

Land-Use and Transport Integration in Scotland (LATIS)

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Document Approval

Primary Author: Chris Robinson

Other Author(s): Matthew Pollard

Reviewer(s): Mike Brewer
David Connolly
Andrew Bagnall

Formatted by: Nicola Milne

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LATIS Commission – Development of Modelling Framework

In August 2006 Transport Scotland commissioned MVA Consultancy to a Term Commission for the maintenance and enhancement of the Transport Model for Scotland (TMfS) and the accompanying Transport, Economic and Land-use Model of Scotland (TELMoS).

A central element of the Commission was to develop and deliver an enhanced 2007-based land-use and transport modelling system. MVA proposed a hierarchical modelling framework, with a single National Strategic Travel demand and Land Use Modelling framework as the upper tier, Regional Travel Demand Models as the mid-tier and detailed local models (eg microsimulation) as the lower tier. The National Modelling Framework has now been developed. It incorporates a number of technical enhancements and new and more robust data and will, in time, replace its predecessor, TMfS/TELMoS:05.

On 6 November 2008, the TMfS Term Commission changed its name to Land-Use and Transport Integration in Scotland (LATIS). The service is provided by Transport Scotland and their supporting consultants and offers a wide range of support and technical advice.

The LATIS service currently includes four distinct elements, as follows:

- a user engagement programme, consultations, discussions and advice on a range of transport and travel planning issues;
- the collection and provision of land-use planning data;
- the collection of transport data through the use of the Data Collection Contract; and
- a travel demand and land-use modelling suite.

The TMfS:07 and TELMoS:07 models are designed to deliver the fourth of these elements.

TMfS:07 & TELMoS:07 Model Reports

This report describes the development of the TMfS:07 National Road Model and is one of a series of eight documents describing the construction, calibration and validation of the TMfS:07 and TELMoS:07 models, as shown below:

TMfS:07 National Travel Demand Model

1. TMfS:07 Demand Model Development Report.

TMfS:07 National Road Model

2. TMfS:07 National Road Model Development Report; and
3. TMfS:07 National Road Model Calibration & Validation Report.

TMfS:07 National Public Transport Model

4. TMfS:07 National Public Transport Model Development Report; and
5. TMfS:07 National Public Transport Model Calibration and Validation Report.

TELMoS:07 National Land Use Model

6. TELMoS:07 Model Description Report;
7. TELMoS:07 Assembly of Planning Policy Inputs; and
8. TELMoS:07 Model Demonstration Report.

1 Introduction

1.1 Background

- 1.1.1 In 2008 MVA Consultancy were commissioned by Transport Scotland to create an enhanced version of the Transport Model for Scotland (TMfS), with a base year of 2007. This new national model, TMfS:07, is more strategic in nature than previous versions of the model and it sits at the top of a model hierarchy with more detailed regional models below.

1.2 Development of the Model

- 1.2.1 This report describes the procedure undertaken to develop the Demand Model element of TMfS:07. It also describes the calibration and the validation of the Demand Model, along with the response to standard sensitivity tests.

1.3 Structure of Report

- 1.3.1 Following this introductory chapter, the remaining chapters of this report are as follows:
- Chapter 2 provides an overview of the model structure;
 - Chapter 3 describes the development of the trip and cost matrices used in the model calibration;
 - Chapter 4 describes the mode and destination choice calibration stage;
 - Chapter 5 gives a description of the Park and Ride station choice calibration;
 - Chapter 6 describes the procedures for the creation of return trips and Non-Home-Based trips;
 - Chapter 7 covers the other choice models that are included with the model;
 - Chapter 8 covers model realism testing;
 - Chapter 9 explains the trip end modelling within the Model;
 - Chapter 10 describes the forecasting procedures; and
 - Chapter 11 contains the conclusions.

2 Model Overview

2.1 Model Structure

2.1.1 The TMfS:07 Demand Model is an extension of the conventional “four-stage” demand model, and incorporates the stages/choices listed below. Traditional elements of a four-stage model are denoted in bold:

- **trip generation;**
- trip frequency;
- **mode choice;**
- **destination choice;**
- park and ride station choice;
- high occupancy vehicle choice; and
- **route choice (assignment).**

2.1.2 The Demand Model calculates changes from the base-year in an incremental manner. The Demand Model forecasts changes to the Highway and Public Transport assignment matrices that arise through changes in forecast planning data and/or changes in future transport costs.

2.1.3 The inputs to the Demand Model are:

- trip productions and attractions;
- generalised costs of travel by highway and public transport modes from the base-year/reference case assignment models;
- a Park and Ride site file; and
- calibrated model parameters.

2.1.4 In preparing the model, the following data sources have been used:

- census travel-to-work data;
- National Rail Travel Survey data;
- public transport survey data;
- generalised costs of travel from the highway and public transport assignment models;
- Scottish Household Survey data;
- roadside interview survey data;
- planning data from TELMoS; and
- trip rates from TEMPRO.

2.2 Zone System

2.2.1 The TMfS:07 national model has the following 720 zones:

- 708 internal zones;
- four airport zones (Aberdeen, Edinburgh, Glasgow and Prestwick); and
- eight external zones covering England and Wales.

2.2.2 The main features of the new zone system are as follows:

- zones are generally larger than in previous versions of TMfS, in line with the more strategic nature of the TMfS:07 model;
- most zones are amalgamations of the 6,505 Scottish Neighbourhood Statistics Data Zones, with typically around nine Data Zones per TMfS:07 zone;
- no zone crosses a Local Authority boundary; and
- where possible, there is at most one train station per zone (the exceptions to this are described in Appendix B).

2.2.3 Some Data Zones do not lend themselves to creating suitable zones for a transport model, (for example where they represent two or more communities with significantly different connections to the strategic transport network). As a result it has been necessary to split thirteen Data Zones within the TMfS;07 zoning system. All the zones were split along census output area boundaries. The TMfS:07 zones in question are listed in Appendix B.

2.2.4 The level of detail in the TMfS:07/TELMoS:07 zone system is illustrated in Figure 2.1 below, which shows a set of zones in the Glasgow area. The full zone system is available to download from the modelling portal of the LATIS website (www.latis.org.uk).

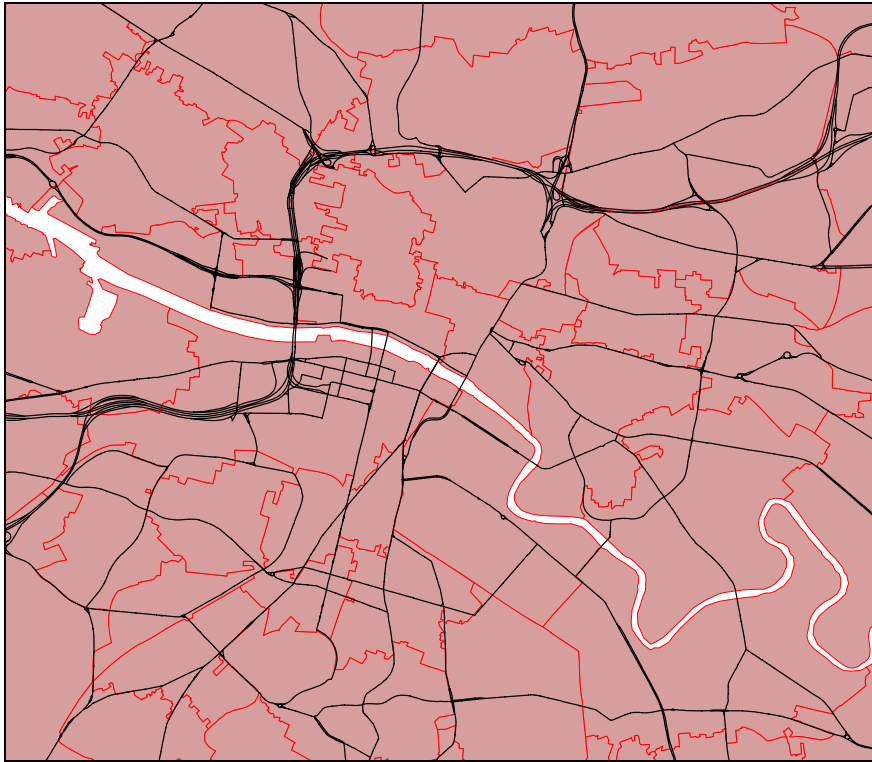


Figure 2.1 TMfS:07 Zone System in Glasgow Area

2.3 Journey Purposes and Time Periods

2.3.1 The Demand Model contains three journey purposes:

- **Home-Based Work (HBW)** – travelling 'From-Home' to work (and back again) – a typical commuting journey (note – this travel purpose does not take place in employer's time);
- **Home-Based Other (HBO)** – travelling 'From-Home' to a non work-related location such as shopping or leisure (but excluding education); and
- **Home-Based Employer's Business (HBEB)** – travelling 'From-Home' to a destination where you are in employer's time as soon as you leave the home.

There are three further purposes modelled, but these are derived by a factoring process rather than the demand model. These are:

- **Non-Home-Based Other (NHBO)** – travel between two *Non-Home-Based* locations (eg from work to shops);
- **Non-Home-Based Employer's Business (NHBEB)** – travelling during employer's time, such as travelling from your place of work to a business meeting, visiting customers etc; and
- **Home-Based Education (HBS)** – travelling 'From-Home' to an education destination (eg school, college etc). These are not part of the main Demand Model, but are added in separately after the mode and destination choice phases.

2 Model Overview

2.3.2 The Demand Model uses four household types:

- **C0** – zero car household (everyone from these is considered to be captive to PT);
- **C1/1** – 1 car, 1 adult household;
- **C1/2+** – 1 car, 2+ adult household; and
- **C2+** – 2+ car household.

(Note: These household types serve as a proxy for car availability).

2.3.3 Five user classes are included in the highway assignment model:

- cars in work time;
- cars in commute time;
- cars in other time (eg shopping, leisure etc);
- light goods vehicles (LGV); and
- heavy goods vehicles (HGV).

2.3.4 There are separate demand models for each time period. Each model (ie mode/destination choice) is for 'From-Home' trips only. The 'To-Home' trips and *Non-Home-Based* Trip Ends are derived from the outputs of the 'From-Home' models. The peak periods and peak hours are defined as follows:

- AM peak period 0700 - 1000;
 - AM peak hour (for assignment modelling) 0800 - 0900;
- Inter peak period 1000 - 1600;
 - Inter peak hour (for assignment modelling) 1/6 of 1000 - 1600;
- PM peak period 1600 - 1900; and
 - PM peak hour (for assignment modelling) 1700 - 1800.

2.4 Generalised Costs

- 2.4.1 The generalised cost coefficients for the base-year highway assignment model were calculated based on the most up-to-date version of TAG Unit 3.5.6 available at the time of model development (April 2009). The highways generalised cost equation by user class is:

$$GC = a \times \text{distance (km)} + b \times \text{time (mins)} + c \times \text{toll (pence)}$$

where a , b and c are the parameters and GC is in generalised time.

Table 2.1 Highways Assignment Model Coefficients for Base-year

Mode	Time	Distance	Toll
Cars In-Work	1.0	0.2329	0.0503
Cars Commute	1.0	0.5299	0.1448
Cars Other	1.0	0.3885	0.1448
LGV	1.0	0.6805	0.0225
OGV	1.0	2.1876	0.0225

2 Model Overview

2.4.2 The base-year generalised cost coefficients for the Public Transport Assignment Model are summarised in Table 2.2. A full description of the generalised cost of PT, can be found in the TMFS:07 National Public Transport Model Development Report.

Table 2.2 Public Transport Assignment Model Parameters

Model Parameter	Value/Factor
Route Enumeration Fare In-vehicle Time Factors:	
- urban bus / inter-urban bus	0.85
- rail / subway / ferry	1.0
Spread Factor	1.25
Spread Constant	5 mins
In-vehicle Time Factors – AM + PM:	
- urban bus	1.2
- inter-urban bus	1.1
- rail / subway / ferry	1.0
In-vehicle Time Factors – IP:	
- urban bus	1.2
- inter-urban bus	1.0
- rail / subway / ferry	1.0
Walk Time Factor	1.6
Minimum Wait Time	0 mins
Maximum Wait Time	60 mins
Boarding Penalty – AM + PM	10 mins
Boarding Penalty – IP	5 mins
Transfer Penalty:	
- rail to rail	5 mins
- bus to bus	5 mins
- rail/underground/tram to bus	5 mins
Value of time (2007 Base Year):	
- in work	21.58 £/hr
- non work	5.11 £/hr

2.4.3 The value of time is used to convert public transport fares into units of generalised time. The values, as in the case of the Highways Assignment Model, were also taken from WebTAG unit 3.5.6.

2 Model Overview

2.4.4 The calculation of the Generalised Cost coefficients is presented in Appendix C.

2.5 Parking Charges

2.5.1 Parking charges are introduced by adding representative costs to the central area zones of:

- Aberdeen;
- Dundee;
- Dunfermline;
- Edinburgh;
- Glasgow;
- Inverness;
- Perth; and
- Stirling.

2.5.2 Different costs are added in for different journey purposes. This is due to different types of journey have different average lengths of stay.

2.5.3 Appendix D describes how the parking charges have been included in the Model. It also describes the calculation of average parking charges in each city/town.

2.6 Highway and Public Transport Assignment Models

2.6.1 The development of the Highway and Public Transport Assignment Models are described in separate reports. Both models consist of calibrated and validated assignment matrices and network models by time period.

2.6.2 The assignment matrices are origin/destination format matrices by one-hour time period for AM peak, Inter-Peak and PM Peak. In the case of the Highway Model, the matrices are PCU matrices for Car In-Work, Car Commute, Car Other, Light Goods Vehicles (LGVs) and Heavy Goods Vehicles (HGVs). In the case of Public Transport, the matrices are person trip matrices for In-Work, Commute and Other.

2.6.3 The PCU factors for the Highway Model are 1.0 for all light vehicles, 1.9 for heavy goods vehicles and 2.2 for buses.

2.6.4 The network assignment models were used to create the base generalised cost matrices, which have been used in the development of the Demand Model.

2.7 Trip Ends

2.7.1 Trip Ends, which contain production and attraction information by purpose, are basic data for the Demand Model. The Trip Ends are required by production and attraction, by mode, by household type, by time period and by the six journey purposes used in the Model.

2 Model Overview

- 2.7.2 Forecasting is undertaken using TEMPRO trip rates and planning data from the TELMoS:07 model. These are used to create growth factors which are then applied to the base TMfS:07 trip ends..

2.8 Demand Model Parameters

- 2.8.1 The demand model parameters control the sensitivity of the various choice processes and also, to some extent, the fit of the model to base-year data.
- 2.8.2 The base-year demand model parameters include distribution model sensitivity parameters, mode choice scaling factors and mode specific constants. The base model also contains Park and Ride model parameters.
- 2.8.3 The sensitivity parameter values have been calculated specifically for this model using local data.
- 2.8.4 These parameters have then been subjected to realism testing as defined by the Variable Demand Model (VADMA) guidance in WebTAG; the implied sensitivities of the model have then been compared to the standard published values.

2.9 Demand Model Process

- 2.9.1 The processes contained in the demand model and their interaction is explained in a series of flow diagrams, which are contained in Appendix A.

2.10 Software

- 2.10.1 Previous versions of the TMfS demand model have been coded in TRIPS software, the TMfS:07 model however has been completely reprogrammed in CUBE VOYAGER (version 5.0.2) software. The calibration of the demand model previously was also carried out using TRIPS software, in TMfS:07, ALOGIT software, has been used to calibrate the mode and destination choice parameters.

3 Matrix Development

3.1 Data

3.1.1 The main data sources used in the development of the matrices for the demand model is as follows:

For the Road Demand Matrices:

- Census travel-to-work data;
- Scottish Household Survey Data;
- Planning data from TELMoS;
- TEMPRO trip rates;
- Generalised costs of travel from the assignment models; and
- Roadside interview data.

For the PT Demand Matrices:

- all sources used for Road demand;
- Data collection for inter urban buses (Autumn 2007).; and
- National Rail Travel Survey data (NRTS).

For the Park and Ride Demand Matrices:

- National Rail Travel Survey data (NRTS); and
- Park and Ride Site Survey data.

3.1.2 It should be noted that all the matrices were developed by each of the four household segments described in Chapter 2.

3.2 Census Travel to Work Data

3.2.1 The census travel to work data has been used to create the From-Home Work Road matrices for the demand model. The Census Travel to Work represents a full day, the AM Peak and Inter Peak matrices have been factored out from this. Firstly the overnight trips were removed using overnight trip factors from TEMPRO, leaving a twelve hour matrix. Scottish Household Survey data was then used to extract the AM and Inter Peak matrices. It should be noted that the Travel to Work Data contains a Home to Work place linkage and that there is no method to turn this into different travel patterns by time period.

3.3 Synthesised Data

3.3.1 The From-Home to Employers Business trips and the From-Home to Other Road matrices have been calculated using a data synthesising process. The stages used to create this data were as follows:

- using TELMoS:05A data from the 2005 base year and the 2012 do minimum forecast, linear interpolation was used to obtain 2007 planning data, which was then compressed to the new 720 zone system of TMfS:07;
- this planning data was combined with trip rate data from TEMPRO, to produce period person trip ends (Productions and Attractions) for the AM Peak and the Inter Peak; and
- finally these trip ends were passed through a gravity model (using destination choice sensitivity parameters and generalised costs from the TMfS:05A model) to get the matrices for 2007. (See TMfS:05 demand model report for details of the destination choice parameters used).

3.4 PT Demand Matrices

3.4.1 The PT From-Home demand model matrices were created using the following process:

- firstly the 'From-Home' elements of the NRTS and Inter Urban Bus Survey data were extracted and combined to create From-Home to Work, Employers Business and Other matrices for AM Peak and Inter Peak;
- any gaps in the From-Home to Work matrices were then filled in using Census Travel to Work PT Data; and
- finally, any gaps in the From-Home to Employers Business and From-Home to Other matrices were filled in using synthesised PT data (created in the same way as the car matrices in section 3.4).

3.4.2 The PT matrices have been built up from the same data in both the Assignment Model and in the Demand Model, but these were developed separately. For the Assignment models, full O-D matrices were created for the peak hours. For the demand model the same data was used to create time period matrices of 'From-Home' trips.

3.5 Park and Ride Demand Matrices

3.5.1 The Park and Ride AM Peak [*note; there is no Inter Peak Park and Ride model*] were created from NRTS data and Park and Ride site survey data. For rail based Park and Ride the matrices were built up by obtaining from the NRTS those trips which accessed stations by car and were From-Home, this was undertaken separately by time period. The Bus Park and Ride matrices were created from surveys at Park and Ride sites, which were expanded using entry and exit counts. These matrices were then combined to get the final Park and Ride matrices.

3.6 Creation of Prior Matrices for Road Assignment Model

- 3.6.1 The processes described in sections 3.2 to 3.6 resulted in a full set of From-Home matrices for Road, PT and Park and Ride. These From-Home matrices along with generalised cost data from the assignment models were then used to calibrate the demand model parameters (see chapter 4).
- 3.6.2 The To-Home and Non-Home-Based demand matrices were then created by putting these From-Home matrices through the reverse and Non-Home-Based trip creation process (see chapter 6). The To-Home Park and Ride Matrices were created by putting the From-Home Park and Ride matrices through the Station Choice model (see chapter 5). *[Note: At this stage the Station Choice Model was un-calibrated, but this process was only designed to get prior matrices for the assignment models.]*
- 3.6.3 These matrices were then combined, with the From-Home matrices, to produce hourly vehicle matrices to be used as prior matrices in the highway assignment calibration.

3.7 Education Matrices

- 3.7.1 The Census Travel to Work data also contains education data (Scotland only). This was extracted from the main commute data. Using factors from TEMPRO, these were split into time periods. These Education trips were added into the Home-Based Other matrices, prior to the calculation of reverse and Non-Home Based trips, but they do not form part of the main demand model. In forecast years they are included as add-in matrices prior to reverse trip calculation.

3.8 Goods Vehicle Matrices

- 3.8.1 The Road Side Interview data along with growthed and compressed TMfS:05A matrices were used to create the goods vehicle matrices in TMfS:07. These were included in the prior matrices prior to the calibration of the Road Network. More detail on the development of these matrices is included in the Road model development report.

4 Destination and Mode Choice Calibration

4.1 Overview

- 4.1.1 The mode and destination choice modules are the main choice mechanisms within the TMFS:07 demand model. The formulation and flow of these modules in application mode are shown in Appendix A.
- 4.1.2 ALOGIT software has been used to calibrate the mode and destination choice parameters. ALOGIT was also used to test the different model structures. ALOGIT is industry standard software for calibrating models of this type. The software calibrates the mode and destination choice parameters simultaneously.
- 4.1.3 This chapter covers data processing, model specification and model estimation. Separate parameters have been calculated by time period, car availability segment, mode and purpose.

4.2 Data

- 4.2.1 The model has 712 (demand model works on internal model zones only) zones generating a demand matrix, incorporating 506,944 origin-destination movements for each segment. For each movement we have data describing the:
 - volume of car trips;
 - volume of public transport trips;
 - volume of park and ride trips;
 - distance (km);
 - generalised cost of travel by car (minutes);
 - generalised cost of travel by public transport (minutes); and
 - generalised cost of travel by park and ride (minutes).
- 4.2.2 These sources of data then form the inputs to the calibration process in ALOGIT. It should be noted that for non-commuting purposes long distance trips (those over 100km) have been excluded from the calculation (these are treated as add-in matrices later on in the process – see chapter 10).

Preliminary Data Inspection

- 4.2.3 Before proceeding to model specification and estimation of the model, a preliminary inspection of the data was undertaken, to identify underlying patterns and trends and check the suitability of the data. The analysis excludes origin-destination pairs with a trip volume less than one and was undertaken using the Travel to Work data only, as this is the biggest travel segment in the model.
- 4.2.4 Figure 4.1 shows a strong positive relationship between the generalised cost of travel (in minutes) and journey distance. It is important to note increasingly larger differences between the generalised cost of car (GCcar) and the generalised cost of public transport

(GCpt) as travel distance increases. These differences will influence the elasticities of demand for each mode.

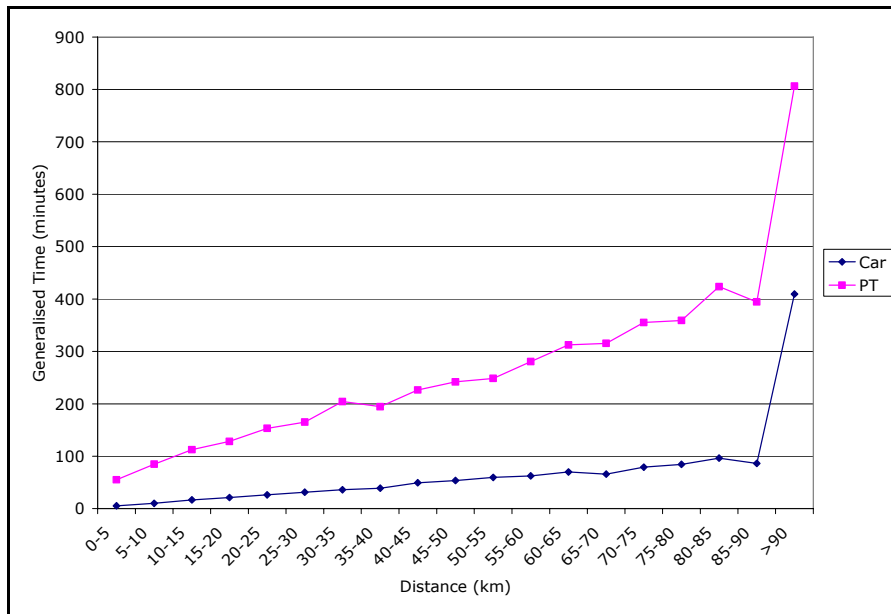


Figure 4.1 Generalised cost of travel by mode

4.2.5 Figure 4.2 shows the relationship between mode share and journey distance. This graph reflects the relative advantage of car travel, in generalised cost terms, for longer distance trips.

