distance (km)	CP	-0.033	-3.9
WalkDist	walk distance (km)	WK	-3.966	-13.8
Toll choice terms:				
TollBonus	constant on car driver toll alternative	CD TL	-0.357	-1.4
CarTDist	car toll distance (km)	CD TL	0.029	6.0
Home–based tour mode constants:				
CarDCarD	home–based and NHB modes car driver	CD	7.801	7.1
CarPCarP	home–based and NHB modes car passenger	CP	5.116	5.7
WalkWalk	home–based and NHB modes walk	WK	1.624	1.5
Car availability terms:				
CarDCCar	company car(s) in household term	CD	1.692	4.1
Other socio-economic terms:				
CarPA1625	aged 16–25 term on car passenger	CP	4.000	6.0
WalkMale	male term on walk	WK	-1.505	-3.3
Mode constants				
CarP	car passenger, 2009/10 to 2012/13 waves	CP	-4.685	-6.1
Train	train, 2009/10 to 2012/13 waves	TR	3.685	2.7
Bus	bus, 2009/10 to 2012/13 waves	BS	1.202	0.9
Walk	walk, 2009/10 to 2012/13 waves	WK	4.415	4.9
Taxi	taxi, 2009/10 to 2002/13 waves	TX	-0.037	0.0
CarP_0508	car passenger, 2005/06 to 2008/09 waves	CP	-4.853	-6.4
Train_0508	train, 2005/06 to 2008/09 waves	TR	2.905	2.1
Bus_0508	bus, 2005/06 to 2008/09 waves	BS	-0.732	-0.5
Walk_0508	walk, 2005/06 to 2008/09 waves	WK	5.654	6.1
Taxi_0508	taxi, 2005/06 to 2008/09 waves	TX	0.391	0.4
Attraction term:				
TotEmp	total employment	all	1.000	n/a
Structural parameters:				
Theta_M_PT	relative sensitivity of main modes and PT modes	n/a	0.674	4.7
Theta_PT_D	relative sensitivity of PT modes and destinations	n/a	1.000	n/a
Theta_D_T	relative sensitivity of destinations and toll choice	n/a	0.655	17.8

5. Model validation

5.1. Implied values of time

The implied values of time (VOTs) have been calculated for each purpose except primary education, as no costs are represented in that model. For all of the purposes where costs are represented the resulting VOTs vary as a function of the tour cost, with VOT increasing as costs increase. Representative values have therefore been calculated using the mean tour costs by mode observed in the estimation sample. In the commute and home–business models, the VOTs also vary as a function of income. For these models a range of VOTs is presented corresponding to the variation in VOT with income band at the mean observed cost for the mode.

Table 24: Representative implied VOTs by purpose (2011 $/hr)

Purpose	Car driver	Train	Bus
commute	10.0–19.9	6.5–12.9	6.9–13.3
home–business	23.2–46.4	9.2–18.4	19.1–38.3
home–secondary education	29.4	18.8	16.7
home–tertiary education	47.4	13.4	14.4
home–shopping	5.5	5.5	4.5
home–other travel	6.9	6.5	5.4
work–business	21.1	15.7	9.2
business detour	29.2	21.6	17.2

Figures 6 to 15 illustrate the variation in the implied VOTs with journey cost and, where applicable, personal income band.

