Transport Model for Scotland

Demand Model Development – 2005 Rebase
Final Report

Prepared for
Transport Scotland

May 2007

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Document Control

Project Title:	**TMfS**
MVA Project Number:	C32142
Document Type:	Report
WP Reference:	mjb
Directory & File Name:	H:\Contracts\Live\C3214200_Transport Model for Scotland\Reports\TMfS05 Cal Val\TMfS05 Demand Model Report\Final\TMfS05 Demand Model Development Report

Document Approval

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Issue	Date	Distribution	Comments
1	5/9/06	Chris Robinson Graham Bell	First Draft
2	11/10/06	Stephen Canning	Draft
3	13/10/06	Kevin Lumsden	Draft for Review
4	29/11/06	Transport Scotland STPR Team TTAA	Draft
5	15/05/2007	Transport Scotland STPR Team TTAA TMfS User Group	Final

1 Introduction

1.1 Model Background

1.1.1 In 2001, MVA was commissioned by the Scottish Executive (now Transport Scotland) to undertake the Transport Model for Scotland (TMfS) project. The purpose was to build on existing transport models (eg CSTM3 and CSTM3A) and develop, support and maintain a methodologically enhanced and geographically expanded multi-modal forecasting tool.

1.1.2 The development of TMfS was completed in August 2004. The model has a Base Year of 2002. Since completion, the model has been used for a range of infrastructure and policy assessments by MVA, other consultants, Local Authorities, the Scottish Executive and Transport Scotland.

1.2 2005 rebase

1.2.1 In December 2005, MVA was instructed by Transport Scotland to undertake a rebase of TMfS to a 2005 Base Year. This work involves the update and enhancement of the model to incorporate newly available data and other procedural enhancements.

1.2.2 This report describes the rebase of the TMfS Demand Model to a 2005 Base Year. Separate reports detail the other aspects of the TMfS 2005 rebase such as the Highway Assignment Model and Public Transport Model as follows:

- TMfS05 HAM Cal Val Final Report, MVA May 2007; and
- TMfS05 PTAM Cal Val Final Report, MVA May 2007.

1.2.3 This report also describes the calibration of the demand model. Throughout the report, reference is made, where appropriate, to the relevant sections of the Enhancement Report, which describe changes to the demand modelling procedure from the original TMfS.

1.2.4 Throughout this report, the original 2002 Base Year TMfS network will be referred to TMfS:02 and the new TMfS 2005 Rebase Model as TMfS:05.

1.2.5 This report assumes that the reader is familiar with the terminology and processes involved in transport model procedures of this nature. For further information, please go to www.tmfs.org.uk.

1.3 Model Objectives

1.3.1 The key objectives of TMfS are to:

- provide robust traffic forecasts on all Trunk Roads within the model area over a twenty year horizon;

- enable traffic, economic and land-use assessments of proposed major inter-urban road schemes for corridor assessment and route option assessment;

- test the effects of the interaction between major inter-urban road and Public Transport schemes and major transport policy options such as;

  - schemes to improve inter-urban Public Transport;

  - schemes or policies aimed at reducing congestion in accordance with the Road Traffic Reduction Act, National Targets Act and Transport White Papers;

  - schemes which introduce road user charging (road tolls or congestion charging); and

- provide consistent information and a framework for local scheme models as a basis for the development of Local Transport Strategies or with a view to testing potential strategies.

1.4 Overall Model Structure

1.4.1 A diagram of the overall model structure is illustrated in Figure 1.1. The demand model components, which are the subject of this report, are shown in red. Appendix A of this report contains the detailed specification of each of the sub-models and processes used within the TMfS demand model. Throughout this report, some of the various modules presented in Appendix A are discussed in more detail with respect to development and performance. As noted in Appendix A, the descriptions included are intended to be sufficiently detailed for readers to understand the functioning of the demand model and its components. It is not intended to include a description of every component of the model.

1.5 Structure of Report

1.5.1 Following this introductory Chapter, this Report includes the following Chapters:

- Chapter 2 describes the model structure;
- Chapter 3 describes the development of the trip and cost matrices used in the model calibration;
- Chapter 4 describes the destination choice model calibration;
- Chapter 5 describes the calibration of the mode choice model;
- Chapter 6 describes the procedures for the creation of return trips and *non-home-based* trips;
- Chapter 7 describes the trip end model;
- Chapter 8 describes time of day choice within TMfS;
- Chapter 9 covers model realism testing;
- Chapter 10 describes the forecasting procedures; and
- Chapter 11 contains the conclusions.

2 Model Overview

2.1 Model Structure

2.1.1 The detailed model structure is shown in Figure 2.1. The model is an enhanced four-stage model, which incorporates the following stages/choices (traditional elements of a four-stage model are denoted in bold):

- **trip generation**;
- trip frequency;
- **mode choice**;
- **destination choice**;
- peak spreading;
- **route choice** (assignment); and
- Park & Ride amendments.

2.1.2 The principal enhancements to model structure in comparison with TMfS:02 is that an additional step has been introduced into the demand model structure to make amendments to reflect Park and Ride usage within the modelled area and that the effects of crowding have been included in the assignment procedure for Public Transport.

2.1.3 The order of choices for mode and destination choice remains the same as for TMfS:02. That is, destination choice is more sensitive than mode choice. This is determined by the relative sizes of the calibrated parameters for mode and destination choice.

2.1.4 The Demand Model is designed to synthesise travel demand, changes in which are used to modify Base Year travel matrices 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.

2.1.5 The inputs to the Demand Model in forecast mode are:

- trip productions and attractions;
- generalised costs of travel by Highway and Public Transport modes from the assignment models; and
- model parameters.

2.1.6 The main model development process was the calibration of the parameters that define the Demand Model. As well as this programming of the model, the model development process consisted of the preparation of the required model inputs and the testing of model procedures. In addition, the sensitivity of the model outputs to changes in generalised cost inputs was tested to demonstrate the various elasticities implied by the model (see Chapter 9).

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

- assignment matrices from the Highway and Public Transport Assignment Models - data sources for these models are described in the relevant calibration/validation reports;
- roadside interview survey data;
- Public Transport survey data;
- generalised costs of travel from the Highway and Public Transport Assignment Models; together with;
- Scottish Household Survey; and
- Planning Data from TELMoS.

2.2 Zone System

2.2.1 The level of spatial detail is illustrated by way of the zone system, in Figures 2.2 to 2.4. The CSTM3 zone system formed the basis of the TMfS:02 zone system, with the principal changes of increasing the geographical coverage of the model to include North East Scotland (and consequently the level of spatial detail in the North East) and that the model boundaries were made compatible with 2001 Census Output Area Boundaries. For TMfS:05, four additional zones were added – namely: Edinburgh Airport, Aberdeen Airport, Prestwick Airport and Royal Bank of Scotland Headquarters at Gogar.

2.2.2 In total, there are 1137 zones, of which zones numbered up to 1096 are internal study area zones. Zones 1097-1100 are the four airport zones (Glasgow Airport having a zone already). The remaining zones (1101 to 1037) are external to the modelled area.

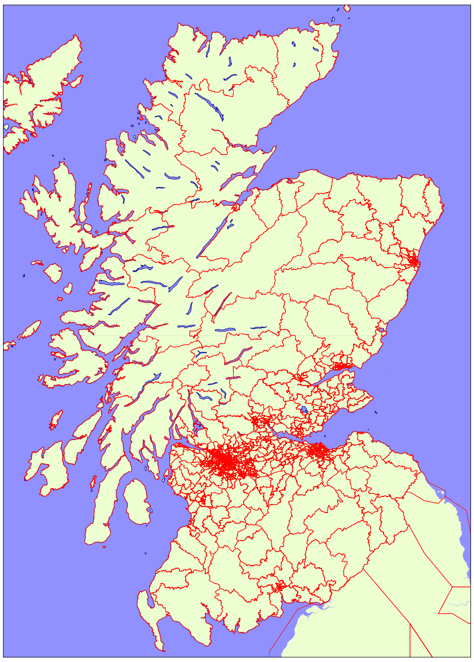


Figure 2.1 TMfS Spatial Detail: Scotland Wide

Figure 2.2 TMfS Spatial Detail: North East Scotland

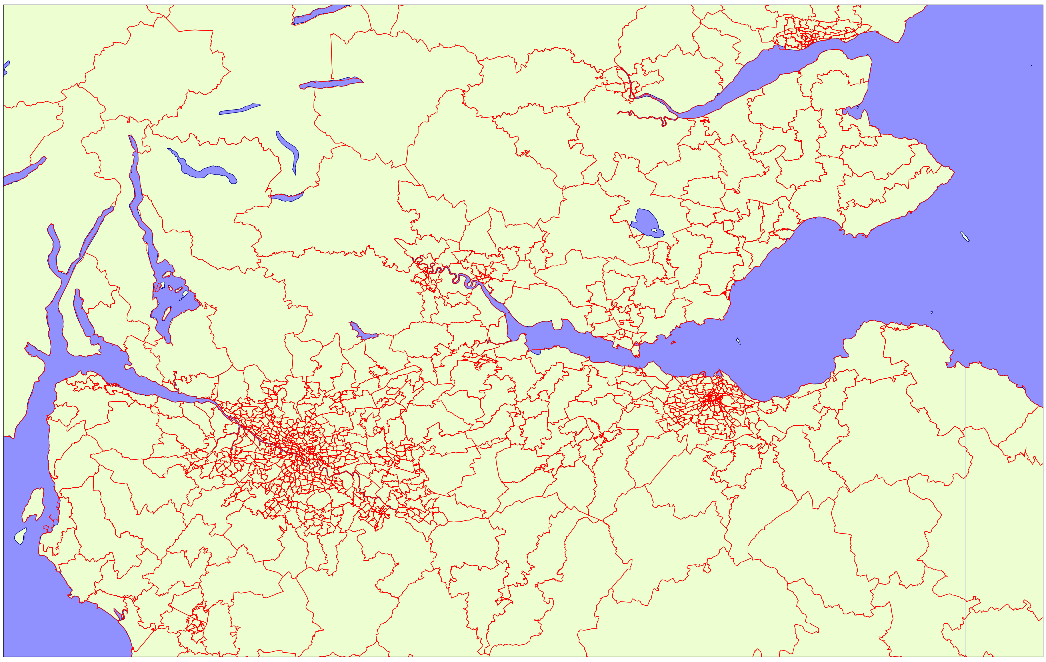


Figure 2.3 TMfS Spatial Detail: Central Scotland

2.2.3 In addition to the zone system, a three sector system was used during the development of the Demand Model parameters. Figure 2.5 presents the three sector zoning system. The correspondence between the zone and the sector system is included in Appendix B.