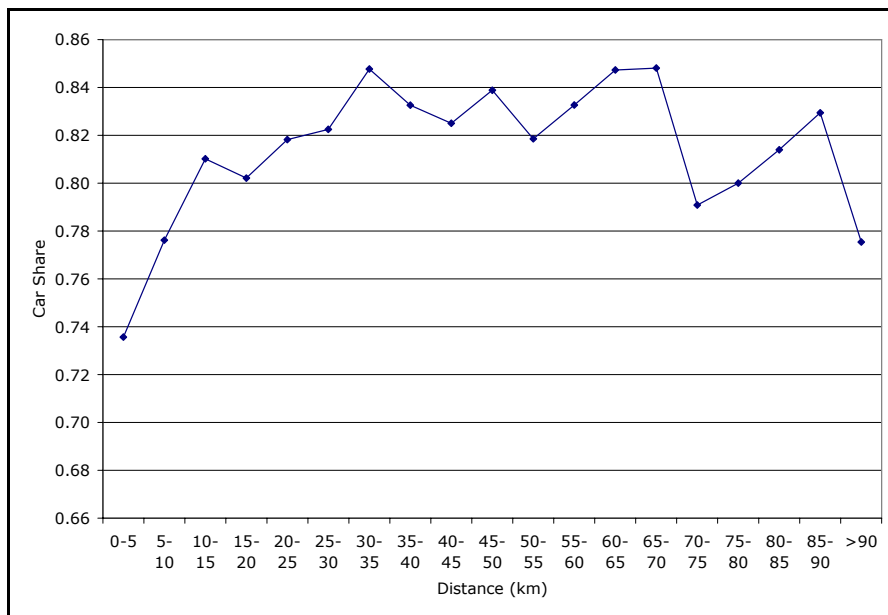


Figure 4.2 Mode share and journey distance

4.2.6 Figure 4.3 shows the distribution of the volume of traffic over journey distance. As expected, the distribution is negatively skewed with a peak value between 0 and 5km.

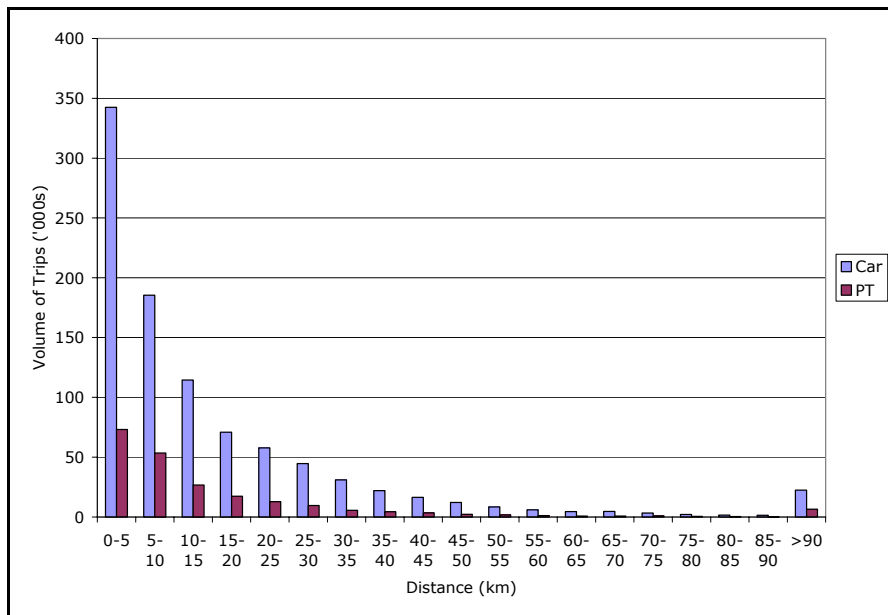


Figure 4.3 Trip volume and journey distance

4.2.7 The preliminary exploration of the data therefore showed plausible patterns and trends in travel demand and travel costs, which suggested that the data was a good foundation on which to develop mode and destination choice models.

4.2.8 *[Note: This preliminary data inspection was undertaken prior to the completion of the calibration of the assignment models and therefore the generalised costs that were used in this inspection are not the final costs used in the model or the calibration process.]*

4.3 Parameter Calibration

Model Specification

4.3.1 Initial tests were undertaken to determine the model structure, using the travel to work data, which is the biggest travel segment in the model, subsequently the process was effectively one of refining the parameters and the utility function. ***[Note: The formulations used in calibration are not the same as those used in application – the formulation of the model in application is set out in Appendix A.]***

4.3.2 After these initial tests of possible model structures, it was found that destination choice was more sensitive than mode choice in the model. This finding was based on the relative size of the scaling parameters.

4.3.3 For the model estimation, the utility of each alternative was then specified as a function of the generalised cost of travel, an additional dummy variable to account for the intra-zonal trips and a set of alternative specific constants, as follows:

$$V_j = \beta_{m0} \text{IntraZonal} + \beta_{m1} \ln(C_{ijm}) + \beta_{m2} C_{ijm} + ASC_j$$

Where

ASC_s are the set of alternative specific constants for each destination;

C_{ijm} is the Generalised cost for mode m between origin i and destination j for mode m ;

β_{m1} is the scaling parameter for the log of the cost term for mode m ;

β_{m2} is the scaling parameter for the cost term for mode m ; and

β_{mo} is the K-factor for the intra-zonal term for mode m .

- 4.3.4 The ASC's are included to ensure that the other parameters are estimated correctly, but in application they are not used.
- 4.3.5 For the nested logit with destination choice conditional on mode choice (m) structure that was used to undertake the calibration, the proportion of Trips (T_{jm}) of choosing destination j from the J alternatives available via mode m is given as:

$$T_{jm} = \frac{e^{V_j}}{\sum_{j' \in J_m} e^{V_{j'}}}; \text{ and}$$

and the proportion choosing each mode (P_m) is given as:

$$P_m = \frac{e^{V_m}}{\sum_{m' \in M} e^{V_{m'}}}$$

where:

$$V_m = \theta \ln \sum_{j \in J_m} e^{V_j}$$

in which θ is the mode split spread parameter.

4.3.6 Once this model structure had been set up in ALOGIT, the process detailed by the bullet points below was used to calibrate the mode and destination choice scaling parameters. This approach exploits the fact that for a given scaling coefficient-vector there exists, a unique set of ASC's such that the predicted shares equal the actual shares. The process was as follows:

- **(1)** Use ALOGIT to estimate scaling coefficients with ASC's equal to zero;
- **(2)** Calculate shares for each choice alternative using the model estimated in (1);
- **(3)** Estimate a new set of ASC's based on the following formula:

$$ASC' = ASC + \ln\left(\frac{S_A}{S_F}\right)$$

Where:

ASC is the base ASC value;
ASC' is the new ASC value;
S_A is the actual share; and
S_F is the modelled share.

- **(4)** Re-estimate scaling coefficients in ALOGIT with ASC's set equal to ASC'.

4.3.7 Then the steps 2, 3 and 4 were iterated between until convergence is reached (ie the ALOGIT estimates displayed only very small changes between iterations). The parameters calibrated on the final iteration were then the ones that were then used in the model.

4.3.8 This process has then been followed for each time period, purpose and household segment within the model to derive the Model Parameters presented in Section 4.5 below.

4.3.9 It should, however, be noted, that whilst the parameters for all segments have been calibrated as described above, in application Home-Based Other and Home-Based Employers Business trips are modelled as singly constrained models in application.

Model Results

4.3.10 Table 4.1 to 4.4 shows the full set of calibrated parameters for each modelled segment within the model. The mode choice parameters are all within the expected range between 0 and 1.

Table 4.1 C1/1 Mode and Destination Choice Parameters

C1/1 Parameters		HBE	HBO	HBW
Home-Based Mode Choice, θ	AM	0.639	0.407	0.241
	IP	0.816	0.205	0.808
Home-Based Ln (C) Params, β_1	AM Car	-0.788	-0.487	-0.551
	IP Car	-0.741	-0.299	-0.714
	AM PT	0.000	-1.786	-3.345
	IP PT	-0.776	-4.434	-0.829
	AM P&R	0.000	-3.198	-4.176
Home-Based C Params, β_2	AM Car	-0.053	-0.060	-0.060
	IP Car	-0.071	-0.077	-0.077
	AM PT	-0.080	-0.015	-0.003
	IP PT	-0.025	0.000	-0.023
	AM P&R	-0.151	-0.003	-0.006
Home-Based Intra Zonal, β_0	AM	-0.054	-0.410	0.901
	IP	-0.228	-0.359	1.028

Table 4.2 C1/2+ Mode and Destination Choice Parameters

C1/2+ Parameters		HBE	HBO	HBW
Home-Based Mode Choice, θ	AM	0.368	0.311	0.291
	IP	0.577	0.206	0.329
Home-Based Ln (C) Params, β_1	AM Car	-0.868	-0.119	-0.627
	IP Car	-1.336	-0.161	-0.896
	AM PT	0.000	-0.617	-1.415
	IP PT	-1.255	-3.046	-1.196
	AM P&R	0.000	-0.825	-3.633
Home-Based C Params, β_2	AM Car	-0.054	-0.070	-0.051
	IP Car	-0.034	-0.079	-0.057
	AM PT	-0.069	-0.015	-0.015
	IP PT	-0.016	-0.003	-0.021
	AM P&R	-0.092	-0.011	-0.005
Home-Based Intra Zonal, β_0	AM	-0.182	-0.242	0.781
	IP	-0.047	-0.288	0.803

Table 4.3 C2+ Mode and Destination Choice Parameters

C2+ Parameters		HBE	HBO	HBW
Home-Based Mode Choice, θ	AM	0.192	0.373	0.323
	IP	0.187	0.201	0.278
Home-Based Ln (C) Params, β_1	AM Car	-0.584	-0.209	-0.529
	IP Car	-0.867	-0.234	-0.600
	AM PT	0.000	0.000	-2.149
	IP PT	-3.981	-4.044	-2.011
	AM P&R	0.000	-0.359	-2.880
Home-Based C Params, β_2	AM Car	-0.072	-0.064	-0.048
	IP Car	-0.067	-0.074	-0.060
	AM PT	-0.036	-0.025	-0.008
	IP PT	-0.005	0.000	-0.016
	AM P&R	-0.018	-0.017	-0.010
Home-Based Intra Zonal, β_0	AM	-0.323	-0.243	1.016
	IP	-0.375	-0.271	0.904

Table 4.4 C0 Mode and Destination Choice Parameters

C0 Parameters		HBE	HBO	HBW
Home-Based Mode Choice, θ	AM	N/A	N/A	N/A
	IP	N/A	N/A	N/A
Home-Based Ln (C) Params, β_1	AM Car	N/A	N/A	N/A
	IP Car	N/A	N/A	N/A
	AM PT	0.000	-0.141	-0.165
	IP PT	0.000	-0.442	0.000
	AM P&R	N/A	N/A	N/A
Home-Based C Params, β_2	AM Car	N/A	N/A	N/A
	IP Car	N/A	N/A	N/A
	AM PT	-0.047	-0.020	-0.028
	IP PT	-0.057	-0.024	-0.036
	AM P&R	N/A	N/A	N/A
Home-Based Intra Zonal, β_0	AM	-0.707	-0.494	-0.102
	IP	-2.732	-0.634	-0.159

4.4 Mode Specific Constants

- 4.4.1 In order to ensure that the synthesised mode split is consistent with the mode split in the base-year Trip Ends, the mode specific constants have been calculated for each zone using the following formulae:

$$K_{i(CAR)} = (U_{i(P\&R)} - U_{i(CAR)}) + \frac{1}{\theta} * \log\left(\frac{P_{i(CAR)}}{P_{i(P\&R)}}\right)$$

and

$$K_{i(PT)} = (U_{i(P\&R)} - U_{i(PT)}) + \frac{1}{\theta} * \log\left(\frac{P_{i(PT)}}{P_{i(P\&R)}}\right)$$

where:

$U_{i(PT)}$ - composite utility for PT for production zone I ;

$U_{i(P\&R)}$ - composite utility for Park and Ride for production zone I ;

$U_{i(CAR)}$ - composite utility for Car for production zone I ;

θ - mode choice scaling factor (see Table 5.2);

$P_{i(CAR)}$ - proportion of Car in base for production zone I ;

$P_{i(P\&R)}$ - proportion of Park and Ride in base for production zone I ; and

$P_{i(PT)}$ - proportion of PT in base for production zone i .

- 4.4.2 These formulae have been derived from the mode split formulation and are carried out for each journey purpose. Note they are pivoted from the Park and Ride Mode Constant, which therefore has a value of zero.

5 Park and Ride Station Choice Calibration

5.1 Overview

- 5.1.1 Park and Ride choice has been included in the main mode choice model. The demand model parameters associated with Park and Ride and their calibration is described in Chapter 4.
- 5.1.2 After the Mode and Destination Choice stages of the model, Park and Ride site choice is undertaken. The calibration of the site choice is described in the remainder of this chapter.
- 5.1.3 The Park and Ride module is applied to the 'From-Home' trips in the AM Peak period only. The corresponding return trips are assumed to take place during the PM Peak period. Unlike previous versions of TMfS, no Park and Ride is considered in the Inter-Peak, this is due to there being little P&R demand in the Inter-Peak compared to the AM Peak.
- 5.1.4 It should be noted that the Park and Ride module only is only applied to those demand segments which have a car available.

5.2 Methodology

- 5.2.1 The inputs to the site choice calibration are the Park and Ride generalised costs and Park and Ride sites. Each site file contains a specification of the site catchment area, which are defined as a list of zones, which in nearly every case are all other zones.
- 5.2.2 The site file also contains the Car Park Charge (if any) and the number of 'official' car parking spaces. Note the Park and Ride station choice model allows users to park outside the 'official' car parking spaces, as is the reality at a number of stations.
- 5.2.3 The full list of Park and Ride sites included within the model is included in Appendix G.
- 5.2.4 Each Park and Ride site also has a calibrated transfer time, which is added to the generalised costs within the car park choice process and is specified in the site file. The transfer time aims to reflect a variety of attributes of the Park and Ride site (eg cleanliness, ease of transfer, security etc) and is used as a calibration tool. This parameter does not vary with car park occupancy.
- 5.2.5 The process checks sites which are over capacity and have cars parking in outside the main car park with the transfer time being increased by an increment per additional car. This is to represent the increasing search and/or walk times associated with using the non 'official' car parking spaces.
- 5.2.6 The Generalised Costs are calculated from combinations of the base highway and PT costs. Park and Ride cost matrices are best path cost matrices (regardless of whether a Park and Ride trip uses the minimum cost path). They are built by finding the minimum cost path from each origin to each Park and Ride site by car and then from there to each destination.

5 Park and Ride Station Choice Calibration

- 5.2.7 Park and Ride trips, which have been calculated by the mode choice model, are then assigned to the Park and Ride sites using the logit formula:

$$P_s = \frac{e^{-\lambda(C_s + TT_s + PC_s)}}{\sum_{s \in S} e^{-\lambda(C_s + TT_s + PC_s)}}$$

Where:

P_s is the proportion of Park and Ride sites from a given origin using site s ;

λ is the spread parameter for the Park and Ride station choice;

C_s is the generalised cost via site s ;

TT_s is the transfer time for site s ; and

PC_s is the parking charge (if any) at sites.

- 5.2.8 The Park and Ride module works separately for each purpose. It calculates Park and Ride demand for Home-Based Work, Home-Based Employers Business and Home-Based other simultaneously. The model then outputs data by site for each purpose.
- 5.2.9 External trips (ie those coming from England and Wales) do not have the choice of using Park and Ride as they are not included in the mode choice process.
- 5.2.10 The Park and Ride module outputs AM 'From-Home' and PM 'to-Home' matrices by purpose and mode. These are then added into the Highway and Public Transport assignment matrices for route choice.

5.3 Calibration of the Park and Ride Site Choice

- 5.3.1 For the rail-based Park and Ride sites, the observed data comes from the NRTS. The bus-based Park and Ride sites come from survey data, which consists of a combination of Origin Destination surveys along with entry/exit counts at each site.
- 5.3.2 The calibration of individual Park and Ride sites is undertaken by varying the transfer time parameter at each site.
- 5.3.3 Table 5.1 shows the total usage of Park and Ride Sites by Local Authority. The total observed trips is in vehicles. The modelled total is calculated from the period person matrices, but with an average occupancy of 1.2 applied. The calibration of Park and Ride by site and by journey purpose is included in Appendix H.

Table 5.1 Park and Rite Site Calibration by Local Authority

Local Authority	Total Observed	Total Modelled	Difference	GEH
Aberdeenshire	392	168	-224	13.37
Angus	166	66	-100	9.28
Argyll & Bute	248	253	5	0.33
City of Aberdeen	721	565	-156	6.14
City of Dundee	129	83	-46	4.46
City of Edinburgh	1,465	1,380	-85	2.25
City of Glasgow	890	980	91	2.97
Clackmannan	0	0	0	0.00
Dumfries & Galloway	34	12	-22	4.60
East Ayrshire	199	181	-18	1.30
East Dunbartonshire	891	937	46	1.53
East Lothian	416	394	-22	1.10
East Renfrewshire	672	658	-15	0.56
Falkirk	1,061	1,062	1	0.02
Fife	1,993	1,944	-49	1.10
Highland	104	46	-58	6.75
Inverclyde	260	306	46	2.73
Midlothian	0	0	0	0.00
Moray	72	50	-21	2.71
North Ayrshire	445	430	-15	0.72
North Lanarkshire	1,841	1,932	91	2.09
Perthshire & Kinross	334	286	-48	2.73
Renfrewshire	804	862	58	2.00
South Ayrshire	513	486	-27	1.22
South Lanarkshire	1,709	1,811	102	2.42

5 Park and Ride Station Choice Calibration

Local Authority	Total Observed	Total Modelled	Difference	GEH
Stirling	719	721	3	0.09
The Borders	0	0	0	0.00
West Dunbartonshire	620	662	42	1.66
West Lothian	1,065	1,068	3	0.10
Total	17,761	17,342	-419	3.16

5.3.4 The table above shows that the model predictions of Park and Ride use are a very good match with observed data at a Local Authority level. At an individual station level, the match is not as good (see Appendix H), but this is to be expected, given the strategic nature of the model and the corresponding lack of zone and network detail.

5.3.5 Those local authorities with the greatest GEH scores tend to be on the edge of the model.

6 Reverse and Non-Home-Based Trips

6.1 Overview

- 6.1.1 The demand model works at for 'From-Home' journey purposes for the AM Peak period and Inter-Peak only. Further factoring procedures are then run to calculate the PM 'From-Home' trips, 'To-Home' and Non-Home-Based trips.
- 6.1.2 This chapter describes the methodology for these detailed factoring processes. The factors used in this process are set out in Appendix I.

6.2 Evening Peak Trips

- 6.2.1 For the Evening Peak, 'From-Home' trips were generated by factoring the 'From-Home' trips for the Inter-Peak time period.
- 6.2.2 We then have:

$$T_{ij}^{(pmpeak)pm} = \delta^{pm} * T_{ij}^{(interpeak)pm}$$

$$\text{where, } \delta^{pm} = \frac{\sum_{T,P,M} V_{TPM}^{(pmpeak)pm}}{\sum_{T,P,M} V_{TPM}^{(interpeak)pm}}$$

6.3 'To-Home' Trips

- 6.3.1 Some definitions need to be made so that the process for creating 'To-Home' trips and its parameters can be defined more precisely. We define:

- **t** the time period of the 'From-Home' trip;
- **p** the journey purpose of the 'From-Home' trip;
- **m** the mode of the 'From-Home' trip;
- **T** the time period of the 'To-Home' trip;
- **P** the journey purpose of the 'To-Home' trip; and
- **M** the mode of the 'To-Home' trip.

- 6.3.2 For the 'From-Home' situation we have three time periods – AM Peak, Inter-Peak and Evening Peak, three home-based purposes – work (HBW), employer's business (HBEB) and other (HBO), and two modes, each by four car availability segments.

6.3.3 The 'To-Home' trips are calculated from the 'From-Home' trips as follows:

$$T_{ij(to)}^{TMP} = \sum_{t,p,m} \{ \alpha_{TPM}^{tpm} * T_{ji(from)}^{tpm} \}$$

where:

$T_{ij(to)}^{TMP}$ = 'To-Home' person trips from origin i to destination j in time period \mathbf{T} for home-based purpose \mathbf{P} by mode \mathbf{M} ;

$T_{ji(from)}^{tpm}$ = 'From-Home' person trips from origin j to destination i in time period \mathbf{t} for home-based purpose \mathbf{p} by mode \mathbf{m} ; and

α_{TPM}^{tpm} = factors by 'From-Home' time period \mathbf{t} , 'From-Home' purpose \mathbf{p} , 'From-Home' mode \mathbf{m} , 'To-Home' period \mathbf{T} , 'To-Home' purpose \mathbf{P} and 'To-Home' mode \mathbf{M} .

Note that $\alpha_{TPM}^{tpm} = 0$ for 'From-Home' time periods later than the 'To-Home' time period, ie 'To-Home' trips in the AM Peak for example, cannot be linked to 'From-Home' trips in the Inter-Peak.

6.3.4 The parameters α_{TPM}^{tpm} were calculated from the results of the tabulations from the Scottish Household Survey. The details of return journeys for each 'From-Home' trip made by the sampled adult were tabulated so that for each $T_{ij(from)}^{tpm}$ the return trips $T_{ji(to)}^{TPM}$ were included. The cell entries in the table can be called V_{TPM}^{tpm} . We then define:

$$\alpha_{TPM}^{tpm} = \frac{V_{TPM}^{tpm}}{\sum_{T,P,M} V_{TPM}^{tpm}}$$

6.4 Non-Home-Based Trips

6.4.1 For Non-Home-Based trips, the origins and destinations for the two Non-Home-Based purposes (In-Work and Non-Work) were calculated based on the destinations of 'From-Home' trips and the origins of 'To-Home' trips. The Non-Home-Based Trip Ends were calculated separately by time period.

6.4.2 For Non-Home-Based origins:

$$O_i^{inm} = \sum_{p,t} \left(\beta_{I(from\ home)}^{nmpm} * D_{i(from\ home)}^{tpm} \right)$$

and for *Non-Home-Based* destinations:

$$D_j^{nm} = \sum_{p,t} \left(\beta_{J(\text{to home})}^{n,tpm} * O_{j(\text{to home})}^{tpm} \right)$$

where:

n is the *Non-Home-Based* purpose ie work or Non-Work.

Note that the factors **β** are zero for time periods later than the *Non-Home-Based* origins/destinations.

- 6.4.3 It is unlikely that the total origins will equal the total destinations when applying this process, so the totals will be constrained to an average of the two. Matrices of Non-Home-Based trips by mode and time period will be created by applying the Trip Ends to a distribution model using appropriate inter-zonal costs. The calibrated parameters for these distribution models are described in Section 6.5.
- 6.4.4 The total trips by mode are calculated simply by adding the origin destination matrices together for Public Transport, and weighting by vehicle occupancy for car trips.

6.5 Non-Home-Based Destination Choice

- 6.5.1 The parameters for Non-Home-Based destination choice have also been calibrated using ALOGIT. The destination choice sensitivity parameters and Intra-Zonal K-Factors are shown in Tables 6.1 to 6.4.

Table 6.1 C1/1 Non Home-Based Destination Choice Parameters

C1/1 Parameters		Non Home-Based Employers Business	Non Home-Based Other
Non Home-Based Ln(C), β_1	AM Car	-0.8169	-1.6116
	IP Car	-2.1683	-1.1878
	PM Car	-0.8506	-0.7441
	AM PT	-1	-0.6484
	IP PT	-1.1179	-1.3682
	PM PT	-1	-0.3742
Non Home-Based C, β_2	AM Car	-0.0311	-0.0238
	IP Car	-0.0075	-0.0422
	PM Car	-0.0286	-0.0487
	AM PT	0	-0.0212
	IP PT	-0.0166	-0.0405
	PM PT	0	-0.0517
Non Home-Based Intra Zonal, β_0	AM	-1.4463	-0.9995
	IP	-1.1241	-0.899
	PM	-1.4178	-0.8419

Table 6.2 C1/2+ Non Home-Based Destination Choice Parameters

C1/2+ Parameters		Non Home-Based Employers Business	Non Home-Based Other
Non Home-Based Ln(C), β_1	AM Car	-1.3962	-1.3994
	IP Car	-2.0956	-1.1262
	PM Car	-1.315	-0.6791
	AM PT	-0.6435	-1.217
	IP PT	-1.7983	-1.5113
	PM PT	-1	-0.7478
Non Home-Based C, β_2	AM Car	-0.0208	-0.03
	IP Car	-0.0091	-0.0413
	PM Car	-0.0288	-0.0475
	AM PT	-0.0321	-0.0304
	IP PT	-0.0362	-0.0287
	PM PT	0	-0.0396
Non Home-Based Intra Zonal, β_0	AM	-0.8012	-1.0024
	IP	-1.101	-0.8995
	PM	-1.2224	-0.8411

Table 6.3 C2+ Non Home-Based Destination Choice Parameters

C2+ Parameters		Non Home-Based Employers Business	Non Home-Based Other
Non Home-Based Ln(C), β_1	AM Car	-1.0755	-1.2259
	IP Car	-1.9186	-1.1143
	PM Car	-1.2121	-0.576
	AM PT	-0.5024	-1.728
	IP PT	-2.0069	-1.6024
	PM PT	-1	-0.5464
Non Home-Based C, β_2	AM Car	-0.033	-0.0338
	IP Car	-0.0148	-0.0404
	PM Car	-0.035	-0.0502
	AM PT	-0.0452	-0.0149
	IP PT	-0.0319	-0.0297
	PM PT	0	-0.0451
Non Home-Based Intra Zonal, β_0	AM	-0.7049	-1.0475
	IP	-1.0433	-0.8757
	PM	-0.5174	-0.8186

Table 6.4 C0 Non Home-Based Destination Choice Parameters

C0 Parameters		Non Home-Based Employers Business	Non Home-Based Other
Non Home-Based Ln(C), β_1	AM Car	N/A	N/A
	IP Car	N/A	N/A
	PM Car	N/A	N/A
	AM PT	-1.6051	-2.182
	IP PT	0	-0.9647
	PM PT	0	-0.4015
Non Home-Based C, β_2	AM Car	N/A	N/A
	IP Car	N/A	N/A
	PM Car	N/A	N/A
	AM PT	-0.0207	-0.0011
	IP PT	0	-0.0318
	PM PT	0	-0.0245
Non Home-Based Intra Zonal, β_0	AM	-0.5492	-0.293
	IP	0	-0.5953
	PM	0	-0.0231

7 Other Choice Models

7.1 Overview

- 7.1.1 As well as the mode and destination choice models within TMfS:07, there are three additional choice models. These are Macro Time of Day Choice, Trip Frequency and High Occupancy Vehicle Modelling. Each of these modules is optional within the model structure and can all be turned off or turned on in any combination that suits the purpose of the model run.