Figure 6: Commute car VOTs

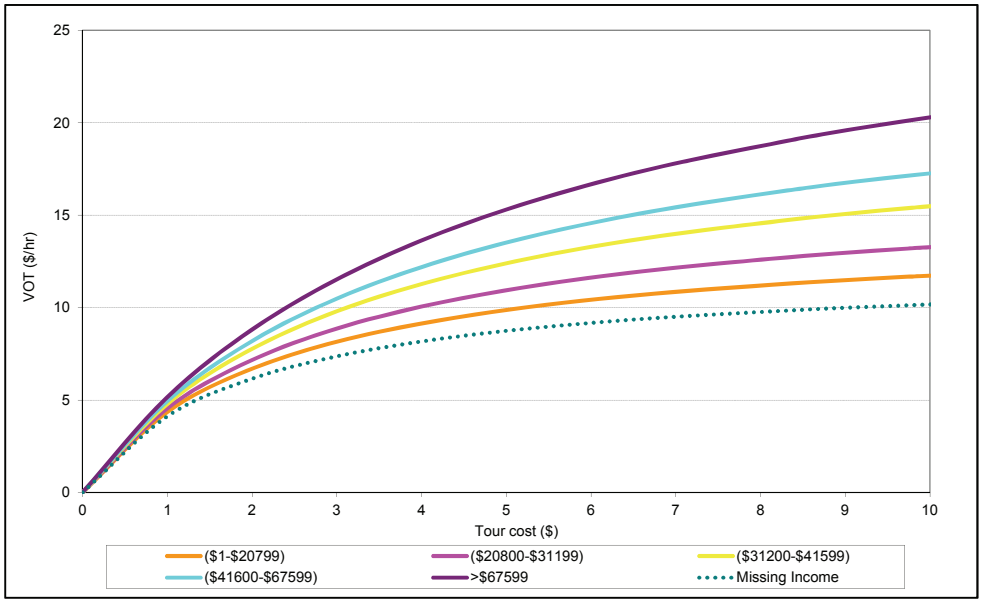


Figure 7: Commute train VOTs

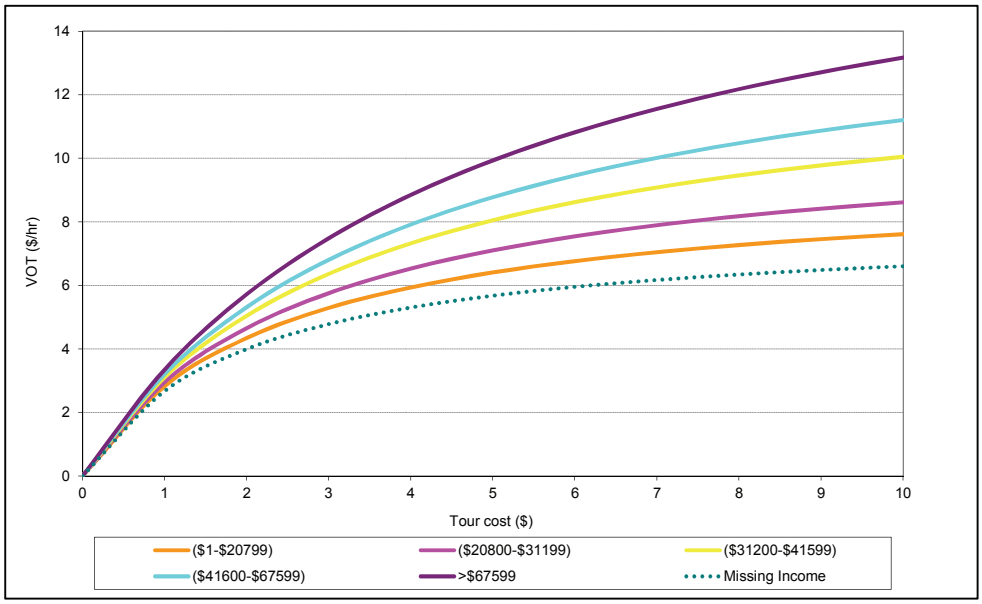


Figure 8: Commute bus VOTs

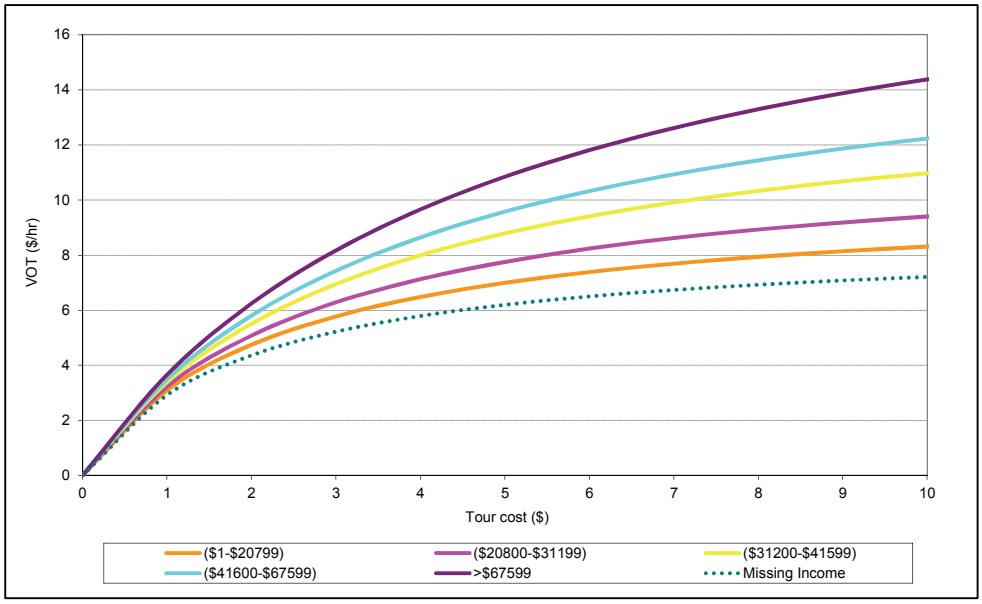


Figure 9: Home–business VOTs

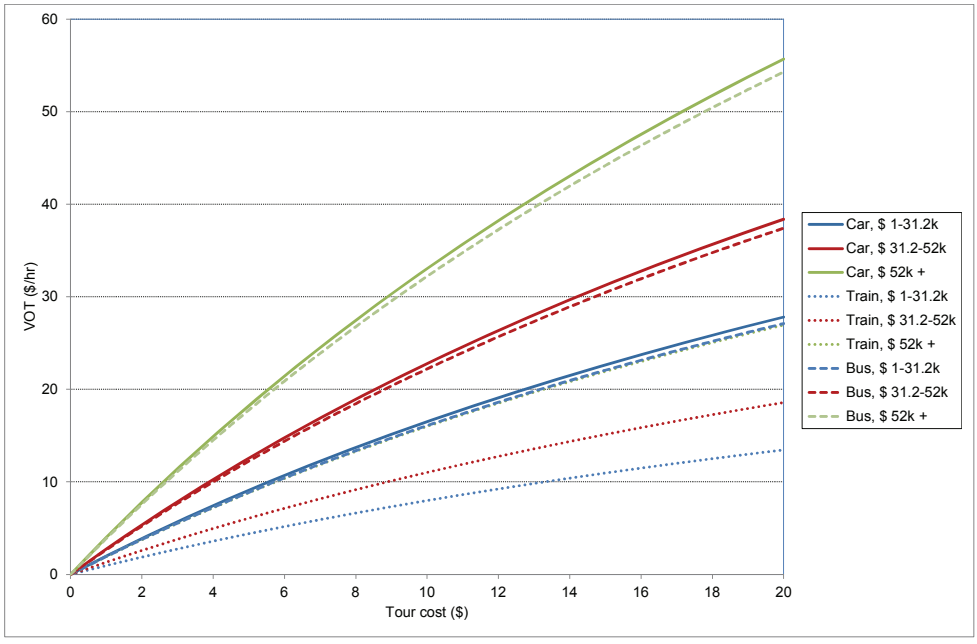


Figure 10: Home–secondary education VOTs

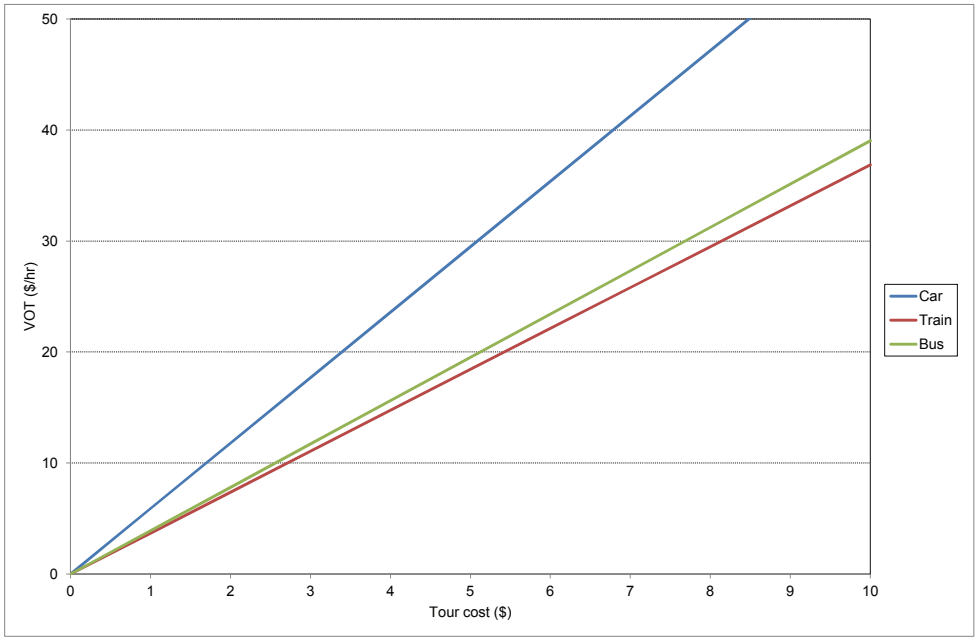


Figure 11: Home–tertiary education VOTs

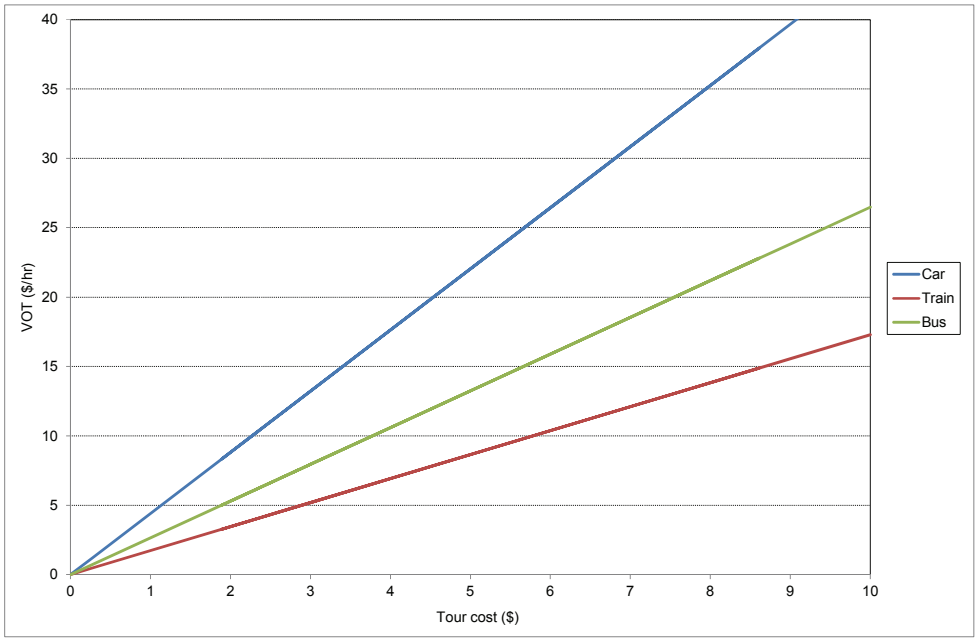


Figure 12: Home–shopping VOTs

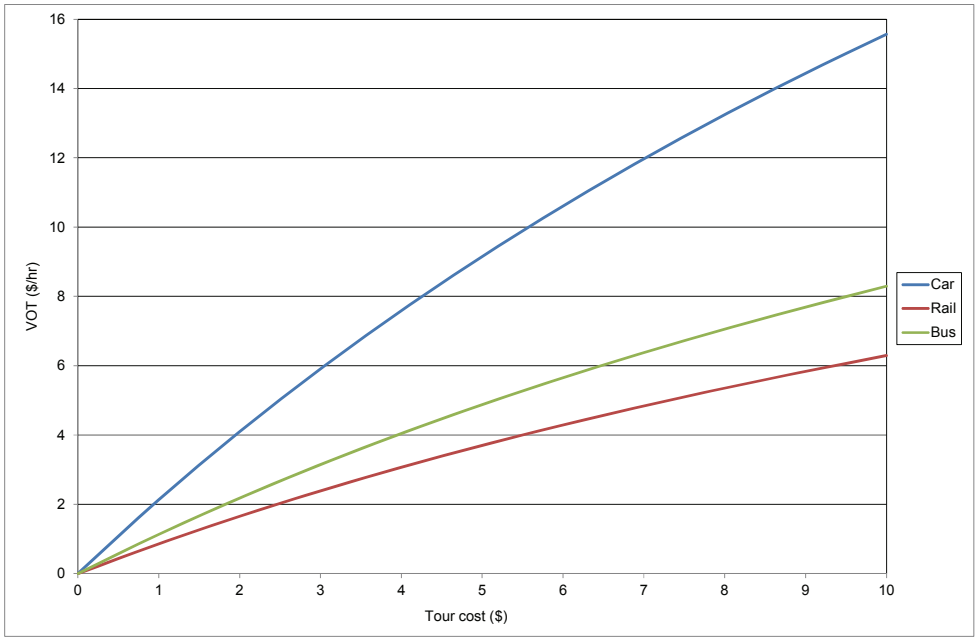


Figure 13: Home–other travel VOTs

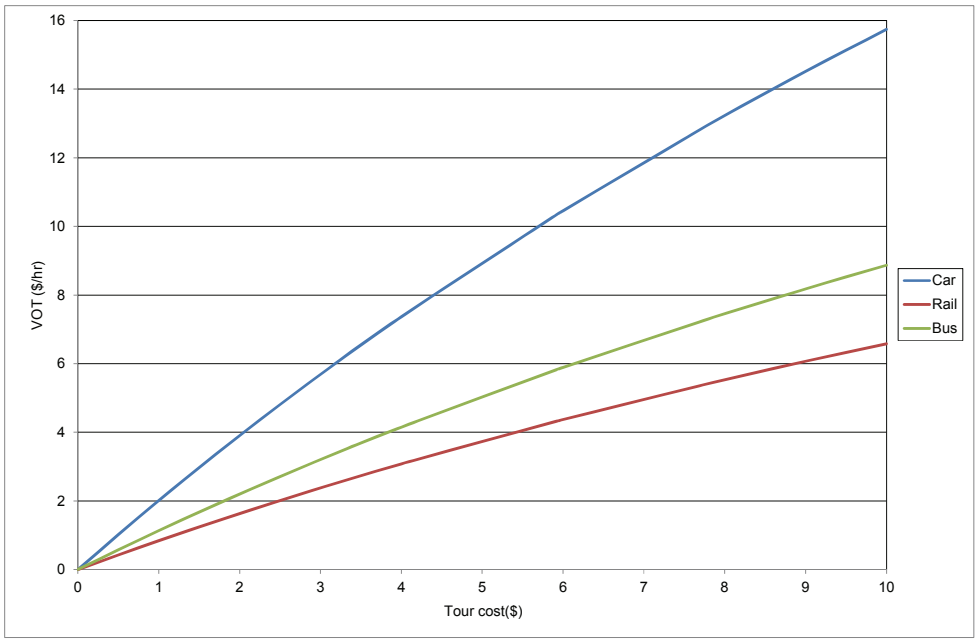


Figure 14: Work–business VOTs

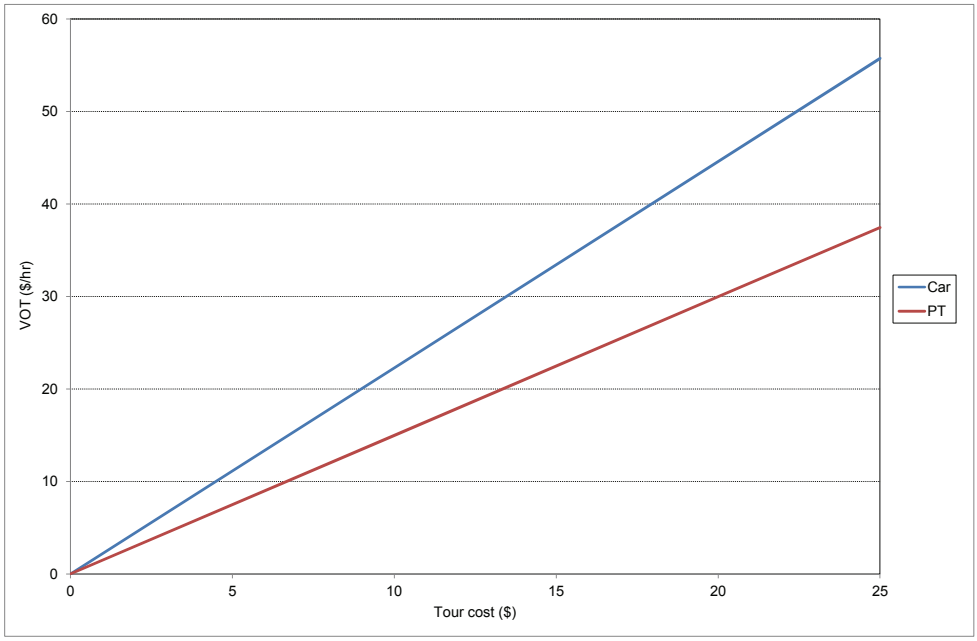
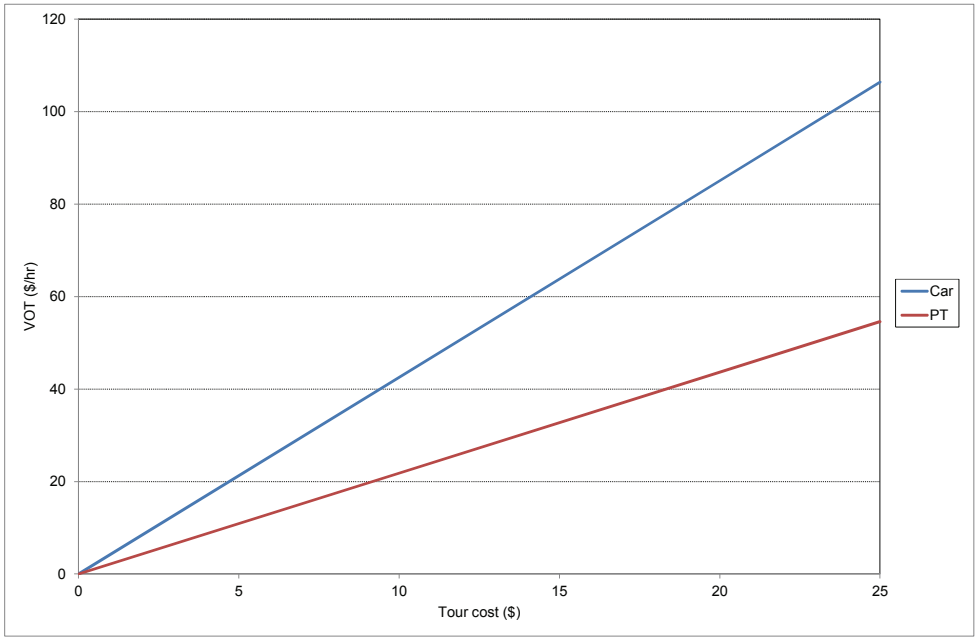


Figure 15: Business detour VOTs



5.2. Model elasticities

Elasticities to cost and time increases were calculated for the previous 2006-base mode-destination models. It is emphasised that the elasticities have not been re-run using the updated mode-destination model results presented in Section 4, and that changes to the cost and in-vehicle time parameters between the 2006-base and 2011-base versions of the models would be expected to impact on the elasticity values.

It should be noted that these elasticity values reflect first-order effects only, i.e. they do not take account of further changes due to changes in congestion on the networks as a result of these increases. All elasticities have been produced by increasing the relevant times or costs by 10 per cent. The results from the elasticity tests are summarised in Tables 25 to 32.

Table 25: Fuel cost elasticities, tours

Purpose	Car driver toll	Car driver no toll	Car driver total	Car passenger
commute	-0.350	-0.051	-0.069	0.045
home–business	-0.025	-0.028	-0.028	0.147
home–secondary education	n/a	n/a	-0.129	0.003
home–tertiary education	n/a	n/a	-0.066	-0.145
home–shopping	-0.265	-0.060	-0.061	-0.141
home–other travel	0.025	-0.044	-0.043	-0.074
work–business	n/a	n/a	-0.140	0.327
business detour	0.141	-0.056	-0.042	0.161

Table 26: Fuel cost elasticities, kilometres

Purpose	Car driver toll	Car driver no toll	Car driver total	Car passenger
commute	-0.557	-0.271	-0.309	0.019
home–business	-0.105	-0.093	-0.096	0.164
home–secondary education	n/a	n/a	-0.250	0.003
home–tertiary education	n/a	n/a	-0.056	-0.136
home–shopping	-0.632	-0.165	-0.179	-0.190
home–other travel	-0.149	-0.158	-0.157	-0.164
work–business	n/a	n/a	-0.115	0.379
business detour	0.109	-0.049	-0.021	0.164

Table 27: Car time elasticities, tours

Purpose	Car driver toll	Car driver no toll	Car driver total	Car passenger
commute	-1.286	-0.053	-0.124	-0.190
home–business	-1.016	0.071	-0.029	-0.143
home–primary education	n/a	n/a	n/a	-0.212
home–secondary education	n/a	n/a	-0.237	-0.195
home–tertiary education	n/a	n/a	-0.372	-0.532
home–shopping	-4.459	-0.069	-0.086	-0.353
home–other travel	-2.900	-0.014	-0.048	-0.119
work–business	n/a	n/a	-0.108	-0.615
business detour	-1.250	0.038	-0.046	-0.143

Table 28: Car time elasticities, kilometres

Purpose	Car driver toll	Car driver no toll	Car driver total	Car passenger
commute	-1.966	-0.754	-0.907	-0.727
home–business	-1.581	-0.628	-0.812	-0.791
home–primary education	n/a	n/a	n/a	-1.188
home–secondary education	n/a	n/a	-1.039	-0.574
home–tertiary education	n/a	n/a	-1.152	-1.106
home–shopping	-6.797	-0.758	-0.904	-1.263
home–other travel	-4.231	-0.798	-0.989	-1.164
work–business	n/a	n/a	-0.976	-1.547
business detour	-1.993	-0.830	-1.023	-0.708

Table 29: Public transport fare elasticities, tours

Purpose	Train P&R	Train K&R	Train other	Train total	Bus
commute	-0.381	-0.321	-0.344	-0.350	-0.241
