TECHNICAL
REPORT

The PRISM Model

Evidence on Model Hierarchy and Parameter Values

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Prepared for the UK Department for Transport

RAND EUROPE

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Preface

The UK Department for Transport (DfT) provides detailed guidance on the appraisal of transport projects and wider advice on scoping and carrying out transport studies through its WebTAG website (www.webtag.org.uk). Part of this advice concerns development of transport models which contain the full range of important demand responses, i.e. trip frequency, mode choice, destination choice, time period choice and route choice, called 'Variable Demand Models', for the evaluation of large highway and public transport infrastructure schemes. For development of this advice, the DfT sought evidence about choice hierarchies and parameter values from existing transport demand models, specifically those that had been subject to rigorous calibration and validation procedures. The Policy Responsive Integrated Strategy Model of the West Midlands (PRISM) developed by RAND Europe and Mott MacDonald met these requirements and therefore RAND Europe was commissioned to undertake this small study to report the model choice hierarchies and model parameter values from the PRISM model.

This report therefore concentrates on the PRISM model structure, specifically the model choice hierarchies and model parameter values. For more detail on the PRISM model, readers are directed to the PRISM model website (http://www.prism-wm.com/).

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Acknowledgments

Much of the thinking for the demand modelling reported here has been developed by RAND Europe staff and others over a number of years. Andrew Daly and James Fox have been especially influential in the development of the PRISM model.

Summary

The UK Department for Transport (DfT) provides detailed guidance on the appraisal of transport projects and wider advice on scoping and carrying out transport studies through its WebTAG website (www.webtag.org.uk). Part of this advice concerns development of transport models which contain the full range of important demand responses, i.e. trip frequency, mode choice, destination choice, time period choice and route choice, called 'Variable Demand Models', for the evaluation of large highway and public transport infrastructure schemes. For development of this advice, the DfT sought evidence about choice hierarchies and parameter values from existing transport demand models, specifically those that had been subject to rigorous calibration and validation procedures. The Policy Responsive Integrated Strategy Model of the West Midlands (PRISM) developed by RAND Europe and Mott MacDonald met these requirements and therefore RAND Europe was commissioned to undertake this small study to report the model choice hierarchies and model parameter values from the PRISM model.

The PRISM model system is a variable demand multi-modal transport model developed for the West Midlands region by RAND Europe and Mott MacDonald. It consists of detailed network models covering the highway and public transport (PT) systems, which are linked to a disaggregate model of travel demand. The demand model reflects a number of traveller responses in a number of interacting modules, including car ownership, PT travel pass ownership, tour frequency, destination choice, mode choice and time of day choice. All of these models, except for the car ownership model and the trip frequency model for business and non-home-based travel, were estimated from local data. Because the mode and destination models have been estimated from local data, the outputs provide evidence on appropriate model structure, particularly the relative sensitivity of mode and destination choice, which is of particular interest to DfT at this time.

The following table summarises the optimal nesting structures for mode and destination choice identified in the estimation of the PRISM models. The tables also report the resulting model sensitivity parameters, defined as 'Lambda' (λ), which identify the relative sensitivity of mode and destination choice responses.

Purpose	Tree Structure	θ	Mode Choice λ	Destination Choice λ
Commuting	Multinomial	1	0.020 to 0.050	0.020 to 0.050
Primary Education	Destination choice below mode choice	0.19	0.008 to 0.027	0.040 to 0.14
Secondary Education	Destination choice below mode choice	0.47	0.007 to 0.028	0.015 to 0.060
Tertiary Education	Destination choice below mode choice	0.35	0.010 to 0.035	0.035 to 0.090
Shopping	Destination choice below mode choice	0.38	0.020 to 0.040	0.050 to 0.100
Other	Destination choice below mode choice	0.27	0.008 to 0.015	0.030 to 0.050

PRISM: Policy-Responsive Integrated Strategy Model of the West Midlands

Overview

The PRISM model system is a variable demand multi-modal transport model developed for the West Midlands region by RAND Europe and Mott MacDonald. It consists of detailed network models covering the highway and public transport (PT) systems, which are linked to a disaggregate model of travel demand. The network (supply) and demand models are run iteratively to ensure consistency between the network travel conditions and travel conditions in the demand model[1]. The demand model reflects a number of traveller responses in a number of interacting modules, including car ownership, PT travel pass ownership, tour frequency, destination choice, mode choice and time of day choice. All of these models, except for the car ownership model and the trip frequency model for business and non-home-based travel, were estimated from local data. A brief description of the model responses and data used for estimation of these models is provided in the summary below. Because the mode and destination models have been estimated from local data, the outputs provide evidence on appropriate model structure and illustrative model parameter values. More detail is therefore provided on these models in this report.

The unit of travel for all home-based travel, except business travel, is a home-based tour. A home-based tour is defined as a series of linked journeys starting and finishing at the traveller's home. Because of a lack of data on home-based employer's business, non-home-based employer's business and non-home-based other travel in the Household Interview survey data, trip-based models were estimated for these three purposes using Road Side Interview data.

Models of mode and destination choice were estimated simultaneously from disaggregate 2001 Household Interview survey data records. Simultaneous estimation of these responses has a number of advantages: firstly, this approach ensures consistent treatment of time and cost terms in the mode and destination choice models, secondly, it allows different model hierarchies to be tested explicitly and, thirdly, it introduces more variation in the time and cost terms making the procedure more statistically efficient for model

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1 Mott MacDonald is responsible for running the model; currently they are running the demand and supply models for three iterations.

estimation. Models representing the choice of PT access mode, specifically car driver, car passenger and other access, were estimated from disaggregate data describing travellers' access to train stations in 2001. The PT access mode choice models were estimated simultaneously with the mode and destination choice models; again, the benefits described above apply. Models of choice of time of travel were estimated using specially collected Stated Preference data. The details of the model estimation are discussed in the section on Model Estimation.

The model is applied as a pivot point incremental model applied to base matrices. Synthetic future O-D matrices are generated by a number of steps, briefly described below.

- Firstly, for future scenarios, a prototypical sampling procedure is run to provide a description of the population of the West Midlands that is representative of the future socio-economic and spatial distribution of the population.
- The car ownership model is then run on the expanded base sample, for each zone.
- At the completion of the car ownership model, the total numbers of persons by purpose and population segment are summed for each origin, for input into the travel demand model.
- The travel demand model then applies the pass ownership, frequency, mode, destination, PT access mode and station choice and the time period choice models.
- A final processing step converts the tours to trips for each mode, purpose and time period, applies the pivoting procedure and then finally adds freight, external trips and trips to and from Birmingham International Airport (predicted in a separate model).

Base matrices are required for the pivoting procedure. For car, base matrices have been produced for the four model time periods by purpose:

- commuting;
- employer's business;
- education;
- other.

The PT base matrices for train, metro and bus modes are split by the four model time periods, but are not segmented by purpose.

The highway base matrices were developed using the ERICA software from a combination of Road Side Interview data, Household Interview data, city centre car park surveys, airport passenger surveys and data from number plate recognition cameras. The PT matrices were based upon matrices from CENTRO's (the metropolitan Public Transport Executive) PT assignment model.

Model Summary: Details

The detailed characteristics and dimensions of the PRISM model are as follows.

Zones:

578 zones in the internal area, i.e. West Midlands County
252 zones in the intermediate area
68 external zones
898 PRISM zones in total
The disaggregate demand model is applied to households within the internal and intermediate areas.

Transport supply[2]:

Network assignment is carried out in VISUM.
Highway networks include:

- All motorways, A-roads and B-roads
- All unclassified roads in the original Regional Transport Model
- All unclassified roads with bus services.

25,500 links, all with link attributes
10,276 nodes, 5,895 coded junctions (all junctions are coded and modelled in the metropolitan part of the highway model).

Detailed public transport network, including detailed representation of all pt services, e.g.:

- 903 train stations, 6284 bus stops.
- 1321 train services, 1311 bus services.

All pt modes are represented separately, but can be integrated to reflect mixed-mode journeys. A hierarchy of modes, i.e. bus-metro-train is used to define journeys for each pt mode, so that bus can be used to access metro and train, and bus and metro can be used to access train. In addition, all pt modes can be accessed by walk links and train and metro can be accessed by car (driver or passenger).

Modes:

Eight main modes are represented in the mode choice model:

- Car driver
- Car passenger
- Train
- Metro
- Bus
- Cycle
- Walk
- Taxi

Park and ride is explicitly represented by distinguishing three

[2] Transport supply information is taken from information provided by Mott MacDonald on http://www.prism-wm.com/ (PRISM-tvv-28092004.pdf)

access modes for rail and metro: car-driver (park and ride), car-passenger and 'other' which includes walk access and access by other PT modes.

Time periods: The PRISM model operates for an average weekday 24-hour period. Four time periods are distinguished in the model:

- Morning peak: peak hour within the period 0700 to 0930
- Inter-peak: average hour over the period 0930 to 1530
- Evening peak: peak hour within the period 1530 to 1900
- Off-peak: average hour within the period 1900 to 0700.

Trip purposes: Seven home-based travel purposes are distinguished:

- Commute
- Employer's business
- Primary education
- Secondary education
- Tertiary education
- Shopping
- Other travel.

Two non-home based travel purposes are also considered:

- Employer's business
- Other travel.

Traveller responses: Frequency, where logit models are used to predict total tours (all modes) for home-based purposes, excluding business and non-home based travel, with accessibility terms explicitly tested. Accessibility is measured using a segment and purpose specific logsum from the mode-destination choice model; significant accessibility terms were observed for commuting, secondary and tertiary education, shopping, personal business, and recreation and leisure travel.

Mode and Destination choice, estimated simultaneously from disaggregate 2001 Household Interview data records for the home-based commuting, primary education, secondary education, tertiary education, shopping and other travel purposes. For the business and non-home-based other purposes, destination choice models only were estimated from 2001 Road Side Interview data (there is no mode choice component in these models).

Public Transport access mode choice, specifically for car (park and ride), estimated from disaggregate 2001 train survey data records, and estimated simultaneously with mode and destination choice, for home-based purposes, excluding business.

Time Period choice, for car drivers only, estimated from stated preference data collected for the study; simplified time period models estimated with time and cost coefficients constrained to values obtained from the mode and destination choice modelling, the key output is information on the relative sensitivity of time period choice and mode choice.

Pass ownership was estimated from the disaggregate 2001 Household Interview data records, accounting for variations in pass ownership across different socio-economic groups.

Car ownership is predicted by using the disaggregate car ownership models from the Department for Transport National Transport Model (as used in TEMPRO) applied to a local sample. The models were recalibrated to match local conditions, in particular higher car ownership in multi-worker households than was predicted by the original National Transport Model car ownership models.

Route choice, highway or public transport route alternatives (rail, bus, metro).

Goods vehicles: Matrices of LGV and HGV movements have been supplied for base and future years by MDS Transmodal.

Assignment: Separate highway assignments are undertaken for each time period and for each different model purpose, e.g. commute, business, education and other. The PT assignment is undertaken for each time period, but is not undertaken separately for each model purpose.

Model form: The model is applied as a pivot point model, applying the predicted (synthetic) increase for each O-D pair, by mode (cars and pt only), time-of-day and purpose to the base matrices. Rules are applied for cases where either the base matrix, the synthetic base matrix or the synthetic future matrix are zero. Special rules have been adopted for 'extreme growth situations', i.e. where there are small numbers of trips in the base matrix.

