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TECHNICAL
REPORT

Application System for Sydney Strategic Travel Model

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Prepared for the Bureau of Transport Statistics, Transport for NSW

RAND EUROPE

The research described in this report was prepared for the Bureau of Transport Statistics, Transport for NSW.

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Preface

RAND Europe was commissioned by the Bureau of Transport Statistics (BTS) of Transport for NSW to implement the new travel frequency, mode and destination model components of the Sydney Strategic Transport Model (STM).

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

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 also occurred with the number of zones approximately trebling in number and the area of coverage increased to include Newcastle and Wollongong. Therefore, in 2009 the BTS decided to commission RAND Europe to re-estimate the STM models.

Following the completion of the re-estimation project, RAND Europe was then commissioned to implement the new frequency, mode and destination components. For each journey purpose, the frequency, mode and destination models are implemented within a single structure referred to as a travel demand (TravDem) model. It is the work to update the TravDem models that is described in this report.

A second project has been commissioned in parallel to this work to update the Population Synthesiser, used to generate future forecasts of the population in the STM study area by segment and zone. In application, the outputs from the Population Synthesiser are used as inputs into the TravDem models.

A third project has also been commissioned in parallel to these to test and improve the pivoting procedure used in the STM. The pivoting procedure combines the forecast travel demands from the TravDem models with base matrix information describing base travel

patterns to provide best-estimate forecasts of the future travel matrices for car and public transport (PT) modes.

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

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CHAPTER 1 Introduction

1.1 Background

The BTS of Transport for NSW operates the Sydney Strategic Travel Model (STM) to inform long term transport planning, policy development and infrastructure assessment in Greater Sydney, Australia.

The current structure of the STM, operated in the EMME[1] environment, was designed by Hague Consulting Group (now RAND Europe) in the mid 1990s. With the availability of more data on current travel behaviour and demographic data from the Household Travel Survey (HTS) and Census, and some modifications to the STM (smaller zones, increased geographic coverage to Wollongong and Newcastle), the BTS engaged RAND Europe to re-estimate the model parameters for the STM. The re-estimation also involved the incorporation of train access modes and car toll nests within the model structure.

This re-estimation is documented in two separate reports, which form key references for this report:

- a mode–destination model report, Fox *et al.*, (2010), referred to as the MD report in the remainder of this document
- a licence, car ownership and frequency models report, Tsang *et al.* (2010), referred to as the LCOF report in the remainder of this document.

This report focuses on the implementation of these models.

1.2 Objective

The BTS engaged RAND Europe to create an application system which implements the re-estimated model structure and parameters within the ALOGIT software. The objective was to translate the model parameters into an application system to provide a 'benchmark' process which the BTS can use as the basis to translate the application system into EMME. The BTS may also use the ALOGIT application system to provide travel demand forecasts prior to implementation in EMME.

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[1] EMME is a transport modelling package that can be used to implement TravDem models. For more information, see: http://www.inro.ca/en/products/emme/modelling.php.

1.3 Structure of the Sydney Strategic Travel Model

The STM system comprises four main components:

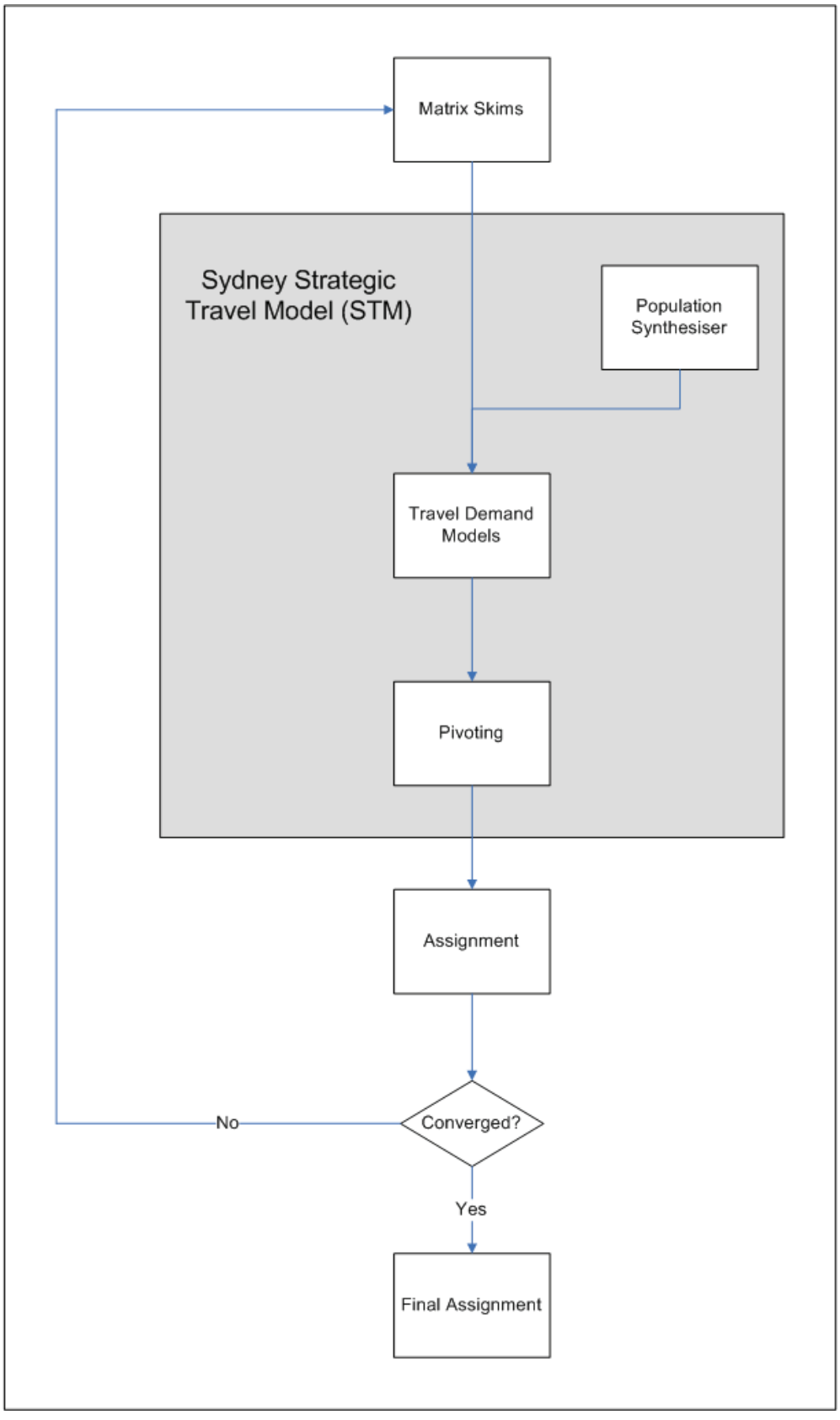
- the TravDem models, the focus of this report
- a Population Synthesiser, which has been updated in a parallel project
- a pivoting procedure, which has been tested and improved in a parallel project
- network assignments, run separately in EMME for highway and PT, which have already been updated for the new STM.

The linkage between these four components is illustrated in Figure 1.

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' by the BTS. The iterative process is controlled by BTS and so is not documented in this report.

We also understand that for some investigations with alternative zonal population totals, the Population Synthesiser is not re-run by the BTS. In these situations the original distributions of population by segment predicted by the Population Synthesiser are retained and scaled in a uniform manner at a zonal level to reflect the change in zonal population (so in a standard model run the scaling factor is 1 for each zone). To investigate the impact of alternative zonal population totals with full precision the Population Synthesiser needs to be re-run.

Figure 1: Structure of the Sydney Strategic Travel Model



1.4 Base year

The TravDem models developed during the Stage 1 and Stage 2 modelling work used a 1996 base year (see HCG and ITS reports 9009-4, 0032-3 and 0032-7). The implementation of these models for seven home-based (HB) and two non-home-based (NHB) travel purposes gave the 1996 base version of the STM.

During 2004, the Population Synthesiser used in the models was updated to use a 2001 base year, taking advantage of the availability of 2001 Census data. However, the TravDem models used in the model retained a 1996 base year, as they were based on data taken to be representative of 1996 travel conditions.

The work recently completed to re-estimate the models in the STM, as documented in the MD and LCOF reports, provides models that are representative of a 2006 base year. Thus, level of service (LOS), costs and other input data refer to 2006 for the base year implementation. A parallel project to this one has updated the Population Synthesiser so that it also reflects a 2006 base year.

1.5 Structure of this report

The next chapter introduces the TravDem models that form the key component of the application system for the STM. Separate sections cover the HB and NHB purposes.

Chapter 3 discusses the segmentations used in the TravDem models. It provides an explanation of the different types of segmentations used in the models, distinguishing the mode–destination and frequency segmentations, and provides a full definition of the segments used for each travel purpose.

Chapter 4 describes the operation of the application system, providing a description of each of the steps in the process used to automate the application of a TravDem model for a given purpose.

Chapter 5 describes the testing that has been undertaken of the updated application system, with sections covering tour rates, mode shares, tour length distributions and elasticities for the new model system.

Finally, Chapter 6 presents a summary of the work to update the TravDem models.

CHAPTER 2 The travel demand models

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

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

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

NHB business travel is also modelled in the STM. Two purposes are modelled:

- work-based (WB) business tours
- NHB business detours made in the course of home–work and home–business tours.

NHB other travel, i.e. NHB travel for purposes other than business, is not currently modelled in the 2006 base STM.

The model alternatives represented in the TravDems are discussed next in Section 2.1. Then the HB TravDems are discussed further in Section 2.2. Finally, the NHB TravDems are discussed in Section 2.3.

2.1 Model alternatives

2.1.1 Modes

The main modes represented in the TravDems are:

- car driver
- car passenger
- train (which also includes light rail and ferry)
- bus only
- bike
- walk
- taxi
- school bus (for primary and secondary education only).

In addition to these main modes, for some model purposes additional modal choices are represented:

- choice between toll and non-toll alternatives for car driver
- choice between park-and-ride (P&R), kiss-and-ride (K&R) and other access modes to train.

The toll road alternatives are discussed in detail in Chapter 4 of the MD report, and the access mode alternatives are discussed further in Chapter 5 of the MD report.

Furthermore, for some purposes a PT nest is used to represent greater cross-elasticity between train and bus modes than between PT and non-PT modes.

A summary of the additional modal choices represented for each purpose is presented in Table 1.

Table 1: Additional behavioural responses represented in the STM by purpose (additional to mode and destination choice)

Purpose	Toll roads	Train access modes	Public transport nest
Commute	Yes	Yes	Yes (same level as train acc. modes, dest.s and stations)
Business	Yes	Yes	Yes (same level as train acc. modes)
Primary education	No	No	Yes
Secondary education	No	Yes (no P&R)	No
Tertiary education	No	Yes	No
Shopping	Yes	Yes	Yes (same level as train acc. modes)
Other travel	Yes	Yes	Yes (same level as train acc. modes)
Work-based business	Assumed all car tours use toll routes if available	No	Yes
NHB business detours	Yes	No	Yes

2.1.2 Destinations

The STM contain 2690 destination alternatives which reflect the 2690 model zones represented in the BTS 2006 zoning system. These zones cover:

- the Sydney Statistical Division (SD)
- the Illawarra SD
- the Newcastle Statistical Sub-Divisions (SSDs).

It is noted that the number of zonal alternatives represents a significant increase on the previous 2001 base version of the STM, where 884 zones were used (covering the Sydney SD only). The zoning system is revised with each new census, which means that the zone system is updated every five years.

2.1.3 Train stations

For those purposes where train access mode choice is explicitly represented (as detailed in Table 1), train station alternatives (including light rail stations and ferry wharves) are also represented as the model predicts the train stations used for P&R and K&R access to train.

For the purpose of creating level-of-service skims each station is coded as a station zone. A pre-processing step is used to identify the most attractive station from the 408 possible station zones, with up to five station alternatives represented for a given origin–destination (OD) pair. A full discussion of the station alternatives is presented in Section 5.3 of the MD report.

Table 2 summarises the number of station alternatives represented for a given OD pair for those travel purposes where train access mode and station choice is explicitly modelled.

Table 2: Station alternatives represented for each OD pair

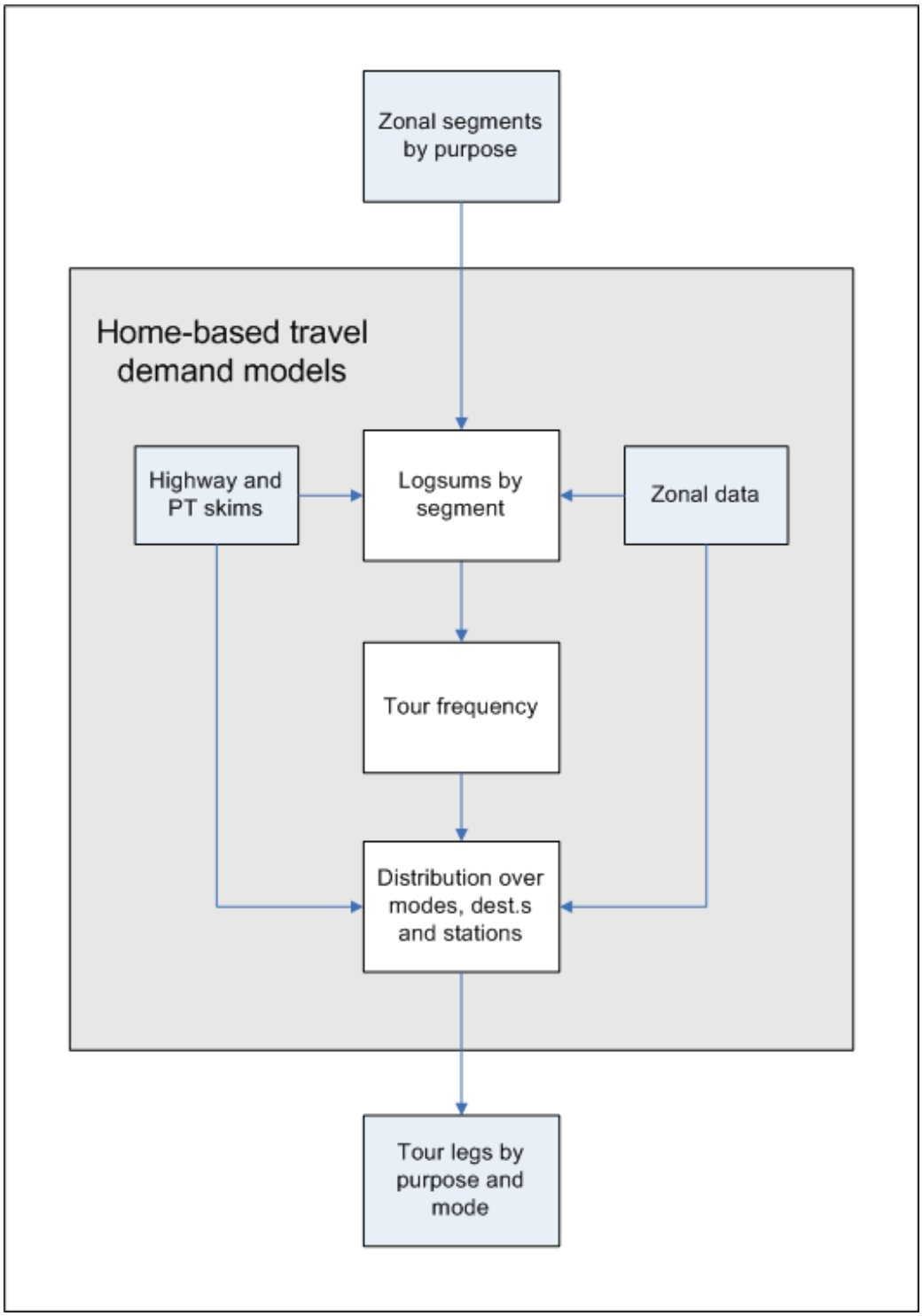
Purpose	P&R access	K&R access
Home–work	5	5
Home–business	5	5
Secondary education	not represented	5
Tertiary education	2	2
Shopping	2	2
Other travel	5	5

It is noted that the stations selected for P&R and K&R access for a given purpose are not necessarily the same. For example, for travel for tertiary education, car access times and costs are doubled for K&R access, representing parents dropping a student at the station and returning home, whereas for P&R access this doubling is not applied, which could then result in different station alternatives being considered. Section 7.6.1 of the MD report provides full details of the assumptions used for each model purpose.

2.2 Home-based purposes

The architecture of the TravDems for HB travel purposes is illustrated in Figure 2. Each of the components is then discussed further in the sub-sections that follow Figure 2, with each sub-section heading corresponding to a box in Figure 2.

Figure 2: Architecture of HB travel demand models



2.2.1 Zonal segments by purpose

Separate input files are defined for each HB travel purpose, which give the number of persons in each model zone for each of the travel segments relevant for that travel purpose.

The zonal segments are generated by the Population Synthesiser (PopFor) module. This module has been updated to a 2006 base as part of a parallel project documented in Fox *et al. (*2011).

2.2.2 Highway and public transport skims

Level-of-service skims from the EMME highway and PT networks provide input to the TravDems.

Highway skims are generated by the BTS for four time periods:

- AM peak: 07:00 to 08:59
- inter-peak: 09:00 to 14:59
- PM peak: 15:00 to 18:59
- off-peak: 00:00 to 06:59, and 19:00 to 24:00.

In the TravDems, level-of-service information for the shoulder periods are generated using these matrices (as discussed below). This is done in order to take account of the LOS experienced in those shoulder periods, where flows are not as high as in the peaks, but higher than the remainder of the inter-peak and off-peak periods.

Table 3 illustrates how these periods relate to the four periods used in the highway assignment models. The colours show the correspondence between the modelled time period (the row) and the four time periods represented in the assignment (the columns). For example, the AM peak shoulder period (orange) is modelled by averaging LOS from the AM-peak and the inter-peak periods. It can be seen from Table 3 that the shoulder periods always use LOS from the relevant peak period together with the inter-peak period; information from the off-peak assignment is never used to model the shoulder periods.

