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Mode-Destination-Time Period and Frequency Models

James Fox, Bhanu Patruni, Andrew Daly

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Prepared for Vejdirektoratet (Danish Road Directorate)

The research described in this report was prepared for Vejdirektoratet
(Danish Road Directorate).

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Preface

The Ørestad Traffic Model (OTM) is used to forecast demand for passenger and freight transport across the Greater Copenhagen area. In 2006, the OTM model was extensively updated to create OTM 5, with a move to a 2004 base year, and the development of completely new passenger demand models. The OTM 6 project extends the passenger demand models developed for OTM 5 so that they are able to predict changes in the number of car trips by time period in response to different congestion charging policies. The OTM 6 work has been undertaken on behalf of Vejdirektoratet by RAND Europe, which has estimated the new passenger demand models, and Significance, which has implemented the new passenger demand models within the OTM forecasting tool.

This document reports on the development of the new OTM 6 passenger demand models by RAND Europe. The report focuses on the extension of the mode-destination models to include time period choice for car drivers, but also briefly documents the estimation of new frequency models.

This report should be of interest to individuals interested in understanding how the passenger demand models within the OTM 6 model were developed. Sections of the report are highly technical in nature, and some knowledge of transport modelling terminology is assumed.

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Abbreviations

HB: Home-Based

LOS: Level-of-Service

NHB: Non-Home-Based

OD: Origin-Destination

OTM: Ørestad Traffic Model

PT: Public Transport

SP: Stated Preference

TP: Time Period

TU data: Danish National Travel Survey data

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CHAPTER 1 Introduction

1.1 Context of the study

This report documents the development of the passenger demand models for version 6 of the Ørestad Traffic Model (OTM), which predicts demand for transport across the Greater Copenhagen Area (GCA). No changes have been made to the freight demand models in the OTM system.

The OTM model was first developed in 1995. In the last major update of the OTM model (OTM 5), a number of changes were made so that the model could be used to predict demand for the Metro City Ring project, the fourth phase of the Copenhagen Metro network. During the OTM 5 development work, the model base year was updated from 1992 to 2004, new values of travel time were estimated, mode and destination choices were modelled simultaneously for the first time within a tour-based framework, and the pivot-point procedure used for forecasting was updated. RAND Europe's role in the OTM 5 work was to estimate new mode-destination and frequency models for passenger travel, and to work together with Significance to implement these new models, work which included advising on changes to the pivot-point process. For more information on the application of the OTM 5 model to predict demand for the Metro City Ring project, please see Vuk *et al.* (2009).

The work described in this report to develop version 6 of the OTM model has been undertaken because there is increasing interest in assessing the impact of charging policies in the GCA area. Version 5 of OTM did not model time of day choice. In order to make the OTM model system responsive to congestion charging policies its functionality needed to be extended. This extension will enable model users to assess the impact of charging policies where the charge varies with time of day.

The majority of the work undertaken was concerned with extending the mode-destination models developed for version 5 of the OTM in 2006 (Fox and Sivakumar, 2006) so that they are able to predict choice of time period (TP) for car driver. The final specifications from the OTM 5 mode-destination models were retained in the new models, and the only changes to the model specifications beyond introducing choice of TP for car driver was the addition of terms to improve the fit to observed tour lengths. For a full explanation of the development of the OTM 5 model specifications see Fox and Sivakumar (2006).

The procedure of introducing TP choice into an existing model of mode and destination choice has been followed in other large-scale modelling studies. In those cases, the mode and destination choice were based on revealed preference data from home interviews (as in this study) and then to conduct a stated choice study of mode and TP choice, which could be merged with the existing model because of the presence of mode choice in both the revealed preference and the stated choice models. Stated choice models from three different areas (London, the West Midlands of England and the Netherlands) were analysed by Hess *et al*. (2007), where indications are given for the appropriate scaling of TP choice to mode choice, which can be applied in large-scale modelling. This work forms the basis of the UK government's current recommendations for travel demand modelling (WebTAG, 2009).

In this study, in contrast, the modelling is based principally on revealed preference data. The success of this approach depends on the existence of sufficient variance in the travel time data, i.e. sufficient variation in congestion that variation in the proportions using the TPs can be correlated with it. The approach makes considerable demands on the accuracy of the assignment algorithm and probably for this reason has not been used much before. The concept of the study was therefore to attempt to estimate models from the revealed preference data, but to keep in reserve the possibility of importing information from elsewhere if that approach was not satisfactory. The alternative would have been to mount an expensive and time-consuming stated choice study in Copenhagen.

Three of the frequency models developed for OTM 5 contained a link to the mode-destination models through logsum accessibility terms. As the mode-destination model logsums change as a result of introducing car driver TP choice into the model structure, it was also necessary to re-estimate these three frequency models, and so those re-estimations are also documented here. For documentation of the development of the frequency model specifications in OTM 5 see Fox (2006).

1.2 Structure of report

The mode-destination choice models incorporating TP choice for car driver are described as simply the models in this section.

Chapter 2 of this report describes the structure of the models, detailing the travel purposes modelled, the mode, destination and TP alternatives represented, the variables included in model estimation, the reasons for excluding data from the estimations, and the different tree structures that have been tested to determine the sensitivity of car driver TP choice relative to the mode and destination choices.

Chapter 3 describes in detail how the TP alternatives represented in the models have been defined. In particular, it documents the definition of TP combination alternatives for the home–based (HB) purposes, where combinations of outward and return TPs need to be considered.

Chapter 4 describes the steps that have been undertaken to estimate and validate the new models with TP choice included. After describing how the OTM 5 models have been resurrected from the archives, the chapter goes on to describe how the choice structures have been extended to include TP choice, how the model structures for each purpose were determined, and the final step where for some travel purposes additional parameters were added following trip length validation.

Chapters 5 to 11 then document the estimation results for the five HB and two non-home–based (NHB) models. For each chapter, sections are presented which document the tree structure tests run to determine the placement of TP choice relative to mode and destination choice, the final model parameters with a comparison to the OTM 5 model parameters, the model elasticities and the fit to the observed tour and trip lengths.

Chapter 12 documents the three frequency models that have been re-estimated using updated accessibility logsums from the mode-destination models, namely the frequency models for home–work, home–shopping and home–leisure.

Finally, Chapter 13 presents a summary of the OTM 6 demand model estimation work.

CHAPTER 2 Model structure

The models of mode, destination and car driver TP choice allow the estimation of these three aspects of travel behaviour simultaneously. This is not because it is believed that the decisions on these aspects of the tour are taken simultaneously, in fact no assumption on this point is necessary. The requirement for simultaneous model estimation arises from considerations of efficiency in the modelling.

The model forms that are investigated for these joint choices are multinomial or nested logit models. These model forms have been proved to be satisfactory for use to represent mode and destination choice in a number of previous important studies. While more general and advanced models are now available for modelling complicated interdependent choices, it remains the case that the scale of the models required for large-scale travel demand models prohibits the use of more advanced model structures.

The following sections describe the structure of the mode-destination choice models, which are common to the five HB purposes and two NHB purposes represented in the OTM 5 demand models. As per the OTM 5 models the base year for model estimation is 2004.

2.1 Model purposes

The purpose definitions used in OTM 5 have been retained.

Five HB purposes are represented, which are modelled as HB tours:

- home–work
- home–business
- home–education
- home–shopping
- home–leisure

A mapping of the detailed purpose codes recorded in the Danish National Travel Survey (TU) data used for estimation of the models was provided in Section 2.2 of Fox and Sivakumar (2006).

Two NHB purposes are included, where trips are modelled:

- NHB business (NHBB)

- NHB other (NHBO)

NHBB includes NHB trips whose purpose was either employer's business, full-time or part-time work. Note that full-time and part-time work can only occur as trip purposes if an individual visits multiple work locations during a HB work tour. NHBO includes NHB trips of all purposes other than those categorised as NHBB.

2.2 Model alternatives

2.2.1 Mode alternatives

The five mode alternatives are unchanged from the OTM 5 models:

- public transport (PT)
- car driver
- car passenger
- cycle
- walk

The PT mode includes travel on the various metro, bus and rail modes across the Greater Copenhagen area.

The separate treatment of car driver and car passenger modes introduced in OTM 5 is retained and allows the impact of policy on car occupancy to be assessed. As all car costs are assumed to be paid by car drivers, the impact of policies that increase the cost of travelling by car is to increase occupancy, as such policies cause a fraction of car driver demand to switch to car passenger. Since the OTM 5 model specifications were developed in 2006, RAND Europe has considered the issue of cost sharing between drivers and passengers (Fox, Daly and Patruni, 2009), and have developed formulations which allocate a proportion of car cost to passengers. These formulations have been found to improve the fit to observed data and should be considered if the mode-destination model specifications in the OTM models were developed further.

In estimation, model alternatives are represented as available according to conditions that depend on the mode and destination alternative in question. No travel is allowed to a destination (by any mode) if there is no attraction variable in the destination zone. Then the availability conditions that apply to particular modes are that:

- PT is available if there is a PT service available, i.e. a non-zero PT in-vehicle time for the OD pair in question
- car driver is available to individuals if they have a driving licence and if there is at least one car in their household
- car passenger is available to all individuals
- cycle is available to all individuals for trips/tours up to a maximum journey length, which depends on the travel purpose

- walk is available to all individuals for trips/tours up to a maximum journey length, which again depends on the travel purpose

The maximum distances that cycle and walk alternatives are available to are summarised in Table 1; again, these are unchanged from OTM 5. For HB purposes, the distances are for the return tour. For NHB purposes the distances are for the one-way trip.

Table 1: Cycle and walk distance cut-offs (km)

Purpose	Cycle distance (km)	Walk distance (km)
home–work	60	15
home–business	60	15
home–education	60	15
home–shopping	30	15
home–leisure	60	15
NHB business	30	15
NHB other	30	15

2.2.2 Destinations alternatives

The zone system used in the 2006 estimations, and implemented in OTM 5.0, used a total of 835 zones (internal zones 1–818 and external zones 819–835). Since then the zoning system has been revised, with two zones in an urban development area split into 16 new zones, and an additional external zone added, resulting in a total of 852 model zones (two of which have no demand). The revised zoning system is used in the current OTM 5.3 model system and will be retained in the new OTM 6.0 model.

Table 2 summarises the relationship between the original and revised zoning systems.

Table 2: Modifications to zoning system

OTM 5.0 zone system	OTM 6.0 zone system	Comments
1–818	1–818	internal zones, unchanged (53 and 54 have no demand)
	819–834	new internal zones, split from zones 53 and 54
819–835	835–851	external zones, sequence unchanged
	852	new external zone

The 852 internal and external zones form the destination alternatives in the models.

Destination alternatives are only available if there is a non-zero attraction variable in the destination zone. The attraction variables that have been used vary according to journey purpose and are summarised in Table 3, together with the variable names used on the zonal data file (zonedata.dat). It should be noted that the zonal data used for model estimation only contain non-zero attraction variables for internal zones (zone numbers 1–834), and therefore all external zones (zone numbers 835–852) are set to be unavailable in model estimation.[1]

[1] No tours to external destinations are observed in the 2003 sample of tours, and just five tours to external destinations are observed in the 2005 sample of tours. Therefore setting external destinations to be unavailable is judged to be reasonable.

Table 3: Destination attraction variables

Purpose	Zonal variables	Definition
home–work	JOBS	total no. of workplaces
home–business	JOBS	total no. of workplaces
home–education	STU	no. of student places
home–shopping	JCOM2 JCOM3	no. of workplaces – retail trade no. of workplaces – other retail trade (shopping goods)
home–leisure	POP JCOM1 JENT JPSE JEDU	total population no. of workplaces – wholesale and repair work no. of workplaces – recreational, cultural, sporting activities no. of workplaces – public administration no. of workplaces – education, health and social service
non-home–business	JOBS	total no. of workplaces
non-home–based other	POP JCOM1 JCOM2 JCOM3 JENT JLSE JPSE JEDU	total population no. of workplaces – wholesale and repair work no. of workplaces – retail trade no. of workplaces – other retail trade (shopping goods) no. of workplaces – recreational, cultural, sporting activities no. of workplaces – liberal service no. of workplaces – public administration no. of workplaces – education, health and social service

In the home shopping model, retail trade jobs (JCOM2) and other retail trade jobs (JCOM3) are summed to give the total retail employment as the attraction variable.

For the home–leisure and NHB other models, size variables are used to represent different attractions with size parameters providing an estimate of the relative attractiveness of each size variable. In these models population is specified as the base size variable.

2.2.3 Car driver time period alternatives

The number of TP alternatives for car driver journeys varies across the different travel purposes, because TPs have been aggregated in different ways to reflect different distributions of travel over the day. Table 4 summarises the number of alternatives represented for car driver. For HB purposes, TP combination alternatives are represented which define the choice of TP for both the outward and return legs of the tours. Chapter 3 documents in detail how these TP alternatives have been defined.

Table 4: Car driver TP alternatives by purpose

Purpose	Alternatives
home–work home–business home–education home–shopping home–leisure	27 TP combinations 19 TP combinations 19 TP combinations 28 TP combinations 36 TP combinations
NHB business NHB other	9 TPs 9 TPs

It is emphasised that TP choice is only modelled for car driver and so these TP alternatives are only represented in the choice structure for the car driver mode.

2.3 Variables in the modelling

2.3.1 Level-of-service variables

Table 5 summarises the level-of-service (LOS) variables represented in the utilities of each of the five modes represented in the models. TetraPlan has supplied an all-day average

LOS that defines these variables for PT, car passenger,[2] cycle and walk and this all-day LOS has been used in model estimation for these modes. For car driver, LOS information is supplied separately for the nine TPs defined in Section 3.1.

Table 5: LOS variables

	PT	Car driver	Car pass.	Cycle	Walk
transfer time	√				
access time	√				
metro in-vehicle time	√				
tram in-vehicle time	√				
city bus in-vehicle time	√				
airport-bus in-vehicle time	√				
local rail in-vehicle time	√				
regional rail in-vehicle time	√				
S-train in-vehicle time	√				
express-bus in-vehicle time	√				
S-bus in-vehicle time	√				
A-bus in-vehicle time	√				
car kilometre cost		√			
car toll cost		√			
parking cost		√			
car free flow time		√	√		
car congested time		√	√		
parking search time		√	√		
free flow car distance			√		
cycle distance				√	
walk distance					√

It is noted that in the 2004 base year, there is no observed travel time on tram or light rail modes, as these modes did not exist in 2004. However, fields for these variables were specified on the PT LOS used in model estimation and therefore they were included in the calculations. In forecasting, the ability to forecast demand for the light rail mode has been retained, using information from stated preference (SP) data collected during the development of earlier versions of the OTM model. Forecasts of demand for the tram alternative were not required from OTM 5 model, and therefore are not forecast by OTM 6.0 either.

The free flow car distance term on the car passenger utility was only included in the models for certain purposes if the validations undertaken during the OTM 5 model development revealed significant differences between observed and predicted tour or trip lengths.

In the HB tour models, parking search times are included at both the home and primary destination ends of the tour, whereas parking costs are included at the primary destination end of the tour only, as it is assumed individuals do not have to pay to park at home. For the NHB models, parking costs and search times are included at the destination end of the trip only.

[2] Near the end of the estimation work, all-day LOS for car passenger weighted to reflect the distribution of base year car demand across time periods was supplied. For most of the estimation work, however, all-day LOS for car passenger was calculated as an unweighted average over the nine time periods.

2.3.2 Intrazonal terms

For the PT, car driver and car passenger modes, non-zero LOS information was supplied for intrazonals (trips or tours with the same origin and destination zone). For walk and cycle modes, intrazonals are not included on the LOS files. However, the zonal data file define intrazonal distances for each zone and therefore this information has been used to specify distances for cycle and walk intrazonal journeys.

Although intrazonal LOS is defined for all modes, our experience is that the proportions of tours that are intrazonal are often underpredicted. Therefore, following the findings from the OTM 5 estimations, intrazonal destination constants were included in all of the models except home–work.[3]

2.3.3 Socio-economic terms

Travellers' social and economic status are also key inputs to forecast travel demand: they may have different behavioural characteristics, e.g. values of time, also the model system may be applied to examine how different population groups will be affected by different transport policies.

The OTM 5 models incorporated two forms of socio-economic segmentation: first, representing variation in values of time by personal income group, and second representing the impact of car ownership on mode choice. These two socio-economic segmentations have been retained in the OTM 6.0 models.

Two types of car availability term have been included to represent the impact of car ownership on mode choice. The first type of term is a car availability constant on the PT utility, applied if the individual has a licence and the household has at least one car (the condition used to specify the availability of the car driver alternative). This constant term represents the lower probability of choosing PT if the individual has a licence and access to a car.

The second type of car ownership term is the number of cars per household member. This specification was tested on the utility of car driver and car passenger alternatives, and can be viewed as a 'car competition' variable. It has the advantage that it can be specified from the zonal data used in forecasting, making the assumption that all households in the zone have the same (average) car ownership level. As the number of cars per person decreases, the probability that a given individual has access to a car as a driver, or can obtain a lift from another household member, decreases. Ideally car competition parameters are specified using household licence holding but this information was not available on the dataset supplied for model estimation.

Table 6 summarises the car availability terms that are included for each of the seven model purposes, following the tests undertaken during the OTM 5 model development.

[3] Validation of the home–work model during the 2006 estimation work did not indicate the need for an intrazonal dummy for that purpose.

Table 6: Car availability terms by purpose

Purpose	Car availability constant on PT	Cars per person on car driver	Cars per person on car pass.
home–work	✓	✓	✓
home–business	✓	✓	✓
home–education			✓
home–shopping		✓	✓
home–leisure	✓	✓	✓
NHB business	✓	✓	✓
NHB other	✓	✓	✓

2.4 Model exclusions

Observations were excluded from model estimation for the following reasons:

- if there is no attraction data in the chosen destination zone (this includes all zones in the external area)
- for certain purposes, tours made by individuals of certain occupation types (for example the education model excludes individuals whose occupation type is not 'school pupil' or 'student')
- all half-tours (cases where only an outward tour leg, or a return tour leg, is recorded)
- tours by modes other than the five modelled modes
- tours where the origin and/or destination zone information is missing
- car driver tours made by individuals without a licence
- car driver tours made by individuals in households with no cars
- PT tours for OD pairs which are not available for PT according to the PT LOS
- cycle tours for distances greater than the maximum specified in the availability condition
- walk tours for distances greater than the maximum specified in the availability condition
- car driver tours by TP combinations which are chosen only very rarely and represented as unavailable in the modelling (these are detailed in Chapter 4)

Fox and Sivakumar (2006) provided a detailed breakdown of the records excluded from the estimations for each model purpose.[4]

[4] The detailed breakdown of the model exclusions does not include the final exclusion criteria listed here because the time period combinations were not considered in the 2006 estimations as only mode and destination choices were modelled.

2.5 Tree structures

The models estimated for home–work and home–business were estimated from a combination of 2003 and 2005 TU data. In these models, a scale parameter was used to represent differences in the level of unexplained error between the two data sets. The scale parameter 2003_scale was used to scale the 2003 data relative to the 2005 data. The models for the other purposes are estimated from 2005 TU data only and therefore no dataset scaling was required.

The key change to the model structure relative to the OTM 5 models was the introduction of car driver TP choice into the model structure. Given that we are only considering TP choice for one mode, i.e. car driver, it must therefore lie at the same level as, or lie beneath, mode choice. This meant that there were three possible tree structures to be considered for each model purpose:

- modes above TP above destinations
- destinations above modes above TP
- modes above destinations above TP

The three nesting structures are presented in Figure 1 to Figure 3, where there are *m* TP combinations and *n*=852 destinations. Note that as TP choice is only modelled for car driver, the TP choice nests only appear beneath the car driver mode. For modes other than car driver, all-day LOS is used to represent average travel conditions across the day in the 2004 base year.

The nesting parameters, the θs, determine the relative sensitivities of adjacent choices in the tree structure. For a structure to be acceptable, all θs must lie between 0 and 1. If a θ parameter is significantly greater than 1 then the structure is rejected. If a θ parameter is fixed to 1 then the two choices adjacent to that θ are equally sensitive to changes in utility and thus are effectively at the same level in the structure. For example, in Figure 1 if θ_{M_TP} is fixed to 1 modes and TPs are effectively at the same level.

Figure 1: Modes above TP above destinations structure

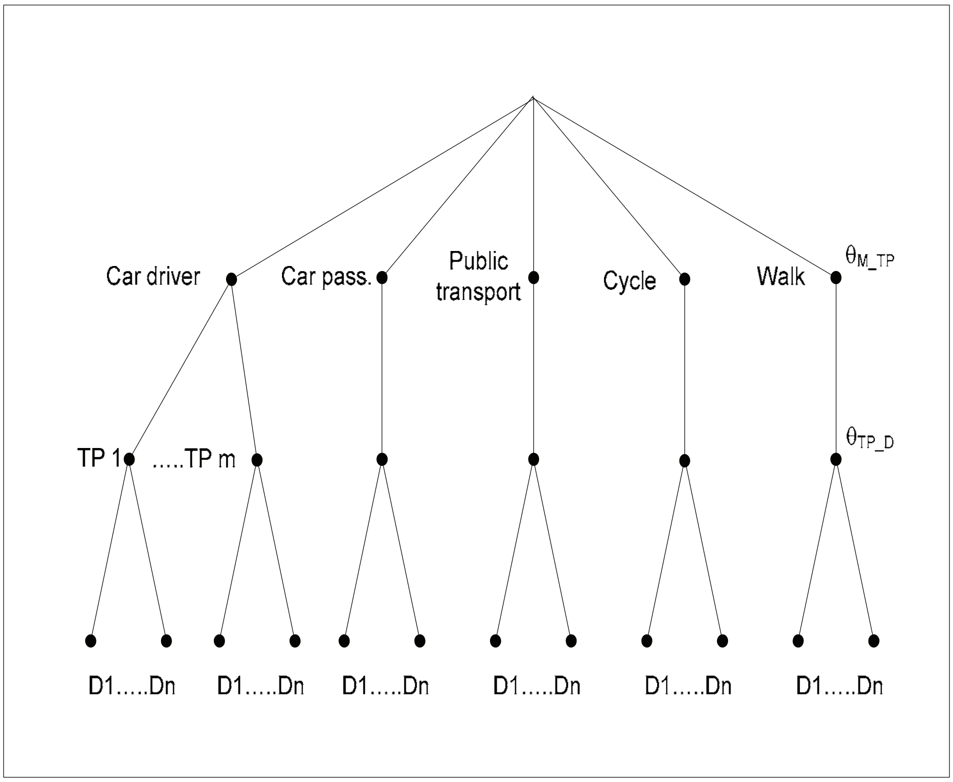


Figure 2: Destinations above modes above TP structure

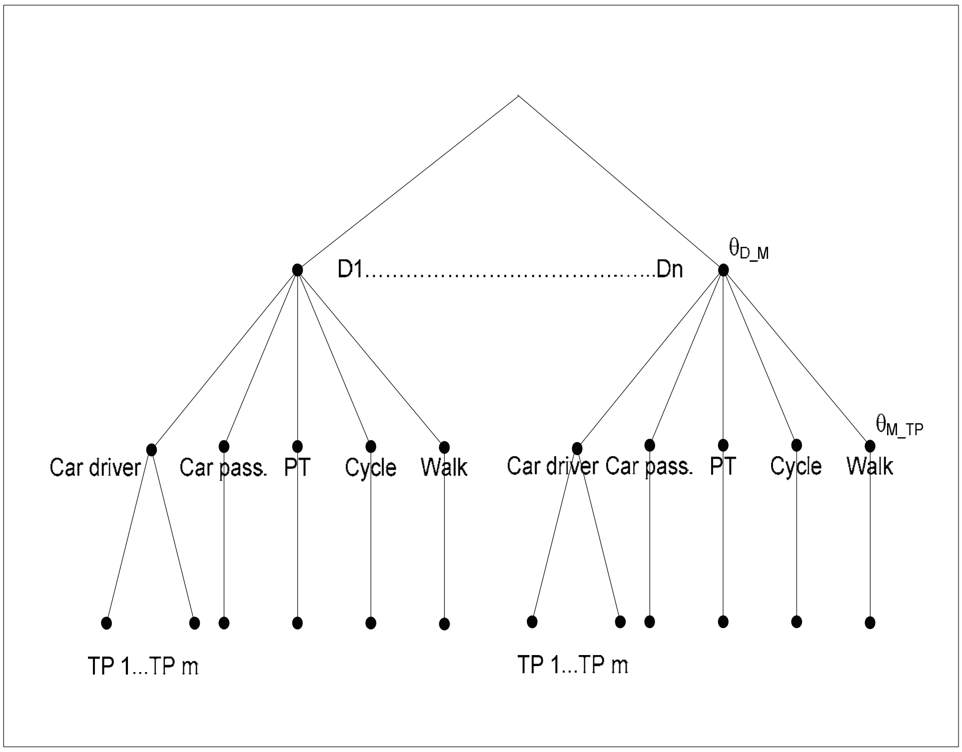
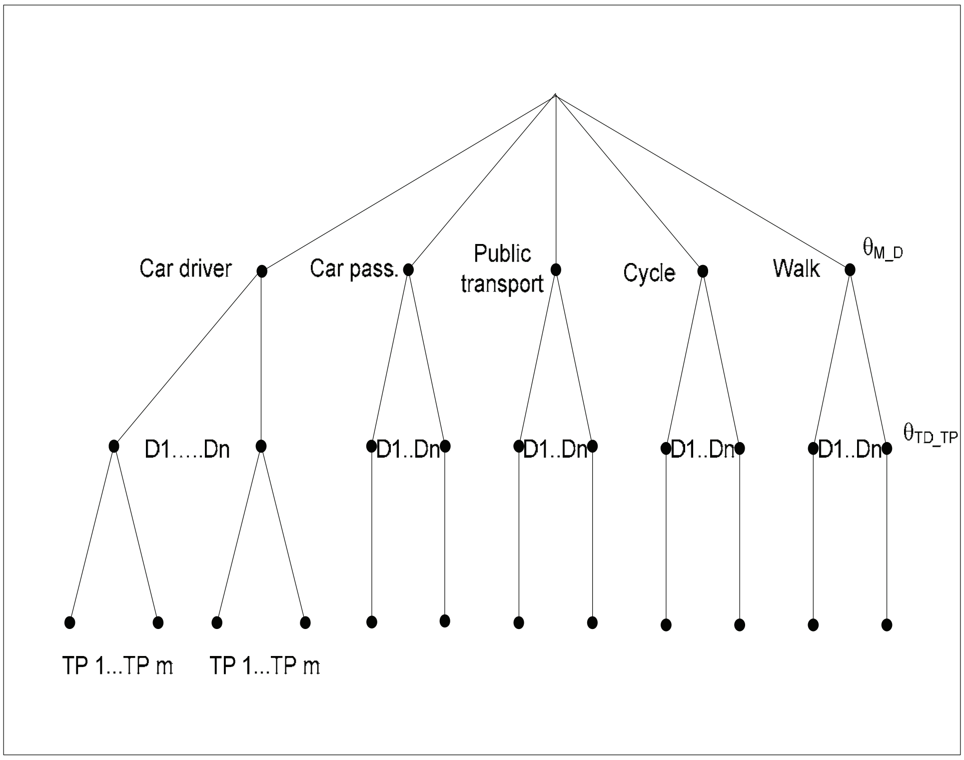


Figure 3: Modes above destinations above TP structure



Choices represented at the lowest level in the structures have lower levels of unexplained error, and are more sensitive to changes in utility. Chapters 5 to 11 summarise the structural tests used to determine which of these three structures to use for each travel purpose.

CHAPTER 3 Time period combination alternatives

3.1 Time period definitions

OTM 5 distinguished seven TPs in the LOS and base matrices (Table 7), but the demand models were applied at the all-day level. OTM 6.0 represents nine TPs following the decision to split the 15:00–17:59 period into three one-hour periods to better represent congestion in the evening peak. The nine periods form the basis for the period combination alternatives represented in the TP choice models, but an additional tenth period results from splitting the time night period (UM1) into two (UM1(E) and UM1(L)), so that trip timings at the beginning and end of the survey day can be distinguished.[5] This additional period is only used in the TP choice models and results are aggregated back to the UM1 period before pivoting.

Table 7 summarises the relationship between the different TP definitions. Grey shading indicates where changes have been made to the TP definitions relative to the definitions used in OTM 5.3 (the latest version of OTM 5).

Table 7: Time period definitions

OTM 5.3		OTM 6.0 LOS, base matrices and pivoting		OTM 6.0 TP choice models	
Name	Time period	Name	Time period	Name	Time period
UM1	21:00–04:59	UM1	21:00–04:59	UM1(L)	21:00–02:59
				UM1(E)	03:00–04:59
UM2	05:00–06:59	UM2	05:00–06:59	UM2	05:00–06:59
MM1	07:00–07:59	MM1	07:00–07:59	MM1	07:00–07:59
MM2	08:00–08:59	MM2	08:00–08:59	MM2	08:00–08:59
UM3	09:00–14:59	UM3	09:00–14:59	UM3	09:00–14:59
EM	15:00–17:59	EM1	15:00–15:59	EM1	15:00–15:59
		EM2	16:00–16:59	EM2	16:00–16:59
		EM3	17:00–17:59	EM3	17:00–17:59
UM4	18:00–21:00	UM4	18:00–20:59	UM4	18:00–20:59

[5] The survey day ran from 03:00 to 02:59 the following day.

3.2 Home–based purposes

For HB purposes tours are modelled and therefore to define TP choice the choice of TP for both the outward leg from the home to the primary destination and the return leg from the primary destination back to home must be considered. This gives rise to TP combination alternatives that define the possible combinations of outward and return tour leg TPs.