7.2 Trip Frequency Model

- 7.2.1 The trip frequency module within the model is a simple elasticity model, with parameters based on a level of sensitivity to travel cost by purpose. The form of the model is given by:

$$P'_i = P_i * \exp(\lambda(U_i - U'_i))$$

where:

P'_i are the new trip end productions for origin zone i ;

P_i are the original trip end productions for origin zone i ;

U'_i are the forecast composite logsum utilities for origin zone i ;

U_i are the reference composite logsum utilities for origin zone i ; and

λ are the trip frequency parameters.

- 7.2.2 The parameters for each purpose within the demand model are as follows:

- home-based employers business: 0;
- home-based other: 0.5; and
- home-based work: 0.

- 7.2.3 In the base year only the Home-Based other purpose has a trip frequency parameter, the Home-Based employers business and the Home-Based commute purposes are deemed to be much less sensitive to changes in cost.

7.3 Macro Time of Day Choice Model

- 7.3.1 The Macro Time of Day Module sits between the Trip Frequency module and the 'Inner Loops' procedure in the model hierarchy.
- 7.3.2 Macro Time of Day Choice is applied to the AM 'From-Home' Trip Ends. As part of the process, a set of residual pre-peak 'From-Home' trip ends by purpose are produced. These trip ends are then converted into matrices using the base costs. These matrices produce return trips in later time periods. The production of reverse trips will be undertaken in the same way as previously described in Chapter 6, on a cell by cell basis.
- 7.3.3 The development of the Macro Time of Day module is described in greater detail in Appendix K.

7.4 High Occupancy Vehicle Choice

- 7.4.1 The High Occupancy Vehicle (HOV) choice Model allows trips to move between single occupancy vehicles and multiple occupancy cars.
- 7.4.2 The Module sits after the Inner Loops procedure within the Model structure. The Module works on the Home-based Work, Home-based Employers Business trips and Home-based other trips for the household segments C1/1, C1/2+ and C2.
- 7.4.3 The occupancy choice takes the form of a logit model using different generalised costs for Single Occupancy and High Occupancy trips. The person trip proportion of low occupancy for a particular ij pair will be:

$$P_{SO} = \frac{\exp(\beta C_{SO})}{\exp(\beta C_{SO}) + \exp(\beta(C_{HO} + \partial))}$$

Where:

C_{SO} is the Generalised Cost for Low Occupancy and C_{HO} is the Generalised Cost for High Occupancy;

β is a sensitivity parameter for the logit model; and

∂ is a high occupancy penalty representing the additional travel and difficulty in arranging passengers.

- 7.4.4 The output of this is 'From-Home' matrices by purpose and segment for High Occupancy and Single Occupancy. These are then passed through the reverse trip process as before. These are then converted into vehicle OD matrices using High Occupancy Vehicle matrices.
- 7.4.5 Finally, Highway Assignment is undertaken. If there are specific High Occupancy Vehicle lanes, they need to be coded into the Model as a separate link type (the Highway Model has link types for HOV only and HOV and HGV). The High Occupancy and Single Occupancy costs are then skimmed separately to be put back into the Demand Model.
- 7.4.6 A more detailed description of the High Occupancy Vehicle module can be found in Appendix J of this report.

8 Model Realism Tests

8.1 Overview

- 8.1.1 The Model Realism Tests have been run according to the most up to date WEBTAG (Variable Demand Modelling) guidance in WebTAG Volume 3.10.4 (June 2006).

8.2 Introduction

- 8.2.1 The advice on Variable Demand Modelling (WEBTAG) recommends carrying out realism tests to check the elasticity of demand with respect to:

- car journey time;
- car fuel price; and
- public transport fares.

- 8.2.2 The demand model runs which are undertaken to test these responses were as follows:

- 20% increase in Generalised Cost (as a proxy for journey times);
- 20% increase in fuel costs; and
- 20% increase in PT fares.

- 8.2.3 For the car realism tests, the elasticities were calculated by weighting the trips by distance to get vehicle kilometres; for PT, it is calculated using the trips weighted by fare to get revenue.

- 8.2.4 The method for calculating the elasticity is shown below using car fuel prices as an example. C and C' are the base and test car fuel prices (indices), and K and K' are the base and test car kilometres.

Then the elasticity is then calculated as:

$$e = \frac{\ln(k') - \ln(k)}{\ln(C') - \ln(C)}$$

- 8.2.5 This method of calculating the elasticity ensures the same resulting elasticity, regardless of the direction of change, and can be thought of as an approximation to a point elasticity at the mid-point of the data.

8.3 Results

- 8.3.1 The results for the sensitivity tests are shown in Tables 8.1 to 8.4 below.

- 8.3.2 Table 8.1 shows the elasticities with respect to fuel cost implied in the model. The WebTAG guidance recommends that elasticities should be in the range -0.1 to -0.4, with Employer's Business trips being closer to -0.1. The Home Based Work and the Home Based Other

segments have elasticities which are in the specified range. The Home-Based Employers Business trips are however at the top end of this range and not closer to -0.1 as indicated by WebTAG.

Table 8.1 Fuel Sensitivity Tests

Journey Purpose	AM			IP		
	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>
Home-Based Employers Business	-0.42	-0.41	-0.42	-0.38	-0.41	-0.46
Home-Based Work	-0.37	-0.36	-0.36	-0.37	-0.42	-0.41
Home-Based Other	-0.26	-0.27	-0.26	-0.31	-0.31	-0.31

8.3.3 Table 8.2 shows the Car Generalised elasticities. These are directly related to the car journey times, as time makes up about 70%-80% of the overall Car Generalised Costs. The WebTAG guidance gives no range for these, but suggests that they should be much greater than the fuel cost elasticities and no greater than -2.0. The modelled elasticities are all of the correct order of magnitude.

Table 8.2 Car Generalised Cost Elasticities

Journey Purpose	AM			IP		
	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>
Home-Based Employers Business	-0.87	-0.85	-0.90	-0.69	-0.68	-0.85
Home-Based Work	-0.95	-0.89	-0.90	-0.88	-0.95	-0.95
Home-Based Other	-0.87	-0.92	-0.88	-0.91	-0.92	-0.91

8.3.4 Table 8.3 shows the elasticities with respect to public transport fares. The WebTAG guidance suggests that PT fares elasticities generally lie in the range -0.2 to -0.4, but can be as high as -0.9 for changes over a long period of time. The main demand model purpose, home base work has elasticities which, lie within these ranges. However the home-based employer's business elasticities are generally low and the AM home based-other trips are generally high, but both demonstrate reasonable changes.

Table 8.3 PT Fare Elasticities

Journey Purpose	AM			IP		
	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>	<i>C1/1 Car</i>	<i>C1/2+ Car</i>	<i>C2 Car</i>
Home-Based Employers Business	-0.16	-0.18	-0.12	-0.07	-0.05	-0.07
Home-Based Work	-0.23	-0.23	-0.21	-0.25	-0.23	-0.21
Home-Based Other	-1.23	-0.88	-0.81	-0.39	-0.47	-0.52

8.4 Summary

- 8.4.1 The elasticities shown above demonstrate that the model has an acceptable level of sensitivity to changes in the modelled costs. The majority of the elasticities within the model fall within the WebTAG guidelines.

9 Trip End Model

9.1 Overview

Car and Public Transport Trip Productions

- 9.1.1 The trip end model for person travel by Car and Public Transport is a growth factor model based on the DfT National Trip End Model (NTEM). This model (NTEM) is an integral part of the DfT's National Transport Model (NTM) for which it provides forecasts of demand growth.
- 9.1.2 NTEM has been integrated by DfT into a set of routines to produce trip end forecasts by mode and time periods. These forecasts are included in TEMPRO 4.2. However the actual NTEM model structure is disaggregate and works at the person level. It is therefore, appropriate to apply the model at a relatively detailed zone system such as that of TMfS.
- 9.1.3 There are three main components to NTEM:
- household Car ownership forecasting;
 - a demographic model which allocates household and person type planning data to a system of 88 person type categories (these are detailed in Appendix L); and
 - calculation of Trip Ends by applying trip rates to the numbers of persons in each of the 88 person type categories.
- 9.1.4 For TMfS there is an associated land use model (TELMoS:07). One of the outputs of this model is planning data and car ownership data for each zone in the study area, for each forecast year. With these disaggregate data inputs provided by TELMOS, the trip end model reduces to a straightforward calculation of Trip Ends by multiplying vectors of trip rates by the planning data person type vectors for each zone.
- 9.1.5 Trip Ends produced for forecast years by this model for each journey purpose, time period and mode/car availability segment combination are then divided by the equivalent Trip Ends produced by the model for the base year to create growth factors. These growth factors are then multiplied by the base year Trip Ends as used in the demand model development to provide the forecast year Trip Ends for input to the TMfS demand model.
- 9.1.6 This process can be described as:

$$P_{fm,t,p} = P_{bm,t,p} * \{ NTEM_{fm,t,p} / NTEM_{bm,t,p} \}$$

Where:

$P_{fm,t,p}$ - forecast year person trip productions by mode/Car availability m, time period t, and journey purpose p;

$P_{bm,t,p}$ - base year person trip productions by mode/Car availability m, time period t, and journey purpose p;

$NTEM_{fm,t,p}$ - forecast year person trip productions by mode/Car availability m, time period t, and journey purpose p produced by NTEM model trip rates; and

$NTEM_{bm,t,p}$ - base year person trip productions by mode/Car availability m, time period t, and journey purpose p produced by NTEM model trip rates.

9 Trip End Model

9.1.7 The NTEM based process is only used for trip productions for the from-home trip purposes, which are included in the demand model. To-home trips and Non-Home-Based Trip Ends are created in a separate process. Chapter 6 describes how the reverse and non-home-based trips are derived.

9.1.8 These 88 person type trip ends are then combined into the following segments for input into the TMfS demand model:

- persons from non car owning households;
- persons from single car owning households with 1 adult;
- persons from single car owning households with 2+ adults; and
- persons from multi car owning households.

9.1.9 There are eight home-based journey purposes of which work, employers business and education are used directly for TMfS. The remaining five purposes are combined to form home-based other (HBO).

9.1.10 The AM Peak, Inter Peak and Evening Peak time periods in NTEM are directly compatible with the TMfS time periods. *[Only the AM and Inter Peak time periods are actually used in the model as the PM period has no explicit demand model]*

9.1.11 The separate modes included in NTEM are:

- Walk;
- Cycle;
- Car driver;
- Car passenger;
- Bus; and
- Rail (including underground).

[Note: Walk and Cycle are not included within the TMfS:07 modelling]

9.2 Trip Attractions and Attraction Factors

9.2.1 The trip attraction process is a parallel procedure in the trip end model to the trip production process.

9.2.2 There are separate trip attractions therefore for each journey purpose and time period, but they are combined by household segment and mode.

9.2.3 Attractions fall into two distinct categories:

- (1) Attractions for Home-Based Work, which is a doubly constrained purpose in the destination choice model; and
- (2) Attraction factors for Home-Based Employer's Business and Home-Based Other, which are singly constrained purposes in the destination choice model.

9 Trip End Model

- 9.2.4 The Attractions in (1) above represent actual Trip Attractions, since they act as constraints in the destination choice process. For (2) however, we have Attraction Factors, which are used along with generalised cost to distribute trips across destinations. In this case there are no constraints for the actual Trip Attractions to equal the Attraction Factors for each zone.
- 9.2.5 The Attraction Factors for the base-year were calculated using an iterative process. This involved successively adjusting Attraction Factors and applying the singly constrained model until the resulting actual trip attractions best matched those for the base matrices used in the destination choice model calibration.

9.3 Airport Growth

- 9.3.1 In previous versions of the model airport trips were dealt with as add-in matrices, they are now included in the main demand model choice mechanisms and therefore have an associated trip end. Trip end growth is undertaken using a combination of planning data and Airport Passenger growth predictions from each of the modelled airport operators.

9.4 Base Year Trip Ends

- 9.4.1 In TMfS:07 there is a much greater level of correlation between the base levels of demand and the base-year planning data, than in previous versions of the TMfS model. This is a result of using planning data and census matrix tools data to create the initial base-year demand matrices.

10 Forecasting Procedures

10.1 Introduction

- 10.1.1 The function of the Base-year Demand Model is to:
- demonstrate and validate the model operation and procedures;
 - test the sensitivity of model parameters; and
 - establish the incremental adjustment matrices.
- 10.1.2 The forecasting process is designed to provide forecast matrices using an incremental procedure. The Base-year Demand Model structure is designed to operate in an iterative manner to deal with the supply/demand convergence issue.
- 10.1.3 The general application of the Demand Model for forecasting requires the following inputs:
- model parameters;
 - trip ends;
 - highway and public transport cost matrices; and
 - highway and public transport networks.
- 10.1.4 The requirements and sources of these inputs are described in Sections 10.4 to 10.7. The treatment of goods vehicles, long distance trips and external trips in forecasting is dealt with in sections 10.9, 10.8 and 10.10 respectively.

10.2 Overall Operation of the Demand Model

- 10.2.1 For a given forecast year and land-use scenario, the Trip End creation procedure is run to produce forecast trip productions and attractions (see Chapter 9). Analyses of the broad travel demand effects of the land-use planning and economic assumptions, excluding the impacts of travel costs, can be undertaken at this stage. The remaining sub-models operate in an iterative manner to produce final road traffic and public transport assignments.
- 10.2.2 The iterative balancing process is described in more detail in Appendix A. There are two main loops:
- Inner Loops - iterate between the Mode Choice and Distribution Choice Models; and
 - External Loops - iterate between Assignment Models and the Mode and Destination Choice Models.
- 10.2.3 The Inner Loops are the primary iterative process to achieve a converged state between the two main travel choices within the Demand Model - mode and distribution choice. It is necessary to undertake the Inner Loops before initiating the External Loop. *[Note: The inner loops are not necessary for the singly constrained purposes, as the composite utilities do not change from loop to loop].*
- 10.2.4 The Inner Loops can be run until a converged state is reached. This may vary with the forecast year and economic assumptions and between a Do-Minimum and Do-Something

test. Testing has shown that four loops are generally adequate, and the model default is set to this.

- 10.2.5 The External Loop provides the link between the Assignment Models and the Demand Model. Infrastructure and pricing changes in a future year will change travel costs within the Assignment Models. The resultant converged state assigned travel costs are skimmed and supplied to the Distribution Choice using the same logsum composite utility calculations as for the Mode Choice Model. The sub-models are then run with the revised costs to complete the External Loop.
- 10.2.6 As standard, the Public Transport costs are set after one external loop of the Demand Model. However, if crowding effects (see PT Model report for a description of Crowding effects) are considered sufficient to cause large changes, it can be run on every external loop. The Highway Assignment Model is run for each External Loop.
- 10.2.7 The External Loop can also be run until a converged state is reached. This would vary with the forecast year and economic assumptions and between a Do-Minimum and Do-Something test. External Loop assignment matrices can be inspected between successive loops to determine whether to select to undertake further External Loops. Tests have shown that five External Loops are generally sufficient for most applications (and as a result this is the default setting in the model), but the number required will depend on the level of congestion on the Highway network.
- 10.2.8 On each external loop of the demand model a process of trip damping takes place, which combines 50% of the current matrix, with 50% of that from the previous loop. This is the same in effect as the fixed step approach, which is included in DIADEM.
- 10.2.9 Gap analysis is undertaken on each External Demand Model Loop. This provides a measure of convergence of the demand model. It is not used as a stopping criteria, but the user can use it to assess if additional demand model loops need to be undertaken. The formulae for calculating the gap is given below as:

$$Gap = \frac{\sum_{ij} C_{ij} |T_{ij} - T'_{ij}|}{\sum_{ij} C_{ij} T'_{ij}} * 100$$

Where:

C_{ij} is the generalised cost on the previous demand model loop;

T_{ij} are the trips on the previous demand model loop; and

T'_{ij} are the trips on the current demand model loop.

For models of this size gaps of less than 0.2 are deemed to be acceptable and below 0.1 is very well converged.

10.3 The Incremental Forecasting Approach

- 10.3.1 The forecasting procedure for TMfS:07 is designed to operate in a multiplicative incremental manner.
- 10.3.2 Mode choice and distribution models can require a large number of factors to ensure a close match with observed data. Applying these models to estimate incremental changes from a well-established base situation removes the reliance on these factors in the forecasting process. The Base-year Matrices are accepted as the best representation of the travel patterns in that year.
- 10.3.3 The Demand Model is operated to produce matrices for the Base year and Forecast year. We define the Forecast Year matrices in the following way:

$$\mathbf{F} = \mathbf{B} + \mathbf{S}_f - \mathbf{S}_b \text{ (1); or}$$

$$\mathbf{F} = \mathbf{B} * \mathbf{S}_f / \mathbf{S}_b \text{ (2).}$$

Where:

B = base observed trips;

S_b = base modelled trips;

S_f = future modelled trips; and

F = future trips.

Then we define five cases:

Case (1) is used where **B** is zero or where we have high **B** and low **S_b**, defined as the case where $\mathbf{B}/\mathbf{S}_b > 2$.

Case (2) is used in the following circumstances:

- low **B**, high **S_b**;
- low **B** low **S_b**; and
- high **B** high **S_b**.

- 10.3.4 In this way, the Incremental Matrix remains constant for all applications and the forecast year synthesised trip matrices produced by a forecast run of the Demand Model are adjusted by the Incremental Matrix before assignment.
- 10.3.5 Once established these incremental matrices are applied to the highway and PT assignment matrices. This is described in greater detail in Appendix F.

10.4 Model Parameters

- 10.4.1 The need to calculate changes to some of the model parameters for a forecast run of the Demand Model is standard. The parameters for which forecast values are required are:
- generalised cost coefficients for highway assignment – these are recalculated in line with TAG Unit 3.5.6;
 - occupancy factors to convert from person to vehicle matrices – these are calculated using growth factors from WebTAG; and
 - values of time and vehicle operating costs – default values are based on relevant WebTAG unit 3.5.6 guidance.
- 10.4.2 The mode specific constants calculated for the Base-year are specific to the Base-year distribution of single and multi-car owning households.

10.5 Highway and Public Transport Cost Matrices

- 10.5.1 Generalised cost matrices by mode and at a zone level are required as inputs to start the Demand Model process. Normally, the cost matrices used are those from the Base-year model, but the user can choose to input forecast cost matrices to kick start a demand model run if they so wish.
- 10.5.2 The Base-year cost matrices by mode are also required for the calculation of the mode specific constants described above.
- 10.5.3 Base or Reference Case Generalised Costs are used as the start point of variance case tests within the TMfS.

10.6 Highway and Public Transport Networks

- 10.6.1 As input to a forecast model year run, there must be forecast year Reference Case and/or variant networks. These should be coded up as described by the Road and PT model development reports, by adding any additional schemes directly into the network models. Consistency between the Highway and PT models should be retained at all times.

10.7 Education Matrices

- 10.7.1 The Education Matrices were built from Census Travel to Work data and are included in the model as add in matrices at the post 'inner loop' stage of a model run.
- 10.7.2 The Education Matrices are growthed using planning data from TELMoS, the trip ends are forecast in a similar way to the other trip purposes and then the trips are distributed using a simple gravity model.

10.8 Goods Vehicles

10.8.1 Goods vehicle trips are not subjected to the Demand Model process within the TMfS model. Forecast matrices are prepared using growth factors from the TELMoS commodity model.

10.8.2 The Base Year Goods PCU matrices at zonal level, are by hour (AM Peak, Inter Peak and PM Peak) and by vehicle type, LGV and HGV. The forecasting process applied to these base matrices has the following three steps:

- calculate percentage growth on a cell by cell basis between TELMoS base year and forecast year commodity matrices (these cover internal goods vehicle movements within the TMfS modelled area);
- apply this percentage growth to the TMfS base year goods vehicle matrices; and
- apply NRTF growth to external movements.

10.9 Long Distance Vehicle Matrices

10.9.1 Long Distance, but internal to Scotland, Employers Business and Other trips are forecast separately from the main demand model, these are added into the assignment matrices at the same stage as the Goods vehicle matrices. *[Long Distance trips are those defined as greater than 100km].*

10.9.2 The forecast procedure for long distance trips uses an elasticity model, based on assumed levels of growth in GDP over time. They are calculated in forecast mode for the full twelve hour (07:00-19:00) time period and then factored to individual time periods. This process of factoring to the individual time periods uses the base year time period splits.

[Note: Long Distance Trips were not treated differently in the base model. They are only treated differently in forecast mode.]

10.10 External Trips

10.10.1 External trips from England and Wales are dealt with as add-on external matrices. In forecast mode these are growthed using National Road Traffic Forecasts (NRTF). The model user can however include whatever growth assumptions they wish.

11 Conclusions and Recommendations

11.1 Conclusions

- 11.1.1 This document has described the development of the Base-year Demand Model for TMfS:07, the Model's sensitivity to a set of example tests and has discussed how the Model will be applied in forecast mode.
- 11.1.2 The model structure has been defined and implemented for the Base-year. The realism tests undertaken have demonstrated a good level of sensitivity. The principal travel purpose of the model, commute trips, has elasticities which fall well within the recommended sensitivity guidelines.

11.2 Recommendations

- 11.2.1 Our view is that the Demand Model is fit for purpose, ie predicting strategic travel responses to changes in future transport provision throughout Scotland.
- 11.2.2 While this report discusses how the model will be applied in forecast model, it does not include consideration of actual applications of the model in forecast mode. Further experience of these applications gained over time will assist in understanding the sensitivity and performance of the Model.
- 11.2.3 Testing of the sensitivity of the High Occupancy Vehicle module, Macro Time of Day Choice and Trip Frequency modules have also not been discussed in detail in this report. These are to be described in separate information notes.
- 11.2.4 **All model applications should be preceded by an appropriate review of the robustness of the model in the area/corridor of interest.**

Appendix A – Model Structure

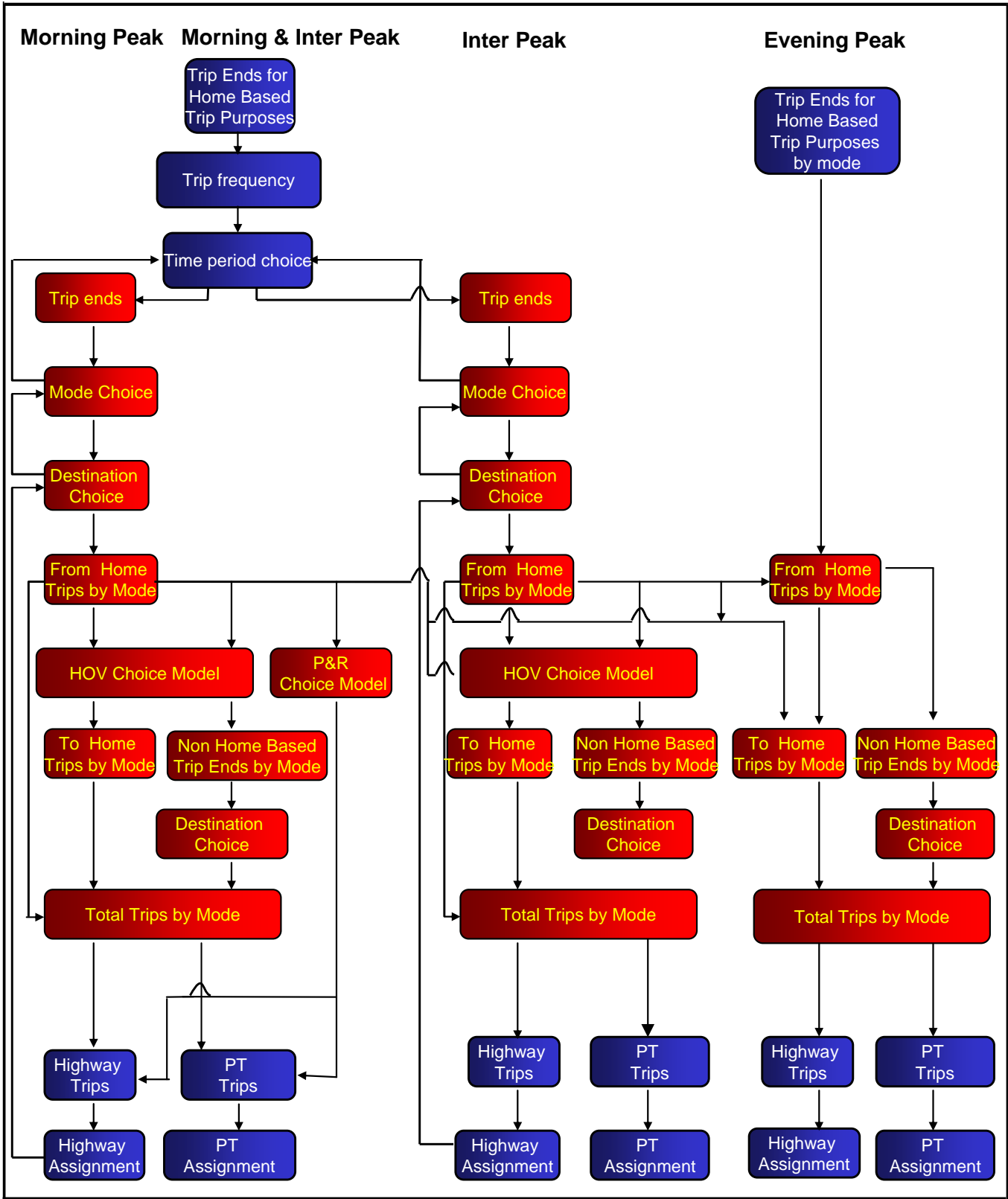
Appendix A: Model Description

- This appendix contains a description of the TMfS:07 Demand Model. It contains a flow diagram for each of the main stages in the process. Each figure is supported by explanatory text, which for convenience is included on the page facing the figure.
- This description is intended to be sufficiently detailed for readers to understand the functioning of the demand model and its components.