Table 3: Time period mapping for level of service

		Off-peak 00:00 to 06:59, 19:00 to 24:00	AM peak 07:00 to 08:59	Inter-peak 09:00 to 14:59	PM peak 15:00 to 18:59
Off-peak	00:00 to 05:59				
AM peak shoulder	06:00 to 06:59				
AM peak	07:00 to 08:59				
AM peak shoulder	09:00 to 09:59				
Rest of inter-peak	10:00 to 13:59				
PM peak shoulder	14:00 to 14:59				
PM peak	15:00 to 17:59				
PM peak shoulder	18:00 to 18:59				
Off-peak	19:00 to 24:00				

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

- travel time (minutes)
- distance (kilometres)
- toll cost (2006 $)
- harbour crossing cost (2006 $).

Skims are generated separately for toll and no-toll networks. Chapter 4 of the MD report discusses the difference between the toll and no-toll networks in more detail.

For PT, only AM-peak networks are available at present, based on a two-hour peak period from 07:00 to 08:59. It is assumed that the LOS from this network is applicable to all time periods. While it is recognised that there are differences in LOS between time periods, the impact of these differences in minimised by making the same assumption in both estimation and application.

Separate PT skim information is provided for a bus-only network, used to model the bus mode in the TravDems, and a train network that includes:

- heavy rail
- light rail
- ferry
- bus (as an access/egress mode).

For the remainder of this chapter 'train' refers to heavy rail, light rail and ferry.

For the bus mode, the following skim information is used in the TravDems:

- bus in-vehicle time (minutes)
- first wait time (minutes), wait time for the first bus service
- other wait time (minutes), wait time for bus services at interchanges
- walk time (minutes), which includes both access and egress time and walk time at interchanges
- number of boardings.

For train the following skim information is used in the TravDems:

- train in-vehicle time (minutes)
- bus in-vehicle time (minutes)
- first wait time (minutes), wait time for the first train service
- other wait time (minutes), wait time for train services at interchanges
- walk time (minutes), which includes both access and egress time and walk time at interchanges
- number of boardings.

2.2.3 **Zonal data**

The zonal data read in by the TravDems comprise:

- attraction data
- parking data
- Central Business District (CBD) information

- shopping centre location information
- area type information.

The attraction variables specify the 'attractiveness' of destinations. The data to describe these, for each journey purpose, are summarised in Table 4. These are specified for each of the model zones.

Table 4: Attraction variables for HB travel purposes

Purpose	Attraction variable
Commute	Employment, segmented by personal income band
Business	Total employment
Primary education	Primary education enrolments
Secondary education	Secondary education enrolments
Tertiary education	Tertiary education employment
Shopping	Retail employment
Other	Population, retail employment, service employment

For commuting, the employment data are segmented by personal income band, so the attraction variable used for an individual is the number of jobs in the destination zone in their personal income band. The following bands are used (2006 prices):

- <$20,799
- $20,800–31,199
- $31,200–41,599
- $41,600–67,599
- >$67,599.

The parking data comprise full day and half day costs (in 2006 $) for the following centres:

- Sydney CBD
- North Sydney
- Ultimo/Pyrmont
- Central to Sydney University
- Redfern/Strawberry Hills
- Surry Hills/Kings Cross
- St Leonards/Crows Nest
- Chatswood
- Parramatta
- Bondi Junction.

For the shopping model, a file is input that defines the zones in which large shopping centres are located.

The CBD definition used in the model covers Sydney CBD[2] only.

Area type information is also read in to some of the TravDems in order to specify terms that reflect differences in mode choice between area types, such as higher use of school bus in outer Sydney. For those purposes where area type mode choice effects are present, a file is read in that classifies each model zone into one of the following five area types:

- inner ring Sydney
- middle ring of Sydney
- outer ring of Sydney
- Lower Hunter
- Illawarra.

For some TravDems, region effects are defined for specific SSDs within the model area, and for these TravDems a file is read in that specifies the SSD that each model zone is located within.

2.2.4 Computing logsums

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

The calculation of the logsums varies somewhat by travel purpose, as the model alternatives represented vary between journey purpose, and the final model structures also differ between purposes. These structures are detailed in full in Section 7.7.2 of the MD report.

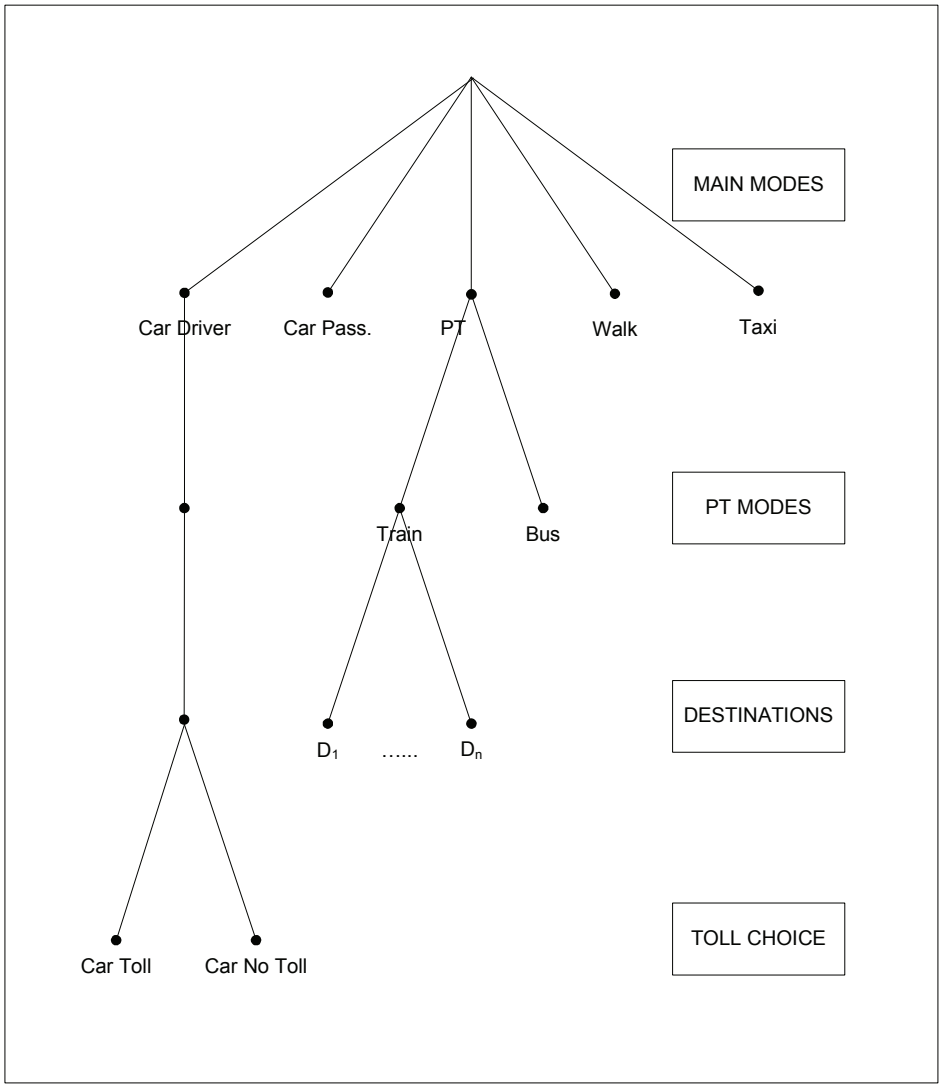
To illustrate the logsum calculations, the structure from the NHBB detour model has been used, which has four behavioural responses represented:

- main modes m
- PT modes p
- destinations d
- toll choice t.

This structure has been chosen to illustrate the logsum calculations as it has fewer behavioural responses represented than the HB TravDems, where up to six behavioural responses are represented. Figure 3 shows the choice structure. Main mode choice is at the top of the structure. For PT alternatives, there is a separate nest to predict demand across the PT alternatives. Destination choice is below main mode choice, for all modes. For car, the choice of tolled and untolled routes is also predicted, and this response falls below destination choice. It is noted that walk is not modelled for NHBB detours.

[2] Specifically, model zones 1 to 166 inclusive.

Figure 3: Example nesting structure



The HB purposes additionally include the choice of access mode to train (P&R, K&R, other) and for the two car access modes the choice of station. As noted above, the simpler structure from the NHBB detour model has been chosen to illustrate how the logsum calculations work with a more straightforward example. The nesting structures used for the HB purposes, and for WB business, are presented in full in Appendix A.

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

$$V_{mpd} = \theta_{dt} \log \sum_{t'} \exp V_{mpdt'} \quad (2.1)$$

$$V_{md} = \theta_{pd} \log \sum_{d'} \exp V_{mpd'} \quad (2.2)$$

$$V_{m} = \theta_{mp} \log \sum_{p'} \exp V_{mp'} \quad (2.3)$$

$$V = \log \sum_{m'} \exp V_{m'} \quad (2.4)$$

where:

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

θ_{dt} defines the relative sensitivity of destination and toll choices

V_{mpd} is the utility for a mode, PT mode and destination combination

θ_{pd} defines the relative sensitivity of PT mode and destination choices

V_{mp} is the utility for a mode and PT mode combination

θ_{mp} defines the relative sensitivity of mode and PT mode choices

V_m is the utility of a mode

V is the overall logsum over all alternatives.

For most HB purposes[3], Equations (2.1) to (2.4) are extended to cover the additional access mode and station choices, maintaining the principle of calculating the logsums by working from the bottom of the structure up.

2.2.5 Tour frequency

The tour frequency models are documented in full in the LCOF report. Section 5.1 of that report presents the structure used for the estimation of the frequency models. In summary, two sub-models are used:

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

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

$$F_{hs} = \frac{P_{1+|hs}}{\left(1 - P_{go|hs}\right)} N_{hs} \quad (2.5)$$

where:

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

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

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

[3] Table 1 and Table 2 summarise the treatment of access mode and station choice by purpose.

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

2.2.6 Distribution over modes, destinations and stations

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

The modes represented in the TravDems are listed in Section 2.1.1.

Leaving the issue of stations to one side for now, for an individual from home zone *h* in segment *s*, the demand by mode *m* to destination *d* can be calculated as follows (where toll is represented separately from the other modes as alternative *t*):

$$T_{hsmdt} = F_{hs}.P_{mdt|hs} \tag{2.6}$$

where:

T_{hsmdt} is the number of tours from zone *h* to zone *d* by mode *m* and toll alternative *t* for segment *s*

F_{hs} is the number of tours from zone *h* for segment *s* (from Equation (2.5))

P_{hsmdt} is the probability of choosing *mdt* for *hs*, calculated from Equations (2.7) to (2.11) below

The probability calculations are set out in the following equations, which use the utilities calculated in Equations (2.1) to (2.4) above. The home zone and segment subscripts *h* and *s* have been dropped for presentation clarity. Opposite to the logsums, the choice probabilities are computed by working from the top to the bottom of the tree structure.

$$P_m = \frac{\exp V_m}{\sum_{m'} \exp V} \tag{2.7}$$

$$P_{p|m} = \frac{\exp V_{p|m}}{\sum_{p'} \exp V_{p'|m}} \tag{2.8}$$

$$P_{d|mp} = \frac{\exp V_{d|mp}}{\sum_{d'} \exp V_{d'|mp}} \tag{2.9}$$

$$P_{t|mpd} = \frac{\exp V_{t|mpd}}{\sum_{t'} \exp V_{t'|mpd}} \tag{2.10}$$

$$P_{mpdt} = P_m P_{p|m} P_{d|mp} P_{t|mpd} \tag{2.11}$$

It is noted that for main modes other than PT there is no PT nest and therefore Equation (2.8) reduces to $P_{p|m}=1$. Similarly for modes other than car driver there is no car toll nest and so Equation (2.10) reduced to $P_{t|mpd}=1$.

For some model purposes (see Table 1) the probability of choosing up to five different stations for P&R and K&R access to train is also represented. The same principles apply for the resulting utility and probability calculations.

2.2.7 Tour legs by mode, purpose and time period

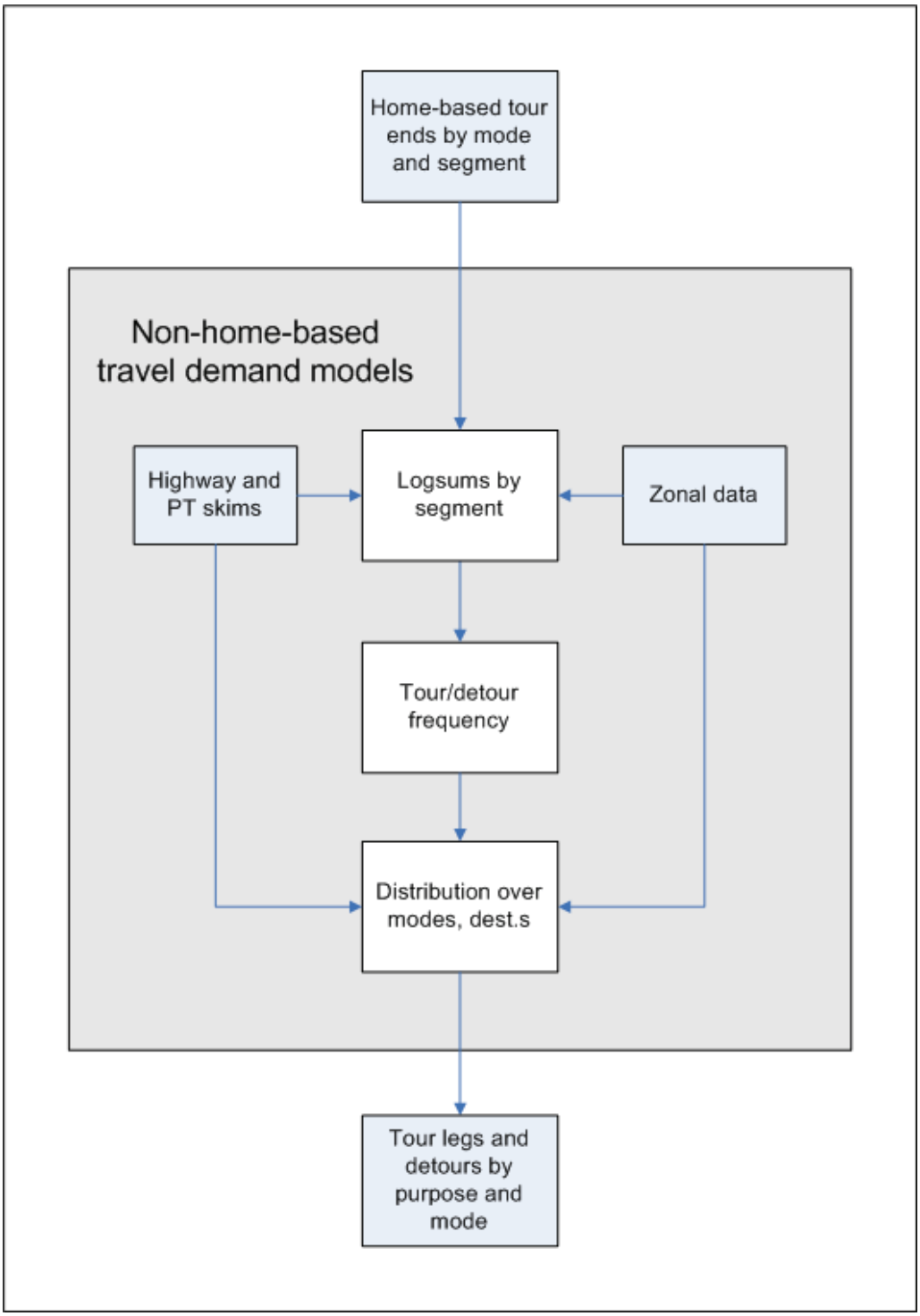
The outputs from the HB tour models are all-day tour matrices which are in Production–Attraction (P→A) format.

These all-day tour matrices feed into the third and final stage of the STM system, the pivoting process. Pivoting is the process which takes the tour matrices created for base and future applications of the TravDem models, and combines these matrices in order to forecast changes relative an observed base matrix. For HB purposes, pivoting is undertaken using all-day tour matrices. For home–work, the base matrices are taken from the 2006 Census journey to work data. For the other HB purposes, expanded HTS data are used to define the base matrices.

2.3 Non-home-based purposes

The architecture of the NHB TravDems is illustrated in Figure 4. Each of the components is then discussed further in the text beneath Figure 4, with each sub-section heading corresponding to a box in Figure 4.

Figure 4: Architecture of the NHB travel demand models



2.3.1 Home-based tour ends by mode and segment

The inputs for the NHB TravDems are the outputs from the HB work and business tour models. Specifically, the number of home–work and home–business tours arriving at each primary destination (PD) zone (i.e. at workplaces and business locations) is summed by (HB) mode and segment. Full details of the segmentations used for summing the HB tour ends are provided in Section 3.3.

These tour ends then form input to the NHB frequency models. For WB business, only home–work tour ends are used. For NHB business detours, both home–work and home–business tour ends are used.

2.3.2 Highway and public transport skims

The treatment of the highway and PT skims in the NHB TravDems is identical to the treatment in the HB TravDems, as documented in Section 2.2.2.

2.3.3 Zonal data

The attraction variables used in the NHB TravDems are listed in Table 5.

Table 5: NHB TravDem attraction variables

Purpose	Attraction variable
WB business tours	Total employment
NHB business detours	Total employment

The other zonal variables are as per the HB TravDems documented in Section 2.2.2.

2.3.4 Logsums by segment

The calculation of logsums by segment follows the same approach as that used for the HB purposes, as detailed in Section 2.2.4.

The following alternatives are represented in the NHB models:

- main modes
- PT nest for train and bus
- destinations
- toll choice (NHB business only).

2.3.5 Tour/detour frequency

The tour/detour frequency models follow similar principles to the frequency models used for the HB purposes (Section 2.2.5). However, an important difference is that the frequency of NHB tour/detour making depends on the mode used for the HB tour. Specifically, NHB tour/detour rates are higher if the HB tour mode is car driver.