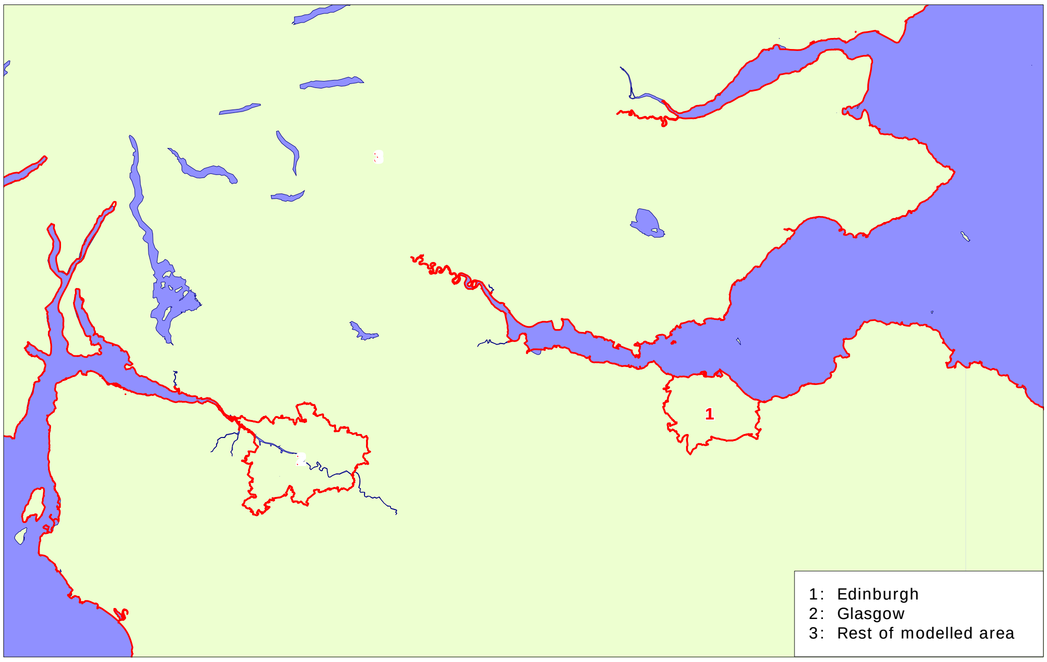


Figure 2.4 3 Sector Area

2.3 Journey Purposes and Time Periods

2.3.1 The Demand Model uses five 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 employers time);
- ***Home-Based* Other (HBO)** – Travelling from home to a Non-Work related location such as shopping or leisure;
- ***Home-Based* Employers Business (HBEB**) – Travelling from home to a destination where you are in employers time as soon as you leave the home;
- ***Non-Home-Based* Other (NHBO)** – Travelling from a *non-home-based* origin to a destination such as from work to shops during lunchtime or from shops to work; and
- ***Non-Home-Based* Employers Business (NHBEB)** – Travelling during employers time such as attending a business meetings through the day.

in addition, two person types:

- **non-Car available**; and
- **Car available**.

(Note: Car availability is defined by the level of household Car ownership.)

2.3.2 Four user classes are included in the highway assignment model:

(1) **Cars Non-Work**;

(2) **Cars In-Work**;

(3) **light goods vehicles**; and

(4) **heavy goods vehicles**.

2.3.3 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 Demand Model requires generalised costs by mode for Non-Work and In-Work, as described in Table 2.1. The generalised costs are skimmed from the Calibrated and Validated AM Peak and Inter Peak highway and Public Transport models, using generalised cost parameters shown in Table 2.2 and Table 2.3.

Table 2.1 Generalised Cost - Journey Purpose Equivalence

Period	Cost Skim	Demand Model Journey Purpose
AM Peak	In-Work	*home-based* employers business
	Non-Work	*home-based* work & *home-based* other
Inter Peak	In-Work	*home-based* employers business
	Non-Work	*home-based* work & *home-based* other

2.4.2 The calculation of generalised cost coefficients for the base year highway assignment model follows the recommended approach in Transport Economics Note (TEN). The parameter values were calculated based on the most up to date version of TAG Unit 3.5.6 available at the time of model development. The highways generalised cost equation by user class is shown in Table 2.2.

Table 2.2 Highways Assignment Model Coefficients for Base Year

Mode	Time coefficient	Distance coefficient	Average Toll coefficient
Cars In-Work	1.0	0.2114	0.0530
Cars Non-Work	1.0	0.3161	0.1511
LGV	1.0	0.6694	0.0237
OGV	1.0	2.5253	0.0237

2.4.3 The average toll co-efficient shown in Table 2.2 was used for cost skimming for input to the demand model. For the highway, assignment procedure the toll co-efficient was subject to variation in order to simulate a distribution of values of time. This process, known as time cost equilibrium, is described in more detail in the Highway Assignment Model Calibration and Validation Report.

2.4.4 The base year generalised cost coefficients for the Public Transport assignment model are summarised in Table 2.3.

Table 2.3 Public Transport Assignment Model Coefficients for Base Year

Description	Coefficient
Parameter:	
In vehicle time:	
bus	1.5
rail	1.0
Wait Time Factor:	
Inter Urban Services	1.0
Urban Services	1.8
Minimum Wait Time	0 minutes
Maximum Wait Time	60 minutes
Walk Time Factor (All Link Types)	1.6
Transfer Penalty	
bus to bus	10 mins
rail to rail or underground and vice versa	5 mins
bus to rail/underground and vice versa	10 mins
Value of time (2002 prices and values):	
In-Work	2016.169/hr
Non-Work	489.781/hr

2.4.5 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 taken from the most up to date version of TAG (Unit 3.5.6) available at the time of model development and are in 2002 prices and values.

2.4.6 It should be noted that the parameters shown in Table 2.3 have changed significantly from TMfS:02, this is due to the introduction of crowding within the PT model.

2.4.7 The calculation of 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;
- Glasgow;
- Edinburgh;
- Perth;
- Stirling:
- Dunfermline; and
- Dundee.

2.5.2 Appendix D details the application of parking charges within the model structure.

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 Non-Work, Light Goods Vehicles (LGVs) and Other Goods Vehicles (OGVs). In the case of Public Transport, the matrices are person trip matrices.

2.6.3 The network assignment models were used to create the base generalised cost matrices, which are required for the development of the Demand Model.

2.7 Trip Ends

2.7.1 Trip Ends are basic data (as opposed to parameters) for the Demand Model. The Trip Ends are required by production and attraction, by mode, by time period and by the five journey purposes (as described in Section 2.3) used in the model. The Trip Ends have been estimated using a factoring process on the base year hourly assignment matrices, leading to the creation of matrices by journey purpose for Morning and Inter Peak periods.

2.7.2 The factors were derived from an analysis of the roadside interviews and Public Transport interviews undertaken for the development of TMfS for the highway matrices and Public Transport matrices respectively. This process is described in Chapter 3.

2.7.3 Forecasting for Trip Ends is undertaken using the trip rates included in the DfT National Trip End Model (NTEM). These rates are, applied by mode, Car availability; time period and journey purpose to planning data provided by the TMfS Land Use Model TELMoS.

2.7.4 It should be noted that because the base level of demand is determined by observed count and travel pattern data, there will be inconsistencies between the base trip ends and the planning data. This is due to a number of factors including; survey inaccuracy, lack of intra-zonal trips and zone size.

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, although the latter is not a prime objective in the case of incremental models.

2.8.2 The base year demand model parameters include distribution model sensitivity parameters, mode choice scaling factors, mode specific constants, and K-factors to adjust model fit if required.

2.8.3 The sensitivity parameter values have been calculated specifically for this model using local data. The derivation of these parameters is described in Chapters 4 and 5.

2.9 Sensitivity Testing

2.9.1 The objective of the sensitivity testing is to see how the model outputs change in response to changes in model inputs. This testing has been used to calculate elasticities for comparison with independent sources and thus demonstrate the acceptability of the model performance.

2.9.2 The sensitivity tests were carried out by making changes to the generalised cost matrices as input to the Demand Model internal loops. As well as for calculating elasticities, the tests were designed to test the overall stability of the Demand Model. Three main tests were specified:

(1) 20% increase in fuel price;

(2) 20% increase in PT fares;

(3) 20% increase in Car journey times; and

2.9.3 The results of these tests are reported in Chapter 9.

2.10 Forecasting Procedures

2.10.1 The main focus of this report is on the tasks carried out in establishing the Base Year Demand Model. In practice, the model is primarily intended as a forecasting tool and therefore, in addition, a description of the necessary procedures for using the model for forecasting is included in Chapter 10.

3 Trip and Cost Matrices

3.1 Introduction

3.1.1 The principal sources of data required for the calibration of the demand model were as follows:

- person trip matrices by journey purpose, mode and time period;
- trip productions and attractions by journey purpose, mode and time period;
- generalised costs of travel from the assignment models, journey purpose, mode and time period;
- roadside interview data. A list of all RSI sites used in model development can be found in the Highways Calibration Report and at the following web link:

  www.tmfs.org.uk/Database/Documents/All%20RSI%20Site%20Descriptions.xls

- parameters for vehicle occupancy and journey purpose breakdowns from TMfS:02 and forecast changes in vehicle occupancy from TAG;
- Scottish Household Survey; and
- Planning Data from TELMoS.

3.1.2 The person trip matrices (by time period and travel purpose) were required for calibration of the demand model sensitivity parameters and constants (K-factors). Generalised cost matrices are also required for calibration of the demand model sensitivity parameters and constants. Parameters for vehicle occupancy and journey purpose breakdown were derived from recent roadside interview data supplemented by existing parameters from CSTM3 in geographical sectors where there was insufficient recent survey data.

3.1.3 The process is described in detail in the remainder of this Chapter.

3.2 Highway Matrix Development

3.2.1 The detailed process for creating the person trip matrices for journey purpose for Car is shown in Figure 3.1. The procedure takes into account zonal planning data in allocating Trip Ends to zones. The intention is to ensure that large numbers of *from-home* trips are not allocated to zones, which are primarily employment zones.

3.3 The process is as follows:

(1) converting the peak hour highway assignment matrices to time period using 'Hour to Period' factors calculated from TMfS RSI matrices. The factors are by 3*3 sectors;

(2) obtaining the initial journey purpose matrices by applying the CSTM3 journey purpose factors to the time period Car matrices, eg:

HBW Car = HBW factors * Car Non-Work

HBO Car = HBO factors * Car Non-Work

HBEB Car = HBEB factors * Car In-Work

NHBO Car = NHBO factors * Car Non-Work

NHBEB Car = NHBEB factors * Car In-Work

(3) the trip end totals by sector (Edinburgh, Glasgow, and Other) from the initial matrices were used as a control total;

(4) create the initial zonal journey purpose Trip Ends by multiplying the highway assignment Trip Ends (by time period) by the Trip Ends parameters;

(5) control the initial zonal Trip Ends to match the trip end totals at the three sector level as described in (3) above to form the final Trip Ends;

(6) create journey purpose Car matrices were generated by Furnessing the initial matrices to the final Trip Ends to give the final journey purpose Car matrices; and

(7) applying the Car occupancy factors to create the final journey purpose person matrices.

Hour to Period Factors

3.3.1 These factors are used to create hourly matrices for assignment from the period matrices created in the demand model. They have also been used in reverse to create time period matrices from hourly assignment matrices, for use in model calibration.

3.3.2 The factors have been calculated at the 3*3 sector level where Sector 1 is Edinburgh, Sector 2 is Glasgow and Sector 3 is the remainder of the study area.

3.3.3 The factors were derived mainly from the TMfS roadside interview data. However, due to insufficient data for intra-Edinburgh trips (Sector 1 to Sector 1) and trips between Edinburgh and Glasgow (Sector 1 to Sector 2 and reverse) the factors for these movements were taken from CSTM3.

3.3.4 For the Inter Peak period, the period to hour factor is 1/6 for both In-Work and Non-Work. The factors for the AM Peak and Evening peak periods are shown in Table 3.1.

Table 3.1: Period to Hour Factors

Sector	1	2	3
Car In-Work AM Peak			
1	0.411	0.329	0.361
2	0.330	0.403	0.375
3	0.366	0.395	0.380
Car Non-Work AM Peak			
1	0.411	0.329	0.351
2	0.330	0.407	0.375
3	0.375	0.394	0.380
Car In-Work Evening peak			
1	0.356	0.335	0.365
2	0.367	0.399	0.394
3	0.361	0.374	0.379
Car Non-Work Evening peak			
1	0.356	0.335	0.375
2	0.367	0.403	0.393
3	0.352	0.374	0.379

Journey Purpose Factors

3.3.5 Journey purpose factors at the 3*3 sector level were taken from CSTM3 in order to create the initial vehicle matrices by purpose. As mentioned above (in Section 3.3.3), there was insufficient data in the TMfS roadside survey data to calculate these factors for all sectors.