Figure 1: Model Structure

This figure shows the overall model structure.

- The figure shows the enhanced four stage structure of the model. It has the traditional Trip Generation, Mode Choice, Destination Choice and Assignment, enhanced by Trip Frequency, Parkand Ride site choice, Time Period Choice and High Occupancy Vehicle Modelling.
- The required data inputs to the model in forecasting mode are a set of trip ends as produced by the trip end model, and highway and public transport networks along with any model parameters which change through time (eg values of time, vehicle operating costs).
- The model is segmented by the following person household types:
 - No Car Households;
 - 1 Car 1 Adult Households;
 - 1 Car 2 Adult Households; and
 - 2+ Car Households.
- It is also segmented by the following six journey purposes:
 - home-based work;
 - home-based employer's business;
 - home-based other;
 - home-based education;
 - non-home-based employer's business; and
 - non-home-based other.
- The model is applied as an incremental model, and not as an absolute model. The absolute forecasts produced are an intermediate step in applying the model incrementally and, as such, have no significance. The incremental approach is implemented in practice by using the model to calculate growth factors at a zone to zone cell level and to apply these to the highway and public transport assignment matrices.



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 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 1: Time Period Demand Model

Figure 2: Iterative Demand/Supply Balancing

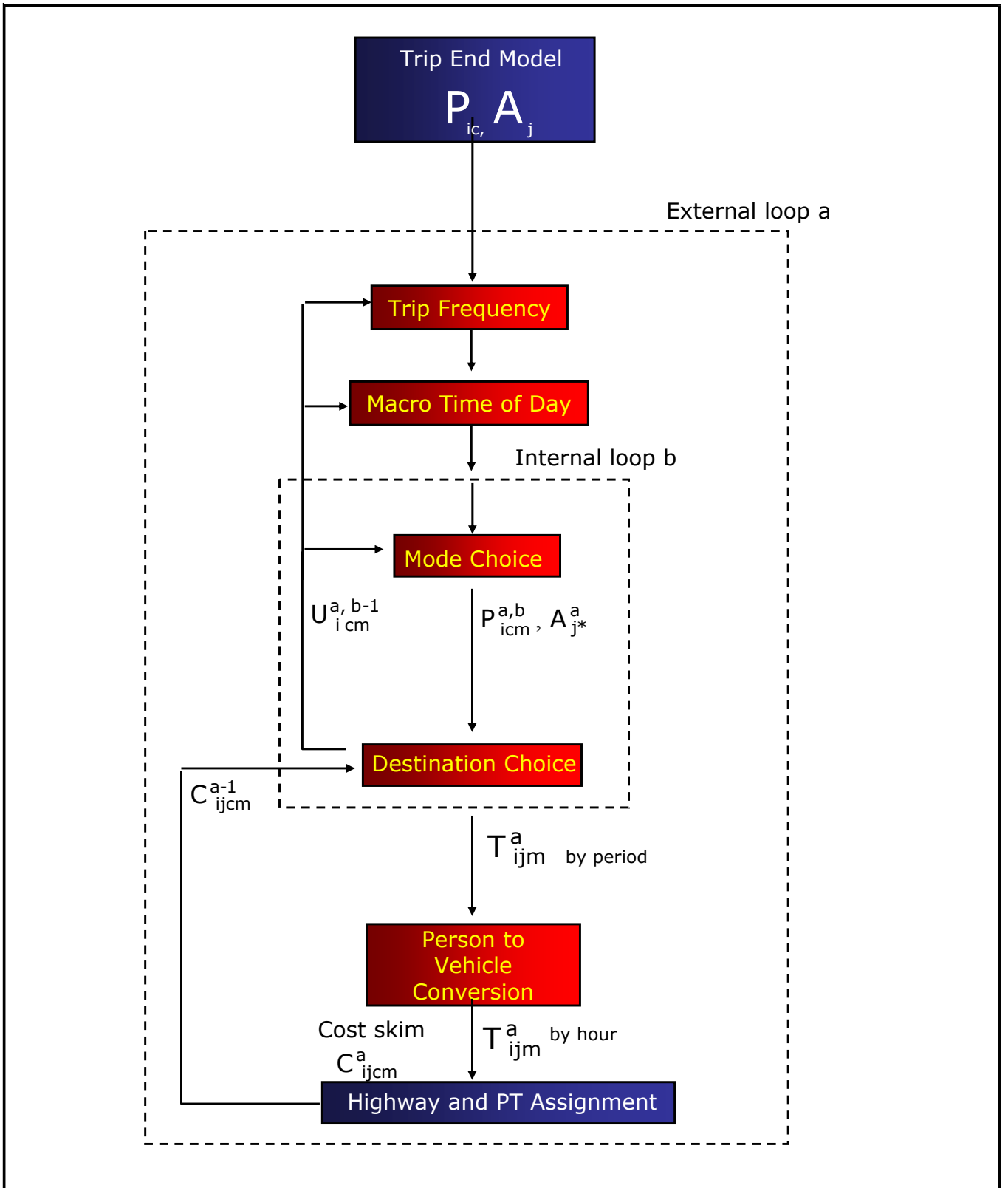
- This figure shows the balancing of the supply and demand parts of the model. The process consists of a feedback of Generalised Costs from the assignment models to the distribution, mode split, trip frequency and time of day components of the demand model.
- Two loops are shown in this figure, the inner loop 'b', which is the loop between the mode and destination choice elements of the model and the outer loop 'a', which is the loop between the demand model and the assignment models.
- The Public Transport costs are set after one external loop of the demand model. However, if crowding effects are considered sufficient to cause large changes in costs, it can be run on every external loop. The Highway Assignment is carried out for each outer loop.
 - **The Key for the forthcoming slides is as follows:**
 - **A** – Zonal Attractions;
 - **C** - Generalised Costs;
 - **K** – Mode Specific Constants;
 - **P** – Zonal Productions;
 - **PC** – Parking Charges;
 - **T** – Trips;
 - **TT** – Transfer Time; and
 - **U** – Logsum Cost Utilities.

The subscript notation is as follows:

- *i* – production zone I;
- *j* – attraction zone j;
- *m* - mode;
- *c* – car availability segment;
- *ca* – car available segments;
- *nca* – non-car available segments; and
- *s* – Park and Ride site.

The superscript notation is as follows:

- *a*– external loop number; and
- *b* – internal loop number.



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Figure 2: Iterative Demand/Supply Balancing

Figure 3: Destination Choice

- This is the destination choice model for from-home purposes, which takes as inputs:
 - trip productions for car and public transport by each car availability segment;
 - trip attractions/attraction factors for all modes and car availability types combined; and
 - generalised costs of travel by car and by public transport.
- These inputs are used to create matrices of person trips, separately by time period and trip purpose, for from-home trips and non-home-based trips. The process is carried out at a zonal level.
- The process is a traditional gravity model process applied in a doubly constrained manner for from-home commute trips and non-home-based trips, and singly constrained for other from-home purposes. There are separate sensitivity parameters for each trip purpose/mode/car availability combination.
- The spread parameters are β_1 , and β_2 . There are also Intra-Zonal factors β_0 , which produce intra-zonal trips in the matrix.
- The outputs of this process are person trip matrices by time period, trip purpose/mode/car availability at zonal level, which are the inputs to the person to vehicle conversion process.

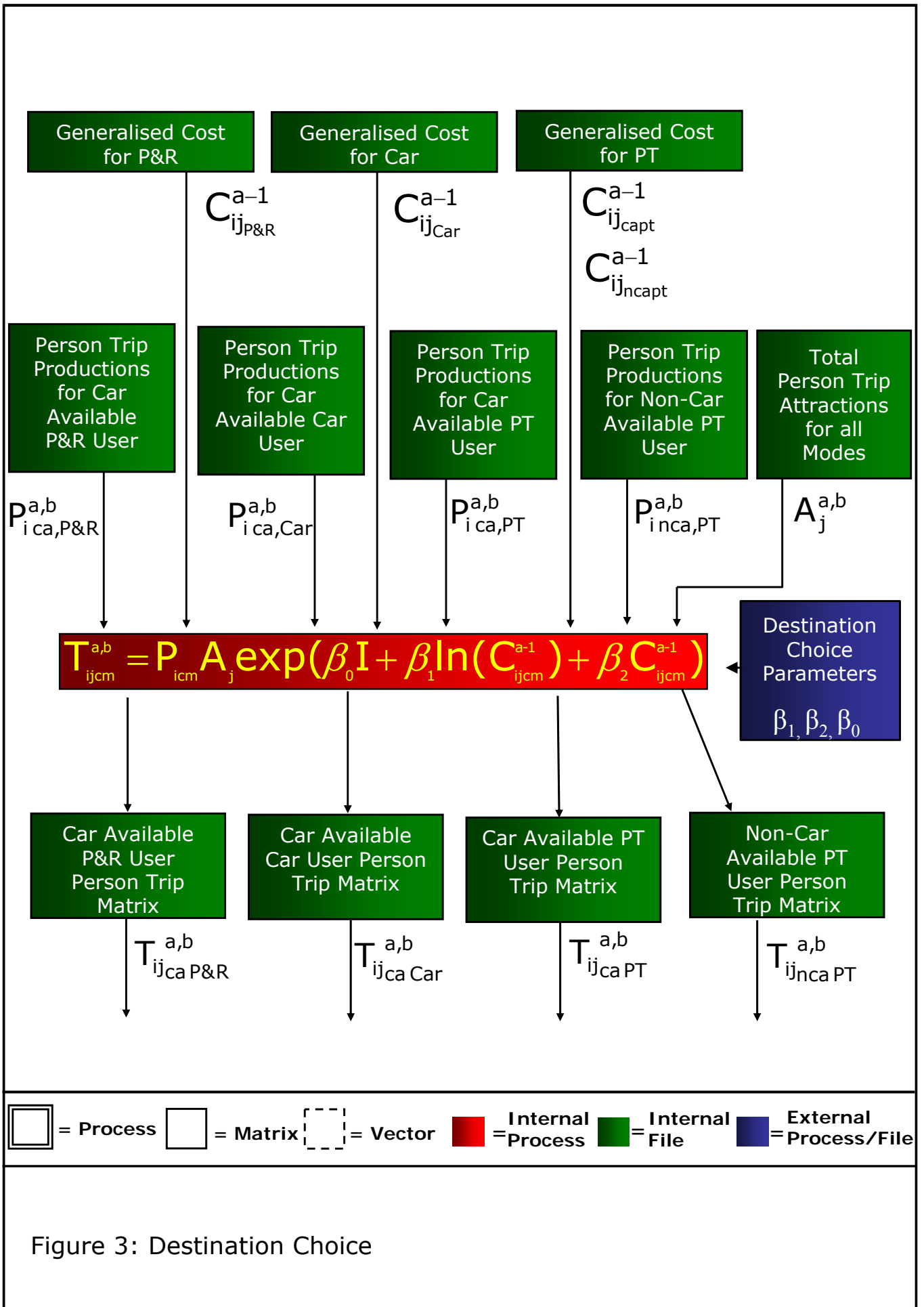
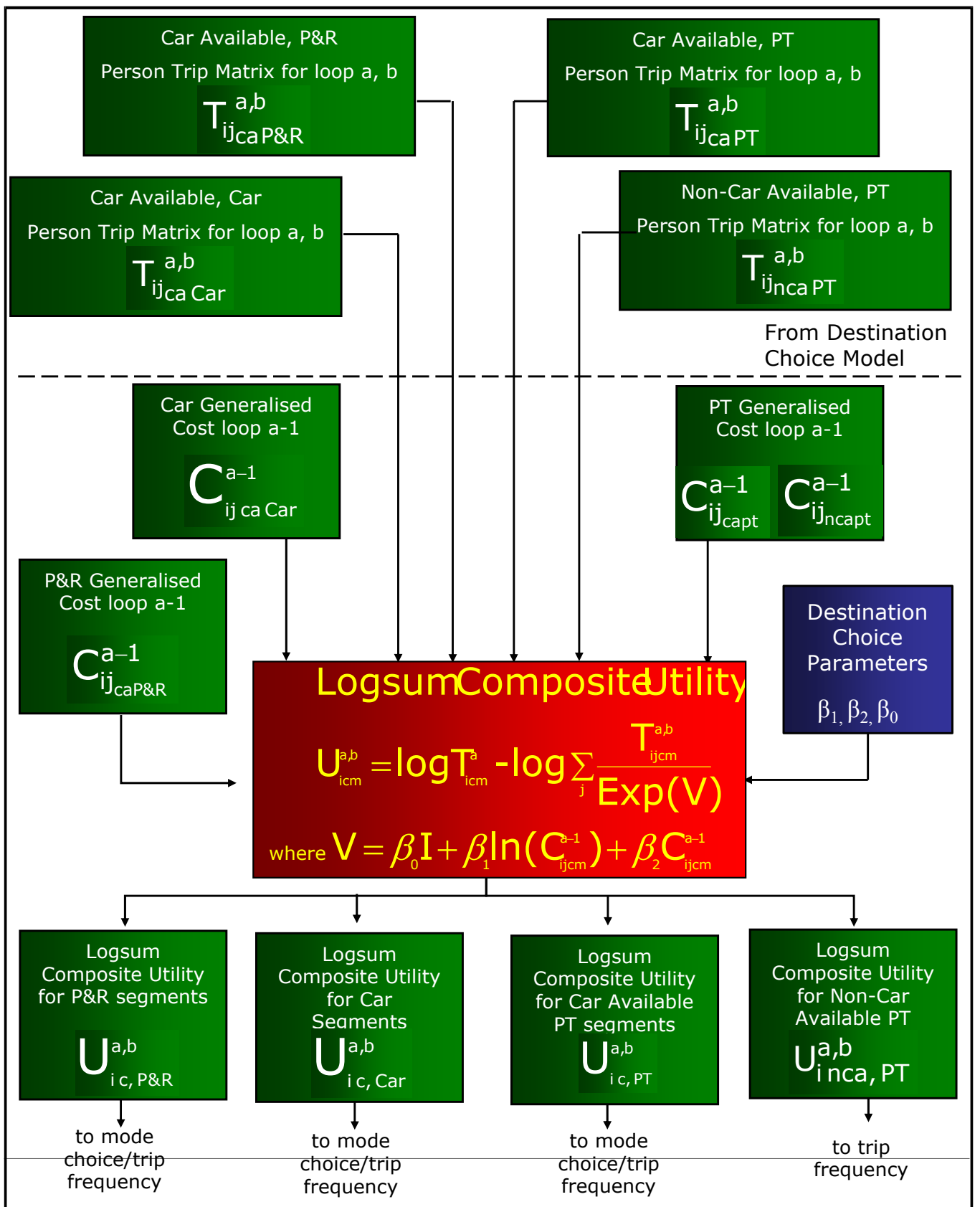


Figure 3: Destination Choice

Figure 4: Calculation of Logsum Composite Utility for Input to Mode Choice

- This process follows the destination choice process and calculates logsum composite utilities at a zonal level for input to the mode choice model.
- The process takes the matrices generated by the destination choice model along with the generalised costs by mode used in the destination choice model, and calculates a logsum composite utility for each zone.
- The process is conducted separately for each from-home trip purpose and car available segment. In the case of car available persons the output utilities are used as input to both the mode choice, time of day choice and trip frequency choice processes. For non-car available there is no mode choice but the utilities are input to the time of day choice and trip frequency choice processes.
- The sensitivity parameters ($\beta_1, \beta_2, \beta_0$) shown in this figure are the same sensitivity parameters used in the destination choice process.



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Figure 4: Calculation of Logsum Composite Utility for input to Mode Choice

Figure 5: Mode Choice

- This figure shows the mode choice process. It is undertaken at the trip end level because of the position of mode choice in the model hierarchy. It takes as inputs:
 - person trip productions by time period for from-home purposes; and
 - logsum composite utilities calculated using the destination choice model.
- The process is carried out for car available persons only; persons from non-car available households are assumed to be captive to public transport..
- The calculation of the logsum composite utilities is undertaken using the process described in Figure 4.
- There are two types of parameter input:
 - The scaling factors (θ) which control the sensitivity of the mode choice process; and
 - The mode specific constants (for car mode only) which ensure that the base mode choice proportions in the model match the base data at a zonal level.
- There are separate scaling parameters for each trip purpose.
- The outputs of the process are vectors of trip productions which are then input to the destination choice process which is shown in Figure 3.

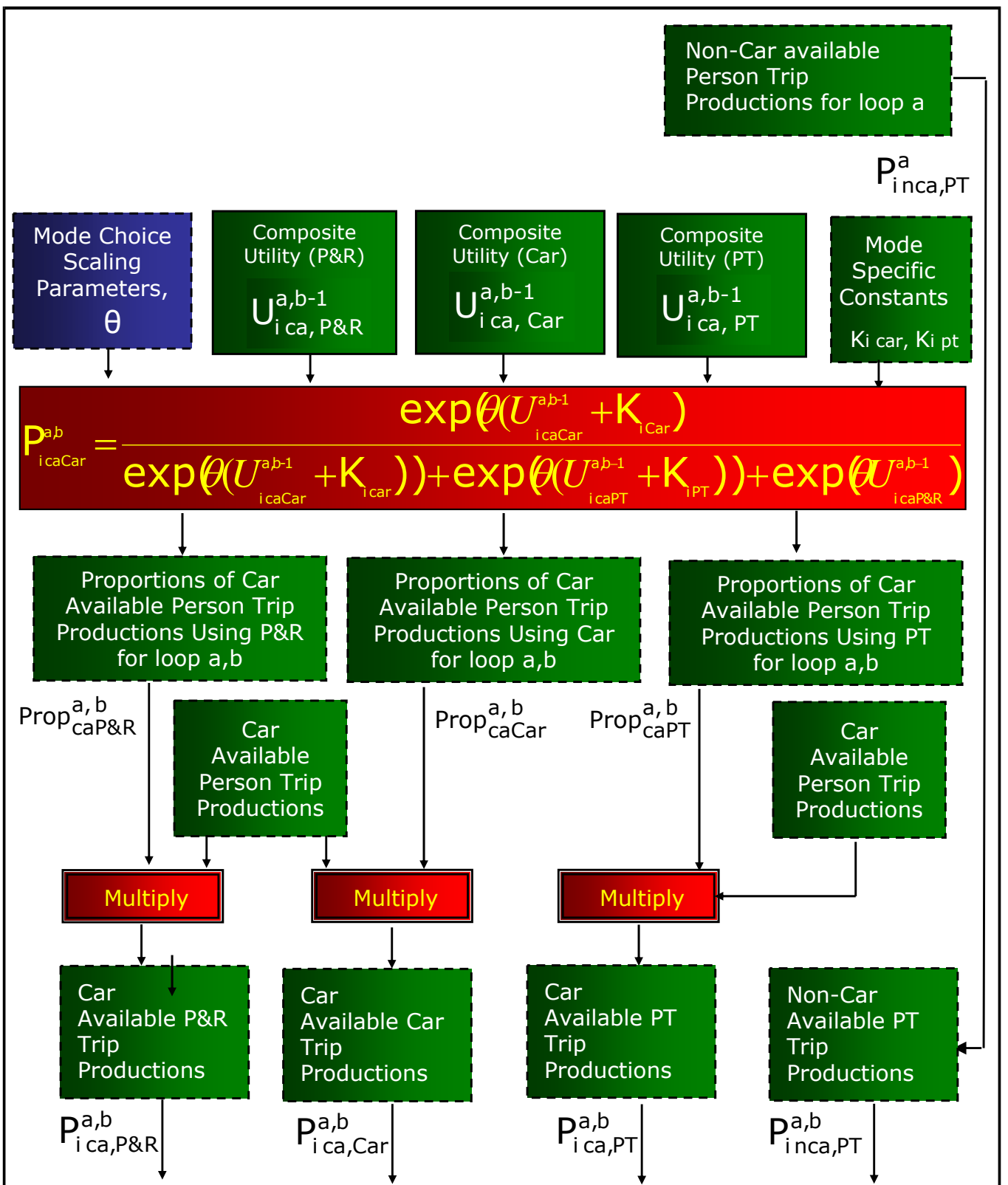
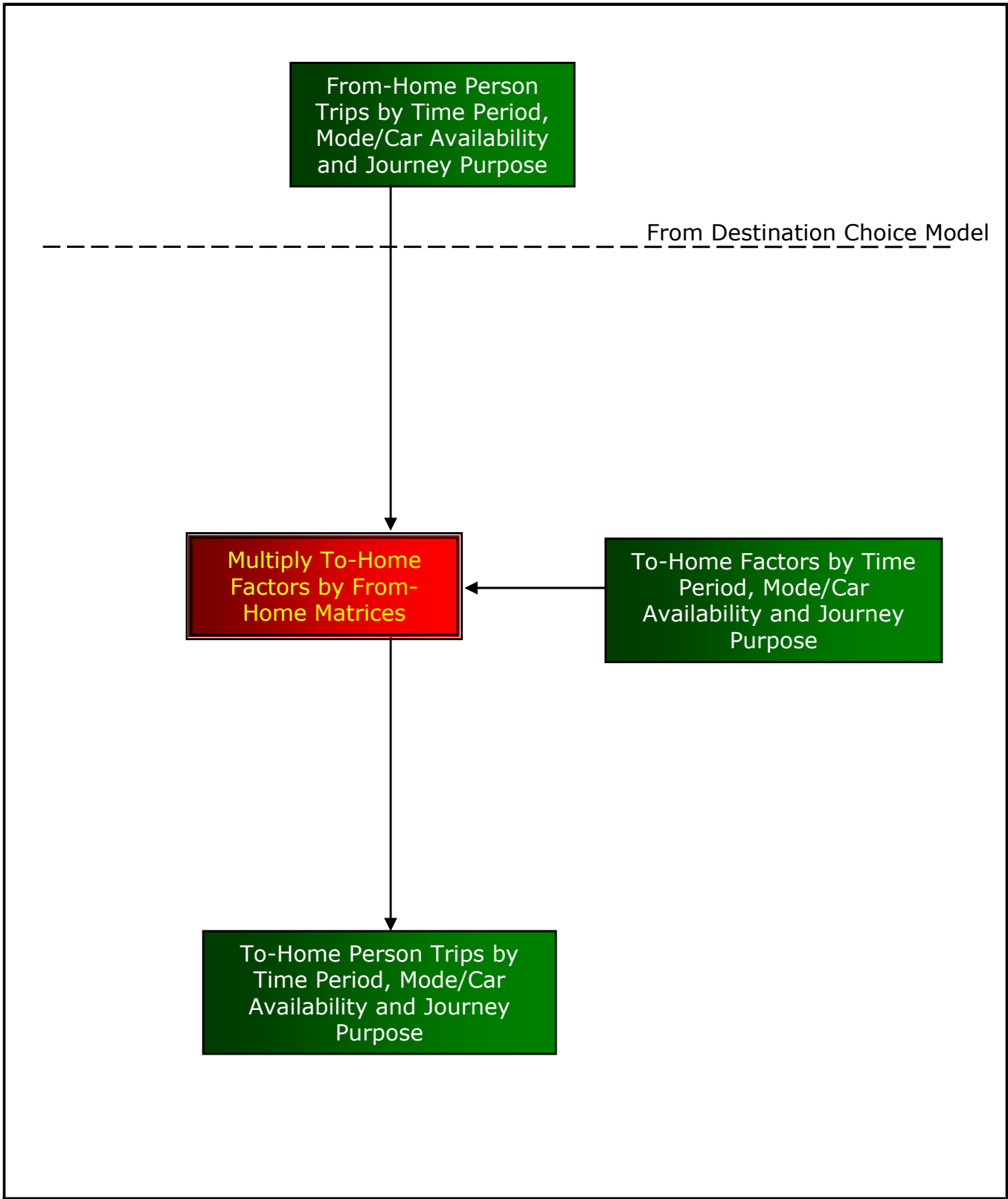


Figure 5: Mode Choice

Figure 6: Creation of To-Home Trips

- This model produces the matrices of to-home trips by mode, car availability, time period and purpose. It takes as input:
 - matrices of from-home trips, by mode, car availability, journey purpose and time period, as produced by the destination choice models; and
 - to-home factors derived from analysis of the Scottish Household Survey.
- The to-home factors are multiplied by the transposed from-home matrices at a cellular level to give to-home matrices by mode, car availability, journey purpose and time period.