For the WB business model, the total number of tours F can be calculated as:

$$F_{zms} = \frac{P_{1+|zms}}{\left(1 - P_{go|zms}\right)} HW_{zms} \qquad (2.12)$$

where:

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

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

HW_{zms} is the number of HB work tours arriving in PD zone z by mode m and segment s

The detour model is a simply binary model with alternatives 'detour' and 'no detour'. However, a complication is that four separate detour models are applied:

- detours made on the outward leg of home–work tours
- detours made on the return leg of home–work tours
- detours made on the outward leg of home–business tours
- detours made on the return leg of home–business tours.

The following equation shows how the number of detours is calculated:

$$F_{pmsr} = P_{1|pmsr} HB_{pms} \quad (2.13)$$

where:

r distinguishes between outward and return detours

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

HB_{pms} is the number of HB tours arriving in PD zone p by mode m and segment s (either work or business)

2.3.6 Distribution over modes, destinations

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

The modes represented in the TravDems were listed in Section 2.1.1.

For WB business, the final structure has mode, PT, destination and toll choices represented. The formulae set out in Equations (2.6) to (2.10) of Section 2.2.6 are applied.

For NHB business detours, the structure is the same except that toll choice is not represented in the structure. As a result, Equations (2.6) to (2.9) apply, and then the final probability calculation is as follows:

$$P_{mpd} = P_m P_{p|m} P_{d|pm} \quad (2.14)$$

2.3.7 Tour legs and detours by purpose and mode

The output from the WB business model is all-day tour matrices in Production-Attraction (P→A) format.

The output from the NHB business detour model is two all-day detour matrices, the first containing detours on the outward (P→A) leg of HB work and business tours, the second containing detours on the return (A→P) leg of HB work and business tours. If the BTS decides to apply a pivot process for the NHB purposes, then the base matrices will be defined using expanded HTS data.

CHAPTER 3 Segmentation

In the implementation of the STM models the population is divided into specific person and household (HH) type segments, which exhibit different travel behaviour in two areas: mode–destination (MD) choice and tour frequency. At the model estimation stage, separate travel frequency and mode–destination models have been developed for each travel purpose. At the implementation stage, the models of mode–destination and frequency are combined to form the 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 chapter presents the mode–destination and frequency segments required to implement the (re-estimated) mode destination and frequency models, which use a 2006 base.

Prior to undertaking this work, the STM used a 2001 base for the Population Synthesiser module[4], and a 1996 base for the travel demand models. The segment definitions have been updated to reflect changes to the final model specifications relative to the earlier version of the STM model.

Section 3.1 of this chapter explains the relationship between mode–destination and frequency segmentations. It also explains how some terms in the final model specifications have been implemented using mean proportions of the variables, rather than segmentations, in order to avoid excessive model run times.

Section 3.2 of this chapter is split into seven sub-sections, one for each HB travel purpose, supported by two appendices. Each sub-section starts by detailing the mode–destination segments, and then goes on to detail the frequency segments. Each of the sub-sections details which of the model terms have been implemented using mean proportions rather than by the segmentations.

Section 3.3 details the segments for the two NHB purposes, following the same format as Section 3.2.

[4] The STM population synthesiser initially used a 1996 base, but was subsequently rebased to a 2001 base during a project undertaken in 2004.

Some of the detail relating to the segmentations is presented in Appendix B, which gives the mean proportions of the variables for the 2006 base year for the model terms implemented using mean proportions rather than additional segmentations.

3.1 Types of segments

As noted in the introduction to this chapter, both MD and frequency segmentations are defined. An important point to note is that the frequency models are applied separately for each MD segment. This structure is necessary so that logsum accessibility measures can be calculated over modes and destinations to feed into the frequency models, and the logsum measures vary according to the MD segmentation. This means that the frequency segments are the *additional* segments necessary to define the frequency models given the definition of MD segments.

The Population Synthesiser produces forecasts of the population by each MD and frequency segment, for base and future years. This means that changes in the distribution of the population between segments, for example due to population ageing, is represented and so has an impact on predicted demand for travel.

In determining the number of segments for the mode–destination and tour frequency models, a trade-off was made by the project team (in consultation with the BTS) between the degree of variation accounted for in the segmentation, and the consequent run time at the implementation stage. In particular, as shown later in Section 4.5, the number of MD segments has a strong impact on the model run times.

With these considerations in mind, some of the socio-economic terms in the mode–destination and tour frequency models have been implemented by using 'mean proportions' of the variable in question, rather than by adding an additional segmentation dimension. In this approach, the mean amount of the variable is used to implement the model term; to take a simple example a parameter relating to males could be implemented using a mean proportion of 50% (assuming exactly 50% of the population were males).

It is noted that for those terms implemented using the mean proportion approach, the impact of changes in the future composition of the population is not captured, as the mean effects of the terms used in implementation relate to the base year HTS data. So in the example given in the previous paragraph, the assumption of 50% males is carried forward to future years. Therefore, mean proportions have only been used for those variables whose impact is small relative to other variables, or where the proportion of individuals in that segment is not expected to show much change over time, for example the proportion of males across the population as a whole.

Sections 3.2 and 3.3 detail the mode–destination and frequency segments used for each model purpose, and highlight those model terms where mean proportions have been used instead of additional segmentation dimensions. The mean proportions themselves are detailed in Appendix B.

3.2 Home-based purposes

Table 6 provides a summary of the number of mode–destination, frequency and total segments for each purpose.

As noted in Section 3.1, the frequency model is applied separately for *each* MD segment. This means that the frequency segments are nested within the MD segments, i.e. for each MD segment there is a further loop over frequency segments. The logsum accessibility terms in the frequency models vary according to the MD 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 MD and frequency segment. Because they are nested within the MD segments the frequency segments are termed 'Additional frequency segments' in Table 6.

Table 6: Total number of segments, HB purposes

Segment type	STM 2001	STM 2006
Home–work		
Mode–destination segments	128	80
Additional frequency segments	3/15	3/15
Total segments	1152	720
Home–business		
Mode–destination segments	72	24
Additional frequency segments	24	24
Total segments	1728	576
Home–primary education		
Mode–destination segments	10	10
Additional frequency segments	4	4
Total segments	40	40
Home–secondary education		
Mode–destination segments	10	3
Additional frequency segments	6	2
Total segments	60	6
Home–tertiary education		
Mode–destination segments	12	12
Additional frequency segments	24	12
Total segments	288	144
Home–shopping		
Mode–destination segments	36	36
Additional frequency segments	27	36
Total segments	972	1296
Home–other travel		
Mode–destination segments	30	25
Additional frequency segments	48	56
Total segments	1440	1400

For home–work, the number of frequency segments varies according to the number of mode–destination segments. Section 3.2.1 explains this feature further.

Table 7 presents a summary of the segments that are incorporated in the mode–destination models for each of the seven HB purposes, thus providing a quick summary of which mode–destination segments are used for which HB purpose.

Table 8 presents the corresponding segments for the frequency model.

Table 7: Mode–destination segmentation summary (HB purposes)

Segment	Home–work	Home–business	Home–shopping	Home–other	Home–primary education	Home–secondary education	Home–tertiary education
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		

Table 8: Frequency segmentation summary (HB purposes)

Segment	Home–work	Home–business	Home–shopping	Home–other	Home–primary education	Home–secondary education	Home–tertiary education
Adult status	Yes	Yes	Yes	Yes			Yes
Age	Yes	Yes	Yes			Yes	
Personal income			Yes				Yes
HH income				Yes			
Occupation type		Yes					
Industry type		Yes					
Number of children				Yes			
Education type							Yes
Child status					Yes		

Sections 3.2.1 to 3.2.7 provide full details of the mode–destination and frequency segments for each of the seven HB purposes.

3.2.1 Home–work

Mode–destination segments

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

1. car availability
2. work status
3. personal income.

Table 9 shows the total number of mode–destination (MD) segments from the STM (2001 base) model and total segments identified in the STM (2006 base) model.

Table 9: Total home–work mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	8	8
Work status	NA	2
Personal income	4	5
Industry and work status	4	NA
Total	**128**	**80**

The car availability segments remain unchanged between the 2001 and 2006 models. The STM (2001 base) home–work model had a distance parameter for persons employed in manufacturing, which was not identified in the STM (2006 base) model. Also, in the STM (2001 base) model, attractions were segmented by manufacturing jobs and non-manufacturing jobs respectively, whereas in the STM (2006 base) model the attractions are segmented by personal income, which better reflects commuting patterns in 2006. The industry and work status segments were reduced to only two work status segments. The personal income segments have changed in number and definition between the models. Note that in the 2001 base version of the STM incomes were defined in 1996 prices; in the 2006 base version incomes are defined in 2006 prices.

The details of the segments are shown in Table 10.

Table 10: Home–work mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	No licence but at least one car	
a3	Competition for car; no company car	
a4	Free car use; one non-company car	
a5	Free car use; several licences in HH; no company car	
a6	Competition for car; one plus company car	
a7	Free car use; one company car	
a8	Free car use; several licences; one plus company car	
Segment	**Industry and work status**	**Work status**
b1	Manufacturing (full time)	Full-time worker
b2	Manufacturing (part time)	Other worker
b3	Non-manufacturing (full time)	NA
b4	Non-manufacturing (part time)	NA
Segment	**Personal income**	**Personal income[5]**
c1	<$15,599	<$20,799
c2	$15,600–25,999	$20,800–31,999
c3	$26,000–36,399	$31,200–41,559
c4	>$36,399	$41,600–67,599
c5	NA	>$67,599

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

1. PRLicence (licence holding term on Park & Ride (P&R)[6]);
2. MaleCrDr (male car driver)
3. MaleBike (male bike user).

These variables have been implemented using mean proportions, which are detailed in Appendix B.

Frequency segments

The home–work frequency model has two segmentation dimensions:

[5] Annual personal income (adjusted based on June 2006 Sydney CPI).

[6] P&R is defined as car access where the car is parked at the access station, and therefore can include both drivers and passengers.

1. age
2. adult status.

Table 11 shows the total number of frequency segments in the home–work frequency model which are additional to the mode–destination segments.

Table 11: Additional home–work frequency segments

Segment	STM (2001 base)	STM (2006 base)
Age	3	3
Adult status	1/5	1/5
Total	3/15	3/15

The total number of segments and the definition of the segments remain unchanged from the 2001 model. Table 12 gives the detailed definition of the segments.

It is noted that 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 2 to 5 are not used. For the second mode–destination segment (other worker), five different segments are defined, as detailed in Table 12. This is what is shown using the 1/5 description above.

Table 12: Home–work frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**Age**	**Age**
1	<40	**Unchanged**
2	40–59	
3	>59	
Segment	**Adult status**	**Adult status**
1	Full-time worker/full-time education	**Unchanged**
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 12. All of these other socio-economic variables are defined by the MD segments, except for variables for males and manufacturing occupation types, for which mean proportions are used in the implementation.

3.2.2 Home–business

Mode–destination segments

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

1. car availability
2. personal income.

Table 13 shows the comparison of MD segments from the STM (2001 base) model and segments identified in the STM (2006 base) model.

Table 13: Total home–business mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	8	8
Personal income	3	3
Activity duration	3	NA
Total	**72**	**24**

The car availability segmentation remains unchanged. In the STM (2001 base) estimation, the full parking costs were applied for all the tours with activity durations more than 6 hours and an hourly rate was used for tours with activities less than 6 hours. In the STM (2006 base) business model all the tours are assigned the full parking costs so there are no segments based on activity duration. Also, the definition of the income segments has changed between the models. The details of the segments are given in Table 14.

There are also other socio-economic variables in the home–business model which lie outside the segmentation given above:

1. TrnManProf (people with managerial and professional occupations using train)
2. pr2pcars (people using P&R from HHs with two or more cars)
3. Prlicence (using P&R and have a licence)
4. carpu25 (people aged under 25 years travelling as car passengers).

These variables have been implemented using the mean proportions detailed in Appendix B.

Table 14: Home–business mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	No licence but at least one car	
a3	Competition for car; no company car	
a4	Free car use; one non-company car	
a5	Free car use; several licences in HH; no company car	
a6	Competition for car; one plus company car	
a7	Free car use; one company car	
a8	Free car use; several licences; one plus company car	
Segment	**Personal income**	**Personal income**
b1	<$15,599	<$31,199
b2	$15,600–25,999	$31,200–51,199
b3	>$26,000	>$51,199
Segment	**Activity duration**	**Activity duration**
c1	0–2 hours	NA
c2	2–6 hours	
c3	6+ hours	

Frequency segments

The home–business frequency model has four segmentation dimensions:

1. age
2. occupation
3. industry
4. adult status.

Table 15 shows the total number of segments in the home–business frequency model which are additional to the mode–destination segments.

Table 15: Additional home–business frequency segments

Segment	STM (2001 base)	STM (2006 base)
Age	2	2
Occupation	3	3
Industry	2	2
Adult status	2	2
Total	24	24

The total number of segments and the definition of the segments remain unchanged in the implementation of the 2006 models. Table 16 gives the detailed definition of the segments.

Table 16: Home–business frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**Age**	**Age**
1	<25	**Unchanged**
2	25 and above	
Segment	**Occupation**	**Occupation**
1	Manual worker	**Unchanged**
2	Non-manual worker	
3	Not employed	
Segment	**Industry**	**Industry**
1	Non-manufacturing	**Unchanged**
2	Manufacturing	
Segment	**Adult status**	**Adult status**
1	Other adults	**Unchanged**
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 16. All of these additional variables lie within the definition of the MD segments.

3.2.3 Home–primary education

Mode–destination segments

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

1. car availability
2. age.

Table 17 gives the total number of MD segments.

Table 17: Total home–primary education mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	5	5
Age	2	2
Total	**10**	**10**

The number and definition of the car ownership and the age segments in the present model remain unchanged from the STM (2001 base) model. Table 18 shows the detailed specification of segments.

Table 18: Home–primary education mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	One non-company car	
a3	Two plus non-company cars	
a4	One company car	
a5	Two plus cars; at least one company car	
Segment	**Age**	**Age**
b1	Aged under 8	**Unchanged**
b2	Aged 8 or above	

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

Frequency segments

The home–primary education frequency model has segmentation dimensions across HH income and school type.

Table 19 shows the total number of segments in the home–primary education frequency model which are additional to the mode–destination segments.

Table 19: Additional home–primary education frequency segments

Segment	STM (2001 base)	STM (2006 base)
Special school	2	2
HH income	2	2
Total	4	4

The total number and definition of special school segments remains unchanged. The number of HH income segments remains the same but the definition is changed. Table 20 gives the detailed definition of the segments.

Table 20: Home–primary frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**Special school**	**Special school**
1	Non-special school	**Unchanged**
2	Special school	
Segment	**HH income**	**HH income**
1	<$52,000	<=$25,000
2	>=$52,000	>$25,000

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

3.2.4 Home–secondary education

Mode–destination segments

The home–secondary education mode–destination model only has one segmentation dimension:

1. car availability.

Table 21 shows the total number of segments in the STM (2001 base) and STM (2006 base) versions of the model.

Table 21: Total home–secondary education mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	5	3
HH income	2	NA
Total	**10**	**3**

The numbers of car ownership segments are reduced to three and there is no income effect observed in the STM (2006 base) model and therefore no HH income segmentation is required. Table 22 shows the detailed specification of the segments in the MD model.

Table 22: Home–secondary education mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car	No car
a2	No licence; one plus car; no company car	No licence; one plus car
a3	Licence; one plus car; no company car	Licence; one plus car
a4	No licence; one plus car; one plus company car	NA
a5	Licence; one plus car; one plus company car	
Segment	**HH income**	**HH income**
b1	<$78,000	**NA**
b2	>=$78,000	

In addition to socio-economic terms defined by the segmentation given in Table 22, the mode–destination model contains a 'Bike_Male' variable, for which a mean proportion has been used (detailed in Appendix B).

Frequency segments

The home–secondary education frequency model has segmentation across age bands only. Table 23 shows the total number of segments in the home–secondary education frequency model which are additional to the mode–destination segments.

Table 23: Additional home–secondary education frequency segments

Segment	STM (2001 base)	STM (2006 base)
HH income	3	NA
Age	2	2
Total	6	2

No HH income effects are observed in the 2006 secondary frequency models. However, the age segments remain unchanged.

Table 24 gives the detailed definition of the segments.

Table 24: Home–secondary education frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**HH income**	**HH income**
1	<$4,160	NA
2	$4,160–35,999	
3	>=$36,000	
Segment	**Age**	**Age**
1	<16	**Unchanged**
2	>=16	

All the socio-economic variables in the home–secondary education frequency model are defined by the segments given in Table 24.

3.2.5 Home–tertiary education

Mode–destination segments

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

1. car availability
2. student status.

Table 25 shows the total number of MD segments.

Table 25: Total home–tertiary education mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	6	6
Student status	2	2
Total	**12**	**12**

The number and definition of both the car ownership segments and student status segments remain unchanged from 2001. Table 26 shows the detailed specification of the segments.

Table 26: Home–tertiary education mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	No licence, but car in HH	
a3	Competition for car; one car	
a4	Free car use; one car	
a5	Competition for car; two plus cars	
a6	Free car use; several licences; two plus cars	
Segment	**Student status**	**Student status**
b1	Full time	**Unchanged**
b2	Part time/other	

All the socio-economic variables in the home–tertiary education model lie within the definition of segments given in Table 26 except for the variable for CmpCrDr (company car driver), for which a mean proportion has been used in the implementation.

Frequency segments

The home–tertiary education frequency model has three segmentation dimensions:

1. personal income
2. education type
3. adult status.

Table 27 shows the total number of segments in the home–tertiary education frequency model which are additional to the mode–destination segments.

Table 27: Additional home–tertiary education frequency segments

Segment	STM (2001 base)	STM (2006 base)
Personal income	2	2
Education type	4	2
Adult status	3	3
Total	24	12

The total number and definition of personal income and adult status segments remains unchanged. The education type segments are reduced from four segments to two segments. Table 28 gives the detailed definition of the segments.