There are ten possible TP choices for each outward and return leg which gives 100 possible TP combination alternatives. Records where the return legs arrived back home after 03:00 the following day were excluded, which reduces the total possible combinations of TPs from 100 to 55 for a loss of only nine records across all the purposes.

In selecting the TP combinations for modelling, a trade-off was made between modelling all the possible TP combinations and the amount of data available in each TP combination to do so. Depending on the amount of data available in each TP combination for the particular purpose in question, TP combination alternatives have been defined in three different ways:

- alternatives where both the outward and return period are represented in full – these cover the frequently chosen TP combinations, for example commuters who travel out during the morning peak and return during the afternoon peak
- early departure alternatives where there is aggregation over outward TPs in the early morning hours but return TPs spread over the remaining hours of the day are represented in full
- late departure alternatives, chosen by a low percentage of individuals who leave home during the afternoon peak or later, where there is aggregation over both outward and return TPs

TP combinations were set to be unavailable for cases where an outward leg period is never chosen or where merging them with another TP combination would not have yielded a sensible definition.

For car driver observations for each purpose, the number of outward and return tour legs was cross-tabulated by TP. When the TP combination choice models are applied, alternatives with full representation of outward and return TP are modelled directly, whereas for aggregated TPs an average LOS across the aggregated time range is used, and the base year proportion of outward and return tours for each TP within this time range is used to assign the predicted demand into the respective TP.

The sub-sections below use tables to illustrate how the TP combination alternatives for each purpose have been defined. In model estimation, there is a slight loss of data relative to the numbers presented in the tables as some records are excluded at the model estimation stage (see Section 2.4).

3.2.1 Home–work time period combinations

Table 8 shows a cross-tabulation between the outward and return tour legs across each TP for car drivers making a home–work tour; TP combinations which are unavailable by definition are shaded in grey.

- Of the 55 possible TP combinations, 86% of the tours occur in 19 combinations, departing between 07:00 and 15:00 and arriving between 08:00 and 02:59. These 19 TP combinations have been represented in full. They are shaded in light green in Table 8.
- 9.5% of the tours depart between 05:00 and 06:59 and arrive in all the possible return legs between 08:00 and 02:59, and 1% of the tours depart between 03:00 and 04:59 and arrive only in some of the possible return legs between 08:00–02:59. We have aggregated the 03:00–04:59 and 05:00–06:59 outward legs into a single outward period from 03:00 to 06:59. This allows us to represent the corresponding return legs from 08:00 to 02:59 in full detail. This results in seven TP combinations, which are shaded in pink in Table 8.
- Tours departing after 15:00 represent just 3% of the sample; all the outward and the return legs within this time range have been aggregated into a single TP combination alternative. This alternative is shaded in light blue in Table 8.
- TPs which are set unavailable are shaded in red. These account for just 0.04% of total home–work tours.

A total of 27 TP combination alternatives are represented in the home–work model.

3.2.2 Home–business time period combinations

Table 9 shows a cross-tabulation between the outward and return tour legs across each TP for car drivers making a home–business journey; TP combinations which are unavailable by definition are shaded in grey.

- Of the 55 possible TP combinations, 66% of the tours occur in 12 combinations departing between 08:00 to 14:59 and arriving between 09:00 to 02:59. These 12 TP combinations have been represented in full, and are shaded in light green in Table 9.
- 14% of the tours depart between 07:00 and 07:59 and arrive in *all* possible return legs between 08:00 and 02:59, and 5% of the tours depart between 05:00 and 06:59 and arrive only in *some* of the possible return legs between 08:00 and 02:59. We have aggregated the 05:00–06:59 and 07:00–07:59 outwards legs into a single outward leg from 05:00 to 07:59. This allows us to represent separately the corresponding return legs from 08:00 to 02:59 in full detail. This results in six TP combinations, which are shaded in pink in Table 9.
- Tours departing after 15:00 and arriving before 03:00 represent 14% of the sample; we have merged all the outward and the return legs within this TP into a single TP alternative, shaded in light blue in Table 9.
- TPs which are set to be unavailable are shaded in red in Table 9. These account for only 0.5% of total home–business car driver tours.

A total of 19 TP combination alternatives are represented in the home–business model.

3.2.3 Home–education time period combinations

Table 10 shows a cross-tabulation between the outward and return tour legs across each TP for car drivers making a home–education journey; TPs which are unavailable by definition are shaded in grey.

- Of the 55 possible TP combinations, 76% of the tours occur in 12 combinations, departing between 08:00 and 14:59 and arriving between 09:00 and 02:59. These 12 TP combination alternatives have been modelled in full detail, and are shaded in light green in Table 10.
- 10% of the tours depart between 07:00 and 07:59 and arrive in *all* possible return legs between 09:00 and 02:59, and 3% of the tours depart between 05:00 and 06:59 and arrive in only *some* of the possible return legs between 09:00 and 02:59. We have aggregated the 05:00–06:59 and 07:00–07:59 outwards legs into a single outward period from 05:00 to 07:59. This allows us to represent the return legs from 08:00 to 02:59 in full. This results in six TP combinations, which are shaded in pink in Table 10.
- Tours departing after 15:00 and arriving before 02:59 represent 11% of the sample; we have merged all the outward and the return legs within this time range into a single TP combination alternative, shaded in light blue in Table 10.
- TP combinations which are set to be unavailable are shaded in red in Table 10. No home–education car driver tours are observed in these TP combinations.

A total of 19 TP combination alternatives are represented in the home–education model.

3.2.4 Home–shopping time period combinations

Table 11 shows a cross-tabulation between the outward and return tour legs across each TP for car-drivers making a home–shopping journey; TPs which are unavailable by definition are shaded in grey.

- Of the 55 possible TPs, 99.8% of the tours occur in 28 TP combinations, departing after 08:00 and arriving in all the possible return TPs. There are a few zeros in some of the return legs for tours departing between 08:00 and 08:59; one option would have been to merge this outward leg with the adjacent outward leg; however, the next available outward leg is three hours long and has 47% of shopping tours, which we preferred to retain separately. Therefore we chose to represent these alternatives separately but set them to be unavailable in the modelling. The 28 TP combination alternatives represented in full detail are shaded in light green in Table 11.
- TP combinations which are set to be unavailable are shaded in red in Table 11. These account for only 0.22% of total home–shopping car driver tours.

A total of 28 TP combination alternatives are represented in the home–shopping model.

3.2.5 Home–leisure time period combinations

Table 12 shows a cross-tabulation between the outward and return tour legs across each TP for car-drivers making a home–leisure journey; TP combinations which are unavailable by definition are shaded in grey.

- Of the 55 possible TP combinations, 99.2% of the tours occur in 36 combinations, namely departing after 07:00 and arriving in all the possible return TPs. These 36 TP combination alternatives have been represented in full detail, and are shaded in light green in Table 12.
- TPs which are set unavailable are shaded in red in Table 12. These account for just 0.5% of total home–leisure car driver tours.

A total of 36 TP combination alternatives are represented in the home–leisure model.

Table 8: Outward and return tour legs by TP for home–work

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	0	0	0	3	14	3	0	0	1	1	22
UM2	05:00–06:59	0	0	0	0	60	49	62	25	38	12	246
MM1	07:00–07:59	0	0	1	1	72	97	199	121	131	42	664
MM2	08:00–08:59	0	0	0	0	84	79	230	268	275	68	1004
UM3	09:00–14:59	2	0	0	0	47	34	92	118	173	90	556
EM1	15:00–15:59	0	0	0	0	0	0	3	1	3	20	27
EM2	16:00–16:59	1	0	0	0	0	0	1	3	5	6	16
EM3	17:00–17:59	0	0	0	0	0	0	0	1	6	6	13
UM4	18:00–20:59	0	0	0	0	0	0	0	0	5	24	29
UM5	21:00–02:59	0	0	0	0	0	0	0	0	0	6	6
Total		3	0	1	4	277	262	587	537	637	275	2583

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	0.00 %	0.00 %	0.00 %	0.12 %	0.54 %	0.12 %	0.00 %	0.00 %	0.04 %	0.04 %	0.85 %
UM2	05:00–06:59	0.00 %	0.00 %	0.00 %	0.00 %	2.32 %	1.90 %	2.40 %	0.97 %	1.47 %	0.46 %	9.52 %
MM1	07:00–07:59	0.00 %	0.00 %	0.04 %	0.04 %	2.79 %	3.76 %	7.70 %	4.68 %	5.07 %	1.63 %	25.71 %
MM2	08:00–08:59	0.00 %	0.00 %	0.00 %	0.00 %	3.25 %	3.06 %	8.90 %	10.38 %	10.65 %	2.63 %	38.87 %
UM3	09:00–14:59	0.08 %	0.00 %	0.00 %	0.00 %	1.82 %	1.32 %	3.56 %	4.57 %	6.70 %	3.48 %	21.53 %
EM1	15:00–15:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.12 %	0.04 %	0.12 %	0.77 %	1.05 %
EM2	16:00–16:59	0.04 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.04 %	0.12 %	0.19 %	0.23 %	0.62 %
EM3	17:00–17:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.04 %	0.23 %	0.23 %	0.50 %
UM4	18:00–20:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.19 %	0.93 %	1.12 %
UM5	21:00–02:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.23 %	0.23 %
Total		0.12 %	0.00 %	0.04 %	0.15 %	10.72 %	10.14 %	22.73 %	20.79 %	24.66 %	10.65 %	100.00%

Table 9: Outward and return tour legs by TP for home–business

Time of the outward leg		UM1(E) 03:00–04:59	UM2 05:00–06:59	MM1 07:00–07:59	MM2 08:00–08:59	UM3 09:00–14:59	EM1 15:00–15:59	EM2 16:00–16:59	EM3 17:00–17:59	UM4 18:00–20:59	UM1(L) 21:00–02:59	Total
		Time of the return leg										
UM1	03:00–04:59	0	0	0	0	0	0	0	0	0	0	0
UM2	05:00–06:59	0	0	0	0	0	1	7	0	0	2	10
MM1	07:00–07:59	0	0	0	1	5	5	8	2	6	2	29
MM2	08:00–08:59	0	0	0	0	9	8	19	8	6	2	52
UM3	09:00–14:59	1	0	0	0	21	13	16	11	15	4	81
EM1	15:00–15:59	0	0	0	0	0	0	1	1	2	0	4
EM2	16:00–16:59	0	0	0	0	0	0	0	0	3	1	4
EM3	17:00–17:59	0	0	0	0	0	0	0	0	5	2	7
UM4	18:00–20:59	0	0	0	0	0	0	0	0	4	9	13
UM5	21:00–02:59	0	0	0	0	0	0	0	0	0	0	0
Total		1	0	0	1	35	27	51	22	41	22	200

Time of the outward leg		UM1(E) 03:00–04:59	UM2 05:00–06:59	MM1 07:00–07:59	MM2 08:00–08:59	UM3 09:00–14:59	EM1 15:00–15:59	EM2 16:00–16:59	EM3 17:00–17:59	UM4 18:00–20:59	UM1(L) 21:00–02:59	Total
		Time of the return leg										
UM1	03:00–04:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
UM2	05:00–06:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.50 %	3.50 %	0.00 %	0.00 %	1.00 %	5.00 %
MM1	07:00–07:59	0.00 %	0.00 %	0.00 %	0.50 %	2.50 %	2.50 %	4.00 %	1.00 %	3.00 %	1.00 %	14.50 %
MM2	08:00–08:59	0.00 %	0.00 %	0.00 %	0.00 %	4.50 %	4.00 %	9.50 %	4.00 %	3.00 %	1.00 %	26.00 %
UM3	09:00–14:59	0.50 %	0.00 %	0.00 %	0.00 %	10.50 %	6.50 %	8.00 %	5.50 %	7.50 %	2.00 %	40.50 %
EM1	15:00–15:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.50 %	0.50 %	1.00 %	0.00 %	2.00 %
EM2	16:00–16:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.50 %	0.50 %	2.00 %
EM3	17:00–17:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	2.50 %	1.00 %	3.50 %
UM4	18:00–20:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	2.00 %	4.50 %	6.50 %
UM5	21:00–02:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Total		0.50 %	0.00 %	0.00 %	0.50 %	17.50 %	13.50 %	25.50 %	11.00 %	20.50 %	11.00 %	100.00 %

Table 10: Outward and return tour legs by TP for home–education

Time of the outward leg		UM1(E) 03:00–04:59	UM2 05:00–06:59	MM1 07:00–07:59	MM2 08:00–08:59	UM3 09:00–14:59	EM1 15:00–15:59	EM2 16:00–16:59	EM3 17:00–17:59	UM4 18:00–20:59	UM1(L) 21:00–02:59	Total
		Time of the return leg										
UM1	03:00–04:59	0	0	0	0	0	0	0	0	0	0	0
UM2	05:00–06:59	0	0	0	0	0	0	3	0	0	0	3
MM1	07:00–07:59	0	0	0	0	6	1	1	1	1	1	11
MM2	08:00–08:59	0	0	0	0	10	6	8	3	3	4	34
UM3	09:00–14:59	0	0	0	0	19	1	8	4	10	6	48
EM1	15:00–15:59	0	0	0	0	0	0	0	0	0	1	1
EM2	16:00–16:59	0	0	0	0	0	0	0	0	1	1	2
EM3	17:00–17:59	0	0	0	0	0	0	0	0	3	2	5
UM4	18:00–20:59	0	0	0	0	0	0	0	0	1	3	4
UM5	21:00–02:59	0	0	0	0	0	0	0	0	0	0	0
Total		0	0	0	0	35	8	20	8	19	18	108

Time of the outward leg		UM1(E) 03:00–04:59	UM2 05:00–06:59	MM1 07:00–07:59	MM2 08:00–08:59	UM3 09:00–14:59	EM1 15:00–15:59	EM2 16:00–16:59	EM3 17:00–17:59	UM4 18:00–20:59	UM1(L) 21:00–02:59	Total
		Time of the return leg										
UM1	03:00–04:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
UM2	05:00–06:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	2.78 %	0.00 %	0.00 %	0.00 %	2.78 %
MM1	07:00–07:59	0.00 %	0.00 %	0.00 %	0.00 %	5.56 %	0.93 %	0.93 %	0.93 %	0.93 %	0.93 %	10.19 %
MM2	08:00–08:59	0.00 %	0.00 %	0.00 %	0.00 %	9.26 %	5.56 %	7.41 %	2.78 %	2.78 %	3.70 %	31.48 %
UM3	09:00–14:59	0.00 %	0.00 %	0.00 %	0.00 %	17.59 %	0.93 %	7.41 %	3.70 %	9.26 %	5.56 %	44.44 %
EM1	15:00–15:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.93 %	0.93 %
EM2	16:00–16:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.93 %	0.93 %	1.85 %
EM3	17:00–17:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	2.78 %	1.85 %	4.63 %
UM4	18:00–20:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.93 %	2.78 %	3.70 %
UM5	21:00–02:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
Total		0.00 %	0.00 %	0.00 %	0.00 %	32.41 %	7.41 %	18.52 %	7.41 %	17.59 %	16.67 %	100.00 %

Table 11: Outward and return tour legs by TP for home–shopping

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	0	0	0	0	0	0	0	0	0	0	0
UM2	05:00–06:59	0	0	1	0	0	0	0	0	0	0	1
MM1	07:00–07:59	0	0	0	0	0	0	0	0	0	0	0
MM2	08:00–08:59	0	0	0	1	4	0	0	0	1	0	6
UM3	09:00–14:59	0	0	0	0	164	30	13	8	4	1	220
EM1	15:00–15:59	0	0	0	0	0	6	11	4	7	0	28
EM2	16:00–16:59	0	0	0	0	0	0	9	17	20	5	51
EM3	17:00–17:59	0	0	0	0	0	0	0	19	41	1	61
UM4	18:00–20:59	0	0	0	0	0	0	0	0	87	7	94
UM5	21:00–02:59	0	0	0	0	0	0	0	0	0	3	3
Total		0	0	1	1	168	36	33	48	160	17	464

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
UM2	05:00–06:59	0.00 %	0.00 %	0.22 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.22 %
MM1	07:00–07:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
MM2	08:00–08:59	0.00 %	0.00 %	0.00 %	0.22 %	0.86 %	0.00 %	0.00 %	0.00 %	0.22 %	0.00 %	1.29 %
UM3	09:00–14:59	0.00 %	0.00 %	0.00 %	0.00 %	35.34 %	6.47 %	2.80 %	1.72 %	0.86 %	0.22 %	47.41 %
EM1	15:00–15:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.29 %	2.37 %	0.86 %	1.51 %	0.00 %	6.03 %
EM2	16:00–16:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.94 %	3.66 %	4.31 %	1.08 %	10.99 %
EM3	17:00–17:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	4.09 %	8.84 %	0.22 %	13.15 %
UM4	18:00–20:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	18.75 %	1.51 %	20.26 %
UM5	21:00–02:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.65 %	0.65 %
Total		0.00 %	0.00 %	0.22 %	0.22 %	36.21 %	7.76 %	7.11 %	10.34 %	34.48 %	3.66 %	100.00 %

Table 12: Outward and return tour legs by TP for home–leisure

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	1	0	0	0	0	0	0	0	0	0	1
UM2	05:00–06:59	0	3	2	0	1	1	0	0	0	0	7
MM1	07:00–07:59	0	0	5	15	6	1	2	1	1	1	32
MM2	08:00–08:59	0	0	0	36	43	2	9	3	3	3	99
UM3	09:00–14:59	0	0	0	0	226	68	48	43	42	24	451
EM1	15:00–15:59	0	0	0	0	0	15	28	12	19	11	85
EM2	16:00–16:59	0	0	0	0	0	0	28	26	45	22	121
EM3	17:00–17:59	0	0	0	0	0	0	0	16	93	65	174
UM4	18:00–20:59	2	0	0	0	0	0	0	0	153	287	442
UM5	21:00–02:59	2	0	0	0	0	0	0	0	0	87	89
Total		5	3	7	51	276	87	115	101	356	500	1501

Time of the outward leg		Time of the return leg										Total
		UM1(E)	UM2	MM1	MM2	UM3	EM1	EM2	EM3	UM4	UM1(L)	
		03:00–04:59	05:00–06:59	07:00–07:59	08:00–08:59	09:00–14:59	15:00–15:59	16:00–16:59	17:00–17:59	18:00–20:59	21:00–02:59	
UM1	03:00–04:59	0.07 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.07 %
UM2	05:00–06:59	0.00 %	0.20 %	0.13 %	0.00 %	0.07 %	0.07 %	0.00 %	0.00 %	0.00 %	0.00 %	0.47 %
MM1	07:00–07:59	0.00 %	0.00 %	0.33 %	1.00 %	0.40 %	0.07 %	0.13 %	0.07 %	0.07 %	0.07 %	2.13 %
MM2	08:00–08:59	0.00 %	0.00 %	0.00 %	2.40 %	2.86 %	0.13 %	0.60 %	0.20 %	0.20 %	0.20 %	6.60 %
UM3	09:00–14:59	0.00 %	0.00 %	0.00 %	0.00 %	15.06 %	4.53 %	3.20 %	2.86 %	2.80 %	1.60 %	30.05 %
EM1	15:00–15:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.00 %	1.87 %	0.80 %	1.27 %	0.73 %	5.66 %
EM2	16:00–16:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.87 %	1.73 %	3.00 %	1.47 %	8.06 %
EM3	17:00–17:59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	1.07 %	6.20 %	4.33 %	11.59 %
UM4	18:00–20:59	0.13 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	10.19 %	19.12 %	29.45 %
UM5	21:00–02:59	0.13 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	5.80 %	5.93 %
Total		0.33 %	0.20 %	0.47 %	3.40 %	18.39 %	5.80 %	7.66 %	6.73 %	23.72 %	33.31 %	100.00 %

3.2.6 Summary

Table 13 shows a summary across HB purposes of the number of alternatives and the numbers of tours by each type of TP combination (TPC) alternative.

Table 13: Summary of TP combination alternatives

Purpose		Outward and return legs represented in full detail	Outward legs aggregated	Both outward and return legs aggregated	Unavailable	Total available TPC alternatives and tours
home–work	TPC alternatives	19	7	1	NA	27
	tours	2221	268	90	4	2579
	% tours	86.0 %	10.4 %	3.5 %	0.1 %	99.9 %
home–business	TPC alternatives	12	6	1	NA	19
	tours	132	38	28	2	198
	% tours	66.0 %	19.0 %	14.0 %	1.0 %	99.0 %
home–education	TPC alternatives	12	6	1	NA	19
	tours	82	14	12	0	108
	% tours	76.0 %	13 %	11 %	0 %	100.0 %
home–shopping	TPC alternatives	28	NA	NA	NA	28
	tours	463	0	0	1	463
	% tours	99.8 %	0 %	0 %	0.2 %	99.8 %
home–leisure	TPC alternatives	36	NA	NA	NA	36
	tours	1489	0	0	7	1489
	% tours	99.2 %	0 %	0 %	0.8 %	99.2 %
Total	TPC alternatives	107	19	3	NA	129
	tours	4387	320	130	14	4837
	% tours	90.4 %	6.6 %	2.7 %	0.3 %	99.7 %

From the total row it can be seen that over 90% of tours are modelled with the outward and return tour legs represented in full detail. Taking account of TP alternatives where either outward legs are aggregated, or both outward and return legs are aggregated, then overall 99.7% of HB car driver tours are covered by the modelled TP combination alternatives, and just 0.3% of tours are excluded because the observed TP combination choice is not represented in the models.

3.3 Non-home–based purposes

There are ten possible TPs for NHB trips. Table 14 shows the distribution of NHB car-driver trips by purpose across the ten TPs, which form the TP alternatives in the NHB models. These alternatives have been shaded green for consistency with the shading used in Table 8 to Table 12 (where green denotes TP alternatives represented in full detail).

Table 14: NHB trips by purpose and TP

Time period		Business		Other	
		Trips	Percentage	Trips	Percentage
UM1	03:00–04:59	1	0.20 %	1	0.04 %
UM2	05:00–06:59	2	0.39 %	11	0.40 %
MM1	07:00–07:59	9	1.78 %	65	2.38 %
MM2	08:00–08:59	23	4.54 %	222	8.13 %
UM3	09:00–14:59	354	69.82 %	909	33.31 %
EM1	15:00–15:59	47	9.27 %	309	11.32 %
EM2	16:00–16:59	33	6.51 %	397	14.55 %
EM3	17:00–17:59	18	3.55 %	320	11.73 %
UM4	18:00–20:59	16	3.16 %	389	14.25 %
UM5	21:00–02:59	4	0.79 %	106	3.88 %
	Total	507	100.00 %	2,729	100.00 %

CHAPTER 4 Model development

This chapter documents the five key stages followed in the development of the OTM 6 mode-destination-TP choice models. The agreed scope of the model development work was to use the OTM 5 mode-destination model specifications as a starting point, and then extend these models to model TP choice for drivers. Re-testing the optimum model specifications was outside the scope of this work, though in fact some minor changes to the model specifications have been made as a result of the tour and trip length validations. For full documentation of the development of the OTM 5 mode-destination model specifications, please refer to Fox and Sivakumar (2006).

Section 4.1 documents the tests undertaken to verify that the estimation results obtained in 2006 could be replicated, and describes an issue with the tour timing information that was corrected before the models could be extended to include TP choice. Then Section 4.2 describes the changes made to the model structures in order to incorporate car driver TP choice. Section 4.3 documents the different tests that have been undertaken to determine the appropriate nesting structures that govern the sensitivity of car driver TP choice relative to the mode and destination choice decisions. Section 4.4 describes the steps that have been undertaken to validate the new OTM 6 models. Finally, Section 4.5 documents some minor changes that have been made to the model specifications to improve the fit of the models to the tour and trip length distributions observed in the samples of tours and trips used for model estimation.

4.1 Retrieve OTM 5 models

The first stage in the model development was to extract the final model files from the OTM 5 mode-destination model estimations. A test run was undertaken for the home–leisure purpose that verified that the original OTM 5 model results could be replicated exactly.

Initial investigations of the tour timing information revealed that the primary destination departure time reported in the existing tour file was inaccurate[6] for 98% of the records in the 2003 data and 96% of the records in the 2005 data. TetraPlan corrected the tour timing information and the percentage of the records with inaccurate primary destination

[6] Specifically, the primary destination departure time was earlier than primary destination arrival time and in most of the cases it was equal to the home departure time.

departure time information was reduced to 4% in the 2003 data and 10% in the 2005 data.

Mid-point timings were used to allocate outward and return tour-legs into the TPs represented in the models. Specifically, the average of the home departure time and primary destination arrival time was used to determine the TP of the outward leg of the tour, and the average of the primary destination departure time and home arrival time was used to determine the TP of the return leg of the tour. However, for records with inaccurate information for the primary destination departure time only the home arrival time was used to allocate the TP to the return leg of the tour. This approximation to the return tour leg mid-point timing was preferred to excluding the record altogether.

Note that the tour timing issue did not cause any errors in the OTM 5 models because they did not use the tour timing information. This is because the OTM 5 models did not model TP choice, and so were estimated using all-day LOS for all travel modes.

Following the supply of revised tour data with the tour timing problem corrected, the OTM 5 version of the home–leisure model was re-run and the results from 2006 were re-verified. The home–leisure model is estimated from 2005 TU data only, but both the 2003 and 2005 TU data were updated with corrected tour timing information. Therefore a second verification test was run for the commute model, which is estimated from both 2003 and 2005 TU data. The test verified that the original OTM 5 model parameters results were replicated when estimating using the corrected tour data.

4.2 Extending the structures to model car driver time period choice

Three changes to the model structure were required in order to incorporate TP choice for car drivers. First, LOS information split by TP needed to be read in, and average values by TP combination calculated (for those purposes where averages were required). Second, the choice of TP combination alternative needed to be defined for car driver observations. Finally, the utility functions needed to be extended to represent the TP combinations. These three changes are described in the following sub-sections.

4.2.1 LOS information split by time period

The LOS data supplied represent average travel conditions on a weekday. All LOS and cost data relate to the 2004 base year.

In order to model car driver TP choice, highway LOS information for travel in free flow and congested conditions has been supplied separately for the nine TPs defined in Table 7. The LOS is further segmented by the four travel purposes distinguished in the highway assignments for passenger transport:

- HW: home–work
- ED: home–education
- WW: business (used to model both HB and NHB business)
- OT: leisure (used to model home–shopping, home–leisure and NHB other)

For each combination of the nine TPs and four travel purposes, the following LOS information is supplied:

- origin
- destination
- travel time in minutes, free flow assignment
- distance in kilometres, free flow assignment
- travel time in minutes, congested assignment
- distance in kilometres, congested assignment
- parking cost in DKK
- toll cost in DKK, congested assignment
- parking search time in minutes, congested assignment

Home–based purposes

Once the LOS information by TP appropriate to the travel purpose has been read into the model, the code loops over the possible combinations of outward and return TP (note that as detailed in Chapter 3 these vary between the different HB purposes). For outward and return combinations, which are modelled in full detail, the LOS information specific to the outward and return TP can be used directly. For TP combinations where there is aggregation over the outward or return legs, the LOS is averaged over the TPs, which are aggregated. The LOS averaging is calculated using the observed numbers of car driver tours in the estimation sample for the TPs over which the averaging is applied.

The LOS information for the outward and return TP combination is then combined as follows:

- free flow time, sum of outward and return contributions
- free flow distance, sum of outward and return contributions
- congested time, sum of outward and return contributions
- congested distance, sum of outward and return contributions
- additional time spent in congestion, congested time minus free flow time
- additional distance due to congestion, congested distance minus free flow distance
- parking cost, primary destination end only as it is assumed individuals do not need to pay for parking at their home location
- toll cost, sum of outward and return contributions
- parking search time, sum of outward and return contributions, i.e. it is assumed individuals have to search for a parking space at both their home and primary destination locations

Each of these individual LOS components is then converted into car free flow time units using the procedure described in Section 5.2 of Fox and Sivakumar (2006). Car free flow time is used as a measure of generalised time in the OTM 5 and OTM 6 mode-destination models.

It is noted that in the final specifications the car passenger mode is modelled using all day demand-weighted average car LOS supplied by TetraPlan.

Non-home–based purposes

For the NHB purposes the calculations were more straightforward, as there is no aggregation over TPs, and therefore LOS for the modelled TP could be used directly. The

NHB models are represented as trips, and therefore the parking costs and search times at the destination end of the trip have been represented.

4.2.2 Choice of time period combinations

Home–based purposes

The choice of TP combination alternative for car driver observations is determined on the basis of the tour-leg timing information. The outward tour-leg TP is determined by taking the mid-point timing for the outward leg, calculated as the average of the home departure time and the primary destination arrival time. Similarly, the return tour-leg TP is determined by taking the mid-point timing for the return tour-leg, calculated as the average of the primary destination departure time and the arrival time back at home. For a low fraction of records, the departure from primary destination information is erroneous. For these records, the time the individual returned to home is used to specify the TP for the return leg. This approach is preferred to excluding the tour altogether as it maximises the amount of data available for estimation.

NHB purposes

For the NHB purposes, the choice of TP alternative for car driver observations is determined on the basis of the trip timing information. The chosen TP is determined from the mid-point timing for the trip, calculated as the average of the trip departure and arrival times. Note that the issues with the timing information for HB tours do not affect the NHB trip records.