Base data: Data for model estimation:

- 2001 Household Interview surveys, for estimation of mode and destination choice, frequency, pass ownership models
- 2001 Road Side Interview surveys, for estimation of destination choice models for certain purposes, and for the development of the highway base matrices

- 2001 Train survey, for estimation of PT access mode choice models (park and ride models)
- SP data, collected locally, for estimation of time period models.

Data for estimation of highway base trip matrices:
- 2001 Road Side Interview data
- 2001 Household Interview data
- City centre car park surveys
- Airport passenger surveys
- Data from number plate recognition cameras.

The PT base matrices are based on CENTRO's matrices, but they have been matrix manipulated by the TFlowFuzzy module within VISUM to match boarding/alighting counts for metro and train, and city centre cordons for bus.

Model Estimation

Mode and Destination Models

For non-business travel purposes, the home-based mode and destination choice models were estimated simultaneously from disaggregate 2001 Household Interview data records.

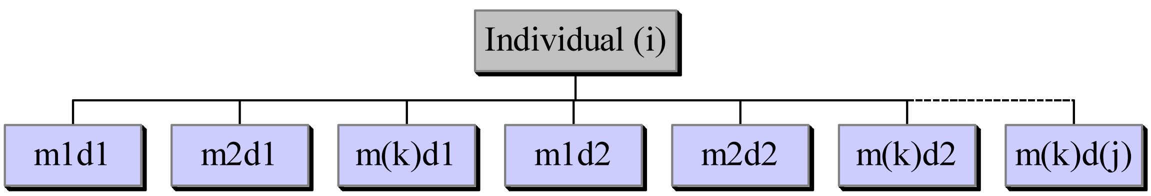
Three different tree structures were explicitly tested for mode and destination choice:

- Tree 0: multinomial mode and destination choice;
- Tree 1: mode choice under destination choice;
- Tree 2: destination choice under mode choice.

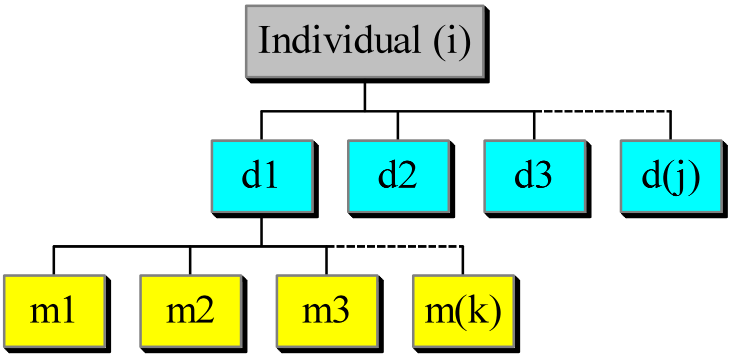
Each tree structure is shown diagrammatically below. In these figures 'm' denotes main mode, 'd' denotes destination. The access and station choice alternatives have been omitted for simplicity (these are discussed further below).

In the Tree 1 and Tree 2 models a structural parameter is estimated which reflects the relative sensitivity of mode and destination choice to changes in utility. The value of this parameter must be less than or equal to 1 in order to main consistency with intuitive response characteristics.

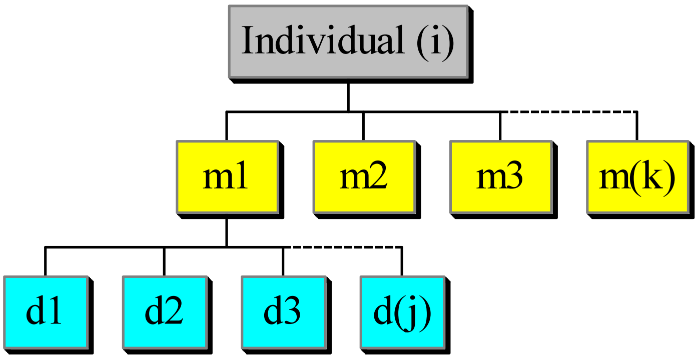
Tree 0: Multinomial Mode and Destination Choice



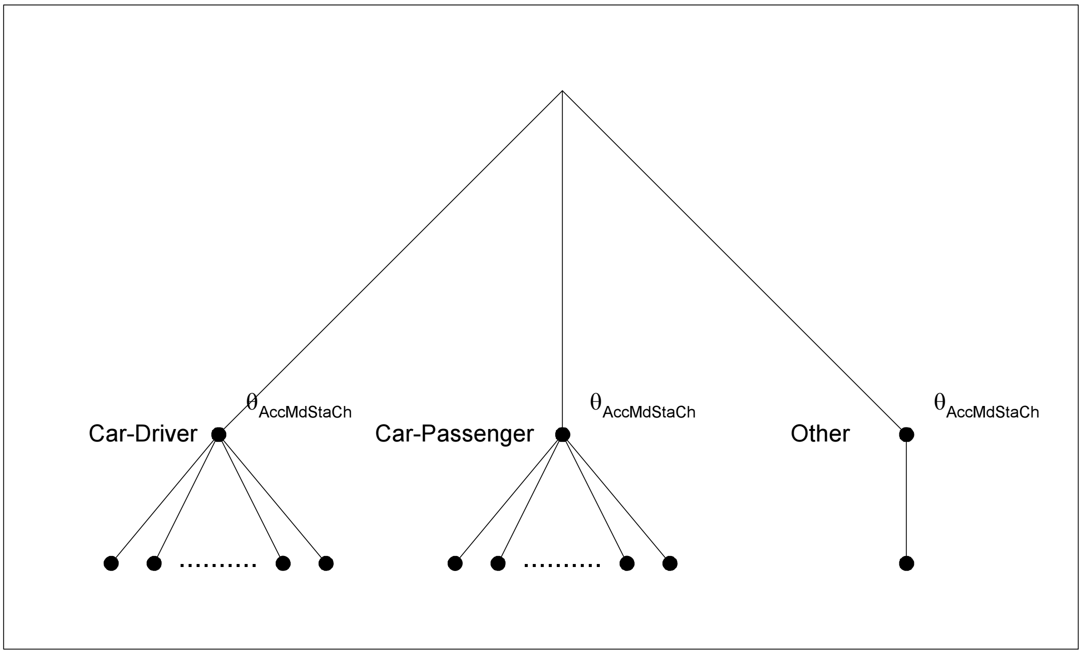
Tree 1: Mode Choice 'below' Destination Choice



Tree 2: Destination Choice 'below' Mode Choice



Additionally, a nesting structure was tested for access mode to the main-mode public transport options, for representation of park and ride policies. The figure below illustrates this structure.



Access Mode and Station Choice Structure

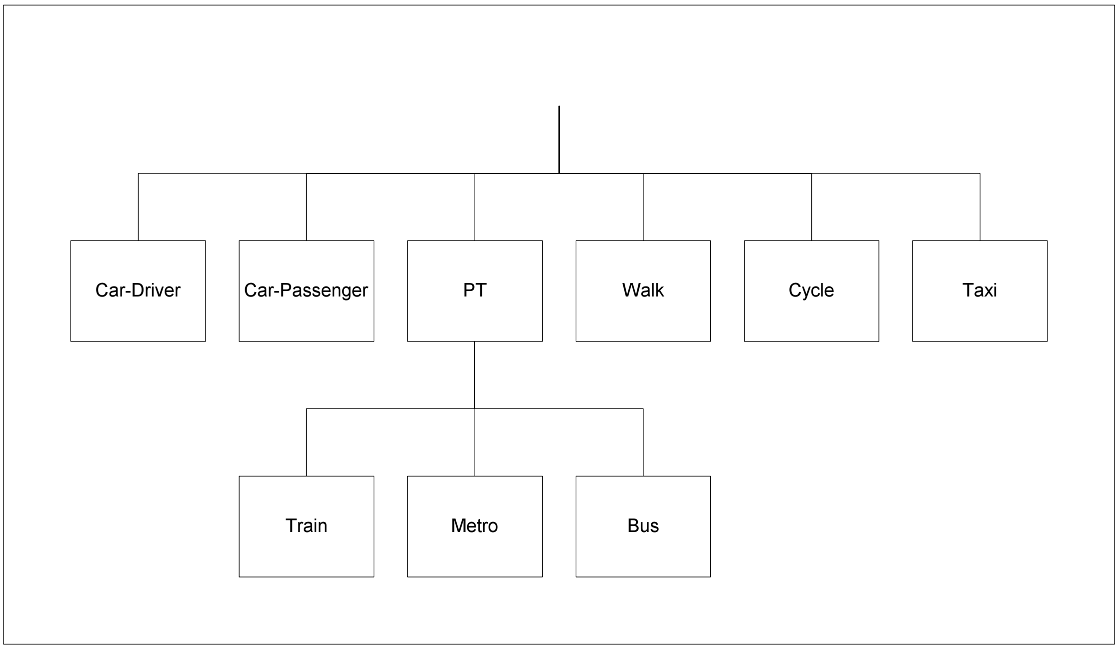
The alternatives below the car-driver and car-passenger access mode alternatives represent different station alternatives. The structural parameter $\theta_{AccMdStaCh}$ represents the relative sensitivity of access mode and station choice.

It is noteworthy that the models of access mode and station choice were estimated from a large survey of train users, not the 2001 Household Interview survey. This model was, however, estimated simultaneously with the models of mode and destination choice, with joint estimation of the key model parameters, giving substantially improved estimates of both models. A scale parameter (ASScale) was applied to the access mode and station choice alternatives described by the train users data to take account of differences in unexplained error variation between the models developed from the two data sets, i.e. the household interview data and the train user data.

A consistent finding from the park and ride modelling was that the estimate of the $\theta_{AccMdStaCh}$ parameter, reflecting the relative sensitivity of access mode and station choice, was around 0.4.

For the commute, shopping and other travel models, a model structure where all public transport modes were grouped together in a nest was also tested. This structure is shown below.

PT Nest Tree Structure



This PT nest structure was tested on the basic mode and destination choice models, without the access mode choice component, for each of the three different mode and destination tree structures described above. The inclusion of this pt nesting structure did not significantly improve the model fit for any of the models tested. This structure was not tested on the models for the three different education purposes.

Model Estimation Details

A number of 'level-of-service' parameters describing both the attractiveness of the modes and destinations were tested during the estimation of the mode and destination choice model. These parameters are summarised in the following table.

Parameters	Car-Driver	Car-Passenger	Train	Metro	Bus	Bike	Walk	Taxi
Driving Cost	Cost							
Parking Cost	Cost							
Train Fare			Cost					
Metro Fare			Cost	Cost				
Bus Fare			Cost	Cost	Cost			
Taxi Fare								Cost
Free-flow Car Time	CarFFTime	CarFFTime						TaxiTime
Congested Car Time	CarCgTime	CarCgTime						TaxiTime
Train Time			TrainTime					
Metro Time			MetroTime	MetroTime				
Bus Time			BusTime	BusTime	BusTime			
Access/Egress Time			AcEgTime	AcEgTime	AcEgTime			
Interchange Walk Time[3]			IntWlkTime	IntWlkTime				
Initial Wait Time			FWaitTime	FWaitTime	FWaitTime			
Other Wait Time			OWaitTime	OWaitTime	OWaitTime			
Transfers			Transfers	Transfers	Transfers			
Distance		CarPDist				CycleDist	WalkDist	

This was the most detailed utility specification tested in the model estimation procedure. In some cases it was not possible to identify all of these parameters with the correct sign or adequate accuracy and in these cases the relevant variables were reformulated, combined with other variables (where appropriate) or omitted.