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Figure 6: Creation of To-Home Matrices

Figure 7: Park and Ride Station Choice

- Park and Ride station choice is applied to the AM From-Home Park and ride trips, which are output for each purpose by the mode/destination choice model.
- The choice model takes as input:
 - The generalised cost of Park and Ride;
 - Park and Ride Sites (including transfer times and car park charges); and
 - Park and Ride Trip Matrices.
- The station choice model then attributes all the Park and Ride trips amongst all the sites available, based on the attributes of the sites.

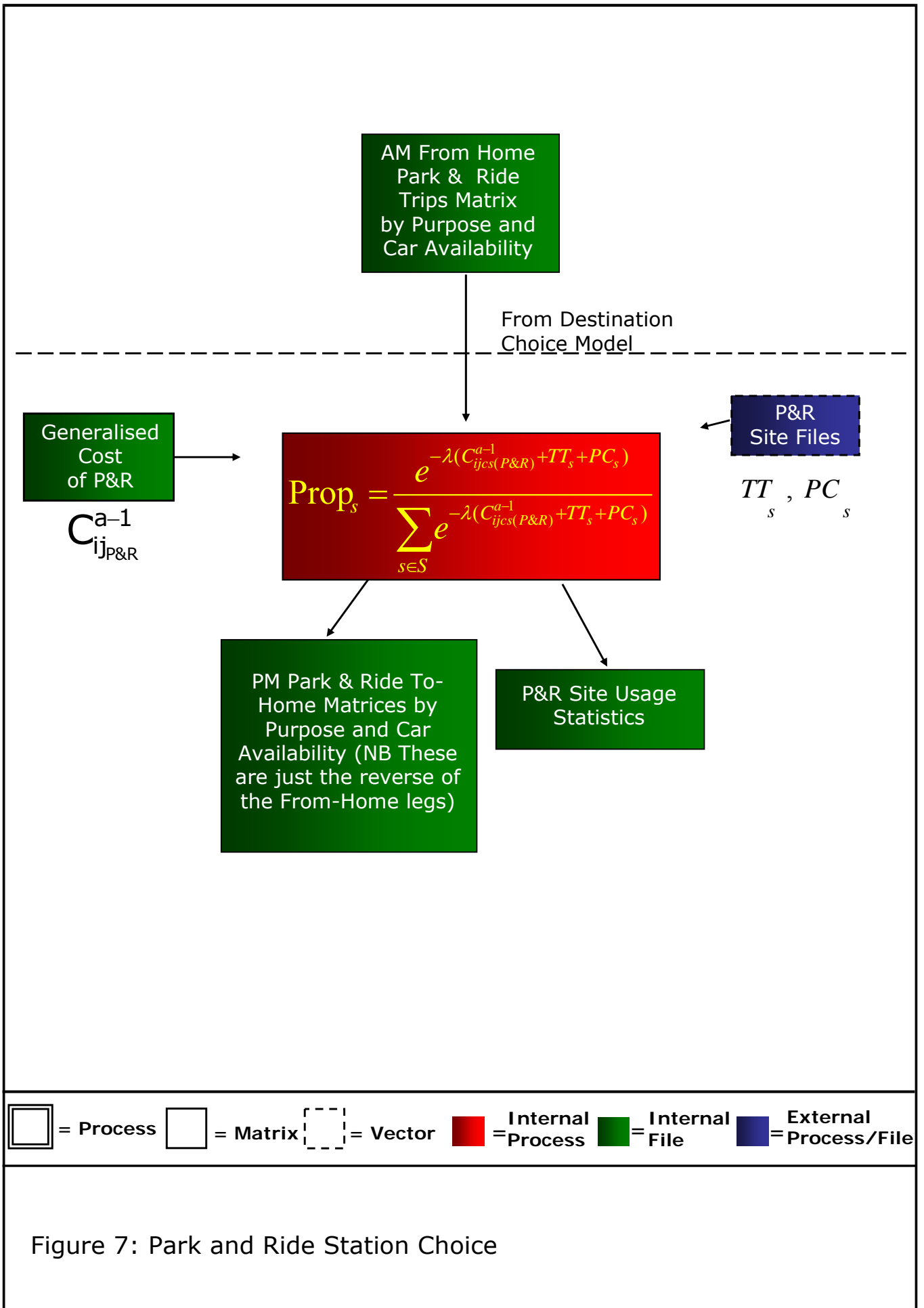
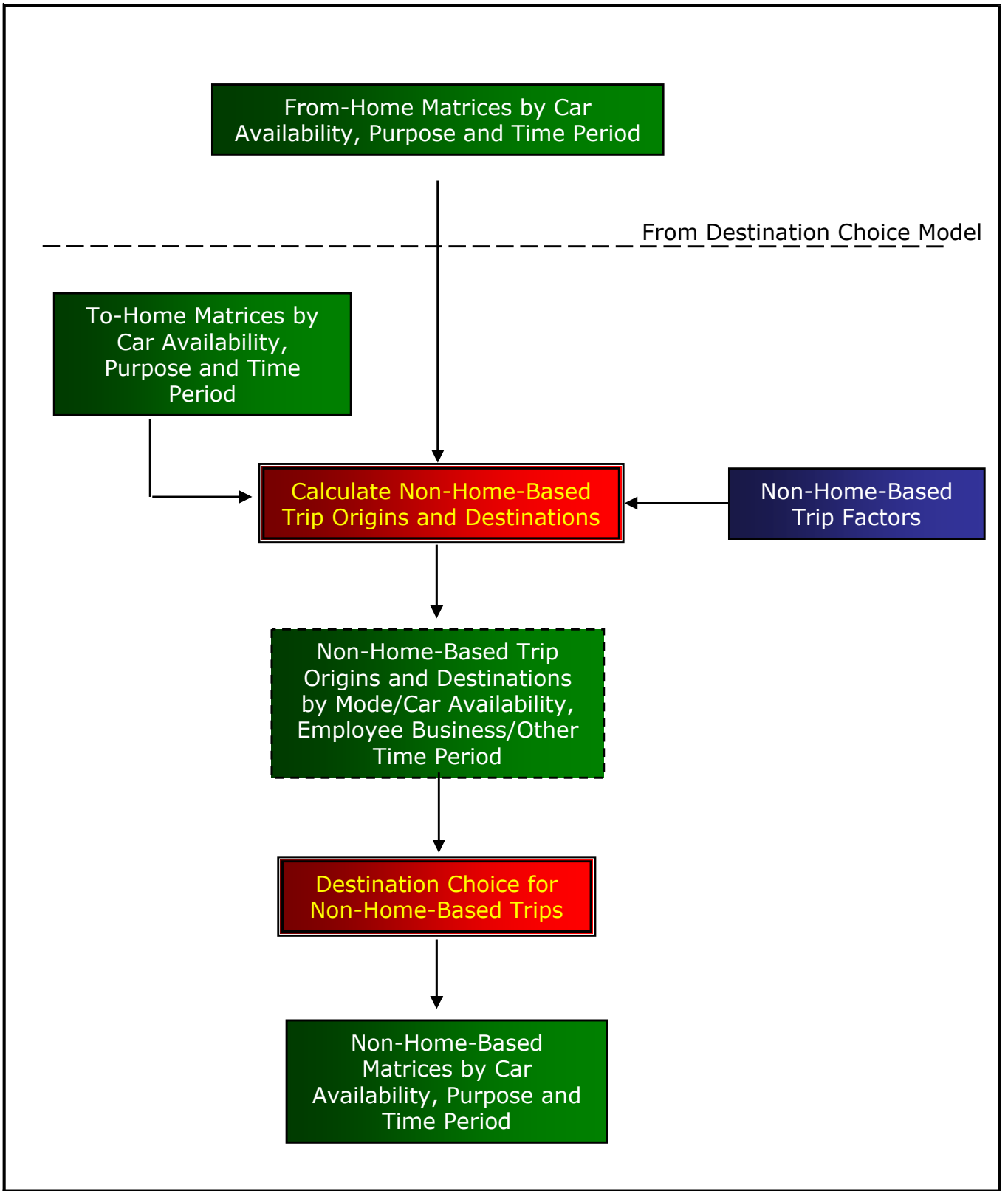


Figure 8: Trip End Model for Non-Home-Based Purposes

- This model produces the trip productions and attractions by mode, time period and purpose for non-home-based trips. It takes as input:
 - trip attractions for From-Home trips, by mode, car availability, journey purpose and time period, as produced by the destination choice models;
 - trip productions for To-Home trips, by mode, car availability, journey purpose and time period;
 - non-home-based production trip rate factors derived from analysis of the Scottish Household Survey; and
 - non-home-based attraction trip rate factors derived from analysis of the Scottish Household Survey.
- The production trip rate factors are multiplied by the From-Home trip attractions to give the Non Home Based trip productions by mode, car availability, journey purpose and time period.
- The attraction trip rate factors are multiplied by the To-Home trip productions to give the Non Home Based trip attractions by mode, car availability, journey purpose and time period.

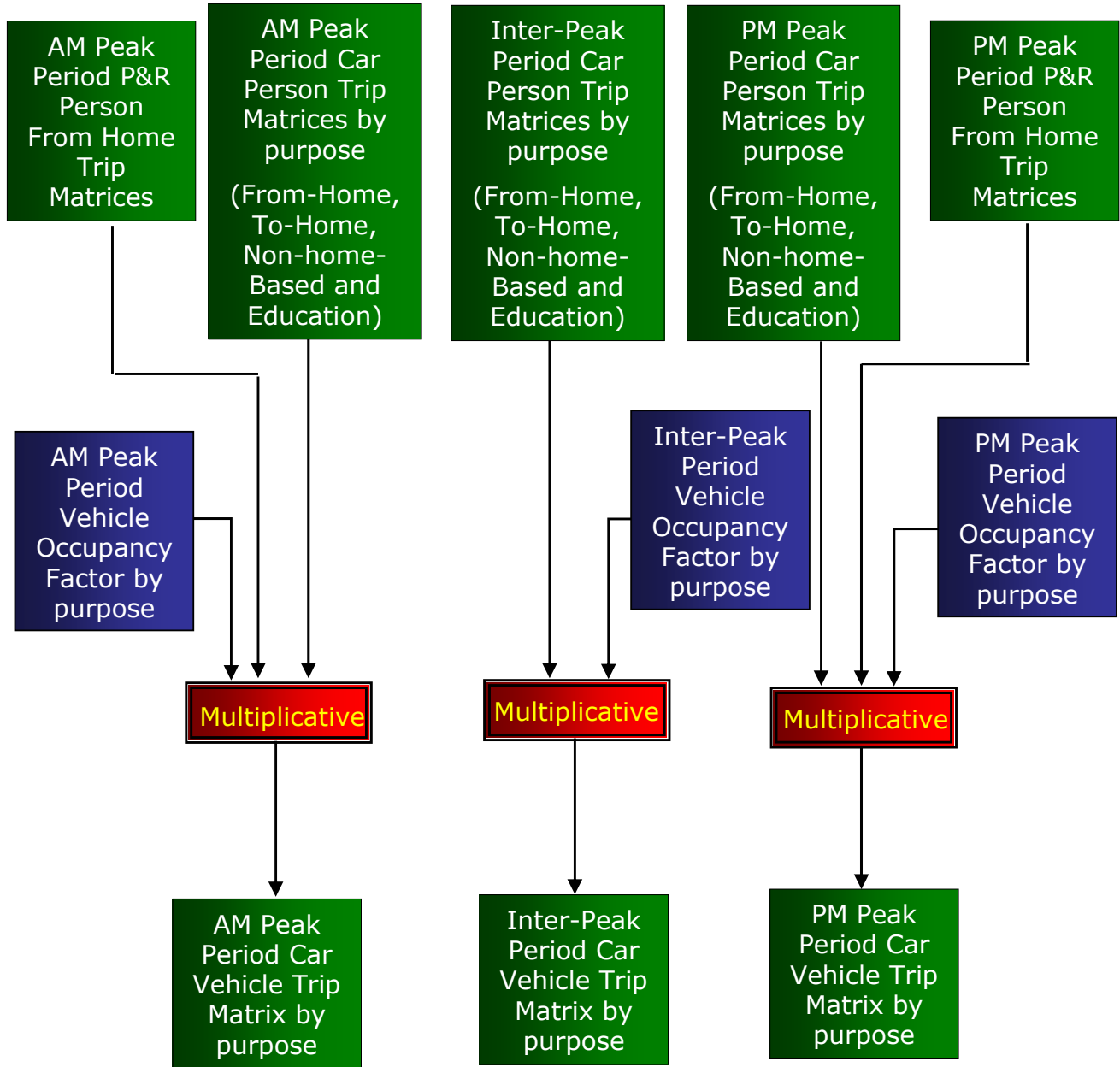


= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 8: Trip End Model for Non-Home-Based Purposes

Figure 9: Person to Vehicle Conversion for Car Trips

- This process takes as input the time period matrices which are output by the processes shown in Figures 3, 6, 7 and 8 as well as Education add-in's, and applies vehicle occupancy factors to convert from person trips to vehicle trips.
- The process is carried out separately for each trip purpose and there are separate vehicle occupancy factors for each time period/trip purpose combination.

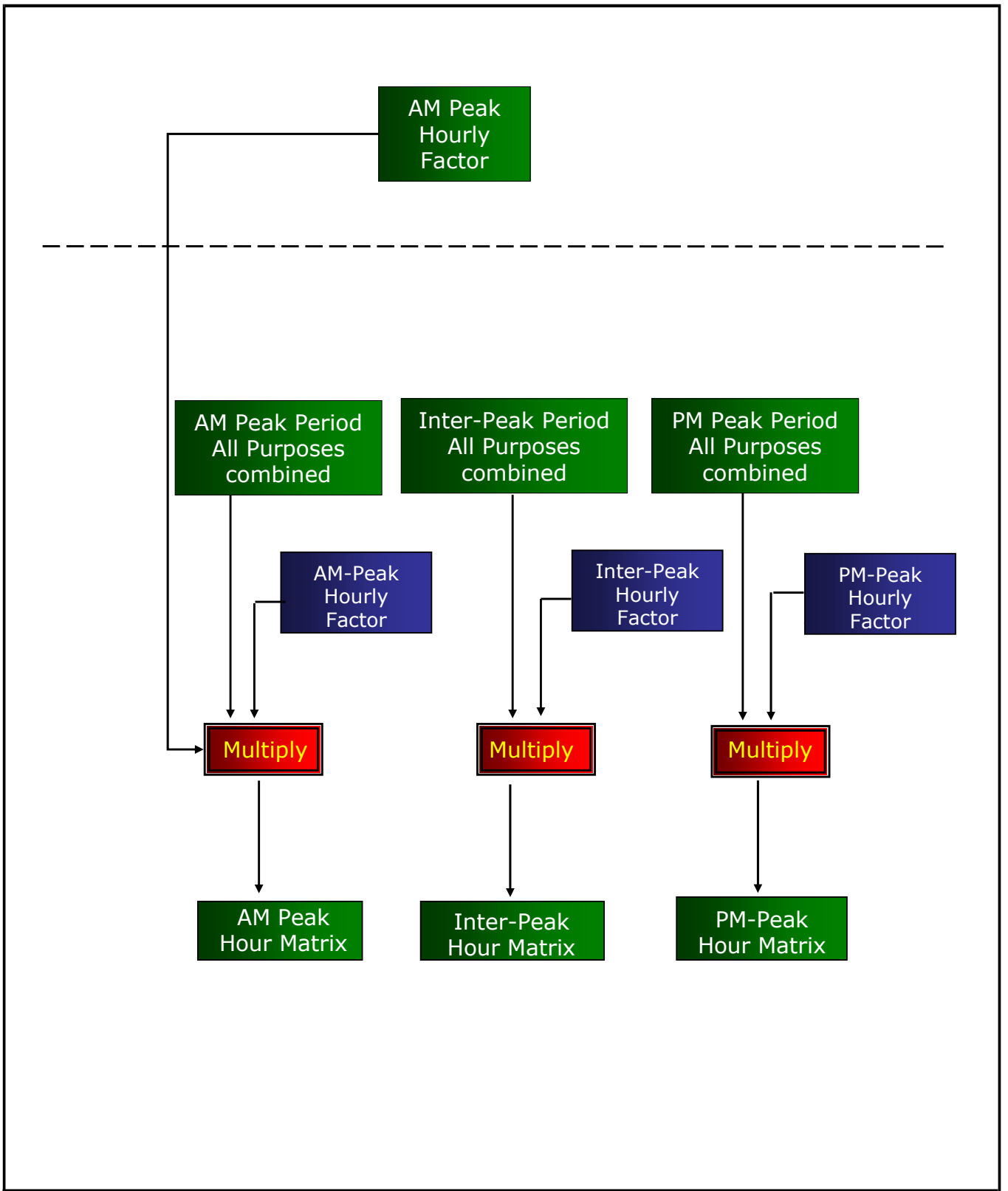


= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 9: Person to Vehicle Conversion for Car Trips

Figure 10: Hourly Matrix Creation for Car and Public Transport

- This process converts the time period matrices by vehicle or person, as appropriate, into hourly matrices.
- The process is carried out for all trip purposes. The Inter-Peak and PM Peak factors will generally remain the same in all forecasting situations.

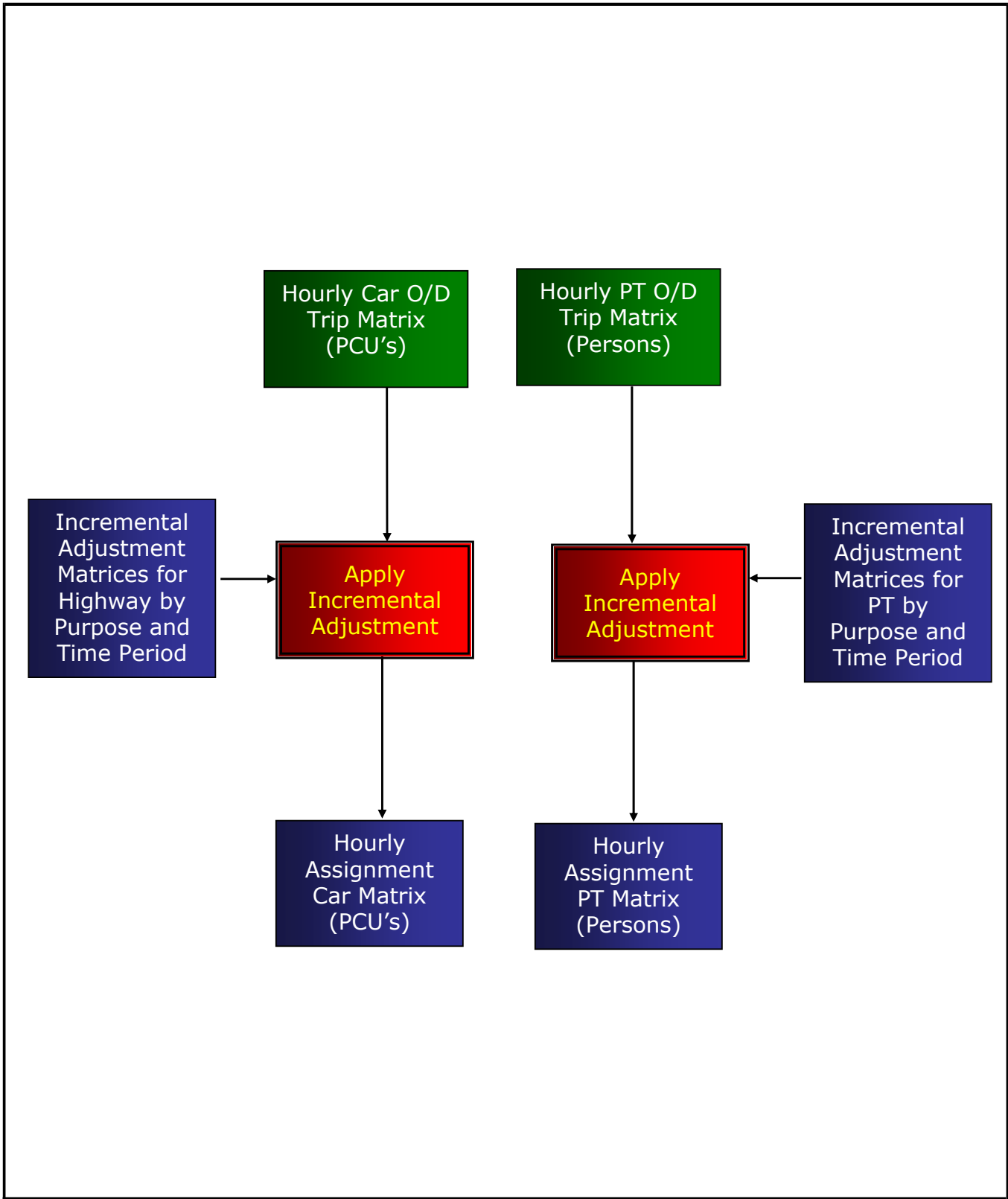


= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 10: Hourly Matrix Creation for car and pt

Figure 11: Incremental Adjustments

- The incremental adjustment process ensures that the model functions in an incremental manner. The incremental adjustment factors are applied to Origin-Destination matrices (separately by hour and mode), to generate the final hourly assignment matrices at zonal level.