4.2.3 Extending the utility files

In the OTM 5 estimations, a utility function was defined separately for each possible combination of mode and destination alternative. For car driver, these utility functions needed to be extended so that a utility function was defined for each combination of destination and TP combination alternative. For modes other than car driver, TP choice is not modelled and therefore no changes to the utility functions were required. As detailed in Table 13, the number of TP combination alternatives varies between the different travel purposes, and therefore the number of utility functions that needed to be defined for each destination varied accordingly.

4.3 Tree structure tests to determine relative sensitivity of time period choice

A key stage in the model development work was to run tests for each model purpose to identify the optimal model structure that determines the sensitivity of car driver TP choice relative to the mode and destination choices. Tests were undertaken for the three model structures presented in Section 2.5:

- modes above TPs above destinations
- destinations above modes above TPs
- modes above destinations above TPs

In each model structure, two structural parameters can be estimated that determine the relative sensitivity of choices adjacent in the tree structure. If either of these two parameters was significantly greater than 1 then the model structure could be rejected altogether.

However, in many of the tests undertaken it was not possible to estimate the two structural parameters simultaneously, and so tests were made where one of the structural parameters was fixed to 1, and the other was estimated. In some cases, it was necessary to fix both structural parameters to 1, so that the model reduces to a multinomial choice between mode, TP and destination alternatives.

In choosing between different candidate structures, the following criteria were considered:

- the overall fit of the model to the data
- the plausibility of the model elasticities, and their consistency with the OTM 5 values
- consistency with SP evidence on the relative sensitivity of mode and TP choices
- consistency with the relative sensitivity of mode and destination choice decisions in the final OTM 5 models

The selection of the final model structure represented a balance between these different criteria. In the following chapters, which detail the results for each travel purpose, the balance of evidence across these four criteria is set out.

4.3.1 Stated preference evidence on relative sensitivities of mode and time period choices

When choosing between different candidate structures, the relative sensitivity of the mode and TP choice decisions was compared to evidence from SP studies. The most appropriate reference for this work is Hess *et al.* (2007), which reports on the development of models where time is aggregated into discrete TPs. Hess *et al.* present a summary of the results from models for mode and TP choice estimated from three datasets of SP interviews with car drivers:

- APRIL data, collected in 1992 from around 1000 car drivers in inner and outer London
- Netherlands data, collected in 2000 from around 1000 car drivers and train users across the Netherlands (the results from models estimated from the car drivers only have been used in this study)
- PRISM data, collected in 2003 from 550 car drivers interviewed in the West Midlands region of the UK

Table 9 of Hess *et al.* presents a summary of the estimates of the relative sensitivity of mode and TP choice decisions from each of these three datasets. These results are presented separately for models using 15-minute TPs, one-hour TPs, and five coarse TPs.[7] The results show that the shorter in duration the TP alternatives are, the more sensitive TP choice is relative to mode choice.

The ten TPs used in the OTM 6 models give a level of detail that lies between using one-hour TPs and five coarse TPs. Interpolating the Table 9 results from Hess *et al.* on this basis, and giving much less weight to the earlier APRIL data, which give less consistent model results, gave the ranges for the structural parameters that define the relative sensitivity of mode and TP choice decisions shown in Table 15. A value of 1 for the

[7] AM off-peak, AM peak, interpeak, PM peak, PM off-peak.

structural parameter implies mode choice and TP choice are equally sensitive to changes in utility. Values less than 1 imply TP choice to be more sensitive than mode choice.

Table 15: Structural parameters for mode and TP choices from SP evidence

OTM 6.0 purpose	Range of structural parameters for mode and TP choice
home–work	0.45–0.90
home–business	0.30–0.90
home–education	no information
home–shopping	0.40–0.60
home–leisure	0.40–0.60
NHB business	no information
NHB other	no information

Source: Table 9, Hess *et al.* (2007).

Thus for purposes where SP evidence exists, the indication from this evidence is that TP choice should lie beneath (is more sensitive than) mode choice in the choice structure.

4.4 Model validation

Once a candidate model was identified from the tree structure tests, three sets of validation tests were undertaken before the model was accepted as the final model:

- review of mode-destination elasticities
- review of TP choice elasticities
- analysis of tour and trip length distributions

These three sets of tests are described in the following sub-sections.

4.4.1 Mode-destination elasticities

Elasticities have been calculated for the 'best' mode-destination-TP models, as described in the following chapters. These models include TP choice for car drivers, but in the elasticity tests described in this section the focus is on the mode and destination choice responses. These elasticities have been calculated by sample enumeration, applied to the sample of TU tour data used to estimate the mode-destination models. It should be emphasised that these elasticities are based on unexpanded samples of tours observed in the TU data, and will therefore be affected by any sampling or response biases that affect the TU data. In particular, the 2005 data were surveyed from two municipalities in central Copenhagen to target areas where the new metro route runs, and consequently the sample of origins reflects the bias towards central areas.

Furthermore, the elasticities are calculated on the basis that no tours are generated or suppressed as a result of the policy changes, i.e. total demand is constant.

For each model purpose, four hypothetical policy changes were tested:

- 10% increase in car costs – applied to distance based costs, toll cost and parking costs
- 10% increase in car times
- 10% increase in PT costs

- 10% increase in all PT in-vehicle times – PT out-of vehicle times are left unchanged

All of these changes are applied to the tour LOS (out and back) in the five HB tour models.

This set of four tests allowed the model elasticities to be compared to the values obtained in the final OTM 5 models. If significant changes in the elasticities are observed between the OTM 5 and OTM 6 models, then this will result in substantial differences in the responsiveness of the two model systems to the same policy test, and therefore the level of consistency with the OTM 5 elasticity values was an important consideration when choosing between different candidate model structures.

The results of the tests for each travel purpose are set out in the following chapters. Note that the car passenger elasticity is positive in the car cost elasticity run, because in the models it is assumed that all car costs are paid by the driver. Thus when the cost of car driver alternatives increases, the utility of car driver decreases and it becomes less attractive relative to car passenger. Some of the demand that switches from car driver moves to car passenger, and an increase in occupancy is observed.

Because the models reflect both mode and destination choice, the policy tests will result in both mode and destination choice changes, the latter leading to changes in tour lengths. These are reflected in the kilometrage elasticities. The differences between the kilometrage and demand figures indicate the size of the tour length elasticities. For example, if the car cost tour elasticity is -0.06 and the kilometrage elasticity is -0.09 then the tour length elasticity is -0.03. It is noted that the own-time elasticities, i.e. car time reduction for car and PT time reduction for PT, incorporate much higher tour length elasticities.

The elasticity calculations assume no changes in car ownership or residential location in response to the policy changes. Therefore the results should be viewed as medium-term elasticity values when comparing them with published elasticity values.

4.4.2 Time period elasticities

To validate the performance of the new TP choice component of the models, an additional validation step was introduced to investigate the sensitivity of the car driver TP choice models to changes in travel conditions in a particular TP. To allow comparison with results from other studies, a TP sensitivity test reported in the literature by De Jong *et al.* (2003) was used. The models reported in De Jong *et al.* differ in that the choice between TP alternatives is modelled using a mixed logit model, which takes account of different levels of correlation between different TP alternatives, in particular that individuals are more likely to switch to TPs close in time to their current TP in response to a change in travel conditions in their current TP. As discussed earlier, the runs times associated with implementing complex models of this type mean they are not yet feasible in large-scale models, and thus are not incorporated in the OTM. Nonetheless, the results reported in De Jong *et al.* do provide external evidence on the level of reduction in demand expected in a TP in response to an increase in travel time in that TP.

De Jong *et al*. applied a 10% increase to travel times for the *outward* tour legs of car driver tours, and then calculated the percentage changes in demand predicted by the model, distinguishing the changes to the distribution of demand over outward tour legs, the changes to the distribution of demand over return tour legs, and the degree of mode shift (to just train in their models). Note that while De Jong *et al.* reported model results for four different travel purposes, they only reported the result of this sensitivity test for the model developed for home–work travel.

Following the test specified by De Jong *et al.,* for the HB purposes, a 10% increase to outward journey times in the 08:00–08:59 TP was applied, and the impact on percentage changes in demand for all the outward and return TPs was calculated, as well as the percentage increase in demands for modes other than car driver. The single exception to this is the home–shopping model, where there are relatively few tours making outward journeys in the 08:00–08:59 TP, and therefore the 10% increase has been applied to the outward journey times in the 09:00–14:59 TP instead.

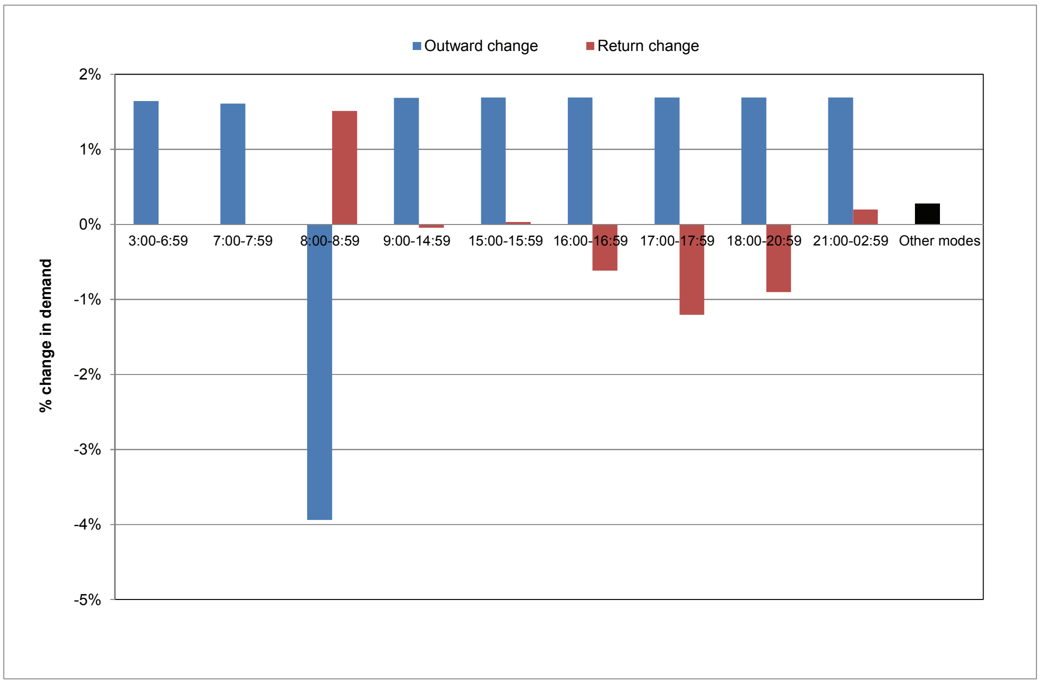
For the *outward* TPs, we expect reductions in demand in the 08:00–08:59 TP, and increases in demand in all of the other outward TPs. In fact, because the choice between different TP combination alternatives is multinomial, we expect the *percentage increases* in demand for the other outward TPs to be uniform. To model greater shifting to adjacent TPs, cross-nested or mixed logit formulations would need to be used (as noted above, De Jong *et al.* applied the mixed logit approach).

For the *return* TPs, demand in a given TP may either increase or decrease following the changes to the outward TP distribution. In most cases the tests demonstrate a shift in the return TP distribution towards later in the day.

In addition to shifts in the TP distributions, the increase in travel times in the 08:00–08:59 period results in a reduction in the attractiveness of the car driver mode as a whole, and as a result some demand shifts to other modes. The degree of shifting to other modes depends on the relative sensitivity of the TP combination alternative and mode choice decisions. The shifts to other modes are presented as a percentage of the base demand for the other modes. The degree of shifting is typically very low as a percentage of base demand for the other modes, but is more substantial when calculated as a fraction of the car driver demand that shifts away from the 08:00–08:59 TP.

Figure 4 illustrates the results from the TP combination elasticity test for the final home–work model, where travel times in the MM2 (08:00–08:59) TP are increased by 10%.

Figure 4: Time period combination elasticity test



The model predicts a reduction in demand of 3.7% in the MM2 period, and uniform increases of 1.6% in demand for the other TPs. For the return distribution, we observe an increase in tours returning in the 08:00–08:59 period as a result of increases in the numbers of tours departing before 08:00 (but the absolute numbers are very small as few tours return in this TP), and reductions in demand between 16:00 and 20:59 when the majority of return tour legs that correspond to outward tours made between during the 08:00–08:59 TP take place. There is a net reduction of trips of 13.88, which shifts to other modes. This represents just 0.28% of base demand for other modes, but represents 37% of the number of trips that shift away from the 08:00–08:59 outward TP.

Similar tests have been undertaken for the NHB models. The results are more straightforward to interpret as we do not consider combinations of TP alternatives in the NHB models. The tests result in a reduction in demand for the 08:00–08:59 TP where the change is made, and uniform increases in demand for the other TPs because the choice between different TPs is multinomial, as well as some increase in demand for modes other than car driver.

4.4.3 Tour and trip length validation

To validate the ability of the OTM 6 models to replicate the tour and trip length distributions observed in the estimation samples, two sets of comparisons have been made:

- a comparison of observed and predicted mean tour/trip lengths for each of the five modes modelled
- comparisons of observed tour/trip length distributions for all modes, and separately for the key PT and car driver modes

When comparing the observed and predicted tour/trip length distributions, it is important to take account of the volume of observed data by tour/trip length band in order to determine whether differences between observed and predicted data are statistically significant. In order to do this, the standard errors for the observed distributions have been calculated assuming a binomial distribution for each trip/tour length band:

$$se_t = \sqrt{np_t q_t}$$

where:

se_t is the standard error associated with the prediction in band t

n is the total number of records

p_t is the predicted probability of choosing band t

q_t is calculated as (1- p_t)

t is the tour or trip length band

The test that has been made is that the predicted distribution lies within two standard errors of the observed. This is approximately equivalent to using 95% confidence limits.

It is noted that as a result of this validation step, some additional terms were added to the models to improve the fit to the observed car and PT tour and trip length distributions.

4.5 Distance correction terms

The plan for this project was to retain the final OTM 5 model specifications, with the only changes to the models being those required to model TP choice for car drivers. However, during validation of the tour and trip length distributions for the candidate models, for some travel purposes significant differences between the observed and predicted distributions were observed for car driver and PT modes. To correct these differences, additional distance correction terms have been added for the car driver and PT modes for these travel purposes. Distance correction terms have not been added for other modes; in particular the treatment of the car passenger mode in each of the models is unchanged relative to the OTM 5 model specifications.

CHAPTER 5 **Home–work model**

5.1 Structural tests

The starting point for the structural tests for the home–work model was the final OTM 5.3 model, which had destinations above modes, with a structural parameter θ_{M_D} of 0.735 (with a t-ratio with respect to one of 10.1).

Given that the OTM 5.3 estimations had identified this structure, model structure 2 was used for the first set of structural tests, because it has destinations above modes above TPs. Table 16 summarises the results of structural tests undertaken with this structure. For the structural parameters (TR_D_M, TR_M_TP) the t-ratios reported are calculated relative to a value of 1.

Table 16: Home–work structural tests, structure 2: destinations above modes above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
5	-56452.5	42	TR_D_M	0.765	7.9	yes	0.104
			TR_M_TP	0.917	0.6		0.919
			CarFFTime	-0.020	-7.1		n/a
8	-56452.6	41	TR_D_M	0.762	8.3	yes	0.827
			TR_M_TP	1.000	*		n/a
			CarFFTime	-0.018	-18.1		n/a
10	-56431.5	43	TR_D_M	0.804	6.1	yes	0.836
			TR_M_TP	1.000	*		n/a
			CarFFTime	-0.017	-17.0		n/a
11	-56433.4	43	TR_D_M	0.823	5.4	yes	0.830
			TR_M_TP	0.700	*		n/a
			CarFFTime	-0.024	-17.0		n/a

In model 5, both structural parameters were estimated. Although both structural parameters lie between 0 and 1, the TR_M_TP parameter was not significantly different from 1, and therefore this parameter was constrained to a value of 1 in model 8.

Model 10 is equivalent to model 8, but with two additional distance correction parameters added to improve the fit to the observed car driver and PT trip length distributions. The magnitude of the TR_D_M structural parameter increases from 0.762 to 0.804, but the parameter remains significantly different from 1.

Finally, model 11 draws on SP evidence to fix the relative sensitivity of the mode and TP choice decisions, which means fixing the TR_M_TP parameter to a value of 0.700 (taken from the range of values presented in Table 15). This results in a small loss of fit to the observed data (1.9 log-likelihood points). Elasticities and trip lengths were compared for models 10 and 11. Model 11 was slightly less elastic than model 10, but the elasticities from model 11 were in line with those obtained during the OTM 5.3 estimations. The fit of the two models to the observed tour lengths was similar. Overall, it was decided to accept the small loss of fit to the data with model 11 in order to provide a model that was consistent with the SP evidence on the relative sensitivity of mode and TP choices.

Model 11 using structure 2 was a candidate model for implementation.

A second set of structural tests was undertaken for model structure 1, with modes above TPs above destinations. The results from these tests are summarised in Table 17.

Table 17: Home–work structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
6	-56472.4	42	TR_M_TP TR_TP_D CarFFTime	0.699 1.056 -0.01346	1.8 0.2 -28.0	yes	-0.04 0.059 n/a
7	-56472.5	41	TR_M_TP TR_TP_D CarFFTime	0.737 1 -0.01347	5.1 * -28.1	yes	0.058 n/a n/a

In model 6, the TR_TP_D parameter was not significantly different from a value of 1, and therefore in model 7 the parameter was fixed to a value of 1. This gives a structure with mode choice at the highest level, with TP and destination choices equally sensitive to changes in utility. The comparable model from Table 16 using structure 2 was model 8. Model 8 fits the data significantly better (the likelihood is 19.9 points higher for the same number of degrees of freedom), and therefore the best model from structure 2, model 11, remained the candidate model for implementation.

Following completion of the structural tests, a change was made to the specification of the car passenger LOS. Model tests up to 11 had calculated all-day LOS for car passenger as an unweighted average of the car LOS over the different model TPs. In the final model that has been used in implementation, model 14, all-day car LOS supplied by TetraPlan has been used, which is weighted by the distribution of base matrix demand over the day.

5.2 Final model parameters

The final model parameters from model COM_CD_TP_V14 are compared to the final OTM 5.3 parameters (model COM_68_T1) in Table 18. We note that there are three fewer observations in the OTM 6.0 specification, because of the exclusion of three car driver records for TP combinations that are not modelled.

Table 18: Home–work parameter comparison

	OTM 5.3	OTM 6.0
File	COM_68_T1.F12	COM_CD_TP_V14.F12
Converged	True	True
Observations	7325	7322
Final log (L)	-49025.0	-56394.4
D.O.F.	15	43
$Rho^2(0)$	0.166	0.162
$Rho^2(c)$	-5.056	-2.705
Estimated	3 Aug 06	1 Aug 13
Scaling	1.0000	1.0000

Attraction variable				
TotEmp	1.000	(*)	1.000	(*)
LOS variables				
CarFFTime	-0.01736	(-20.0)	-0.02516	(-19.3)
PTWtTfrTm	-0.02967	(-9.6)	-0.03714	(-7.7)
PTAcEgTm	-0.01147	(-4.2)	-0.01537	(-5.2)
CarPDist	-0.03336	(-7.3)	-0.04499	(-7.4)
CycleDist	-0.1803	(-32.0)	-0.2429	(-30.9)
WalkDist	-0.8355	(-26.1)	-1.159	(-26.0)
Distance correction parameters				
M3DistCD			0.2359	(3.2)
M2DistPT			0.3518	(4.5)
Car availability parameters				
PTCarAv	-0.7478	(-11.1)	-1.072	(-11.4)
CarPCarHH	1.538	(8.2)	2.141	(8.1)
CarDCarHH	1.341	(11.1)	1.908	(11.4)
Mode specific constants				
CarP	-2.757	(-19.2)	-0.4038	(-1.8)
PT	0.4732	(3.8)	3.875	(19.7)
Cycle	1.270	(14.3)	5.093	(31.5)
Walk	2.435	(17.3)	6.713	(30.2)
Scaling parameter				
2003_scale	1.474	(29.8)	1.225	(37.0)
Structural parameters				
TR_D_M	0.7350	(28.0)	0.8070	(27.4)
TR_M_TP			0.7000	(*)
Time period combination constants				
TP_14			-3.476	(-5.2)
TP_15			-0.2269	(-1.5)
TP_16			-0.3682	(-2.2)
TP_17			-0.2774	(-1.7)
TP_18			-1.228	(-5.4)
TP_19			-1.035	(-5.1)
TP_110			-2.052	(-6.6)
TP_310			-0.7993	(-4.2)
TP_34			-4.151	(-4.2)
TP_35			-0.1256	(-0.8)
TP_36			0.4222	(3.0)
TP_37			0.8813	(6.8)
TP_38			0.3737	(2.7)
TP_39			0.3026	(2.2)
TP_44			*-99.000*	*(*)*
TP_45			0.02386	(0.2)
TP_46			0.1521	(1.0)
TP_47			1.155	(9.3)
TP_48			1.230	(10.2)
TP_49			1.090	(9.0)
TP_410			-0.2225	(-1.4)
TP_510			-0.1347	(-0.9)
TP_55			-0.6804	(-3.8)
TP_56			-0.7938	(-4.1)
TP_57			0.1177	(0.8)
TP_58			0.3221	(2.3)
TP_59			0.4611	(3.5)
TP_oth			0	(*)

It can be seen that two additional distance correction terms have been added to the model specification to improve the fit to the observed car driver and PT tour length distributions:

- M3DistCD, for car driver tours in the 20–40 km band
- M2DistPT, for PT tours in the 10–20 km band

The 'TP_oth' constant is the base TP alternative (all tours leaving the home after 15:00). The 'TP_44' constant is set to -99 and the TP alternative set to be unavailable as there were no observed tours for that TP combination (both outward and return tour legs in the 08:00–08:59 TP).

5.3 Model elasticities

The mode-destination tour elasticities for the final OTM 6.0 and 5.3 models are compared in Table 19. Direct elasticities are highlighted in bold.

Table 19: Home–work tour elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.092	0.143	**-0.378**	**-0.355**
Car driver	**-0.207**	**-0.269**	0.066	0.070
Car passenger	0.190	**-0.346**	0.140	0.135
Cycle	0.098	0.155	0.151	0.137
Walk	0.082	0.128	0.136	0.112
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.083	0.143	**-0.352**	**-0.341**
Car driver	**-0.197**	**-0.267**	0.063	0.069
Car passenger	0.178	**-0.349**	0.135	0.134
Cycle	0.097	0.158	0.145	0.135
Walk	0.088	0.131	0.131	0.110
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	11.3%	0.3%	7.5%	4.2%
Car driver	5.2%	0.7%	5.5%	1.9%
Car passenger	6.7%	-1.0%	3.6%	0.4%
Cycle	1.3%	-1.9%	4.3%	1.5%
Walk	-7.0%	-2.4%	3.6%	2.2%
Total	n/a	n/a	n/a	n/a

Most of the OTM 6.0 tour elasticities show modest increases in sensitivity relative to the OTM 5.3 values. The sensitivities to car time and PT in-vehicle time changes remain relatively low.

Table 20 compares the kilometrage elasticities in the final OTM 6.0 and 5.3 models.

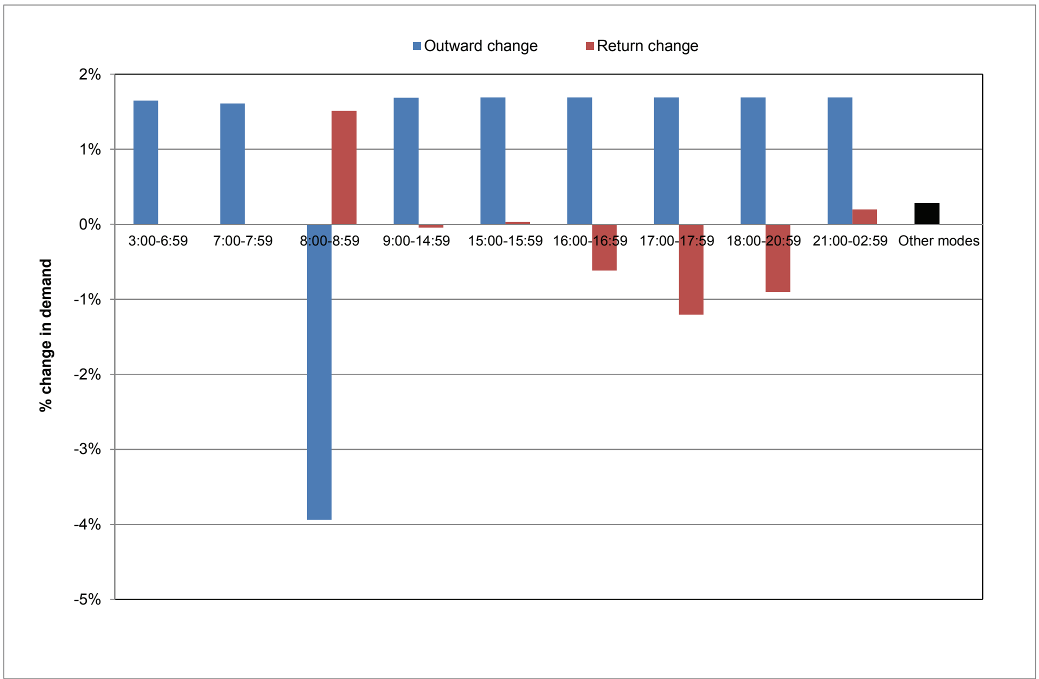
Table 20: Home–work kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.154	0.210	**-0.536**	**-0.572**
Car driver	**-0.427**	**-0.487**	0.084	0.094
Car passenger	0.256	**-0.553**	0.169	0.166
Cycle	0.107	0.170	0.161	0.151
Walk	0.084	0.131	0.138	0.116
Total	-0.122	-0.143	-0.084	-0.092
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.119	0.195	**-0.494**	**-0.550**
Car driver	**-0.398**	**-0.532**	0.076	0.088
Car passenger	0.217	**-0.571**	0.160	0.162
Cycle	0.104	0.174	0.154	0.150
Walk	0.089	0.135	0.134	0.114
Total	-0.117	-0.164	-0.089	-0.102
Changes	Car cost	Car time	PT cost	PT time
PT	29.7%	7.8%	8.6%	4.1%
Car driver	7.4%	-8.5%	10.4%	6.4%
Car passenger	18.0%	-3.2%	5.5%	2.5%
Cycle	3.0%	-2.0%	4.3%	1.0%
Walk	-5.5%	-2.8%	3.2%	1.4%
Total	4.3%	-12.6%	-5.7%	-10.0%

Most of the kilometrage elasticity changes are modest.

To test the sensitivity of the car driver TP choice model to changes in travel conditions in the peak periods, a 10% increase has been applied to outward level travel times in the 08:00–08:59 TP. Figure 5 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

Figure 5: Changes in home–work car driver demand, 10% increase to outward times in 08:00–08:59 period



Examining first the impact on the outward distribution, there is a 3.7% decline in demand in the 08:00–08:59 TP, which implies a direct elasticity of -0.42. There is a uniform increase in demand for all other outward TP bands of 1.7%, which occurs because the choice between TP combinations is multinomial, so each alternative outward TP alternative is equally attractive. De Jong *et al.* (2009) reported a 3.9% decline in demand for AM peak commute travel in response to a 10% increase in travel times in the AM peak in a comparable test applied to models estimated from Dutch SP data. Thus the direct tour elasticity response in the OTM 6.0 model is very similar to that obtained by De Jong *et al.* for commute travel.

As detailed in Section 3.2.1, only return TPs after 08:00 are modelled for home–work. For the return distribution, we observe an increase in tours returning in the 08:00–08:59 period as a result of increases in the numbers of tours departing before 08:00 (but the absolute numbers are very small as few tours return in this TP), and reductions in demand between 16:00 and 20:59 when the majority of return tour legs that correspond to outward tours departing during the 08:00–08:59 TP take place. There is a net reduction of trips of 13.88, which results in a 0.3% increase in demand for other modes. The number of trips that shift to other modes (13.88) is equivalent to 37% of the number of trips that shift away from the 08:00–08:59 outward TP (37.57).

5.4 Tour lengths

Table 21 compares mean observed and predicted tour lengths for each of the five modes of travel represented in the home–work model.

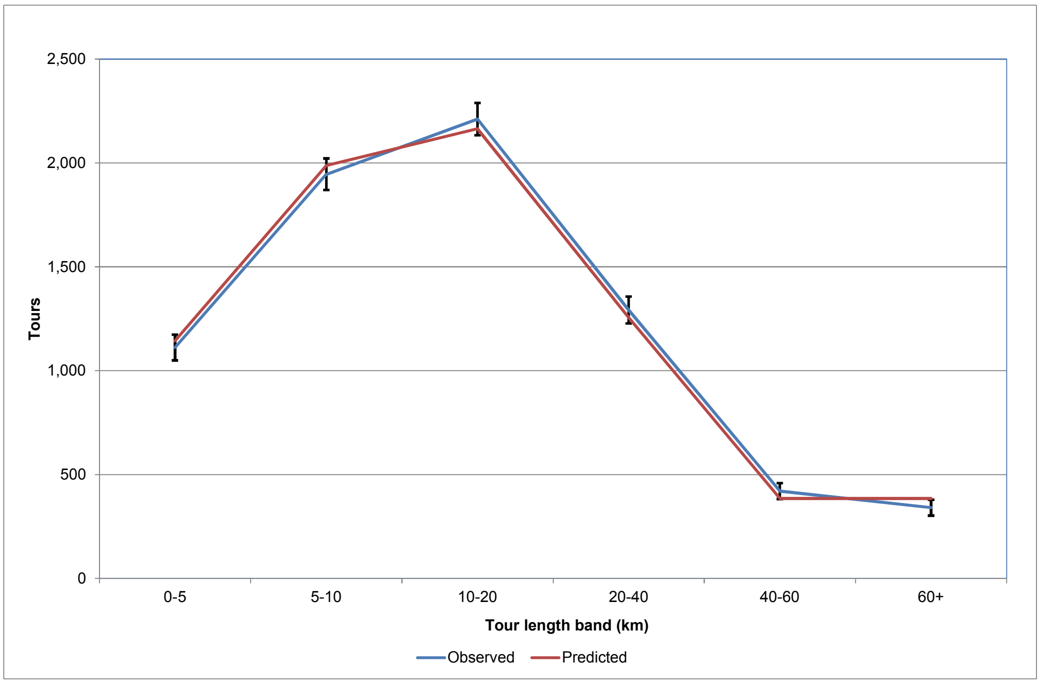
Table 21: Home–work tour lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	23.13	23.81	2.95%
car driver	26.22	26.47	0.95%
car passenger	19.10	18.80	-1.60%
cycle	9.45	9.40	-0.56%
walk	3.19	3.31	3.96%
Total	18.13	18.35	1.24%

Overall tour lengths are predicted closely with an error of just 1.2%, and tour lengths for individual modes are all predicted within ±4.0%. The largest difference is the 4.0% over-prediction of walk tour lengths.