It is noted that the cost term enters the utilities of the car driver, train, metro, bus and taxi alternatives. Car costs include driving costs, parking costs and (possible) toll costs. Public transport costs include fares, taking account of the probability of owning a travel pass, plus access costs. A logarithmic cost formulation was tested in all segments, and was found to improve significantly the model fit for the commuter, tertiary education, shopping and other travel segments. This formulation has therefore been adopted in these models.[4]

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3 Interchange walk time data was not available in the original bus network.

4 All costs are summed before taking the log and a minimum cost of 1p is specified.

The impact of the logarithmic term is that the resulting values of time vary (continuously) with distance, so that values of time for longer journeys will be larger than for shorter journeys. Theoretically, the value of time calculation in a log-cost model is given by the differentiation of the utility function, i.e. if we assume a simple utility equation with time and log(cost), then:

$$V_{ni} = \alpha T_{ni} + \beta \log C_{ni}$$

and the value of time will be defined by:

$$VOT = \frac{dV/dT}{dV/dC}$$

$$VOT = \frac{\alpha}{\frac{1}{c} * \beta}$$

where α is the time coefficient, β is the log(cost) coefficient and c is the cost.

The problem here, for validation of the resulting values of time, is that the implied value of time is proportional to the trip cost.

For PRISM, two value of time measures were calculated, using different formulations for the calculation of the average cost. In both measures the average cost for the chosen mode was used (E(c)). It would have been equally possible to use the average costs of the chosen mode to the chosen destinations, as well as other possible formulations. The measures used in PRISM are shown below (E(c) ≠ 1 / E(1/c) in normal circumstances):

$$VOT_1 = \frac{\alpha}{\beta} * E(c)$$

$$VOT_2 = \frac{\alpha}{\beta} * \frac{1}{E(1/c)}$$

In addition to these terms, a number of other terms are included in the mode and destination utility functions:

- intrazonal constants, for modes for which intrazonal tours were observed;
- CBD constants, for commute, shopping and other travel, to take account of the dominant effect of the Central Business District (CBD) (mode-specific and destination constants);
- car availability terms;
- socio-economic terms, identified during the model estimation phase from examination of predicted and observed mode and destination choices;
- attraction variables to represent destination choice.

The model results, for each trip purpose, are presented in Appendix B. The structural coefficients are highlighted.

The model structures adopted in the final models are highlighted in the following table. The values of the structural parameters are provided (note that TR_D_M is the structural parameter for the tree with modes below destinations and TR_M_D is the structural parameter for the tree with destinations below modes).

Purpose	Tree 0: MNL Mode and Destination Choice	Tree 1: Mode Choice below Destination Choice	Tree 2: Destination Choice below Mode Choice
Commuting	Multinomial AccMdStaCh = 0.41	TR_D_M > 1 AccMdStaCh = 0.41	TR_M_D = 0.48 AccMdStaCh = 0.41
Primary Education	Multinomial	TR_D_M > 1	TR_M_D = 0.19
Secondary Education	Multinomial	TR_D_M > 1	TR_M_D = 0.47
Tertiary Education	Multinomial	TR_D_M > 1	TR_M_D = 0.35
Shopping	Multinomial AccMdStaCh = 0.41	TR_D_M > 1 AccMdStaCh = 0.41	TR_M_D = 0.38 AccMdStaCh = 0.37
Other Travel	Multinomial AccMdStaCh = 0.43	TR_D_M > 1 AccMdStaCh = 0.43	TR_M_D = 0.27 AccMdStaCh = 0.43

For all models, the introduction of a tree structure with destination choice below mode choice significantly improved the fit of the model. For commuting, the multinomial (Tree 0) model was adopted, however, on the basis that the implied values of time for driving were judged to be more plausible (around £5 per hour compared with £2 - £3 per hour for the Tree 2 model).

It is noteworthy that in the other travel models, the structural parameter for the relative elasticity of access mode and station choice ($\theta_{AccMdStaCh}$) has been constrained to a value of 0.433. This parameter could not be identified in the estimation of the mode, destination and access mode model (it was converging to zero, suggesting a lack on information on access mode choice) and therefore it was constrained to 0.433, which is the value from the equivalent other travel model estimated from the train user data alone.

Incorporation of Time Period Choice

Time period choice models, for car drivers, were developed from SP data, using a sequential estimation procedure. Essentially, the cost and time parameters from the final mode-destination models were imported into the time period choice models, ensuring consistency between the mode and destination and time period choice models and consistency with utility theory. Time period constants were also included for each possible time-period combination, with AM-peak (departure) – PM-peak (return) being specified as the base alternative. Mode choice constants were also included (for the public transport alternative, measured relative to car).

The key output from the time period choice model is information on the relative placement of time of day choice relative to mode choice in the overall model structure. The following findings were observed from the SP time period choice model:

- For commute, the recommended model structure was one with mode and time period choice at the same level.
- For other travel (including shopping) the recommended model structure was again multinomial, with mode and time period choice at the same level.

Because time period choice is implemented for car drivers only, and for efficiencies in model run time, it is more straightforward to implement if it is at the lowest level in the tree. The table in Appendix A presents the various possible tree structures and discusses the implications of each on model estimation, implementation and run time.

For commute, it was possible to specify time period choice at the lowest level of the tree with a structural parameter of 1 (implying a multinomial structure). For shopping and other travel the best model structure was one with destination choice below mode choice, which complicated the implementation of the time period choice model (which implies that time period choice is at the same level as mode choice, i.e. above destination choice). Because of run time and budgetary constraints, additional tests were made to examine the impact of representing time period choice at the same level as destination choice. For shopping, the loss of fit was negligible and so it was deemed to be reasonable to assume that time-period choice was at the same level as destination choice. For other travel the loss in model fit was larger, but here it was felt that the loss of fit was more than balanced by the run time implications of incorporating time period choice at the same level as mode choice in the combined model structure. So in all of the models, time-period choice has been implemented at the same level as destinations at the bottom of the tree.

Demand Model Validation

A number of checks were undertaken to validate the models, specifically:

- Checking that the mean distances, travel times and (where applicable) costs of the chosen alternatives were plausible (input data check).
- Checking the sign of model parameters.
- Checking the significance of model parameters. Apart from the constants, all parameters retained in the models are significant to a 95 % confidence level unless explicitly stated otherwise in the PRISM model estimation reports.
- Checking the relative values of model parameters. The relative values of the different time terms were compared to ensure that the ratios were plausible and in line with other studies, for example the ratio of PT wait time to PT in-vehicle time.
- In particular, checking that the values-of-time implied by the model were reasonable and consistent with published values; in this model, this check is complicated because of the logarithmic formulation of the cost variable.
- Checking that the model elasticities were reasonable and consistent with comparable model systems and published values.

- Checking that the model reproduced the observed tour length distributions reasonably well and that observed variations in tour length by mode were also predicted by the model.

Elasticities were calculated for the 'best' mode and destination models, as described above. It is emphasised that these elasticities have been estimated for the mode and destination demand structure only, i.e.:

- there is no 'second order' response as a result of changes in the highway network conditions;
- no tours are generated or suppressed as a result of the policy changes, i.e. total demand is constant.

The elasticities have been calculated by sample enumeration, applied to the sample of HI data used to estimate the mode-destination models. It should be emphasised that these elasticities are based on the unexpanded samples of tours observed in the HI, and as such will be affected by any sampling or response biases which affect the HI.

Four hypothetical policy changes were tested for calculation of elasticities:

- P1 = 10% reduction in car costs;
- P2 = 10% reduction in car times;
- P3 = 10% reduction in PT costs;
- P4 = 10% reduction in PT times.

All of these reductions were applied to the complete tour (out and back).

The results of the tests for each travel purpose and each of the three tree structures are described in Appendix C.

Note that the car travel time reductions are only applied to car as a main mode. The car passenger demand increases when car time is reduced, a negative elasticity, because car passenger travel time is set equal to the car travel time, and the negative car time parameters in the models mean that as car time increases the utility (attractiveness) of both the car alternatives reduces. Similarly for those models where a significant taxi time parameter has been estimated, taxi use will also increase when car time is reduced, because the taxi time parameter is also negative.

For the public transport time reduction tests, only train, metro and bus in-vehicle times are reduced. Thus for train journeys, bus access times are also reduced, but access times and wait times are kept unchanged.

Because the models reflect both mode and destination choice changes, 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, the car cost tour elasticity is –0.06, the kilometrage elasticity is –0.09; the tour length elasticity is therefore about –0.03. It is noted that the own-time elasticities, i.e. car time reduction for car and public transport time reduction for public transport, incorporate much higher tour length elasticities.

Lastly, 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 with published values, as they incorporate changes in job locations, etc..

Evidence on Values of Lambda (λ) from PRISM

A key part of the advice set out for Variable Demand Modelling (TAG Unit 3.10.3) is the use of a hierarchical logit model formulation to represent choices between discrete travel alternatives, i.e. modes, destinations, time periods. The WebTAG advice states that 'wherever possible the variable demand mechanisms should be calibrated on local data to reflect the local strengths of the choice mechanisms'. Our interpretation is that this advice applies to the estimation of the model sensitivity parameter, defined as 'Lambda' (λ), which identifies the relative sensitivity of different responses and the appropriate hierarchy of the model. The WebTAG advice also provides illustrated parameter values for cases where it is deemed unnecessary or too difficult to establish local values.

Specifically, Lambda is the logit scale parameter, i.e.:

$$P_{ni} = \frac{e^{\lambda V_{ni}}}{\sum_{ni' \in J} e^{\lambda V_{ni'}}}$$

where V_{ni} is the deterministic component of the utility equation for alternative 'i' by user 'n'. As discussed below, V_{ni} can be measured in different units including time, cost or general units of utility.

Given the units in which V_{ni} is measured, the scale parameter λ is inversely related to the variance of random utility (or 'error'), i.e.:

$$\text{var}(\varepsilon_{ni}) = \pi^2 / 6\lambda^2$$

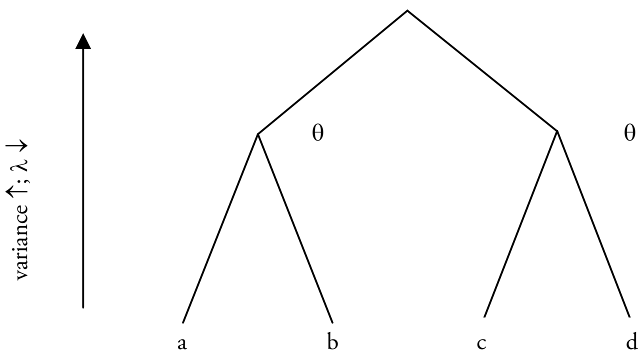
Essentially then, λ governs the sensitivity of the choice: the smaller the model error, the larger is λ and the more discriminating the choice will be between one alternative and another with a different utility, which will be associated with a greater responsiveness to changes. Alternatively, the greater the model error, the smaller is λ and the closer the choice probabilities will tend to 1/J for all J alternatives.

The relationship between Lambda and hierarchical model structural parameters

In the estimation of hierarchical logit models, a structural parameter is estimated to reflect the probability of nests of alternatives, or composite alternatives. This parameter is applied to the logsum of the composite or nested alternatives.

This structural parameter reflects the ratio of the Lambdas for different response mechanisms, as you move up the tree structure. It should be less than 1 to maintain consistency with intuitive response characteristics.

The following diagram illustrates a nested model structure.



Whereby:

$$\theta^2 = \frac{\text{var}(a-b)}{\text{var}(a-c)}$$

$$\theta = \frac{\sqrt{\text{var}(a-b)}}{\sqrt{\text{var}(a-c)}} = \frac{\lambda_{upper}}{\lambda_{lower}} \leq 1$$

Why does Lambda vary?