3.3.6 The journey purpose factors are shown in Tables 3.2 and 3.3.

Table 3.2: Journey Purpose Factors AM Peak Period

Sector	1	2	3
HBW *from-home*			
1	0.605	0.756	0.769
2	0.820	0.588	0.688
3	0.788	0.758	0.692
HBO *from-home*			
1	0.229	0.154	0.111
2	0.043	0.241	0.105
3	0.161	0.172	0.175
HBEB *from-home*			
1	0.408	0.479	0.433
2	0.464	0.454	0.222
3	0.438	0.595	0.382
NHBO			
1	0.075	0.059	0.048
2	0.116	0.079	0.059
3	0.028	0.045	0.053
NHBEB			
1	0.573	0.517	0.549
2	0.536	0.524	0.748
3	0.550	0.396	0.599

Table 3.3: Journey Purpose Factors Inter Peak Period

Sector	1	2	3
HBW *from-home*			
1	0.117	0.095	0.079
2	0.138	0.094	0.075
3	0.110	0.142	0.106
HBO *from-home*			
1	0.356	0.295	0.255
2	0.239	0.387	0.206
3	0.441	0.358	0.390
HBEB *from-home*			
1	0.091	0.067	0.062
2	0.058	0.098	0.036
3	0.086	0.155	0.09
NHBO			
1	0.241	0.349	0.192
2	0.400	0.238	0.207
3	0.224	0.212	0.179
NHBEB			
1	0.835	0.860	0.835
2	0.908	0.822	0.848
3	0.881	0.769	0.836

Initial Zonal Trip Ends

3.3.7 The process for calculating the initial trip productions and attractions by journey purpose and time period was developed from the TMfS roadside survey data along with zonal planning data giving the level of employment and employed persons in each zone. The process used was the same as that used for TMfS:02.

3.3.8 The set of parameters to obtain vehicle trips productions and attractions in AM Peak and Inter Peak periods are by journey purpose:

- HBW *from-home*;
- HBEB *from-home*;
- HBO *from-home*;
- NHBEB; and
- NHBO.

3.3.9 The process used two data sets:

- zonal planning data; and
- TMfS roadside survey data.

3.3.10 The planning data used in this process was the output planning data for 2005 from the TELMoS model.

3.3.11 The planning data used in this process are total employment and total employed persons. The number of employed persons and number of jobs define the P parameter, which is used to categorise groups of zones in obtaining the trips end parameters. P is defined as:

$$P = \frac{EmployedPerson}{EmployedPerson + Employment}$$

3.3.12 P ranges in value between zero and one. Thus, values of P that are closer to one indicate zones, which are mainly residential whereas zones with small values of P are mainly employment zones.

3.3.13 The process only includes the internal zones of the study area, which covers Edinburgh, Glasgow, Rest of Central Scotland, and Aberdeen area (1096 zones out of 1137 zones).

3.3.14 Zones were allocated to one of twelve groups, which represent ranges of the P parameter. Table 3.4 shows the zone group definition based on the tabulation of number of person trip productions in the roadside survey data in AM Peak period.

3.3.15 In Table 3.4, the total number of trips remains consistent with TMfS.02, however the numbers within each P range changes as a result of the amended planning data used within the TMfS.05.

Table 3.4: Zone Groups Tabulation

Group	P	Total Trips	From Home Trips	From Home Proportion
1	0.00-0.05	1145	288	0.252
2	0.05-0.08	354	143	0.404
3	0.08-0.10	254	88	0.349
4	0.10-0.25	4296	1640	0.382
5	0.25-0.35	2166	1418	0.655
6	0.35-0.45	7031	5140	0.731
7	0.45-0.55	13622	10857	0.797
8	0.55-0.60	20384	17345	0.851
9	0.60-0.65	16373	14311	0.874
10	0.65-0.70	16371	14320	0.875
11	0.70-0.75	9941	8757	0.881
12	>0.75	8514	7631	0.896
Total		**100449**	**81937**	

3.3.16 The trip end parameters were calculated directly from the data. There will be sets of parameters for the productions and attractions, for three time periods, by the defined group, and for three journey purposes:

- HBW *from-home* $= \dfrac{\text{From Home To Work Car Trips}}{\text{Non - Work Car Trips}}$
- HBEB *from-home* $= \dfrac{\text{From Home To Employers Business Car Trips}}{\text{In - Work Car Trips}}$
- HBO *from-home* $= \dfrac{\text{From Home To Other Car Trips}}{\text{Non - Work Car Trips}}$
- NHBEB $= \dfrac{\text{Non Home Based Employers Business Car Trips}}{\text{In - Work Car Trips}}$
- NHBO $= \dfrac{\text{Non Home Based Other Car Trips}}{\text{Non - Work Car Trips}}$

3.3.17 Tables 3.5 to Table 3.8 show the tabulation of Trip Ends and the parameters by zone group for productions and attractions in AM and IP period. Again, the split of trips in the p ranges differs from TMfS.02 due to the differing planning data used in the development of the two models.

Table 3.5: From-Home Trip Production Parameters – AM Peak

		From Home Trips			Total Trips		Parameters		
Group	P	To Work	To EB	To Other	In-Work	Non-Work	To Work	To EB	To Other
1	0.00-0.05	202	33	53	375	770	0.262	0.087	0.069
2	0.05-0.08	104	8	31	118	236	0.443	0.066	0.131
3	0.08-0.10	54	16	19	55	199	0.271	0.286	0.095
4	0.10-0.25	1390	54	196	1284	3011	0.462	0.042	0.065
5	0.25-0.35	1073	102	243	387	1778	0.603	0.263	0.137
6	0.35-0.45	4069	269	803	1237	5794	0.702	0.217	0.139
7	0.45-0.55	8209	759	1889	2256	11365	0.722	0.336	0.166
8	0.55-0.60	13886	771	2687	2229	18154	0.765	0.346	0.148
9	0.60-0.65	11467	579	2265	1602	14771	0.776	0.361	0.153
10	0.65-0.70	11326	669	2325	1610	14761	0.767	0.415	0.158
11	0.70-0.75	7051	301	1405	863	9078	0.777	0.349	0.155
12	> 0.75	6163	478	990	830	7684	0.802	0.576	0.129

Table 3.6: From-Home Trip Attractions Parameters – AM Peak

		From Home Trips			Total Trips		Parameters		
Group	P	To Work	To EB	To Other	In-Work	Non-Work	To Work	To EB	To Other
1	0.00-0.05	10487	469	1691	1359	13132	0.799	0.345	0.129
2	0.05-0.08	3379	218	383	522	4106	0.823	0.418	0.093
3	0.08-0.10	1882	119	468	215	2597	0.725	0.555	0.180
4	0.10-0.25	10052	560	1990	2012	13111	0.767	0.278	0.152
5	0.25-0.35	2826	269	833	593	3933	0.718	0.455	0.212
6	0.35-0.45	11305	516	2273	1816	15543	0.727	0.284	0.146
7	0.45-0.55	6445	576	1177	1703	8545	0.754	0.338	0.138
8	0.55-0.60	5259	320	1076	1130	7242	0.726	0.283	0.149
9	0.60-0.65	6011	433	1516	1661	8563	0.702	0.261	0.177
10	0.65-0.70	3203	299	671	844	4589	0.698	0.354	0.146
11	0.70-0.75	2572	194	598	767	3840	0.670	0.253	0.156
12	> 0.75	1694	111	262	476	2433	0.696	0.234	0.108

Table 3.7: From-Home Trip Productions Parameters – Inter Peak

		From Home Trips			Total Trips		Parameters		
Group	P	To Work	To EB	To Other	In-Work	Non-Work	To Work	To EB	To Other
1	0.00-0.05	58	19	129	1707	3327	0.018	0.011	0.039
2	0.05-0.08	53	0	57	381	809	0.066	0.000	0.071
3	0.08-0.10	30	0	85	407	612	0.049	0.000	0.139
4	0.10-0.25	271	53	686	3760	8280	0.033	0.014	0.083
5	0.25-0.35	215	36	808	1443	3602	0.060	0.025	0.224
6	0.35-0.45	663	171	2662	3828	8794	0.075	0.045	0.303
7	0.45-0.55	1359	308	5662	5348	14108	0.096	0.058	0.401
8	0.55-0.60	2056	440	8465	4712	18806	0.109	0.093	0.450
9	0.60-0.65	1742	277	6473	4067	14533	0.120	0.068	0.445
10	0.65-0.70	2133	510	6583	3621	13444	0.159	0.141	0.490
11	0.70-0.75	1195	187	4013	1952	8072	0.148	0.096	0.497
12	> 0.75	1106	182	3351	1003	6043	0.183	0.182	0.555

Table 3.8: From-Home Trip Attractions Parameters – Inter Peak

		From Home Trips			Total Trips		Parameters		
Group	P	To Work	To EB	To Other	In-Work	Non-Work	To Work	To EB	To Other
1	0.00-0.05	1867	345	6565	3670	12322	0.151	0.094	0.533
2	0.05-0.08	569	64	1266	1311	2877	0.198	0.049	0.440
3	0.08-0.10	254	74	1505	656	2803	0.091	0.113	0.537
4	0.10-0.25	1502	347	5726	4647	11808	0.127	0.075	0.485
5	0.25-0.35	456	124	2186	1307	4069	0.112	0.095	0.537
6	0.35-0.45	1961	253	7246	4548	17637	0.111	0.056	0.411
7	0.45-0.55	889	483	3355	4095	9638	0.092	0.118	0.348
8	0.55-0.60	980	206	3015	2911	9973	0.098	0.071	0.302
9	0.60-0.65	1197	234	4338	4265	12830	0.093	0.055	0.338
10	0.65-0.70	613	112	1899	2066	7497	0.082	0.054	0.253
11	0.70-0.75	424	102	1512	2005	5613	0.076	0.051	0.269
12	> 0.75	290	55	940	1139	4122	0.070	0.048	0.228

3.3.18 Tables 3.9 to 3.12 show the tabulation of the *non-home-based* Trip Ends parameters for AM Peak and Inter Peak periods.