Observed and predicted car driver tour length distributions are compared in Figure 6.

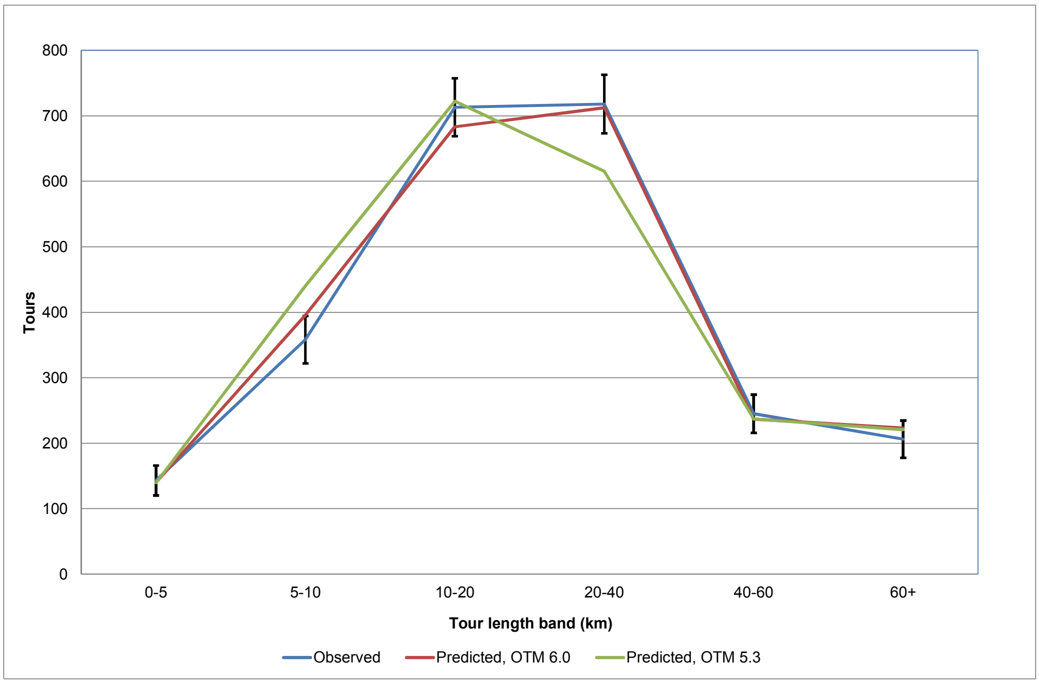
Figure 6: Home–work tour length distributions, all modes



The predicted distribution lies within twice the standard error of the observed values for all of the trip length bands.

Figure 7 plots the tour length distributions for car driver. To demonstrate the impact of the additional distance correction term for tours in the 20–40 km band, the predicted distributions are plotted for both the OTM 5.3 and OTM 6.0 models.

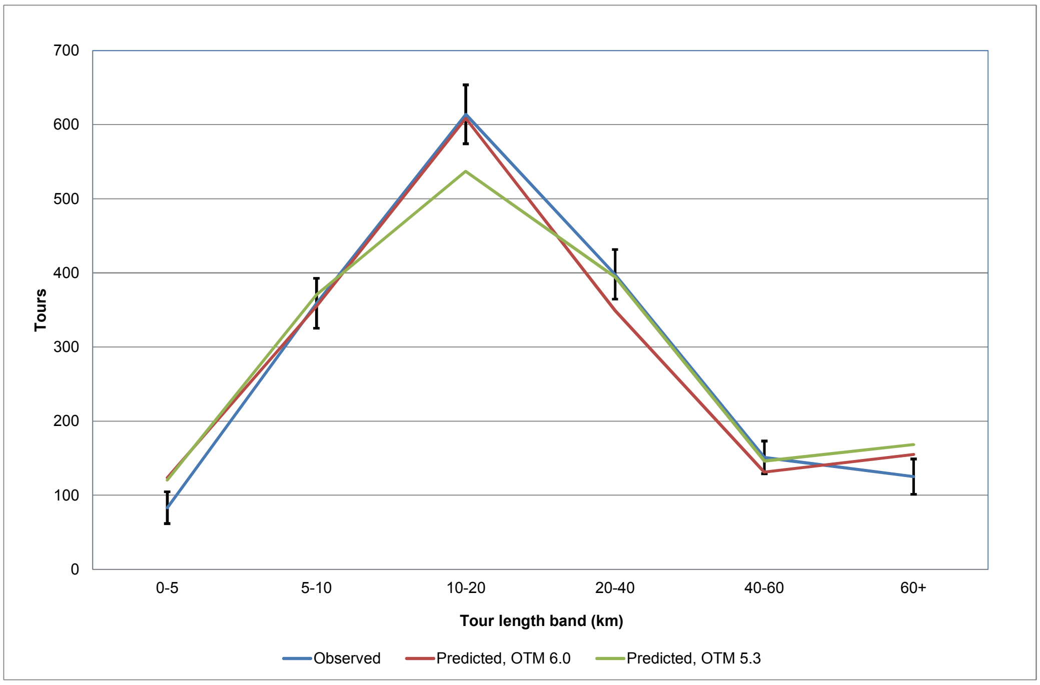
Figure 7: Home–work tour length distributions, car driver



In the OTM 6.0 model, the predicted distribution fits the observed well, lying within the standard deviations for the observed values for all but one of the tour length bands (5–10km).

Figure 8 plots the tour length distributions for PT. To demonstrate the impact of the additional distance correction term for tours in the 10–20 km band, the predicted distributions are plotted for both the OTM 5.3 and OTM 6.0 models.

Figure 8: Home–work tour length distributions, PT



The fit to the observed distribution is reasonable in OTM 6.0. Now that tours in the 10–20 km band are predicted exactly there is some under-prediction in the 20–40 km band. Adding further distance correction terms may result in higher errors for other tour length bands, and would be likely to reduce the magnitude of the generalised car free flow parameter, which would damp the sensitivity of the models. Therefore the OTM 6.0 PT tour length distribution, which shows an improvement in fit to the data relative to OTM 5.3, was judged to be acceptable.

CHAPTER 6 Home–business model

6.1 Structural tests

The starting point for the structural tests was the final OTM 5.3 model structure, which had a multinomial structure for mode and destination choice.

Models were run for all three of the candidate structures described in Section 2.5. Table 22 to Table 25 summarise the results obtained for each model specification.

Table 22: Home–business structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
9	-2720.1	32	TR_M_TP TR_TP_D CarFFTime	0.254 3.153 -0.00535	1.5 0.4 -5.4	yes	-0.133 0.143 n/a

In model 9 the TR_TP_D parameter was much greater than 1, implying that destination choice should be above TP choice. Therefore no further model development was undertaken with structure 1.

Table 23: Home–business structural tests, structure 2: destinations above modes above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
6	-2719.2	32	TR_D_M TR_M_TP CarFFTime	1.238 0.154 -0.02494	0.9 7.1 -1.5	yes	0.011 0.864 n/a
10	-2719.7	31	TR_D_M TR_M_TP CarFFTime	1 0.2113 -0.02506	* 5.2 -1.5	yes	N/A 0.964 n/a
15	-2720.2	30	TR_D_M TR_M_TP CarFFTime	1 0.6 -0.00897	* * -5.5	yes	n/a n/a n/a

In model 6, the TR_D_M parameter was not significantly greater than 1, and so in model 10 the parameter was fixed to a value of 1. In model 10, destination and mode choice are equally sensitive to changes in utility, consistent with the final OTM 5.3 model structure for business. The TR_M_TP parameter is low in magnitude, which implies a high sensitivity to TP choice relative to main mode choice.

In model 15, the value for the TR_M_TP parameter was imported from SP evidence (using the mid-point of the range of values presented in Table 15). This resulted in a small loss of fit to the data (0.5 log-likelihood points) relative to model 10. However, the mode-destination elasticities were slightly higher and more plausible in model 15, and therefore it was decided to accept the small loss of fit to the observed data in order to achieve consistency with the SP evidence on the relative sensitivity of mode and TP choices, and to yield slightly higher and more plausible mode-destination elasticities.

Thus model 15 was a candidate model for implementation.

Table 24: Home–business structural tests, structure 3: modes above destinations above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
7	-2764.3	32	TR_M_D TR_D_TP CarFFTime	2.602 0.0688 -0.04462	11.1 55.5 -3.7	yes	-0.364 0.609 n/a

The TR_M_D parameter was significantly greater than 1 in this test, and therefore this model structure was rejected.

On completion of the structural tests, model 15 was identified as the candidate model for implementation. After the structural tests had been completed, the final model specification was re-estimated using weighted all-day car LOS for car passenger, rather than using all-day LOS calculated as an unweighted average over TPs. This change was incorporated in model 17, which is the final model that has been implemented.

6.2 Final model parameters

The final model parameters from model BUS_CD_TP_V17 are compared to the final OTM 5.3 parameters (model HBEB_29) in Table 25. There are four fewer observations in the OTM 6.0 model because car driver observations were excluded where the chosen TP combination is not modelled.

Table 25: Home–business parameter comparison

```
                              OTM 5.3              OTM 6.0
File                      HBEB_29.F12  BUS_CD_TP_V17.F12
Converged                        True                 True
Observations                      340                  336
Final log (L)                 -2331.7              -2719.3
D.O.F.                             12                   30
Rho²(0)                         0.148                0.124
Rho²(c)                        -5.173               -2.490
Estimated                    7 Aug 06             1 Aug 13
Scaling                        1.0000               1.0000

Attraction variable
TotEmp                 1.000      (*)       1.000      (*)

LOS variables
CarFFTime           -0.00524  (-5.8)    -0.00913  (-5.5)
PTWtTfrTm           -0.03839  (-2.8)    -0.06953  (-2.6)
CarPDist            -0.03279  (-2.2)    -0.05549  (-2.2)
CycleDist            -0.1742  (-7.6)     -0.2879  (-7.6)
WalkDist             -0.5816  (-5.8)     -0.9619  (-5.8)

Intrazonal constant
Intra                  1.699   (5.1)       2.900   (5.2)
```

Car availability parameters				
CarDCarHH	1.307	(2.7)	2.102	(2.6)
PTCarAv	-1.466	(-4.3)	-2.502	(-4.4)
Mode specific constants				
CarP	-1.651	(-3.5)	-0.8683	(-1.1)
PT	1.069	(2.6)	2.916	(4.0)
Cycle	1.233	(3.3)	3.881	(6.0)
Walk	1.922	(3.8)	5.008	(5.7)
Scaling parameter				
2003_scale	1.000	(*)	1.000	(*)
Structural parameters				
TR_D_M			1.000	(*)
TR_M_TP			0.6000	(*)
Time period combination constants				
TP_25			-1.772	(-3.3)
TP_26			-1.729	(-3.2)
TP_27			-0.7945	(-2.1)
TP_28			-3.120	(-3.1)
TP_29			-1.780	(-3.3)
TP_210			-2.107	(-3.4)
TP_45			-1.352	(-3.0)
TP_46			-0.8940	(-2.3)
TP_47			-0.2235	(-0.7)
TP_48			-1.026	(-2.5)
TP_49			-2.458	(-3.3)
TP_410			-2.063	(-3.4)
TP_55			-0.2570	(-0.8)
TP_56			-0.8448	(-2.2)
TP_57			-0.8085	(-2.1)
TP_58			-1.083	(-2.7)
TP_59			-0.9073	(-2.4)
TP_510			-2.527	(-3.4)
TP_oth			0	(*)

The ‘TP_oth’ constant is the base TP alternative (all tours leaving the home after 15:00).

6.3 Model elasticities

The mode-destination tour elasticities of the final OTM 6.0 and 5.3 models are compared in Table 26. Direct tour elasticities are highlighted in bold.

Table 26: Home–business tour elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.070	0.050	**-0.080**	**-0.273**
Car driver	**-0.131**	**-0.068**	0.009	0.033
Car passenger	0.165	**-0.089**	0.032	0.106
Cycle	0.130	0.088	0.033	0.108
Walk	0.117	0.078	0.036	0.111
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.065	0.051	**-0.072**	**-0.259**
Car driver	**-0.120**	**-0.068**	0.008	0.033
Car passenger	0.153	**-0.089**	0.029	0.102
Cycle	0.125	0.090	0.030	0.103
Walk	0.115	0.080	0.032	0.105
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	7.0%	-1.4%	11.0%	5.4%
Car driver	9.3%	0.7%	9.0%	1.2%
Car passenger	8.0%	-0.1%	10.6%	4.3%
Cycle	4.4%	-2.7%	11.5%	4.7%
Walk	1.9%	-2.0%	13.1%	5.7%
Total	n/a	n/a	n/a	n/a

In most cases the OTM 6.0 tour elasticities have increased relative to the OTM 5.3 values, showing an increase in model sensitivity, particularly in response to cost changes.

Table 27 compares the kilometrage elasticities in the final OTM 6.0 and 5.3 models.

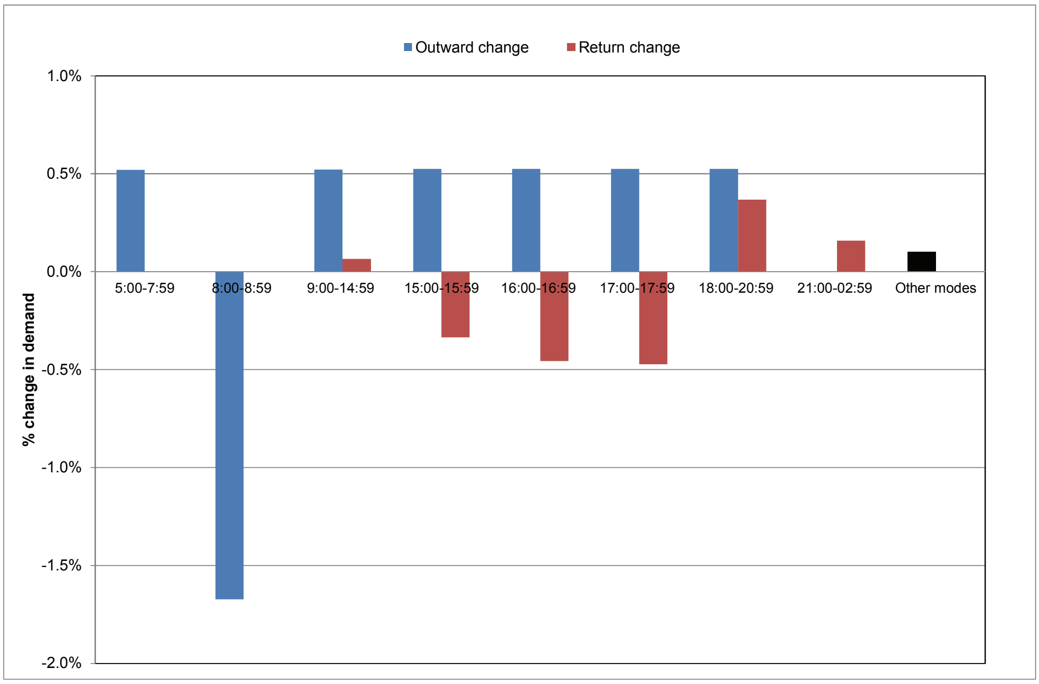
Table 27: Home–business kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.094	0.060	**-0.127**	**-0.502**
Car driver	**-0.366**	**-0.150**	0.009	0.036
Car passenger	0.211	**-0.159**	0.032	0.108
Cycle	0.141	0.094	0.032	0.106
Walk	0.120	0.081	0.035	0.110
Total	-0.183	-0.078	-0.017	-0.070
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.088	0.061	**-0.115**	**-0.499**
Car driver	**-0.338**	**-0.166**	0.008	0.036
Car passenger	0.191	**-0.168**	0.029	0.103
Cycle	0.134	0.096	0.029	0.101
Walk	0.116	0.083	0.032	0.104
Total	-0.176	-0.091	-0.015	-0.067
Changes	Car cost	Car time	PT cost	PT time
PT	6.9%	-1.9%	10.2%	0.5%
Car driver	8.2%	-9.5%	14.8%	1.4%
Car passenger	10.5%	-5.3%	10.0%	5.1%
Cycle	5.4%	-2.2%	10.8%	5.3%
Walk	3.3%	-2.4%	10.0%	5.4%
Total	3.8%	-14.3%	16.6%	5.0%

The percentage changes in the kilometrage elasticities are in line with the changes in the tour elasticities. Thus the increase in model sensitivity comes about principally as a result of increased mode switching rather than through increases in destination switching.

To test the sensitivity of the car driver TP choice model to changes in travel conditions in the peak periods, a 10% increase has been applied to outward level travel times in the 08:00–08:59 TP. Figure 9 plots the changes in demand for outward and return TPs and the extent of the shift to other modes.

Figure 9: Changes in home–business car driver demand, 10% increase to outward times in 08:00–08:59 period



Considering first outward tour legs, the 10% increase in travel time in the 08:00–08:59 period results in a 1.67% decrease in demand for that TP, implying a direct elasticity of just -0.18. Thus the business model is less sensitive to changes in generalised car free flow time – such as would be expected from a tolling policy – relative to the commute model.[8] As the choice between TP combination alternatives is multinomial we observe uniform increases in demand for the other possible TPs of 0.52%.

The impact of the test on the return TP distribution is to shift the return distribution to later in the day, with decreases in demand in the three peak periods between 15:00 and 17:59, and increases in demand in the 18:00–20:59 and 21:00–02:59 periods.

A small amount of demand shifts to other modes as a result of the test, resulting in an increase in demand for other modes of 0.10%. Expressed in numbers of trips, the shift to other modes represents 24% of the demand that shifts out of the 08:00–08:59 outward TP as a result of the test.

Overall the business model is relatively insensitive to changes in generalised car free flow time, in particular TPs, such as those resulting from increases in travel time or the addition of a toll. By comparison the commute model was more than twice as sensitive when subjected to the same test.

[8] It is noted that De Jong *et al.* (2003) only report results of simulation tests with a 10% increase in AM peak travel time for commute travel and so provide no evidence on the sensitivity of business travel to changes in AM peak travel times.

6.4 Tour lengths

Table 28 compares mean observed and predicted tour lengths for each of the five modelled modes.

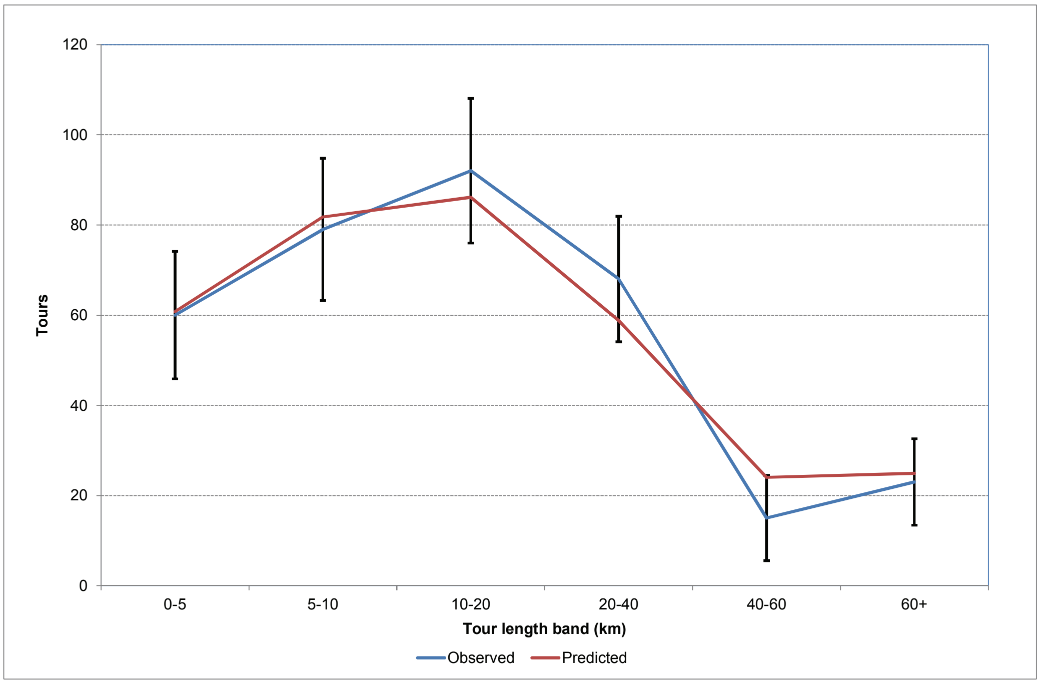
Table 28: Home–business tour lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	19.60	23.10	17.84%
car driver	27.60	27.98	1.36%
car passenger	18.71	18.71	0.00%
cycle	8.36	8.25	-1.29%
walk	3.35	3.29	-1.97%
Total	19.55	20.38	4.24%

Mean tour lengths are predicted accurately for car passenger, cycle and walk because of the use of distance terms for these modes. Mean tour distances for car driver are also predicted accurately. However, there is an 18% over-prediction of mean PT tour lengths and as a consequence overall tour lengths are over-predicted by 4%.

Figure 10 compares observed and predicted tour length distributions using data from all modes. The confidence intervals plotted are calculated as twice the standard error.

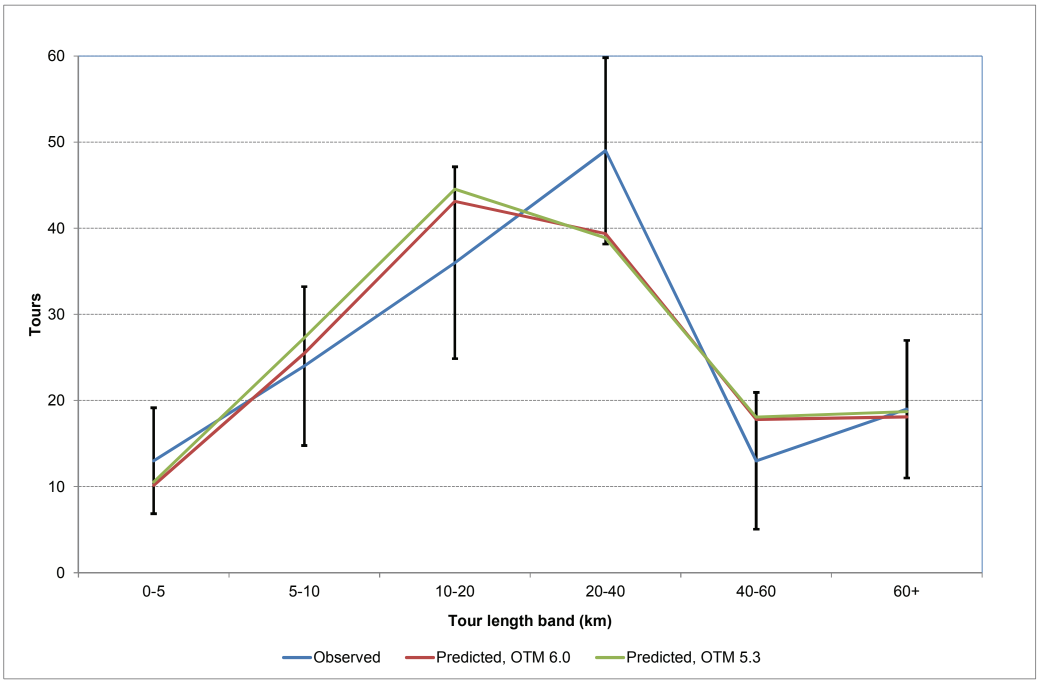
Figure 10: Home–business tour length distributions, all modes



The overall distribution is predicted well, with the predicted distribution lying within the confidence intervals for all of the bands.

Figure 11 compares observed and predicted tour length distributions for car driver.

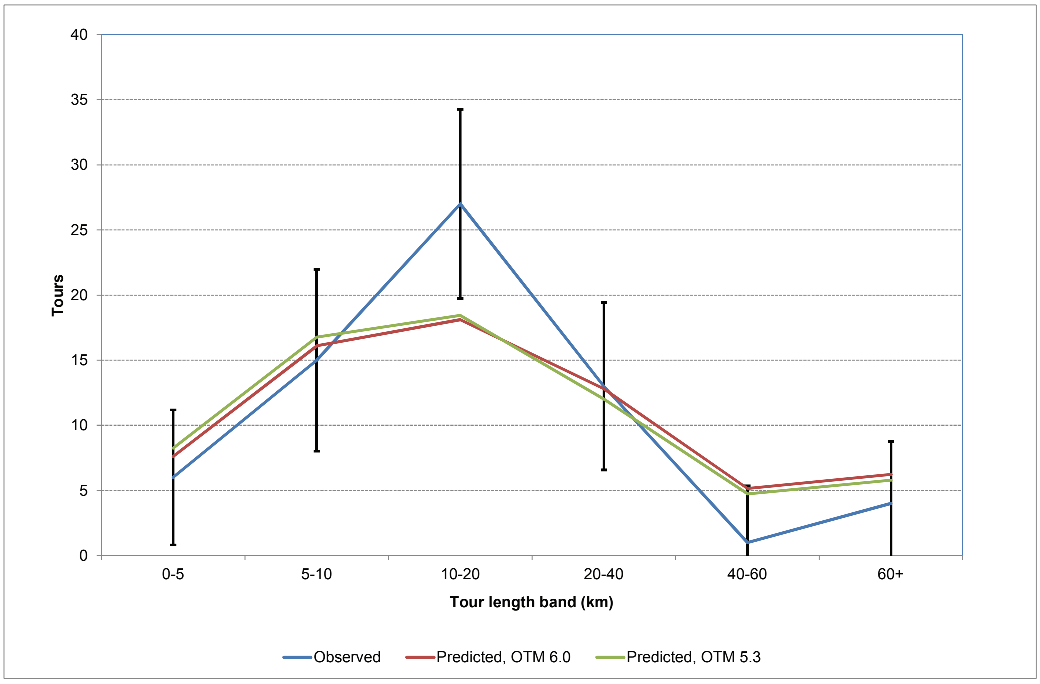
Figure 11: Home–business tour length distributions, car driver



There are some discrepancies between the observed and predicted tour length distributions for car driver tours in the OTM 6.0 models, but these differences lie within the confidence intervals for the observed distribution. No additional distance correction terms have been added to the OTM 6.0 model and therefore the predicted distribution closely matches that predicted by the OTM 5.3 model.

Figure 12 compares observed and predicted tour length distributions using data from PT.

Figure 12: Home–business tour length distributions, PT



For PT, the predicted distribution lies within the confidence intervals for the observed for all but one of the tour length bands. It was decided not to add a distance correction term for the 10–20 km band because the model elasticities are already low, and adding a distance correction term would be expected to suppress the magnitude of the generalised car free flow time parameter and therefore further reduce the model sensitivity.

CHAPTER 7 Home–education model

7.1 Structural tests

In the final OTM 5.3 home–education model, a multinomial structure was identified with mode and destination choices equally sensitive to changes in utility.

Structural tests were undertaken for structure 1 (modes above TPs above destinations) and structure 3 (modes above destinations above TPs). It was clear from the tests undertaken with structures 1 and 3 that destination choice should not appear above mode choice for home–education, and therefore no tests were undertaken for structure 2 (destinations above modes above TPs). It is noted that there was no SP evidence on the relative sensitivity of mode and TP choices for education travel (please refer to the discussion in Section 4.3.1).

Model development was undertaken with structure 3 first, and therefore results obtained using this structure are reported first.

Table 29 summarises the results of structural tests undertaken using structure 3.

Table 29: Home–education structural tests, structure 3: modes above destinations above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
4	-9548.7	29	TR_M_D TR_D_TP CarFFTime	0.1939 0.1303 -0.08629	9.6 4.0 -0.6	yes	-0.006 0.997 n/a
7	-9548.8	28	TR_M_D TR_D_TP CarFFTime	0.1942 1 -0.01125	9.5 * -8.3	yes	-0.005 n/a n/a
13	-9587.6	27	TR_M_D TR_D_TP CarFFTime	1 1 -0.01119	* * -8.5	yes	n/a n/a n/a

In model 4, both structural parameters are significantly different from 1. However, the TR_D_TP parameter is highly correlated with car free flow time, and as a result the car free flow time parameter is insignificant.

In model 7, the TR_D_TP parameter was fixed to a value of 1. This results in only a slight loss of fit to the data, and a significant estimate for the car free flow time parameter was obtained. However, when the mode-destination elasticities were calculated for model 7 they were substantially lower than the elasticities for the final OTM 5.3 model.