Because the value of Lambda is related to the unexplained error in the model, its value will vary depending on the specification of the model. In the case of hierarchical models, the specification of each model component could be affected differentially. For example, for mode and destination choice the quality of the models will depend on a number of factors including:

- number of modes considered in the mode choice model;
- zone size;
- degree of segmentation;
- quality of network data;
- inclusion of zonal constants, e.g. CBD dummies;
- whether trip ends are balanced;
- the level of detail in the utility functions (which may depend on how much data there is for the estimation of the models);
- inclusion of socio-economic constants;
- general quality of the modelling.

Lambda values from the PRISM models

In the estimation of the logit model, it is not possible to identify λ separately from V_n and therefore it is commonly assumed to be equal to 1. It is noteworthy that if the coefficients for the utility equation are transferred from other sources, however, then the λ parameter can be estimated directly. For PRISM the first case applies: all coefficients in the utility equation were estimated as part of the model estimation procedure. We therefore examine the definition of λ for this case.

First we consider an example where the utility equation consists of a simple time and cost term, i.e.:

$$V_{ni} = \alpha T_{ni} + \beta C_{ni}$$

If we divide through by the cost coefficient β then we have the formulation in generalised cost terms, i.e.:

$$V_{ni} = {}^{\alpha}\!/_{\beta} T_{ni} + C_{ni}$$

where α/β is the 'value of time'. It is noteworthy that the use of the log(cost) formulation in the PRISM models, which improves the model fit substantially, means that the value of time is not simply the ratio of the time and log(cost) parameters.

In the generalised cost formulation λ is therefore simply equal to the cost coefficient β (at the lowest level of the tree structure), i.e.:

$$V_{ni} = \beta({}^{\alpha}\!/_{\beta} T_{ni} + C_{ni})$$

In the generalised time formulation, which is consistent with the structure discussed in the WebTAG advice, λ is equal to the time coefficient α (at the lowest level of the tree structure), i.e.:

$$V_{ni} = \alpha(T_{ni} + {}^{\beta}\!/_{\alpha} C_{ni})$$

where β/α is the value of money in units of time.

The further complexity in the PRISM model is that there is a number of different time coefficients for different modes and travel conditions, e.g. car time, congested car time, bus time, train time and metro time. The resulting time coefficients for each mode and purpose are presented in the following table.

Purpose	Free flow Car time	Congested Car time	Bus time	Train time	Metro Time
Commuting	-0.029	-0.026	-0.026	-0.018	
Primary Education	-0.140		-0.037		
Secondary Education	-0.059		-0.014		
Tertiary Education	-0.087		-0.035		
Shopping	-0.096		-0.050		
Other	-0.049		-0.033		

It is noteworthy that for commuting both free-flow and congested car time coefficients are identified, where the congested car time coefficient reflects the *additional* valuation of congested time in a vehicle as a car driver or car passenger. This parameter is about 90 % of the magnitude of the (free-flow) car time parameter, which implies that congested time is weighted at about 1.9 times as highly as free-flow time. In all other models, only a general car time coefficient, incorporating both free-flow and congested travel time, could be identified.

Additionally, for commute, separate bus and train/metro time coefficients were identified. For all other models, only a general public transport travel time coefficient was identified.

For primary education, car time is weighted about four times as highly as public transport in-vehicle time. An important point here is that primary schools are usually located near the home, i.e. there is a greater resistance to separation than for other purposes. Additionally, the weighting of car time may reflect the weighting of the parent driving the child to school and possibly returning home again, whereas the public transport time may correspond to the child travelling alone. It is noteworthy that only about 8% of the primary education tours are by public transport (bus), whereas 34.2% are as car-passenger and 57.4 by walking.

Approximate Lambda values for mode and destination choice by purpose of travel, from the PRISM models, are summarised in the table below. The proposed values cover the range of travel time coefficients observed in the PRISM model.

Purpose	**Tree Structure**	**θ**	**Mode Choice λ**	**Destination Choice λ**
Commuting	Multinomial	1	0.020 to 0.050	0.020 to 0.050
Primary Education	Destination choice below mode choice	0.19	0.008 to 0.027	0.040 to 0.14
Secondary Education	Destination choice below mode choice	0.47	0.007 to 0.028	0.015 to 0.060
Tertiary Education	Destination choice below mode choice	0.35	0.010 to 0.035	0.035 to 0.090
Shopping	Destination choice below mode choice	0.38	0.020 to 0.040	0.050 to 0.100
Other	Destination choice below mode choice	0.27	0.008 to 0.015	0.030 to 0.050

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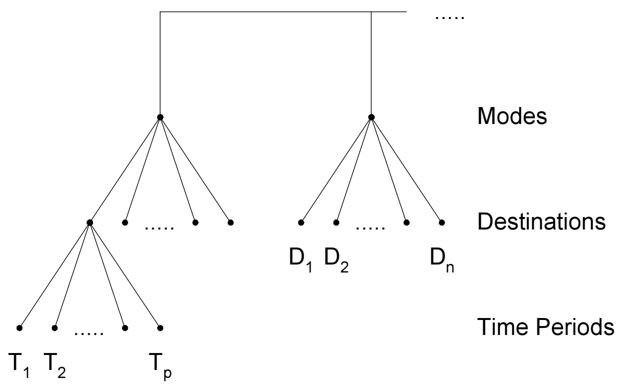
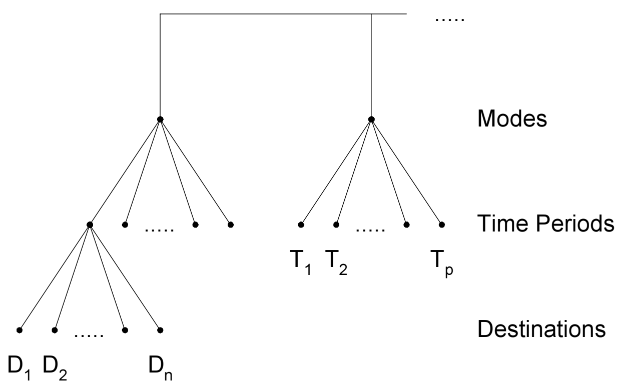
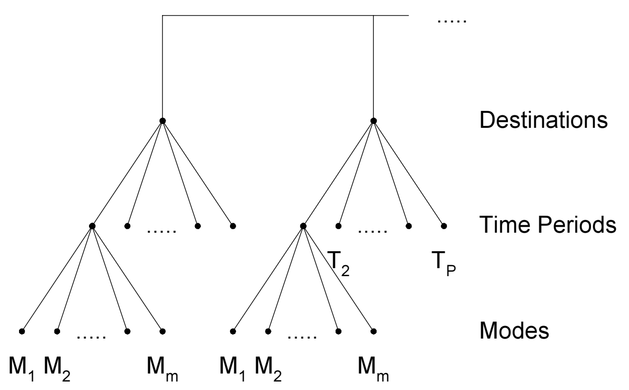
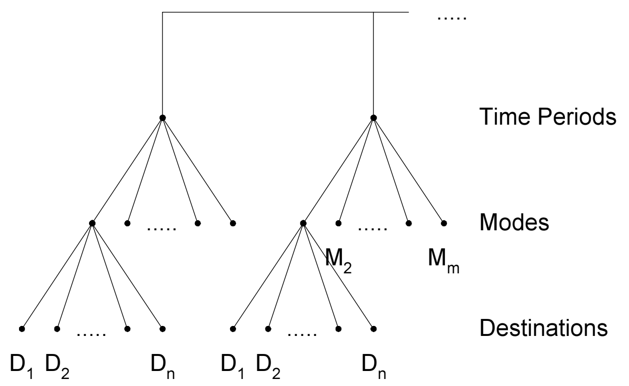
APPENDICES

Appendix A: Tree Structures and Run Times

The following table describes the model estimation and application characteristics, particularly with regard to run time, for a number of possible tree structures for mode, destination and time of day choice.

It is noteworthy that the PRISM model contains 8 modes, about 900 destinations, 4 time periods resulting in 13 outward-return time period combinations and from 68 (tertiary education) to 225 (shopping) segments.

Tree Structure	Comments
	**Time Period choice at lowest level** (order of mode and destination choice is irrelevant) Time period choice can easily be implemented for a subset of modes, e.g. car-driver, pt. **Estimation:** Simultaneous estimation of all responses preferable. In sequential estimation logsums from the time period choice model required for input into the mode and destination choice model. **Application:** Logsums easily calculated over time periods for appropriate modes only (usually car-driver). Usually very little segmentation in time period choice model so the time period model can be run once for each destination; run times are therefore reasonable.
	**Destination choice below time period choice below mode choice** Time period choice can easily be implemented for a subset of modes, e.g. car-driver, pt. **Estimation:** Simultaneous estimation of all responses preferable. In sequential estimation observed departure time used for destination choice, logsums over destinations/time periods required for higher-level choices. **Application:** Run time may be problematic if segmentation in the destination choice model, e.g. by work status (full-time or part-time working) or for cost, because the destination component will have to be run for each segment for each time period.

<table>
<tr>
<td>
</td>
<td>Mode choice below time period choice below destination choice
All modes require time period information – in many cases this information may not vary between time periods, e.g. for slow modes.
Estimation:
Simultaneous estimation of all responses preferable.
In sequential estimation observed departure time used for mode choice, logsums over modes/time periods required for higher-level choices.
Application:
Run time is likely to be a problem because of segmentation in the mode choice model: the mode choice model will have to be run for each segment for each time period and destination combination.</td>
</tr>
<tr>
<td>
</td>
<td>Time Period choice at top of tree
(order of mode and destination choice is irrelevant)
All modes require time period information – in many cases this information may not vary between time periods, e.g. for slow modes.
Estimation:
Simultaneous estimation of all responses preferable.
In sequential estimation observed departure time to be used in estimation of mode and destination choice models.
Application:
Run time is likely to be a serious problem because of segmentation in the mode and destination choice models: the mode and destination models will have to be run for each time period.</td>
</tr>
</table>

Appendix B: Detailed Model Coefficient Results

In this appendix, the ALOGIT model results for the PRISM model are presented. For each model two sets of values are presented:

1. Model summary statistics;
2. Model coefficient values and their associated t-ratios.

The model summary statistics presented are defined in the following Table.

Statistic	Definition
File	This defines the name of the model run.
Converged	This indicates whether the model run converged at optimum values for the parameters.
Observations	The number of observations included in the model estimation.
Final log (L)	This indicates the value of the log-likelihood at convergence. The log-likelihood is defined as the sum of the log of the probabilities of the chosen alternatives, and is the function that is maximised in model estimation. The value of log-likelihood for a single model has no obvious meaning. However comparing the log-likelihood of two models with different specifications allows the statistical significance of new model parameters to be assessed properly.
D.O.F.	Degrees of freedom, i.e. the number of parameters estimated in this model. Note that if a parameter is constrained to a fixed value (indicated by(*)) then it is not a degree of freedom.
$Rho^2(0)$	The rho-squared measure compares the log-likelihood (LL(final)) to the log-likelihood of a model with all parameters restricted to zero (LL(0)): $Rho^2(0) = 1 - LL(final)/LL(0)$ A higher value indicates a better fitting model.
$Rho^2(c)$	If we compare the log-likelihood (LL(final)) value obtained with the log-likelihood of a model with only constants (LL(c)) we get: $Rho^2(c)$: $1 - LL(final)/LL(c)$ Again a higher value indicates a better fitting model.
Scaling	It is possible to scale all the model parameters by a constant for presentation purposes, for example to present utility values in monetary units. The default is to present the models unscaled, i.e. scale = 1.