Table 3.9: Non-Home-Based Trip Productions Parameters – AM Peak

		Non-home-based Trips		Total Trips		Parameters	
Group	P	EB	Other	In-work	Non-Work	EB	Other
1	0.00-0.05	321	256	375	770	0.856	0.332
2	0.05-0.08	105	72	118	236	0.890	0.307
3	0.08-0.10	38	59	55	199	0.700	0.295
4	0.10-0.25	1197	842	1284	3011	0.932	0.280
5	0.25-0.35	282	339	387	1778	0.727	0.191
6	0.35-0.45	942	629	1237	5794	0.761	0.109
7	0.45-0.55	1488	820	2256	11365	0.660	0.072
8	0.55-0.60	1450	973	2229	18154	0.650	0.054
9	0.60-0.65	1007	661	1602	14771	0.629	0.045
10	0.65-0.70	930	852	1610	14761	0.578	0.058
11	0.70-0.75	557	412	863	9078	0.646	0.045
12	> 0.75	343	350	830	7684	0.414	0.046

Table 3.10: Non-Home-Based Trip Attraction Parameters – AM Peak

		Non-home-based Trips		Total Trips		Parameters	
Group	P	EB	Other	In-work	Non-Work	EB	Other
1	0.00-0.05	883	901	1359	13132	0.650	0.069
2	0.05-0.08	300	300	522	4106	0.574	0.073
3	0.08-0.10	96	205	215	2597	0.445	0.079
4	0.10-0.25	1449	861	2012	13111	0.720	0.066
5	0.25-0.35	323	228	593	3933	0.545	0.058
6	0.35-0.45	1273	1477	1816	15543	0.701	0.095
7	0.45-0.55	1114	566	1703	8545	0.654	0.066
8	0.55-0.60	786	485	1130	7242	0.696	0.067
9	0.60-0.65	1201	471	1661	8563	0.723	0.055
10	0.65-0.70	536	323	844	4589	0.635	0.070
11	0.70-0.75	560	293	767	3840	0.730	0.076
12	> 0.75	343	178	476	2433	0.722	0.073

Table 3.11: Non-Home-Based Trip Productions Parameters – Inter Peak

		Non-home-based Trips		Total Trips		Parameters	
Group	P	EB	Other	In-work	Non-Work	EB	Other
1	0.00-0.05	1565	1557	1707	3327	0.917	0.468
2	0.05-0.08	355	235	381	809	0.932	0.291
3	0.08-0.10	368	251	407	612	0.906	0.410
4	0.10-0.25	3438	2857	3760	8280	0.914	0.345
5	0.25-0.35	1322	1567	1443	3602	0.916	0.435
6	0.35-0.45	3453	2819	3828	8794	0.902	0.321
7	0.45-0.55	4671	3247	5348	14108	0.874	0.230
8	0.55-0.60	4006	4074	4712	18806	0.850	0.217
9	0.60-0.65	3546	2845	4067	14533	0.872	0.196
10	0.65-0.70	2952	2405	3621	13444	0.815	0.179
11	0.70-0.75	1667	1471	1952	8072	0.854	0.182
12	> 0.75	741	854	1003	6043	0.739	0.141

Table 3.12: Non-Home-Based Trip Attraction Parameters – Inter Peak

		Non-home-based Trips		Total Trips		Parameters	
Group	**P**	**EB**	**Other**	**In-work**	**Non-Work**	**EB**	**Other**
1	0.00-0.05	3303	3682	3670	12322	0.900	0.299
2	0.05-0.08	1237	913	1311	2877	0.943	0.317
3	0.08-0.10	564	806	656	2803	0.860	0.288
4	0.10-0.25	4220	3209	4647	11808	0.908	0.272
5	0.25-0.35	1132	983	1307	4069	0.866	0.242
6	0.35-0.45	4081	5067	4548	17637	0.897	0.287
7	0.45-0.55	3325	2205	4095	9638	0.812	0.229
8	0.55-0.60	2499	2252	2911	9973	0.858	0.226
9	0.60-0.65	3661	2232	4265	12830	0.858	0.174
10	0.65-0.70	1741	1373	2066	7497	0.842	0.183
11	0.70-0.75	1670	982	2005	5613	0.833	0.175
12	> 0.75	883	547	1139	4122	0.776	0.133

Car Occupancy

3.3.19 The Car occupancy factors were for the base year were derived from specific local RSI data. Unlike in TMfS:02, the occupancy factors in TMfS:05 change over time in line with guidance from TAG unit 3.5.6. Previously the occupancy factors were kept the same for all modelled years.

3.3.20 Tables 3.13 to 3.18 present the Car occupancy factors for the base year of the model.

Table 3.13: Car Occupancy Factors - AM Peak Period

Sector		**1**	**2**	**3**
HBW *from-home*				
	1	1.098	1.098	1.098
	2	1.159	1.240	1.159
	3	1.211	1.173	1.166
HBO *from-home*				
	1	1.702	1.702	1.702
	2	1.452	1.476	1.452
	3	1.549	1.448	1.487
HBEB *from-home*				
	1	1.114	1.114	1.114
	2	1.096	1.320	1.096
	3	1.159	1.168	1.159
NHBO				
	1	1.367	1.367	1.367
	2	1.279	1.287	1.279
	3	1.370	1.279	1.323
NHBEB				
	1	1.245	1.245	1.245
	2	1.225	1.176	1.225
	3	1.358	1.191	1.252

Table 3.14: Car Occupancy Factors – Inter Peak Period

Sector	1	2	3
HBW *from-home*			
1	1.225	1.225	1.175
2	1.227	1.228	1.214
3	1.149	1.162	1.172
HBO *from-home*			
1	1.600	1.600	1.786
2	1.608	1.583	1.591
3	1.624	1.594	1.652
HBEB *from-home*			
1	1.198	1.198	1.283
2	1.613	1.287	1.161
3	1.268	1.197	1.222
NHBO			
1	1.520	1.520	1.639
2	1.322	1.361	1.411
3	1.632	1.418	1.464
NHBEB			
1	1.524	1.524	1.171
2	1.324	1.186	1.153
3	1.198	1.139	1.180

Table 3.15: Car Occupancy Factors – Evening Peak Period

Sector	1	2	3
HBW *from-home*			
1	1.365	1.365	1.141
2	1.366	1.231	1.256
3	1.216	1.234	1.302
HBO *from-home*			
1	1.750	1.750	1.428
2	1.598	1.618	1.670
3	1.750	1.748	1.758
HBEB *from-home*			
1	1.290	1.290	1.324
2	1.597	1.324	1.324
3	1.324	1.324	1.324
NHBO			
1	1.645	1.645	1.436
2	1.498	1.373	1.339
3	1.557	1.359	1.527
NHBEB			
1	1.643	1.643	1.324
2	1.497	1.223	1.324
3	1.231	1.252	1.247

Table 3.16: Car Occupancy Factors - AM Peak Period To-Home Trips

Sector		1	2	3
HBW *to-home*				
	1	1.570	1.570	1.570
	2	1.156	1.115	1.156
	3	1.076	1.083	1.173
HBO *to-home*				
	1	1.229	1.229	1.229
	2	1.357	1.225	1.357
	3	1.482	1.153	1.274
HBEB *to-home*				
	1	1.182	1.182	1.182
	2	1.182	1.182	1.182
	3	1.182	1.182	1.182

Table 3.17: Car Occupancy Factors - Inter Peak Period To-Home Trips

Sector		1	2	3
HBW *to-home*				
	1	1.204	1.204	1.184
	2	1.207	1.181	1.160
	3	1.128	1.110	1.160
HBO *to-home*				
	1	1.562	1.562	1.733
	2	1.570	1.642	1.566
	3	1.590	1.645	1.587
HBEB *to-home*				
	1	1.144	1.144	1.192
	2	1.540	1.385	1.130
	3	1.079	1.148	1.172

Table 3.18: Car Occupancy Factors - Evening Peak Period To-Home Trips

Sector		1	2	3
HBW *to-home*				
	1	1.254	1.254	1.247
	2	1.254	1.171	1.174
	3	1.141	1.132	1.167
HBO *to-home*				
	1	1.678	1.678	1.707
	2	1.532	1.586	1.597
	3	1.654	1.546	1.680
HBEB *to-home*				
	1	1.146	1.146	1.218
	2	1.418	1.223	1.295
	3	1.135	1.153	1.165

3.4 Public Transport Matrix Development

3.4.1 The detailed process for creating the person trip matrices by journey purpose and time period for Public Transport is shown in Figure 3.2. The process is similar to the process for Car trips but without the need for vehicle occupancy. The process followed is the same as that used in TMfS:02.

3.4.2 Therefore, the process involved the following steps:

(1) convert hourly Public Transport assignment matrices to time period using factors from CSTM3;

(2) calculate journey purpose Trip Ends by multiplying the Public Transport period Trip Ends by the journey purpose trip end factors; eg

HBW Public Transport Trip Ends = HBW factors * total Public Transport Trip Ends

HBO Public Transport Trip Ends= HBO factors * total Public Transport Trip Ends

HBEB Public Transport Trip Ends= HBEB factors * total Public Transport Trip Ends

NHBO Public Transport Trip Ends= NHBO factors * total Public Transport Trip Ends

NHBEB Public Transport Trip Ends= NHBEB factors * total Public Transport Trip Ends

(3) apply Car availability proportions (Car available, non Car available) to the journey purpose Trip Ends to create final Trip Ends; and

(4) furness the Public Transport matrix to the final trip end controls to give the final Public Transport journey purpose matrices.

Period to Hour Factors

3.4.3 The period to hour, factors for Public Transport were, taken from CSTM3. For the AM Peak, the factor is 0.498, for the Inter Peak period the factor is 1/6 and for the PM Peak the factor is 0.420.

Zonal Trip End Factors

3.4.4 This process for Public Transport followed the same method as recorded for Car trips except that the TMfS Public Transport interview data was used instead of the roadside survey data.

3.4.5 The parameters derived from the analysis for *home-based* trip purposes are shown in Tables 3.19 and 3.20. For *non-home-based* trips, there was insufficient data to develop separate factors by group and single overall parameters were calculated instead. These are shown in Table 3.21. As with the highway Trip Ends, the total trips remain consistent with TMfS.02, but the p ranges show a different split of trips due to the change in planning data.

Table 3.19: From-Home Trip End Parameters – AM Peak

		Productions			Attractions		
Group	P	To Work	To EB	To Other	To Work	To EB	To Other
1	0.00-0.05	0.768	0.036	0.196	0.583	0.018	0.400
2	0.05-0.08	0.815	0.037	0.148	0.781	0.034	0.185
3	0.08-0.10	0.262	0.024	0.714	0.496	0.007	0.496
4	0.10-0.25	0.581	0.037	0.381	0.678	0.015	0.307
5	0.25-0.35	0.780	0.033	0.186	0.671	0.044	0.286
6	0.35-0.45	0.522	0.034	0.444	0.554	0.037	0.409
7	0.45-0.55	0.586	0.028	0.386	0.572	0.021	0.407
8	0.55-0.60	0.656	0.034	0.310	0.568	0.048	0.384
9	0.60-0.65	0.559	0.029	0.412	0.613	0.024	0.364
10	0.65-0.70	0.595	0.015	0.391	0.716	0.022	0.263
11	0.70-0.75	0.562	0.027	0.411	0.710	0.018	0.272
12	> 0.75	0.595	0.014	0.391	0.396	0.018	0.586

Table 3.20: From-Home Trip End Parameters – Inter Peak

		Productions			Attractions		
Group	P	To Work	To EB	To Other	To Work	To EB	To Other
1	0.00-0.05	0.253	0.151	0.597	0.136	0.011	0.853
2	0.05-0.08	0.176	0.000	0.824	0.078	0.099	0.823
3	0.08-0.10	0.000	0.133	0.867	0.069	0.056	0.875
4	0.10-0.25	0.125	0.008	0.867	0.075	0.141	0.784
5	0.25-0.35	0.127	0.037	0.836	0.125	0.043	0.832
6	0.35-0.45	0.124	0.042	0.834	0.149	0.023	0.828
7	0.45-0.55	0.168	0.034	0.799	0.127	0.026	0.847
8	0.55-0.60	0.206	0.035	0.759	0.341	0.020	0.638
9	0.60-0.65	0.188	0.064	0.747	0.284	0.008	0.708
10	0.65-0.70	0.162	0.033	0.805	0.141	0.063	0.796
11	0.70-0.75	0.185	0.173	0.642	0.154	0.096	0.750
12	> 0.75	0.122	0.018	0.860	0.141	0.021	0.838

Table 3.21: Non-Home-Based Trip Ends Parameters

				Final Parameter	
	Total NHB in Total Trips	NHBEB in Total NHB	NHBO in Total NHB	NHBEB	NHBO
AM Period					
Productions	0.039	0.139	0.861	**0.0055**	**0.0339**
Attractions	0.039	0.125	0.875	**0.0048**	**0.0338**
IP Period					
Productions	0.081	0.131	0.869	**0.0106**	**0.0704**
Attractions	0.080	0.129	0.871	**0.0104**	**0.0700**

4 Destination Choice Model Calibration

4.1 Overview

4.1.1 In the model structure for TMfS:05, as for TMfS:02, destination choice is more sensitive than mode choice. The calibration of the destination choice sensitivity parameters and constants must precede the calibration of the mode choice parameters. Thereafter, the mode choice calibration requires as inputs, composite costs output by the destination choice model.