Table 28: Home–tertiary education frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**Personal income**	**Personal income**
1	<$15,600	**Unchanged**
2	>=$15,600	
Segment	**Education type**	**Education type**
1	TAFE[7]	University
2	University	Other
3	Other	NA
4	No education type	
Segment	**Adult status**	**Adult status**
1	FT student	**Unchanged**
2	FT worker	
3	Other adults	

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

3.2.6 Home–shopping

Mode–destination segments

The home–shop mode–destination model has two segmentation dimensions:

1. car availability
2. age and adult status.

Table 29 shows the comparison of MD segments from the models with a 2001 base and with a 2006 base respectively.

Table 29: Total home–shopping mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	6	6
Age and adult status	6	6
Total	**36**	**36**

The number and definition of the car ownership and the age and adult status segment remain unchanged in the implementation of the 2006 model. Table 30 shows the detailed specification of segments.

[7] Technical and Further Education.

Table 30: Home–shop mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	No licence, but car in HH	
a3	Competition for car; one car	
a4	Free car use; one car	
a5	Competition for car; two plus cars	
a6	Free car use; several licences; two plus cars	
Segment	**Age and adult status**	**Age and adult status**
b1	Aged under 10	**Unchanged**
b2	Aged 10–19; concessionary fare	
b3	Aged 15–19; full fare	
b4	Aged 20–59; concessionary fare	
b5	Aged 20 plus; full fare	
b6	Aged 60 plus; pensioner; concessionary fare	

All the socio-economic variables lie within the definition of segments given in Table 30 except for the following variables for which segment definitions were deemed less important:

1. CmpCrDr (car driver; HH owns at least one a company car)
2. Bus_Male (males less likely to use bus).

These variables have been implemented using mean proportions detailed in Appendix B.

Frequency segments

The home–shopping frequency model has three segmentation dimensions:

1. personal income
2. adult status
3. age.

Table 31 shows the total number of segments in the home–shopping frequency model which are additional to the mode–destination segments.

Table 31: Additional home–shop frequency segments

Segment	STM (2001 base)	STM (2006 base)
Personal income	3	2
Adult status	3	6
Age	3	3
Total	27	36

Table 32 gives the detailed definition of the segments.

Table 32: Home–shop frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**Personal income**	**Personal income**
1	<$4,160	<$26,000
2	$4,160–26,000	>=$26,000
3	>$26,000	NA
Segment	**Adult status**	**Adult status**
1	FT workers and FT students	FT student
2	PT worker	PT student
3	Other types	FT worker
4	NA	Unemployed
5		Looking after home
6		"Other"
Segment	**Age**	**Age**
1	10–14	**Unchanged**
2	15–29	
3	>29	

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

3.2.7 Home–other travel

Mode–destination segments

The home–other travel mode–destination model has three segmentation dimensions:

1. car availability
2. age and adult status
3. personal income.

Table 33 shows the comparison of MD segments.

Table 33: Total home–other travel mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	5	5
Age and adult status	6	5
Personal income	2	NA
Total	**60**	**25**

The number and definition of car availability segments remain unchanged. The age and adult status segments also largely remain unchanged except for the merging of two age and adult status segments in the STM (2006 base) model where no substantial difference in value was observed. No personal income segmentation was identified in the STM (2006

base) model. Table 34 shows the detailed specification of the segments. There are also other socio-economic variables in the home–other model. All the socio-economic variables lie within the definition of segments except for the following variables, for which segment definitions were deemed less important:

1. CmpCrDr (car driver; persons from HHs with at least one company car)
2. CarD_Drpu (car driver; dropping and pick up sub-purpose)
3. CarP_Male (car passenger; male)
4. CarP_Enter (car passenger; entertainment sub-purpose)
5. PT_Enter (PT modes; entertainment sub-purpose)
6. Walk_Male (walk; males)
7. Walk_recr (walk; recreation sub-purpose).

These variables have been implemented using mean proportions.

Table 34: Home–other travel mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No car in HH	**Unchanged**
a2	No licence, but car in HH	
a3	Competition for car; one car	
a4	Free car use; one car	
a5	Free car use; several licences; two plus cars	
Segment	**Age and adult status**	**Age and adult status**
b1	Aged under 10	Aged under 10
b2	Aged 10–19; concessionary fare	Aged 10–19; concessionary fare
b3	Aged 15–19; full fare	Aged 15–19; full fare
b4	Aged 20–59; concessionary fare	Aged 20+; concessionary fare
b5	Aged 20 plus; full fare	Aged 20 plus; full fare
b6	Aged 60 plus; pensioner; concessionary fare	NA
Segment	**Personal income**	**Personal income**
c1	<$4,160	NA
c2	>=$4,160	NA

Frequency segments

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

1. HH income
2. number of children
3. adult status.

Table 35 shows the total number of segments in the home–other travel frequency model which are additional to the mode–destination segments.

Table 35: Additional home–other travel frequency segments

Segment	STM (2001 base)	STM (2006 base)
HH income	3	2
Child	4	4
Adult status	4	7
Total	48	56

The number of HH income segments has been reduced from three in the STM (2001 base) to two in STM (2006 base) model. The total number and definition of child segments remain unchanged. The adult status segments are extended to represent the other significant adult status effects observed in the STM (2006 base) model. Table 36 gives the detailed definition of the segments.

Table 36: Home–other travel frequency model segments

	STM (2001 base)	STM (2006 base)
Segment	**HH income**	**HH income[8]**
1	<$8,320	<$104,000
2	$8,320–103,999	>=$104,000
3	>=$104,000	NA
Segment	**Children**	**Children**
1	No children	**Unchanged**
2	1 child	
3	2 children	
4	3+ children	
Segment	**Adult status**	**Adult status**
1	FT worker	FT student
2	FT student	FT worker
3	Pensioner/unemployed	PT worker
4	Other adults and all children	Unemployed
5	NA	Looking after home
6		Retired
7		"Other"

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

[8] Annual HH income adjusted (based on June 2006 Sydney CPI).

3.3 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 MD segments defined for the home–work and home–business models.

Sections 3.3.1 and 3.3.2 provide full details of the segments used for the two NHB models.

3.3.1 Work-based business tours

Mode–destination segments

The WB business mode–destination model has four segmentation dimensions:

1. car availability
2. adult status
3. personal income
4. HB tour mode.

Table 37 shows the total number of MD segments.

Table 37: Total WB business model mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	3	3
Personal income	3	2
Job classification	4	NA
Tour mode	2	2
Total	72	24

The number and definition of car availability and tour mode segments are unchanged but the remaining segmentations have changed. Table 38 shows the detailed specification of the segments.

Table 38: WB business mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No licence	**Unchanged**
a2	Licence, but no company car in HH	
a3	Licence; company car in HH	
Segment	**Adult status**	**Adult status**
b1	NA	Full-time worker
b2		Part-time worker
Segment	**Personal income**	**Personal income**
c1	<$15,599	<$41,600
c2	$15,600–36,400	>=$41,600
c3	>$36,400	NA
Segment	**HB tour mode**	**HB tour mode**
d1	Car driver	**Unchanged**
d2	Other STM mode	
Segment	**Job classification**	**Job classification**
b1	FT manufacturing	NA
b2	PT manufacturing	
b3	FT non-manufacturing	
b4	PT non-manufacturing	

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.

Frequency segmentation

The terms in the WB 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 39 shows the relationship between the frequency model terms for the WB business tour and the home–work segments.

Table 39: Relationship between WB business tour frequency terms and home–work segments

Tour frequency term	STM (2001 base)	STM (2006 base)
Compcar_0	Car availability a=6,7,8	Car availability a=6,7,8
Manuf_0	Job classification b=1,2	NA
FTwk_0	Job classification b=1,3	Adult status b=1
PI>36.4K_0	Personal income c=4	NA
PI>41.6k_0	NA	Personal income c=4,5

3.3.2 Non-home-based business detours

Mode–destination segments

The NHBB detour mode–destination model has the three segmentation dimensions:

1. car availability
2. personal income
3. HB tour mode.

Table 40 shows the total number of MD segments.

Table 40: Total NHB business detour model mode–destination segments

Segment	STM (2001 base)	STM (2006 base)
Car availability	3	3
Personal income	4	3
Tour mode	7	8
Total	84	72

The number and definition of car availability segments are unchanged but the remaining segmentation dimensions have changed in number as well as definition. Table 41 shows the detailed specification of the segments.

Table 41: WB business mode–destination model segments

	STM (2001 base)	STM (2006 base)
Segment	**Car availability**	**Car availability**
a1	No licence	**Unchanged**
a2	Licence, but no company car in HH	
a3	Licence; company car in HH	
Segment	**Personal income**	**Personal income**
b1	<$15,599	<$31,200
b2	$15,600–25,999	$31,200–67,600
b3	$25,999–36,399	>$67,600
b4	>$36,399	NA
Segment	**HB tour mode**	**HB tour mode**
c1	Car driver	Car driver, toll
c2	NA	Car driver, no toll
c3	Car passenger	**Unchanged**
c4	Train	
c5	Bus	
c6	Bike	
c7	Walk	
c8	Taxi	

All the socio-economic variables lie within the definition of segments given in Table 41 except for the variables CarPA1625 (car passenger in-between 16 to 25 years of age) and a constant for males on the walk alternative, for which mean proportions have been used in the implementation.

Frequency segmentation

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

1. outward detours (work PD)
2. return detours (work PD)
3. outward detours (business PD)
4. return detours (business PD).

Consequently, separate frequency segmentation dimensions have to be used for detours made in the course of home–work and HB tours. The terms in the NHB tour 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 42 shows the mapping of the home–work model to the NHB PD work frequency model, and Table 43

shows the mapping of the home–business model to the NHB PD business frequency model.

Table 42: Relationship between NHB business detour (PD work) tour frequency terms and home–work segments

Tour frequency term	STM (2001 base)	STM (2006 base)
Compcar_0	Car availability a=6,7,8	Car availability a=6,7,8
Manuf_0	Job classification b=1,2	NA
PI>36.4K_0	Personal income c=4	NA
PI>67.6k_0	NA	Personal income c=5

Table 43: Relationship between NHB business detour (PD business) tour frequency terms and home–business segments

Tour frequency term	STM (2001 base)	STM (2006 base)
Compcar_0	Car availability a=6,7,8	Car availability a=6,7,8
PI>15.6K_0	Personal income c=1	NA
PI<31.2k_0[9]	NA	Personal income c=1,2

[9] This variable is applicable only to the outward detour frequency model for detours made where the PD is business.

CHAPTER 4 Operation of application system

The operation of the TravDem models is controlled by nine DOS batch files, one for each of the HB and two NHB purposes currently modelled in the STM. The BTS may wish to call these nine batch files from a single control batch file once the nine TravDems are operational on their system.

The TravDem models need to be run for both base and future years. For a given future year a number of different scenarios may be run. A scenario is defined by both assumptions about the future transport networks coded in EMME, and a set of planning assumptions about the future population, which the Population Synthesiser uses to generate forecasts of the future population by segment (the 'zonal segments').

Typically a single set of planning assumptions is used for a given forecast year, but a number of different sets of future networks are tested. However, it is also possible to run the STM system to test the impact of different planning assumptions on the predicted transport flows.

Each of the batch files described above carries out the seven steps required to run a TravDem for a given base or future scenario:

1. create scenario directory
2. copy fixed inputs
3. copy scenario-specific inputs
4. run the station choice LOS
5. run the TravDem
6. run the post-processing stage
7. copy output files and clean up.

These seven steps are described in Sections 4.1 to 4.7.

A useful improvement to the functionality of ALOGIT, namely the use of 'environment variables' to specify directory paths for input files, has been incorporated into the ALOGIT versions of the application system delivered to the BTS. The use of environment variables is discussed further below.

4.1 Create scenario directory

The TravDem code, and the batch files that call them, use relative referencing. The use of relative referencing means that provided the relative directory structure used by the TravDem is maintained the batch files can be run on different machines with different drive letters without difficulty.

The first step of the TravDem batch process is then to create a scenario output directory, using the '%1' argument supplied to the batch file.

4.2 Copy fixed inputs

The next step of the process is to copy into the directory where the TravDem is run a number of fixed input files that do not vary according to the model scenario. The files define:

- zone number and zone rank definitions
- lists of station zones
- definitions of Sydney SD areas in the model zone system
- the location of large shopping centres in the 2006 base year.

The location of these and other files is controlled through the use of 'environment variables' in the batch files that control each of the TravDems. For example, the directory for the attraction variables is specified by the 'stm3_attraction' environment variable, and then the ALOGIT code refers to '%stm3_attraction%' when reading in the attraction variables. This approach avoids the need for lengthy directory paths in the main ALOGIT code, and allows flexibility as the location of input files can be modified by changing the controlling batch file, which summarises all the file locations together without the need to modify all of the different file references in the ALOGIT code.

4.3 Copy scenario-specific inputs

A second set of inputs are copied to the directory where the TravDem is run. These inputs vary according to the model scenario, and are copied across from a scenario specific input directory. The scenario-specific inputs cover:

- attraction variables for each purpose (employment, population or enrolments)
- parking cost data
- for HB purposes, the zonal segments file created by the Population Synthesiser.

Again, environment variables are used to specify the location of scenario-specific inputs.

It is noted that in the TravDems delivered to the BTS by RAND Europe, the LOS measures need to be placed in the following directories for highway and PT modes:

```
\\data\LOS\Highway
\\data\LOS\PT
```

When the new STM system is fully operational, the BTS will need to set up a process that copies in the LOS for the scenario in question. Furthermore, when the STM is run in iterative operation, a process will be required to update the highway LOS to take account of the changes in congestion and LOS with each iteration. No crowding is represented in the PT assignment, and therefore for a given scenario the PT LOS will not change between iterations.

4.4 Create the station choice level of service

For all of the HB purposes except primary education, train access mode and station choice models are incorporated in the model structure. A special processing step is required to create the required LOS files to implement these choice models for the two car access alternatives: P&R and K&R.

To create the station choice LOS, this processing step reads in highway LOS from home zones to stations representing travel conditions on the car access legs to stations, and train LOS from stations to zones representing travel conditions on the train legs from the station on to the PD. Next, for each home zone to PD pair, the most attractive station alternatives for P&R, and the most attraction station alternatives for K&R are identified. Either five or two stations are identified for each origin–destination pair (Table 2 defined the number identified for each travel purpose).

For the machines RAND Europe used to test the base year application system, the run times for the station choice LOS processing vary between four and five hours, depending on the model purpose[10]. Therefore for future year runs it is not recommended that this step is re-run for each iteration of the highway assignment. Depending on the importance of representing highway congestion in the vicinity of stations, the BTS may choose to run for the first iteration or the first and final iterations, only.

4.5 Run the TravDem

Once the fixed input files have been copied, the correct LOS is in place, and if necessary the station choice LOS has been created, the TravDem is run.

To give an indication of the time that is required to run the TravDems, Table 44 summarises the run times for each of the TravDems[11], together with the number of mode–destination (MD) segments.

[10] The run timings have been made on a run machine with a 2.40 GHz processor and 8.00GB of memory.

[11] The run timings have been made on a run machine with a 2.40 GHz processor and 8.00GB of memory.

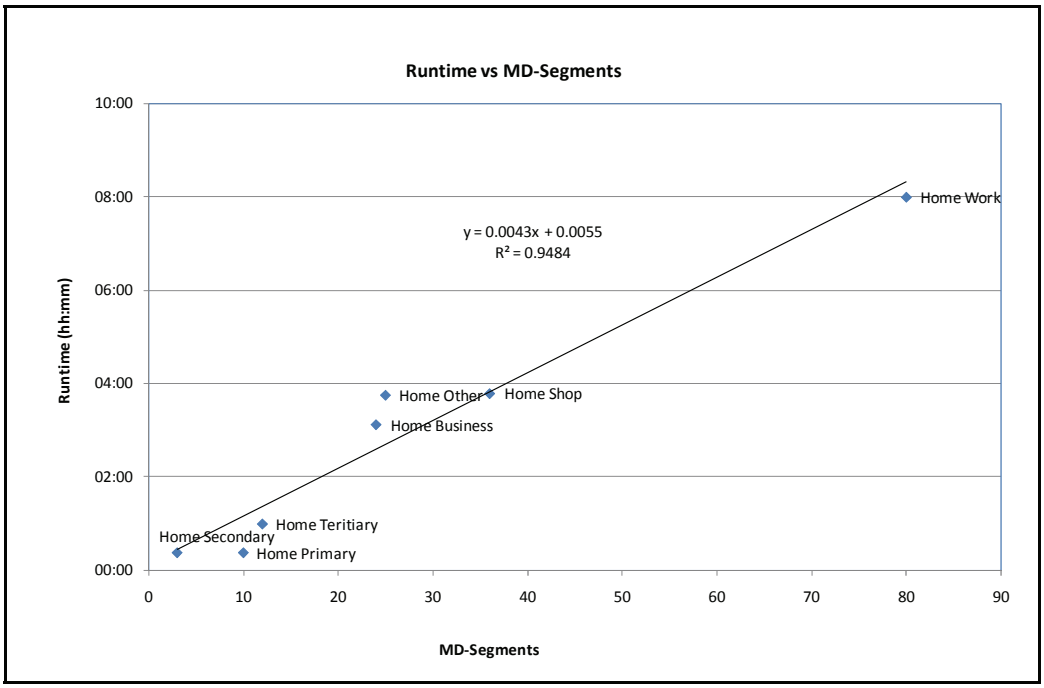
Table 44: TravDem run times

Purpose	MD segments	Run times (hh:mm)
Home–work	80	08:00
Home–business	24	03:07
Home–primary education	10	00:22
Home–secondary education	3	00:22
Home–tertiary education	12	00:59
Home–shopping	36	03:47
Home–other travel	25	03:45

These run times relate to the machines used by RAND Europe to test the TravDems for the base year. Once the system is established on the BTS's system run times can be obtained to allow BTS to determine how long the STM system as a whole needs to be run per iteration. A strategy the BTS may choose to employ to speed up total run times is to run different travel purposes in parallel on different machines.

It can be observed from Table 44 that the run time varies significantly between the different travel purposes. To investigate this pattern of variation further, Figure 5 plots how the run times for each travel purpose vary with the number of mode–destination segments.