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

Some parameters are multiplied by variables and therefore reflect the disutility per unit of the variable. For example if travel cost is measured in pence and enters the utilities in a linear form, then the cost parameter determines the disutility per pence. Other parameters are simply dummy terms, which are either applied as a constant value or not applied at all.

The relative magnitude of parameters indicates their impact on utility *but* parameters are only comparable if they are measured in the same units. For example if separate journey time coefficients in utils per minute are estimated for train and bus modes, then their relative magnitudes can be compared to see which has more impact on utility. However these terms cannot be directly compared to (for example) a gender dummy. All dummy terms are simply measures in utils and therefore are directly comparable.

The value shown in brackets after the parameter value is the t-ratio which defines the significance of the parameter estimate. A higher t-ratio indicates a more significant estimate. A parameter should have a t-value greater than 1.96 to be significantly different from zero (at a 95% confidence level). The 95% confidence interval has been applied consistently in model development to determine which parameters to retain in the model. Departures from this rule are explicitly noted. If the parameter is constrained to a fixed value then an asterisk is reported instead of the t-ratio.

Commute Model Results

File	COM_161_AS.F12		COM_161_AS_T1.F12		COM_161_AS_T2.F12	
Converged	True		True		True	
Observations	10360		10360		10360	
Final log (L)	-40596.2		-40387.3		-40491.2	
D.O.F.	58		59		59	
Rho²(0)	0.446		0.449		0.447	
Rho²(c)	-1.436		-1.424		-1.430	
Prepared	28 Jan 04		25 Feb 04		25 Feb 04	
Estimated	28 Jan 04		25 Feb 04		25 Feb 04	
Scaling	1.0000		1.0000		1.0000	
Attraction Variables:						
TotEmp	1.00	(*)	1.00	(*)	1.00	(*)
TotSpaces	1.00	(*)	1.00	(*)	1.00	(*)
CoreNoPR	3.46	(33.8)	3.47	(33.9)	3.46	(33.8)
InterStat	4.22	(30.1)	4.20	(30.0)	4.21	(30.2)
General Constants:						
CarP	-5.07	(-23.6)	-3.75	(-20.3)	-9.31	(-17.4)
Train	-2.52	(-7.9)	-2.38	(-10.3)	-6.91	(-9.8)
Metro	-2.02	(-5.2)	-2.59	(-7.5)	-7.79	(-7.7)
Bus	-0.280	(-1.4)	-0.757	(-4.8)	-2.23	(-5.6)
Cycle	-6.78	(-17.3)	-5.99	(-16.4)	-14.2	(-14.1)
Walk	-2.28	(-11.4)	-1.82	(-11.7)	-5.74	(-12.5)
Taxi	-2.24	(-5.9)	-2.96	(-8.3)	-6.66	(-8.4)
CarP_AcMd	0.138	(1.0)	0.0627	(0.9)	0.149	(1.0)
Oth_AcMd	1.89	(14.0)	0.944	(11.8)	1.99	(13.8)
IntraDest	0.485	(5.8)	0.0593	(1.6)	0.164	(1.9)
CarPIZ	0.783	(3.9)	0.397	(2.6)	1.05	(4.8)
CycleIZ	0.313	(0.7)	-0.231	(-0.6)	0.664	(1.5)
WalkIZ	0.738	(5.1)	0.532	(5.9)	0.942	(6.2)
CBDDest	0.259	(5.4)	0.138	(6.8)	0.303	(6.3)
CBDCarP	-0.441	(-3.7)	-0.570	(-6.2)	-0.512	(-4.3)
CBDTrain	0.533	(2.2)	0.358	(2.4)	0.491	(2.0)
BirmDest	-0.0611	(-1.0)	-0.0130	(-0.5)	-0.0380	(-0.6)
WalsDest	0.483	(4.3)	0.191	(4.2)	0.488	(4.3)
Jointly Estimated Level-of-Service Parameters:						
TrMtTime	-0.0182	(-12.8)	-0.0082	(-10.2)	-0.0186	(-12.4)
BusTime	-0.0257	(-19.3)	-0.0110	(-12.5)	-0.0261	(-19.0)
AcEgTime	-0.0310	(-13.2)	-0.0165	(-11.4)	-0.0339	(-13.0)
FWaitTime	-0.0196	(-2.5)	-0.0123	(-2.9)	-0.0202	(-2.4)
OWaitTime	-0.0127	(-4.4)	-0.0068	(-4.3)	-0.0149	(-4.9)
Transfers	-0.219	(-4.6)	-0.113	(-4.4)	-0.195	(-4.0)
MxD Level-of-Service Parameters:						
LogCost	-0.652	(-28.4)	-0.399	(-21.5)	-0.994	(-28.7)
CarTime	-0.0291	(-34.5)	-0.0077	(-13.0)	-0.0215	(-23.4)
CarCgTime	-0.0262	(-6.2)	-0.0065	(-3.6)	-0.0191	(-4.5)
CarPDist	-0.0334	(-12.2)	-0.0123	(-5.8)	-0.0428	(-14.7)
WalkDist	-0.325	(-24.4)	-0.203	(-17.8)	-0.378	(-23.5)
CycleDist	-0.163	(-10.7)	-0.0840	(-6.8)	-0.162	(-10.2)
TaxiTime	-0.0695	(-5.5)	-0.0339	(-3.0)	-0.0599	(-4.6)
PTwkrdist	-0.0362	(-13.0)	-0.0106	(-8.8)	-0.0320	(-11.7)
Access Mode Choice Level-of-Service Parameters:						
LogCostAS	-0.0805	(-7.4)	-0.0402	(-7.1)	-0.0837	(-7.4)
CarAccTime	-0.0705	(-19.0)	-0.0340	(-14.0)	-0.0730	(-18.4)
MxD Socio-Economic Parameters:						
FreeCarUse	1.27	(8.4)	1.14	(8.3)	2.54	(7.6)
OneCarComp	-0.660	(-4.7)	-0.610	(-4.8)	-1.40	(-4.8)
PassOpt	0.785	(6.3)	0.449	(4.2)	1.57	(5.9)
FreeUseCrP	-0.478	(-2.7)	-0.848	(-4.8)	-1.14	(-3.0)
BusMale	-0.698	(-5.7)	-0.720	(-6.8)	-1.51	(-5.9)
CarPMale	-0.500	(-4.3)	-0.533	(-5.0)	-1.09	(-4.5)
WalkMale	-0.574	(-4.7)	-0.849	(-8.3)	-1.37	(-5.3)

CycleMale	1.54	(4.6)	1.41	(4.3)	3.07	(4.3)
TaxiMale	-1.26	(-3.0)	-1.32	(-3.1)	-2.71	(-3.0)
CarPManag	-0.434	(-3.8)	-0.350	(-3.4)	-0.891	(-3.7)
Bus_16_24	0.915	(7.2)	0.696	(6.8)	1.74	(6.7)
TrainPass	3.01	(7.0)	2.38	(8.4)	7.39	(8.0)
Access Mode Choice Socio-Economic Parameters:						
CrDAccMale	-0.707	(-7.0)	-0.343	(-6.6)	-0.731	(-6.9)
CrDAc16t19	-2.01	(-3.9)	-0.979	(-3.9)	-2.08	(-3.9)
CrDAc20t24	-0.561	(-4.0)	-0.272	(-3.9)	-0.578	(-4.0)
CrDAcc1Car	-1.25	(-9.8)	-0.607	(-8.9)	-1.29	(-9.7)
CrPAccMale	-0.871	(-6.9)	-0.423	(-6.5)	-0.899	(-6.9)
CrPAc35t44	-0.552	(-4.2)	-0.268	(-4.1)	-0.570	(-4.2)
CrPAcc0Car	-3.48	(-5.9)	-1.68	(-5.7)	-3.58	(-5.9)
OthAccRlOn	-0.308	(-3.4)	-0.147	(-3.3)	-0.313	(-3.4)
Structural Parameters:						
TR_D_M			2.54	(21.0)		
TR_M_D					0.480	(18.6)
AccMdStaCh	0.412	(13.9)	0.412	(14.1)	0.414	(14.0)
ASScale	2.37	(18.1)	4.88	(13.6)	2.29	(17.5)

Primary Education Model Results

File	PRIM_37.F12		PRIM_37_T1.F12		PRIM_37_T2.F12	
Converged	True		True		True	
Observations	1324		1324		1324	
Final log (L)	-4464.7		-4393.6		-4424.0	
D.O.F.	19		20		20	
Rho²(0)	0.578		0.585		0.582	
Rho²(c)	-3.136		-3.070		-3.098	
Prepared	29 Nov 03		8 Jan 04		29 Nov 03	
Estimated	29 Nov 03		8 Jan 04		29 Nov 03	
Scaling	1.0000		1.0000		1.0000	
Attraction Variable:						
PrimEnrol	1.00	(*)	1.00	(*)	1.00	(*)
General Constants:						
TrainMetro	-3.73	(-3.4)	-2.48	(-2.5)	-23.2	(-2.1)
Bus	-0.0042	(-0.0)	0.181	(0.6)	-0.507	(-0.4)
Cycle	-1.95	(-1.9)	-2.85	(-2.8)	-19.4	(-2.0)
Walk	3.87	(14.8)	2.99	(13.2)	14.1	(3.1)
Taxi	-0.732	(-0.5)	-1.81	(-1.5)	-14.4	(-2.0)
IntraDest	1.56	(12.3)	0.535	(5.9)	1.60	(12.2)
WalkIZ	0.153	(1.0)	-0.0176	(-0.2)	-0.102	(-0.6)
Level of Service Parameters:						
Cost	-0.0033	(-2.8)	-0.0015	(-1.6)	-0.0032	(-2.5)
CarTime	-0.146	(-25.8)	-0.0329	(-5.8)	-0.140	(-25.1)
PTTime	-0.0368	(-7.5)	-0.0052	(-1.7)	-0.0371	(-7.3)
Transfers	-0.369	(-3.1)	-0.245	(-3.4)	-0.366	(-3.0)
SlowDist	-0.465	(-22.7)	-0.227	(-12.8)	-0.561	(-21.6)
Socio-Economic Parameters:						
PassOpt	1.35	(6.7)	1.11	(6.1)	7.00	(2.5)
CrPCarComp	0.773	(4.8)	0.552	(4.0)	3.86	(2.4)
CrP2PlCars	1.34	(8.5)	0.902	(6.1)	7.07	(2.5)
CarP1Child	0.881	(4.9)	0.619	(4.1)	4.66	(2.4)
CarP_10_11	-0.500	(-3.5)	-0.421	(-3.5)	-2.66	(-2.2)
Bus_11	1.20	(4.9)	0.967	(5.5)	5.82	(2.4)
BusPass	2.77	(5.6)	1.78	(5.1)	16.5	(2.4)
Structural Parameters:						
TR_D_M			2.92	(11.7)		
TR_M_D					0.192	(2.7)