4.1.2 The destination choice sensitivity parameters have been calibrated for each of the five journey purposes, two time (AM and IP) periods and three mode/Car available segments (Car available Car users (C1C), Car available PT users (C1PT) and non Car available PT users (C0PT)). The Cube program 'MVGRAM' was used to calibrate the sensitivity parameters and, based on previous experience in CSTM3 and TMfS:02, separate parameters were calibrated for four area groups in the case of highway trips. These were based on the sector system:

- Sector 1: Edinburgh;
- Sector 2: Glasgow; and
- Sector 3: Remainder of Study Area.

The area groups are then:

- Area 1: sector 1 – sector 1;
- Area 2: sector 2 – sector 2;
- Area 3: sector 3 – sector 3; and
- Area 4: all other sector pairs.

4.1.3 For the *from-home* journey purposes 'employer's business,' (HBEB) and 'other' (HBO), the destination choice models will be run as singly constrained. This enables trips to change destination as a result of a scheme or policy test, which might change accessibility. There are no constraints on the numbers of trips, which must be attracted to zones. This is in contrast with the *home-based* work (HBW) travel purpose, which will be run as doubly constrained. The reason for this is that it is assumed that there is a balance between workers and jobs. In addition, for a particular planning scenario, level of employment related trips in any zone must always remain the same (ie consistent with the planning data).

4.1.4 For *calibration* of the destination choice models, however, all purposes are treated as doubly constrained. For forecasting, in the case of singly constrained models, separate trip attraction parameters are calibrated and input to the process instead of the normal Trip Ends.

4.2 Highway Model Sensitivity Parameter Calibration

4.2.1 The calibration process required the input of person trip matrices for each journey purpose/time period combination along with appropriate generalised cost matrices.

4.2.2 The calibrated sensitivity parameters are shown in Tables 4.1 and 4.2. The values compare well with the parameters calibrated for CSTM3 and TMfS:02.

Table 4.1: Destination Choice Sensitivity Parameters – AM Peak

Area	HBW	HBEB	HBO	NHBEB	NHBO
1	-0.0495	-0.0521	-0.0504	-0.0506	-0.0521
2	-0.1318	-0.1430	-0.1302	-0.1360	-0.1296
3	-0.0614	-0.0637	-0.0613	-0.0625	-0.0636
4	-0.0676	-0.0686	-0.0679	-0.0660	-0.0664

Table 4.2: Destination Choice Sensitivity Parameters – Inter Peak

Area	HBW	HBEB	HBO	NHBEB	NHBO
1	-0.0930	-0.0908	-0.0936	-0.0943	-0.0996
2	-0.1736	-0.1668	-0.1722	-0.1612	-0.1704
3	-0.0679	-0.0622	-0.0663	-0.0629	-0.0671
4	-0.0812	-0.0575	-0.0771	-0.0561	-0.0785

4.3 Public Transport Model Sensitivity Parameter Calibration

4.3.1 As was the case with the Highways calibration, the calibration for PT was carried out for each of the five travel purposes, two time periods and two Car availability groups. However, there was insufficient data to calibrate separate parameters by area group as in the case of the Highway calibration. Single parameters were calibrated therefore, covering the whole matrix.

4.3.2 In some zones there is no easy access to the Public Transport network and consequently the cost matrices contains very large costs for movements to and from these zones. These zones, situated in the outskirts of the model, were excluded from the calibration process.

4.3.3 The sensitivity parameters are shown in Tables 4.3 and 4.4. The parameters compare well with those calibrated previously for CSTM3 and TMfS:02.

Table 4.3: PT Destination Choice Sensitivity Parameters – AM Peak

Travel Purpose	Car Availability	Parameters
HBW	NCA	-0.0194
	CA	-0.0228
HBEB	NCA	-0.0296
	CA	-0.0306
HBO	NCA	-0.0186
	CA	-0.0229
NHBEB	NCA	-0.0295
	CA	-0.0316
NHBO	NCA	-0.0182
	CA	-0.0225

Table 4.4: PT Destination Choice Sensitivity Parameters – Inter Peak

	Car Availability	Parameters
HBW	NCA	-0.0381
	CA	-0.0385
HBEB	NCA	-0.0456
	CA	-0.0472
HBO	NCA	-0.0350
	CA	-0.0376
NHBEB	NCA	-0.0437
	CA	-0.0454
NHBO	NCA	-0.0350
	CA	-0.0380

4.4 Destination Choice Constants

4.4.1 The inclusion of constants (K-factors) ensures that the destination choice model produces trip matrices, which match the matrices input to the calibration process at a sector level. The 3*3 sector system was used for the calculation of K-factors.

4.4.2 The procedure adopted was to run the destination choice model in forecast mode in which there are three production groups (C1C, C1PT, C0PT) and a single combined attraction group.

4.4.3 Comparisons of the model output matrices with the matrices input to the calibration process allowed the calculation of K-factors for each of the sector to sector movements in the three sector system. This process was iterative until the output matrices matched the input matrices to within less than 1% for each sector to sector movement. The results of the validation process are contained in Appendix E.

4.4.4 The calibrated K-factors are presented in Appendix F. There is little concern of the variability of K-factors as they are calculated to ensure goodness of fit. The higher range of variability tends to be within travel purposes that are applied singly constrained as opposed to doubly constrained (eg HBO, HBEB) and where there are lower absolute values of trips, for example in the Inter Peak.

5 Mode Choice Model Calibration

5.1 Overview

5.1.1 Mode choice in TMfS, as in TMfS:02, is less sensitive than destination choice. It is carried out at the trip end level therefore with the output of the model being total Trip Ends by mode (Car (C1C) and Car available Public Transport (C1PT)) and time period for each zone. As well as the calibration of sensitivity parameters, mode constants are calibrated to ensure that the base mode split is replicated.

5.1.2 The mode split is not carried out for the non-Car available segment (C0PT) as this is deemed to be captive to Public Transport. Also, it is not carried out for *non-home-based* trips as the process for creating these trips (as described in Chapter 6) creates Trip Ends by mode as well as by time period.

5.1.3 The inputs to the calibration process are:

- Trip Ends by mode and journey purpose for each zone; and
- Logsum composite costs as calculated using the standard method based on the outputs of the destination choice model. For each zone, these costs represent a weighted average of all costs of travel by mode across all destinations.

5.1.4 The logsum composite costs are calculated based on the inclusion of parking costs for zones, where parking costs have been included. These are the city centre areas in Edinburgh, Glasgow, Stirling, Dunfermline, Perth, Dundee and Aberdeen, as noted in Section 2.5.

5.1.5 The sensitivity parameter calibration was carried out using the maximum likelihood method.

5.2 Sensitivity Parameter Calibration

5.2.1 The mode choice model used the standard binary logit model. The equation is:

$$P_{Car} = 1/\{1 + \exp[\beta * (U_{pt}-U_{Car}-K)]\}$$

Where

P_{Car} = modelled proportion of Car
β = sensitivity parameter
K = constant
U_{Car} = Car logsum composite utility
U_{pt} = Public Transport logsum composite utility

5.2.2 Preliminary analysis of the mode choice data calculated suggested that the variation in average mode choice between zones was masking a much wider variation between groups of destination zones. For this reason, calibration data was prepared based on a sector system rather than preparing single logsum composite utilities and modal proportions for each zone. This increased the number of observations for each sector and created more variation in the utilities and modal shares.

5.2.3 The sector system used was;

For origin zones:

- Edinburgh;
- Glasgow; and
- Other Areas.

For destination zones:

- Edinburgh City Centre;
- Edinburgh Other;
- Glasgow City Centre;
- Glasgow Other; and
- Other Areas.

5.2.4 The sector system is defined in Table 5.1.

Table 5.1: Mode Choice Data Preparation Sector System

	Edinburgh		Glasgow		Other Area
	Other	City centre	Other	City centre	
Edinburgh	A	B	C	D	E
Glasgow	F	G	H	I	J
Other Area	K	L	M	N	O

5.2.5 Data in sectors A, C, D, F and G had either limited numbers of observations or, in the case of sector A showed relatively poor levels of Public Transport service and consequently usage. Data in these sectors was not used in calibration.

5.2.6 The calibration method was defined as follows:

- Parameter for Edinburgh was calibrated using two sets of composite utilities data, which were calculated by column Edinburgh city centre (Cell B) and column Other Area (Cell E);
- Parameter for Glasgow was calibrated using two sets of composite utilities data, which were calculated by column Glasgow other + Other Area (Cell H and Cell J) and column Glasgow city centre (Cell I);
- Parameter for Other Area was calibrated using three sets of composite utilities data, which were calculated by column Edinburgh all (Cell K and Cell L), column Glasgow all (Cell M and Cell N) and column Other Area (Cell O).

5.2.7 The mode choice sensitivity parameters are in Table 5.2.

Table 5.2: Mode Choice Sensitivity Parameters

	Edinburgh	Glasgow	Other Area
AM Peak Period			
HBW	0.836	0.705	0.911
HBO	0.450	0.641	1.000
HBEB	0.648	0.419	0.644
Inter Peak Period			
HBW	0.298	0.453	0.054
HBO	0.238	0.284	0.035
HBEB	0.390	0.055	0.098

5.2.8 The parameters demonstrate that mode choice is more sensitive in the AM Peak compared with the Inter Peak.

5.3 Mode Specific Constants

5.3.1 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 formula:

$$K = (U_{pt} - U_{Car}) + \{(1/\beta) * \log(P_{Car}/(1 - P_{Car}))$$

where:

U_{pt} composite utility for PT

U_{Car} composite utility for Car

β mode choice scaling factor (see Table 5.2)

P_{Car} proportion of Car in base.

5.3.2 This formula has been derived from the mode split formulation and is carried out for each journey purpose. Mode choice scaling factors are required to calculate the constants.

5.3.3 For each forecast year, the mode specific constants are re-calculated to ensure that the implied mode choice when using base year costs is the same as the mode split in the Trip Ends output by the trip end model. This is undertaken using the same formula as for the base, with P_{Car} in this case being the proportion derived from the forecast year Trip Ends rather than the base.

5.3.4 The mode specific constants have not been included in the report, as they are only required to make a match with the base year. These numbers cannot be interpreted, on their own, and therefore there is no benefit in supplying these numbers.

6 Reverse Trips and Non-Home-Based Trip Ends

6.1 Overview

6.1.1 The demand model for TMfS:05 works at the individual time period level with separate models for *from-home* journey purposes for AM Peak, Inter Peak and Evening Peak. Consequently, a different procedure was required for the *to-home* trips, which are now linked to the equivalent *from-home* trips. The opportunity was also taken to link the *non-home-based* trips to *home-based* trips rather than treat as a free standing journey purpose.

6.1.2 The methodology for these processes involved a detailed factor based process, and is described in the remainder of this Chapter.

6.2 *To-Home* Trips

6.2.1 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.

6.2.2 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 three modes – Car, PT Car available and PT non Car available (C1C, C1PT and C0PT respectively).

6.2.3 For *the to-home* situation, there is an additional time period (eg overnight), and additional modes (eg walk, cycle). These were included in the analysis as additional categories to check the calculation of parameters for completeness.