In model 13, the TR_M_D parameter was fixed to 1. This results in a significant loss of fit to the data (38.8 points) but the elasticities were substantially higher and more plausible and therefore model 13 was preferred.

Thus model 13 was a candidate model for implementation.

Table 30 summarises the results of structural tests undertaken using structure 1.

Table 30: Home–education structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
9	-9548.8	28	TR_M_TP TR_TP_D CarFFTime	0.1942 1 -0.01125	9.1 * -8.3	yes	-0.005 N/A n/a
11	-9548.8	29	TR_M_TP TR_TP_D CarFFTime	0.3985 0.4865 -0.01125	0.9 0.6 -8.3	yes[9]	-0.001 -0.001 n/a

In model 9, the starting values for the structural parameters were taken from model 7 as a test that identical results were obtained for the two model structures (in models 7 and 9 destinations and TPs are constrained to lie at the same level and so the structures are equivalent).

In model 11, the TR_TP_D parameter was released from a value of 1. Both structural parameters lie between 0 and 1, but neither parameter is significant, and it is not clear that the model has actually converged. Therefore it was decided not to proceed with structure 1.

At the end of the structural tests, model 13 with a multinomial structure for mode, destination and TP choice was the candidate model for implementation. Following completion of the structural tests, the models were improved by using car LOS for car-passenger that was calculated as a demand-weighted average over the day, rather than using an unweighted average over TPs. Thus model 15, which is model 13 with the revision to the car passenger LOS and a correction to the calculation of parking costs, was taken forward for implementation.

7.2 Final model parameters

Table 31 compares the final model parameters from the EDU_CD_TP_V15 model to the final OTM 5.3 model (EDU_27).

[9] There was a loss of likelihood at the final iteration, so this may be a false convergence. As this structure has not been taken forward for implementation, the results are reported as they are rather than making further tests to try and verify the final parameter values.

Table 1: Home–education parameter comparison

File	EDU_27.F12		EDU_CD_TP_V15.F12	
Converged	True		True	
Observations	1588		1588	
Final log (L)	-9851.0		-9580.8	
D.O.F.	12		27	
Rho²(0)	0.161		0.214	
Rho²(c)	-4.674		-3.946	
Estimated	4 Aug 06		2 Aug 13	
Scaling	1.0000		1.0000	
Attraction variable				
TotStu	1.000	(*)	1.000	(*)
LOS variables				
CarFFTime	-0.00779	(-7.0)	-0.01185	(-8.9)
PTWtTfrTm	-0.04897	(-8.5)	-0.02426	(-3.5)
CrPDist	-0.03774	(-2.6)	-0.02934	(-2.2)
CycleDist	-0.2167	(-25.4)	-0.2052	(-23.1)
WalkDist	-0.8716	(-21.1)	-0.9138	(-21.6)
Intrazonal constant				
Intra	0.4584	(3.2)	0.7710	(5.1)
Distance correction parameters				
ShDistCrP	2.072	(5.8)	2.078	(5.9)
Car availability parameters				
CarPcarhh	1.362	(3.4)	1.346	(3.4)
Mode specific constants				
CarP	-2.851	(-7.3)	-0.8313	(-1.5)
PT	1.067	(5.8)	2.768	(6.0)
Walk	3.930	(17.1)	6.040	(12.5)
Cycle	2.221	(11.0)	4.114	(8.7)
Structural parameters				
TR_M_D			1.000	(*)
TR_D_TP			1.000	(*)
Time period combination constants				
TP_25			-0.9146	(-1.1)
TP_26			*-99.000*	*(*)*
TP_27			*-99.000*	*(*)*
TP_28			-1.591	(-1.5)
TP_29			*-99.000*	*(*)*
TP_210			-1.616	(-1.5)
TP_45			0.1942	(0.3)
TP_46			-0.8810	(-1.1)
TP_47			-0.8688	(-1.0)
TP_48			-0.8876	(-1.1)
TP_49			-0.5023	(-0.7)
TP_410			-0.5070	(-0.7)
TP_55			0.9442	(1.8)
TP_56			-1.597	(-1.5)
TP_57			0.02463	(0.0)
TP_58			-0.9107	(-1.1)
TP_59			-0.5256	(-0.7)
TP_510			-0.9358	(-1.1)
TP_oth			0	(*)

Both models have a multinomial structure, and therefore the magnitudes of the different parameters can be compared directly between the two models. The car free flow time parameter, which governs the sensitivity of the model to cost and time changes, is higher in magnitude in the OTM 6.0 model, indicating that the model will be more sensitive to time and cost changes than the OTM 5.3 model.

The 'TP_oth' constant represents the base alternative (all tours leaving the home after 15:00). The 'TP_26', 'TP_27' and 'TP_29' constants are set to -99 and the TP alternatives set to be unavailable as there are no observed tours for these TP combinations.

7.3 Model elasticities

Table 32 compares the tour elasticities in the final OTM 6.0 model to those from the final OTM 5.3 model. Direct elasticities are highlighted in bold.

Table 32: Home–education tour elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.013	0.017	**-0.464**	**-0.267**
Car driver	**-0.354**	**-0.254**	0.156	0.096
Car passenger	0.019	**-0.209**	0.204	0.122
Cycle	0.012	0.016	0.207	0.122
Walk	0.010	0.014	0.185	0.104
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.010	0.012	**-0.297**	**-0.183**
Car driver	**-0.297**	**-0.202**	0.100	0.064
Car passenger	0.017	**-0.139**	0.131	0.083
Cycle	0.010	0.012	0.134	0.083
Walk	0.010	0.011	0.131	0.079
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	25.3%	39.9%	56.3%	46.0%
Car driver	19.2%	25.7%	56.4%	49.3%
Car passenger	13.3%	50.5%	55.6%	47.0%
Cycle	17.6%	31.2%	54.4%	46.6%
Walk	4.1%	26.6%	41.5%	32.0%
Total	n/a	n/a	n/a	n/a

The OTM 6.0 tour elasticities are consistently higher than the OTM 5.3 values, a consequence of the larger car free flow time parameter. The OTM 6.0 values are not high relative to other model systems and therefore the OTM 6.0 values are judged to be acceptable.

Table 33 compares the kilometrage elasticities in the final OTM 6.0 model to those from the final OTM 5.3 model. Again, direct elasticities are highlighted in bold.

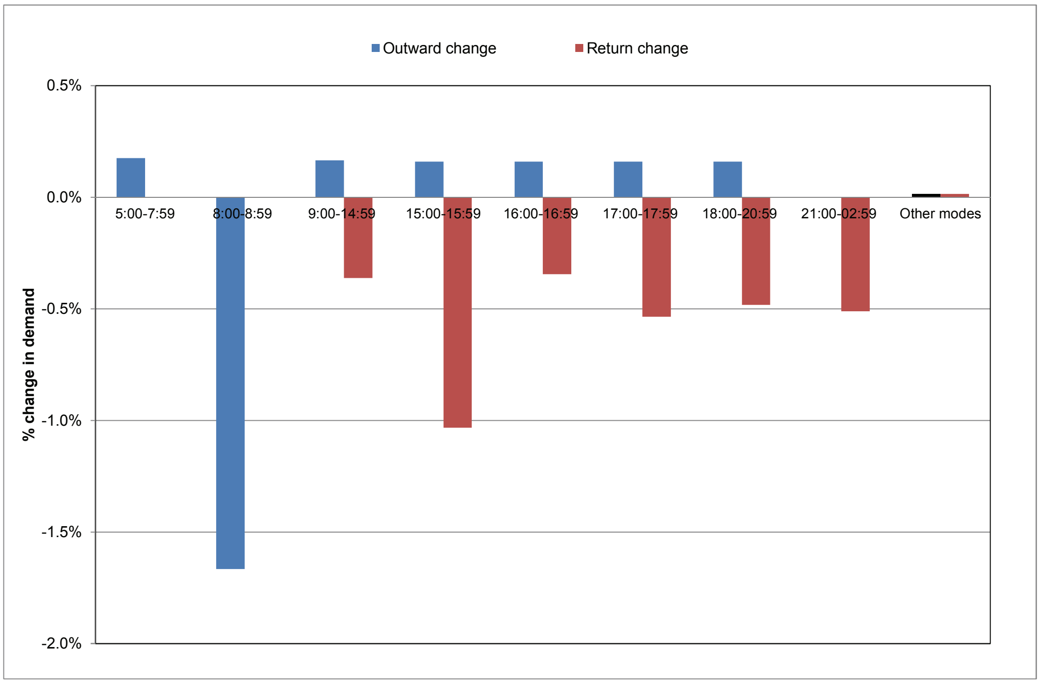
Table 33: Home–education kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.013	0.017	**-0.676**	**-0.485**
Car driver	**-0.700**	**-0.426**	0.159	0.099
Car passenger	0.020	**-0.422**	0.217	0.135
Cycle	0.012	0.016	0.215	0.130
Walk	0.011	0.014	0.191	0.108
Total	-0.028	-0.022	-0.268	-0.205
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.010	0.012	**-0.440**	**-0.343**
Car driver	**-0.571**	**-0.348**	0.101	0.065
Car passenger	0.017	**-0.275**	0.135	0.087
Cycle	0.010	0.012	0.135	0.085
Walk	0.010	0.011	0.131	0.080
Total	-0.031	-0.023	-0.177	-0.147
Changes	Car cost	Car time	PT cost	PT time
PT	27.9%	43.2%	53.5%	41.4%
Car driver	22.6%	22.5%	57.6%	52.0%
Car passenger	19.0%	53.6%	60.9%	55.6%
Cycle	22.9%	37.3%	59.5%	52.7%
Walk	7.9%	31.1%	46.1%	35.6%
Total	-9.5%	-3.9%	51.2%	39.5%

The increases in the kilometrage elasticities between the OTM 5.3 and 6.0 models are consistent with the increases in the tour elasticities. The higher kilometrage elasticities in OTM 6.0 are generally plausible, though the car cost elasticity is on the high side.

To test the sensitivity of the car driver TP choice model to changes in travel conditions in the peak periods, a 10% increase has been applied to outward level travel times in the 08:00–08:59 TP. Figure 13 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

Figure 13: Changes in home–education car driver demand, 10% increase to outward times in 08:00–08:59 period



Considering the impact on the outward TP distribution first, demand in the 08:00–08:59 period reduces by 1.59% as a result of the test, equivalent to a direct elasticity of -0.18. Uniform increases in the percentage of demand for the other outward TPs are observed as the choice between TP combination alternatives is multinomial.

As a high fraction of education tours travel out in the 08:00–08:59 period, we observe reductions in demand for all return TPs as a result of this test, with the highest percentage reduction corresponding to the 15:00–15:59 return period (influenced by the TP combination where the outward leg is 08:00–08:59 and the return leg is 15:00–15:59).

The changes result in only a slight increase in demand for other modes (0.02%). This response is low in percentage terms as car driver only comprises 3% of all education tours. However, when calculated as a percentage of the reduction of car driver trips in the outward 08:00–08:59 period, the relative impact of mode shifting can be seen to be more significant, representing 80% of the number of tours where the outward leg shifts out of the 08:00–08:59 period.

7.4 Tour lengths

Table 34 compares mean observed and predicted tour lengths for each of the five modelled modes.

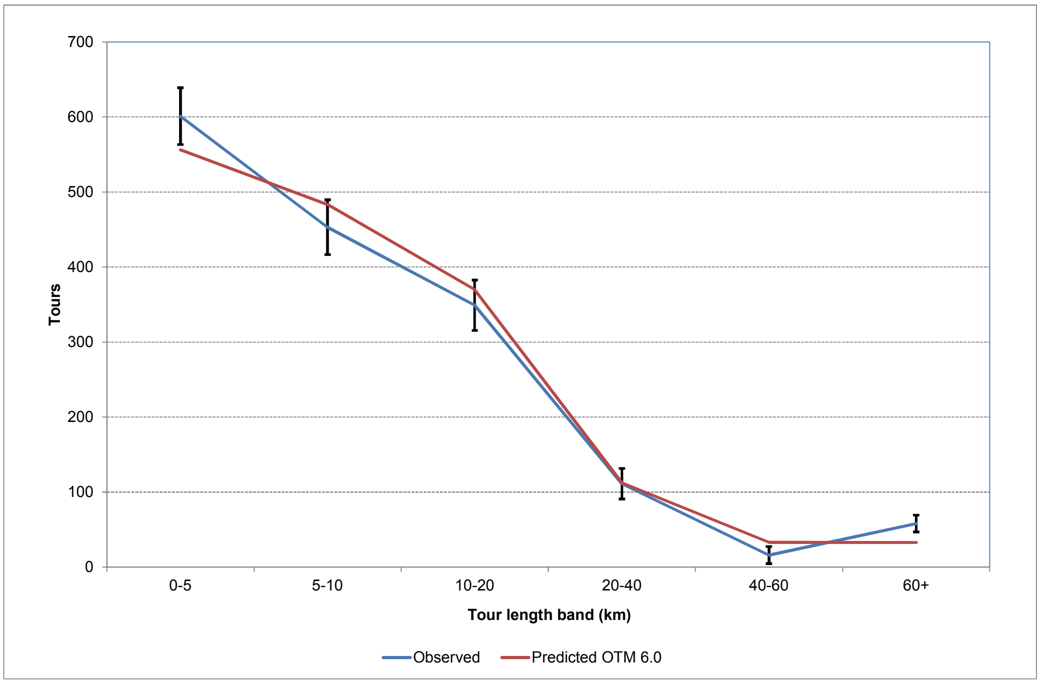
Table 34: Home–education tour lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	19.90	19.90	-0.01%
car driver	20.36	19.59	-3.78%
car passenger	10.90	10.90	0.01%
cycle	7.77	7.72	-0.68%
walk	2.54	2.68	5.34%
Total	11.10	11.07	-0.26%

Overall tour lengths are predicted accurately, with an error of just -0.26%, and tour lengths for PT, car passenger and cycle modes are all predicted to within 1%. Car driver tour lengths are under-predicted by 4%, whereas walk tour lengths are over-predicted by a slightly higher amount.

Figure 14 compares observed and predicted tour length distributions for all modes. Confidence intervals are plotted, which are calculated as twice the standard error for the observed distribution.

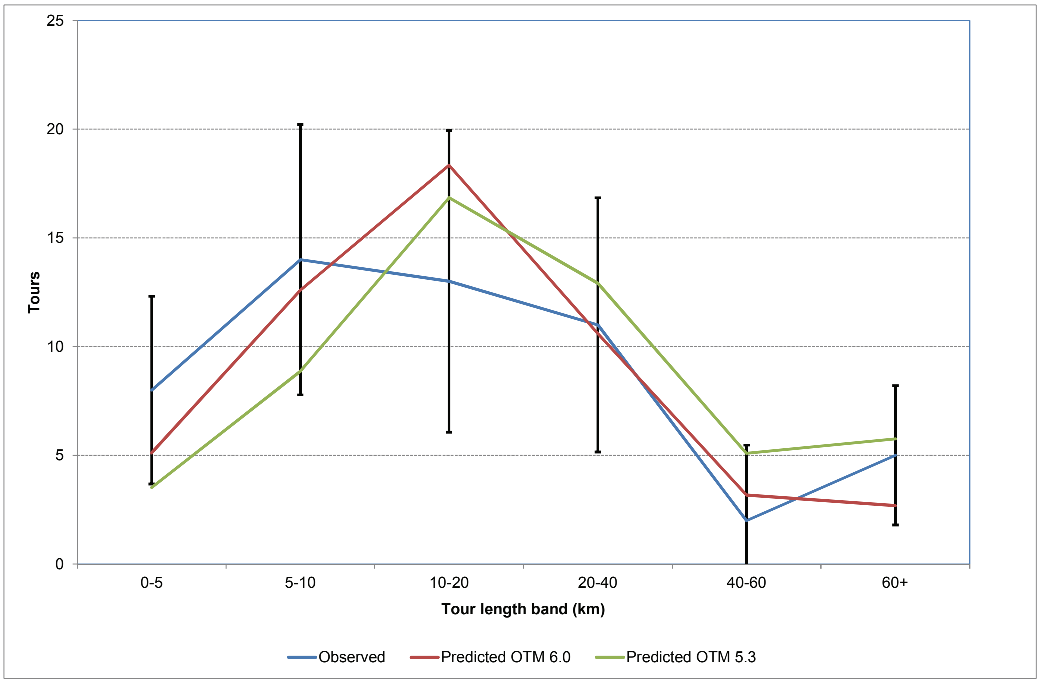
Figure 14: Home–education tour length distributions, all modes



There is some under-prediction of the shortest tours (0–5 km), and significant discrepancies for the 40–60 km and 60+ km bands. However, the observed and predicted distributions correspond well for tours in the 5–40 km bands.

Figure 15 compares observed and predicted tour length distributions plotted for car driver.

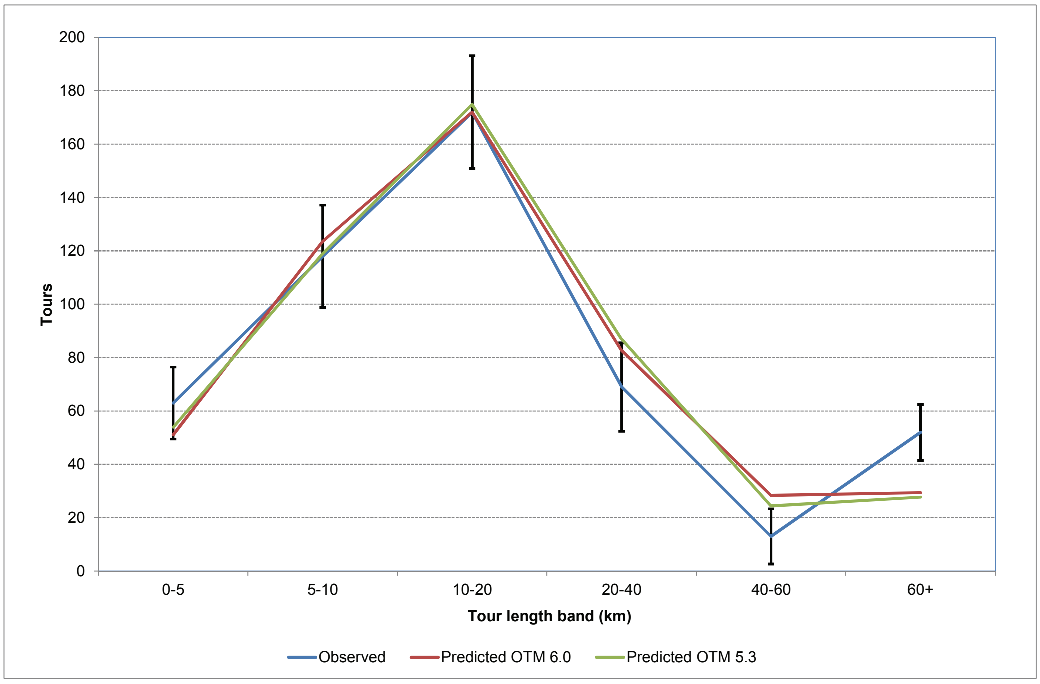
Figure 15: Home–education tour length distributions, car driver



While there are large differences between the observed and predicted tour length distributions, the low volumes of data result in wide confidence intervals, and as a result all of the OTM 6.0 model predictions lie within the confidence intervals for the observed data.

Figure 16 compares observed and predicted tour length distributions plotted for PT.

Figure 16: Home–education tour length distributions, PT



For short and medium distance education tours, the predicted tour length distribution for PT tours lies within the confidence intervals plotted around the observed distribution. However, for tours in the 40–60 km tour length band there is some over-prediction relative to the observed distribution, whereas for the 60+ km band tours are under-predicted relative to the observed. It is noted that over-predictions and under-predictions balance for the overall tour length, so that observed and predicted tour lengths match very closely (see Table 34).

CHAPTER 8 Home–shopping model

8.1 Structural tests

The starting point for the structural tests was the final model identified in the OTM 5.3 estimations, which has a multinomial structure for mode and destination choice.

Initial model development commenced with structure 1, which has a modes above TPs above destinations structure. Table 35 summarises the results from the tests undertaken. The t-ratios for the structural parameters are calculated relative to a value of 1.

Table 35: Home–shopping structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
3	-17317.1	39	TR_M_TP TR_TP_D CarFFTime	15.88 0.03701 -0.03905	1.3 36.4 -20.7	no	0.037 0 n/a
4	-17317.7	38	TR_M_TP TR_TP_D CarFFTime	0.588 1 -0.03902	8.7 * -20.7	yes	0.345 N/A n/a
5	-17317.4	38	TR_M_TP TR_TP_D CarFFTime	1 0.586 -0.03906	* 8.8 -20.7	yes	0.345 n/a n/a
10	-17317.7	38	TR_M_TP TR_TP_D CarFFTime	0.588 1 -0.03902	8.7 * -20.7	yes	0.345 n/a n/a
11	-17215.0	38	TR_M_TP TR_TP_D CarFFTime	0.829 1 -0.01942	2.8 * -10.8	yes	0.380 n/a n/a

In model 3, it was not possible to estimate both structural parameters simultaneously, and the TR_TP_D parameter was tending towards a value of 0. Therefore two tests were made where one of the structural parameters was fixed to a value of 1. In model 4, the TR_TP_D parameter was fixed to 1, whereas in model 5 the TR_M_TP model parameter was fixed to a value of 1. The fit of the model results was similar to the data, and the value and significance of the structural parameter that was estimated. Although the fit was marginally worse in model 4, this model was preferred to model 5 because the structure for the relative sensitivity of mode and TP choices is consistent with the SP evidence summarised in Section 4.3.1.

Model 10 was based on model 4, but incorporated a minor correction to the treatment of the tour timing information used to allocate tours into the modelled TPs. The impact of this change on the model parameters was very small relative to model 4.

Model 11 also incorporates a correction, this time to the specification of the short distance correction term applied to car tours in the 0–5 km band so that the term referenced the correct distance information for the TP alternative combination. This correction had a more significant impact on the model results, with an improvement in model fit of 102.7 log-likelihood points, a substantial increase in the magnitude of the TR_M_TP structural parameter from 0.588 to 0.829, and a halving in the magnitude of the car free flow time parameter. The SP evidence presented in Section 4.3.1 suggested a range of 0.4–0.6 for the TR_M_TP structural parameter, and so the estimate from model 11 indicates a lower TP choice sensitivity relative to main mode choice than the SP evidence.

Model 11 was the candidate model for implementation that emerged from the tests run with model structure 1.

Tests were also undertaken for structure 2 (Table 36) and structure 3 (Table 37). These tests were run before the corrections to the tour timing calculations and the car short distance correction term, and therefore the results from these tests should be compared to models 3 to 5 estimated using structure 1.

Table 36: Home–shopping structural tests, structure 2: destinations above modes above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
9	-17348.7	38	TR_D_M TR_M_TP CarFFTime	1 14.06 -0.00239	* 2.1 -2.3	no	n/a n/a n/a

Model 9 did not converge, and therefore no correlations were reported in the LOG file. The results at the point at which the run failed suggest that the final value for the TR_M_TP parameter would be significantly greater than 1, and therefore structure 2 was rejected.

Table 37: Home–shopping structural tests, structure 3: modes above destinations above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
7M	-17315.6	38	TR_M_D TR_D_TP CarFFTime	0.5862 137.2 -0.03167	12.4 0.6 -1.9	no	n/a n/a n/a

Model 7M did not converge either. The magnitude of the TR_D_TP parameter at the point at which the run failed suggests that the destinations above TPs structure is strongly rejected, and therefore no further tests were undertaken using structure 3.

Thus the candidate model which emerged from the structural tests was model 11, with modes above TPs and destinations. Subsequent to the structural tests, all-day average demand-weighted car LOS was supplied by TetraPlan for modelling car passenger tours. This LOS was an improvement on the unweighted average car LOS used to make the structural tests. Thus the final model that has been implemented is model 15, which is the model 11 specification estimated using the updated car LOS for car passenger and incorporating a correction to the calculation of parking costs.

8.2 Final model parameters

Table 38 compares the final OTM 6.0 model parameters from the SHOP_CD_TP_V15 model to the final OTM 5.3 model (SHOP_22).

Table 38: Home–shopping parameter comparison

	OTM 5.3		OTM 6.0	
File	SHOP_22.F12		SHOP_CD_TP_V15.F12	
Converged	True		True	
Observations	3712		3711	
Final log (L)	-16604.3		-17205.9	
D.O.F.	15		38	
$Rho^2(0)$	0.429		0.460	
$Rho^2(c)$	-2.939		-2.326	
Estimated	3 Aug 06		1 Aug 13	
Scaling	1.0000		1.0000	
Attraction variable				
TotShop	1.000	(*)	1.000	(*)
LOS variables				
CarFFTime	-0.01697	(-13.7)	-0.01369	(-11.8)
PTWtTfrTm	-0.07135	(-8.7)	-0.09778	(-10.0)
PTAcEgTm	-0.02655	(-4.0)	-0.04360	(-6.6)
CycleDist	-0.7013	(-36.8)	-0.7076	(-36.8)
WalkDist	-1.199	(-57.3)	-1.205	(-56.7)
Intrazonal constant				
Intra	0.3424	(5.8)	0.3355	(5.6)
Distance correction parameters				
ShDistPT	1.336	(9.3)	1.363	(9.5)
ShDistCar	2.292	(19.7)	2.462	(20.8)
M1Dist	0.8693	(9.3)	0.9375	(9.9)
Car availability parameters				
CarPCarHH	1.078	(5.2)	1.189	(5.0)
PTCarAv	-1.203	(-8.2)	-1.276	(-7.1)
Mode specific constants				
CarP	-3.072	(-24.4)	1.804	(2.9)
PT	1.411	(6.3)	6.817	(11.0)
Cycle	3.604	(23.3)	8.880	(14.8)
Walk	5.932	(40.5)	11.32	(19.1)
Structural parameters				
TR_M_TP			0.9062	(15.1)
TR_TP_D			1.000	(*)
Time period combination constants				
TP_44			-1.051	(-0.9)
TP_45			-0.3770	(-0.4)
TP_46			*-99.000*	*(*)*
TP_47			*-99.000*	*(*)*
TP_48			*-99.000*	*(*)*
TP_49			-1.072	(-0.9)
TP_410			*-99.000*	*(*)*
TP_55			3.970	(6.8)
TP_56			2.331	(3.8)
TP_57			1.503	(2.3)
TP_58			0.7168	(1.0)

TP_59	0.00978	(0.0)
TP_510	-1.093	(-0.9)
TP_66	0.5577	(0.8)
TP_67	1.259	(1.9)
TP_68	0.04219	(0.1)
TP_69	0.7216	(1.0)
TP_610	*-99.000*	*(*)*
TP_77	0.7597	(1.1)
TP_78	1.900	(3.1)
TP_79	1.987	(3.2)
TP_710	0.5480	(0.8)
TP_88	1.135	(1.7)
TP_89	2.753	(4.6)
TP_810	-1.079	(-0.9)
TP_99	3.340	(5.7)
TP_910	0.8510	(1.2)
TP_10	0	(*)

The 'TP_10' constant represents the base alternative (tours where both the outward and return legs are made in the 21:00–02:59 period). The 'TP_46', 'TP_47', 'TP_48', 'TP_410' and 'TP_610' constants are set to -99 and the TP alternatives set to be unavailable as there are no observed tours for these TP combinations.

8.3 Model elasticities

The mode-destination tour elasticities for the final OTM 6.0 and 5.3 models are compared in Table 39. Direct tour elasticities are highlighted in bold.

Table 39: Home–shopping tour elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.020	0.029	**-0.728**	**-0.237**
Car driver	**-0.258**	**-0.126**	0.032	0.014
Car passenger	0.067	**-0.278**	0.097	0.036
Cycle	0.037	0.036	0.097	0.032
Walk	0.033	0.032	0.091	0.030
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.025	0.042	**-0.974**	**-0.341**
Car driver	**-0.315**	**-0.161**	0.046	0.069
Car passenger	0.085	**-0.394**	0.140	0.134
Cycle	0.046	0.049	0.136	0.135
Walk	0.041	0.043	0.125	0.110
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	-20.3%	-31.3%	-25.3%	-30.6%
Car driver	-18.0%	-21.8%	-29.9%	-80.0%
Car passenger	-21.0%	-29.5%	-30.8%	-73.3%
Cycle	-19.2%	-26.8%	-28.4%	-76.2%
Walk	-18.8%	-26.1%	-27.5%	-73.2%
Total	n/a	n/a	n/a	n/a

Overall, the OTM 6.0 elasticity values are lower than the OTM 5.3 values, which follows from the reduction in the magnitude of the car free flow time parameter in the OTM 6.0 model. Focusing on the direct tour elasticities highlighted in bold, we observe a 18% decrease for car cost, 22% and 30% decreases for car time, and close to a one-third decrease for both PT cost and for PT time. The cross-elasticities also show significant decreases.