Figure 5: TravDem run times by MD segments



From the plot and regression, it can be concluded that the TravDem run times are closely related to the number of MD segments. A linear relationship gives a good fit to the data, with a rho-squared value of 0.95. It is interesting to note that the fixed overhead, shown by the intercept of the regression at zero MD segments, is low. This means that assuming run times to be directly proportional to the number of MD segments is reasonable.

4.6 Run the post-processing stage

The post-processing stage performs two steps.

The first is to take the tour matrices by mode created by the TravDem run in compressed MinUTP matrix format[12], and convert these to text format to facilitate analysis by the BTS of the model outputs. The tour matrices by mode are required in MinUTP format to feed into the subsequent pivoting process.

The second step, run for those purposes that include train access mode and station choice models, is to create two files for P&R and K&R tours, where the station zone used is required for analysis:

1. a file that details the number of P&R and K&R tours for each home zone and station zone combination
2. a file that details the number of P&R and K&R tours for each destination zone and station zone combination.

It is noted that the numbers of individuals predicted to use P&R includes both drivers and passengers of cars which are parked at a station. Therefore the predicted numbers of P&R tours need to be divided by mean car occupancies to provide forecasts of the numbers of cars parking at each station.

4.7 Copy output files and clear up

The final stage is to copy the output files to the scenario specific outputs directory, and then clean the directory in which the TravDem is stored ready for the next run.

[12] MinUTP matrix format is a compressed binary format that stores data very efficiently and allows for more rapid reading and writing of data.

CHAPTER 5 Verification and validation

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

1. replication of the mode–destination logsums obtained with the estimation set-ups
2. comparison of observed and predicted tour rates
3. comparison of observed and predicted mode shares
4. comparison of observed and predicted mean tour lengths
5. comparison of application elasticities to the model estimation values.

These five validation tests are documented in Sections 5.1 to 5.5, which present summary results for each of the model purposes. Detailed validation results are presented in Appendix C.

5.1 Logsums

The mode–destination model includes main mode, PT mode, train access mode, train access station, destination and toll road choices. For a given home zone and model segment combination, a mode–destination logsum can be calculated over each of these choices (as per Equation 2.4).

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

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

The mode–destination logsums have been validated exactly against the estimation values for the seven HB purposes. For the two NHBB purposes, this check is not possible because logsums were not extracted at the estimation phase, and so the validation for these purposes relies on validation tests 2 to 5.

5.2 Tour rates

Two checks have been made which relate to the tour frequency component of the TravDems.

The first check is on the mean tour rate, which is the number of tours made per average workday, compared with the rate observed in the unweighted HTS estimation sample. This check validates that the frequency model from the re-estimation work has been implemented correctly in the TravDem.

The results from the tour frequency rate checks are presented in Table 45.

Table 45: Tour frequency rate validation, HB purposes

Purpose	HTS estimation sample tour rate	TravDem 2006 base tour rate	Percent diff.
Home–work	0.502	0.499	-0.67 %
Home–business	0.104	0.105	0.82 %
Home–primary education	0.719	0.669	-6.98 %
Home–secondary education	0.665	0.648	-2.60 %
Home–tertiary education	0.026	0.027	4.76 %
Home–shopping	0.177	0.179	1.03 %
Home–other travel	0.615	0.616	0.09 %

For home–work, home–business, home–other travel and WB business the predicted tour rates are within 1% of those observed in the estimation samples, and for shopping the difference in tour rates is just over 1%. For these purposes, which cover 89% of overall tours, the match to the observed tour rates is excellent. For the three education purposes, some larger differences are observed, though only for primary education is the difference greater than 5%.

Table 46: Tour frequency rate validation, NHBB purposes

Purpose	HTS estimation sample rate	TravDem 2006 base rate	Percent diff.
WB business tours	0.0971	0.0972	0.12 %
NHBB detours, PD work, out	0.029	0.026	-10.16 %
NHBB detours, PD work, return	0.033	0.031	-6.52 %
NHBB detours, PD bus., out	0.243	0.230	-5.22 %
NHBB detours, PD bus., return	0.281	0.278	-1.28 %

The WB detour rate matches the estimation rate very closely. For NHBB detours, detour rates are lower than those observed in the HTS, particularly for detours made in the course of HB work tours. Given that the differences in some of the detour rates were high relative to other purposes, detailed line-by-line checks of the implementation code were undertaken but no errors were found.

The second check is on the total number of tours predicted, which have been compared to expanded HTS data below. It is noted that the expanded HTS tour totals include half

tours as well as full tours, i.e. they include all observed travel. The frequency models are consistent with this definition, because they too include half-tours[13].

Table 47: Total tours validation, HB purposes

Purpose	HTS data (2004–2009)	TravDem 2006 base	Percent diff.
Home–work	1,524,033	1,556,863	2.2 %
Home–business	421,964	436,537	3.5 %
Home–primary education	329,878	310,326	-5.9 %
Home–secondary education	266,722	244,125	-8.5 %
Home–tertiary education	103,566	107,060	3.4 %
Home–shopping	930,090	917,997	-1.3 %
Home–other travel	3,175,979	3,162,352	-0.4 %
Total HB	6,752,233	6,735,260	-0.3 %

For home–work and home–business, the total number of predicted tours is around 2% to 4% higher than the expanded HTS data, despite the mean tour rate matching the estimation sample closely. The TravDem predictions depend on the output from the Population Synthesiser, which even in the 2006 base year is an expansion to meet the zonal target totals. Differences between this expanded population and the population in the 2004–2009 HTS data explain the differences in total tours.

For the three education models, there are differences of up to 8% between the expanded HTS and predicted numbers of tours, which are caused by the differences between observed and predicted tour rates highlighted in Table 47, and differences between the expanded population and the population in the 2004–2008 HTS data.

For shopping and home–other travel, the expanded HTS figures are matched well, particularly for home–other travel, which is the most important travel purpose in terms of number of tours.

The total number of overall HB tours is predicted to within 0.3%, as over-predictions of travel for some purposes are balanced by under-predictions for other purposes. Therefore the prediction of total HB travel is accurate.

Table 48 presents validation of total trips for the two NHBB purposes. Note that in calculating the total NHBB trips, each WB business tour is counted as two trips, whereas each NHBB detour is counted as a single trip.

[13] In the frequency model estimation, each outward half tour was taken to be equivalent to one full tour, whereas return half tours were dropped as they were judged to be more susceptible to coding errors.

Table 48: Total trips validation, NHBB purposes

Purpose	HTS data (2004–2009)	TravDem 2006 base	Percent diff.
WB business tours	138,457	151,355	9.32 %
NHBB detours	311,053	308,314	-0.88 %
Total NHBB trips	587,967	611,024	3.92 %

WB business tours are over-predicted by 9.3% despite the close match between the estimation and TravDem tour rates shown in Table 46. This over-prediction follows in part from the over-prediction of home–work tours, as WB business tours are predicted as a function of the number of home–work tours.

For NHBB detours, the total number of detours matches the HTS data closely. Table 46 demonstrated that the application detour rates were lower than those observed in the HTS, but these lower detour rates are applied to predicted home–work and home–business tour totals that are higher than those observed in the HTS data, and the net result is that predicted NHBB detours match the HTS data closely.

Given that the over-prediction of WB tours results in an over-prediction of total NHBB travel, it was decided to apply an adjustment factor to the WB business tour model so that the total number of WB business tours matched the weighted HTS data exactly. Table 49 summarises the impact of that adjustment on total NHBB trips.

Table 49: Total trips validation, NHBB purposes, adjusted WB business model

Purpose	HTS data (2004–2009)	TravDem 2006 base	Percent diff.
WB business tours	138,457	138,457	0.00%
NHBB detours	311,053	308,314	-0.88%
Total NHBB trips	587,967	585,228	-0.47%

Following this adjustment to the WB business tour model frequency rate, total NHBB trips are predicted within under half of 1%.

5.3 Mode shares

To calculate a summary measure of the replication of mode share to observed HTS data, two root-mean-square (RMS) measures have been used. The first, *RMS(MF)*, provides an RMS measure for each of the detailed modes represented in the TravDems (including the car toll and train access mode alternatives) and so provides a performance measure specific to the new 2006 base STM with its extended treatment of the modal alternatives. The second, *RMS(MM)*, provides a measure for the seven main modes only, which allows the performance of the new 2006 base STM to be compared to the previous 2001 base STM.

These two RMS measures are defined as follows:

$$RMS(MF) = \sqrt{\frac{\sum_{mf}\left(HTS_{mf} - TD_{mf}\right)^2}{MF}} \qquad (5.1)$$

$$RMS(MM) = \sqrt{\frac{\sum_{mm}\left(HTS_{mm} - TD_{mm}\right)^2}{MM}} \quad (5.2)$$

where: *mf* are the detailed (full) modes, with *MF* detailed modes in total

mm are the main modes, with *MM* main modes in total

HTS_{mf} and HTS_{mm} are the mode shares from the expanded HTS data

TD_{mf} and TD_{mm} are the mode shares predicted by the TravDems

Table 50 summarises the measures obtained for each of the HB travel purposes. Detailed comparisons of mode share for each travel purpose are presented in Appendix C. For consistency with the mode–destination model estimation, the HTS validation figures include full tours only.

Table 50: Mode share validation, HB purposes

Purpose	RMS(MF) 2006 base	RMS(MM) 2006 base	RMS(MM) 2001 base
Home–work	0.59 %	0.85 %	1.94 %
Home–business	0.66 %	0.92 %	0.26 %
Home–primary education	1.01 %	1.02 %	2.47 %
Home–secondary education	1.39 %	1.67 %	1.13 %
Home–tertiary education	1.50 %	1.29 %	2.85 %
Home–shopping	0.81 %	0.97 %	1.26 %
Home–other travel	0.51 %	0.63 %	1.23 %
Total HB	0.65 %	0.81 %	1.42 %

The *RMS(MF)* measure shows that the models achieve a good match to the mode shares observed in the expanded 2004–2009 HTS data, with RMS values less than 1% for all purposes apart from education. The third and fourth columns of the table demonstrate that for all purposes except business, the fit to the main modes shares is improved relative to that achieved for the 2001 base version of the model.

Table 51 presents the mode share validation for the NHBB purposes. Note that for WB business, the modes represented have not changed relative to the 2001 base version of the TravDem and therefore the *RMS(MF)* and *RMS(MM)* measures are the same. In the 2006 base version of the NHBB detour model, car driver has been split into toll and no-toll alternatives and so for that model the *RMS(MF)* and *RMS(MM)* measures differ.

Table 51: Mode share validation, NHBB purposes

Purpose	RMS(MF) 2006 base	RMS(MM) 2006 base	RMS(MM) 2001 base
WB business tours	0.56 %	0.56 %	2.72 %
NHBB detours	0.56 %	0.78 %	1.03 %
Total NHBB	0.56 %	0.60 %	1.86 %

The RMS measures demonstrate a good match between to the mode shares observed in the 2004–2009 HTS data, with RMS values less than 1% for both NHBB purposes. Comparison of the third and fourth columns of the table demonstrates that the fit to the main mode shares has improved relative to the 2001 base version of the model.

In summary, the 2006 base TravDem predictions closely match the mode shares observed in the 2004–2009 HTS data.

5.4 Tour lengths

The mean tour lengths predicted for each HB purpose are compared to expanded HTS data in Table 52.

Table 52: Overall tour lengths (km), HB purposes

Purpose	HTS data (2004–2009)	TravDem 2006	Percent diff.
Home–work	31.9	30.1	-5.7 %
Home–business	44.1	36.1	-18.1 %
Home–primary education	7.3	6.6	-10.0 %
Home–secondary education	14.9	13.7	-7.8 %
Home–tertiary education	31.3	34.9	11.5 %
Home–shopping	10.6	8.8	-17.3 %
Home–other travel	13.8	12.3	-11.1 %
Total HB	19.0	17.6	-7.2 %

It can be seen that the HB TravDems consistently under-predict mean tour lengths relative to the weighted HTS data. The under-predictions in Table 53 come about through a combination of two effects. First, the TravDems are estimated using unweighted HTS data, and the mean tour lengths in the unweighted HTS data are slightly lower than the weighted values presented in Table 52. Second, the application of the model using the weighted 2006 population leads to lower mean tour lengths than those predicted when the models were applied to the unweighted estimation sample. So the under-prediction of tour lengths arises through a combination of the impact of weighting in the HTS data, and the use of weighted 2006 population in application.

NHB tour and detour lengths are compared to expanded HTS data in Table 53.

Table 53: Overall tour and detour lengths (km), NHBB purposes

Purpose	HTS data (2004–2009)	TravDem 2006	Percent diff.
WB business tours	15.3	15.6	2.2 %
NHBB detours	14.6	13.8	-5.8 %
Total NHBB trips	14.9	14.7	-1.6 %

There is a slight over-prediction of WB business tour lengths, whereas NHBB detour lengths are under-predicted, so that overall NHBB trip lengths are under-predicted by just 1.6%.

To summarise the match to observed tour lengths by mode, RMS measures have been calculated over modes, using a weighted RMS formula where the weighting is by observed mode share:

$$RMS = \sqrt{\sum_{mf} SO_{mf} \left(O_{mf} - P_{mf}\right)^2} \qquad (5.3)$$

where: SO_{mf} is the observed mode share (noting these sum to 1 over the modes)

O_{mf} is the observed tour length for mode mf

P_{mf} is the predicted tour length for mode mf

there are MF detailed modes in total

Two sets of RMS comparisons have been undertaken; these are described in Table 54.

Table 54: Definitions of RMS measures of tour length fit over modes

Measure	Observed	Predicted	What is measured
RMS1	Weighted 2004–2009 HTS data	TravDem predicted	How well the TravDem predictions match expanded HTS data
RMS2	Unweighted HTS estimation sample	TravDem predicted	How well the TravDem predictions match the unweighted samples used to estimate the mode–destination models, to assess the impact of the HTS weighting on the tour length differences

The RMS measures calculated for each HB purpose are presented in Table 55.

Table 55: RMS measures of tour length fit over modes, HB purposes

Purpose	RMS1	RMS2
Home–work	11.26 %	9.24 %
Home–business	17.20 %	10.64 %
Home–primary education	26.66 %	9.66 %
Home–secondary education	11.97 %	9.28 %
Home–tertiary education	20.24 %	17.06 %
Home–shopping	16.95 %	11.91 %
Home–other travel	17.71 %	13.87 %
Total	16.33 %	12.02 %

The RMS1 column demonstrates that the fit to mean tour length is not as close as the fit to tour frequency or mode share, with a RMS difference at the modal level of 16.3% overall, which follows from the general tendency for under-prediction of tour lengths. One hypothesis is that the RMS measures reflect differences between the unweighted HTS tour lengths in model estimation, and the weighted HTS tour lengths used for this validation stage. However, the RMS2 column demonstrates that most of the differences remain when unweighted HTS data are taken as the observed, i.e. differences between the unweighted and weighted HTS data have a relatively small impact on the overall RMS differences. Thus most of the difference in tour length comes about because of the use of weighted population data in application.

The RMS measures of fit are presented for the two NHBB purposes in Table 56.

Table 56: RMS measures of tour/detour length fit over modes, NHBB purposes

Purpose	RMS1	RMS2
WB business tours	8.01 %	5.60 %
NHBB detours	7.56 %	7.95 %
Total	7.78 %	6.79 %

The RMS1 measures of fit for the two NHBB purposes are similar, and show a better fit to the data than the HB purposes, though the values are still considerably higher than those observed for mode share. For WB business, the RMS2 column demonstrates most of the difference remains if unweighted HTS data are taken as observed, i.e. weighting has a relatively small impact and so does not explain the differences. For the NHBB detour model weighting has no impact at all on the RMS measure. Thus the differences are a result of differences between the model predictions and observed data.

Two points should be noted when considering the relatively high RMS values for tour and detour lengths. First, distance parameters are only used for certain modes, specifically car passenger, walk and bike, whereas in the mode choice models constants are used for each mode and so a better fit would be expected to observed mode shares. Second, the use of the pivoting procedure means that in base-year application the models re-produce the mean trips lengths observed in the base matrices, rather than the TravDems. So while an acceptable level of correspondence to base tour lengths would be expected for the base year validation, it is not essential that observed and predicted tour lengths match exactly.

Detailed comparisons of tour length by mode are presented in Appendix C for each of the HB and NHBB purposes. For consistency with model estimation, the HTS validation figures include full tours only.

5.5 Elasticities

The objective of the elasticity verification is to ensure that the values obtained from the base year application of the TravDems are in line with the values obtained when the models were applied to the unweighted samples of tours used for model estimation.

The elasticity values obtained from the unweighted estimation samples were discussed and agreed with the BTS during the estimation work. Section 8.1 of the MD estimation report provides a discussion of the acceptability of those elasticity values.

We would not expect the elasticity values from the base year application to be exactly the same as those obtained from the unweighted estimation samples, because in the TravDem the models are applied to the expanded base year population rather than the unweighted estimation sample. However, the two sets of elasticities are expected to be comparable as the same mode–destination models underlie the resulting values.

The elasticity validation tests that have been run for the four policy tests that were run during the estimation work, specifically:

- a 10% increase in fuel cost[14]
- a 10% increase in car time
- a 10% increase in PT fare
- a 10% increase in PT in-vehicle time.

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

$$E_{m,p} = \frac{\ln\left(\frac{D_{m,p}}{D_{m,b}}\right)}{\ln\left(\frac{110}{100}\right)} \qquad (5.1)$$

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

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

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

It should be emphasised that the elasticities are first order elasticities only; they do not take into account network effects. When the models are applied iteratively, so that changes in demand impact on the supply costs, the elasticities would be expected to be slightly lower, because of network effects damping the model response.

Table 57 compares the estimation and application elasticities for the home–work model.

[14] For business purposes, fuel costs are not modelled directly; instead the casual business kilometrage rate is represented, and so the elasticities calculated are kilometrage rate elasticities.