home–business	-0.179	-0.173	-0.223	-0.202	-0.184
home–secondary education	n/a	-0.199	-0.272	-0.242	-0.252
home–tertiary education	-0.100	-0.086	-0.163	-0.138	-0.165
home–shopping	-0.864	-0.859	-0.699	-0.732	-0.457
home–other travel	-0.438	-0.435	-0.526	-0.494	-0.288
work–business	n/a	n/a	n/a	-0.544	-0.226
business detour	n/a	n/a	n/a	-0.380	-0.100

Table 30: Public transport fare elasticities, kilometres

Purpose	Train P&R	Train K&R	Train other	Train total	Bus
commute	-0.474	-0.420	-0.438	-0.448	-0.365
home–business	-0.221	-0.216	-0.253	-0.235	-0.222
home–primary education	n/a	-0.250	-0.319	-0.288	-0.296
home–secondary education	-0.115	-0.102	-0.175	-0.147	-0.176
home–tertiary education	-1.174	-1.171	-0.807	-0.935	-0.668
home–shopping	-0.602	-0.600	-0.623	-0.613	-0.498
home–other travel	n/a	n/a	n/a	-0.619	-0.527
work–business	n/a	n/a	n/a	-0.466	-0.318
business detour	-0.474	-0.420	-0.438	-0.448	-0.365

Table 31:Public transport fare elasticities, tours

Purpose	Train P&R	Train K&R	Train other	Train total	Bus
commute	-0.848	-0.614	-0.445	-0.568	-0.527
home–business	-0.331	-0.261	-0.419	-0.370	-0.365
home–secondary education	n/a	n/a	n/a	-1.400	-0.566
home–tertiary education	n/a	-0.848	-0.851	-0.849	-0.724
home–shopping	-0.464	-0.605	-0.636	-0.610	-0.515
home–other travel	-1.167	-1.149	-0.763	-0.843	-0.328
work–business	-0.669	-0.656	-0.495	-0.553	-0.014
business detour	n/a	n/a	n/a	-0.704	-0.230

Table 32: Public transport fare elasticities, kilometres

Purpose	Train P&R	Train K&R	Train other	Train total	Bus
commute	-1.420	-1.177	-0.865	-1.116	-0.981
home–business	-0.678	-0.616	-0.686	-0.673	-0.753
home–secondary education	n/a	n/a	n/a	-2.179	-1.135
home–tertiary education	n/a	-1.576	-1.465	-1.515	-1.243
home–shopping	-0.901	-1.095	-1.082	-1.063	-1.050
home–other travel	-2.277	-2.263	-1.278	-1.619	-0.758
work–business	-1.332	-1.322	-0.918	-1.100	-0.251
business detour	n/a	n/a	n/a	-1.265	-0.770

6. Segmentation

In the implementation of the STM3 models the population is divided into specific person and household type segments, which exhibit different travel behaviour in two areas, mode-destination choice and tour frequency. At the implementation stage, the models of mode-destination and frequency are combined to form the travel demand (TravDem) models, which predict how much travel is made, and over which modes and destinations that travel is distributed. The TravDems incorporate different segmentations for different purposes, as the traveller characteristics that influence travel behaviour vary according to travel purpose.

This section presents the mode-destination and frequency segments used to implement the STM3 mode destination and frequency models.

Section 6.1 of this chapter is split into seven sub-sections, one for each home-based travel purpose. Each sub-section starts by detailing the mode-destination segments, and then goes on to detail the frequency segments. The sub-sections also detail which of the model terms have been implemented using mean proportions rather than by the segmentations. Introducing additional segmentations results in increases in model run time, and so some socio-economic terms that are either less important, or are not expected to change substantially in the future, have been implemented using mean proportions to represent the average effect observed in the estimation sample.

Section 6.2 details the segments for the two non-home-based (NHB) purposes, following the same format as Section 6.1.

6.1. Home-based purposes

Table 33 provides a summary of the number of mode-destination, frequency and total segments for each purpose.