Table 40: Home–shopping kilometrage elasticity comparison

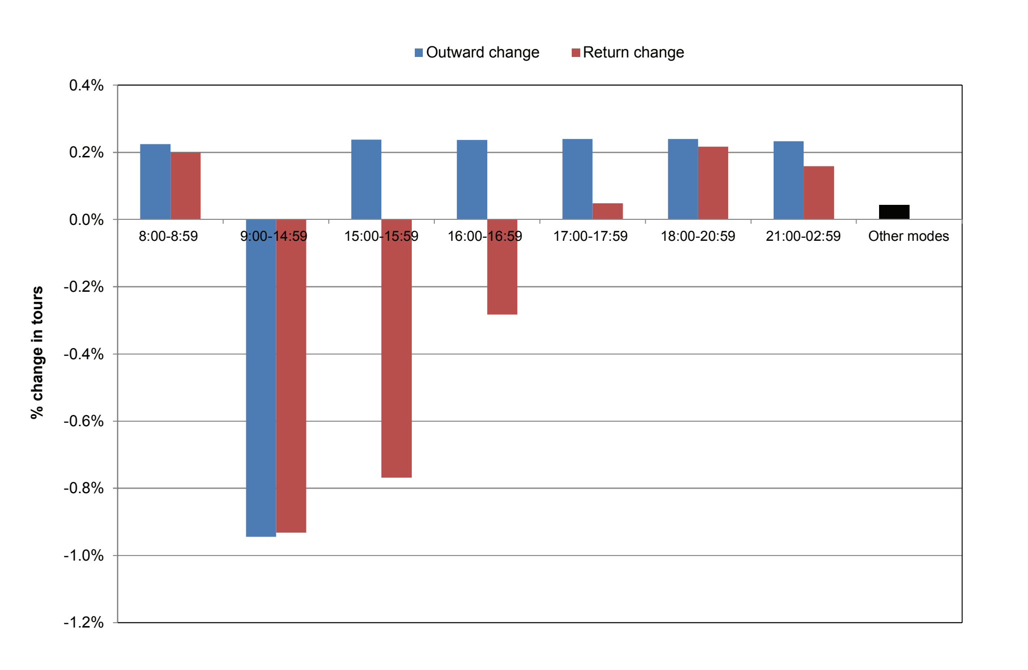
OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.023	0.034	-0.815	-0.410
Car driver	-0.661	-0.337	0.033	0.015
Car passenger	0.076	-0.632	0.103	0.040
Cycle	0.041	0.040	0.103	0.035
Walk	0.037	0.035	0.095	0.032
Total	-0.134	-0.169	-0.094	-0.058
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.030	0.050	**-1.104**	**-0.532**
Car driver	**-0.749**	**-0.409**	0.049	0.022
Car passenger	0.096	**-0.862**	0.151	0.057
Cycle	0.051	0.054	0.145	0.047
Walk	0.045	0.047	0.132	0.042
Total	-0.142	-0.213	-0.141	-0.079
Changes	Car cost	Car time	PT cost	PT time
PT	-24.0%	-32.9%	-26.1%	-22.9%
Car driver	-11.7%	-17.7%	-32.0%	-30.4%
Car passenger	-20.8%	-26.7%	-31.6%	-30.0%
Cycle	-19.1%	-25.5%	-29.0%	-26.6%
Walk	-17.9%	-24.6%	-27.8%	-25.0%
Total	-5.8%	-20.6%	-33.3%	-27.1%

The changes to the kilometrage elasticities between OTM 5.3 and 6.0 (shown in Table 40) are similar to the changes to the tour elasticities. Thus the reduction in sensitivity manifests itself principally through a reduction in mode choice sensitivity, rather than though reduced destination switching.

To test the sensitivity of the car driver TP choice model to changes in travel conditions, a 10% increase has been applied to outward leg travel times in the 09:00–14:59 TP.[10] Figure 17 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

[10] Very few shopping tours depart between 08:00 and 08:59, and so the 10% change was applied to the 09:00–14:59 period rather than to the 08:00–08:59 period.

Figure 17: Changes in home–shopping car driver demand, 10% increase to outward times in 09:00–14:59 period



The 10% increase in outward travel times in the 09:00–14:59 period results in a 0.9% reduction in outward leg demand in the 09:00–14:59 period, equivalent to an elasticity of -0.10.

Nearly all (98.7%) of the tours that return in the 09:00–14:59 TP travel out in the same TP, and therefore the reduction in return tour leg demand in the 09:00–14:59 period is almost as high in percentage terms as the reduction in outward leg demand in that TP. Reductions in demand are also observed in the 15:00–15:59 and 16:00–16:59 TPs as a result of reductions in demand for TP combinations travelling out in the 09:00–14:59 period. There is some increase in demand for return TP combinations from 17:00 onwards as a result of a shift in the return distribution towards return tour legs later in the day, and an increase in tours that go out and return in the 08:00–08:59 peak period is also observed.

There is a slight increase in demand for other modes. The increase is slight as a percentage of total demand for other modes (0.04%), but the shift represents 72% of the reduction in car driver trips in the 09:00–14:59 period, so the mode switching effect is substantial proportional to the TP shifting effects.

8.4 Tour lengths

Table 41 compares mean observed and predicted tour lengths for each of the five modelled modes.

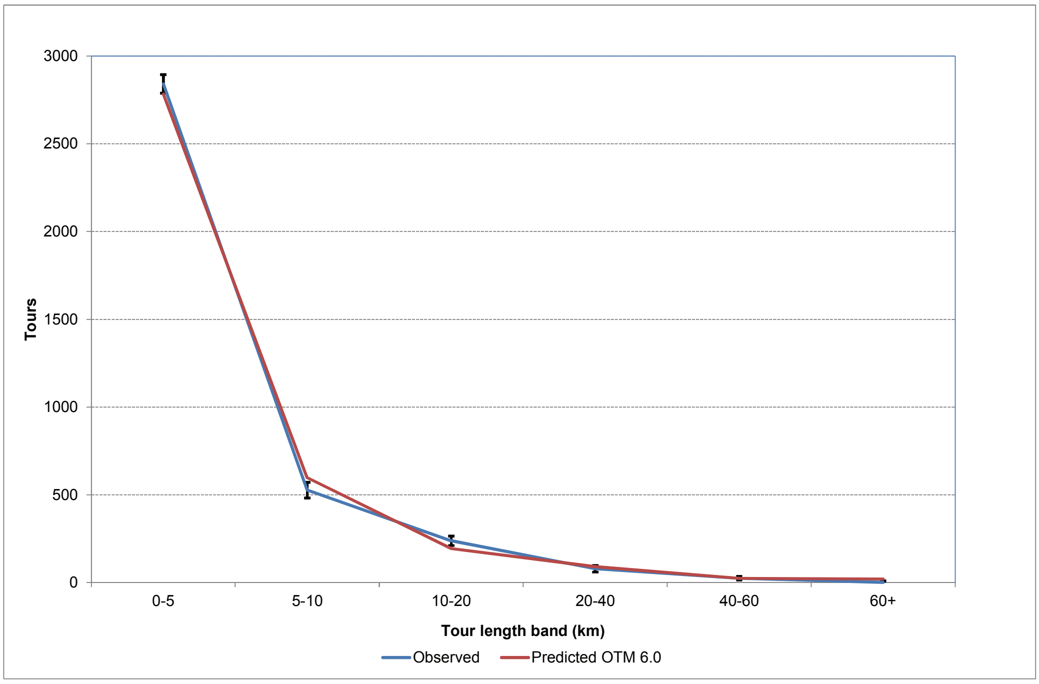
Table 41: Home–shopping tour lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	8.57	9.21	7.55%
car driver	9.93	10.81	8.91%
car passenger	11.58	18.75	61.96%
cycle	3.59	3.61	0.51%
walk	2.11	2.21	4.90%
Total	4.42	4.98	12.56%

Tour lengths are over-predicted by 7% overall. Car passenger tour lengths are significantly over-predicted (consistent with the OTM 5.3 specification there is no car passenger distance term) whereas observed tour distances for the other modes are predicted more accurately.

Figure 18 compares observed and predicted home–shopping tour length distributions for all modes. Confidence intervals are plotted, which are calculated using the formula given in Section 4.4.3.

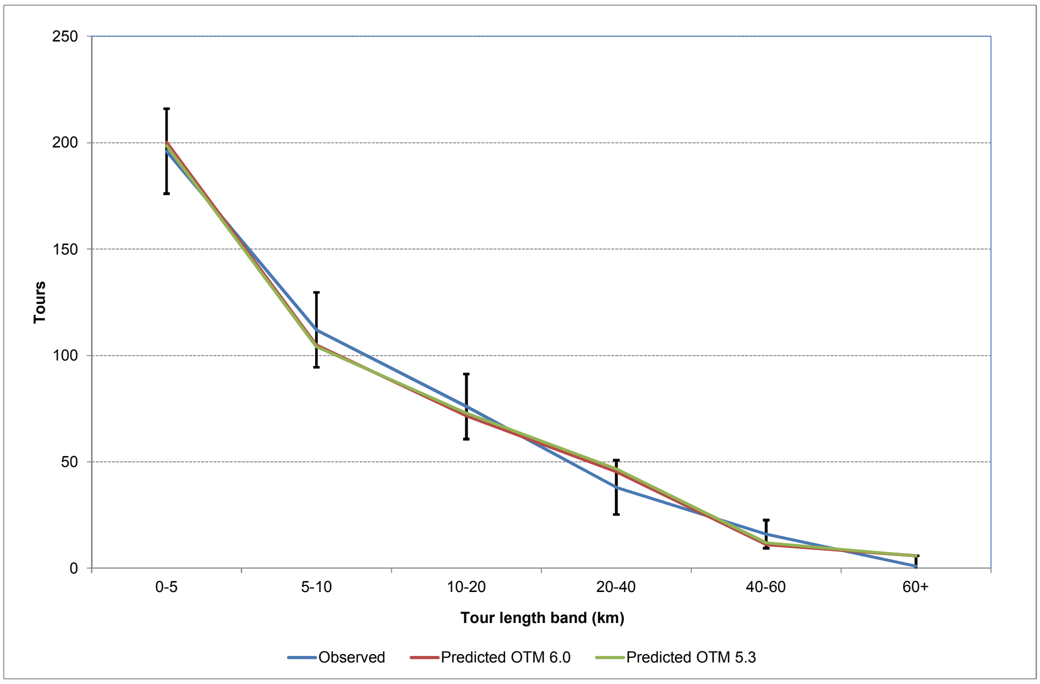
Figure 18: Home–shopping tour length distributions, all modes



The predicted distribution matches the observed well for most bands. For the 5–10 km band, there is a significant over-prediction relative to the observed distribution.

Figure 19 compares observed and predicted home–shopping tour length distributions for car driver.

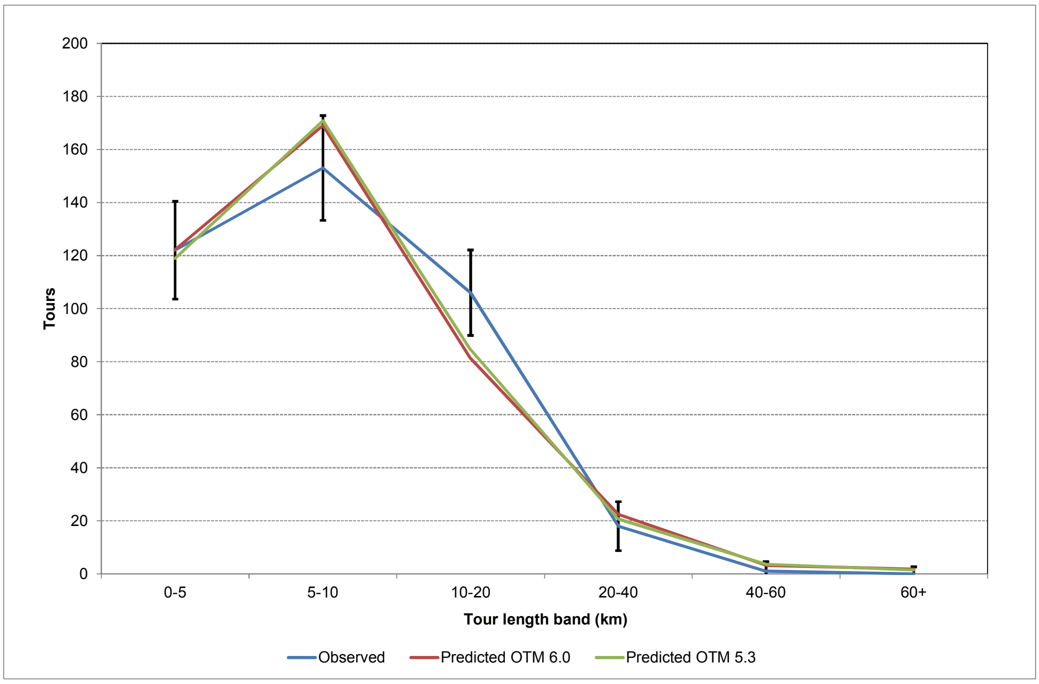
Figure 19: Home–shopping tour length distributions, car driver



The predicted distribution lies within the confidence intervals for the observed for distance bands up to 20–40 km, and for the 60+ km band. Tours in the 40–60 km band are under-predicted.

Figure 20 compares observed and predicted home–shopping tour length distributions for PT.

Figure 20: Home–shopping tour length distributions, PT



The predicted distribution lies within the confidence intervals plotted around the observed for all distance bands.

CHAPTER 9 Home–leisure model

9.1 Structural tests

The starting point for the structural tests was the final OTM 5.3 model, which had a structure with modes above destinations with a structural parameter of 0.549 (with a t-ratio relative to a value of one of 9.4).

Structural tests have been run for each of the three possible tree structures presented in Section 4.3. Results from structure 1, with modes above TPs above destinations, are presented first, in Table 42. The t-ratios for the structural parameters are calculated relative to a value of 1.

Table 42: Home–leisure structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
21	-48184.5	55	TR_M_TP TR_TP_D CarFFTime	0.5152 1 -0.01822	10.4 * -21.4	yes	0.219 n/a n/a
23	-48184.4	55	TR_M_TP TR_TP_D CarFFTime	1 0.5142 -0.01824	* 10.6 -21.4	yes	n/a 0.220 n/a
24	-48184.2	56	TR_M_TP TR_TP_D CarFFTime	4.77 0.115 -0.01817	0.1 0.8 -25.3	no	n/a n/a n/a

In models 21 and 23, one of the two structural parameters is fixed to 1 so that the model converges. The fit of the results is similar to the data, and both models imply a theta for the relative sensitivity of the mode and destination choice decisions of around 0.51, close to the value of 0.55 identified in the final OTM 5.3 model. Model 21 is preferred to model 23 because it gives a structure where TP choice is nested beneath mode choice. This is consistent with the SP evidence presented in Section 4.3.1, which gives TR_M_TP parameter values in the range 0.4–0.6, whereas model 23 implies a multinomial structure for mode and TP choice.

In model 24 an attempt was made to estimate both of the structural parameters. However, this model did not converge, and therefore model 21 remained the candidate model.

Tests were also undertaken for structures 2 and 3. These tests are reported in Table 43 and Table 44.

Table 43: Home–leisure structural tests, structure 2: destinations above modes above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
10	-48179.5	56	TR_D_M TR_M_TP CarFFTime	0.513 1.378 -0.02033	3.4 8.6 -3.6	yes	0.967 0.220 n/a
11	-48236.6	55	TR_D_M TR_M_TP CarFFTime	0.7928 1 -0.01987	0.8 * -3.0	yes	0.990 n/a n/a

Model 10 converged successfully with both parameters freely estimated, however the TR_M_TP parameter was significantly greater than 1. In model 11, the TR_M_TP parameter was constrained to a value of 1. This model does not fit the data as well as model 21 and therefore model 21 remained the candidate model for implementation.

Table 44: Home–leisure structural tests, structure 3: modes above destinations above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
22	-41184.5	55	TR_M_TP TR_TP_D CarFFTime	0.5152 1 -0.01822	10.5 * -21.4	no	n/a n/a n/a

Model 22 did not converge. However, using the model 21 parameters as starting values the model does report an initial log-likelihood that is equal to the final log-likelihood in model 21, which verifies that the model has been specified correctly. Note that no correlations are reported for model 22 because the model did not converge.

Model 21 estimated using structure 1 remained the candidate model for implementation.

After the structural tests were complete, TetraPlan supplied revised LOS for car passenger that is calculated as a demand-weighted average over the day, an improvement relative to the unweighted average LOS over TPs used for the structural tests. Thus candidate model specification 21 was re-estimated using the updated car passenger LOS and incorporating a correction to the calculation of parking costs, giving model 28, which was taken forward for implementation.

9.2 Final model parameters

Table 45 compares the model parameters from the final LEIS_CD_TP_V28 model to the final OTM 5.3 model (LEIS_17_T2).

Table 45: Home–leisure parameter comparison

	OTM 5.3		OTM 6.0	
File	LEIS_17_T2.F12		LEIS_CD_TP_V28.F12	
Converged	True		True	
Observations	7041		7032	
Final log (L)	-44388.8		-48161.2	
D.O.F.	22		55	
Rho²(0)	0.214		0.242	
Rho²(c)	-3.835		-2.699	
Estimated	3 Aug 06		1 Aug 13	
Scaling	1.0000		1.0000	
Size variables				
L_S_M	1.000	(*)	1.000	(*)
sz_com1	1.211	(8.8)	1.171	(8.3)
sz_edu	1.130	(15.6)	1.114	(15.4)
sz_lse	-0.4126	(-1.9)	-0.4439	(-2.0)
sz_ent	3.113	(60.8)	3.104	(60.9)
LOS variables				
CarFFTime	-0.01498	(-22.5)	-0.01716	(-22.7)
PTTfrTm	-0.02782	(-2.5)	-0.05324	(-3.8)
PTWtTm	-0.04833	(-8.0)	-0.03968	(-5.7)
PTAcEgTm	-0.02655	(-7.4)	-0.02046	(-7.5)
CycleDist	-0.3268	(-45.4)	-0.3270	(-45.3)
WalkDist	-0.8365	(-59.7)	-0.8360	(-59.6)
Intrazonal constant				
Intra	0.6052	(11.5)	0.6050	(11.5)
Distance correction parameters				
ShDistCarD	1.240	(15.8)	1.162	(14.5)
ShDistCarP	1.673	(14.2)	1.590	(13.4)
M1DistCar	0.6425	(10.5)	0.5571	(8.9)
Car availability parameters				
CarDCarHH	1.308	(5.3)	1.306	(5.4)
CarPCarHH	1.954	(6.5)	1.914	(6.6)
PTCarAv	-1.839	(-8.5)	-1.816	(-8.8)
Mode specific constants				
CarP	-4.384	(-11.4)	-1.362	(-3.6)
PT	0.6221	(2.8)	3.386	(14.3)
Cycle	1.605	(9.1)	4.449	(21.8)
Walk	3.867	(23.8)	6.705	(34.6)
Structural parameters				
TR_M_D	0.5491	(11.4)		
TR_M_TP			0.5573	(11.9)
TR_TP_D			1.000	(*)
Time period combination constants				
TP_33			-3.119	(-5.3)
TP_34			-1.429	(-5.2)
TP_35			-2.339	(-5.9)
TP_36			-4.223	(-4.2)

TP_37	-3.497	(-4.9)
TP_38	-4.242	(-4.2)
TP_39	*- 99.000*	*(*)*
TP_310	*- 99.000*	*(*)*
TP_44	-0.6793	(-3.3)
TP_45	-0.5683	(-2.9)
TP_46	-4.197	(-4.2)
TP_47	-1.968	(-5.6)
TP_48	-3.523	(-4.9)
TP_49	-3.575	(-5.0)
TP_410	-3.588	(-5.0)
TP_55	1.028	(7.8)
TP_56	-0.06707	(-0.4)
TP_57	-0.4617	(-2.4)
TP_58	-0.6655	(-3.3)
TP_59	-0.8037	(-3.9)
TP_510	-1.511	(-5.7)
TP_66	-1.785	(-5.5)
TP_67	-0.7494	(-3.5)
TP_68	-1.803	(-5.6)
TP_69	-1.362	(-5.2)
TP_610	-1.963	(-5.8)
TP_77	-0.8836	(-3.8)
TP_78	-0.8552	(-3.8)
TP_79	-0.4870	(-2.5)
TP_710	-1.169	(-4.8)
TP_88	-1.738	(-5.6)
TP_89	0.2358	(1.5)
TP_810	-0.2632	(-1.5)
TP_99	0.6294	(4.5)
TP_910	1.244	(9.7)
TP_10	0	(*)

The 'TP_10' constant represents the base alternative (tours where both the outward and return legs are made in the 21:00–02:59 period). The 'TP_39' and 'TP_310' constants are set to -99 and the alternatives set to be unavailable as there are no observed tours for these TP combinations.

9.3 Model elasticities

The mode-destination tour elasticities of the final OTM 6.0 and 5.3 models are compared in Table 46. Direct tour elasticities are highlighted in bold.

Table 46: Home–leisure tour elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.018	0.040	**-0.325**	**-0.210**
Car driver	**-0.132**	**-0.124**	0.022	0.018
Car passenger	0.051	**-0.241**	0.067	0.045
Cycle	0.034	0.057	0.075	0.048
Walk	0.033	0.055	0.075	0.047
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.017	0.038	**-0.273**	**-0.184**
Car driver	**-0.129**	**-0.122**	0.019	0.015
Car passenger	0.048	**-0.225**	0.056	0.039
Cycle	0.034	0.056	0.064	0.042
Walk	0.034	0.054	0.064	0.042
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	4.0%	4.6%	19.0%	14.2%
Car driver	2.5%	1.5%	16.9%	17.1%
Car passenger	5.2%	7.0%	18.9%	14.4%
Cycle	0.8%	1.4%	17.6%	14.9%
Walk	-2.0%	1.7%	16.6%	12.2%
Total	n/a	n/a	n/a	n/a

Relatively small increases in the car elasticities are observed between OTM 5.3 and 6.0, whereas the PT elasticities have increased by up to one-fifth.

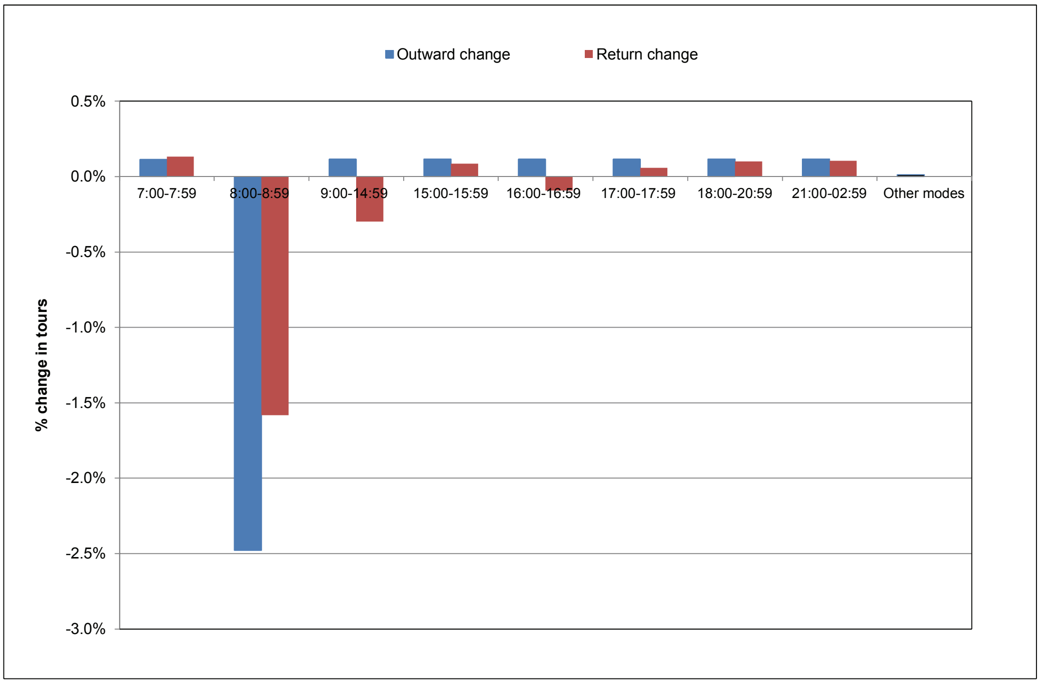
Table 47: Home–leisure kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.019	0.042	**-0.520**	**-0.420**
Car driver	**-0.431**	**-0.412**	0.022	0.018
Car passenger	0.054	**-0.706**	0.068	0.046
Cycle	0.036	0.060	0.076	0.050
Walk	0.034	0.056	0.075	0.047
Total	-0.114	-0.194	-0.105	-0.090
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.016	0.041	**-0.520**	**-0.423**
Car driver	**-0.436**	**-0.403**	0.022	0.018
Car passenger	0.046	**-0.751**	0.066	0.045
Cycle	0.031	0.059	0.075	0.048
Walk	0.030	0.055	0.073	0.046
Total	-0.114	-0.196	-0.107	-0.092
Changes	Car cost	Car time	PT cost	PT time
PT	16.6%	1.3%	-0.1%	-0.8%
Car driver	-1.0%	2.4%	3.2%	3.6%
Car passenger	17.9%	-6.0%	3.2%	4.3%
Cycle	16.8%	1.8%	2.3%	3.3%
Walk	13.4%	1.5%	1.8%	2.4%
Total	-0.7%	-0.8%	-1.2%	-2.3%

With the exception of the car cost values, the kilometrage elasticities show small changes between OTM 5.3 and 6.0.

To test the sensitivity of the car driver TP choice model to changes in travel conditions, a 10% increase has been applied to outward leg travel times in the 08:00–08:59 TP. Figure 21 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

Figure 21: Changes in home–leisure car driver demand, 10% increase to outward times in 08:00–08:59 period



Demand in the 08:00–08:59 period has reduced by 2.5% as a result of the test, and therefore the direct tour elasticity to changes in car travel times in that TP is -0.26. This gives a sensitivity that is around 60% of the equivalent sensitivity for the home–work model. The TP choice model is multinomial between TP combination alternatives, and therefore the increases in demand for other outward TPs are uniform (0.12%). These 0.12% increases in demand are small relative to the 2.5% reduction in the 08:00–08:59 period because only a low fraction (6.5%) of home–leisure tours have their outward leg in the 08:00–08:59 period in the base case.

The redistribution across different TP combination alternatives that follows from the test results in a return TP distribution that is in general shifted later in the day, with small increases in demand predicted in the return TP alternatives departing after 17:00. However, we also observe increases in tours returning in the 07:00–07:59 and 15:00–15:69 TPs.

The increase in demand for modes other than car driver is small as a percentage of total demand for other modes (0.013%). However, the impact on the number of trips is more substantial – the number of trips shifting to other modes represents one-third of the reduction in outward trips in the 08:00–08:59 period.

9.4 Tour lengths

Table 48 compares mean observed and predicted tour lengths for each of the five modelled modes.

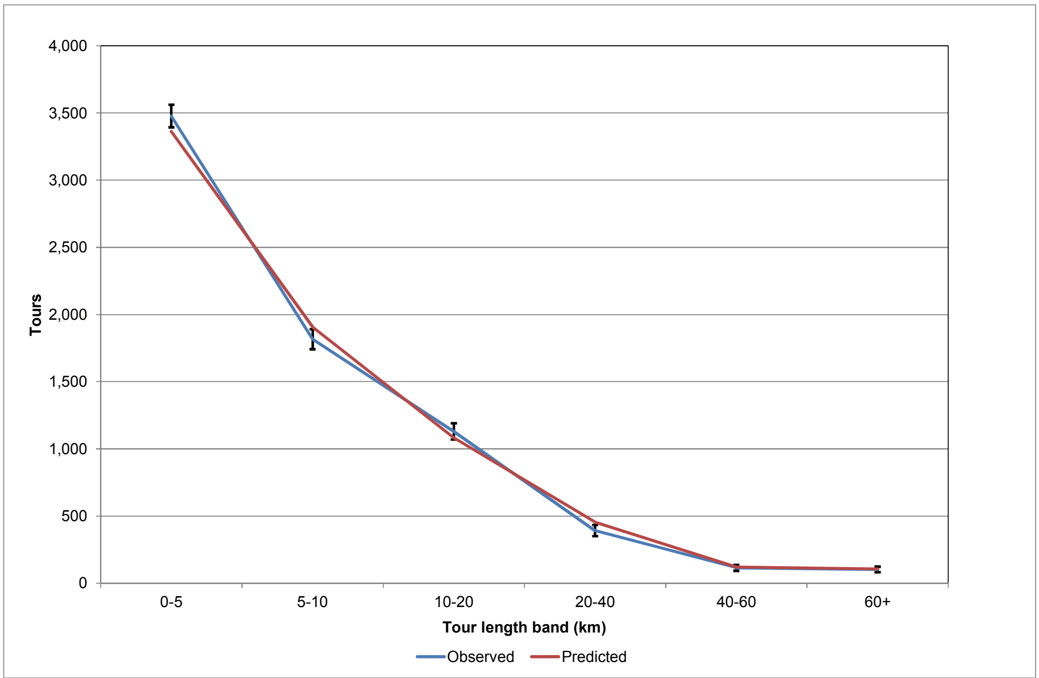
Table 48: Home–leisure tour lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	14.84	15.60	5.10%
car driver	15.61	14.91	-4.49%
car passenger	15.19	19.45	27.99%
cycle	6.00	6.03	0.36%
walk	2.74	2.76	0.55%
Total	8.85	9.11	2.97%

Overall tour distances are predicted well, with a difference between observed and predicted values of just under 3%. Given that a single car free flow time parameter is estimated, we expect a good match to total tour distances, but for individual modes a good match is only expected if a mode-specific distance term is estimated. For car driver, a 4% under-prediction of tour distances is observed. For car passenger, mean tour distances are significantly over-predicted (consistent with the OTM 5.3 specification there is no car passenger distance term in the model). Distances for walk and cycle modes are predicted accurately because of the mode specific distance terms used for these modes.

Figure 22 compares observed and predicted tour length distributions for all modes. Confidence intervals are plotted, which are calculated as twice the standard error for the observed distribution.