6.2.4 The *to-home* trips can be calculated as follows:

$$T_{ij(to)}^{TMP} = \sum_{t,p,m} \{ \alpha_{TPM}^{tpm} * T_{ji(from)}^{tpm} \} \quad (1)$$

where

$T_{ij(to)}^{TMP}$ = *to-home* person trips from origin *i* to destination *j* in time period **T** for *home-based* purpose **P** by mode **M**

$T_{ji(from)}^{tpm}$ = *from-home* person trips from origin *j* to destination *i* in time period **t** for *home-based* purpose **p** by mode **m**

α_{TPM}^{tpm} = factors by *from-home* time period **t**, *from-home* purpose **p**, *from-home* mode **m**, *to-home* period **T**, *to-home* purpose **P** and *to-home* mode **M**.

6.2.5 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.

6.2.6 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:

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

6.3 Evening Peak Trips

6.3.1 For the Evening Peak, *from-home* trips were generated by factoring the *from-home* trips for the previous time periods.

6.3.2 We then have:

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

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

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.

For *non-home-based* origins:

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

and for *non-home-based* destinations

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

where:

n is the *non-home-based* purpose ie work or Non-Work.

6.4.2 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 the total origins. 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.

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. In addition, In-Work purposes and Non-Work purposes will form two separate user classes in the highway assignment model.

7 Trip End Model

7.1 Car and Public Transport Trip Productions

7.1.1 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.

7.1.2 NTEM has been integrated by DfT into a set of routines to produce trip end forecasts by mode and time period for UK Local Authority Districts. 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.

7.1.3 There are three main components to NTEM:

(1) household Car ownership forecasting;

(2) a demographic model which allocates household and person type planning data to a system of 88 person type categories; and

(3) calculation of Trip Ends by applying trip rates to the numbers of persons in each of the 88 person type categories.

7.1.4 For TMfS there is an associated land use model (TELMOS). 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.

7.1.5 Trip Ends produced for forecast years by this model for each journey purpose, time period and mode/Car availability 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.

7.1.6 This process can be described as:

$$P^f_{m,t,p} = P^b_{m,t,p} * \{ NTEM^f_{m,t,p} / NTEM^b_{m,t,p} \}$$

Where

$P^f_{m,t,p}$ forecast year person trip productions by mode/Car availability m, time period t, and journey purpose p.

$P^b_{m,t,p}$ base year person trip productions by mode/Car availability m, time period t, and journey purpose p.

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

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

7.1.7 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.

7.1.8 The NTEM person type categories are 11 person types and eight household types giving 88 categories in total. The person types are:

- Children (0 to 15);
- Males in full time employment (16 to 64);
- Males in part time employment (16 to 64);
- Male students (16 to 64);
- Male not employed/students (16 to 64) – unemployed plus other inactive;
- Male 65+;
- Females in full time employment (16 to 64);
- Females in part time employment (16 to 64);
- Female students (16 to 64);
- Female not employed/students (16 to 64) – unemployed plus other inactive; and
- Female 65+.

The household types are:

- 1 adult household with no Car;
- 1 adult household with one or more Cars;
- 2 adult households with no Car;
- 2 adult households with one Car;
- 2 adult households with two or more Cars;
- 3+ adult households with no Car;
- 3+ adult households with one Car; and
- 3+ adult households with two or more Cars.

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

7.1.10 The AM Peak, Inter Peak and Evening Peak time periods in NTEM are directly compatible with the TMfS time periods.

7.1.11 The separate modes included in NTEM are:

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

7.2 Trip Attractions and Attraction Factors

7.2.1 The trip attraction process is a parallel procedure in the trip end model to the trip production process. Trip attractions are forecast in NTEM by applying attraction parameters to the number of jobs in each zone. The total employment in each zone is disaggregated into a number of categories of employment based on the standard industrial classification codes (SIC).

7.2.2 The forecasts trip attractions are then used to calculate growth factors by zone to apply to the base year trip attractions, in the same manner as for the trip productions.

7.2.3 Base year trip attractions are for all modes/Car availability categories combines. There are separate trip attractions therefore for each journey purpose and time period. Attractions, however fall into two distinct categories:

(1) attractions for *home-based* work (HBW), which is a doubly constrained purpose in the destination choice model; and

(2) attraction factors *for home-based* employer's business (HBEB) and *home-based* other (HBO) which are singly constrained purposes in the destination choice model.

7.2.4 The attractions in (1) above represent actual Trip Ends, 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.

7.2.5 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 matched those for the base matrices used in the destination choice model calibration.

8 Time of Day Choice

8.1 Background

8.1.1 This Chapter discusses the implementation of Time of Day choice within the TMfS model. Both Peak Spreading and Macro Time of Day choice were tested as part of the model development, however only Peak Spreading has been included in the standard demand model structure.

8.1.2 Peak Spreading is where traffic moves between the Peak hour and the Shoulder Peaks, but remains within the Peak period. This is usually as a result of increased congestion within the Peak hour. The implementation of Peak Spreading is discussed in detail in section 8.2.

8.1.3 Macro Time of Day Choice (MTODC) is where there is a shift out of the Peak period into other time periods. This is usually as a result of road user charging schemes, which have significantly different charges by Time Period.

8.1.4 MTODC was implemented in accordance with VADMA Draft guidance, ie to be less sensitive than mode choice and destination choice. It was, however decided after testing, not to include this as part of the standard demand model. This is discussed in a separate Information Note (MVA, November 2006).

8.2 Peak Spreading

8.2.1 The peak spreading implemented in the model is intended to cover supply led active peak spreading (type (1) above) where increased congestion forces travellers to change their departure time to avoid the worst congestion. A description of the process is included in paragraphs 4.6.4 to 4.6.6 of CSTM3 Final Demand Model Report (MVA, December 1998).

8.2.2 The process is based on the recommendations included in DMRB and is a simplified implementation of an incremental logit model. It is applied to both Do Minimum and Do Something forecasts but is not sensitive to Do Something schemes or policies.

8.2.3 The TMfS peak spreading model is an incremental logit model but operates at the matrix cell level rather than for the whole matrix in aggregate. It is therefore responsive to schemes and policies as well as taking into account the effects of overall traffic growth.

8.2.4 The demand side of the model has the standard incremental logit formula. However, given the run time penalties which would be incurred if additional shoulder peak assignments were to be carried out, the generalised costs for the shoulder peak hours have been approximated (type (2) above) based on the peak hour costs.

8.2.5 The basis of the peak spreading model is that at each outer loop in the demand model we find an approximation of the peak spreading supply/demand equilibrium. This is undertaken by making use of linear approximations to the supply and demand functions, which are valid in the area of interest.

8.2.6 The demand function can be written as:

$$P_{forecast} = P_{base} / [P_{base} + \{ (1 - P_{base}) * (\exp([\beta * \Delta C]) \}]$$

where $\Delta C = (C'_{shoulder} - C'_{peak}) - (C_{shoulder} - C_{peak})$

P_{base} is the base peak hour to period factor

β is a sensitivity parameter

8.2.7 It should be noted that the assumption was made that the flow levels in the two shoulder peaks are equal.

8.2.8 This can be re-written as:

$P_{forecast} = 1 / [1 + \{ ([1/P_{base}]-1) * (\exp([\beta * \Delta C]) \}\}$

8.2.9 A linear approximation of the form:

$P_{forecast} = P_{base} + slope * \Delta C$

can be developed by calculating the slope between two extremes of interest for $P_{forecast}$. If we use the range 0.3 to 0.6 for our extremes then we get the formula

$slope = (0.6-0.3) * \beta / (\ln((1/0.6)-1) - \ln((1/0.3)-1))$

$= 0.3 * \beta / (\ln(0.6667/2.3333))$

$= - 0.2315 * \beta$

8.2.10 The prediction of $P_{forecast}$ using the linear formula was compared with the prediction using the full formula for a range β values. The results showed the linear formula to be a good representation for the range of $P_{forecast}$ considered. The results are independent of the value of β, the value of which determines the sensitivity to ΔC.

8.2.11 For the supply side formulae we have to make an assumption that a linear approximation is valid for our needs. The supply formula has to show the relationship between the peak proportion and the associated cost difference (ΔC) on the assumption of a fixed peak period demand.

8.2.12 Shoulder peak costs are estimated by a procedure whereby:

- link flows from a converged assignment are reduced by a percentage which represents the *average* ratio of shoulder peak to peak flows;
- link journey times are modified to be consistent with the reduced flows; and
- minimum costs are then skimmed from the network.

8.2.13 This method then gives an estimate of the shoulder peak costs for each cell in the matrix. It is however an approximation since we have to use an average flow reduction rather than cell specific reductions. It was judged however to be a suitable basis for estimating supply functions for each matrix cell.

8.2.14 The method for estimating shoulder costs therefore gives us an estimate of ΔC at each outer loop of the model for each cell in the matrix. We therefore know one point on the supply curve. This point is (P_n, ΔC_n) where n is the number of the outer loop.

8.2.15 There is also another point on the supply curve, which is known. When $P_{forecast}$ =1/3 then ($C'_{shoulder} - C'_{peak}$) = 0. Therefore $\Delta C = -(C_{shoulder} - C_{peak})$. For convenience this can be called ΔC_{base}. The second point therefore is (1/3, ΔC_{base}).

8.2.16 The supply relationship can be defined as:

$P = \mathbf{a}_s + (\mathbf{b}_s * \Delta C)$

Where $\mathbf{a}_s$ and $\mathbf{b}_s$ are parameters.

8.2.17 From the two known points we have:

$0.333 = \mathbf{a}_s + (\mathbf{b}_s * \Delta C_{base})$

$P_n = \mathbf{a}_s + (\mathbf{b}_s * \Delta C_n)$

From which we calculate

$\mathbf{b}_s = (P_n – 0.333)/(\Delta C_n - \Delta C_{base})$

$\mathbf{a}_s = 0.333 - (\mathbf{b}_s * \Delta C_{base})$

8.2.18 We can express the linear approximation to the demand relationship as:

$P = \mathbf{a}_d + (\mathbf{b}_d * \Delta C)$

where $\mathbf{a}_d = P_{base}$ and $\mathbf{b}_d = -0.2315 * \beta$

8.2.19 The estimated equilibrium position is the point at which these two lines meet:

$P'_n = \mathbf{a}_d + (\mathbf{b}_d * (\mathbf{a}_s - \mathbf{a}_d)/(\mathbf{b}_d – \mathbf{b}_s))$

8.2.20 This process is shown diagrammatically in Figure 8.1. The supply and demand lines have been labelled SS and DD but the diagram is not meant to be in strict economics format.