The frequency models are applied separately for *each* mode-destination segment. This means that the frequency segments are nested within the mode-destination segments, i.e. for each mode-destination segment there is a further loop over frequency segments. The logsum accessibility terms in the frequency models vary according to the mode-destination segment, whereas the other terms in the frequency models vary according to the frequency segments, so it is necessary to apply the frequency models for each

combination of mode-destination and frequency segment. Because they are nested within the mode-destination segments the frequency segments are termed 'Additional frequency segments' in Table 33.[2]

Table 33: Total number of segments, HB purposes

Purpose	Mode-destination segments	Frequency segments	Total segments
home–work	80	3/15	720
home–business	24	24	576
home–primary education	10	4	40
home–secondary education	3	2	6
home–tertiary education	12	12	144
home–shopping	36	36	1,296
home–other travel	25	56	1,400

For home–work, the number of frequency segments varies across the mode-destination segments. This feature is explained further in Section 6.1.1.

Table 34 summarises the segments in the frequency models.

Table 34: Frequency segmentation summary (home-based purposes)

Segmentation	Commute	Home–business	Home–primary education	Home–secondary education	Home–tertiary education	Home–shopping	Home–other travel
car availability	yes	yes	yes	yes	yes	yes	yes
work status	yes				yes		
personal income	yes	yes					
age and adult status						yes	yes
age			yes				

Sections 6.1.1 to 6.1.7 provide full details of the mode-destination and frequency segments for each of the seven home-based purposes.

6.1.1. Home–work

The home–work mode-destination model has three segmentation dimensions:

- Car availability
- Work status
- Personal income.

The details of the segments are shown in Table 35.

Table 35: Commute mode-destination model segments

[2]The frequency models are very much quicker in application than the mode-destination models, so there is little time penalty from this extended segmentation.

Segment	Car availability
a1	no car in household
a2	no licence but at least 1 car
a3	competition for car, no company car
a4	free car use, 1 non-company car
a5	free car use, several licences in household, no company car
a6	competition for car, 1+ company car
a7	free car use, 1 company car
a8	free car use, several licences, 1+ company car
Segment	Work status
b1	full-time worker
b2	other worker
Segment	Personal income
c1	<$20,799 p.a.
c2	$20,800–31,999 p.a.
c3	$31,200–41,559 p.a.
c4	$41,600–67,599 p.a.
c5	>$67,599 p.a.

There are other socio-economic variables in the home–work mode-destination model, which are not defined by these segmentations:

- PRLicence (licence-holding term on park & ride)
- MaleCrDr (male car driver)
- MaleBike (male bike user).

These variables have been implemented using mean proportions.

The commute frequency model has two segmentation dimensions:

- Age
- Adult status.

There are three or 15 frequency segments in the home–work frequency model that are additional to the mode-destination segments (see Table 36). Adult status is used as a segmentation dimension for both the mode-destination model and the frequency model. For the first mode-destination segment (full-time worker) only one frequency segment is defined (i.e. full-time worker), and segments two to five are not used. For the second mode-destination segment (other worker), five different segments are defined, as detailed in Table 36.

Table 36: Home–work frequency model segments

Segment	Age
1	<40
2	40–59
3	>59
Segment	Adult status
1	full-time worker/full-time education
2	not used/part-time education
3	not used/part-time worker
4	not used/casual worker
5	not used/voluntary worker

There are other socio-economic variables in the home–work frequency model in addition to those defined by Table 36. All of these are defined by the mode-destination segments, except for variables for males and manufacturing occupation types, for which mean proportions are used in the implementation.

6.1.2. Home–business

The home–business mode-destination model has two segmentation dimensions:

- Car availability
- Personal income.

These segments are detailed in Table 37.

Table 37: Home–business mode-destination model segments

Segment	Car availability
a1	no car in HH
a2	no licence but at least 1 car
a3	competition for car, no company car
a4	free car use, 1 non-company car
a5	free car use, several licences in HH, no company car
a6	competition for car, 1+ company car
a7	free car use, 1 company car
a8	free car use, several licences, 1+ company car
Segment	**Personal income**
b1	<$31,199 p.a.
b2	$31,200–$51,199 p.a.
b3	>$51,199 p.a.

There are other socio-economic variables in the home–business mode-destination model that lie outside the segmentation given in Table 37:

- TrnManProf (people with managerial and professional occupations using train)
- PR2pCars (people using P&R from households with two or more cars)
- Prlicence (using P&R and holding a licence)
- CarPu25 (people under 25 travelling as car passengers).

These variables have been implemented using mean proportions.

The home–business frequency model has four segmentation dimensions:

- Age
- Occupation
- Industry
- Adult status.

Table 38 provides a detailed definition of the segments.

Table 38: Home–business frequency model segments

Segment	Age
1	<25
2	>25
Segment	Occupation
1	manual worker
2	non-manual worker
3	not employed
Segment	Industry
1	non-manufacturing
2	manufacturing
Segment	Adult status
1	other adults
2	FT students and pensioners

There are also other socio-economic variables in the home–business frequency model in addition to those defined by the segments given in Table 38. All these additional variables lie within the definition of the mode-destination segments.

6.1.3. Home–primary education

The home–primary education mode-destination model has two segmentations:

- Car availability
- Age.

Table 39 shows the detailed specification of segments.

Table 39: Home–primary education mode-destination model segments

Segment	Car availability
a1	no car in household
a2	1 non-company car
a3	2+ non-company cars
a4	1 company car
a5	2+ cars, at least 1 company car
Segment	Age
b1	<8
b2	>8

One additional variable, 'Bike_Male' (male and using bike), lies outside these segments and so has been implemented using a mean proportion.

The home–primary education frequency model has segmentation dimensions across household income and school type. Table 40 gives the detailed definition of the segments.

Table 40: Home–primary education frequency model segments

Segment	Special school
1	non-special school
2	special school
Segment	Household income
1	≤$25,000 p.a.
2	>$25,000 p.a.

All the socio-economic variables in the home–primary education frequency model are defined by these segments.

6.1.4. Home–secondary education

Car availability is the only segmentation dimension in the home–secondary education mode-destination model, detailed in Table 41.

Table 41: Home–secondary education mode-destination model segments

Segment	Car availability
a1	no car
a2	no licence, 1+ car
a3	licence, 1+ car

In addition to the socio-economic terms defined by the segmentation in Table 41, the mode-destination model contains a 'Bike_Male' variable, for which a mean proportion has been used.

The home–secondary education frequency model has segmentation across age bands only, shown in Table 42.

Table 42: Home–secondary education frequency model segments

Segment	Age
1	<16
2	>16

All the socio-economic variables in the home–secondary education frequency model are defined by the segments in Table 42.

6.1.5. Home–tertiary education

The home–tertiary education mode-destination model has two segmentation dimensions:

- Car availability
- Student status.

Table 43 shows the detailed specification of the segments.

Table 43: Home–tertiary education mode-destination model segments

Segment	Car availability
a1	no car in household
a2	no licence, but car in household
a3	competition for car, 1 car
a4	free car use, 1 car
a5	competition for car, 2+ cars
a6	free car use, several licences, 2+ cars
Segment	Student status
b1	full-time
b2	part-time/other

All the socio-economic variables in the home–tertiary education model lie within the segments given in Table 43 except for the CmpCrDr variable (company car driver), for which a mean proportion has been used in the implementation.

The home–tertiary education frequency model has three segmentation dimensions, shown in Table 44:

- Personal income
- Education type
- Adult status.

Table 44: Home–tertiary education frequency model segments

Segment	Personal income
1	<$15,600
2	≥$15,600
Segment	Education type
1	university
2	other
Segment	Adult status
1	full-time student
2	full-time worker
3	other adults

There are other socio-economic variables in the home–tertiary education frequency model. All of these lie within the definition of the mode-destination segments, except for an age constant (15–18) for which a mean proportion has been used.

6.1.6. Home–shopping

The home–shop mode-destination model has two segmentation dimensions, detailed in Table 45:

- Car availability
- Age and adult status.

Table 45: Home–shop mode-destination model segments

Segment	Car availability
a1	no car in household
a2	no licence, but car in household
a3	competition for car, 1 car
a4	free car use, 1 car
a5	competition for car, 2+ cars
a6	free car use, several licences, 2+ cars
Segment	Age and adult status
b1	<10
b2	10–19, concessionary fare
b3	15–19, full fare
b4	20–59, concessionary fare
b5	20–59, full fare
b6	60+, pensioner, concessionary fare

All the socio-economic variables lie within the definition of segments given in Table 45 except for the following variables for which segment definitions were deemed less important:

- CmpCrDr (car driver, household owns at least one a company car)
- Bus_Male (males less likely to use bus)

These variables have been implemented using mean proportions.

The home–shopping frequency model has three segmentation dimensions:

- Personal income
- Adult status
- Age.

Table 46 gives the detailed definition of the frequency segments.

Table 46: Home–shop frequency model segments

Segment	Personal income
1	<$26,000 p.a.
2	≥$26,000 p.a.
Segment	Adult status
1	full-time student
2	part-time student
3	full-time worker
4	unemployed
5	looking after home
6	other
Segment	Age
1	10–14
2	15–29
3	>29

There are a number of socio-economic variables in the home–shopping frequency model that lie within the definition of the mode-destination segmentations and therefore require no additional frequency segments. Furthermore, there is a term for males that has been implemented using a mean proportion.

6.1.7. Home–other travel

The home–other travel mode-destination model has three segmentation dimensions, specified in Table 47:

- Car availability
- Age and adult status
- Personal income.

Table 47: Home–other travel mode-destination model segments

Segment	Car availability
a1	no car in household
a2	no licence, but car in household
a3	competition for car, 1 car
a4	free car use, 1 car
a5	free car use, several licences, 2+ cars
Segment	Age and adult status
b1	<10
b2	10–19, concessionary fare
b3	15–19, full fare
b4	20+, concessionary fare
b5	20+, full fare

There are other socio-economic variables in the home–other model. All lie within the definition of segments except for the following variables, for which segment definitions were deemed less important:

- CmpCrDr (car driver, persons from households with at least one company car)
- CarD_DrPu (car driver, drop off and pick up sub-purpose)
- CarP_Male (car passenger, male)
- CarP_Enter (car passenger, entertainment sub-purpose)
- PT_Enter (PT modes, entertainment sub-purpose)
- Walk_Male (walk, males)
- Walk_Recr (walk, recreation sub-purpose)

These variables have been implemented using mean proportions.

The home–other travel frequency model has three segmentation dimensions:

- Household income
- Number of children
- Adult status.

These segmentations are defined in Table 48.