Table 57: Home–work elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-0.355	-0.398	-0.043	-0.563	-0.612	-0.049
Car No-Toll	-0.062	-0.081	-0.019	-0.280	-0.316	-0.036
Car Driver Total	-0.080	-0.106	-0.026	-0.318	-0.364	-0.046
Car Passenger	0.030	0.026	-0.004	0.001	-0.013	-0.014

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-1.263	-1.328	-0.065	-1.904	-2.001	-0.097
Car No-Toll	-0.083	-0.120	-0.037	-0.752	-0.818	-0.066
Car Driver Total	-0.154	-0.213	-0.059	-0.901	-1.003	-0.102
Car Passenger	-0.277	-0.300	-0.023	-0.794	-0.861	-0.067

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.420	-0.428	-0.008	-0.508	-0.504	0.004
Train K&R	-0.331	-0.359	-0.028	-0.427	-0.446	-0.019
Train Other	-0.502	-0.519	-0.017	-0.621	-0.619	0.002
Train Total	-0.449	-0.467	-0.018	-0.542	-0.548	-0.006
Bus	-0.282	-0.315	-0.033	-0.41	-0.440	-0.030

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.597	-0.630	-0.033	-0.978	-1.003	-0.025
Train K&R	-0.346	-0.430	-0.084	-0.700	-0.810	-0.110
Train Other	-0.518	-0.616	-0.098	-0.856	-0.975	-0.119
Train Total	-0.518	-0.585	-0.067	-0.867	-0.951	-0.084
Bus	-0.563	-0.598	-0.035	-1.012	-1.065	-0.053

For fuel cost, the base year TravDem elasticities are somewhat larger in magnitude (more negative) than the estimation sample values. For car time, the TravDem values are again slightly larger than the estimation sample values. For PT fare, the differences between the two sets of elasticities are small. For PT in-vehicle time, the TravDem values are again slightly larger. Overall, the two sets of elasticity values are consistent, with the base year TravDem slightly more elastic than the estimation sample. This higher elasticity results from the use of the weighted 2006 population in the base year TravDems.

Table 58 compares the estimation and application elasticities for the home–business model.

Table 58: Home–business elasticity comparison

P1: Car kilometrage rate

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-0.026	-0.039	-0.013	-0.106	-0.129	-0.023
Car No-Toll	-0.029	-0.046	-0.017	-0.094	-0.114	-0.020
Car Driver Total	-0.028	-0.045	-0.017	-0.096	-0.117	-0.021
Car Passenger	0.149	0.124	-0.025	0.167	0.130	-0.037

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-1.019	-1.075	-0.056	-1.584	-1.720	-0.136
Car No-Toll	0.069	-0.005	-0.074	-0.631	-0.739	-0.108
Car Driver Total	-0.032	-0.089	-0.057	-0.815	-0.902	-0.087
Car Passenger	-0.150	-0.238	-0.088	-0.800	-0.901	-0.101

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.147	-0.146	0.001	-0.174	-0.172	0.002
Train K&R	-0.143	-0.145	-0.002	-0.176	-0.174	0.002
Train Other	-0.230	-0.248	-0.018	-0.263	-0.275	-0.012
Train Total	-0.192	-0.202	-0.010	-0.215	-0.221	-0.006
Bus	-0.197	-0.203	-0.006	-0.236	-0.246	-0.010

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.265	-0.246	0.019	-0.556	-0.541	0.015
Train K&R	-0.170	-0.177	-0.007	-0.455	-0.463	-0.008
Train Other	-0.476	-0.510	-0.034	-0.745	-0.758	-0.013
Train Total	-0.370	-0.383	-0.013	-0.630	-0.634	-0.004
Bus	-0.341	-0.339	0.002	-0.711	-0.720	-0.009

For the two car policy tests, the base year TravDem elasticities are somewhat larger than the estimation sample values. For PT fare, the two sets of value match closely, and while for PT in-vehicle time the TravDem values are more elastic overall (for train in total and for bus) the differences are small. Overall, the two sets of elasticities are judged to be consistent, with the TravDem values slightly more elastic overall.

Table 59 compares the estimation and application elasticities for the home–primary education model.

Table 59: Home–primary education elasticity comparison

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Passenger	-0.211	-0.228	-0.017	-1.187	-1.247	-0.060

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train	-1.202	-1.197	0.005	-1.977	-1.965	0.012
Bus	-0.591	-0.596	-0.005	-1.163	-1.218	-0.055

It is noted that no costs are included in the primary education model, and so only time elasticities can be compared. For car time, slightly larger elasticities are obtained for the TravDem, but the differences are small. For PT the sign of the small differences varies between train and bus. Overall the two sets of values were judged to be consistent.

Table 60 compares the estimation and application elasticities for the home–secondary education model.

Table 60: Home–secondary education elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Total	-0.110	-0.130	-0.020	-0.183	-0.203	-0.020
Car Passenger	0.003	0.002	-0.001	0.003	0.002	-0.001

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Total	-0.246	-0.264	-0.018	-1.115	-1.131	-0.016
Car Passenger	-0.227	-0.231	-0.004	-0.617	-0.643	-0.026

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train K&R	-0.113	-0.121	-0.008	-0.122	-0.136	-0.014
Train Other	-0.224	-0.230	-0.006	-0.249	-0.252	-0.003
Train Total	-0.178	-0.184	-0.006	-0.182	-0.192	-0.010
Bus	-0.230	-0.232	-0.002	-0.254	-0.254	0.000

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train K&R	-0.688	-0.686	0.002	-1.176	-1.181	-0.005
Train Other	-0.867	-0.904	-0.037	-1.499	-1.512	-0.013
Train Total	-0.793	-0.811	-0.018	-1.328	-1.339	-0.011
Bus	-0.693	-0.697	-0.004	-1.230	-1.274	-0.044

The pattern of difference for the fuel cost, car time and PT in-vehicle time elasticities is consistent with the home–work and home–business models, with the TravDem slightly more elastic than the values obtained when the models were applied to the unweighted estimation sample. For PT fare, smaller differences are observed between the elasticities. The two sets of elasticity values were judged to be consistent overall.

Table 61 compares the estimation and application elasticities for the home–tertiary education model.

Table 61: Home–tertiary education elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Total	-0.080	-0.125	-0.045	-0.067	-0.116	-0.049
Car Passenger	-0.181	-0.209	-0.028	-0.168	-0.211	-0.043

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Total	-0.319	-0.509	-0.190	-1.061	-1.304	-0.243
Car Passenger	-0.407	-0.531	-0.124	-0.895	-1.097	-0.202

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.111	-0.119	-0.008	-0.129	-0.124	0.005
Train K&R	-0.081	-0.096	-0.015	-0.085	-0.090	-0.005
Train Other	-0.199	-0.208	-0.009	-0.216	-0.216	0.000
Train Total	-0.163	-0.180	-0.017	-0.170	-0.181	-0.011
Bus	-0.204	-0.222	-0.018	-0.22	-0.230	-0.010

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.376	-0.440	-0.064	-0.760	-0.791	-0.031
Train K&R	-0.507	-0.624	-0.117	-0.894	-1.017	-0.123
Train Other	-0.705	-0.649	0.056	-1.178	-1.109	0.069
Train Total	-0.626	-0.627	-0.001	-1.051	-1.061	-0.010
Bus	-0.435	-0.534	-0.099	-0.918	-1.033	-0.115

The two sets of car elasticities once again show the base year application of the TravDem to be more elastic than the tests of the estimation sample, particularly for car time. For PT fare, the differences in elasticity values are small. For PT in-vehicle time, the TravDem values are slightly larger, except for the train other access mode. Overall the two sets of elasticity values were judged to be consistent, noting the larger car time elasticities for the TravDem.

Table 62 compares the estimation and application elasticities for the home–shopping model.

Table 62: Home–shopping elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-0.272	-0.345	-0.073	-0.650	-0.630	0.020
Car No-Toll	-0.055	-0.101	-0.046	-0.168	-0.241	-0.073
Car Driver Total	-0.056	-0.102	-0.046	-0.183	-0.252	-0.069
Car Passenger	-0.131	-0.192	-0.061	-0.190	-0.294	-0.104

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-4.325	-3.707	0.618	-6.574	-5.386	1.188
Car No-Toll	-0.058	-0.131	-0.073	-0.738	-0.866	-0.128
Car Driver Total	-0.074	-0.147	-0.073	-0.880	-0.965	-0.085
Car Passenger	-0.302	-0.392	-0.090	-1.205	-1.388	-0.183

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.679	-0.685	-0.006	-0.879	-0.887	-0.008
Train K&R	-0.681	-0.687	-0.006	-0.880	-0.888	-0.008
Train Other	-0.625	-0.654	-0.029	-0.734	-0.759	-0.025
Train Total	-0.637	-0.661	-0.024	-0.785	-0.805	-0.020
Bus	-0.425	-0.446	-0.021	-0.637	-0.628	0.009

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.926	-0.920	0.006	-2.041	-2.032	0.009
Train K&R	-0.916	-0.908	0.008	-2.033	-2.022	0.011
Train Other	-0.749	-0.779	-0.030	-1.291	-1.329	-0.038
Train Total	-0.786	-0.810	-0.024	-1.549	-1.572	-0.023
Bus	-0.262	-0.277	-0.015	-0.653	-0.662	-0.009

For fuel cost, the base year TravDem values are once again larger than the estimation sample values. For car time, larger values are observed for car driver no toll (the majority of car driver observations) and car passenger, and lower values for car driver toll. For the two PT policy tests the two sets of elasticity values correspond well. Overall the two sets of elasticity values were judged to be consistent.

Table 63 compares the estimation and application elasticities for the home–other travel model.

Table 63: Home–other travel education elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	0.017	-0.137	-0.154	-0.106	-0.254	-0.148
Car No-Toll	-0.045	-0.097	-0.052	-0.162	-0.248	-0.086
Car Driver Total	-0.045	-0.098	-0.053	-0.158	-0.248	-0.090
Car Passenger	-0.076	-0.132	-0.056	-0.168	-0.251	-0.083

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
CarD Toll	-0.517	-0.722	-0.205	-0.813	-1.102	-0.289
Car No-Toll	-0.039	-0.099	-0.060	-0.831	-0.941	-0.110
Car Driver Total	-0.045	-0.109	-0.064	-0.829	-0.952	-0.123
Car Passenger	-0.119	-0.193	-0.074	-1.151	-1.275	-0.124

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.428	-0.451	-0.023	-0.575	-0.603	-0.028
Train K&R	-0.428	-0.451	-0.023	-0.573	-0.603	-0.030
Train Other	-0.509	-0.493	0.016	-0.610	-0.568	0.042
Train Total	-0.482	-0.480	0.002	-0.593	-0.582	0.011
Bus	-0.314	-0.335	-0.021	-0.533	-0.515	0.018

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train P&R	-0.647	-0.640	0.007	-1.295	-1.299	-0.004
Train K&R	-0.635	-0.623	0.012	-1.278	-1.278	0.000
Train Other	-0.648	-0.671	-0.023	-1.148	-1.159	-0.011
Train Total	-0.645	-0.659	-0.014	-1.120	-1.210	-0.090
Bus	0.014	0.002	-0.012	-0.199	-0.225	-0.026

For fuel cost, the base year TravDem values are again larger than the estimation sample values, and the TravDem car time values are also larger. Smaller differences are observed between the two sets of PT elasticities. Overall the two sets of elasticities were judged to be consistent, noting the larger car elasticities in the TravDems compared to the estimation sample values.

Table 64 compares the estimation and application elasticities for the WB business model.

Table 64: WB business elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver	-0.140	-0.145	-0.005	-0.114	-0.131	-0.017
Car Passenger	0.326	0.321	-0.005	0.378	0.356	-0.022

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver	-0.108	-0.108	0.000	-0.997	-0.960	0.037
Car Passenger	-0.614	-0.624	-0.010	-1.546	-1.570	-0.024

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train	-0.535	-0.510	0.025	-0.615	-0.617	-0.002
Bus	-0.230	-0.242	-0.012	-0.529	-0.547	-0.018

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train	-0.743	-0.734	0.009	-1.334	-1.352	-0.018
Bus	-0.233	-0.255	-0.022	-0.770	-0.829	-0.059

The two sets of WB business elasticity values match closely.

Table 65 compares the estimation and application elasticities for the NHB business detour model.

Table 65: NHB business detour elasticity comparison

P1: Fuel cost

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Toll	0.142	0.105	-0.037	0.109	0.091	-0.018
Car Driver Non-Toll	-0.056	-0.063	-0.007	-0.049	-0.055	-0.006
Car Driver Total	-0.042	-0.046	-0.004	-0.021	-0.025	-0.004
Car Passenger	0.162	0.166	0.004	0.165	0.173	0.008

P2: Car time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Car Driver Toll	-1.259	-0.950	0.309	-1.990	-1.509	0.481
Car Driver Non-Toll	0.038	0.041	0.003	-0.830	-0.982	-0.152
Car Driver Total	-0.046	-0.059	-0.013	-1.022	-1.085	-0.063
Car Passenger	-0.140	-0.141	-0.001	-0.698	-0.687	0.011

P3: PT fare

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train	-0.380	-0.359	0.021	-0.466	-0.463	0.003
Bus	-0.129	-0.139	-0.010	-0.343	-0.355	-0.012

P4: PT in-vehicle time

Mode	Tours			Kilometrage		
	Estimation Sample	TravDem 2006 Base	Difference	Estimation Sample	TravDem 2006 Base	Difference
Train	-0.894	-0.873	0.021	-1.688	-1.717	-0.029
Bus	-0.259	-0.277	-0.018	-0.913	-0.939	-0.026

For car driver toll, less elastic responses are observed in the TravDem compared to the estimation sample. For car driver no-toll the elasticities match closely, as do the values for car passenger. The differences between the PT elasticities are generally small.

Overall the two sets of elasticities were judged to be consistent, given that the estimation sample is unweighted data, whereas the 2006 base TravDem results are expanded to the total 2006 population.

CHAPTER 6 Summary

The Application System for the STM comprises nine TravDem models, one for each of the seven HB and two NHB purposes represented in the STM. The TravDem for a given purpose implements both the tour frequency and the mode–destination choice models for that purpose.

The TravDems have been updated to use the new frequency and mode–destination model parameters that reflect a 2006 base year. The scope of the TravDems has also been updated to reflect the substantial increase in the number of model zones, and the incorporation of train access mode and station choice, and toll road choice, within the model structure.

The segmentations in the TravDems have also been updated. In most cases, the segmentations used are the same as those used during in the current 2001 base version of the STM. However, some changes have been made, in particular to the definitions of the income segments.

The TravDems have been delivered to the BTS as ALOGIT files together with control batch files. These batch files allow the implementation of the TravDems to be automated. This enables the BTS to operate the new model in ALOGIT in the interim prior to implementing the new TravDems in EMME. To facilitate batch file operation, the functionality of the ALOGIT software has been extended so that it can work with 'environment variables' that allow the directory locations of input files to be specified in a clearer and more flexible manner.

The TravDems have been validated by making runs for the 2006 base year, and comparing the results to expanded HTS data. Travel frequency validates reasonably well, and while the total numbers of HB tours by purpose show differences of up to 8% compared with expanded HTS data, total HB travel summed across all purposes matches the HTS data to within 0.3%. Following an adjustment to the WB business frequency model, total NHB business travel matches expanded HTS data to within 0.5%. The mode share validation shows an excellent match between modelled and observed data, and furthermore the correspondence is improved relative to the 2001 base version of the model. Finally, the tour and detour length validation shows a reasonable correspondence between modelled and observed data, with a general tendency for the TravDems to under-predict the tour and detour lengths observed in the expanded HTS data.

In addition to the comparisons to HTS data, application system elasticities have been run and have been compared to the values obtained from the unweighted estimation samples during the recent re-estimation work. Overall, the two sets of elasticities are consistent,

with a general tendency for somewhat higher car cost and car time elasticities to be observed in the TravDems relative to the unweighted estimation sample values.

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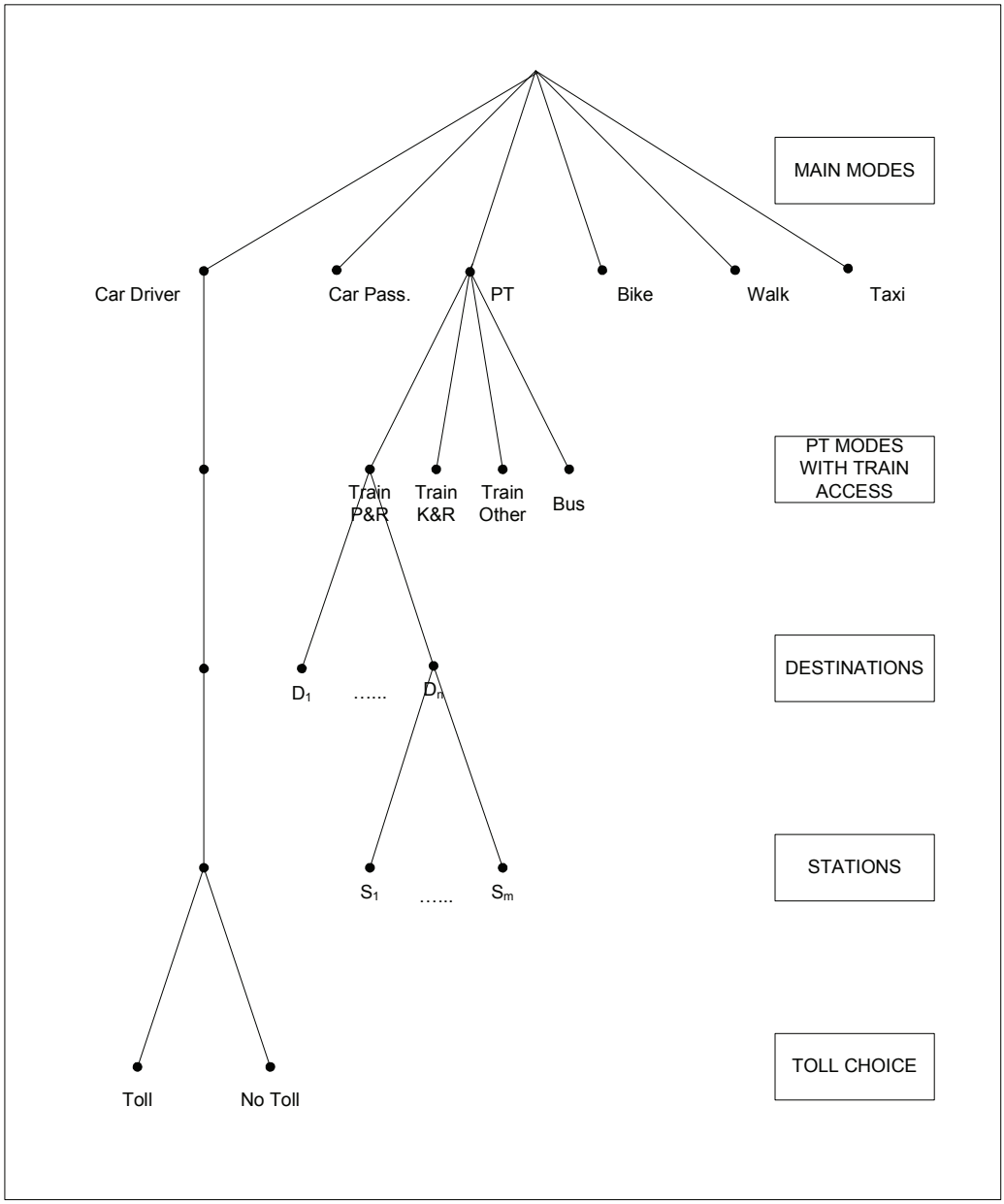
APPENDICES

Appendix A: Tree structures

Section 2.2.4 presented the nesting structure for the non-home–business detour model in order to illustrate the logsum calculations using a less complex model structure. This appendix presents the three other tree structures used in the 2006 base version of the STM.