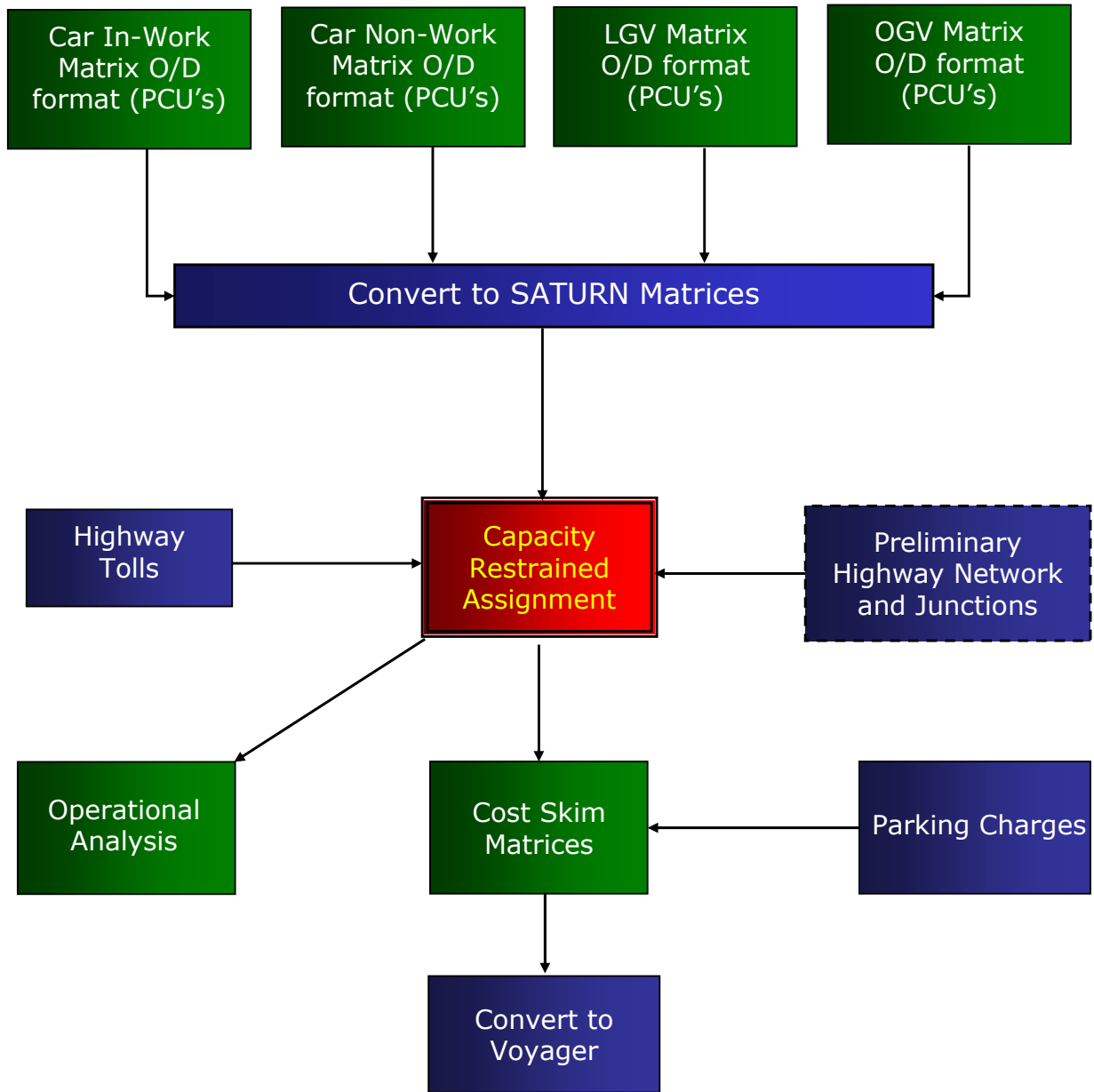


= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 11: Incremental Adjustment

Figure 12: Highway Assignment

- This is a conventional capacity restrained equilibrium multi-class assignment procedure. It is run using the SATURN program. There are five user classes:
 1. Car In-Work;
 2. Car Commute;
 3. Car Other;
 4. Light goods vehicles; and
 5. Heavy goods vehicles.
- The cost skims are created at a zonal level from the assignment model. Parking charges are added into the cost skims where appropriate.

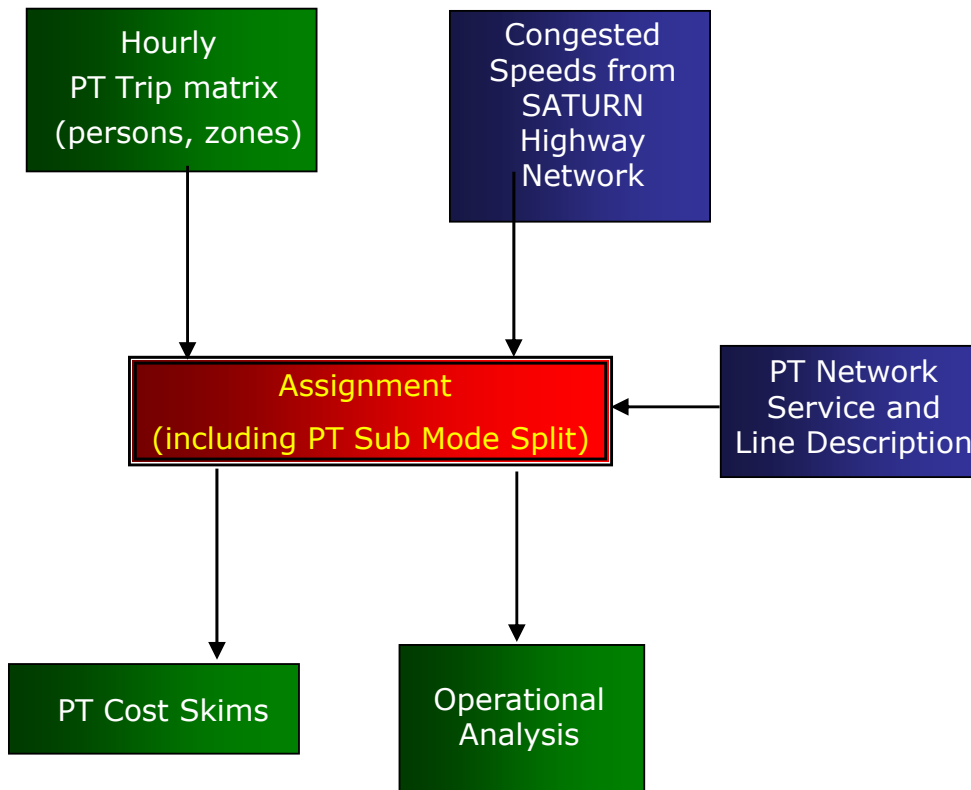


= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 12: Highway Assignment

Figure 13: Public Transport Passenger Assignment

- This is a standard PT assignment procedure, with sub-mode choice, undertaken in VOYAGER. This includes the effects of crowding. It is standard to skim the PT costs only on the first and last loops of the demand model. However, if crowding is considered to have a large impact on a particular test, it can be skimmed on every loop of the model.



 = Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 13: Public Transport Passenger Assignment

Figure 14: Calculation of Logsum Composite Utility for Input to the Trip Frequency Model

- This process takes as input the logsum composite utilities (output from the destination choice model on external loop a-1) by mode for car available persons and calculates a single logsum composite utility (by all modes) for input to the trip frequency model.
- The calculation is undertaken separately for each trip purpose and household segment type and the formulation is based on the mode choice model.
- For the No Car Household (Non-Car Available) segment just the PT logsum utility is used.

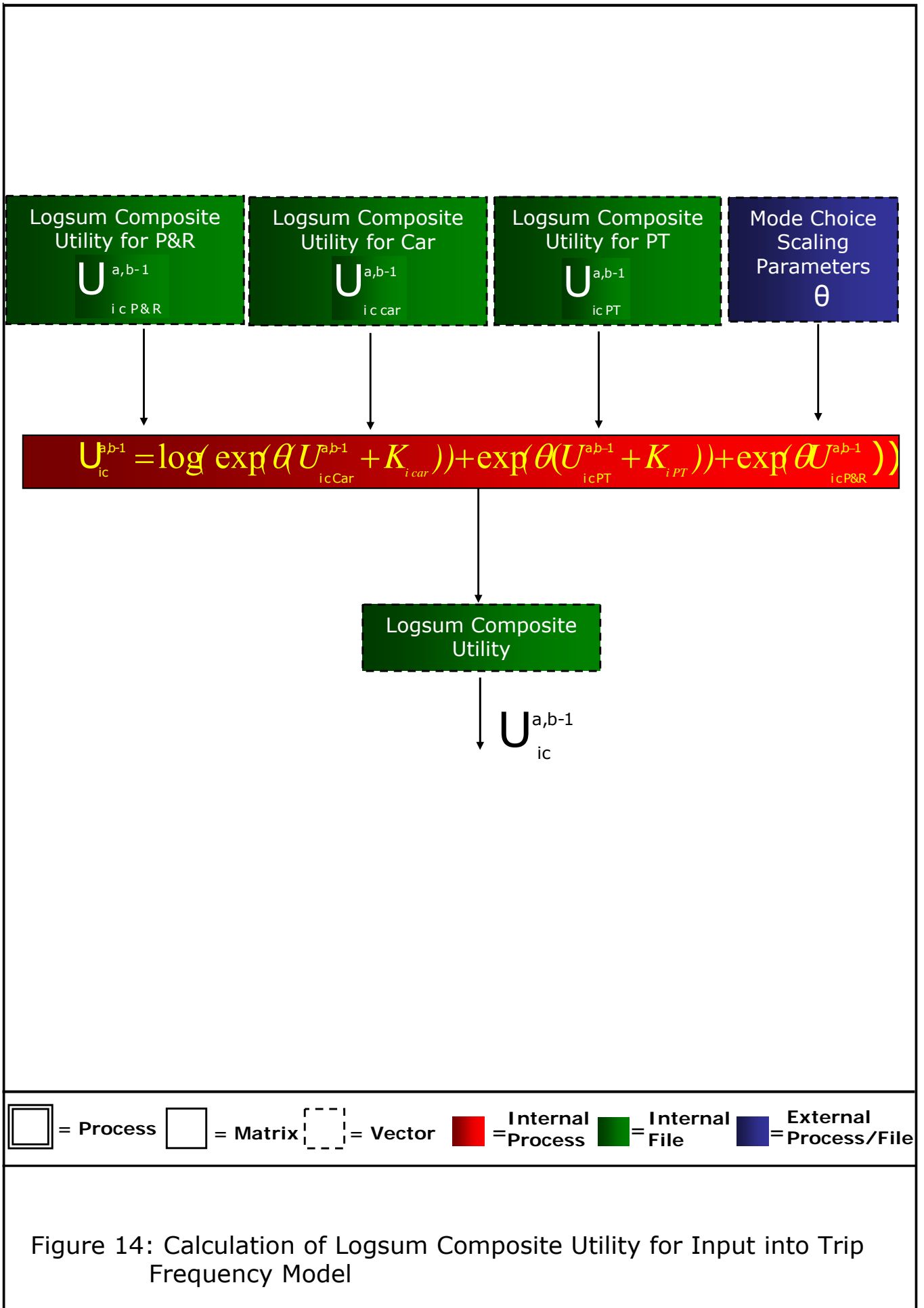
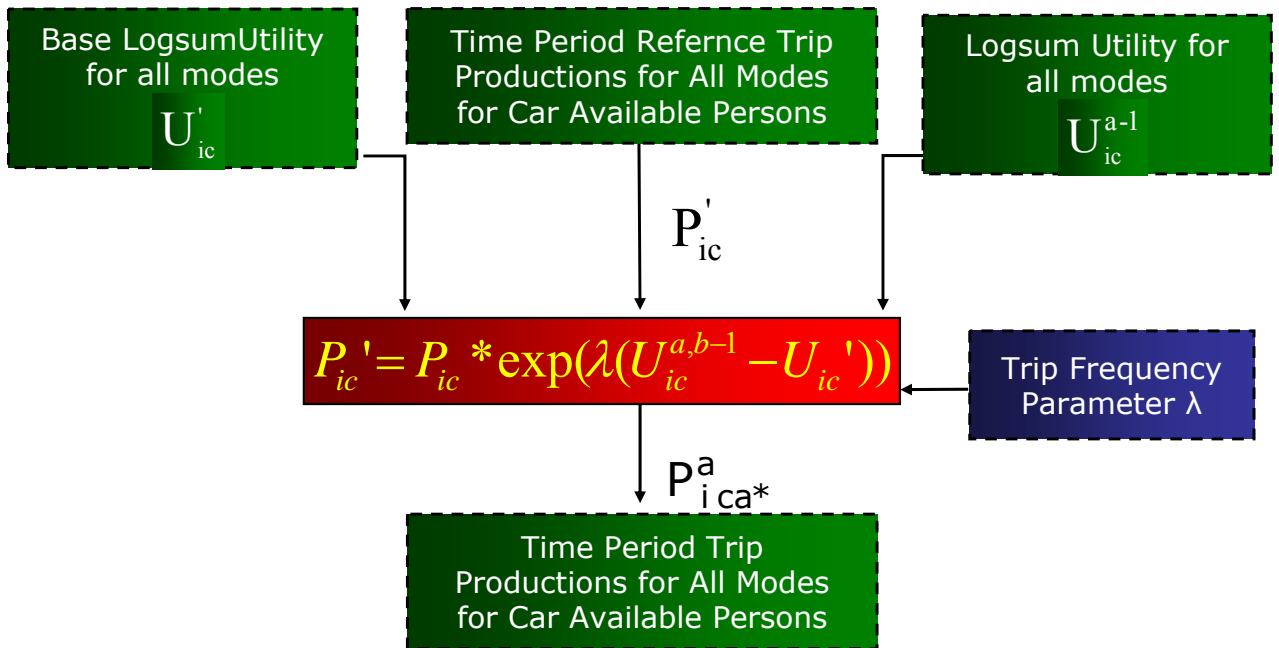


Figure 15: Trip Frequency Choice for Home-Based Purposes

- The trip frequency choice process changes the trip ends which are created in the trip end models according to whether the zonal level generalised costs of travel in the forecast situation are higher or lower than those in the base year.
- The inputs to the process are:
 - logsum composite utility for all modes and purposes for the base year, by zone;
 - logsum composite utility for all modes and purposes for the forecast year, by zone; and
 - trip productions for all modes in persons.
- The trip productions are adjusted using a straightforward elasticity model, trip attractions are unaffected.
- The logsum composite utilities are calculated as shown in Figure 15. The process is applied separately for each from-home trip purpose. The outputs of the process are person trip productions by time period for all modes for car available persons. These form the inputs to the time period choice/mode choice.



= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 15: Trip Frequency Choice for Home-Based Purposes – Car Available Persons

Figure 16: Macro Time of Day Choice

- The time of day choice module takes as inputs logsum composite costs and trip ends (as amended by the trip frequency module if it is turned on).
- It is an incremental logit model, which compares the base and the forecast logsum utilities to amend the proportions of travellers in each time period.
- Time of Day choice outputs are trip ends by each car availability segment, which then go into the inner loops.

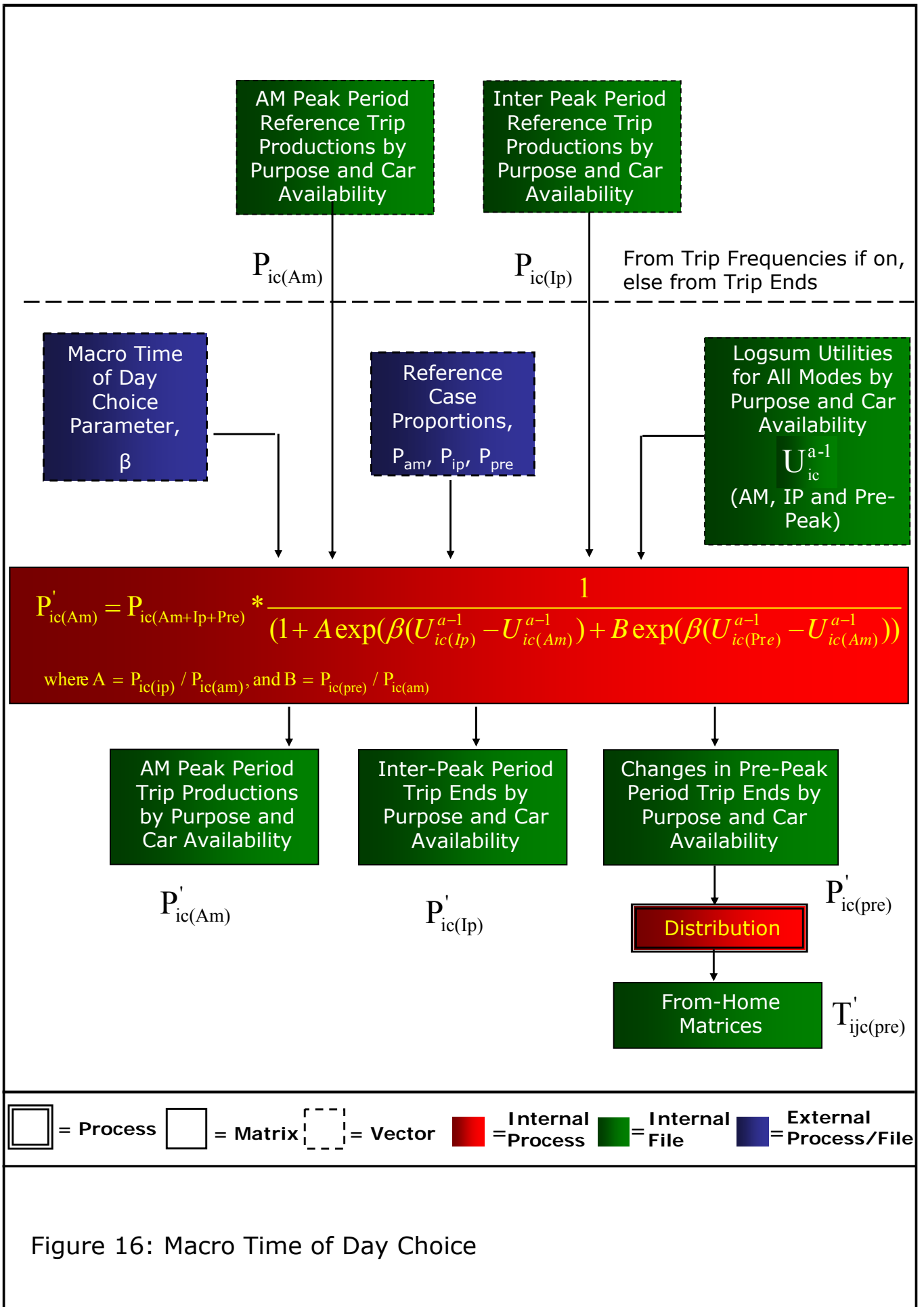
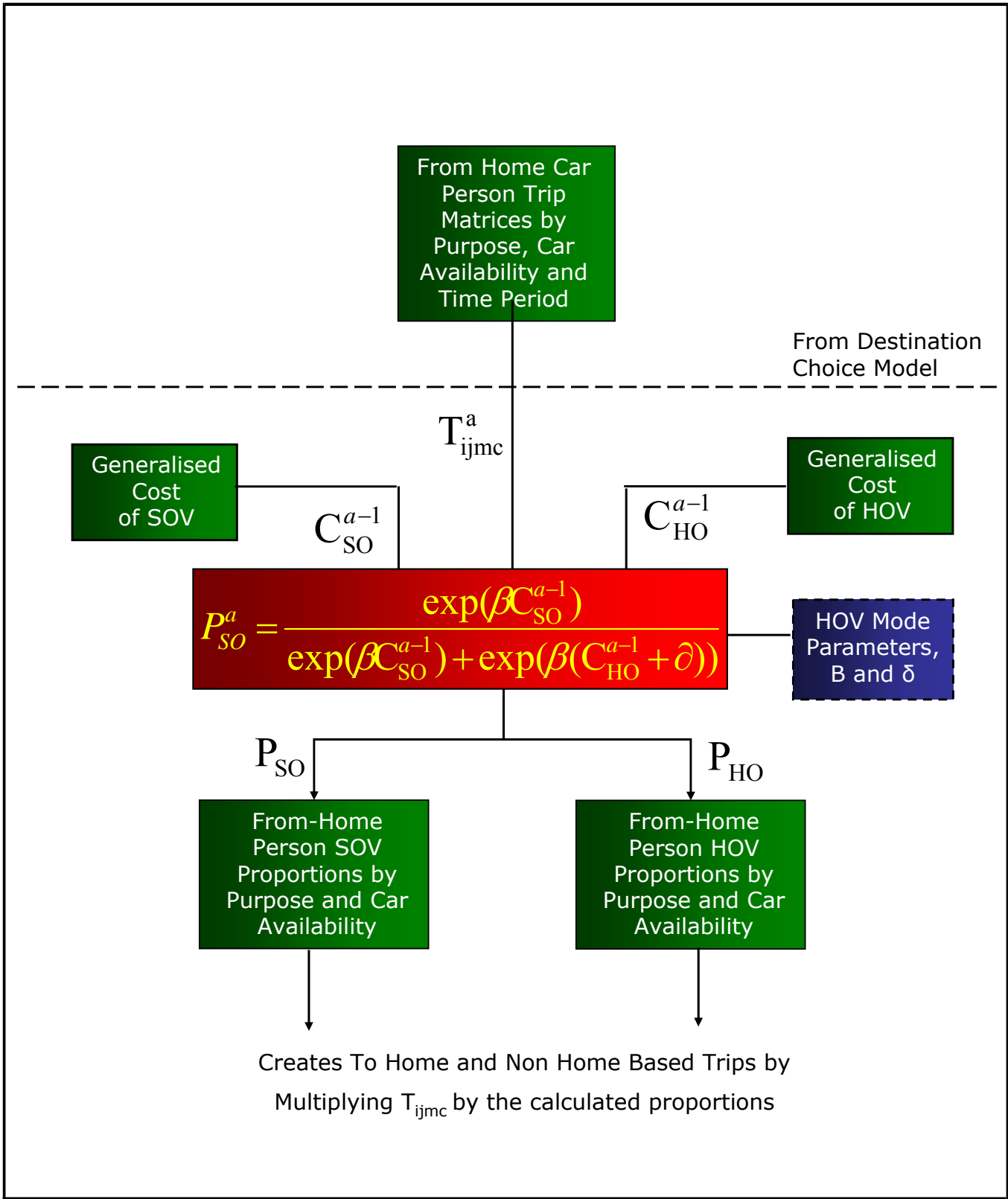


Figure 17: High Occupancy Vehicle Modelling

- The High Occupancy vehicle module takes in the From-Home matrices from the Destination Choice module.
- It also takes in High Occupancy and Single Occupancy generalised costs from an assignment.
- It uses these costs along with a sensitivity parameter to split the From-Home trips between High Occupant and Single Occupant Matrices.
- *Note: The implementation of HOV Modelling has impacts in a number of places in the model structure. This diagram just shows the main choice model element of the HOV model.*



= Process
 = Matrix
 = Vector
 = Internal Process
 = Internal File
 = External Process/File

Figure 17: High Occupancy Vehicle Modeling

Appendix B – TMfS:07 Zones

TMfS:07 Zone Structure

Table B1 below shows the number of zones in each Local Authority and the ratio of data zones to TMfS zones in each.

Table B1 Zones by Local Authority

Local Authority	TMfS07 Zones	Data Zones	Ratio
Dumfries & Galloway	21	193	9.2
The Borders	14	130	9.3
East Lothian	14	120	8.6
Midlothian	11	112	10.2
City of Edinburgh	60	569	9.5
West Lothian	24	211	8.8
South Lanarkshire	41	414	10.1
East Ayrshire	17	154	9.1
South Ayrshire	15	147	9.8
North Ayrshire	18	179	9.9
East Renfrewshire	13	120	9.2
City of Glasgow	78	694	8.9
North Lanarkshire	49	433	8.8
Falkirk	21	197	9.4
East Dunbartonshire	13	127	9.8
Renfrewshire	25	214	8.6
Inverclyde	15	110	7.3
West Dunbartonshire	13	103	7.9

Local Authority	TMfS07 Zones	Data Zones	Ratio
Stirling	12	110	9.2
Clackmannan	7	64	9.1
Fife	49	453	9.2
Perthshire & Kinross	20	175	8.8
City of Dundee	19	179	9.4
Angus	14	142	10.1
Aberdeenshire	29	285	9.8
City of Aberdeen	26	247	9.5
Moray	12	116	9.7
Argyll & Bute	16	122	7.6
Islands	5	93	18.6
Highland	41	292	7.1

Zones with more than one train station

The zones which contain more than one train station are as follows:

- Zone 7 (SANQUHAR/KIRKCONNEL) – Sanquhar and Kirkconnel;
- Zone 220 (ARDROSSAN WEST) - Ardrossan Harbour and Ardrossan Town;
- Zone 294 (POSSIL PARK) - Possil Park and Ashfield;
- Zone 458 (CRAINLARICH) - Crainlarich, Upper Tyndrum and Lower Tyndrum;
- Zone 572 (BARRY) - Barry Links and Golf Street;
- Zone 653 (CONNEL) - Connel Ferry and Taynult;
- Zone 656 (DALMALLY) - Dalmally, Loch Awe, Falls of Cruachan and Bridge of Orchy;
- Zone 657 (TARBET) - Arrochar & Tarbet and Ardlui;
- Zone 667 (MALLAIG) - Mallaig, Moror, Arisaig and Beasdale;
- Zone 668 (BANAVIE) - Banavie, Corpach, Loch Eil, Locheilside, Glenfinnan and Lochailort;
- Zone 669 (KYLE OF LOCALSH) - Kyle of Localsh, Durinish, Plockton, Duncraig, Stromeferry, Attadale, Strathcarron and Achnashellach;
- Zone 672 (SPEAN BRIDGE) - Spean Bridge, Roy Bridge, Tulloch and Corroul;

- Zone 673 (ACHNASHEEN) - Achnasheen, Achanalt, Garve and Lochluichart;
- Zone 677 (CULRAIN) - Culrain, Ardgay, Lairg and Invershin;
- Zone 682 (KINGUSSIE) - Kingussie, Newtonmore and Dalwhinnie;
- Zone 695 (GOLSPIE) – Golspie and Dunrobin Castle;
- Zone 701 (HELMSDALE & LYBSTER) - Helmsdale, Kinbrace and Kildonan; and
- Zone 704 (HALKIRK) - Scotscalder, Georgemas Junction and Altnabreac.