Table 48: Home–other travel frequency model segments

Segment	Household income
1	<$104,000 p.a.
2	≥$104,000 p.a.
Segment	Children
1	no children
2	1 child
3	2 children
4	3+ children
Segment	Adult status
1	full-time student
2	full-time worker
3	part-time worker
4	unemployed
5	looking after home
6	retired
7	other

There are other socio-economic variables in the home–other frequency model, all of which lie within the definition of the mode-destination segments.

6.2. Non-home-based purposes

The NHB models are applied conditional on the output of the home–work and home–business models. As a result, the segmentations used in the models must lie within the mode-destination segments defined for the home–work and home–business models.

6.2.1. Work-based business tours

The work-based business mode-destination model has four segmentation dimensions:

- Car availability
- Adult status
- Personal income
- Home-based tour mode.

These four segments are defined in Table 49.

Table 49: Work-based business mode-destination model segments

Segment	Car availability
a1	no licence
a2	licence, but no company car in household
a3	licence, company car in household
Segment	Adult status
b1	full-time worker
b2	part-time worker
Segment	Personal income
c1	<$41,600 p.a.
c2	≥$41,600 p.a.
Segment	Home-based tour mode
d1	car driver
d2	other modes

There is one more socio-economic variable in the mode-destination model, a male dummy for walking (WalkMale). A mean proportion has been used to implement this term.

The terms in the work-based business tour frequency model are all defined by either the home–work mode-destination segments or the home–work tour mode, except the constant for males on the no-tour alternative. A mean proportion has been used to implement this variable. Table 50 shows the relationship between the frequency model terms and the home–work segments.

Table 50: Relationship between work-based business tour frequency terms and home–work segments

Tour frequency term	Home–work segments
Compcar_0	car availability a = 6,7,8
FTwk_0	adult status b = 1
PI>41.6k_0	personal income c = 4,5

6.2.2. Non-home-based business detours

The non-home-based business (NHBB) detour mode-destination model has the three segmentation dimensions:

- Car availability
- Personal income
- Home-based tour mode.

Table 51 shows the detailed specification of the segments.

Table 51: NHBB detour mode-destination model segments

Segment	Car availability
a1	no licence
a2	licence, but no company car in household
a3	licence, company car in household
Segment	Personal income
b1	<$31,200 p.a.
b2	$31,200–$67,599 p.a.
b3	≥$67,600 p.a.
Segment	Home-based tour mode
c1	car driver, toll
c2	car driver, no toll
c3	car passenger
c4	train
c5	bus
c6	bike
c7	walk
c8	taxi

All the socio-economic variables lie within the definition of segments given in Table 51, except for the variable CarPA1625 (car passenger aged 16–25) and a constant for males on the walk alternative, for which mean proportions have been used in the implementation.

The following detour frequency models have been estimated for home-based tours to work and business primary destinations (PD):

- Outward detours (work PD)
- Return detours (work PD)
- Outward detours (business PD)
- Return detours (business PD).

Consequently, separate frequency segmentation dimensions have to be used for detours made in the course of home–work and home–business tours. The terms in the NHB detour frequency models are all defined by either the home–work/home–business mode-destination segments, or the home–work/home–business tour mode, except for the constant for males on the no-tour alternative, for which a mean proportion is used.

Table 52 shows the mapping of the home–work model to the NHB PD work frequency model, and Table 53 shows the mapping of the home–business model to the NHB PD business frequency model.

Table 52: Relationship between NHB business detour PD work tour frequency terms and home–work segments

Detour frequency term	Home–work segments
Compcar_0	car availability a = 6,7,8
PI>67.6k_0	personal income c = 5

Table 53: Relationship between NHB business detour PD business tour frequency terms and home–business segments

Detour frequency term	Home–business segments
Compcar_0	car availability a = 6,7,8
PI<31.2k_0	personal income c = 1,2

7. Base-year travel demand

This section presents tables that summarise the numbers of (de)tours and kilometres predicted by the TravDems for the 2006 base year. These tables will be updated once demand from the 2011-base version of the model is available. The tables compare the mode shares and (de)tour lengths to those observed in the expanded 2004–9 Household Travel Survey (HTS) data.

For mode share, an overall root mean square (RMS) measure has been calculated indicating the difference between the observed and predicted shares, defined as follows:

$$RMS(M) = \sqrt{\frac{\sum_m \left(SO_m - SP_m\right)^2}{M}} \tag{7.1}$$

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

SO_m is the observed mode share from the expanded HTS data

SP_m is the predicted mode share.

For (de)tour lengths, an RMS measure has been calculated that is weighted by the observed mode share:

$$RMS(T) = \sqrt{\sum_m SO_m \left(\frac{TO_m - TP_m}{TO_m}\right)^2} \tag{7.2}$$

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

TO_m is the observed tour length for mode m

TP_m is the predicted tour length for mode m.

The base-year demand by purpose and associated RMS measures are summarised in Tables 54–62.

Table 54: Commute demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver toll	80,295	4,922,271	5.1 %	4.2 %	61.3	30.9
car driver no toll	908,223	24,945,215	58.3 %	61.8 %	27.5	
car passenger	113,170	2,534,596	7.3 %	6.4 %	22.4	21.7
train, P&R	54,024	3,903,158	3.5 %	3.4 %	72.2	71.3
train, K&R	36,834	2,280,760	2.4 %	2.5 %	61.9	58.0
train, walk	122,512	4,926,436	7.9 %	8.4 %	40.2	37.5
train, bus	23,436	1,207,616	1.5 %		51.5	
bus	113,673	2,131,083	7.3 %	6.5 %	18.7	18.7
bike	8,481	96,263	0.5 %	0.7 %	11.4	10.0
walk	92,515	288,474	5.9 %	5.5 %	3.1	3.3
taxi	5,976	61,575	0.4 %	0.7 %	10.3	18.3
Total	1,559,138	47,297,446	100.0 %	100.0 %	30.3	31.9
			RMS(M):	1.3 %	RMS(T):	5.7 %

Table 55: Home–business demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver toll	37,486	2,741,106	8.7 %	8.1 %	73.1	44.2
car driver no toll	308,844	10,114,548	72.0 %	75.9 %	32.7	
car passenger	31,176	1,147,642	7.3 %	5.8 %	36.8	46.9
train, P&R	6,500	476,758	1.5 %	1.6 %	73.4	84.3
train, K&R	2,563	162,307	0.6 %	0.7 %	63.3	59.2
train, walk	12,239	640,104	2.9 %	3.2 %	52.3	55.4
bus	11,836	213,741	2.8 %	1.8 %	18.1	23.7
bike	3,278	25,565	0.8 %	0.4 %	7.8	7.2
walk	12,358	53,708	2.9 %	2.0 %	4.3	5.0
taxi	2,520	62,555	0.6 %	0.4 %	24.8	21.6
Total	428,800	15,638,035	100.0 %	100.0 %	36.5	44.1
			RMS(M):	1.4 %	RMS(T):	16.2 %

Table 56: Home–primary education demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car passenger	212,531	1,506,135	68.5 %	68.2 %	7.1	7.9
train	1,334	34,226	0.4 %	0.5 %	25.7	18.2
bus	8,714	131,546	2.8 %	4.2 %	15.1	9.7
school bus	18,837	191,329	6.1 %	7.1 %	10.2	12.7
bike	2,923	9,242	0.9 %	0.9 %	3.2	2.4
walk	64,942	145,368	20.9 %	18.9 %	2.2	4.3
taxi	871	7,356	0.3 %	0.1 %	8.4	7.3
Total	310,152	2,025,204	100.0 %	100.0 %	6.5	7.3
			RMS(M):	1.0 %	RMS(T):	26.2 %

Table 57: Home–secondary education demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver	3,366	1,945	1.4 %	2.3 %	18.4	23.1
car passenger	88,333	999,713	36.2 %	33.7 %	11.3	13.1
train, K&R	10,200	316,642	4.2 %	3.5 %	31.0	37.4
train, other	14,377	368,000	5.9 %	9.2 %	25.6	22.3
bus	36,319	621,018	14.9 %	14.8 %	17.1	15.9
school bus	48,191	773,613	19.7 %	20.3 %	16.1	18.4
bike	3,778	16,498	1.5 %	1.7 %	4.4	4.2
walk	39,102	110,608	16.0 %	14.4 %	2.8	2.9
taxi	464	6,971	0.2 %	0.0 %	15.0	0.0
Total	244,129	3,275,008	100.0 %	100.0 %	13.4	14.9
			RMS(M):	1.5 %	RMS(T):	12.0 %

Table 58: Home–tertiary education demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver	42,517	1,366,288	39.9 %	37.7 %	32.1	37.4
car passenger	9,947	247,686	9.3 %	8.4 %	24.9	21.6
train, P&R	2,788	167,304	2.6 %	2.8 %	60.0	65.6
train, K&R	5,564	362,635	5.2 %	6.4 %	65.2	52.4
train, other	17,762	875,954	16.7 %	17.7 %	49.3	36.3
bus	15,868	327,855	14.9 %	15.8 %	20.7	21.3
bike	1,598	14,131	1.5 %	1.2 %	8.8	8.7
walk	10,460	32,504	9.8 %	9.8 %	3.1	3.0
taxi	132	4,397	0.1 %	0.1 %	33.3	1.9
Total	106,637	3,398,754	100.0 %	100.0 %	31.9	31.3
			RMS(M):	1.0 %	RMS(T):	19.1 %

Table 59: Home–shopping demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver toll	2,698	131,054	0.3 %	0.3 %	48.6	11.6
car driver no toll	529,206	4,805,386	57.8 %	60.5 %	9.1	
car passenger	135,399	1,663,347	14.8 %	14.4 %	12.3	14.2
train, P&R	1,368	90,912	0.1 %	0.2 %	66.4	50.6
train, K&R	1,080	70,866	0.1 %	0.1 %	65.6	24.5
train, walk	10,320	339,879	1.1 %	1.4 %	32.9	37.3
bus	38,000	442,434	4.1 %	4.2 %	11.6	10.6
bike	5,340	23,045	0.6 %	0.6 %	4.3	5.3
walk	191,014	402,328	20.9 %	17.9 %	2.1	2.1
taxi	1,347	8,952	0.1 %	0.4 %	6.6	6.1
Total	915,773	7,978,204	100.0 %	100.0 %	8.7	10.6
			RMS(M):	1.3 %	RMS(T):	17.1 %