Secondary Education Model Results

File	SEC_34.F12		SEC_34_T1.F12		SEC_34_T2.F12	
Converged	True		True		True	
Observations	1261		1261		1261	
Final log (L)	-4494.9		-4457.6		-4475.6	
D.O.F.	22		23		23	
Rho²(0)	0.511		0.515		0.513	
Rho²(c)	-2.854		-2.822		-2.837	
Prepared	11 Dec 03		8 Jan 04		4 Dec 03	
Estimated	11 Dec 03		8 Jan 04		4 Dec 03	
Scaling	1.0000		1.0000		1.0000	
Attraction Variable:						
SecEnrol	1.00	(*)	1.00	(*)	1.00	(*)
General Constants:						
CarP	-2.72	(-5.9)	-2.54	(-6.1)	-5.51	(-4.4)
TrainMetro	-5.32	(-6.4)	-4.67	(-6.0)	-12.0	(-4.5)
Bus	-1.55	(-3.7)	-1.25	(-3.4)	-2.75	(-3.0)
Cycle	-4.26	(-6.0)	-4.26	(-6.1)	-8.69	(-5.0)
Walk	1.47	(3.4)	1.10	(2.9)	1.53	(1.8)
Taxi	-5.41	(-6.6)	-5.18	(-7.4)	-10.6	(-5.2)
IntraDest	0.108	(0.4)	-0.0875	(-0.4)	0.111	(0.4)
CycleIZ	1.08	(1.4)	1.06	(1.3)	1.03	(1.1)
WalkIZ	0.676	(2.3)	0.509	(2.0)	0.572	(1.7)
Level of Service Parameters:						
Cost	-3.8e-4	(-1.0)	-1.4e-4	(-0.4)	-5.9e-4	(-1.4)
CarTime	-0.0551	(-5.5)	-0.0313	(-4.5)	-0.0592	(-5.6)
PTTime	-0.0109	(-3.2)	-0.0079	(-4.0)	-0.0136	(-3.8)
Transfers	-0.177	(-3.5)	-0.105	(-3.6)	-0.175	(-3.4)
CycleDist	-0.102	(-2.2)	-0.0553	(-1.2)	-0.131	(-2.2)
WalkDist	-0.403	(-15.9)	-0.288	(-13.8)	-0.504	(-14.7)
Dist12to15	-0.141	(-11.3)	-0.0423	(-5.0)	-0.129	(-9.9)
Dist16Pl	-0.0634	(-5.8)	-0.0158	(-2.5)	-0.0520	(-4.6)
Socio-Economic Parameters:						
PassOpt	1.44	(5.4)	1.40	(5.4)	3.02	(4.1)
CarPOneCar	-0.458	(-2.7)	-0.449	(-2.8)	-0.957	(-2.5)
Walk_17_18	-0.383	(-1.9)	-0.346	(-2.3)	-1.05	(-2.3)
TrainPass	3.76	(3.6)	3.97	(4.8)	8.33	(3.2)
BusPass	2.64	(13.3)	2.29	(13.5)	5.48	(5.9)
Structural Parameters:						
TR_D_M			2.09	(13.2)		
TR_M_D					0.472	(6.5)

Tertiary Education Model Results

File	TER_54.F12		TER_54_T1.F12		TER_54_T2.F12	
Converged	True		True		True	
Observations	843		843		843	
Final log (L)	-3534.7		-3497.3		-3505.4	
D.O.F.	27		28		28	
Rho²(0)	0.499		0.504		0.503	
Rho²(c)	-3.447		-3.399		-3.410	
Prepared	6 Jan 04		6 Jan 04		6 Jan 04	
Estimated	6 Jan 04		6 Jan 04		6 Jan 04	
Scaling	1.0000		1.0000		1.0000	
Size Variables:						
SizeMult	1.00	(*)	1.00	(*)	1.00	(*)
EnrolFTstu	2.44	(16.0)	2.36	(15.5)	2.49	(16.0)
General Constants:						
CarP	-6.79	(-16.3)	-5.40	(-14.6)	-17.7	(-6.8)
Train	-8.21	(-10.5)	-5.48	(-9.0)	-18.4	(-5.7)
Metro	-5.50	(-7.2)	-4.16	(-6.3)	-16.7	(-4.6)
Bus	-4.37	(-15.8)	-3.30	(-14.0)	-10.7	(-6.3)
Cycle	-7.06	(-6.9)	-6.54	(-7.4)	-21.5	(-6.0)
Walk	-1.18	(-3.6)	-1.46	(-5.6)	-6.04	(-5.1)
Taxi	-5.90	(-4.3)	-5.78	(-5.6)	-16.9	(-4.6)
IntraDest	0.986	(5.3)	0.306	(3.0)	0.574	(2.8)
WalkIZ	0.531	(2.2)	0.367	(2.6)	0.767	(2.9)
Level-of-Service Parameters:						
LogCost	-0.498	(-10.3)	-0.360	(-9.2)	-1.07	(-8.7)
CarTime	-0.108	(-22.1)	-0.0386	(-7.0)	-0.0870	(-13.0)
PTTime	-0.0366	(-9.1)	-0.0131	(-4.8)	-0.0353	(-8.1)
Transfers	-0.207	(-2.4)	-0.141	(-2.9)	-0.220	(-2.4)
CycleDist	-0.282	(-2.9)	-0.123	(-1.5)	-0.213	(-2.3)
WalkDist	-0.529	(-16.2)	-0.287	(-9.5)	-0.584	(-15.7)
TaxiDist	-0.143	(-1.6)	-0.0391	(-0.7)	-0.164	(-1.9)
FTstuDist	0.0359	(8.0)	0.0172	(5.9)	0.0390	(6.8)
NoCarDist	-0.0254	(-1.9)	-0.0066	(-1.2)	-0.0457	(-2.8)
Socio Economic Parameters:						
CarComp	-1.53	(-6.9)	-1.29	(-6.3)	-4.17	(-4.7)
PassOpt	0.967	(2.9)	0.757	(2.6)	2.50	(2.5)
WalkMale	-0.720	(-3.0)	-0.442	(-2.4)	-1.73	(-2.5)
CarDFTstu	-0.857	(-2.7)	-0.643	(-2.2)	-2.74	(-2.7)
BusFTstu	0.964	(2.9)	0.882	(2.9)	2.41	(2.5)
WalkFTstu	-1.24	(-3.8)	-0.989	(-3.7)	-4.18	(-3.6)
CarPDisab	2.11	(4.0)	1.44	(3.4)	5.94	(3.4)
TrainPass	2.55	(3.2)	1.86	(3.1)	6.15	(2.6)
Structural Parameters:						
TR_D_M			2.34	(10.1)		
TR_M_D					0.353	(6.5)

Shopping Model Results

File	SHOP_70_AS.F12		SHOP_70_AS_T1.F12		SHOP_70_AS_T2.F12	
Converged	True		True		True	
Observations	4527		4527		4527	
Final log (L)	-17624.9		-17452.0		-17531.1	
D.O.F.	51		52		52	
Rho²(0)	0.510		0.515		0.513	
Rho²(c)	-2.264		-2.232		-2.247	
Prepared	17 Mar 04		18 Mar 04		18 Mar 04	
Estimated	17 Mar 04		18 Mar 04		18 Mar 04	
Scaling	1.0000		1.0000		1.0000	
Attraction Variables:						
RetailEmp	1.00	(*)	1.00	(*)	1.00	(*)
TotSpaces	1.00	(*)	1.00	(*)	1.00	(*)
CoreNoPR	2.60	(7.9)	2.64	(8.1)	2.64	(8.0)
InterStat	3.76	(8.3)	3.70	(8.3)	3.71	(8.0)
General Constants:						
CarP	-4.76	(-25.2)	-4.08	(-23.7)	-11.9	(-13.1)
Train	-4.42	(-8.9)	-2.55	(-8.8)	-11.8	(-9.4)
Metro	-2.39	(-6.8)	-2.01	(-6.8)	-9.99	(-7.5)
Bus	-0.385	(-2.3)	-0.511	(-3.8)	-2.09	(-5.0)
Cycle	-6.18	(-11.2)	-5.91	(-10.9)	-17.2	(-10.4)
Walk	-1.92	(-10.8)	-1.69	(-11.4)	-6.73	(-10.1)
Taxi	-4.32	(-9.3)	-4.32	(-9.2)	-12.3	(-9.6)
CarP_AcMd	-1.45	(-0.8)	-1.05	(-1.3)	-3.94	(-1.5)
Oth_AcMd	5.23	(5.2)	2.32	(4.8)	5.23	(4.2)
IntraDest	0.249	(2.2)	0.0103	(0.2)	-0.0887	(-0.7)
CarPIZ	0.327	(1.7)	0.322	(2.7)	0.814	(3.8)
CycleIZ	1.34	(2.5)	0.973	(1.9)	1.68	(2.9)
WalkIZ	1.07	(6.5)	0.743	(7.4)	1.16	(6.4)
CBDDest	0.0461	(0.9)	-0.0083	(-0.4)	0.0586	(1.1)
DudleyDest	0.625	(6.5)	0.283	(6.7)	0.624	(6.3)
SolihlDest	0.939	(6.8)	0.423	(6.9)	1.01	(7.2)
WalsDest	1.35	(13.4)	0.538	(10.5)	1.36	(13.1)
WolverDest	0.567	(5.5)	0.230	(5.2)	0.608	(5.8)
BirmTrain	1.49	(2.9)	0.257	(0.8)	2.00	(3.4)
Jointly Estimated Level-of-Service Parameters:						
LogCost	-0.282	(-16.9)	-0.217	(-15.9)	-0.674	(-13.9)
PTTime	-0.0490	(-28.6)	-0.0192	(-13.6)	-0.0500	(-28.0)
AcEgTime	-0.0326	(-9.2)	-0.0239	(-10.7)	-0.0534	(-11.3)
WaitTime	-0.0310	(-6.0)	-0.0156	(-5.0)	-0.0422	(-6.7)
Transfers	-0.212	(-3.9)	-0.154	(-4.8)	-0.118	(-1.9)
MD Level-of-Service Parameters:						
CarTime	-0.108	(-56.6)	-0.0383	(-14.7)	-0.0957	(-43.1)
CycleDist	-0.241	(-5.9)	-0.129	(-3.3)	-0.227	(-5.2)
WalkDist	-0.343	(-24.5)	-0.228	(-18.9)	-0.401	(-23.2)
TaxiTime	-0.148	(-5.5)	-0.0742	(-2.7)	-0.143	(-4.6)
AS Level-of-Service Parameters:						
CarAccTime	-0.203	(-6.8)	-0.0901	(-6.5)	-0.226	(-6.2)
MD Socio-Economic Parameters:						
OneCarFree	0.426	(2.9)	0.410	(3.0)	1.13	(2.9)
2PlCarFree	0.912	(5.7)	0.933	(6.2)	2.46	(5.4)
PassOp2Hh	2.52	(18.1)	2.17	(16.9)	6.42	(11.0)
PassOp3PHh	1.72	(11.6)	1.46	(10.8)	4.37	(8.9)
1CrCompCrP	0.490	(3.2)	0.398	(2.9)	1.16	(2.9)
2PlCompCrP	1.02	(3.7)	0.889	(3.3)	2.51	(3.4)
CarPMale	-1.19	(-9.5)	-1.06	(-9.1)	-3.00	(-7.9)
BusMale	-0.350	(-3.4)	-0.214	(-2.5)	-0.854	(-3.2)
CycleMale	1.11	(2.5)	1.08	(2.5)	2.93	(2.5)
CarPFTstu	0.629	(2.8)	0.722	(3.6)	1.85	(3.2)
CarPRetir	0.736	(6.3)	0.671	(6.2)	1.85	(5.8)
CarPDisab	0.409	(2.8)	0.377	(2.8)	1.03	(2.7)

WalkFTwkr	-0.847	(-3.4)	-0.753	(-3.7)	-2.07	(-3.2)
WalkPTwkr	0.618	(3.0)	0.508	(3.2)	1.46	(2.7)
Walk1Hh	0.435	(3.2)	0.402	(3.9)	1.03	(3.0)
SlowDisab	-0.494	(-2.7)	-0.179	(-1.3)	-1.36	(-2.9)
AS Socio-Economic Parameters:						
CarD1Car	-2.14	(-2.2)	-1.00	(-2.3)	-2.81	(-2.1)
CarP0Cars	-9.18	(-2.0)	-4.26	(-2.2)	-12.1	(-2.0)
Structural Parameters:						
TR_D_M			2.43	(19.9)		
TR_M_D					0.384	(13.8)
AccMdStaCh	0.412	(3.4)	0.413	(3.7)	0.373	(3.2)
ASScale	0.776	(6.7)	1.66	(6.6)	0.651	(6.5)