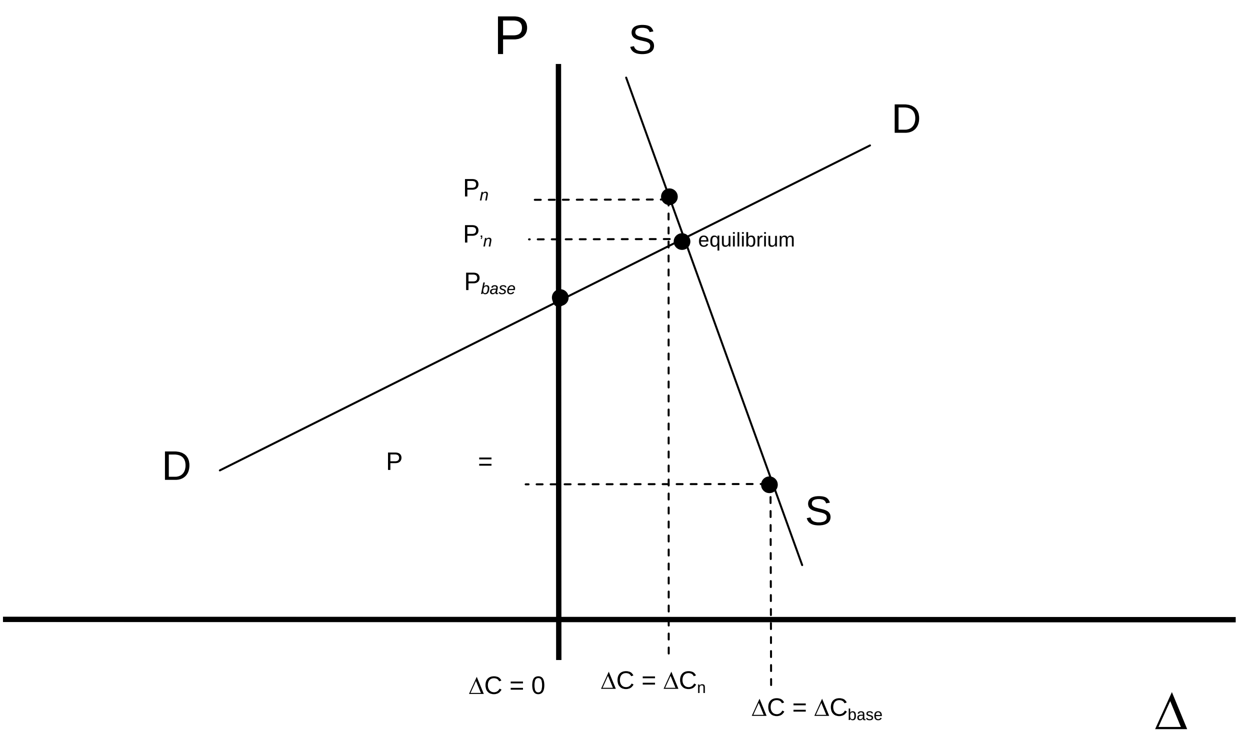


Figure 8.1 Peak Spreading Equilibrium Process

8.2.21 The value of ΔC_n has been calculated (as described in 8.2.8) for each cell in the matrix but using a flow reduction factor based on the average value of the ratio of shoulder to peak flows. An adjustment to ΔC_n can be made to give a better estimate for each matrix cell. The adjustment is:

$$\Delta C_n = \Delta C_{n(average)} * (1 - a_{ij})/(1 - Av)$$

Where a_{ij} is the ratio of shoulder to peak flow for cell ij

Av is the average ratio of shoulder to peak flow for the whole matrix

9 Model Realism Tests

9.1 Introduction

9.1.1 The draft advice on Variable Demand Modelling (VADMA) from the DfT contains guidance to carrying out model realism tests to ensure that the model is behaving in a realistic manner. In order to assess the realism of the model, three model runs were defined to check the elasticity of demand with respect to:

- Car journey time;
- Car fuel price; and
- Public Transport fares.

9.1.2 These tests were defined as follows:

(1) 20% increase in fuel price;

(2) 20% increase in PT fares; and

(3) 20% increase in Car journey times.

9.1.3 The measure of demand for the Car fuel price and journey time tests was distance weighted Car trips. For the Public Transport fares test, the equivalent measure was fares weighted Public Transport trips (ie total revenue).

9.1.4 The method for calculating the elasticity is shown below using Car fuel prices as an example. P and P' are the base and test Car fuel prices (indices), and D and D' are the base and test Car kilometres (matrix totals).

Then $P_{av} = (P + P') / 2$

$D_{av} = (D + D') / 2$

$\Delta P = P - P'$

$\Delta D = D - D'$

The elasticity is then calculated as:

$$E = [(\Delta D / D_{av}) / (\Delta P / P_{av})]$$

9.1.5 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.

9.2 Elasticity Guidance

9.2.1 The guideline range of elasticities for each test is taken from paragraphs 27.7 and 27.8 of the VADMA draft guidance. The guidelines are intended to cover a range of circumstances; for example, different journey purposes, different area types and different levels of modal competition.

9.2.2 In this respect it can be noted that TMfS covers a very wide geographic area which has urban and rural areas. Whereas some models may be dominated by urban areas, the effects of higher modal competition can, to a degree, be diluted by the rural areas included in TMfS.

9.2.3 The principal objective of the realism tests is to demonstrate that the overall model performance can be considered plausible. We have therefore calculated aggregate elasticities for the whole of the study area and compared these with the VADMA guideline ranges, which can encompass a wide range of sensitivities. This is also consistent with the previous methodology used in CSTM3/3A and TMfS:02 models.

9.3 Test 1

9.3.1 The first of these sensitivity tests is a 20% increase in fuel price. In order to run this test, the following steps were taken:

- recalculate generalised cost equation based on 20% increase in fuel price;
- carry out full model run with five outer loops; and
- weight resulting Car matrices by a distance matrix to give Car kilometres.

9.3.2 Table 9.2 presents the elasticity guidance and the resultant long term modelled elasticities for 20% increase in fuel prices.

Table 9.1: Fuel Price Elasticities

Journey purpose	Elasticity Guidance	AM Peak	Inter Peak
In-Work	-0.15 to -0.30	-0.1192	-0.1592
Non-Work	for all purposes	-0.1716	-0.2237

9.3.3 The Non-Work elasticities are within the guideline range, but it is more sensitive for the Inter Peak. The In-Work is just outside the range in the AM Peak, and just inside at the lower end of the range for the Inter Peak. The In-Work distance weighting in the generalised costs equation for assignment and skimming is smaller than that for Non-Work so the increase in fuel prices can be expected to have a smaller impact. This means that, for TMfS, Non-Work is more sensitive than In-Work to changes in fuel prices. This is intuitively correct.

9.4 Test 2

9.4.1 The Public Transport fares test was carried out in the same manner as the Car fuel test but with a 20% increase in Public Transport fares instead of the fuel price increase. Table 9.3 presents the results of this test.

Table 9.2: PT Fares Elasticities

Journey purpose	Elasticity Guidance	AM Peak	Inter Peak
All	-0.20 to -0.40	-0.1458	-0.0421

9.4.2 The results of this tests show that the model is fairly insensitive and both time periods fall outside the guidelines. However, the AM Peak is more sensitive than the Inter Peak. In general, we would expect Inter Peak fares to be lower than Peak fares and thus a higher level of percentage fare increase would be required to represent the equivalent Peak elasticity.

9.4.3 It should be noted that these elasticities cannot really be compared with those for TMfS:02. The PT methodology within TMfS:05 have the effects of crowding within them unlike those for TMfS:02.

9.4.4 In comparing with the VADMA guidelines, it is also important to recognise that the walk and cycle alternative to Public Transport are not available within the model and this will lower the outcome elasticity to fares.

9.5 Test 3

9.5.1 The third sensitivity test was to assess a 20% increase in highway journey times for Car trips. These data were prepared as follows:

- skim generalised cost from highways network, using a time weighting of 1.2 in the generalised cost formula;
- run one set of internal loops in the demand model ie with no assignment/cost feedback; and
- weight output Car matrices by distance.

Table 9.4 presents the elasticity guidance and the resultant long-term modelled elasticities for this sensitivity test.

Table 9.3: Car Journey Time Elasticities

Journey purpose	Elasticity Guidance	AM Peak	Inter Peak
In-Work	-0.15 to -0.70	-0.451	-0.5099
Non-Work	for all purposes	-0.4291	-0.4738

9.5.2 The results demonstrate that all the elasticities are within the VADMA guidance range. The elasticities are similar for each time period, with the Inter Peak being slightly more sensitive and the In-Work purpose generally being more sensitive than the Non-Work.

9.6 Summary

9.6.1 It is our judgement that the realism tests show that the model has acceptable sensitivities, and that adjustment of the model sensitivity parameters, therefore, is not required.

9.6.2 The majority of the tests fall within the VADMA guidelines. Highway elasticities tend to be more sensitive for the Inter Peak, with PT being more sensitive to changes in the AM Peak. Non-Work trips are more sensitive to changes in cost than In-Work, whereas In-Work trips are more sensitive to changes in Time than Non-Work trips.

9.6.3 It should, be noted that these elasticities depend on more than just the sensitivity parameters described elsewhere in this report, as full demand model runs are undertaken to produce them. They also include changes in costs based on adjustments made for park and ride and crowding within the PT network. As a result of this, and updated generalised cost parameters, these elasticities cannot be directly compared with those for TMfS:02.

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, which will be used in the forecasting process.

10.1.2 The TMfS 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. The general sequence of tasks is described in Section 10.3. and the incremental forecasting procedure is outlined in Section 10.4.

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 10.5 to 10.8. The treatment of Goods Vehicles and external trips in forecasting is dealt with in Sections 10.9 and 10.10 respectively.

10.2 Overall Operation of the Demand Model

10.2.1 Chapter Two outlined the structure of the Demand Model and the development each of the component sub-models and procedures was described in Chapters 4 and 5. Appendix A Figure 1 shows the model structure, which includes the necessary feedback loops to provide the balance between supply and demand when operated in forecast modes.

10.2.2 For a given forecast year and land use scenario the Trip End creation procedure is run to produce forecast trip productions and attractions. 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.

10.2.3 Appendix A Figure 2 describes in more detail the iterative balancing process. There are two main loops:

- Internal Loop b - iterates between the Mode Choice and Distribution Choice Models; and
- External Loop a - iterates between Assignment Models and the Mode and Destination Choice Models (ie the Internal Loop b).

10.2.4 The Internal Loop is the primary iterative process to achieve a converged state between the two main travel choices within the Demand Model - mode and distribution. It is necessary to undertake the Internal Loop before initiating the External Loop.

10.2.5 The Internal Loop 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. Inner loop matrices can be inspected between successive loops to determine whether to select to undertake further Internal Loops, based upon the extent to which both the distribution and totals of the matrices change. Tests have shown that four Internal Loops is sufficient for most applications, but the number required does depend on the level of congestion on the highway network.

10.2.6 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 (including the Internal Loop) are then run with the revised costs to complete the External Loop.

10.2.7 As standard 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 it can be run on every external loop. The Highway Assignment Model is run for each External Loop.

10.2.8 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 is sufficient for most applications, but the number required does depend on the level of congestion on the Highway network.

10.3 Sequence of Tasks

10.3.1 The methodology for applying the inputs to the Demand Model will vary according to whether the forecast is for the Reference Case (ie Do-Minimum), or for a scheme option or policy test, a Variant Case (ie Do-Something), relative to the Reference Case.

10.3.2 The steps required to calculate the Reference Case are as follows:

(1) Trip End Procedure – from the TELMoS planning data for a given year, calculate the forecast Trip Ends (productions and attractions) by trip purpose, mode/Car availability at a zonal level for the particular forecast year and growth scenario;

(2) prepare forecast goods vehicle matrices and external matrices;

(3) define and code Highway and Public Transport networks to include all of the Reference Case assumptions on schemes, service levels and fares;

(4) define and code model parameters such as value of time, vehicle operating cost parameters etc;

(5) run the Demand Model – the Demand model will bring in Trip Ends and cost matrices and undertake the first External Loop;

(6) Highway Assignment Model – The Highways Model will run to convergence and prepare both costs (for the Demand Model) and new highway travel times (for the PT Model);

(7) Public Transport Model - transfer the new highway travel times to the Public Transport Network to reflect changes in bus running times (Note: this stage will, by default only take place during External Loop 1 (as noted in section happen 10.2.7); and

(8) the Demand Model will continue through the remaining Internal and External Loops, including highway capacity restrained assignments, to a converged state. Thereafter, the model will undertake Highways and Public Transport assignments. The model will then make adjustments for Park and Ride before undertaking a final Highway and PT assignment for operational and secondary analysis.