Zones which have been created by splitting data zones

Some data zones which were either strange shapes or that contained development areas, which needed to be considered separately from the rest of the model area, have been split. The zones boundaries in question are as follows:

- Barry and Carnoustie – Zones 572 and 573;
- Tranent and Wallyford – Zones 39 and 41;
- Millerhill and Bonnyrigg – Zones 54 and 56;
- Bishopston, Langbank and Erskine – Zones 407, 411 and 417;
- West Kilbride and Fairlie – Zones 218 and 217;
- Westhill West and Westhill East – Zones 594 and 598;
- Cullen and Buckie– Zones 644 and 645;
- Burntisland and Dalgety Bay East/Aberdour – Zones 493 and 497;
- Tayport and Newport on Tay – Zones 520 and 523;
- Auchinleck and Cumnock – Zones 195 and 197;
- Whitburn East and Addiewell/Stoneyburn – Zones 124 and 126;
- Briech and West Calder – Zones 125 and 134; and
- Oakley & Saline and Dunfermline North East– Zones 479 and 483.

All the zones were split along census output area boundaries.

Airport Zones

The airport zones have also been cut from data zones to just be a small shape around the airport. None of the attributes of the data zone they were cut from have been attributed to the airports. All the attributes have gone into the zone the rest of the data zone was included into. These zones are:

- Edinburgh Airport – 709;
- Prestwick Airport – 710;
- Glasgow Airport – 711; and
- Aberdeen Airport – 712.

All other airports in Scotland are not considered as separate zones.

Zone Centroids

Zone centroid lengths have been calculated by considering the zone to be a circle and then calculating the average radial distance of the circle if all points within it are evenly distributed. From the zonal area the zone length can thus be calculated using the following formula:

$$\frac{2}{3} \sqrt{\frac{area}{\pi}}$$

Appendix C – Generalised Cost Parameters

Calculation of Base Year Demand Model Cost Coefficients

These parameters have been calculated following the guidance in the most up to date version of WebTAG unit 3.5.6 available at the time of the model development (April 2009). Generalised Cost coefficients are calculated separately for all the assigned purposes (for both Highway and PT).

Highway Coefficients

Car Non-Work time generalised cost parameters were calculated in accordance with WebTAG, as follows:

Time Cost Parameter = 1

Distance cost parameter = (Fuel Cost + Vehicle Operating Cost)/VOT (*mins per kilometre*).

Toll cost parameter = 1/(VOT for tolling) (*mins per pence*).

Where:

Fuel Cost = consumption_{petrol} × price_{petrol} × Prop_{petrol} + consumption_{diesel} × price_{diesel} × Prop_{diesel};

Consumption = a + bV + cV² + dV³ (a, b, c and d are coefficients from WebTAG Table 13).

Vehicle Operating Cost = a + b/V (a and b are coefficients from WebTAG Table 15).

Note [1]: the appropriate growth factors have been applied to each step to bring the model values up to 2007. The fuel efficiency savings over time are also applied.

Note [2]: that for the purpose of the calculations the average speed in the modelled area has been calculated as 52 km/h.

The Generalised Cost coefficients for all possible forecast years are shown in table C1.

PT Coefficients

For the PT Model the Values of Time used in the assignment are taken from WebTAG unit 3.5.6 Tables 1 and 2. These are then growthed up to 2007 using the values in WebTAG Table 3 (Unit 3.5.6).

It should be noted that Commute and Other purposes use the same value of time in assignment. This is a weighted average of the two Values of Time.

The Values of Time for all possible Modelled Years is shown in Table C1.

Table C1 Generalised Cost Coefficients by Year

Year	Car In Work			Car Non Work (Commuting)			Car Non Work (Other)			LGV			OGV			PT	
	Time	Distance	Tolls	Time	Distance	Tolls	Time	Distance	Tolls	Time	Distance	Tolls	Time	Distance	Tolls	NW	IW
2007	1	0.2329	0.0503	1	0.5299	0.1448	1	0.3885	0.1448	1	0.6805	0.0225	1	2.1876	0.0225	511.266	2157.901
2008	1	0.2284	0.0492	1	0.5230	0.1423	1	0.3842	0.1423	1	0.6686	0.0220	1	2.1566	0.0220	575.917	2430.775
2009	1	0.2215	0.0481	1	0.5033	0.1398	1	0.3703	0.1398	1	0.6459	0.0216	1	2.0770	0.0216	586.053	2473.556
2010	1	0.2152	0.0471	1	0.4862	0.1374	1	0.3584	0.1374	1	0.6264	0.0211	1	2.0105	0.0211	596.368	2517.091
2011	1	0.2102	0.0461	1	0.4759	0.1350	1	0.3515	0.1350	1	0.6160	0.0206	1	1.9780	0.0206	606.864	2561.392
2012	1	0.2058	0.0452	1	0.4661	0.1330	1	0.3449	0.1330	1	0.6069	0.0202	1	1.9494	0.0202	616.270	2601.093
2013	1	0.2013	0.0443	1	0.4552	0.1309	1	0.3374	0.1309	1	0.5971	0.0199	1	1.9180	0.0199	625.823	2641.410
2014	1	0.1966	0.0435	1	0.4434	0.1289	1	0.3292	0.1289	1	0.5868	0.0195	1	1.8839	0.0195	635.523	2682.352
2015	1	0.1920	0.0427	1	0.4318	0.1270	1	0.3212	0.1270	1	0.5766	0.0191	1	1.8505	0.0191	645.373	2723.929
2016	1	0.1874	0.0419	1	0.4198	0.1250	1	0.3128	0.1250	1	0.5666	0.0187	1	1.8176	0.0187	655.377	2766.149
2017	1	0.1829	0.0411	1	0.4081	0.1231	1	0.3046	0.1231	1	0.5568	0.0184	1	1.7854	0.0184	665.535	2809.025
2018	1	0.1784	0.0403	1	0.3962	0.1212	1	0.2963	0.1212	1	0.5467	0.0180	1	1.7522	0.0180	675.851	2852.565
2019	1	0.1742	0.0395	1	0.3851	0.1194	1	0.2885	0.1194	1	0.5373	0.0177	1	1.7211	0.0177	686.327	2896.779
2020	1	0.1700	0.0388	1	0.3744	0.1176	1	0.2810	0.1176	1	0.5279	0.0174	1	1.6906	0.0174	696.965	2941.679
2021	1	0.1669	0.0380	1	0.3692	0.1158	1	0.2776	0.1158	1	0.5188	0.0170	1	1.6606	0.0170	707.768	2987.275
2022	1	0.1644	0.0374	1	0.3646	0.1143	1	0.2746	0.1143	1	0.5114	0.0168	1	1.6360	0.0168	716.544	3024.318
2023	1	0.1620	0.0369	1	0.3606	0.1129	1	0.2721	0.1129	1	0.5044	0.0165	1	1.6132	0.0165	725.429	3061.819
2024	1	0.1597	0.0363	1	0.3566	0.1116	1	0.2696	0.1116	1	0.4976	0.0163	1	1.5906	0.0163	734.424	3099.786
2025	1	0.1573	0.0357	1	0.3527	0.1102	1	0.2671	0.1102	1	0.4908	0.0160	1	1.5684	0.0160	743.531	3138.223
2026	1	0.1551	0.0352	1	0.3493	0.1088	1	0.2649	0.1088	1	0.4841	0.0158	1	1.5464	0.0158	752.751	3177.137
2027	1	0.1529	0.0347	1	0.3455	0.1075	1	0.2625	0.1075	1	0.4772	0.0155	1	1.5235	0.0155	762.085	3216.534
2028	1	0.1508	0.0341	1	0.3422	0.1062	1	0.2604	0.1062	1	0.4707	0.0153	1	1.5022	0.0153	771.535	3256.419
2029	1	0.1486	0.0336	1	0.3389	0.1049	1	0.2584	0.1049	1	0.4643	0.0151	1	1.4812	0.0151	781.102	3296.798
2030	1	0.1466	0.0331	1	0.3357	0.1036	1	0.2563	0.1036	1	0.4580	0.0148	1	1.4605	0.0148	790.788	3337.678
2031	1	0.1444	0.0326	1	0.3318	0.1023	1	0.2538	0.1023	1	0.4513	0.0146	1	1.4382	0.0146	800.593	3379.066
2032	1	0.1417	0.0320	1	0.3268	0.1007	1	0.2504	0.1007	1	0.4428	0.0143	1	1.4101	0.0143	813.323	3432.793
2033	1	0.1390	0.0313	1	0.3218	0.0992	1	0.2471	0.0992	1	0.4344	0.0140	1	1.3826	0.0140	826.255	3487.374
2034	1	0.1363	0.0307	1	0.3170	0.0976	1	0.2438	0.0976	1	0.4262	0.0138	1	1.3556	0.0138	839.392	3542.823
2035	1	0.1337	0.0301	1	0.3122	0.0961	1	0.2405	0.0961	1	0.4182	0.0135	1	1.3292	0.0135	852.739	3599.154

Appendix D – Parking Charges

Calculation of Parking Charges

Parking charges are required as an input to the calculation of generalised cost for use in the Demand Model, with average cost per car used. These have been calculated for the major urban areas within the TMfS:07 model area. Table D1 shows where these have been applied, and to which zones.

Table D1 Destination zones where parking charges are applied

City	Destination zones
Aberdeen	627,628
Glasgow	290,291,297,298,302
Dunfermline	482
Perth	539
Stirling	466
Dundee	552,555
Edinburgh	86,90,94,96,98-100
Inverness	683,686,687

There are three types of parking charges in the model, these are:

- Long Stay Parking - this is appropriate for home based commute trips. We assume that 15% of total trips to the city centre for work are variations of 'kiss and ride' so no cost for parking is incurred, and also that 40% park in private non residential car parks. It is therefore assumed that 45% of total trips will pay this cost;
- Short Stay - this is applied to home based other and non-home based other trips. It is assumed that 80% of total trips will pay this charge; and
- No Charge – this is applied to Employers Business trips as it is perceived that even if they pay a parking charge they will not perceive the cost.

Average Charges

The average charges for each city are shown in Table D2. These are in 2007 prices and are the space weighted average car park charge over all car park sites in the area.

Table D2 Average charges

	Short Term (HO)	Long Term (HW)
Aberdeen	£1.71	£6.27
Glasgow	£2.67	£11.22
Dunfermline	£1.26	£3.40
Perth	£1.33	£4.06
Stirling	£1.74	£2.53
Dundee	£2.37	£5.79
Edinburgh	£3.61	£9.14
Inverness	£1.30	£3.18

Application

These costs will be added to the base year generalised cost skim matrices after first being multiplied by the tolling parameter of the generalised cost equation. The costs will only be added to the zones defined in Table D1. Table D3 shows the calculated values for addition to the cost matrices. The values are also halved for input into the demand model (ie half of the cost is perceived in each direction).

Table D3 Parking Charges as Generalised Cost (Mins)

City	Short Term Cost	Long Term Cost
Aberdeen	10.94	22.61
Glasgow	17.10	40.53
Dunfermline	8.05	12.26
Perth	8.52	14.63
Stirling	11.17	9.11
Dundee	15.20	20.87
Edinburgh	23.18	32.97
Inverness	8.37	11.47

(NB the long stay parking charge for Stirling in Generalised Minutes is less than the Short Term charge. This is due to the proportion of people paying the charge and the small differential between the two in monetary terms).

Appendix E – Software Versions

Software Versions

The following software versions have been used in the TMfS:07 Model:

- Demand, Highway and PT models Model – CUBE VOYAGER v5.0.2;
- Demand Model Calibration – ALOGIT4 – v2.3; and
- Model Control – CUBE CLUSTER and Visual Basic.

Appendix F – Incremental Adjustment Factors

Incremental Adjustment Factors

This appendix describes an approach for applying incremental factors to the assignment matrices for the TMfS:07 Model.

Typically in previous versions of TMfS we have applied the model incrementally by applying absolute models and using the outputs to modify a base 'observed' matrix. We have done this as follows (on a cell by cell basis):

B = base observed trips;

S_b = base modelled trips;

S_f = future modelled trips; and

F = future trips.

Then:

$$\mathbf{F} = \mathbf{B} + \mathbf{S}_f - \mathbf{S}_b$$

This formula has been applied to all cells of the matrix. In other projects we have used a multiplicative approach rather than additive, eg:

$$\mathbf{F} = \mathbf{B} * \mathbf{S}_f / \mathbf{S}_b$$

This method is based on the assumption that in both base and future years all modelled cells in the matrix will be non zero, which is likely to be the case so long as we don't have zero K-factors in the destination choice model. Also if the base year is zero then so will all of the future years.

The aims of the process are to ensure that zero **B** case is taken into account and that the changes in trips are in keeping with the scale of **B** and that we avoid applying large growth factors base on small values of **S_f** and **S_b** to cells with large **B**.

We can define five cases:

- (1) zero **B**;
- (2) low **B**, high **S_b**;
- (3) low **B** low **S_b**;
- (4) high **B** high **S_b**; and
- (5) high **B** low **S_b**.

For (1) the forecasts trips will be **S_f** minus **S_b**. The growth factor method does not work here, so we use the additive form of the equation.

For (2), (3) and (4) we use the multiplicative form. In the case of (2) use of the incremental could add a large amount to a cell which has relatively small number of base trips. For (3) and (4) it could make little overall difference if we used incremental or multiplicative.

For (5) we use the additive form. This is the case where relatively large growth factors based on small modelled flows could create excessive growth when applied to high base.

Each cell in the matrix is identified as being increments or multiplicative, by use of a matrix of flags. In the case of (5) the critical value of $\mathbf{B/S}_b$ such that values above this will be considered as case (5) and those below as cases (2), (3) and (4) is set at 2.

Appendix G – Park and Ride Site Files

Park and Ride Sites

Table G1 below shows all the Park and Ride sites included in the TMFS:07 base model. Note, those sites in italics are bus based park and ride sites.

Table G1 Park and Ride Sites by Local Authority

Local Authority	Sites
Aberdeenshire	Ellon Huntly Insch Inverurie Portlethen Stonehaven
Angus	Arbroath Carnoustie Montrose
Argyll & Bute	Cardross Helensburgh Central Oban
City of Aberdeen	Aberdeen Bridge of Don Dyce Kingswell
City of Dundee	Dundee
City of Edinburgh	Brunstane Curriehill Dalmeny Edinburgh Park Hermiston Ingilston Newcraighall South Gyle Wester Hailes Waverley Haymarket
City of Glasgow	Anniesland Bellgrove Bridgeton Cardonald Cathcart Charing Cross Drumchapel Easterhouse

Local Authority	Sites
	Garrowhill High Street Glasgow Hyndland Muirend Partick Scotstounhill Shettleston Glasgow Central Glasgow Queen Street
Dumfries & Galloway	Dumfries Gretna Kirkconnel Lockerbie
East Ayrshire	Auchinleck Kilmarnock Kilmaurs New Cumnock Stewarton
East Dunbartonshire	Bearsden Bishopbriggs Hillfoot Lenzie Milngavie Westerton
East Lothian	Drem Dunbar Longniddry Musselburgh North Berwick Prestonpans Wallyford
East Renfrewshire	Barrhead Clarkston Giffnock Neilston Patterton Thornliebank Whitecraigs Williamwood
Falkirk	Camelon Falkirk Grahamston Falkirk High Larbert Polmont
Fife	Aberdour Burntisland Cardenden

Local Authority	Sites
	Cupar Dalgety Bay
	Dunfermline Queen Margaret Dunfermline Town Ferrytoll Glenrothes Inverkeithing Kirkcaldy Ladybank Leuchars Markinch North Queensferry Rosyth
Highland	Aviemore Fort William Inverness Kingussie Kyle of Lochalsh Nairn Stromeferry
Inverclyde	Branchton Fort Matilda Gourock Greenock Central Greenock West Port Glasgow Wemyss Bay
Moray	Elgin Forres Keith
North Ayrshire	Ardrossan South Beach Dalry Glengarnock Irvine Kilwinning Saltcoats West Kilbride
North Lanarkshire	Airdrie Bargeddie Bellshill Blairhill Cleland Coatbridge Sunnyside Coatdyke Croy Cumbernauld Drumgelloch

Local Authority	Sites
	Gartcosh Greenfaulds Holytown Motherwell Shotts Stepps Whifflet Wishaw
Perthshire & Kinross	Broxden Dunkeld & Birnam Gleneagles Perth Pitlochry Rannoch
Renfrewshire	Bishopston Hawkhead Howwood Johnstone Paisley Canal Paisley Gilmour
South Ayrshire	Ayr Girvan Prestwick Troon
South Lanarkshire	Blantyre Cambuslang Carluke Croftfoot East Kilbride Hairmyres Hamilton Cental Hamilton West Lanark Larkhall Merryton Newton Rutherglen Uddingston
Stirling	Bridge of Allan Dunblane Springkerse Stirling Upper Tyndrum
West Dunbartonshire	Alexandria Balloch Clydebank Dalmuir

Local Authority	Sites
	Dalreoch Drumry Dumbarton Central Dumbarton East Singer
West Lothian	Bathgate Kirknewton Linlithgow Livingston North Livingston South Uphall

[NB. The Park and Ride sites to be modelled were those which had either more than 20 car parking spaces and/or those with more than 20 cars accessing the site (from NRTS).]

Appendix H – Park and Ride Model Calibration

Park and Ride Calibration

Table H1 below shows the calibration of Park and Ride by site.

Table H1 Park and Ride Calibration in TMfS:07

Site	Observed	Modelled	GEH
Ellon	163	120	3.61
Huntly	8	2	2.48
Insch	18	4	4.47
Inverurie	49	22	4.61
Portlethen	4	2	0.86
Stonehaven	149	98	4.56
Arbroath	39	14	4.73
Carnoustie	29	18	2.23
Montrose	98	61	4.16
Cardross	21	20	0.10
Helensburgh Central	218	272	3.48
Oban	9	0	4.32
Aberdeen	165	120	3.76
Bridge of Don	354	277	4.32
Dyce	30	10	4.61
Kingswell	172	113	4.96
Dundee	129	91	3.58
Brunstane	41	40	0.14
Curriehill	10	0	4.49
Dalmeny	94	110	1.59
Edinburgh Park	59	84	2.95
Hermiston	440	526	3.90
Ingilston	499	526	1.18
Newcraighall	132	97	3.25
South Gyle	15	10	1.52
Wester Hailes	0	0	0.00
Waverley	122	179	4.62
Haymarket	53	49	0.50
Anniesland	23	42	3.34
Bellgrove	23	44	3.61
Bridgeton	14	30	3.46
Cardonald	36	56	3.06
Cathcart	44	55	1.66
Charing Cross	5	19	4.25
Drumchapel	7	26	4.71
Easterhouse	43	70	3.54
Garrowhill	25	32	1.30
High Street Glasgow	18	28	1.92
Hyndland	55	85	3.64

Site	Observed	Modelled	GEH
Muirend	118	110	0.71
Partick	66	76	1.09
Scotstounhill	9	25	3.78
Shettleston	143	197	4.11
Glasgow Central	82	116	3.45
Glasgow Queen Street	178	197	1.38
Dumfries	10	2	3.00
Gretna	0	0	0.00
Kirkconnel	8	5	1.26
Lockerbie	16	25	1.95
Auchinleck	26	8	4.20
Kilmarnock	103	109	0.60
Kilmaurs	19	16	0.71
New Cumnock	7	0	3.84
Stewarton	44	46	0.17
Bearsden	156	180	1.87
Bishopbriggs	111	132	1.88
Hillfoot	52	56	0.58
Lenzie	253	251	0.13
Milngavie	191	168	1.72
Westerton	128	145	1.48
Drem	102	90	1.22
Dunbar	64	35	4.21
Longniddry	42	37	0.78
Musselburgh	10	17	1.95
North Berwick	75	59	2.03
Prestonpans	90	134	4.22
Wallyford	32	43	1.74
Barrhead	51	59	1.02
Clarkston	135	149	1.16
Giffnock	130	140	0.89
Neilston	101	84	1.78
Patterton	86	102	1.68
Thornliebank	8	13	1.75
Whitecraigs	133	139	0.52
Williamwood	28	30	0.31
Camelon	37	32	0.83
Falkirk Grahamston	18	17	0.37
Falkirk High	550	460	4.02
Larbert	183	152	2.37
Polmont	273	198	4.87
Aberdour	9	6	1.12
Burntisland	28	19	1.72
Cardenden	12	2	3.67
Cupar	30	34	0.69
Dalgety Bay	128	126	0.19
Dunfermline Queen			
Margaret	31	25	1.13

Site	Observed	Modelled	GEH
Dunfermline Town	58	55	0.42
Ferrytoll	452	485	1.52
Glenrothes	8	14	1.84
Inverkeithing	657	607	2.00
Kirkcaldy	418	353	3.32
Ladybank	14	6	2.52
Leuchars	42	44	0.35
Markinch	61	55	0.77
North Queensferry	23	13	2.23
Rosyth	21	20	0.13
Aviemore	7	2	2.18
Fort William	2	0	2.00
Inverness	73	38	4.61
Kingussie	3	0	2.57
Kyle of Lochalsh	5	0	3.18
Nairn	14	11	0.81
Stromeferry	0	0	0.00
Branchton	7	8	0.57
Fort Matilda	11	10	0.32
Gourock	108	71	3.91
Greenock Central	34	29	0.86
Greenock West	15	6	2.69
Port Glasgow	78	68	1.07
Wemyss Bay	9	8	0.24
Elgin	29	16	2.87
Forres	31	28	0.61
Keith	11	4	2.86
Ardrossan South Beach	27	23	0.87
Dalry	7	11	1.13
Glengarnock	41	38	0.44
Irvine	155	130	2.12
Kilwinning	186	170	1.17
Saltcoats	21	18	0.67
West Kilbride	7	2	2.18
Airdrie	366	323	2.31
Bargeddie	9	25	4.03
Bellshill	143	139	0.32
Blairhill	84	94	0.97
Cleland	13	17	1.02
Coatbridge Sunnyside	128	118	0.93
Coatdyke	76	76	0.01
Croy	460	394	3.19
Cumbernauld	60	74	1.75
Drumgelloch	49	53	0.60
Gartcosh	28	38	1.79
Greenfaulds	22	31	1.69
Holytown	13	32	4.02
Motherwell	194	164	2.23

Site	Observed	Modelled	GEH
Shotts	17	22	0.95
Stepps	60	73	1.60
Whifflet	32	38	1.14
Wishaw	88	70	2.07
Broxden	179	170	0.65
Dunkeld & Birnam	4	1	1.54
Gleneagles	15	14	0.03
Perth	130	100	2.81
Pitlochry	7	2	2.08
Rannoch	0	0	0.00
Bishopton	92	95	0.26
Hawkhead	31	54	3.53
Howwood	1	4	1.62
Johnstone	320	390	3.74
Paisley Canal	77	108	3.22
Paisley Gilmour	283	320	2.17
Ayr	353	300	2.92
Girvan	9	1	3.33
Prestwick	35	44	1.43
Troon	117	114	0.23
Blantyre	90	106	1.61
Cambuslang	204	242	2.54
Carluke	100	84	1.62
Croftfoot	29	58	4.30
East Kilbride	260	229	2.00
Hairmyres	195	174	1.57
Hamilton Cental	45	60	2.02
Hamilton West	369	313	3.02
Lanark	84	52	3.89
Larkhall	0	5	3.10
Merryton	0	2	2.19
Newton	89	94	0.49
Rutherglen	59	85	3.07
Uddingston	185	175	0.70
Bridge of Allan	66	66	0.02
Dunblane	150	121	2.50
Springkerse	228	269	2.59
Stirling	274	310	2.07
Upper Tyndrum	0	0	0.00
Alexandria	12	13	0.30
Balloch	50	40	1.51
Clydebank	14	17	0.82
Dalmuir	288	323	1.97
Dalreoch	80	60	2.44
Drumry	11	19	2.19
Dumbarton Central	126	109	1.59
Dumbarton East	13	20	1.87
Singer	26	38	2.18

Site	Observed	Modelled	GEH
Bathgate	357	304	2.95
Kirknewton	18	24	1.23
Linlithgow	340	283	3.24
Livingston North	196	259	4.19
Livingston South	85	91	0.71
Uphall	68	74	0.72
Total	17,761	17,386	2.83

The following table shows the calibration of Park and Ride by Local Authority and by Journey Purpose.