Other Model Results

File	OTH_52_AS.F12		OTH_52_AS_T1.F12		OTH_52_AS_T2.F12	
Converged	True		True		True	
Observations	4031		4031		4031	
Final log (L)	-18513.4		-18285.7		-18397.9	
D.O.F.	48		49		49	
Rho²(0)	0.403		0.410		0.407	
Rho²(c)	-2.528		-2.484		-2.506	
Prepared	8 Apr 04		15 Apr 04		13 Apr 04	
Estimated	8 Apr 04		15 Apr 04		13 Apr 04	
Scaling	1.0000		1.0000		1.0000	
Attraction Variables:						
SizeMult	1.00	(*)	1.00	(*)	1.00	(*)
RetailEmp	1.77	(6.9)	1.61	(5.2)	1.81	(7.0)
ServiceEmp	1.23	(9.6)	1.36	(10.9)	1.29	(10.0)
TotSpaces	1.00	(*)	1.00	(*)	1.00	(*)
CoreNoPR	4.58	(25.3)	4.65	(25.6)	4.67	(25.8)
InterStat	4.81	(18.1)	4.80	(17.8)	4.80	(17.9)
General Constants:						
CarP	-5.15	(-27.6)	-4.02	(-27.5)	-16.1	(-10.1)
Train	-5.12	(-12.4)	-4.12	(-14.1)	-20.4	(-7.3)
Metro	-3.64	(-8.4)	-3.83	(-10.8)	-19.9	(-6.5)
Bus	-2.08	(-9.9)	-2.12	(-17.2)	-9.43	(-7.4)
Cycle	-6.45	(-14.4)	-6.04	(-16.0)	-22.9	(-9.0)
Walk	-2.01	(-10.3)	-2.41	(-18.4)	-9.45	(-8.3)
Taxi	-3.04	(-10.7)	-3.29	(-13.5)	-15.6	(-7.2)
CarP_AcMd	1.37	(2.8)	0.0385	(0.2)	0.522	(0.8)
Oth_AcMd	3.74	(6.5)	1.02	(4.6)	3.86	(5.1)
IntraDest	1.03	(10.8)	0.164	(5.3)	0.667	(6.5)
CarPIZ	0.0041	(0.0)	0.0431	(0.4)	0.514	(2.5)
CycleIZ	0.725	(1.2)	0.196	(0.3)	1.07	(1.7)
WalkIZ	0.931	(6.0)	0.571	(7.5)	1.03	(6.2)
CBDDest	0.134	(2.2)	0.0254	(1.7)	0.157	(2.6)
Jointly Estimated Level-of-Service Parameters:						
LogCost	-0.322	(-14.4)	-0.218	(-16.9)	-0.677	(-16.2)
PTTime	-0.0306	(-16.5)	-0.0080	(-8.5)	-0.0327	(-16.3)
AcEgTime	-0.0177	(-4.1)	-0.0094	(-4.5)	-0.0342	(-5.9)
FWaitTime	-0.0282	(-2.8)	-0.0126	(-3.0)	-0.0415	(-3.4)
Transfers	-0.370	(-8.2)	-0.152	(-7.6)	-0.354	(-7.1)
MD Level-of-Service Parameters:						
CarTime	-0.0572	(-36.6)	-0.0076	(-9.8)	-0.0492	(-29.6)
CarCgTime	-0.113	(-10.2)	-0.0228	(-7.2)	-0.113	(-10.0)
CycleDist	-0.138	(-5.5)	-0.0371	(-2.0)	-0.138	(-5.2)
WalkDist	-0.317	(-20.3)	-0.144	(-13.8)	-0.408	(-18.8)
TaxiTime	-0.127	(-8.8)	-0.0515	(-4.3)	-0.117	(-7.4)
AS Level-of-Service Parameters:						
CarAccTime	-0.118	(-10.9)	-0.0394	(-8.6)	-0.141	(-9.7)

MD Socio-Economic Parameters:						
OneCarComp	-0.813	(-7.0)	-0.872	(-8.0)	-3.04	(-5.6)
PassOp2Hh	2.03	(14.2)	1.28	(11.1)	7.21	(7.4)
PassOp3PHh	1.58	(10.8)	0.910	(8.0)	5.63	(6.8)
CarP5to12	1.51	(5.5)	0.889	(5.3)	5.99	(4.9)
CarPMale	-0.897	(-7.9)	-0.543	(-6.1)	-3.08	(-5.9)
CarPRetir	0.507	(3.8)	0.424	(3.8)	1.40	(2.9)
BusUnemp	0.774	(4.8)	0.554	(5.0)	2.36	(4.0)
WalkFTwkr	-0.901	(-4.0)	-0.503	(-3.3)	-3.59	(-4.0)
WalkRetir	-0.427	(-2.9)	-0.0573	(-0.6)	-2.13	(-3.5)
CarPDisab	0.653	(3.9)	0.376	(2.8)	2.08	(3.3)
SlowDisab	-0.907	(-3.8)	-0.181	(-1.4)	-3.50	(-3.7)
BusOnlyPss	0.752	(3.2)	0.414	(2.5)	3.99	(4.0)
FTwkrDist	0.0090	(5.3)	1.0e-3	(2.4)	0.0102	(5.7)
AS Socio-Economic Parameters:						
CrDAc16t19	-3.44	(-2.7)	-1.28	(-2.7)	-4.43	(-2.7)
CrDAc20t24	-4.48	(-3.2)	-1.66	(-3.2)	-5.74	(-3.2)
CrDAcc1Car	-3.34	(-5.7)	-1.24	(-5.5)	-4.29	(-5.6)
CrPAcc0Car	-8.13	(-5.4)	-2.99	(-5.2)	-10.4	(-5.3)
CrPAcc1Car	-2.79	(-4.4)	-1.03	(-4.4)	-3.57	(-4.4)
Structural Parameters:						
TR_D_M			4.16	(17.2)		
TR_M_D					0.274	(8.9)
AccMdStaCh	0.433	(*)	0.433	(*)	0.433	(*)
ASScale	0.946	(10.6)	2.58	(9.3)	0.742	(9.9)

Appendix C: PRISM Model Elasticities

The elasticities shown in the following sections have been generated from the unexpanded samples of tours observed in the Household Interview data, for the mode and destination demand structure only and as such:

- there is no response as a result of changes in the highway network conditions;
- no tours are generated or suppressed as a result of the policy changes, i.e. total demand is constant;
- no changes in car ownership or residential location are taken into account.

The results should therefore be viewed medium-term elasticity values when comparing with published values, as they incorporate changes in job locations, etc..

The presented elasticities have been generated from four hypothetical policy changes:

- P1 = 10% reduction in car costs;
- P2 = 10% reduction in car times;
- P3 = 10% reduction in PT costs;
- P4 = 10% reduction in PT times.

Direct elasticities are highlighted in bold, for example PT time enters the utilities of train, metro and bus modes and so the elasticities for those modes are direct elasticities in P4.

Commute Elasticities

Commute Model Tour Elasticities

	COM_161_AS				COM_161_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	-0.073	-0.083	0.019	0.040	-0.056	-0.032	0.016	0.022
Car-Passenger	0.196	-0.326	0.136	0.252	0.144	-0.125	0.105	0.135
Train	0.125	0.342	-0.251	-0.395	0.104	0.132	-0.194	-0.231
Metro	0.156	0.422	-0.422	-0.867	0.133	0.167	-0.333	-0.644
Bus	0.114	0.341	-0.282	-0.553	0.095	0.139	-0.228	-0.301
Cycle	0.219	0.590	0.135	0.250	0.165	0.215	0.101	0.133
Walk	0.198	0.511	0.128	0.226	0.146	0.190	0.104	0.132
Taxi	0.182	-1.064	0.150	0.268	0.139	-0.464	0.111	0.139
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Commute Model Kilometrage Elasticities

	COM_161_AS				COM_161_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	-0.066	-1.081	0.017	0.037	-0.052	-0.964	0.015	0.021
Car-Passenger	0.201	-0.754	0.133	0.255	0.149	-0.432	0.104	0.138
Train	0.154	0.436	-0.352	-1.263	0.122	0.160	-0.255	-0.817
Metro	0.191	0.458	-0.382	-1.221	0.131	0.163	-0.359	-0.948
Bus	0.119	0.364	-0.289	-1.062	0.099	0.148	-0.234	-0.791
Cycle	0.210	0.608	0.136	0.262	0.165	0.227	0.103	0.145
Walk	0.194	0.539	0.144	0.255	0.144	0.199	0.110	0.137
Taxi	0.192	-1.940	0.149	0.277	0.150	-1.218	0.107	0.150
Total	-0.021	-0.879	-0.003	-0.053	-0.018	-0.792	-0.001	-0.047

For both demand and kilometrage, the T2 model elasticities are around two-thirds of the T0 values on average. Thus the T2 model is less elastic.

Table 6.11 of Balcombe et al (2004) quotes the short-run conditional elasticities for the UK, calculated when the fare on all PT modes are changed. In the following table these values, which are not specific to commuting, are compared to the demand elasticities in the T0 and T2 models. The ‘number of values’ column details the numbers of different elasticity values used to determine the UK mean.

Comparison with Short-Run UK Fare Elasticities (Trips)

Mode	UK Mean Elasticity	No of values	T0 Model	T2 Model
Suburban rail	-0.49	10	-0.251	-0.194
Metro	-0.26	10	-0.422	-0.333
Bus	-0.39	18	-0.282	-0.228

For train and bus, the model elasticities are lower than the UK averages, although the values in the T0 model are closer than the values in the T2 model. For metro the model elasticities are higher than the UK average.

Primary Education Elasticities

Because there is no car-driver alternative in the primary education model, the car cost elasticities were not run (it is assumed in all of the models that the cost of the car alternative is borne by the driver).

Primary Education Model Tour Elasticities

	PRIM_37			PRIM_37_T2		
	P2	P3	P4	P2	P3	P4
Car Passenger	**-0.976**	0.049	0.086	**-0.193**	0.008	0.015
Train	0.701	**-1.227**	**-1.062**	0.123	**-0.262**	**-0.308**
Metro	0.575	**-1.149**	**-1.609**	0.114	**-0.256**	**-0.541**
Bus	0.551	**-0.581**	**-1.028**	0.091	**-0.110**	**-0.202**
Bike	0.550	0.060	0.100	0.100	0.010	0.020
Walk	0.501	0.053	0.093	0.101	0.011	0.019
Taxi	0.607	0.067	0.113	0.110	0.013	0.020
Total	0.000	0.000	0.000	0.000	0.000	0.000

Primary Education Model Kilometrage Elasticities

	PRIM_37			PRIM_37_T2		
	P2	P3	P4	P2	P3	P4
Car Passenger	**-2.117**	0.056	0.098	**-1.339**	0.009	0.016
Train	0.726	**-1.552**	**-1.650**	0.112	**-0.495**	**-0.757**
Metro	0.655	**-1.338**	**-2.335**	0.113	**-0.327**	**-0.987**
Bus	0.606	**-0.649**	**-1.671**	0.098	**-0.179**	**-0.801**
Bike	0.600	0.066	0.114	0.112	0.010	0.020
Walk	0.565	0.059	0.103	0.114	0.011	0.020
Taxi	0.651	0.069	0.120	0.116	0.011	0.020
Total	-0.714	-0.060	-0.188	-0.583	-0.022	-0.116

The Tree 2 model is significantly less elastic than the Tree 0 model. The Tree 2 demand elasticities are about 25 % of the Tree 0 values, whereas in Tree 2 kilometrage elasticities are about 50 % of the Tree 0 values. Both of these percentages are approximate figures as there is considerable variation between individual pairs of values.