Table 60: Home–other travel demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver toll	21,190	1,152,045	0.7 %	0.6 %	54.4	15.3
car driver no toll	1,442,361	16,888,466	46.1 %	46.9 %	11.7	
car passenger	883,187	13,104,113	28.3 %	29.2 %	14.8	16.8
train, P&R	7,579	572,925	0.2 %	0.3 %	75.6	67.8
train, K&R	10,294	770,538	0.3 %	0.3 %	74.9	63.2
train, walk	46,160	2,447,734	1.5 %	1.3 %	53.0	37.5
bus	72,185	1,460,324	2.3 %	1.8 %	20.2	13.1
bike	29,718	182,958	1.0 %	1.0 %	6.2	6.4
walk	598,935	1,373,643	19.2 %	18.1 %	2.3	2.5
taxi	13,981	158,144	0.4 %	0.5 %	11.3	9.9
Total	3,125,591	38,110,889	100.0 %	100.0 %	12.2	13.8
			RMS(M):	0.5 %	RMS(T):	17.4 %

Table 61: Work–business demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	KM	TravDem	HTS	TravDem	HTS
car driver	86,333	1,617,345	62.4 %	63.7 %	18.7	18.6
car passenger	9,773	291,192	7.1 %	6.4 %	29.8	31.6
train	1,798	74,017	1.3 %	1.4 %	41.2	26.0
bus	719	6,209	0.5 %	0.6 %	8.6	13.9
walk	31,906	58,673	23.0 %	22.7 %	1.8	1.8
taxi	7,896	91,082	5.7 %	5.2 %	11.5	11.3
Total	138,424	2,138,519	100.0 %	100.0 %	15.4	15.3
			RMS(M):	0.6 %	RMS(T):	7.7 %

Table 62: Business detour demand comparison

Mode	TravDem		Mode share		Tour lengths	
	Tours	km	TravDem	HTS	TravDem	HTS
car driver toll	18,330	550,402	5.9 %	5.6 %	30.0	16.2
car driver no toll	229,709	3,259,420	74.0 %	75.4 %	14.2	
car passenger	23,893	307,960	7.7 %	7.1 %	12.9	16.8
train	2,289	21,251	0.7 %	1.2 %	9.3	10.1
bus	256	588	0.1 %	0.1 %	2.3	4.6
walk	32,988	32,831	10.6 %	9.9 %	1.0	0.9
taxi	3,087	19,763	1.0 %	0.7 %	6.4	5.6
Total	310,552	4,192,214	100.0 %	100.0 %	13.5	14.6
			RMS(M):	0.7 %	RMS(T):	8.4 %

8. Overview of purpose differences

8.1. Alternatives represented

Table 63 summarises whether the toll road and train access mode and station choices are represented for each model purpose. For model purposes where train access mode and station choice are not modelled it is assumed that all access to train is by bus and/or walk.

Table 63: Summary of alternatives represented by purpose

Purpose	Toll roads	Train access mode and station choice
commute	yes	yes
home–business	yes	yes
home–primary education	no	no
home–secondary education	no	yes (no P&R)
home–tertiary education	no	yes
home–shopping	yes	yes
home–other travel	yes	yes
work-based business	no[3]	no
NHB business detours	yes	no

For purposes where train access mode and station choice are modelled, the choice between either two or five station alternatives is represented for each origin-destination (OD) pair. For some model purposes it is assumed that for K&R access the driver returns home after dropping off the passenger, and therefore the cost and time associated with the access trip from the home to the station is doubled in the utilities.

Table 64 summarises the number of stations represented and the treatment of the car access leg for K&R for each purpose where train access mode and station choice are modelled.

[3] It is assumed work-based business tours use toll routes if the toll skims identify them as an option.

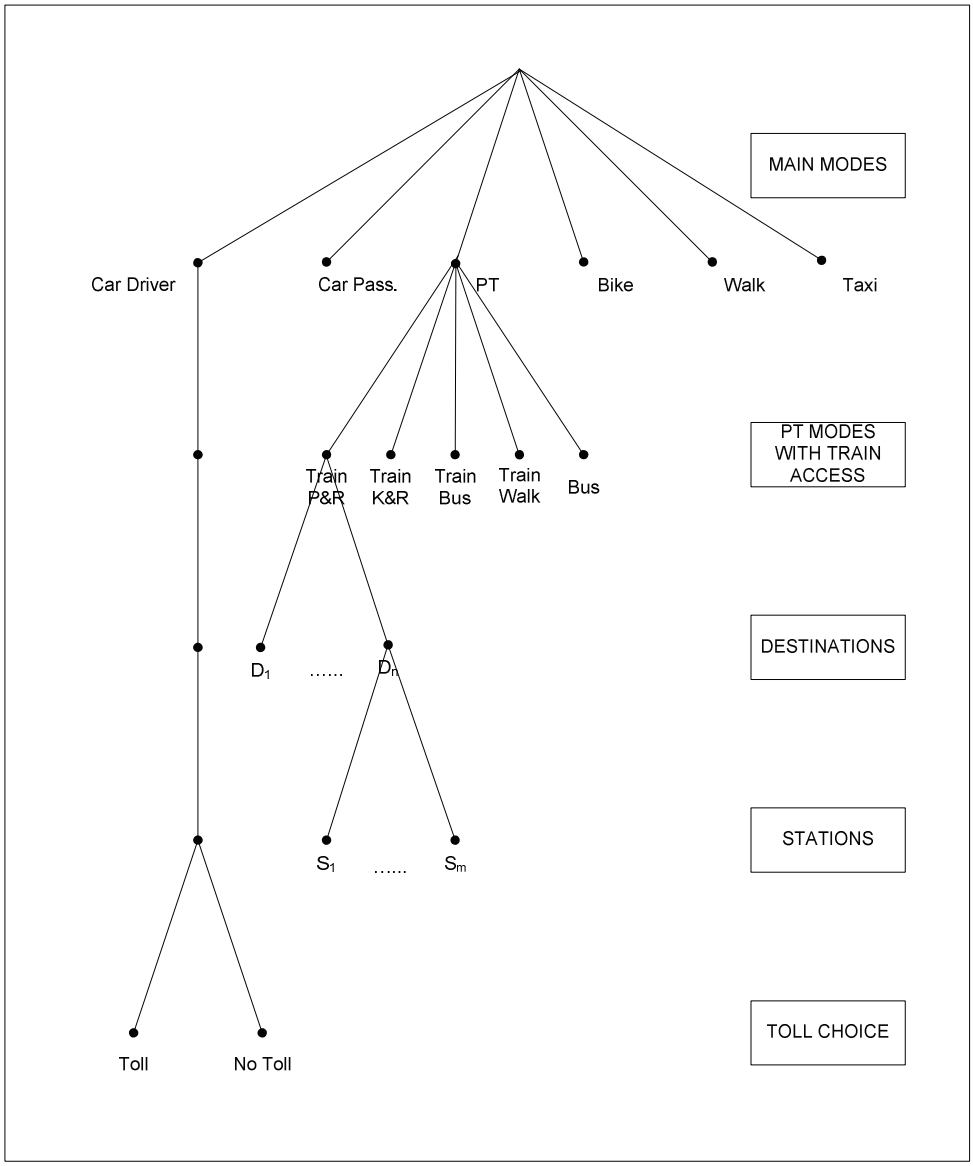
Table 64: Treatment of P&R and K&R by purpose

Purpose	P&R stations	K&R stations	Weight on car access leg for K&R
commute	5	5	1
home–business	5	5	1
home–secondary education	n/a	5	2
home–tertiary education	2	2	2
home–shopping	2	2	1
home–other travel	5	5	1

8.2. Model structure

Seven different tree structures are used for the nine different travel purposes. Figure 16 plots the tree structure used for home–work.

Figure 16: Tree structure 1: home–work

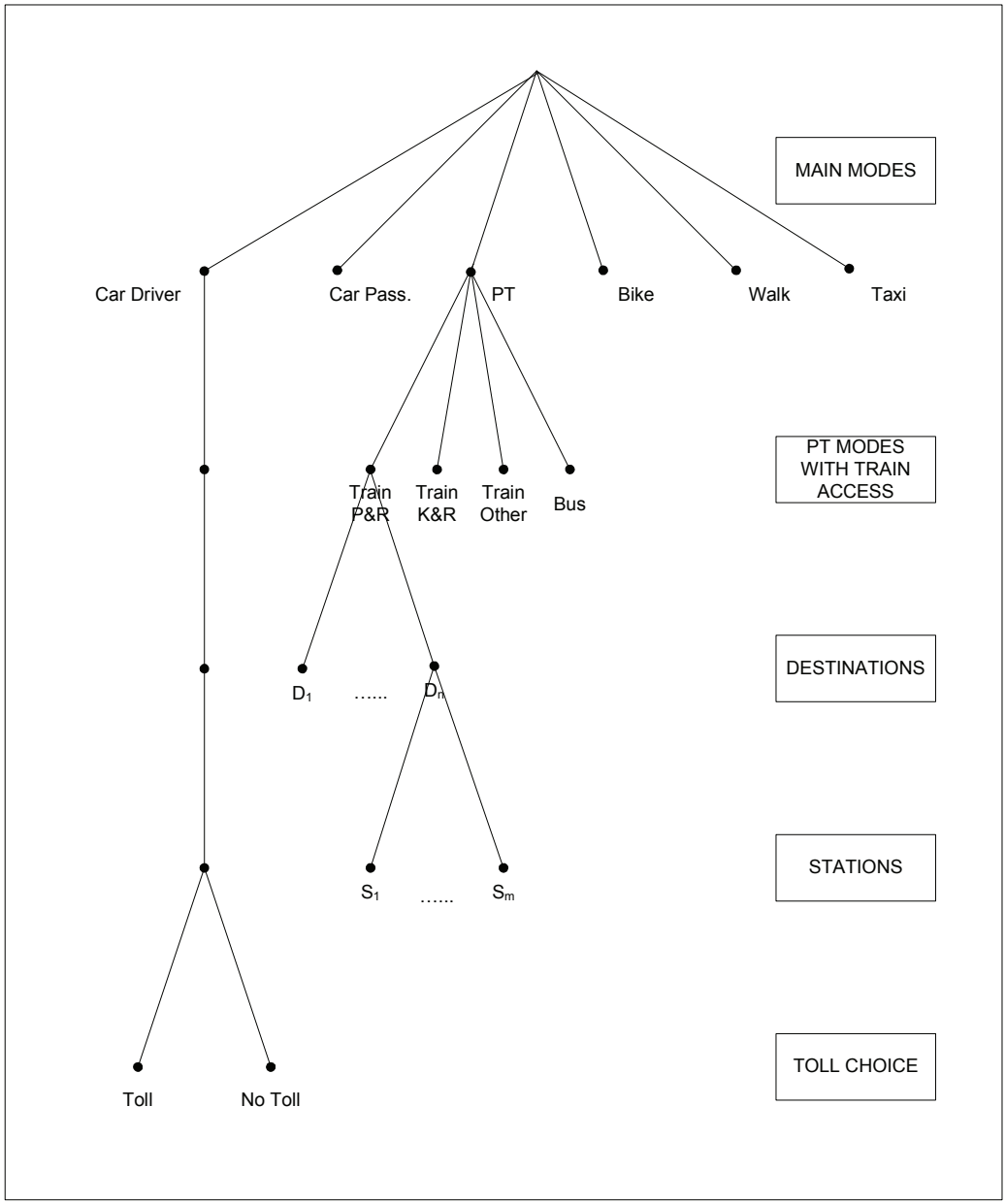


As a number of the structural parameters have been fixed to 1, this structure collapses to a three-level choice:

- Mode choice
- PT modes with train access, destinations and stations
- Toll choice.