Figure 6 summarises the tree structure used for commute, home–business, home–shopping and home–other travel.

Figure 6: Tree Structure 1, Home–work, home–business, home–shopping and other travel



For commute and 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:

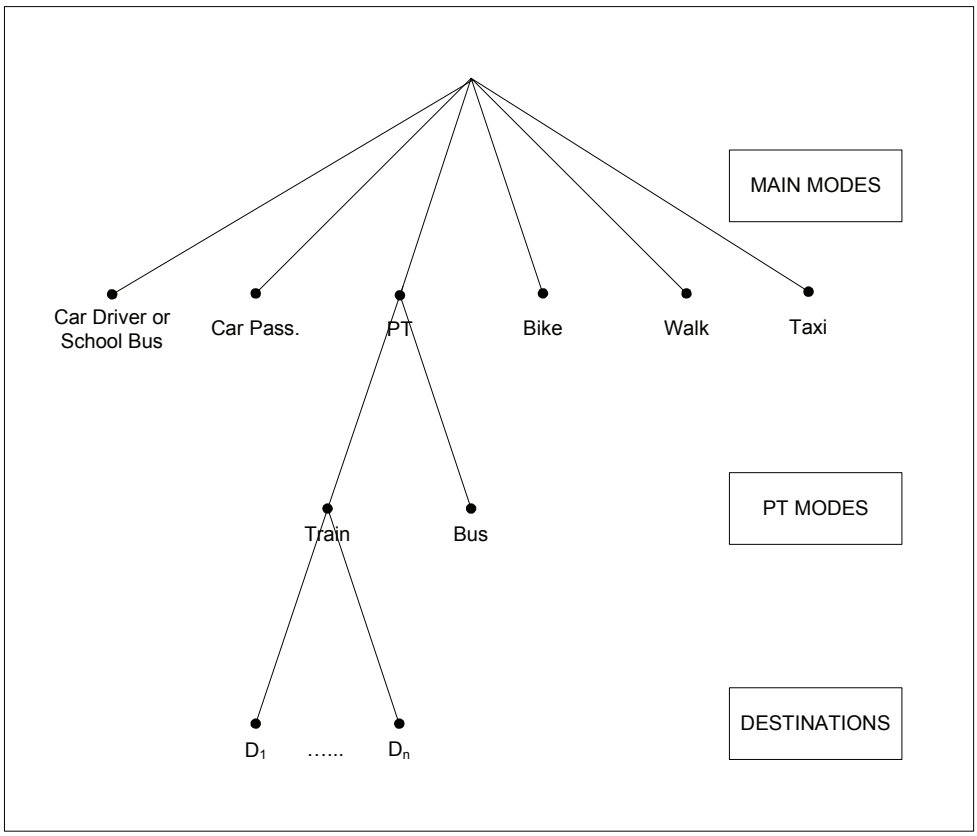
- mode choice, PT modes with train access
- destinations, stations and toll choice

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 and WB business, the structure is simpler as neither the toll choice nor the access mode and station choices are modelled.

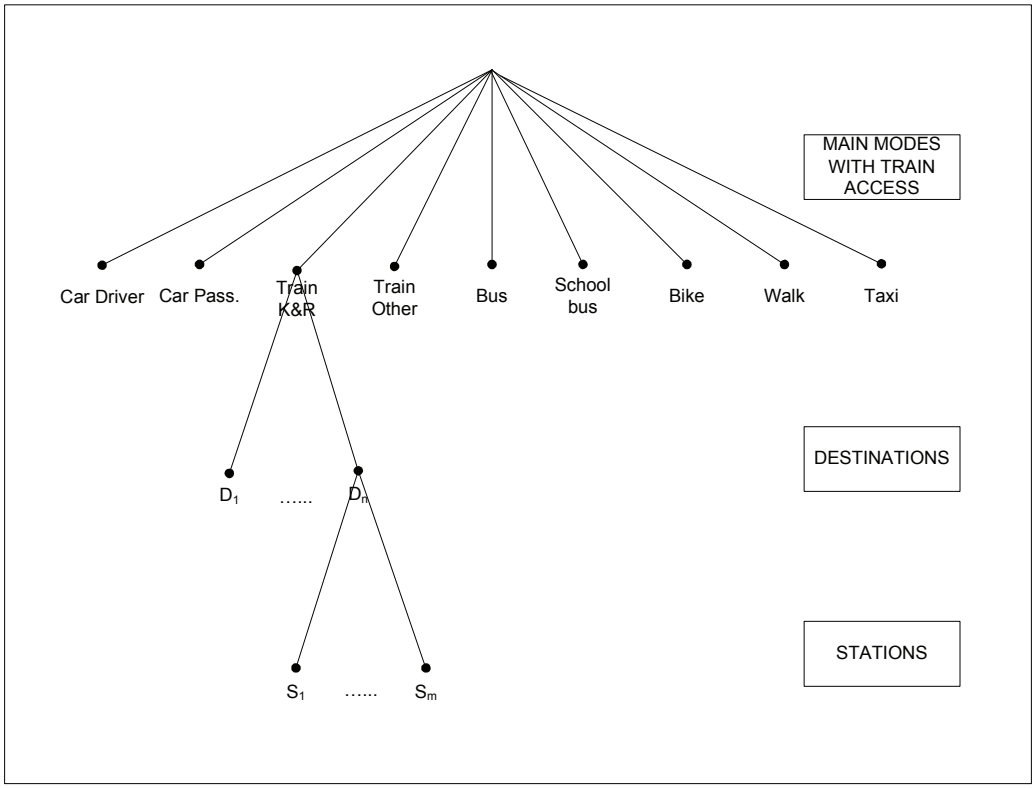
Figure 7: Tree Structure 2, Home–primary education, WB business



In primary education, both structural parameters have been identified, and so the structure has two levels as shown in Figure 7. For WB business, main modes and PT modes appear on the same level so the structure reduces to a two-level choice.

It should be noted that for primary education, car driver is not modelled but school bus is included, whereas for WB business car driver is modelled but school bus is not. Finally, bike is not modelled for WB business.

Figure 8: Tree Structure 3, 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.

Appendix B: Mean proportions

As discussed in Section 3.1, some model terms have been implemented by using mean proportions of the variable, rather than adding an additional segmentation dimension. The tables presented in this appendix detail the mean proportions that have been used for each model purpose.

The mean proportions for variables used in the tour models are based on unweighted samples of tours for the purpose in question. The mean proportions for variables used in the frequency models are based on unweighted samples of individuals able to make tours for that purpose.

The mean values may vary according to other segment definitions, for example in the commute model there is a licence holding term for the P&R model. For some car availability segments, licence holding is zero for all observed tours, whereas for other segments mean licence holding is close to one. Therefore the mean proportions have been segmented by car availability so that they better reflect the variation observed across the base population.

Table 66: Mean proportions for home–work mode–destination model

Model term		Mean variable proportion
Licence holding term on P&R alternatives:		
Car avail a1	No car in HH	0.000
Car avail a2	No licence, but at least one car	0.000
Car avail a3	Competition for car; no company car	0.944
Car avail a4	Free car use; one non-company car	0.863
Car avail a5	Free car use; several lic. in HH; no comp. car	0.966
Car avail a6	Competition for car; one plus company car	0.954
Car avail a7	Free car use; one company car	0.872
Car avail a8	Free car use; several licences; one plus company car	0.968
Male term on car driver		0.522
Male term on bike		0.522

Table 67: Mean proportions for home–work frequency model

Model term		Mean variable proportion
Male term on zero tours:		0.526
Manufacturing term on zero tours:		
Work status b1	Full-time worker	0.121
Work status b2	Part-time worker	0.033

Table 68: Mean proportions for home–business mode–destination model

Model term		Mean variable proportion
Manager and professional occupation type on train:		
Pers inc b1	<$31,199	0.233
Pers inc b2	$31,200–51,199	0.230
Pers inc b3	>$51,199	0.456
Two-plus cars term on P&R:		
Pers inc b1	<$31,199	0.688
Pers inc b2	$31,200–51,199	0.758
Pers inc b3	>$51,199	0.772
Aged under 25 term on car passenger		0.087
Licence holding term on P&R		0.955

Table 69: Mean proportions for home–primary education mode–destination model

Model term	Mean variable proportion
Male term on bike	0.51

Table 70: Mean proportions for home–secondary education mode–destination model

Model term	Mean variable proportion
Male term on bike	0.51

Table 71: Mean proportions for home–tertiary education mode–destination model

Model term		Mean variable proportion
Company car term on car driver:		
Car avail a1	No car in HH	0.000
Car avail a2	No licence, but car in HH	0.000
Car avail a3	Competition for car; one car	0.005
Car avail a4	Free car use; one car	0.010
Car avail a5	Competition for car; two plus cars	0.038
Car avail a6	Free car use; several licences; two plus cars	0.104

Table 72: Mean proportions for home–tertiary education frequency model

Model term		Mean variable proportion
Aged 15–18 term on zero tours:		
Edu Type fb1	University	0.088
Edu Type fb2	Other	0.132

Table 73: Mean proportions for home–shopping mode–destination model

Model term		Mean variable proportion
Company car term on car driver:		
Car avail a1	No car in HH	0.000
Car avail a2	No licence, but car in HH	0.000
Car avail a3	Competition for car; one car	0.050
Car avail a4	Free car use; one car	0.460
Car avail a5	Competition for car; two plus cars	0.090
Car avail a6	Free car use; several licences; two plus cars	0.812
Male term on bus		0.396
Retired person term for car passenger		0.294

Table 74: Mean proportions for home–shopping frequency model

Model term	Mean variable proportion
Male term on zero tours	0.492

Table 75: Mean proportions for home–other mode–destination model

Model term		Mean variable proportion
Company car term on car driver:		
Car avail a1	No car in HH	0.000
Car avail a2	No licence, but car in HH	0.000
Car avail a3	Competition for car; one car	0.129
Car avail a4	Free car use; one car	0.105
Car avail a5	Free car use; several licences; two plus cars	0.766
Drop/pick-up sub-purpose term for car driver		0.190
Male terms on car passenger and walk		0.449
Entertainment sub-purpose terms for car passenger, bus and train		0.143
Recreation sub-purpose term for walk		0.143
Aged between 10 and 20 term for bike		0.114
Aged under 10 term for car passenger		0.196

Table 76: Mean proportions for home–other frequency model

Model term	Mean variable proportion
Licence term for zero cars on zero tours	0.270
Term for two or more cars on zero tours	0.607

Table 77: Mean proportions for WB business mode–destination model

Model term	Mean variable proportion
Male term for walk	0.692

Table 78: Mean proportions for WB business frequency model

Model term		Mean variable proportion
Male terms on zero tours:		
Work Status b1	Full-time worker	0.597
Work Status b2	Part-time worker	0.264

Table 79: Mean proportions for NHB business detour (work PD) frequency model

Model term		Mean variable proportion
Male terms on zero tours:		
Pers inc b1	<$31,199	0.438
Pers inc b2	$31,200-67,199	0.562
Pers inc b3	>$67,200	0.640

Appendix C: Detailed TravDem validation

Home–work

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver Toll	85,121	5,054,437	4.2%	4.2%	5.5%	1.30%
Car Driver No Toll	965,738	25,685,395	61.7%	61.8%	62.0%	0.23%
Car Passenger	102,429	2,225,755	6.8%	6.4%	6.6%	0.21%
Train, P&R	48,562	3,628,293	3.3%	3.4%	3.1%	-0.31%
Train, K&R	36,804	2,317,003	2.4%	2.5%	2.4%	-0.12%
Train, other	112,579	5,584,565	7.3%	8.4%	7.2%	-1.16%
Bus	105,483	1,861,877	7.5%	6.5%	6.8%	0.29%
Bike	7,682	86,296	0.7%	0.7%	0.5%	-0.21%
Walk	87,272	273,434	5.7%	5.5%	5.6%	0.12%
Taxi	5,172	51,513	0.4%	0.7%	0.3%	-0.34%
Total	1,556,841	46,768,568	100.0%	100.0%	100.0%	0.00%
					RMS:	0.59%

Comparison of STM 2006 and STM 2001 for main modes:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Driver	66.0%	67.5%	1.53%	62.9%	67.5%	4.67%
Car Passenger	6.4%	6.6%	0.21%	7.1%	8.0%	0.92%
Train	14.3%	12.7%	1.59%	17.3%	13.7%	3.59%
Bus	6.5%	6.8%	0.29%	7.1%	5.9%	1.27%
Bike	0.7%	0.5%	0.21%	0.7%	0.5%	0.23%
Walk	5.5%	5.6%	0.12%	4.3%	4.0%	0.31%
Taxi	0.7%	0.3%	0.34%	0.6%	0.4%	0.18%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
		Mean Absolute Error:	0.61%		Mean Absolute Error:	1.60%
		RMS:	0.86%		RMS:	2.31%

Tour length comparisons

Mode	RMS1 Comparison			RMS2 Comparison		
	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver Toll	30.9	29.3	-5.41%	66.1	59.4	-10.11%
Car Driver No Toll				28.5	26.6	-6.83%
Car Passenger	21.7	21.7	-0.08%	22.5	21.7	-3.39%
Train, P&R	71.3	74.7	4.73%	74.1	74.7	0.89%
Train, K&R	58.0	63.0	8.48%	55.1	63.0	14.33%
Train, other	37.5	49.6	32.13%	40.3	49.6	22.97%
Bus	18.7	17.7	-5.42%	18.5	17.7	-4.48%
Bike	10.0	11.2	11.92%	11.1	11.2	1.30%
Walk	3.3	3.1	-4.90%	3.1	3.1	0.04%
Taxi	18.3	10.0	-45.49%	17.5	10.0	-42.97%
Total	31.9	30.0	-5.75%	30.2	30.0	-0.52%
		RMS:	11.25%		RMS:	9.23%

Home–business

Mode share comparisons

Comparison of mode shares to weighted HTS data:

Mode	TravDem (2006 Base)		Mode Shares			
	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver Toll	29,561	2,262,718	8.1%	8.1%	6.8%	-1.36%
Car Driver No Toll	329,706	10,844,720	75.5%	75.9%	75.5%	-0.40%
Car Passenger	29,655	1,094,110	6.7%	5.8%	6.8%	0.97%
Train, P&R	6,935	515,814	1.5%	1.6%	1.6%	-0.05%
Train, K&R	2,158	133,118	0.5%	0.7%	0.5%	-0.24%
Train, other	10,981	571,429	2.4%	3.2%	2.5%	-0.65%
Bus	10,679	208,253	2.1%	1.8%	2.4%	0.67%
Bike	3,046	23,768	0.6%	0.4%	0.7%	0.30%
Walk	11,486	49,918	2.2%	2.0%	2.6%	0.64%
Taxi	2,333	57,987	0.5%	0.4%	0.5%	0.13%
Total	436,541	15,761,836	100.0%	100.0%	100.0%	0.00%
					RMS:	0.66%

Comparison of STM 2006 and STM 2001 for main modes:

	STM 2006		STM 2001		
Mode	Weighted HTS	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Driver	84.1%	1.76%	83.4%	83.4%	0.06%
Car Passenger	5.8%	0.97%	6.0%	6.2%	0.20%
Train	5.5%	0.94%	5.4%	4.9%	0.57%
Bus	1.8%	0.67%	2.5%	2.3%	0.17%
Bike	0.4%	0.30%	0.3%	0.4%	0.06%
Walk	2.0%	0.64%	2.0%	2.2%	0.20%
Taxi	0.4%	0.13%	0.4%	0.6%	0.23%
Total	100.0%	0.00%	100.0%	100.0%	0.00%
		0.77%		Mean Absolute Error:	0.21%
		0.92%		RMS:	0.26%

Tour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver Toll	44.2	36.5	-17.43%	88.3	85.2	-3.56%
Car Driver No Toll				36.5	36.5	-0.08%
Car Passenger	46.9	36.9	-21.32%	39.2	38.8	-1.09%
Train, P&R	84.3	74.4	-11.80%	77.7	76.9	-0.97%
Train, K&R	59.2	61.7	4.19%	51.2	60.8	18.73%
Train, other	55.4	52.0	-6.03%	44.8	48.4	8.13%
Bus	23.7	19.5	-17.71%	20.8	19.4	-6.59%
Bike	7.2	7.8	8.10%	8.8	8.0	-9.35%
Walk	5.0	4.3	-13.54%	3.8	4.4	16.22%
Taxi	21.6	24.9	15.04%	17.6	25.8	47.14%
Total	44.1	36.1	-18.09%	40.4	40.3	-0.28%
		RMS:	17.20%		RMS:	10.64%