Table 6.32 of Balcombe at al (2004) quotes PT fare demand elasticities by specific travel purposes. A value for non-university education of –0.84 from Paris is quoted, which is noted as being high. The Tree 0 values for train and metro are higher still, whereas the Tree 2 values range from –0.110 for bus to –0.256 for metro. In the Sydney model system, primary education is identified separately and the PT fare elasticities are –0.14 for train and –0.15 for bus. Overall the lower Tree 2 model elasticities are more consistent with these sources than the high Tree 0 values.

Secondary Education Elasticities

As the T1 model was rejected on the basis of the structural parameter, elasticity results are not presented here.

Secondary Education Model Tour Elasticities

	SEC_34				SEC_34_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.025**	**-0.418**	0.014	0.121	**-0.019**	**-0.222**	0.010	0.077
Car-Passenger	0.000	**-0.668**	0.027	0.142	0.000	**-0.351**	0.019	0.084
Train	0.000	0.152	**-0.045**	**-0.082**	0.000	0.075	**-0.040**	**-0.097**
Metro	0.004	0.197	**-0.103**	**-0.364**	0.000	0.094	**-0.085**	**-0.346**
Bus	0.000	0.125	**-0.033**	**-0.171**	0.000	0.062	**-0.025**	**-0.108**
Cycle	0.000	0.183	0.026	0.135	0.000	0.090	0.019	0.082
Walk	0.000	0.136	0.021	0.108	0.000	0.075	0.017	0.071
Taxi	0.000	0.207	0.030	0.160	0.000	0.096	0.020	0.087
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Secondary Education Model Kilometrage Elasticities

	SEC_34				SEC_34_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.047**	**-0.889**	0.014	0.126	**-0.054**	**-0.735**	0.011	0.079
Car-Passenger	0.001	**-1.053**	0.030	0.163	0.000	**-0.777**	0.021	0.095
Train	0.000	0.167	**-0.068**	**-0.214**	0.000	0.082	**-0.079**	**-0.272**
Metro	0.001	0.215	**-0.118**	**-0.562**	0.000	0.104	**-0.102**	**-0.538**
Bus	0.000	0.138	**-0.039**	**-0.352**	0.000	0.069	**-0.036**	**-0.337**
Cycle	0.000	0.211	0.029	0.154	0.000	0.103	0.021	0.091
Walk	0.000	0.152	0.023	0.116	0.000	0.083	0.018	0.075
Taxi	0.000	0.234	0.032	0.181	0.000	0.109	0.021	0.098
Total	0.000	-0.090	-0.012	-0.147	-0.001	-0.095	-0.014	-0.163

Overall the secondary education model is significantly less elastic than the primary education model, particularly for the P1 and P3 cost elasticities. The low responsiveness to cost is a result of the weakly estimated cost parameter, which is small in magnitude.

The Tree 2 model demand elasticities are about half the size of the Tree 0 model values for car time, and closer to the Tree values for PT cost and PT time. The Tree 2 kilometrage values are similar to the Tree 0 values.

Tertiary Education Elasticities

Elasticity results are not presented for the Tree 1 model as the model was rejected on the basis of the structural parameter.

Tertiary Education Model Tour Elasticities

	TER_54				TER_54_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	-0.133	-0.349	0.021	0.120	-0.105	-0.095	0.017	0.042
Car-Passenger	0.122	-1.684	0.090	0.434	0.092	-0.627	0.070	0.153
Train	0.107	0.758	-0.139	-1.694	0.076	0.211	-0.098	-0.541
Metro	0.056	0.566	-0.289	-1.425	0.064	0.200	-0.253	-0.865
Bus	0.067	0.551	-0.181	-0.745	0.055	0.188	-0.156	-0.278
Cycle	0.091	0.617	0.095	0.350	0.074	0.207	0.077	0.140
Walk	0.097	0.498	0.041	0.159	0.077	0.155	0.037	0.064
Taxi	0.096	0.694	0.099	0.400	0.074	0.206	0.077	0.140
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Tertiary Education Model Kilometrage Elasticities

	TER_54				TER_54_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	-0.132	-1.463	0.025	0.154	-0.107	-1.091	0.021	0.055
Car-Passenger	0.132	-3.076	0.101	0.546	0.102	-2.175	0.078	0.195
Train	0.119	0.986	-0.247	-3.530	0.087	0.302	-0.166	-1.485
Metro	0.070	0.666	-0.295	-2.445	0.081	0.255	-0.256	-1.560
Bus	0.077	0.670	-0.187	-1.541	0.066	0.237	-0.159	-0.977
Cycle	0.093	0.663	0.098	0.380	0.079	0.233	0.076	0.156
Walk	0.098	0.527	0.046	0.176	0.079	0.166	0.041	0.069
Taxi	0.103	0.786	0.103	0.460	0.079	0.234	0.077	0.157
Total	0.000	-0.637	-0.039	-0.557	0.002	-0.670	-0.023	-0.271

The Tree 0 model is more elastic than the Tree 2. However the elasticities do not vary as significantly between the three tree structures as in the primary and secondary education models.

The time elasticities are significantly higher than the cost elasticities.

Table 6.32 of Balcombe et al (2004) quotes PT fare demand elasticities by specific travel purposes from a model system for Paris. For university travel, which is comparable to the tertiary education purpose, a value of –0.29 is quoted. Both the Tree 0 and Tree 2 elasticity values are lower than this, particularly for train.

Shopping Elasticities

Elasticity results are not presented for the Tree 1 model as the model was rejected on the basis of the structural parameter.

Shopping Model Tour Elasticities

	SHOP_70_AS				SHOP_70_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.069**	**-0.210**	0.012	0.128	**-0.064**	**-0.062**	0.012	0.051
Car-Passenger	0.056	**-0.835**	0.037	0.372	0.052	**-0.344**	0.036	0.152
Train	0.035	0.645	**-0.080**	**-0.515**	0.035	0.220	**-0.070**	**-0.380**
Metro	0.027	0.473	**-0.064**	**-0.891**	0.027	0.191	**-0.064**	**-0.873**
Bus	0.031	0.575	**-0.065**	**-0.608**	0.030	0.212	**-0.065**	**-0.249**
Cycle	0.058	0.688	0.067	0.517	0.050	0.254	0.063	0.225
Walk	0.044	0.624	0.060	0.493	0.039	0.238	0.062	0.225
Taxi	0.044	**-1.469**	0.069	0.556	0.038	**-0.506**	0.063	0.231
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The cost elasticities for the Tree 0 and Tree 2 models are very similar, whereas the time elasticities are lower for the Tree 2 model, particular for car time.

The PT fare elasticity values are low when compared to other model systems. For example Table 6.32 of Balcombe at al (2004) quotes PT fare demand elasticities by specific travel purposes from a model system for the greater Paris area. In this model the PT fare elasticity was –0.80 for regular shopping, and –0.30 for other shopping. The car cost elasticities are also low in both the Tree 0 and Tree 2 models.

Shopping Model Kilometrage Elasticities

	SHOP_70_AS				SHOP_70_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.068**	**-1.209**	0.012	0.132	**-0.064**	**-0.941**	0.013	0.054
Car-Passenger	0.055	**-1.963**	0.038	0.380	0.052	**-1.466**	0.037	0.154
Train	0.039	0.674	**-0.103**	**-1.202**	0.035	0.228	**-0.085**	**-0.787**
Metro	0.026	0.489	**-0.064**	**-1.561**	0.031	0.204	**-0.063**	**-1.432**
Bus	0.032	0.624	**-0.072**	**-1.171**	0.031	0.231	**-0.071**	**-0.762**
Cycle	0.053	0.748	0.071	0.581	0.050	0.277	0.066	0.239
Walk	0.041	0.685	0.068	0.563	0.038	0.260	0.065	0.237
Taxi	0.040	**-2.504**	0.073	0.599	0.040	**-1.314**	0.067	0.244
Total	-0.002	-0.757	-0.003	-0.162	0.001	-0.673	-0.002	-0.150

The pattern in the kilometrage elasticities is similar to that in the demand elasticities, with the Tree 0 and Tree 2 models having similar cost elasticities, but with the Tree 2 model being less elastic for changes in time. The direct demand elasticities for time are around 25 % lower in the Tree 2 model than the Tree 0 model.

Other Elasticities

Elasticity results are not presented for the Tree 1 model as the model was rejected on the basis of the structural parameter.

Other Travel Model Tour Elasticities

	OTH_52_AS				OTH_52_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.068**	**-0.108**	0.009	0.064	**-0.040**	**-0.015**	0.006	0.019
Car-Passenger	0.081	**-0.666**	0.028	0.203	0.048	**-0.217**	0.019	0.063
Train	0.075	0.917	**-0.167**	**-1.625**	0.033	0.225	**-0.092**	**-0.458**
Metro	0.043	0.600	**-0.100**	**-1.071**	0.029	0.200	**-0.086**	**-0.614**
Bus	0.049	0.700	**-0.114**	**-0.745**	0.031	0.195	**-0.078**	**-0.231**
Cycle	0.074	0.930	0.052	0.322	0.043	0.239	0.030	0.096
Walk	0.073	0.836	0.050	0.284	0.040	0.222	0.033	0.093
Taxi	0.070	**-1.127**	0.052	0.327	0.041	**-0.277**	0.030	0.100
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The Tree 2 demand elasticities are lower than those for the Tree 0 model. The cost elasticities are about one-third lower but the time elasticities are significantly lower.

Table 6.32 of Balcombe at al (2004) quotes PT fare demand elasticities by specific travel purposes from a model system for the Greater Paris area. The value for other travel is –0.45 which is significantly higher than both the Tree 0 and Tree 2 values.

Other Travel Model Kilometrage Elasticities

	OTH_52_AS				OTH_52_AS_T2			
	P1	P2	P3	P4	P1	P2	P3	P4
Car-Driver	**-0.065**	**-1.421**	0.008	0.061	**-0.039**	**-1.273**	0.006	0.019
Car-Passenger	0.082	**-1.936**	0.026	0.191	0.050	**-1.541**	0.018	0.060
Train	0.113	1.157	**-0.256**	**-4.023**	0.051	0.264	**-0.125**	**-1.611**
Metro	0.042	0.649	**-0.100**	**-1.724**	0.035	0.219	**-0.088**	**-1.007**
Bus	0.052	0.752	**-0.128**	**-1.400**	0.033	0.211	**-0.086**	**-0.836**
Cycle	0.072	0.971	0.054	0.336	0.043	0.251	0.031	0.100
Walk	0.067	0.870	0.055	0.309	0.038	0.234	0.034	0.095
Taxi	0.068	**-2.188**	0.053	0.338	0.041	**-1.139**	0.031	0.103
Total	-0.001	-1.190	-0.005	-0.127	0.003	-1.112	-0.001	-0.083

The kilometrage elasticities are also lower for the Tree 2 model. The Tree 0 model has some very high elasticity values for time changes, for example the car passenger elasticity for car time changes is –1.9 and the train elasticity for PT in-vehicle time changes is –4.0. The corresponding Tree 2 time elasticities are significantly lower and more plausible.