Figure 17 plots the tree structure used for home–business, home–shopping and home–other travel purposes. Note that this structure is almost identical to the structure used for home–work. The only difference is that in home–work separate bus and walk access modes to train are represented, whereas in home–business, home–shopping and home–other travel these train access modes are represented by a single other access mode alternative.

Figure 17: Tree structure 2: home–business, shopping and other travel



For business, this structure collapses to a three-level choice:

- Mode choice
- PT modes with train access, destinations and stations
- Toll choice.

For shopping, the structure collapses to a two-level choice:

- Mode choice, PT modes with train access
- Destinations, stations and toll choice.

For other travel, the structure collapses to a different three-level choice:

- Mode choice

- PT modes with train access
- Destinations, stations and toll choice.

For primary education the structure is simpler as neither the toll choice nor the train access mode and station choices is modelled.

Figure 18: Tree structure 3: home–primary education

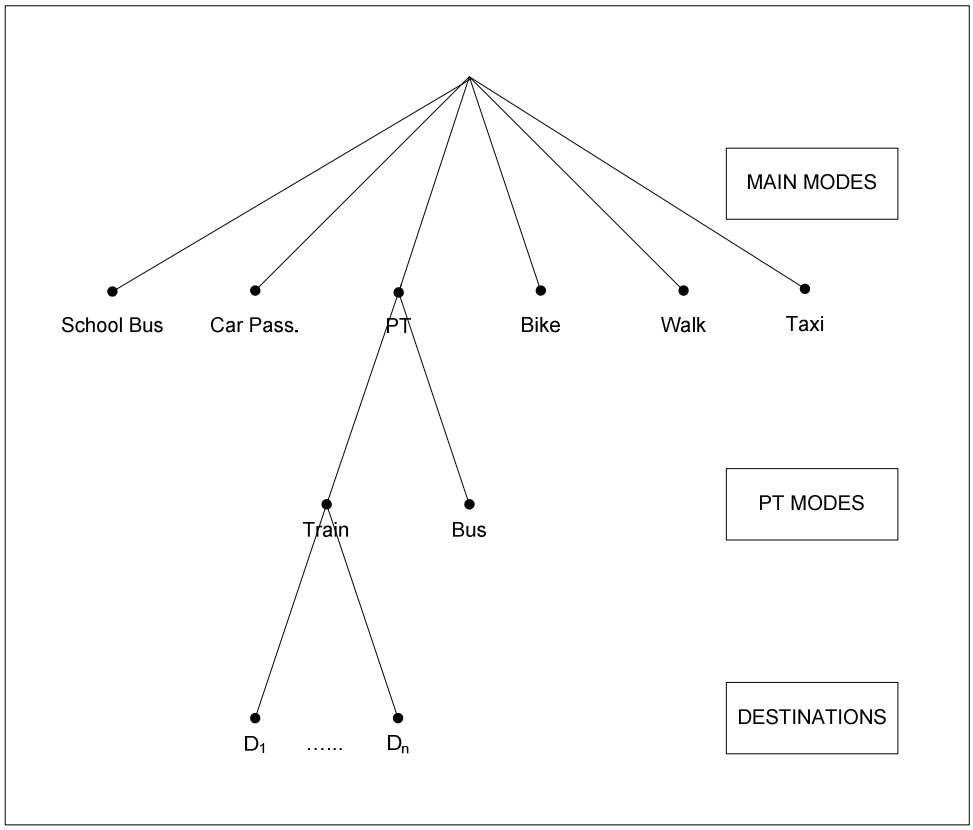
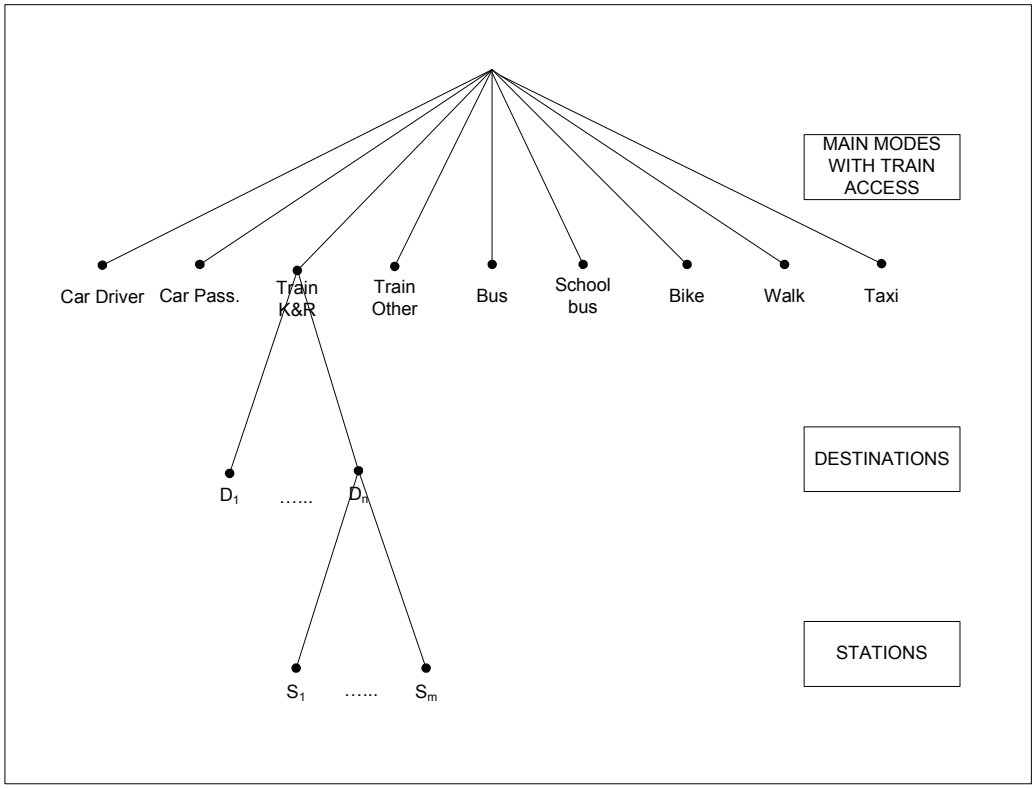
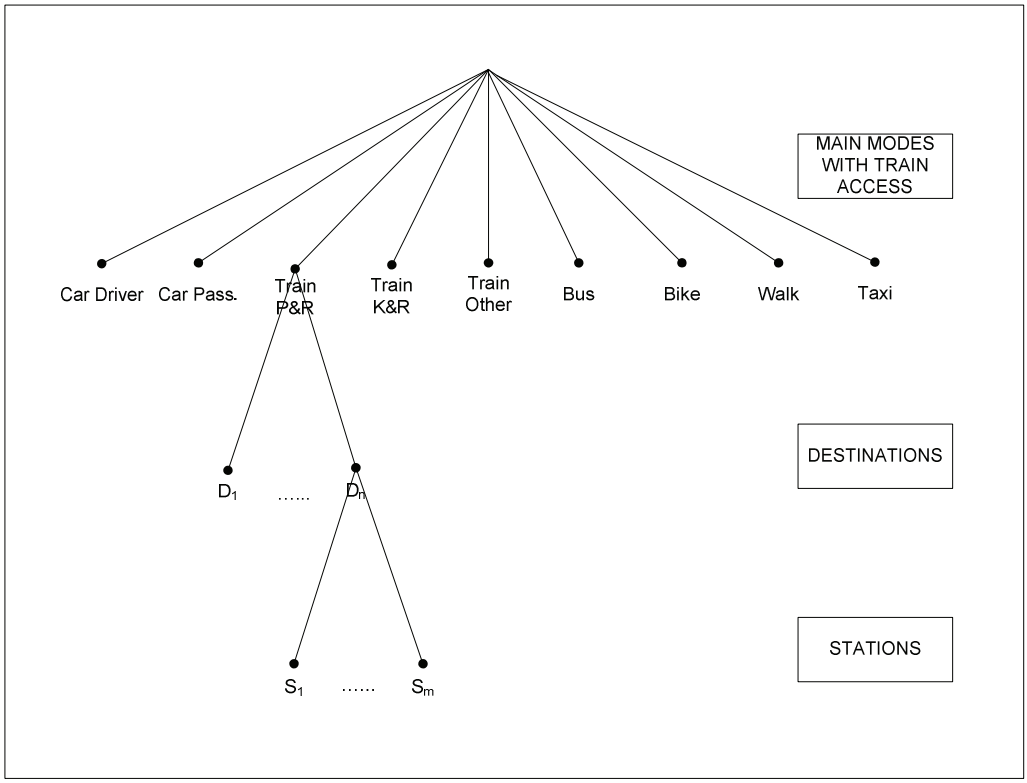


Figure 19: Tree structure 4: home–secondary education



Stations are plotted beneath destinations for clarity, but in fact they are equally sensitive to utility and so this is a two-level choice.