Home–primary education

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Difference
Car Passenger	214,220	1,517,379	68.9%	68.2%	69.0%	0.84%
Train	1,280	36,250	0.4%	0.5%	0.4%	-0.12%
Bus	8,620	133,148	2.9%	4.2%	2.8%	-1.43%
School Bus	18,545	188,394	6.2%	7.1%	6.0%	-1.17%
Bike	2,878	9,093	1.1%	0.9%	0.9%	0.01%
Walk	63,925	143,162	20.1%	18.9%	20.6%	1.74%
Taxi	857	7,246	0.3%	0.1%	0.3%	0.13%
Total	310,326	2,034,672	100.0%	100.0%	100.0%	0.00%
					RMS:	1.01%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Passenger	68.2%	69.0%	0.84%	63.0%	68.6%	5.63%
Train	0.5%	0.4%	0.12%	0.8%	0.5%	0.30%
Bus	4.2%	2.8%	1.43%	5.4%	3.2%	2.19%
School Bus	7.1%	6.0%	1.20%	6.2%	5.6%	0.58%
Bike	0.9%	0.9%	0.01%	0.6%	0.5%	0.11%
Walk	18.9%	20.6%	1.74%	23.9%	21.5%	2.39%
Taxi	0.1%	0.3%	0.13%	0.2%	0.1%	0.07%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
	Mean Absolute Error:		0.78%	Mean Absolute Error:		1.61%
		RMS:	1.02%		RMS:	2.47%

Tour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Passenger	7.9	7.1	-10.39%	7.8	7.1	-9.59%
Train	18.2	28.3	55.61%	24.4	28.3	15.82%
Bus	9.7	15.4	59.45%	14.1	15.4	9.67%
School Bus	12.7	10.2	-20.17%	12.3	10.2	-17.30%
Bike	2.4	3.2	32.96%	3.9	3.2	-19.28%
Walk	4.3	2.2	-47.91%	2.3	2.2	-1.32%
Taxi	7.3	8.5	16.06%	12.7	8.5	-33.34%
Total	7.3	6.6	-9.98%	7.2	6.6	-9.11%
		RMS:	26.66%		RMS:	9.66%

Home–secondary education

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Difference
Car Driver	3,473	63,927	2.2%	2.3%	1.4%	-0.93%
Car Passenger	90,019	1,016,750	35.5%	33.7%	36.9%	3.16%
Train, K&R	9,777	353,716	4.3%	3.5%	4.0%	0.48%
Train, other	13,958	354,485	6.1%	9.2%	5.7%	-3.44%
Bus	36,055	643,807	15.0%	14.8%	14.8%	0.01%
School Bus	48,052	772,367	20.7%	20.3%	19.7%	-0.66%
Bike	3,730	16,276	1.4%	1.7%	1.5%	-0.17%
Walk	38,604	109,400	14.5%	14.4%	15.8%	1.37%
Taxi	457	8,085	0.2%	0.0%	0.2%	0.19%
Total	244,125	3,338,812	100.0%	100.0%	100.0%	0.00%
					RMS:	1.68%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car	2.3%	1.4%	0.93%	1.9%	3.6%	1.68%
Car Passenger	33.7%	36.9%	3.16%	30.5%	32.0%	1.58%
Train	12.7%	9.7%	2.96%	14.2%	12.4%	1.82%
Bus	14.8%	14.8%	0.01%	18.7%	19.2%	0.53%
School Bus	20.3%	19.7%	1.20%	16.5%	15.6%	0.89%
Bike	1.7%	1.5%	0.17%	1.1%	0.5%	0.61%
Walk	14.4%	15.8%	1.37%	17.0%	16.6%	0.40%
Taxi	0.0%	0.2%	0.19%	0.2%	0.1%	0.08%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
	Mean Absolute Error:		1.25%	Mean Absolute Error:		0.95%
		RMS:	1.75%		RMS:	1.16%

Tour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver	23.1	18.4	-20.14%	17.4	18.4	6.04%
Car Passenger	13.1	11.3	-13.72%	12.2	11.3	-7.55%
Train, K&R	37.4	36.2	-3.39%	37.2	36.2	-2.71%
Train, other	22.3	25.4	13.70%	21.5	25.4	18.39%
Bus	15.9	17.9	12.10%	17.1	17.9	4.50%
School Bus	18.4	16.1	-12.55%	18.7	16.1	-14.11%
Bike	4.2	4.4	4.69%	4.5	4.4	-3.43%
Walk	2.9	2.8	-3.38%	2.9	2.8	-1.46%
Taxi	*0.0*	*17.7*	*0.00%*	*35.3*	*17.7*	*-49.88%*
Total	14.9	13.7	-8.25%	14.6	14.9	1.90%
		RMS:	12.10%		RMS:	9.32%

Note: the estimation sample comprised 1999–2008 HTS data, and included four taxi tours; therefore taxi was included as a mode in the model. The weighted 2004–2009 HTS data used for the TravDem validation do not include any taxi tours. This difference means the RMS1 and RMS2 measures have been calculated excluding taxi.

Home–tertiary education

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Difference
Car Driver No Toll	44,178	1,572,436	39.4%	37.7%	41.5%	3.83%
Car Passenger	9,819	245,659	9.0%	8.4%	9.2%	0.84%
Train, P&R	2,600	150,721	2.2%	2.8%	2.4%	-0.38%
Train, K&R	5,753	368,225	4.8%	6.4%	5.4%	-1.02%
Train, other	16,776	825,078	14.2%	17.7%	15.8%	-1.96%
Bus	15,481	347,350	15.9%	15.8%	14.6%	-1.21%
Bike	1,538	13,605	1.7%	1.2%	1.4%	0.22%
Walk	10,057	31,220	12.7%	9.8%	9.5%	-0.31%
Taxi	130	4,852	0.1%	0.1%	0.1%	-0.02%
Total	106,331	3,559,147	100.0%	100.0%	100.0%	0.00%
					RMS:	1.56%

Comparison of STM 2006 and STM 2001:

Mode	STM 2006			STM 2001		
	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Driver	39.4%	41.5%	3.83%	37.2%	40.3%	3.11%
Car Passenger	9.0%	9.2%	0.84%	8.1%	10.2%	2.11%
Train	21.2%	23.6%	3.35%	26.7%	29.3%	2.63%
Bus	15.9%	14.6%	1.21%	18.7%	14.7%	3.95%
Bike	1.7%	1.4%	0.22%	0.6%	0.7%	0.09%
Walk	12.7%	9.5%	0.31%	8.7%	4.2%	4.46%
Taxi	0.1%	0.1%	0.02%	0.0%	0.5%	0.48%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
		Mean Absolute Error:	1.40%		Mean Absolute Error:	2.40%
		RMS:	2.01%		RMS:	2.85%

Tour length comparisons

Mode	RMS1 Comparison			RMS2 Comparison		
	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver No Toll	37.4	35.6	-4.80%	34.1	35.6	4.23%
Car Passenger	21.6	25.0	15.58%	22.3	25.0	11.96%
Train, P&R	65.6	58.0	-11.65%	66.9	58.0	-13.28%
Train, K&R	52.4	64.0	22.13%	60.3	64.0	6.16%
Train, other	36.3	49.2	35.58%	39.1	49.2	25.84%
Bus	21.3	22.4	5.22%	17.6	22.4	27.62%
Bike	8.7	8.8	1.13%	7.9	8.8	12.25%
Walk	3.0	3.1	3.92%	2.9	3.1	7.22%
Taxi	*1.9*	*37.4*	*1870.92%*	*1.9*	37.4	*1870.92%*
Total	31.3	33.5	6.8%	28.7	33.5	16.73%
		RMS:	17.16%		RMS:	15.84%

Note: The mean taxi observed tour lengths are based on small sample sizes, which result in big percentage differences compared with the predicted values, and therefore taxi has been excluded from the RMS calculations.

Home–shopping

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver Toll	2,798	135,316	0.3%	0.3%	0.3%	0.02%
Car Driver No Toll	537,162	4,831,494	59.0%	60.5%	58.9%	-1.61%
Car Passenger	131,920	1,605,422	15.5%	14.4%	14.5%	0.04%
Train, P&R	1,521	81,578	0.2%	0.2%	0.2%	-0.02%
Train, K&R	1,219	64,791	0.1%	0.1%	0.1%	0.07%
Train, other	9,672	302,275	1.1%	1.4%	1.1%	-0.34%
Bus	36,096	433,030	4.0%	4.2%	4.0%	-0.20%
Bike	5,115	21,604	0.6%	0.6%	0.6%	-0.01%
Walk	185,005	385,666	19.0%	17.9%	20.3%	2.36%
Taxi	1,274	8,371	0.1%	0.4%	0.1%	-0.31%
Total	911,782	7,869,548	100.0%	100.0%	100.0%	0.00%
					RMS:	0.92%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car	60.8%	59.2%	1.59%	55.3%	53.9%	1.40%
Car Passenger	14.4%	14.5%	0.04%	15.6%	16.7%	1.11%
Train	1.6%	1.4%	0.28%	2.5%	1.4%	1.00%
Bus	4.2%	4.0%	0.20%	5.2%	4.1%	1.11%
Bike	0.6%	0.6%	0.01%	0.5%	0.5%	0.06%
Walk	17.9%	20.3%	2.36%	20.9%	23.2%	2.38%
Taxi	0.4%	0.1%	0.31%	0.2%	0.1%	0.05%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
	Mean Absolute Error:		0.68%	Mean Absolute Error:		1.02%
		RMS:	1.09%		RMS:	1.26%

Tour length comparisons

Mode	RMS1 Comparison			RMS2 Comparison		
	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver Toll	11.6	9.2	-20.60%	74.2	48.4	-34.80%
Car Driver No Toll				10.6	9.0	-15.39%
Car Passenger	14.2	12.2	-14.39%	13.2	12.2	-7.74%
Train, P&R	50.6	53.6	6.04%	64.0	53.6	-16.17%
Train, K&R	24.5	53.1	116.99%	80.7	53.1	-34.18%
Train, other	37.3	31.3	-16.30%	31.6	31.3	-1.08%
Bus	10.6	12.0	13.04%	10.9	12.0	9.72%
Bike	5.3	4.2	-20.07%	4.4	4.2	-4.56%
Walk	2.1	2.1	-1.72%	2.0	2.1	2.64%
Taxi	6.1	6.6	7.37%	9.2	6.6	-28.68%
Total	10.6	8.6	-18.63%	10.0	8.6	-13.49%
		RMS:	17.60%		RMS:	12.69%

Home–other travel

Mode share comparisons

Comparison of mode shares to weighted HTS data:

Mode	TravDem (2006 Base)		Mode Shares			
	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver Toll	23,303	1,302,999	0.6%	0.6%	0.7%	0.10%
Car Driver No Toll	1,509,325	17,667,864	45.5%	46.9%	47.7%	0.82%
Car Passenger	881,168	13,057,150	30.5%	29.2%	27.9%	-1.32%
Train, P&R	8,060	605,156	0.3%	0.3%	0.3%	0.00%
Train, K&R	11,084	821,956	0.4%	0.3%	0.4%	0.07%
Train, other	43,409	2,138,619	1.2%	1.3%	1.4%	0.08%
Bus	69,351	1,506,720	2.1%	1.8%	2.2%	0.36%
Bike	28,693	176,543	1.1%	1.0%	0.9%	-0.10%
Walk	572,962	1,315,678	17.9%	18.1%	18.1%	0.03%
Taxi	15,019	176,533	0.4%	0.5%	0.5%	-0.05%
Total	3,162,373	38,769,218	100.0%	100.0%	100.0%	0.00%
					RMS:	0.51%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Driver	47.5%	48.5%	0.92%	47.0%	49.2%	2.15%
Car Passenger	29.2%	27.9%	1.32%	28.6%	29.9%	1.36%
Train	1.8%	2.0%	0.15%	3.3%	2.4%	0.86%
Bus	1.8%	2.2%	0.36%	2.6%	1.8%	0.87%
Bike	1.0%	0.9%	0.10%	0.9%	0.6%	0.23%
Walk	18.1%	18.1%	0.03%	17.4%	15.8%	1.58%
Taxi	0.5%	0.5%	0.05%	0.3%	0.3%	0.02%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
		Mean Absolute Error:	0.42%		Mean Absolute Error:	1.01%
		RMS:	0.63%		RMS:	1.23%

Tour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver Toll	15.3	12.4	-18.98%	69.5	55.9	-19.52%
Car Driver No Toll				14.2	11.7	-17.70%
Car Passenger	16.8	14.8	-11.57%	16.6	14.8	-10.83%
Train, P&R	67.8	75.1	10.78%	78.6	75.1	-4.44%
Train, K&R	63.2	74.2	17.40%	69.5	74.2	6.74%
Train, other	37.5	49.3	31.49%	41.9	49.3	17.59%
Bus	13.1	21.7	66.27%	19.2	21.7	12.99%
Bike	6.4	6.2	-3.61%	5.6	6.2	9.29%
Walk	2.5	2.3	-6.85%	2.4	2.3	-4.03%
Taxi	9.9	11.8	18.98%	10.5	11.8	11.49%
Total	13.8	12.3	-11.09%	13.8	12.3	-11.43%
		RMS:	17.75%		RMS:	13.88%

Work-based business tours

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Tours	KM	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver	97,264	1,812,796	63.2%	63.7%	64.3%	0.59%
Car Passenger	10,404	311,550	6.6%	6.4%	6.9%	0.46%
Train	1,894	79,330	1.3%	1.4%	1.3%	-0.15%
Bus	726	6,545	0.5%	0.6%	0.5%	-0.12%
Walk	32,776	60,953	23.0%	22.7%	21.7%	-1.08%
Taxi	8,290	97,367	5.4%	5.2%	5.5%	0.31%
Total	151,355	2,368,540	100.0%	100.0%	100.0%	0.00%
					RMS:	0.56%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car	63.7%	64.3%	0.59%	64.9%	70.0%	5.17%
CarP	6.4%	6.9%	0.46%	6.0%	5.5%	0.54%
Train	1.4%	1.3%	0.15%	1.8%	1.0%	0.82%
Bus	0.6%	0.5%	0.12%	1.1%	0.7%	0.41%
Walk	22.7%	21.7%	1.08%	22.3%	18.3%	4.00%
Taxi	5.2%	5.5%	0.31%	3.9%	4.5%	0.61%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
	Mean Absolute Error:		0.45%	Mean Absolute Error:		1.93%
		RMS:	0.56%		RMS:	2.72%

Tour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
CarD	18.6	18.6	0.23%	20.2	18.6	-7.54%
CarP	31.6	29.9	-5.37%	36.5	29.9	-17.98%
Train	26.0	41.9	61.00%	31.2	41.9	34.02%
Bus	13.9	9.0	-35.33%	18.0	9.0	-49.99%
Walk	1.8	1.9	2.51%	1.7	1.9	7.74%
Taxi	11.3	11.7	4.39%	11.1	11.7	5.60%
Total	15.3	15.6	2.19%	16.6	15.6	-5.95%
		RMS:	8.01%		RMS:	5.60%

Non-home-based business detours

Mode share comparisons

Comparison of mode shares to weighted HTS data:

	TravDem (2006 Base)		Mode Shares			
Mode	Detours (out plus return)	KM (out plus return)	HTS Estim. Sample	Weighted HTS	TravDem Predicted	% Diff.
Car Driver No Toll	25,669	768,736	5.6%	5.6%	8.3%	2.71%
Car Driver Toll	219,585	3,086,977	74.6%	75.4%	71.2%	-4.15%
Car Passenger	24,212	310,666	7.9%	7.1%	7.9%	0.77%
Train	2,318	22,804	0.6%	1.2%	0.8%	-0.44%
Bus	257	698	0.1%	0.1%	0.1%	-0.04%
Walk	33,005	33,293	10.3%	9.9%	10.7%	0.83%
Taxi	3,267	21,247	1.0%	0.7%	1.1%	0.32%
Total	308,314	4,244,420	100.0%	100.0%	100.0%	0.00%
					RMS:	0.56%

Comparison of STM 2006 and STM 2001:

	STM 2006			STM 2001		
Mode	Weighted HTS	TravDem Predicted	Abs % Difference	Weighted HTS	TravDem Predicted	Abs % Difference
Car Driver	81.0%	79.5%	1.44%	81.4%	83.4%	1.95%
Car Passenger	7.1%	7.9%	0.77%	7.5%	6.8%	0.66%
Train	1.2%	0.8%	0.44%	2.2%	1.0%	1.12%
Bus	0.1%	0.1%	0.04%	0.4%	0.3%	0.01%
Walk	9.9%	10.7%	0.83%	7.5%	6.7%	0.72%
Taxi	0.7%	1.1%	0.32%	1.2%	1.8%	0.55%
Total	100.0%	100.0%	0.00%	100.0%	100.0%	0.00%
		Mean Absolute Error:	0.64%		Mean Absolute Error:	0.84%
		RMS:	0.78%		RMS:	1.03%

Detour length comparisons

	RMS1 Comparison			RMS2 Comparison		
Mode	Weighted HTS	TravDem Predicted	% Diff.	HTS Estim. Sample	TravDem Predicted	% Diff.
Car Driver No Toll	16.2	15.7	-3.24%	37.5	29.9	-20.20%
Car Driver Toll				13.4	14.1	4.64%
Car Passenger	16.8	12.8	-23.77%	14.5	12.8	-11.40%
Train	10.1	9.8	-3.09%	9.9	9.8	-0.30%
Bus	4.6	2.7	-40.55%	1.9	2.7	41.92%
Walk	0.9	1.0	6.88%	0.7	1.0	40.07%
Taxi	5.6	6.5	15.72%	5.5	6.5	17.95%
Total	14.6	13.8	-5.79%	13.4	13.8	2.45%
		RMS:	7.56%		RMS:	7.95%