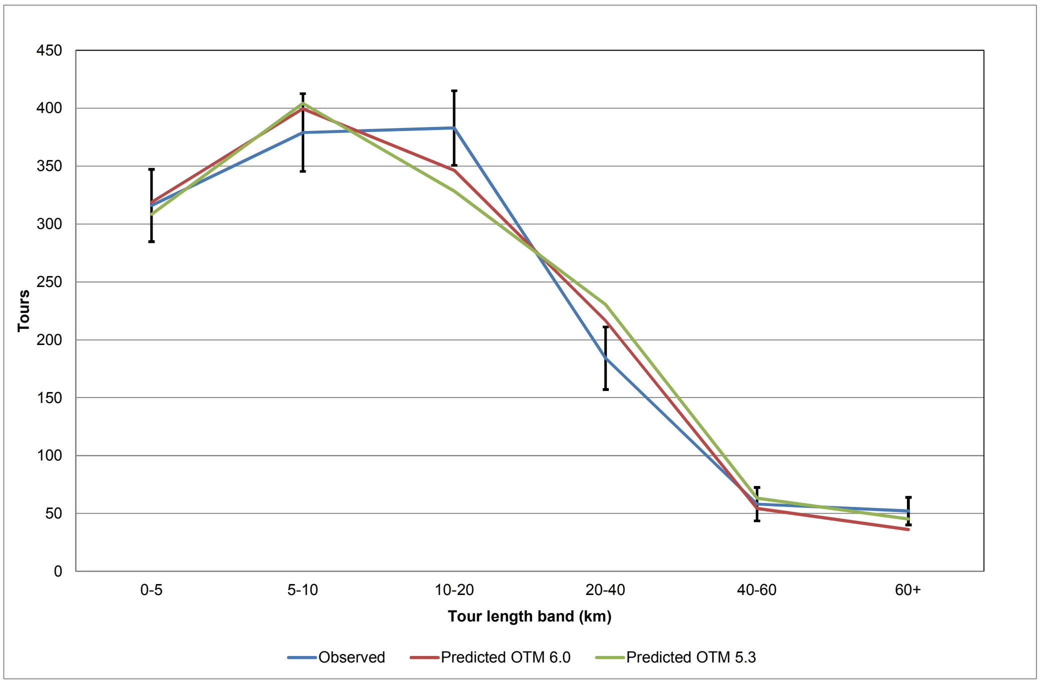
Figure 22: Home–leisure tour length distributions, all modes



The large volumes of data for home–leisure mean that the confidence intervals are tight. Thus the differences between the observed and predicted distributions are significant for the 0–5 km and 5–10 km bands, though the differences are not large in percentage terms. Overall, the predicted distribution matches the shape of the observed well.

Figure 23 compares observed and predicted tour length distributions for car driver.

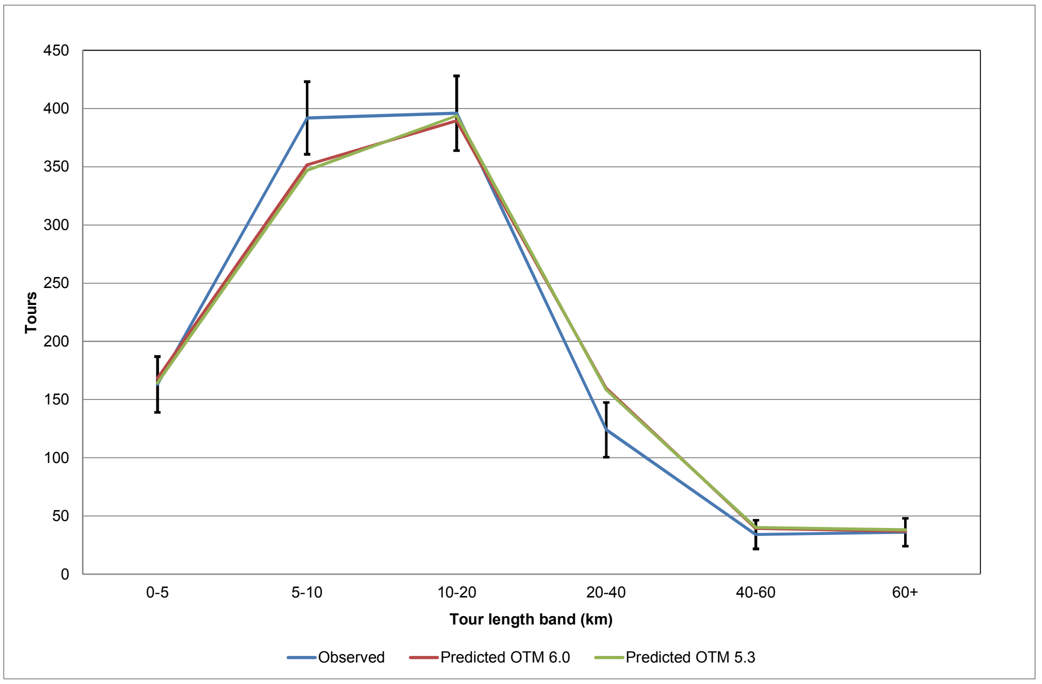
Figure 23: Home–leisure tour length distributions, car driver



The distribution predicted by the OTM 6.0 model lies within the confidence intervals plotted for the observed distribution for all distances bands except 60+ km, where the model under-predicts the number of tours. This under-prediction of the longest tours is consistent with the overall under-prediction of mean car driver tour lengths.

Figure 24 compares observed and predicted tour length distributions for PT.

Figure 24: Home–leisure tour length distributions, PT



There is a significant under-prediction of tours in the 5–10 km band, and a significant over-prediction of tours in the 20–40 km band. Tours in other distance bands are predicted accurately. The net impact of the differences in the 5–10 km and 20–40 km bands is not large, with PT tour distances over-predicted by just 4% overall.

Overall, it was decided that the discrepancies between the observed and predicted tour length distributions for car driver and PT were not large enough to warrant additional distance correction terms. An important consideration was that such correction terms would result in a reduction in model sensitivity, and the current model specification exhibits a relatively low elasticity to changes in car driver and PT costs and travel times.

CHAPTER 10 Non-home–based business model

10.1 Structural tests

The starting point for the structural tests was the final OTM 5.3 NHB business model, where a multinomial structure for mode and destination choice was used.

The first set of models estimated used structure 1, with modes above TPs above destinations. Table 49 summarises the model results obtained. For the structural parameters the t-ratios presented are calculated relative to a value of 1. It is noted that there was no information on the relative sensitivities of mode and TP choice decisions for NHB business travel in the SP evidence reviewed in Section 4.3.1.

Table 49: NHB business structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
8	-7074.9	22	TR_M_TP TR_TP_D CarFFTime	1 1 -0.02073	* * -14.0	yes	n/a n/a n/a
9	-7074.1	24	TR_M_TP TR_TP_D CarFFTime	0.4832 2.337 -0.02064	1.2 0.6 -14.0	yes	-0.068 0.072 n/a
10	-7074.3	23	TR_M_TP TR_TP_D CarFFTime	1.13 1 -0.02068	9.7 * -11.2	yes	0.032 n/a n/a
14	-7065.3	23	TR_M_TP TR_TP_D CarFFTime	1 1 -0.01774	* * -11.2	yes	n/a n/a n/a

In model 8 both structural parameters are fixed to a value of 1, and so mode, TP and destination choices are all equally sensitive to changes in utility. When both structural parameters are released from 1 in model 9, the resulting TR_TP_D structural parameter is greater than 1 (but not significantly so). When this parameter is fixed to a value of 1 in model 10, the estimate for the other structural parameter (TR_M_TP) is significantly greater than 1. Therefore the multinomial structure estimated in model 8 remains the candidate model for implementation.

Model 14 is based on model 8, but with an additional short distance trip correction term for car driver trips. This results in a substantial improvement in model fit (9.6 log-likelihood points), though it should be noted that the car free flow time parameter reduces in magnitude; thus adding the distance correction term has resulted in a reduction in overall model sensitivity.

Given that the candidate model to emerge from the tests with structure 1 has a multinomial structure for mode, TP and destination choice, structural tests were also run for the other two possible model structures to search for an alternative model structure (Table 50 and Table 51).

Table 50: NHB business structural tests, structure 2: destinations above modes above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
13	-7060.6	24	TR_D_M TR_M_TP CarFFTime	1.519 38.7 -3.23e-4	4.1 0.8 n/a	yes	0.02 0.996 n/a

The TR_D_M parameter is significantly greater than 1, and the high TR_M_TP parameter estimate indicates that there is no information in the data to explain the sensitivity of TP choice relative to main mode choice, and therefore structure 2 was rejected.

Table 51: NHB business structural tests, structure 3: modes above destinations above TPs

2Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
11	-7074.3	23	TR_M_D TR_D_TP CarFFTime	1.13 1 -0.02068	1.1 * -14.1	yes	0.032 n/a n/a
12	-7079.6	24	TR_M_D TR_D_TP CarFFTime	1.076 147.9 -1.36e-4	0.7 0.0 -14.4	no	n/a n/a n/a

In model 11, where only the TR_M_D parameter is released from 1, the structural parameter is greater than 1 (but not significantly so). In model 12 both structural parameters were released, and the very high estimate for the TR_D_TP parameter indicates that there is no information in the data to explain the sensitivity of TP choice relative to destination choice.

Overall the conclusion from the structural tests was that it was not possible to obtain any evidence on the relative sensitivities of mode, destination and TP choices from the data. Therefore model 14, with a multinomial structure, remained the candidate model for implementation.

Following completion of the structural tests an additional model was run, model 15, which used improved all-day LOS for car passenger. The improved car passenger LOS was calculated as a demand weighted average over TPs, an improvement on the assumption used to model car passenger in the structural tests where car passenger LOS was calculated as an unweighted average over TPs.

10.2 Final model parameters

Table 52 compares the OTM 5 and OTM 6 NHB other model parameters.

Table 52: NHB business parameter comparison

	OTM 5.3		OTM 6.0	
File	NHBB_6.F12		NHBB_CD_TP_V15.F12	
Converged	True		True	
Observations	1020		1001	
Final log (L)	-6643.6		-7065.1	
D.O.F.	13		23	
Rho²(0)	0.196		0.204	
Rho²(c)	-4.872		-3.291	
Estimated	4 Aug 06		8 Feb 12	
Scaling	1.0000		1.0000	
Attraction variable				
TotEmp	1.000	(*)	1.000	(*)
LOS variables				
CarffTime	-0.02121	(-14.9)	-0.01777	(-11.2)
PTTfrWtTm	-0.09061	(-3.8)	-0.1273	(-4.3)
PTAcEgTm	-0.05426	(-2.5)	-0.04633	(-2.7)
CycleDist	-0.6507	(-18.5)	-0.6505	(-18.7)
WalkDist	-1.488	(-12.9)	-1.430	(-13.4)
Intrazonal constant				
Intra	0.2762	(1.7)	-0.2628	(-1.4)
Distance correction parameters				
ShDistCarD			0.5306	(4.4)
Car availability parameters				
PTCarAv	-1.046	(-3.6)	-1.031	(-3.6)
CarDcarhh	1.997	(5.7)	1.897	(5.5)
CarPcarhh	1.845	(4.5)	1.742	(4.3)
Mode specific constants				
PT	0.2100	(0.5)	0.8778	(2.3)
CarP	-3.309	(-13.5)	-2.642	(-10.5)
Cycle	1.922	(8.2)	2.690	(10.9)
Walk	2.419	(8.5)	3.016	(10.5)
Structural parameters				
TR_M_TP			1.000	(*)
TR_TP_D			1.000	(*)
Time combination constants				
TP_1			-5.807	(-5.8)
TP_2			-5.802	(-5.8)
TP_3			-3.755	(-9.8)
TP_4			-2.681	(-11.6)
TP_5			0	(*)
TP_6			-1.913	(-11.8)
TP_7			-2.239	(-11.5)
TP_8			-2.870	(-11.5)
TP_9			-3.083	(-11.7)
TP_10			-4.421	(-8.8)

The 'TP_5' constant represents the base alternative. This represents the UM3 period (09:00–14:59), which has been set as the base as it is the most frequently chosen alternative.

10.3 Model elasticities

The mode-destination trip elasticities for the final OTM 6.0 and 5.3 models are compared in Table 53. Direct trip elasticities are highlighted in bold.

Table 53: NHB business trip elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.074	0.074	**-0.161**	**-0.516**
Car driver	**-0.169**	**-0.065**	0.004	0.016
Car passenger	0.298	**-0.267**	0.024	0.081
Cycle	0.126	0.096	0.028	0.083
Walk	0.149	0.109	0.026	0.077
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.086	0.101	**-0.185**	**-0.618**
Car driver	**-0.182**	**-0.078**	0.005	0.019
Car passenger	0.342	**-0.320**	0.029	0.109
Cycle	0.148	0.123	0.032	0.101
Walk	0.152	0.120	0.029	0.089
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	-14.5%	-27.1%	-12.8%	-16.5%
Car driver	-7.1%	-17.2%	-13.2%	-16.7%
Car passenger	-13.0%	-16.6%	-18.8%	-26.0%
Cycle	-15.1%	-22.0%	-13.8%	-17.8%
Walk	-1.9%	-9.5%	-11.5%	-13.4%
Total	n/a	n/a	n/a	n/a

The demand (mode choice) elasticities are lower in the OTM 6 model, consistent with the reduction in the magnitude of the car free flow time parameter which governs the overall sensitivity of the model (the parameter has reduced from -0.0212 in the final OTM 5.3 model to -0.0178 in the final OTM 6.0 model). The car free flow time parameter reduced in magnitude when the car driver short distance correction parameter was added to the model during the OTM 6.0 model development, i.e. adding distance correction terms has resulted in a reduction in model sensitivity.

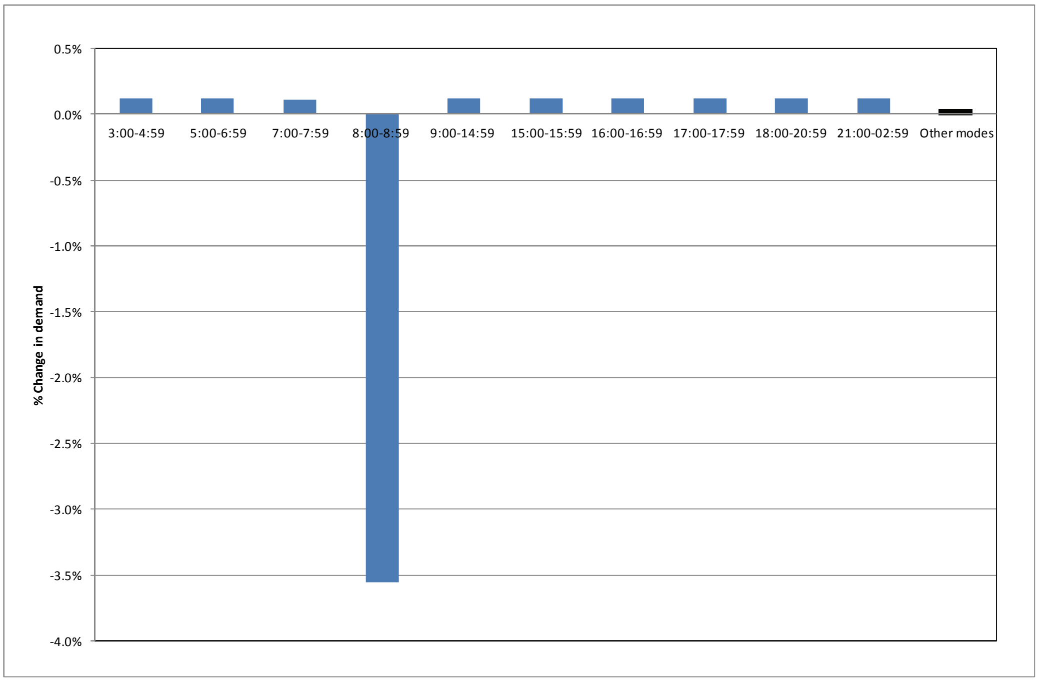
Table 54: NHB business kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.099	0.093	**-0.216**	**-0.815**
Car driver	**-0.465**	**-0.178**	0.004	0.017
Car passenger	0.361	**-0.413**	0.023	0.080
Cycle	0.128	0.099	0.029	0.091
Walk	0.150	0.111	0.026	0.079
Total	-0.224	-0.150	-0.011	-0.041
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.116	0.138	**-0.248**	**-1.018**
Car driver	**-0.482**	**-0.224**	0.005	0.021
Car passenger	0.411	**-0.521**	0.031	0.120
Cycle	0.147	0.128	0.034	0.111
Walk	0.148	0.119	0.030	0.093
Total	-0.239	-0.187	-0.012	-0.053
Changes	Car cost	Car time	PT cost	PT time
PT	-14.4%	-32.3%	-12.9%	-19.9%
Car driver	-3.6%	-20.3%	-13.1%	-21.2%
Car passenger	-12.3%	-20.8%	-26.7%	-33.4%
Cycle	-13.2%	-22.6%	-14.2%	-18.1%
Walk	1.2%	-6.9%	-13.1%	-15.0%
Total	-6.1%	-20.0%	-10.7%	-22.0%

The percentage reductions in the kilometrage elasticities are very similar to the percentage reductions in the tour elasticities (Table 54). Again, the reduction in sensitivity is driven by the reductions to the magnitude of the car free flow time parameter.

To test the sensitivity of the car driver TP choice model to changes in travel conditions, a 10% increase has been applied to travel times in the 08:00–08:59 TP. Figure 25 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

Figure 25: Changes in NHB business car driver demand, 10% increase to travel times in 08:00–08:59 period



The 10% increase in travel times in the 08:00–08:59 period results in a 3.7% reduction in demand in that TP, which gives a direct elasticity of -0.38. This level of responsiveness is comparable to that observed for commute travel, but is significantly higher than the responsiveness of the HB business model, where the direct elasticity was just -0.01.

The TP choice model is multinomial between TP alternatives, and therefore a uniform 0.1% increase in demand is observed for all other TPs. There is a very slight increase in demand for other modes (an increase of just 0.04% relative to base demand for other modes). However, if the increase in the number of trips for other modes is expressed as a percentage of the reduction in demand in the 08:00–08:59 period we get 29%, i.e. the mode shift impact is relatively substantial compared to the TP shift impacts.

10.4 Trip lengths

Table 55 compares mean observed and predicted trip lengths for each of the five modelled modes.

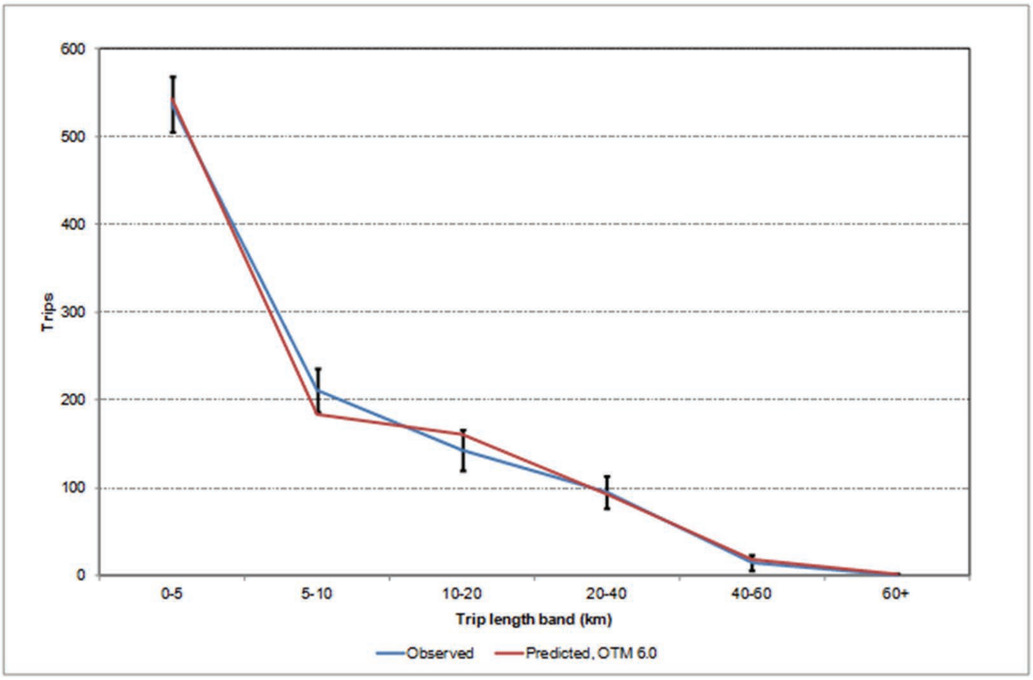
Table 55: NHB business trip lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	11.08	9.07	-18.17%
car driver	11.46	12.09	5.45%
car passenger	13.53	18.67	37.94%
cycle	2.90	2.96	2.25%
walk	1.43	1.56	8.94%
Total	8.05	8.50	5.64%

The overall mean trip length is over-predicted by just over 5%. More substantial differences are observed for PT, where mean trip lengths are under-predicted by 18%, and car passenger, where mean trip lengths are over-predicted by 38%. It is noted that consistent with the OTM 5.3 specification there is no distance parameter on car passenger in the NHB business model.

Figure 26 compares observed and predicted trip length distributions for all modes. Confidence intervals are plotted using the formula given in Section 4.4.3.

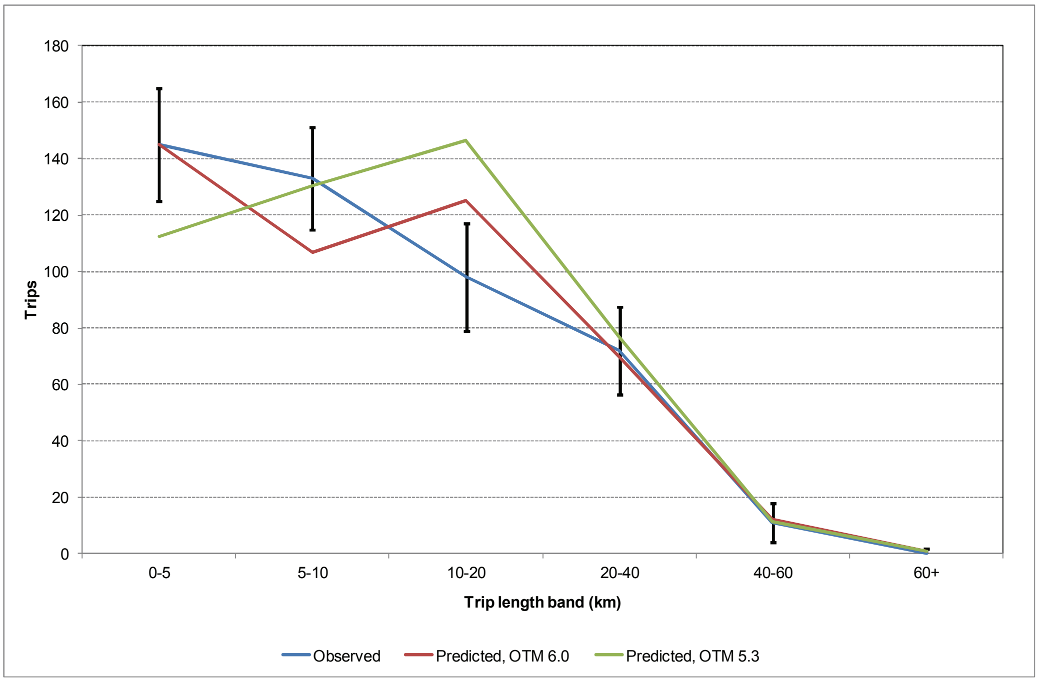
Figure 26: NHB business trip length distributions, all modes



The predicted distribution lies within the confidence intervals plotted around the observed for each of the six trip length bands.

Figure 27 compares observed and predicted trip length distributions for car driver.

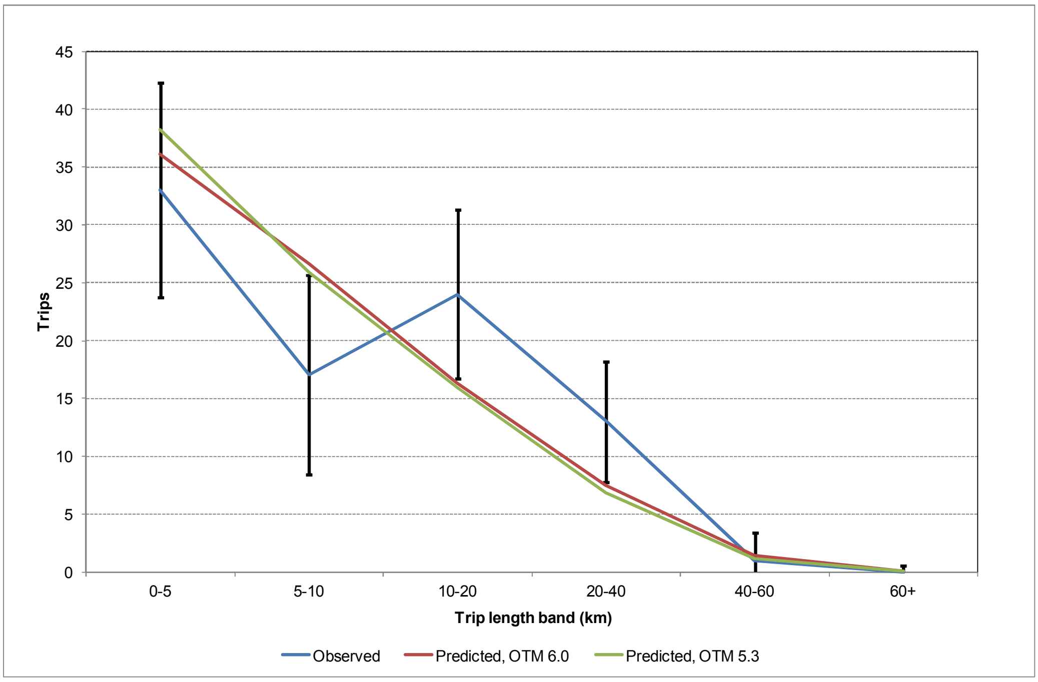
Figure 27: NHB business trip length distributions, car driver



The fit to the observed distribution is improved relative to OTM 5.3 as a result of the addition of a short distance band correction term for trips in the 0–5 km band. However, there are significant differences between the observed and predicted distributions in the next two distance bands, 5–10 km and 10–20 km. Adding further distance correction terms to correct for these differences would have resulted in further reductions in model sensitivity, and therefore it was decided to accept the discrepancies in the 5–10 km and 10–20 km bands.

Figure 28 compares observed and predicted trip length distributions for PT.

Figure 28: NHB business trip length distributions, PT



The predicted distribution lies just outside the confidence intervals plotted around the observed distribution for the 5–10 km, 10–20 km and 20–40 km bands. However, the observed distribution is lumpy in this region because of the small numbers of trips, and the smoother predicted distribution does not look unreasonable.

CHAPTER 11 Non-home–based other model

11.1 Structural tests

In the OTM 5.3 models, the final NHB other model specification had a multinomial choice between modes and destinations.

Tests have been undertaken using structures 1 and 3. The results from the models estimated using structure 1 are summarised in Table 56. The t-ratios presented for the structural parameters are calculated relative to a value of 1. It is noted that there was no information on the relative sensitivities of mode and TP choice decisions for NHB other travel in the SP evidence reviewed in Section 4.3.1.

Table 56: NHB other structural tests, structure 1: modes above TPs above destinations

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
11	-73886.1	31	TR_M_TP TR_TP_D CarFFTime	1 1 -0.0272	* * -30.5	yes	n/a n/a n/a
12	-73881.9	32	TR_M_TP TR_TP_D CarFFTime	1.114 1 -0.02673	2.9 * -29.7	yes	0.19 n/a n/a
13	-73881.8	33	TR_M_TP TR_TP_D CarFFTime	1.665 0.6688 -0.02675	0.4 0.5 -29.7	yes	-0.031 0.038 n/a
14	-73881.8	33	TR_M_TP TR_TP_D CarFFTime	1 1.114 -0.02673	* 0.1 -29.7	yes	n/a 0.194 n/a

Model 11 has a multinomial choice between modes, TPs and destinations, consistent with the OTM 5.3 model structure.

In model 12, the TR_M_TP parameter was released from 1, but the resulting parameter estimated was significantly higher than 1. In model 13 both structural parameters were released; again the TR_M_TP parameter was higher than 1 and therefore the model was rejected. Finally, in model 14, the TR_M_TP parameter was fixed to 1 and the TR_TP_D parameter was estimated. The TR_TP_D parameter estimate was slightly greater than 1, but not significantly so.

Overall model 11 with a multinomial structure was the best candidate model from the tests undertaken using structure 1.

The second set of structural tests undertaken have been made using structure 3, with a modes above destinations above TPs structure. The results from these tests are reported in Table 57.

Table 57: NHB other structural tests, structure 3: modes above destinations above TPs

Model	Log-likelihood	Degrees of freedom	Coefficient	Value	T-ratio	Converged?	Correlation with CarFFTime
15	-73881.9	32	TR_M_D TR_D_TP CarFFTime	1.114 1 -0.02673	2.9 * -29.7	yes	0.032 n/a n/a
16	-73878.2	33	TR_M_D TR_D_TP CarFFTime	1.113 3.708 -7.23e-3	2.9 0.9 -1.3	no	n/a n/a n/a

In model 15, the TR_D_TP parameter was fixed to 1 and the TR_M_D parameter was estimated. This model replicates the results from model 12, which was estimated from structure 1.

In model 16 both structural parameters were released from 1. The model did not converge, but at the point at which the run failed both structural parameters had values greater than 1, and therefore there was no evidence that the run was converging towards a feasible solution.