Figure 20: Tree structure 5: home–tertiary education



In the final model all of the structural parameters have been constrained to a value of one, so the structure collapses to a multinomial choice between all of the alternatives.

Figure 21: Tree structure 6: work-based business

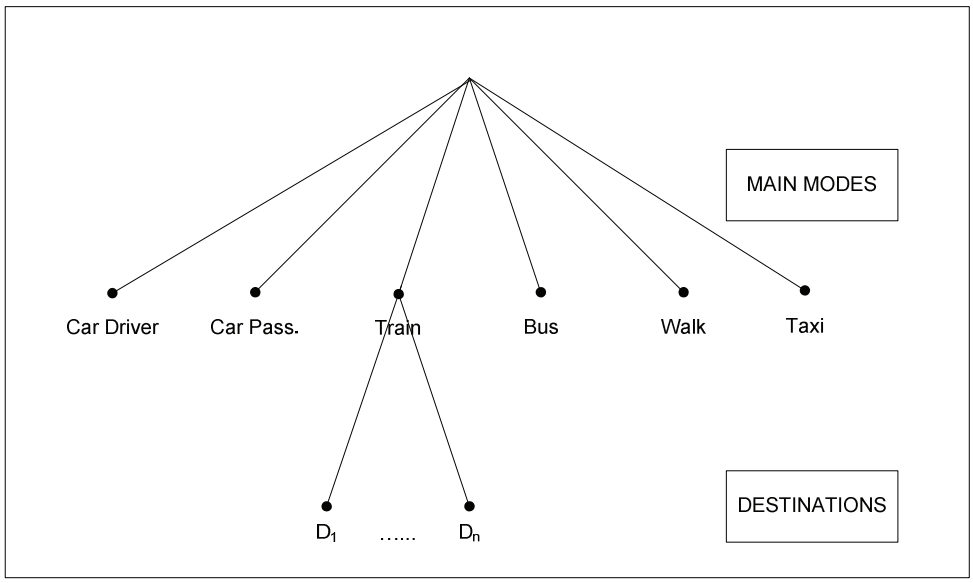
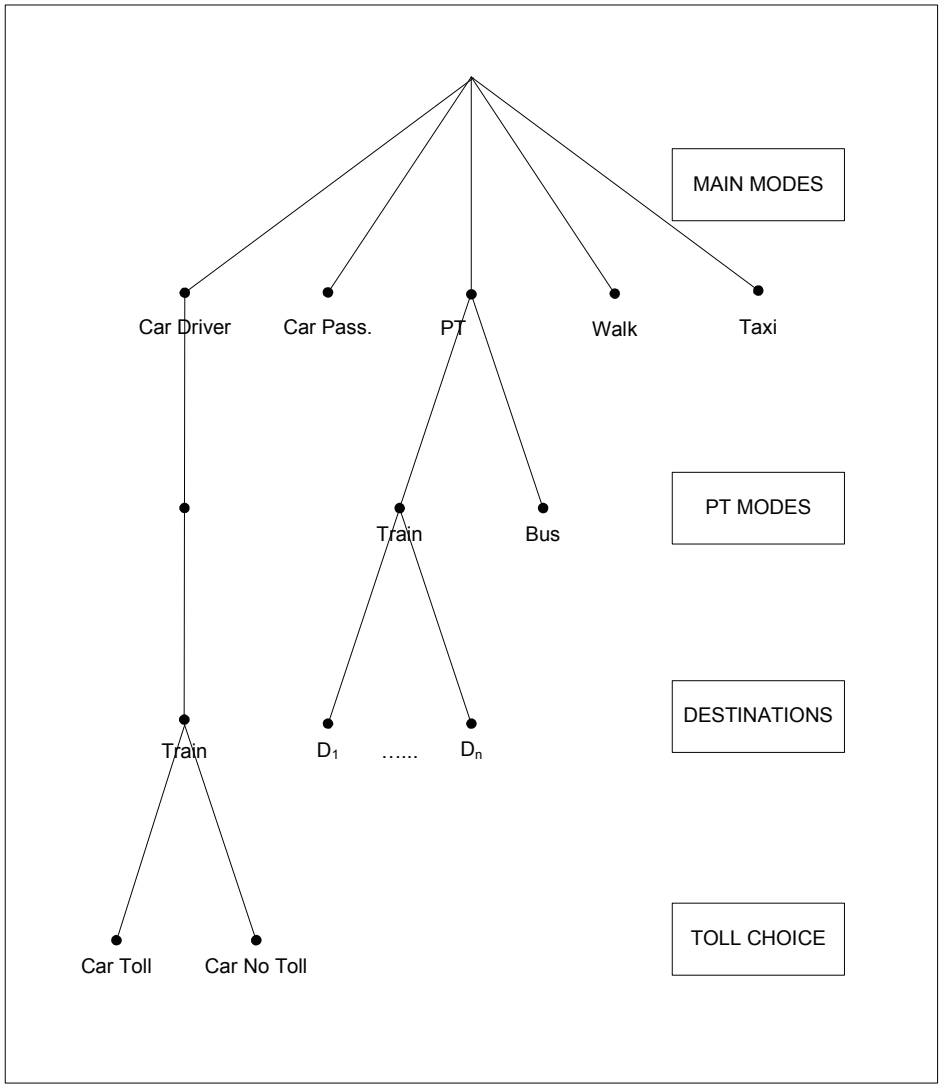


Figure 22: Tree structure 7: non-home–based business detours



PT modes and destinations are plotted separately for clarity but are in fact equally sensitive to choice, so in terms of sensitivity the structure has three levels:

- Main modes
- PT modes and destinations
- Toll choice.

8.3. Cost formulations

The formulation of the cost variables varies between the different travel purposes. The starting point for the cost formulation tests was to estimate separate linear and log-cost terms. However, for many purposes this did not yield acceptable models in terms of values of time and/or elasticities and therefore a number of purposes use a 'gamma formulation'. The gamma formulation defines a mixture of linear and log cost effects, with the relative contribution of linear and log effects controlled by the gamma parameter. This was achieved using a cost term specified as follows:

$$\beta_{\cos t}\left\{\gamma.\text{cost}+(1-\gamma)\log(\text{cost}).\frac{\text{E(cost)}}{\text{E(log(cost))}}\right\} \tag{8.1}$$

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

E(cost) is the mean cost

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

the term E(cost)/E(log(cost)) ensures linear and logarithmic cost use the same scale so that γ gives a true indication of their relative importance.

Table 65 summarises the cost formulations used for each model purpose.

Table 65: Cost formulations by purpose

Purpose	Cost formulation
commute	separate linear and log-cost terms, linear cost segmented by income
home–business	gamma formulation segmented by income, γ = 0.05
home–primary education	no costs represented
home–secondary education	separate linear and log-cost terms
home–tertiary education	log-cost term
home–shopping	gamma formulation, γ = 0.025
home–other travel	gamma formulation, γ = 0.025
work-based business	log-cost term
NHB business detours	log-cost term

8.4. Treatment of car costs

The treatment of car costs varies between the different travel purposes. For non-business purposes, fuel costs per kilometre are calculated as a function of speed, and are added to non-fuel costs, which are calculated on a kilometre basis. For the non-fuel costs, it is assumed travellers attribute only a fraction of the costs to the tour, and the fraction varies between travel purposes. For business purposes, a fixed per-kilometre cost that individuals can reclaim is used instead of separate fuel and non-fuel costs.

Parking costs for ten centres across the study area have been defined. However, for shopping and other travel parking costs are only represented for CBD zones on BTS's advice. Depending on the purpose, parking costs are represented as either all-day costs or half-day costs converted into a cost per hour. For some purposes it is assumed that only a fraction of individuals actually have to pay the parking costs as free parking may be provided in zones in the ten centres, e.g. workplace parking or car parks provided at shopping locations. The fraction of travellers who are assumed to have to pay for parking varies with purpose.

For non-business purposes, tests were undertaken during the model estimation procedure to investigate whether a better fit to the observed data was achieved if it is assumed that passengers pay a proportion of the car costs. The proportion of car costs that are shared was determined from the basis of model fit and varies between travel purposes. For business purposes it is assumed that the driver reclaims the cost of the journey and so cost sharing is not represented.

Table 66 summarises these how the different treatment of car costs varies between travel purposes.

Table 66: Treatment of car costs

Purpose	Perceived VOC fractions	Parking costs represented	Proportions paying for parking	Car passenger cost-sharing proportions
commute	0.25	all-day costs	0.30	0.50
home–business	n/a	all-day costs	1.00	n/a
home–primary education	n/a	n/a	n/a	n/a
home–secondary education	0.25	all-day costs	0.30	0.00
home–tertiary education	0.25	all-day costs	0.30	0.50
home–shopping	0.10	hourly costs in CBD zones	0.50	1.00
home–other travel	0.10	hourly costs in CBD zones	0.50	1.00
work-based business	n/a	all-day costs	1.00	n/a
NHB business detours	n/a	all-day costs	1.00	n/a

8.5. Treatment of PT costs

In implementation, the treatment of PT costs varies between different model purposes as a function of the different model segmentations. Furthermore, for those purposes where train access mode and station choice are represented, the PT fare calculations are undertaken for a single representative segment, rather than separately by segment. This simplification is made because of the high run times associated with the station choice processing step, and because variations in rail fare with segment have a relatively small impact on the choice of train access station.

Table 67 details the variation in the treatment of PT costs between the different purposes.

Table 67: Treatment of PT costs

Purpose	Treatment of PT costs in main travel demand model	Treatment of PT costs in station choice processing
commute	full-time workers: weekly fare converted to per-trip cost part-time workers: single fare	weekly fare converted to a per-trip cost
home–business	average fare calculated from both weekly and single fare values	average fare calculated from both weekly and single fare values
home–primary education	no PT fares represented	n/a
home–secondary education	50% of single fare	50% of single fare
home–tertiary education	full-time students: 50% of single fare others: average fare calculated from both weekly and single fare values	50% of single fare
home–shopping	concessionary fare payers: 50% of single cost others: average fare calculated from both weekly and single fare values	average fare calculated from both weekly and single fare values
home–other travel	concessionary fare payers: 50% of single cost others: average fare calculated from both weekly and single fare values	average fare calculated from both weekly and single fare values
work-based business	average fare calculated from both weekly and single fare values	n/a
NHB business detours	average fare calculated from both weekly and single fare values	n/a

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