Table H2 Park and Ride Calibration by Local Authority and Purpose

Local Authority	Home Based Employers									Total		
	Home Based Work			Business			Home Based Other					
Aberdeenshire	215	120	7.36	61	59	0.30	115	70	4.74	392	248	8.01
Angus	92	41	6.31	43	25	3.11	30	28	0.49	166	94	6.35
Argyll & Bute	162	160	0.15	24	25	0.17	62	108	4.97	248	293	2.72
City of Aberdeen	377	325	2.77	78	100	2.28	266	95	12.73	721	520	8.09
City of Dundee	26	30	0.82	61	35	3.81	42	26	2.64	129	91	3.58
City of Edinburgh	1,190	1,406	6.02	121	78	4.27	155	136	1.58	1,465	1,620	3.95
City of Glasgow	679	908	8.14	131	90	3.87	80	211	10.88	890	1,210	9.88
Clackmannan	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
Dumfries & Galloway	10	7	0.97	6	5	0.53	18	20	0.55	34	32	0.29
East Ayrshire	133	142	0.71	13	14	0.29	53	23	4.85	199	179	1.48

Local Authority	Home Based Employers											
	Home Based Work			Business			Home Based Other			Total		
East Dunbartonshire	718	757	1.43	89	42	5.83	84	133	4.77	891	932	1.37
East Lothian	340	341	0.06	27	16	2.45	49	59	1.30	416	415	0.03
East Renfrewshire	541	598	2.38	112	32	9.35	20	86	9.17	672	716	1.68
Falkirk	888	619	9.79	110	142	2.84	64	98	3.85	1,061	859	6.53
Fife	1,679	1,463	5.46	117	235	8.88	196	168	2.10	1,993	1,866	2.89
Highland	13	25	2.91	36	13	4.53	56	13	7.25	104	52	5.94
Inverclyde	223	152	5.14	15	24	1.97	22	24	0.41	260	200	3.94
Midlothian	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
Moray	45	34	1.77	7	4	1.38	20	10	2.73	72	47	3.22
North Ayrshire	375	258	6.59	30	58	4.12	39	77	4.95	445	392	2.56

Local Authority	Home Based Employers										Total	
	Home Based Work			Business			Home Based Other					
North Lanarkshire	1,593	1,441	3.89	117	152	3.08	132	187	4.40	1,841	1,781	1.42
Perthshire & Kinross	162	119	3.66	36	84	6.21	136	85	4.79	334	288	2.59
Renfrewshire	707	803	3.49	67	56	1.30	30	112	9.64	804	971	5.61
South Ayrshire	315	305	0.55	92	70	2.53	106	85	2.15	513	460	2.43
South Lanarkshire	1,465	1,411	1.42	124	106	1.73	120	162	3.54	1,709	1,679	0.74
Stirling	524	408	5.36	90	212	9.95	105	145	3.61	719	766	1.72
The Borders	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00
West Dunbartonshire	280	504	11.34	13	36	4.53	327	100	15.59	620	640	0.77
West Lothian	940	851	3.00	60	107	5.06	64	78	1.69	1,065	1,036	0.90
Total	13,690	13,228	3.99	1,681	1,819	3.29	2,390	2,339	1.04	17,761	17,386	2.83

Appendix I – Other Model Parameters

Occupancy Factors

The occupancy factors for the Base modelled year are shown in table I1. The occupancy factors have been developed by applying growth factors to those used in the TMfS:05A, which came from RSI data. Over time these values change in line with guidance from WebTAG Unit 3.5.6 Table 6.

Table I1 Base Year Occupancies by Sector and Purpose

Purpose / Direction	AM Peak		Inter Peak		PM Peak	
	Edinburgh	Elsewhere	Edinburgh	Elsewhere	Edinburgh	Elsewhere
Home Based Employers Business From Home	1.11	1.16	1.2	1.27	1.29	1.32
Home Based Employers Business To Home	1.18	1.18	1.14	1.08	1.14	1.13
Home Based Employers Business Non Home Based	1.24	1.35	1.52	1.2	1.64	1.23
Home Based Other From Home	1.69	1.54	1.59	1.62	1.74	1.74
Home Based Other To Home	1.23	1.48	1.55	1.58	1.67	1.65

	AM Peak		Inter Peak		PM Peak	
Home Based Other Non Home Based	1.36	1.37	1.51	1.62	1.64	1.55
Home Based Work From Home	1.1	1.21	1.22	1.15	1.36	1.21
Home Based Work To Home	1.56	1.07	1.2	1.13	1.25	1.14
Home Based Education From Home	2.43	2.43	1.44	1.44	1.4	1.4
Home Based Education To Home	2.43	2.43	1.44	1.44	1.4	1.4

Period to Hour Factors

The Period to Hour factors used in TMfS:07 are as follows:

- AM Peak – 0.38 for Highway and 0.5 for PT;
- Inter Peak – 1/6 for Highway and PT; and
- PM Peak – 0.36 for Highway and 0.42 for PT.

These factors are applied to all user classes and all purposes and in all forecast years. The Peak PT factors are greater than the Highway as they have more 'peaky' peak hours.

PM Factors

In the Model the PM *From-Home* matrices are derived by factoring the Inter-Peak *From-Home* matrices. The factors used are shown in Table I2 below. The factors are applied to the entire matrices.

Table I2 Inter Peak to PM *From-Home* Factors

	<i>C11C, C12C,C2C</i>	<i>C11P,C12P,C2P</i>	<i>COP</i>
<i>HE</i>	0.286	0.167	0.200
<i>HO</i>	0.355	0.122	0.067
<i>HW</i>	0.226	0.158	0.244

Reverse Factors – To Home and Non Home Based

The Factors used in the Reverse process to go from *From-Home* trips to *To-Home* trips are shown in table I3, with the From Home purposes listed vertically and the To-Home purposes horizontally. The factors to create *Non-Home Based* Productions from *From-Home* trips are shown in table I4, again the From-Home purposes are down the vertical with the non-home based purposes on the horizontal. The factors to create *Non-Home Based* Attractions from *To-Home* trips are shown in table I4, the To-Home purposes are down the vertical with the non-home based purposes on the horizontal.

It should be noted that C1 in the tables below means car is available these factors are then applied to C11, C12 and C2 household segments. All cells in the tables below coloured in orange are structurally zero.

Table I3 To Home Factors

			hbw	hbw	hbw	hbeb	hbeb	hbeb	hbo	hbo	hbo	hbw	hbw	hbw	hbeb	hbeb	hbeb	hbo	hbo	hbo	hbw	hbw	hbw	hbeb	hbeb	hbeb	hbo	hbo	hbo
			am	am	am	am	am	am	am	am	am	inter	inter	inter	inter	inter	inter	inter	inter	inter	pm	pm	pm	pm	pm	pm	pm	pm	pm
			car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0
hbw	am	car	0.009	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.244	0.003	0.001	0.003	0.001	0.000	0.021	0.000	0.000	0.689	0.007	0.001	0.011	0.000	0.000	0.054	0.001	0.000
hbw	am	pt 1+	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.018	0.169	0.000	0.000	0.000	0.000	0.012	0.015	0.000	0.065	0.653	0.000	0.003	0.006	0.000	0.024	0.009	0.000
hbw	am	pt 0	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.183	0.000	0.000	0.004	0.000	0.000	0.022	0.070	0.000	0.652	0.000	0.000	0.004	0.013	0.000	0.022
hbeb	am	car	0.000	0.000	0.000	0.031	0.000	0.000	0.009	0.000	0.000	0.050	0.000	0.000	0.255	0.003	0.000	0.075	0.000	0.000	0.069	0.000	0.000	0.453	0.000	0.000	0.075	0.000	0.000
hbeb	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000
hbeb	am	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	am	car	0.002	0.000	0.000	0.001	0.000	0.000	0.164	0.000	0.000	0.018	0.001	0.000	0.004	0.000	0.000	0.495	0.005	0.002	0.054	0.000	0.000	0.005	0.000	0.000	0.246	0.005	0.001
hbo	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.005	0.000	0.024	0.490	0.000	0.014	0.033	0.000	0.000	0.010	0.000	0.038	0.362	0.000	0.000
hbo	am	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.000	0.000	0.020	0.000	0.000	0.004	0.040	0.000	0.611	0.004	0.000	0.016	0.000	0.000	0.000	0.024	0.000	0.210
hbw	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.146	0.000	0.000	0.002	0.000	0.000	0.019	0.000	0.000	0.412	0.000	0.000	0.004	0.000	0.000	0.042	0.000	0.000
hbw	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.132	0.000	0.000	0.000	0.000	0.000	0.000	0.132	0.184	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.000
hbw	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.341	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.383	0.000	0.000	0.071	0.000	0.000	0.026	0.000	0.000	0.364	0.000	0.000	0.071	0.000	0.000
hbeb	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.167	0.000
hbeb	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000
hbo	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.631	0.003	0.001	0.003	0.000	0.000	0.001	0.000	0.000	0.314	0.002	0.001
hbo	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.051	0.520	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.044	0.297	0.000
hbo	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.013	0.000	0.635	0.000	0.000	0.001	0.000	0.000	0.000	0.020	0.000	0.298
hbw	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.000
hbw	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.000	0.205	0.000	0.000	0.000	0.000	0.000
hbeb	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.002	0.000	0.000	0.384	0.001	0.001
hbo	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.167	0.000
hbo	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.196

Table I2 Production Factors for Non Home Based Trips

			nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo	nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo	nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo
			am	am	am	am	am	am	inter	inter	inter	inter	inter	inter	pm	pm	pm	pm	pm	pm
			car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0
hbw	am	car	0.027	0.001	0.000	0.006	0.000	0.000	0.035	0.001	0.000	0.044	0.001	0.000	0.002	0.000	0.000	0.041	0.001	0.000
hbw	am	pt 1+	0.003	0.005	0.000	0.000	0.003	0.000	0.003	0.005	0.000	0.010	0.018	0.000	0.000	0.000	0.000	0.016	0.021	0.000
hbw	am	pt 0	0.000	0.000	0.011	0.000	0.000	0.000	0.007	0.000	0.000	0.007	0.000	0.036	0.000	0.000	0.000	0.007	0.000	0.040
hbeb	am	car	0.042	0.000	0.000	0.031	0.000	0.000	0.092	0.008	0.000	0.034	0.000	0.000	0.003	0.000	0.000	0.005	0.000	0.000
hbeb	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	am	pt 0	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	am	car	0.006	0.000	0.000	0.063	0.002	0.000	0.003	0.000	0.000	0.057	0.001	0.000	0.001	0.000	0.000	0.005	0.000	0.000
hbo	am	pt 1+	0.000	0.000	0.000	0.000	0.033	0.000	0.004	0.000	0.000	0.017	0.066	0.000	0.000	0.000	0.000	0.000	0.017	0.000
hbo	am	pt 0	0.000	0.000	0.003	0.000	0.000	0.052	0.003	0.000	0.000	0.003	0.000	0.081	0.000	0.000	0.000	0.000	0.000	0.007
hbw	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.004	0.000	0.087	0.002	0.000	0.010	0.000	0.000	0.028	0.000	0.000
hbw	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
hbw	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.068	0.000	0.000	0.000	0.000	0.000	0.023
hbeb	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.103	0.000	0.000	0.058	0.000	0.000	0.032	0.000	0.000	0.006	0.000	0.000
hbeb	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	inter	car	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.119	0.002	0.000	0.001	0.000	0.000	0.019	0.000	0.000
hbo	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.053	0.000	0.000	0.000	0.000	0.000	0.025	0.000
hbo	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.012
hbw	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.097	0.000	0.000
hbw	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.068	0.000	0.000	0.000	0.000	0.000
hbeb	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
hbo	pm	car	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.044	0.000	0.000
hbo	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.024	0.000
hbo	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000

Table I3 Attraction Factors for Non Home Based Trips

			nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo	nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo	nhbeb	nhbeb	nhbeb	nhbo	nhbo	nhbo
			am	am	am	am	am	am	inter	inter	inter	inter	inter	inter	pm	pm	pm	pm	pm	pm
			car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0	car	pt 1+	pt 0
hbw	am	car	0.000	0.000	0.000	0.385	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	am	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	am	car	0.182	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	am	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	am	car	0.000	0.000	0.000	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	am	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	am	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	inter	car	0.003	0.000	0.000	0.024	0.000	0.000	0.044	0.000	0.000	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	inter	pt 1+	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.034	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbw	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.000	0.000	0.098	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	inter	car	0.047	0.000	0.000	0.000	0.000	0.000	0.154	0.007	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	inter	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	inter	car	0.001	0.000	0.000	0.009	0.000	0.000	0.004	0.000	0.000	0.140	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	inter	pt 1+	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.007	0.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbo	inter	pt 0	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.003	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000
hbw	pm	car	0.002	0.000	0.000	0.009	0.000	0.000	0.041	0.000	0.000	0.041	0.000	0.000	0.026	0.001	0.000	0.010	0.000	0.000
hbw	pm	pt 1+	0.004	0.000	0.000	0.000	0.004	0.000	0.004	0.004	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.004	0.000	0.000
hbw	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.006	0.018	0.000	0.006	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	car	0.044	0.000	0.000	0.000	0.000	0.000	0.151	0.004	0.000	0.012	0.000	0.000	0.119	0.008	0.000	0.012	0.000	0.000
hbeb	pm	pt 1+	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hbeb	pm	pt 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000
hbo	pm	car	0.000	0.000	0.000	0.003	0.000	0.000	0.006	0.000	0.000	0.093	0.002	0.001	0.006	0.000	0.000	0.179	0.007	0.002
hbo	pm	pt 1+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.078	0.000	0.000	0.000	0.000	0.010	0.094	0.000
hbo	pm	pt 0	0.000	0.000	0.003	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.090	0.000	0.000	0.000	0.003	0.000	0.093

Appendix J – High Occupancy Vehicle Modelling

Overview

This appendix describes the implementation of High Occupancy Vehicles (HOV) modelling in the model. It explains the changes required to the network to undertake HOV modelling and the implementation of occupancy choice in the demand model.

Network

To undertake HOV assignments an additional links, with the HOV only link type, must be coded into the networks. Single Occupant Vehicles (SOV) are then unable to use these links.

The public transport network, and particularly the PT lines file, must be adjusted to incorporate the modifications made to the Highway network. The main issue is to keep the node sequence in the lines file consistent with the Highway network where new nodes were introduced.

Tolls must also be adjusted where appropriate to reflect costs on the HOV lane. In most cases the HOV lane toll will be zero. The tolls on the existing links can remain as they were or be changed as appropriate.

Demand Model

The demand model outputs an assignment matrix with the normal purposes, but with each of the car purposes split into SOV and HOV. The output assignment matrix has the following tables:

- Car In Work SOV;
- Car In Work HOV;
- Car Commute SOV;
- Car Commute HOV;
- Car Other SOV;
- Car Other HOV;
- LGV; and
- HGV.

After the assignment stage the SOV purposes and the HOV purposes are skimmed separately. These are then combined for input into the trip frequency, macro time of day choice mode and destination choice stages (These stages are not affected by the implementation of HOV Modelling). There is a separate stage below about how the combination of HOV and SOV costs is undertaken.

At the end of the 'inner loops', the Occupancy Choice module has been introduced to split the *From-Home* demand matrices between SO and HO person matrices.

The occupancy choice takes the form of a logit model, using different generalised costs for Single Occupant (SO) and High Occupancy (HO) person trips.

The person trip proportion of single occupancy for a particular ij pair will be:

$$P_{so} = \frac{\exp(\beta C_{so})}{\exp(\beta C_{so}) + \exp(\beta(C_{HO} + \partial))}$$

Where:

C_{SO} is the generalised cost for Single Occupancy and C_{HO} is the generalised cost for High Occupancy.

β is a sensitivity parameter and ∂ is a high occupancy penalty representing the additional travel and difficulty in arranging passengers.

∂ is calibrated to match observed HOV and SOV splits. For forecast years, ∂ can be calculated from the forecast year Reference Case runs.

The next step is the calculation of *To-Home* and *Non-Home Based* matrices for AM peak and Inter-Peak periods, and *From-Home*, *To-Home* and *Non-Home Based* matrices for the PM peak period. This is undertaken through the normal reverse processing method, where the same reverse factors are applied to HOV trips and SOV trips.

The person peak period are then reduced from peak period to peak hour and converted from person to vehicle using HOV Occupancy Matrices (SOV occupancy is 1). The HOV occupancy matrices must be created by the user for the particular study.

Then, incremental adjustments are applied. These are not split between SOV and HOV. They apply to the whole car vehicle matrices. The SOV / HOV split before the incremental adjustments is saved and applied to the post incremental adjustments car matrix.

No change occurs to the creation of the PT matrices.

Cost Skimming / Generalised Cost Calculation

The generalised cost matrices are skimmed from the Highway and PT assignments. However with the HOV modelling, the Highway cost skimming produces separate cost matrices for SOV and HOV.

The two generalised cost matrices for Car SOV and Car HOV need to be combined to get a unique Generalised Cost matrix, as required for the mode split and the destination choice for the start of the next external demand model loop.

SOV and HOV cost were initially combined to calculate an average cost. However, during initial testing this average cost resulted in an increase for both HOV and SOV demand. The increase in the SOV flow was quite significant and not in line with expectations.

After investigation, it was clear that the use of average cost was the source of the problem. Therefore, it was decided to use change in composite cost instead of average cost, as explained below.

For average costs:

$$C_{AV} = C_{HO} + P_{SO} * (C_{SO} - C_{HO}) \quad (1)$$

For composite cost:

$$C_{COMP} = C_{SO} - (\ln P_{SO} / \beta) \quad (2)$$

For both equations P_{SO} is the person proportion for single occupancy, not the vehicle proportion.

We use the change in composite costs between 'base' and 'scheme' to add to the base costs for input to the destination choice. Using formula (2) above for the low occupancy only:

$$\Delta C_{COMP} = C_{SCHEME} - C_{BASE} + \ln (P_{BASE} / P_{SCHEME}) / \beta$$

Adding in C_{BASE} this then reduces to:

$$C = C_{SCHEME} + \ln (P_{BASE} / P_{SCHEME}) / \beta \quad (3)$$

For O/D movements which are not in scope for the scheme is being tested then equation (3) reduces to C_{SCHEME} which is the standard cost for both low and high occupancy. So there is no need to make any corrections to the calculation, it will apply to all movements.

HOV Modelling Feature

The HOV modelling new feature has no significant impact on model results when no specific HOV lane is introduced (ie no network change). This means the demand matrices created by the demand model – with or without HOV modelling feature – will be similar, but not the same, when adding SOV and HOV car matrices together.

As the matrices will not be quite the same when running Reference Case runs with HOV turned On/Off, it is recommended that any tests with HOV have a reference case with HOV turned on.

Parameter Calibration

The parameters used in the HOV Model are derived from a stated preference survey, for which the outcomes are contained in separate report (TMfS High Occupancy Vehicle Lane: Stated Preference Research, MVA Consultancy, September 2008).

Appendix K – Macro Time of Day Choice Modelling

Macro Time of Day Choice

Macro Time of Day (MTOD) choice relates to changing the time period of travel in response to relative changes in the costs of travel between time periods.

Methodology

The methodology for implementation of MTOD, including the conditions for when it is recommended for inclusion in the demand model, the position in the model hierarchy and the choice of parameter values, is contained in the Guidance on Variable Demand Modelling published in WebTAG unit 3.10. The key points in the guidance are:

- Paragraph 1.8.3 of TAG Unit 3.10.3 says, “Macro time period choice should be considered when strong cost differentials between time periods are expected to develop or change.” In particular the introduction of differential charges for road use or public transport between peak and inter peak time periods; and
- Paragraph 1.11.17 of TAG Unit 3.10.3 says, “when long time periods, of the order of three hours are being modelled, macro time period choice should be positioned either just before or just after main mode choice in the model hierarchy with parameter values similar in magnitude to the main mode choice parameter values.”

Given that there has been little practical experience on implementing this choice process it was deemed appropriate to take on board this guidance in developing MTOD in TMfS:07, since this guidance was developed taking on board all currently available research on the topic.

Implementation

The implementation of MTOD has the following features:

- it has been implemented before main mode choice in the model choice hierarchy, which is consistent with the guidance;
- the logsum composite costs are used in the MTOD choice process. The implication of this is that changes in relative road congestion between time periods will also influence time period choice. The reason for this is that average tolls by time period cannot be used alone for MTOD choice because it is possible that average toll paid per vehicle in the inter peak could be larger than that for the morning peak even though the basic toll rates are lower in the inter peak;
- the scaling parameter will need to lie between 0.0 and 1.0 and preferably close to 1.0 in order to be consistent with the guidance. The value initially input into the model is 0.8, however, this may be refined when testing a live application;
- it has been included in the demand model as an optional feature. It is recommended that it is used only for model applications where there is the introduction of differential charging for road use between time periods, which is also consistent with the guidance;

- it is implemented for the morning peak and the inter peak periods only since it applies only to 'From-Home' trips, which are not modelled explicitly in the Evening Peak; and
- the process generates a pre-peak matrix for the morning peak. The pre-peak matrix creates 'To-Home' in the other time periods, using the Morning Peak reverse factors. The process is done by journey purpose and at the person trip stage. The model is applied separately for each row in the matrix.

The model is based on an incremental logit formulation. For the morning peak we have the model formulae:

P_{pre} , P_{peak} , P_{inter} are the base proportions in each time period. Note that we do not have P_{pre} so an estimate is made and it is set to 0.2; and

P'_{pre} , P'_{peak} , P'_{inter} are the forecast proportions in each time period.

Then the Macro Time of Day Choice is calculated as:

$$P'_{PEAK} = \frac{1}{(1 + A \exp(\beta(U_{IP} - U_{PEAK})) + B \exp(\beta(U_{PRE} - U_{PEAK})))}$$

$$P'_{INTER} = \frac{1}{(1 + A \exp(\beta(U_{PEAK} - U_{INTER})) + B \exp(\beta(U_{PRE} - U_{INTER})))}$$

$$P'_{PRE} = 1 - P'_{INTER} - P'_{PEAK}$$

$$\text{where : } A = P_{IP} / P_{PEAK}, B = P_{PRE} / P_{PEAK}$$

and:

P'_i are the new trip end productions for origin zone i by time period;

P_i are the original trip end productions for origin zone i by time period;

U_i are the composite logsum utilities for origin zone i by time period; and

β are the macro time of day choice parameters.

The base proportions of 'From-Home' trips in the Morning Peak and Inter-Peak were calculated from model data at the 'From-Home' trip end level, along with the assumption that $P_{pre}=0.2$.

The position of Macro Time of Day Choice within the model hierarchy is shown in Appendix A.

Appendix L – Trip Generation

Trip End Model

The Trip End Model Uses 88 person/household types in the calculations it undertakes. These are a combination of 11 person types and 8 household types.

The person types used are:

- Children (0-15);
- Males in Full Time Employment (16-64);
- Males in Part Time Employment (16-64);
- Male Students (16-64);
- Male Unemployed (16-64);
- Male 65+;
- Females in Full Time Employment (16-64);
- Females in Part Time Employment (16-64);
- Female Students (16-64);
- Female Unemployed (16-64); and
- Female 65+.

The Household Types used are:

- 1 Adult with No Car;
- 1 Adult with 1+ Car;
- 2 Adult with No Car;
- 2 Adult with 1 Car;
- 2 Adult with 2+ Car;
- 3+ Adult with No Car;
- 3+ Adult with 1 Car; and
- 3+ Adult with 2+ Car.

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For more information visit www.mvaconsultancy.com

Abu Dhabi

Suite 118
The Avenue Business Centre, Emirates Tower
P.O. Box 33763, Abu Dhabi, UAE
T: +971 (0)2 412 4118

Birmingham

Second Floor, 37a Waterloo Street
Birmingham B2 5TJ United Kingdom
T: +44 (0)121 233 7680 F: +44 (0)121 233 7681

Dubai

Office 402, Building 49, Dubai Healthcare City
PO Box 123166, Dubai, UAE
T: +971 (0)4 433 0530 F: +971 (0)4 423 3613

Dublin

First Floor, 12/13 Exchange Place
Custom House Docks, IFSC, Dublin 1, Ireland
T: +353 (0)1 542 6000 F: +353 (0)1 542 6001

Edinburgh

Stewart House, Thistle Street, North West Lane
Edinburgh EH2 1BY United Kingdom
T: +44 (0)131 220 6966 F: +44 (0)131 220 6087

Glasgow

Seventh Floor, 78 St Vincent Street
Glasgow G2 5UB United Kingdom
T: +44 (0)141 225 4400 F: +44 (0)141 225 4401

London

Second Floor, 17 Hanover Square
London W1S 1HU United Kingdom
T: +44 (0)20 7529 6500 F: +44 (0)20 7529 6556

Lyon

11, rue de la République, 69001 Lyon, France
T: +33 (0)4 72 10 29 29 F: +33 (0)4 72 10 29 28

Manchester

25th Floor, City Tower, Piccadilly Plaza
Manchester M1 4BT United Kingdom
T: +44 (0)161 236 0282 F: +44 (0)161 236 0095

Marseille

76, rue de la République, 13002 Marseille, France
T: +33 (0)4 91 37 35 15 F: +33 (0)4 91 91 90 14

Paris

12-14, rue Jules César, 75012 Paris, France
T: +33 (0)1 53 17 36 00 F: +33 (0)1 53 17 36 01

Woking

Dukes Court, Duke Street, Woking
Surrey GU21 5BH United Kingdom
T: +44 (0)1483 728051 F: +44 (0)1483 755207

Email: info@mvaconsultancy.com

Offices also in

Bangkok, Beijing, Hong Kong, Shenzhen and Singapore

mvaconsultancy