The conclusion from the structural tests was that no nesting structure could be identified from the data for NHB other, and therefore model 11 with a multinomial structure for mode, destination and TP choice was the candidate model for implementation.

Following completion of the structural tests, revised car passenger LOS was supplied by TetraPlan, calculated as a demand weighted average over the day. This was incorporated in the final model used for implementation, model 17.

11.2 Final model parameters

Table 58 compares NHB other parameters.

Table 58: NHB other parameter comparison

	OTM 5.3		OTM 6.0	
File	NHBO_13.F12		NHBO_CD_TP_V17.F12	
Converged	True		True	
Observations	11055		11052	
Final log (L)	-68841.8		-73887.1	
D.O.F.	23		31	
Rho²(0)	0.228		0.220	
Rho²(c)	-3.816		-2.861	
Estimated	4 Aug 06		8 Feb 12	
Scaling	1.0000		1.0000	
Size variables				
L_S_M	1.000	(*)	1.000	(*)
sz_com1	0.8563	(5.9)	0.7766	(5.0)
sz_com2	3.205	(47.6)	3.262	(49.3)
sz_com3	3.030	(45.4)	3.103	(47.6)
sz_edu	0.7859	(10.1)	0.7940	(10.1)
sz_ent	2.220	(32.9)	2.352	(35.7)
sz_lse	0.2722	(2.3)	-0.2557	(-1.3)
sz_pse	-0.5700	(-2.7)	-0.07665	(-0.5)
LOS variables				
CarffTime	-0.03206	(-34.8)	-0.02724	(-30.5)
PTTfrWtTm	-0.1011	(-14.0)	-0.1246	(-14.9)
PTAcEgTm	-0.03323	(-5.9)	-0.03543	(-7.7)
CycleDist	-0.6094	(-62.7)	-0.6119	(-63.2)
WalkDist	-1.663	(-67.7)	-1.572	(-67.4)
Intrazonal constant				
Intra	0.2066	(4.8)	-0.2842	(-5.7)
Distance correction parameters				
ShDistCarD	0.9467	(20.1)	1.083	(23.1)
ShDistCarP	1.315	(16.7)	1.396	(17.8)
ShDistPT	0.2772	(4.2)	0.2645	(4.0)
Car availability parameters				
PTcarav	-1.017	(-13.2)	-1.001	(-13.1)
CarDcarhh	0.9173	(8.8)	0.9122	(9.0)
CarPcarhh	1.283	(11.2)	1.273	(11.3)
Mode specific constants				
PT	0.4210	(3.2)	1.819	(14.4)
CarP	-3.068	(-35.4)	-1.761	(-19.6)
Cycle	1.925	(23.1)	3.397	(40.0)
Walk	3.674	(42.3)	4.963	(56.5)
Structural parameters				
TR_TP_D			1.000	(*)
TR_M_TP			1.000	(*)
Time period combination constants				
TP_1			*-99.00*	*(*)*
TP_2			-4.562	(-13.6)
TP_3			-2.536	(-19.3)
TP_4			-1.272	(-16.6)

```
TP_5                                         0      (*)
TP_6                                   -0.9144 (-13.6)
TP_7                                   -0.5952  (-9.6)
TP_8                                   -0.9223 (-13.8)
TP_9                                   -0.8518 (-13.6)
TP_10                                   -2.065 (-20.4)
```

The 'TP_5' constant represents the base alternative. This represents the UM3 period (09:00–14:59), which has been set as the base as it is the most frequently chosen alternative. The 'TP_1' constant is set to -99 and the alternative set to be unavailable as there are no observed trips for this TP.

11.3 Model elasticities

The mode-destination trip elasticities of the final OTM 6.0 and 5.3 models are compared in Table 59. Direct trip elasticities are highlighted in bold.

Table 59: NHB other trip elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.036	0.071	**-0.516**	**-0.284**
Car driver	**-0.204**	**-0.176**	0.024	0.017
Car passenger	0.119	**-0.340**	0.084	0.049
Cycle	0.059	0.090	0.090	0.049
Walk	0.062	0.091	0.086	0.046
Total	0.000	0.000	0.000	0.000
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.044	0.089	**-0.586**	**-0.324**
Car driver	**-0.243**	**-0.177**	0.029	0.021
Car passenger	0.146	**-0.417**	0.107	0.064
Cycle	0.074	0.103	0.106	0.057
Walk	0.072	0.090	0.098	0.051
Total	0.000	0.000	0.000	0.000
Changes	Car cost	Car time	PT cost	PT time
PT	-18.8%	-20.5%	-12.0%	-12.4%
Car driver	-16.1%	-0.5%	-16.1%	-17.9%
Car passenger	-18.6%	-18.6%	-21.5%	-22.9%
Cycle	-19.9%	-12.7%	-14.8%	-14.3%
Walk	-13.6%	1.1%	-11.8%	-9.7%
Total	n/a	n/a	n/a	n/a

The OTM 6.0 trip elasticities show modest reductions in the sensitivity of the model relative to the OTM 5.3 model. The reductions in sensitivity are in line with the 15% reduction in magnitude of the car free flow time parameter between the OTM 5.3 and OTM 6.0 models.

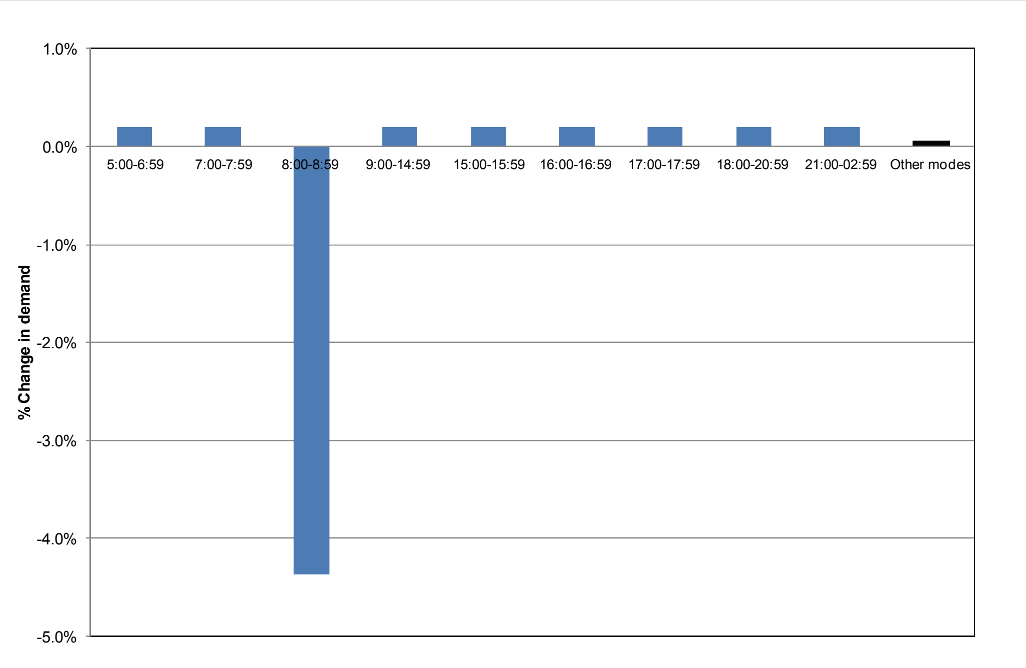
Table 60: NHB other kilometrage elasticity comparison

OTM 6.0	Car cost	Car time	PT cost	PT time
PT	0.044	0.086	**-0.687**	**-0.445**
Car driver	**-0.473**	**-0.407**	0.025	0.019
Car passenger	0.153	**-0.676**	0.088	0.053
Cycle	0.063	0.097	0.094	0.052
Walk	0.066	0.096	0.087	0.047
Total	-0.149	-0.215	-0.088	-0.059
OTM 5.3	Car cost	Car time	PT cost	PT time
PT	0.056	0.118	**-0.787**	**-0.520**
Car driver	**-0.506**	**-0.448**	0.030	0.024
Car passenger	0.193	**-0.884**	0.122	0.076
Cycle	0.076	0.112	0.111	0.062
Walk	0.072	0.094	0.100	0.052
Total	-0.149	-0.242	-0.108	-0.073
Changes	Car cost	Car time	PT cost	PT time
PT	-20.6%	-27.3%	-12.7%	-14.4%
Car driver	-6.5%	-9.1%	-17.3%	-22.0%
Car passenger	-20.9%	-23.5%	-27.9%	-29.7%
Cycle	-16.9%	-13.8%	-15.4%	-15.5%
Walk	-8.2%	2.4%	-13.0%	-10.5%
Total	n/a	n/a	n/a	n/a

The percentage reductions in the kilometrage elasticities between OTM 6.0 and OTM 5.3 (Table 60) are consistent with the reductions in the trip elasticities observed in Table 59. Again, the reduction in sensitivity is driven by the reduction in the magnitude of the car free flow time parameter that results from the introduction of car driver TP choice to the model structure.

To test the sensitivity of the car driver TP choice model to changes in travel conditions, a 10% increase has been applied to travel times in the 08:00–08:59 TP. Figure 29 plots the changes in demand for outward and return TP and the extent of the shift to other modes.

Figure 29: Changes in NHB other car driver demand, 10% increase to travel times in 08:00–08:59 period



The 10% increase in travel times in the 08:00–08:59 period results in a 4.4% reduction in demand in that TP, giving a direct elasticity of -0.47, i.e. the model is almost twice as elastic as the home–leisure model.

As the choice between TP alternatives is multinomial, there are uniform increases in demand for other TP alternatives of 0.2% as a result of the change in travel times.

There is a very small increase (0.05%) in demand for other modes because some car driver demand switches to other modes as a result of the test. The increase in demand for other modes represents 49% of the shift of trips away from the 08:00–08:59 TP alternative, i.e. the mode shift effect is relatively significant compared to the TP shift effect.

11.4 Trip lengths

Table 61 compares mean observed and predicted trip lengths for each of the five modelled modes.

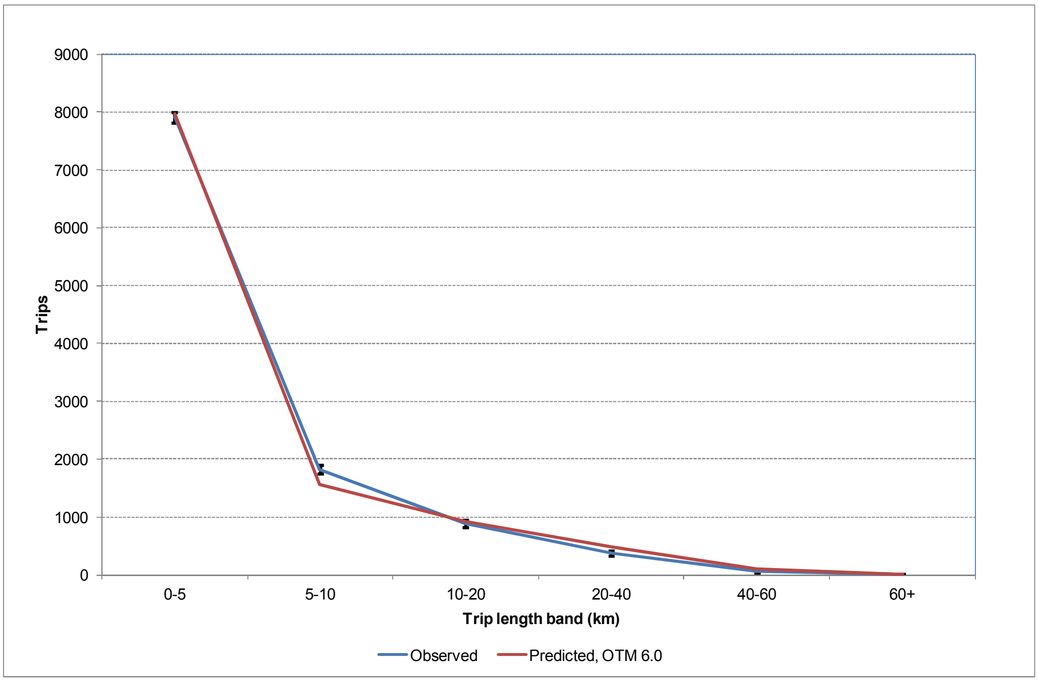
Table 61: NHB other trip lengths by mode (km)

Mode	Observed	Predicted	Difference
PT	8.60	8.79	2.17%
car driver	8.73	9.78	12.06%
car passenger	8.24	11.80	43.20%
cycle	3.10	3.11	0.48%
walk	1.35	1.47	8.83%
Total	4.95	5.48	10.63%

The overall mean trip length is over-predicted by 10%, higher than the over-predictions for the other purposes. Significant over-predictions are observed for car driver (consistent with the OTM 5.3 specification the model does not contain a car passenger distance term).

Figure 30 compares observed and predicted trip length distributions for all modes. Confidence intervals are plotted, which are calculated as twice the standard error for the observed distribution.

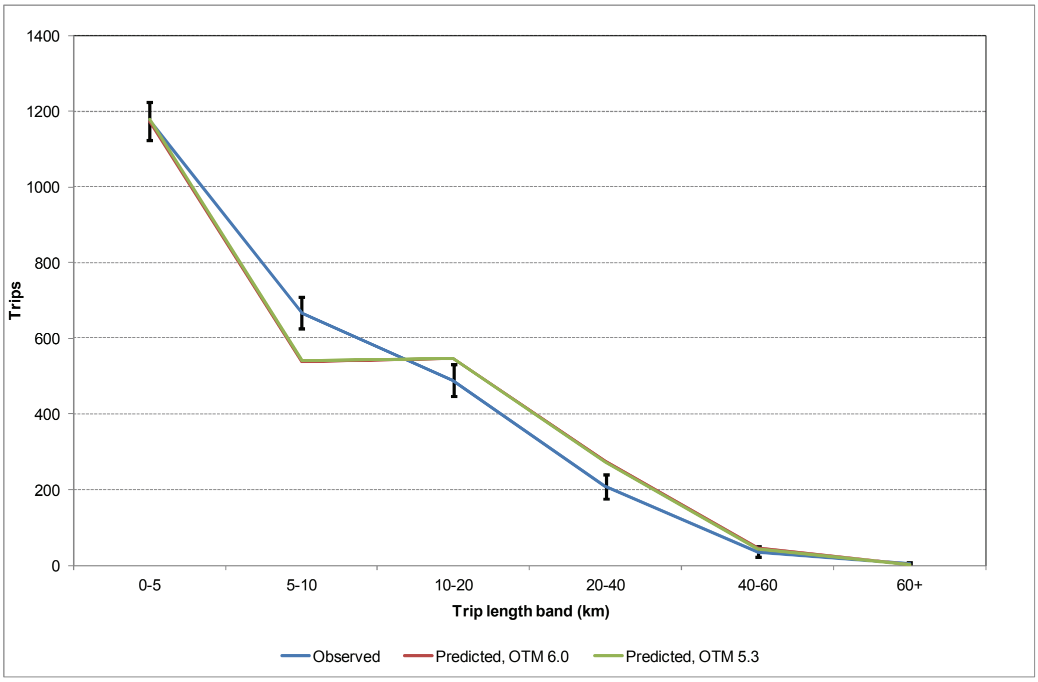
Figure 30: NHB other trip length distributions, all modes



The predicted distribution lies outside the confidence intervals plotted for the observed for the 5–10 km and 20–40 km bands. However, the confidence intervals for these bands are relatively tight due to the high volume of observed data for NHB other trips, and overall the predicted distribution matches the shape of the observed distribution well.

Figure 31 compares observed and predicted trip length distributions for car driver.

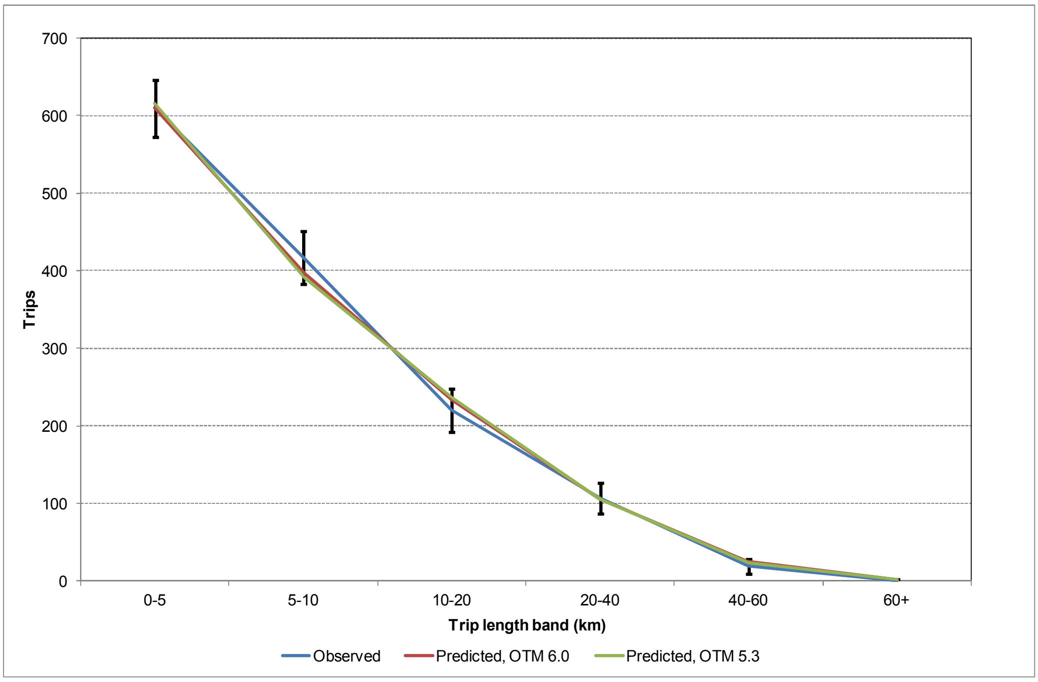
Figure 31: NHB other trip length distributions, car driver



The car driver short distance correction terms present in the OTM 5.3 and OTM 6.0 model specifications ensure that observed and predicted data match exactly for the tours in the 0–5 km band. The models then under-predict tours in the 5–10 km band, and over-predict tours in the 10–20 km and 20–40 km bands, with predictions for these bands falling outside the relatively tight confidence intervals plotted around the observed distribution. However, adding further distance correction terms to correct to the observed distribution would further damp the sensitivity of the model – introducing TP choice into the structure has already damped the sensitivity to generalised car free flow time – and therefore no changes were made to the OTM 6.0 model specification.

Figure 32 compares observed and predicted trip length distributions for PT.

Figure 32: NHB other trip length distributions, PT



The predicted trip length distributions for PT matches the observed closely, lying within the confidence intervals for all six of the trip length bands. It is noted that both the OTM 5.3 and 6.0 models include a short distance correction term for PT tours in the 0–5 km band, which ensures that observed and predicted data match exactly for this band.

CHAPTER 12 Frequency models

In the OTM 5 model development work, a significant link between travel frequency and accessibility, measured by the logsum from the mode-destination models, was identified for home–work, home–shopping and home–leisure. These three frequency models have therefore been re-estimated using updated logsums from the final mode-destination-TP choice models for these purposes. For the remaining model purposes the frequency models estimated during the OTM 5 model development work have no link to accessibility and so the OTM 5 model specifications have been retained.

The following sections compare the OTM 5.3 and 6.0 frequency model parameters for the three purposes where new models have been estimated in OTM 6.0. For a full description of the structure of the frequency models, please refer to Fox (2006).

12.1 Home–work

Table 62: Home–work frequency model comparison

	OTM 5.3		OTM 6.0	
File	HW_FREQ_33.F12		HW_FREQ_45.F12	
Converged	True		True	
Observations	11239		11239	
Final log (L)	-7822.5		-7823.3	
D.O.F.	7		7	
$Rho^2(0)$	0.612		0.612	
$Rho^2(c)$	0.014		0.014	
Estimated	21 Jul 06		4 Sep 13	
Scaling	1.0000		1.0000	
Structural parameter				
theta	0	(*)	0	(*)
Constants				
none	1.575	(2.7)	2.017	(2.7)
stop	8.289	(3.0)	10.66	(2.9)
Occupation parameter				
Zero_SlfEm	0.7675	(11.1)	0.7678	(11.1)
Personal income parameters				
Zero_PI1_2	0.6159	(9.1)	0.6185	(9.2)
Zero_PI3	0.1966	(4.2)	0.1982	(4.3)

Accessibility parameters				
Zero_lsum	-0.2128	(-4.2)	-0.1890	(-3.8)
Stop_lsum	-0.3852	(-1.6)	-0.4439	(-1.9)

The logsum term for the stop alternative, which implies individuals are less likely to make multiple tours in zones where accessibility is higher (so more likely to make multiple tours in zones where accessibility is higher), increases in magnitude and significance in the OTM 6.0 model, whereas the term on zero tours reduces slightly in magnitude and significance.

12.2 Home–shopping

Table 63: Home–shopping frequency model comparison

File	HS_FREQ_13.F12		HS_FREQ_24.F12	
Converged	True		True	
Observations	16350		16350	
Final log (L)	-9313.0		-9315.7	
D.O.F.	8		7	
Rho²(0)	0.682		0.682	
Rho²(c)	0.029		0.029	
Estimated	21 Jul 06		4 Sep 13	
Scaling	1.0000		1.0000	
Structural parameter				
theta	0	(*)	0	(*)
Constants				
none	1.324	(31.8)	1.345	(33.7)
stop	4.700	(5.4)	5.580	(4.0)
Occupation parameters				
Zero_Unemp	-0.6422	(-7.5)	-0.6408	(-7.5)
Zero_ScPup	1.009	(7.8)	0.9891	(7.7)
Zero_Pens	-0.8572	(-14.1)	-0.8554	(-14.1)
Zero_WgErn	0.2230	(4.5)	0.2399	(4.9)
Car availability parameters				
Zero_CarAv	0.07107	(1.7)	0	(*)
Accessibility parameters				
Stop_lsum	-0.2402	(-2.9)	-0.2219	(-2.5)

In the OTM 5.3 model, there was a term on zero tours that implied that individuals with a car available were more likely to make zero shopping tours. This term was counter-intuitive, as normally we expect higher tour rates for car available persons, and the term was not significant at a 95% confidence level (but it was significant at a 90% confidence level). Therefore this term has been dropped from the OTM 6.0 model.

12.3 Home–leisure

Table 64: Home–leisure frequency model comparison

	OTM 5.3		OTM 6.0	
File	HL_FREQ_15.F12		HL_FREQ_26.F12	
Converged	True		True	
Observations	16350		16350	
Final log (L)	-14166.4		-14165.2	
D.O.F.	11		11	
Rho²(0)	0.606		0.606	
Rho²(c)	0.016		0.016	
Estimated	21 Jul 06		4 Sep 13	
Scaling	1.0000		1.0000	
Structural parameter				
theta	0	(*)	0	(*)
Constants				
none	2.101	(2.9)	2.922	(3.3)
stop	2.608	(2.0)	2.609	(1.7)
Occupation parameters				
Zero_WgErn	0.2439	(6.0)	0.2445	(6.0)
Zero_Pens	-0.4647	(-8.4)	-0.4668	(-8.5)
Zero_OsLf	-0.6385	(-5.7)	-0.6396	(-5.7)
Zero_Unemp	-0.8547	(-10.9)	-0.8555	(-10.9)
Stop_Unemp	-0.6155	(-6.7)	-0.6161	(-6.7)
Car availability parameters				
Zero_CarAv	-0.1350	(-2.5)	-0.1412	(-3.1)
Stop_CarAv	-0.2629	(-2.7)	-0.2904	(-3.7)
Accessibility parameters				
Zero_lsum	-0.1788	(-2.0)	-0.2196	(-2.5)
Stop_lsum	-0.1355	(-0.8)	-0.1054	(-0.7)

The logsum parameter on zero tours has a stronger impact in the OTM 6.0 home–leisure frequency model now that car driver TP combination choice has been incorporated into the mode-destination model structure.

CHAPTER 13 Summary

13.1 Mode-destination-time period choice models

The mode-destination models estimated for the OTM 5 model in 2006 have been extended so that they are able to predict TP choice for car drivers. The OTM 5 model specifications have been retained in this work, with only some minor changes to improve the fit to the observed tour and trip length distributions. For full documentation of the development of the OTM 5 mode-destination model specifications, please refer to Fox and Sivakumar (2006).

The extension of the models to represent TP choice drew on revealed preference information alone for the majority of the travel purposes, and for the other two purposes drew on a combination of revealed and SP data. Traditionally TP choice has been incorporated into mode-destination models using SP data alone.

Time period alternatives

In order to model TP choice for car drivers, car LOS has been supplied separately by nine TPs. Then an additional tenth TP has been identified by splitting the night TP (21:00–04:59) into two to distinguish between travel made at the start and the end of the survey day.

For the five HB purposes, it is necessary to model the choice of TP for both the outward and return legs of the tour, which meant that TP combination alternatives needed to be defined. These alternatives were defined separately for each of the five HB purposes based on the observed distribution of car driver tours over the possible TP combinations. For TP combinations where the volumes of car driver tours are relatively low, TPs have been aggregated for the purposes of the modelling. TP combinations that are never chosen, or only chosen in a few cases, have been set to be unavailable in the modelling.

For the two NHB purposes, the TP alternatives for car driver are simply the ten different TPs as these purposes are modelled as one-way trips.

Structural tests

Tests have been undertaken to determine the relative sensitivity of mode, destination and car driver TP choices for three candidate nested logit tree structures:

- modes above TPs above destinations
- destinations above modes above TPs
- modes above destinations above TPs

These structures have been estimated from the samples of tours and trips in the 2003 and 2005 revealed preference TU data used for model estimation. For some purposes, the relative sensitivity of mode and TP choices has been imported using SP evidence. Table 65 summarises the results from the structural tests, presenting a comparison to the final structure identified during the OTM 5 work, and summarising the structural parameters that define the relative sensitivity of mode and TP choices, and where this information has been imported using SP evidence. In Table 65 M denotes modes and D denotes destinations.

Table 65: Summary of structural tests

Purpose	Comparison of structures		Relative sensitivity of modes and TPs	
	OTM 5.3	OTM 6.0	θ_{M_TP}	SP import?
home–work	D > M	D > M = TP	0.70	yes
home–business	M = D	M = D > TP	0.60	yes
home–education	M = D	M = D = TP	1.00	no
home–shopping	M = D	M > D = TP	0.91	no
home–leisure	M > D	M > D = TP	0.56	no
NHB business	M = D	M = D = TP	1.00	no
NHB other	M = D	M = D = TP	1.00	no

The relative placements of the mode and destination choice decisions are consistent between the OTM 5.3 and 6.0 models for all purposes except home–shopping.

Before finalising the new OTM 6.0 models, validation was undertaken of the model elasticities and a comparison was made between observed and predicted trip/tour lengths. The findings from these two validation steps are summarised below.

Model elasticities

Mode-destination elasticities have been compared between the OTM 5.3 and OTM 6.0 models to assess the impact that introducing car driver TP choice has had on model sensitivity. For home–work, home–business and home–leisure, the two sets of elasticities are similar. For home–education higher elasticities are obtained in the new OTM 6.0 model, whereas for home–shopping, NHB business and NHB other the elasticities are lower in OTM 6.0.

The sensitivities of the new car driver TP choice responses have been assessed by making 10% increases to travel times in a single TP, and assessing the reduction in demand in that TP, changes in the distribution of demand over other TPs, and the extent of the shift to other modes. For HB purposes, the time increase is applied to outward tour legs in the 08:00–08:59 TP.[11] For NHB purposes, the time increase is applied to trips in the 08:00–08:59 TP. Table 66 presents a cross-purpose comparison of the results of the TP elasticity tests.

[11] Except for home–shopping, where the 10% increase was applied to travel times for outward tour legs in the 09:00–14:59 period.

Table 66: Summary of TP elasticity tests

Purpose	Direct elasticity for outward TP where 10% increase in travel times applied	Shift to other modes as a percentage of reduction in tours/trips in outward period where 10% increase is applied
home–work	-0.42	37%
home–business	-0.18	24%
home–education	-0.18	80%
home–shopping	-0.10	72%
home–leisure	-0.26	33%
NHB business	-0.38	29%
NHB other	-0.47	49%

The highest sensitivities to the peak travel time increase test are observed for home–work and NHB other purposes, with home–business the least sensitive model. Shifting to other modes is influenced by the base share of car driver, and the structural parameter defining the relative sensitivity of mode and TP choice decisions. Comparison of Table 65 and Table 66 shows that lower shifting to other modes is observed where the θ_{M_TP} parameter is lower in value, as would be expected.

Tour and trip length validation

For each purpose, observed and predicted tour and trip lengths have been compared across the five modelled modes. Furthermore, observed and predicted tour and trip length distributions have been compared for the all modes distributions, and for car driver and PT modes. In general the OTM 5 and OTM 6 models achieve similar levels of fit to the observed data. Some additional distance correction terms have been added to the home–work and NHB business models to improve the fit to the observed tour length distributions for these purposes. Distance correction terms have only been added to correct for larger differences between observed and predicted data, as they have the effect of damping the overall sensitivity of the models.

It should be noted that an exact match between observed and predicted tour length distributions is not an essential requirement for the OTM 6 models because in model application the model predictions are pivoted on the base matrices, which will replicate the base tour and trip length distributions exactly.

13.2 Frequency models

Three of the frequency models in the OTM 5 model (home–work, home–shopping and home–leisure) contained an accessibility term linking journey frequency with accessibility over modes and destinations, calculated as a logsum over mode-destination alternatives. The frequency models for these three purposes have been re-estimated using logsums from the mode-destination-TP choice models.

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