10.3.3 For testing an option or scheme in a Do-Something run (ie a Variant Case), a considerably simplified procedure can be adopted. The mode specific constants, model parameters and Trip Ends can be taken directly from the Reference Case. The network definition and coding will need to be undertaken specifically for each scheme or option to be tested.

10.4 The Incremental Forecasting Approach

10.4.1 As was the case with TMfS:02, the forecasting procedure for TMfS:05 is designed to operate in an incremental manner.

10.4.2 As is usual practice, the Trip End Model operates in an incremental way by calculating the ratio of Forecast Year to Base Year synthesised Trip Ends for each zone. The resultant growth factors are then applied to the Base Year (observed) Trip Ends to provide the forecast year Trip Ends at the start of the Demand Model forecast process. There is a procedure to check for abnormal growth (eg greenfields sites) and amend the forecast Trip Ends. The Trip End Model procedure and the necessary input data are described in Chapter 7.

10.4.3 Mode choice and distribution models can require (to differing extents) 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 (BYM) are accepted as the best representation of the travel patterns in that year, ie assigned trips by mode and time period.

10.4.4 The Demand Model is operated to produce synthetic matrices for the Base Year and forecast year (S^{base} and S^{future}). We therefore define the Forecast Year Matrices (FYM) as:

$$FYM = (S^{future} - S^{base}) + BYM$$

10.4.5 This can then be redefined for the general case:

$$FYM = S^{future} + \text{Incremental Matrix}.$$

where:

$$\text{Incremental Matrix} = BYM - S^{base}.$$

10.4.6 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.

10.5 Model Parameters

10.5.1 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:

- mode specific constants - these will vary with each Reference Case as the distribution of single and multi-Car owning households varies with each planning and economic growth scenario;
- 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 TAG; and
- values of time and vehicle operating costs - these are related to forecasts in growth of GDP and suitable values are included in TEN and do not need to be included here.

10.5.2 In general, the need for mode specific constants is to allow for any model biases which are not included explicitly in the model formulation, and also to allow for the variation in person type segmentation by area. For example, in TMFS, there is only one Car available person type, 1+, whereas in practice it would be expected that persons from 2+ Car available households would have different modal propensities from persons from a single Car owning household, all other things being equal.

10.5.3 The mode specific constants calculated for the Base Year are specific to the Base Year distribution of single and multi-Car owning households. In forecasting for a particular year and growth scenario, we need to amend the mode specific constants to reflect a possibly different distribution of Car availability.

10.5.4 This is achieved by re-running the process which calculates mode specific constants using as inputs:

- Trip Ends forecast by the Trip End Model; and
- composite logsum utilities as output by a single Internal Loop of the Demand Model using the Base Year generalised costs by mode.

10.5.5 Since the Trip End Model is considered to forecast growth in trips under the assumption of no change in the network level of service (ie the Base Year conditions apply), this method is valid.

10.5.6 The process is only required for each Reference Case. For each related Variant Case there will be no change in the distribution of Car ownership from the Reference Case and thus the Reference Case mode specific constants remain valid.

10.6 Trip Ends

10.6.1 Forecast Trip Ends are prepared using planning data from the TMfS Land Use model (TELMoS) and applying the trip rates included in the DfT National Trip End Model (NTEM). The trip rates are applied by mode, Car availability, time period and journey purpose to produce production and attraction levels.

10.7 Highway and Public Transport Cost Matrices

10.7.1 Generalised cost matrices by mode and at a zone level are required as inputs to start the Demand Model process. For the Reference Case, the cost matrices used are those from the Base Year model.

10.7.2 The Base Year cost matrices by mode are also required for the calculation of Reference Case mode specific constants described, above.

10.7.3 Base or Reference Case Generalised Costs are, used as the start point of variance case tests within the TMfS.

10.8 Highway and Public Transport Networks

10.8.1 Highway and Public Transport network specifications are required for the Reference Case and all Variant Cases covering infrastructure, service and fare/toll changes. These are defined and coded in the conventional manner.

10.8.2 It should be noted that the Highway and Public Transport networks should be linked. For the Reference Case the starting point for the Public Transport network must be the Reference Case Highway network. For the Variant Cases, the associated Public Transport network could use either the Reference Case or the Variant Case highway network depending on the impact of road network changes to the Public Transport services.

10.9 Goods Vehicles

10.9.1 Goods vehicle trips are not subjected to the Demand Model process within the TMfS demand model structure. Forecast matrices are prepared from a combination of Base Year Goods vehicles matrices and Goods vehicle data from the Land Use Model (TELMoS). These matrices need to be prepared independently of the Demand Model for each future year and economic growth scenario.

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

(1) calculate forecast year percentage growth on a cell by cell basis between TELMoS base year and forecast year matrices (these cover internal goods vehicle movements within the TMfS modelled area);

(2) apply this percentage growth to the TMfS base year goods vehicle matrices; and

(3) apply NRTF growth to resultant goods vehicle external movements.

10.9.3 Part of this process is to undertake checks on a zone by zone basis to check the growth is consistent with the planning data

10.10 External Trips

10.10.1 External trips are those trips with one or both Trip Ends external to the TMFS modelled area. These trips are also not included in the Demand Model. They are contained in the hourly matrices (AM Peak, Off Peak and PM peak) by mode (Car, Public Transport) and are added in to the matrices created in the Demand Model process prior to assignment.

10.10.2 The external trip elements, with the exception of the airport zones, of the forecast Car vehicle and Public Transport passenger matrices are derived by applying a single overall factor to these elements of the Base Year matrices. For Car trips this will be derived from National Road Traffic Forecasts (NRTF) and segregated by Car In-Work and Car Non-Work. For Public Transport an overall growth factor will be derived from the application of the Public Transport Trip End Model for the internal areas of the study area.

10.10.3 For the airport zones (1197-1110) forecast year demand is obtained by applying airport growth predictions to the base airport travel demand. These predictions come from British Airports Authority for Edinburgh, Glasgow and Aberdeen and from Infratil for Prestwick.

11 Conclusions

11.1 Conclusions

11.1.1 This document has described the development of the Base Year Demand Model for TMfS, the model's sensitivity to a set of example tests and discussed how the model will be applied in forecast mode.

11.1.2 The principal functions of the Base Year Demand model are to:

- demonstrate and validate the model operation and procedures;
- test the sensitivity of model parameters; and
- establish the incremental adjustment matrices, which will be used in the forecasting process.

11.1.3 The model structure has been defined and implemented for the Base Year. The realism tests undertaken have demonstrated an acceptable level of sensitivity. Although, in some cases sensitivities are lower than the guidelines, this is deemed acceptable for a model the nature of TMfS and intuitive that they are less sensitive. The principal travel purpose of the model (ie Non-Work highway trips) has elasticities which fall within the recommended sensitivity guidelines. It is also accepted that the majority of guideline model elasticities are not be specifically directed towards a model such as TMfS.

11.1.4 Our conclusion and recommendation is that the demand model is suitable for use in forecasting.

11.1.5 Demonstration of the model in forecast model does not form part of this report. As noted above, this report discusses how the model will be applied in forecast model. Over time, model testing and experience, still to be gained in live applications of the model, will further assist in understanding the sensitivity of the model beyond these Base Year tests.

Appendix A: Model Description

- This appendix contains a description of the TMfS Demand Model. It is a detailed description provided by a set of 20 figures, each showing a flow diagram of the model operations. 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. It is not intended to include a description of every component of the model.

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 stages, enhanced by trip frequency, an element of time of day choice in peak spreading and adjustments for Park and Ride.

- 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 types:

  - non-car available; and
  - car available.

- It is also segmented by the following journey purposes:

  - home-based work;
  - home-based employer’s business;
  - home-based other;
  - non-home-based employer’s business;
  - 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.

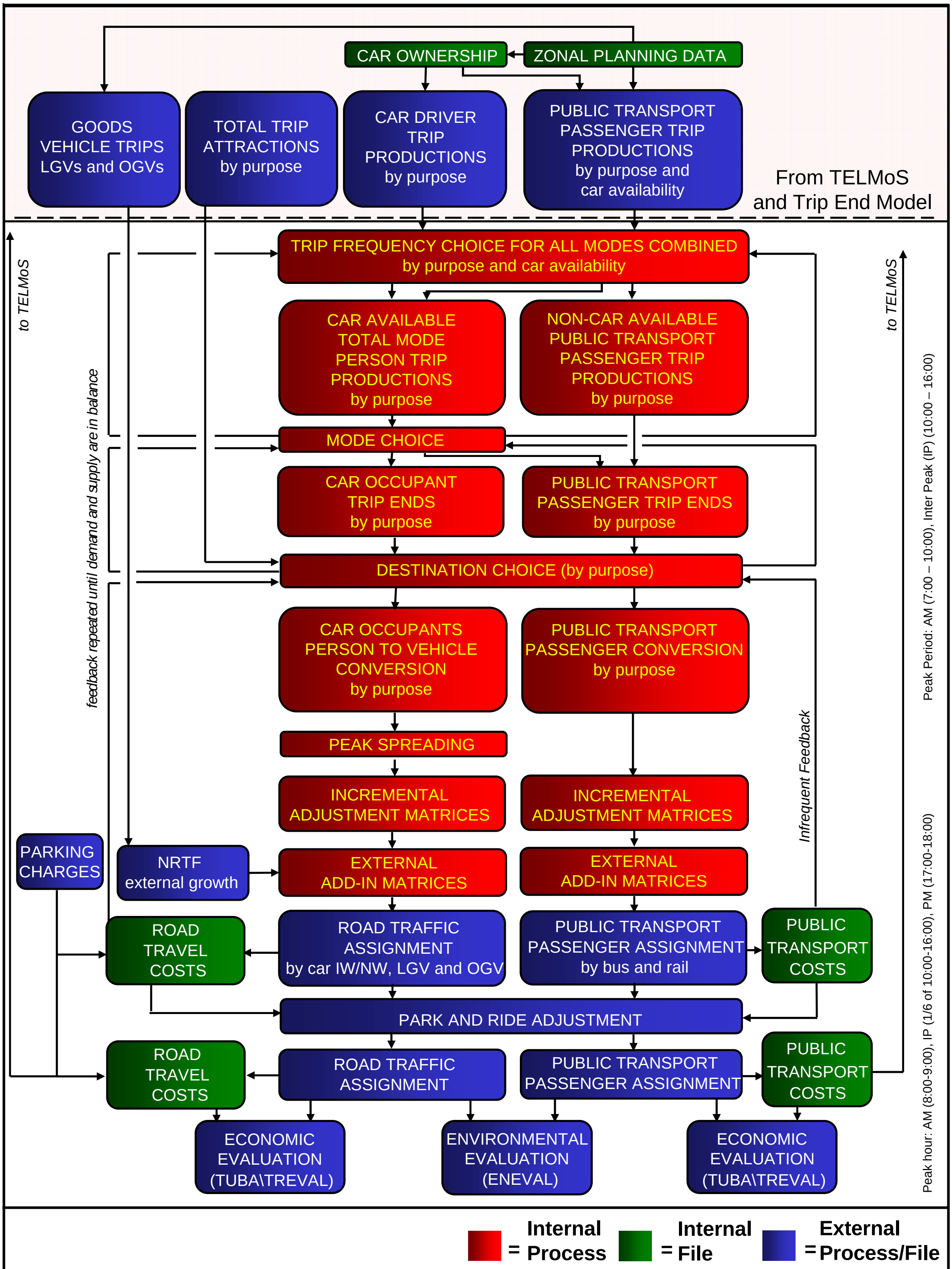


Figure 1: Transport Model for Scotland: Model Structure

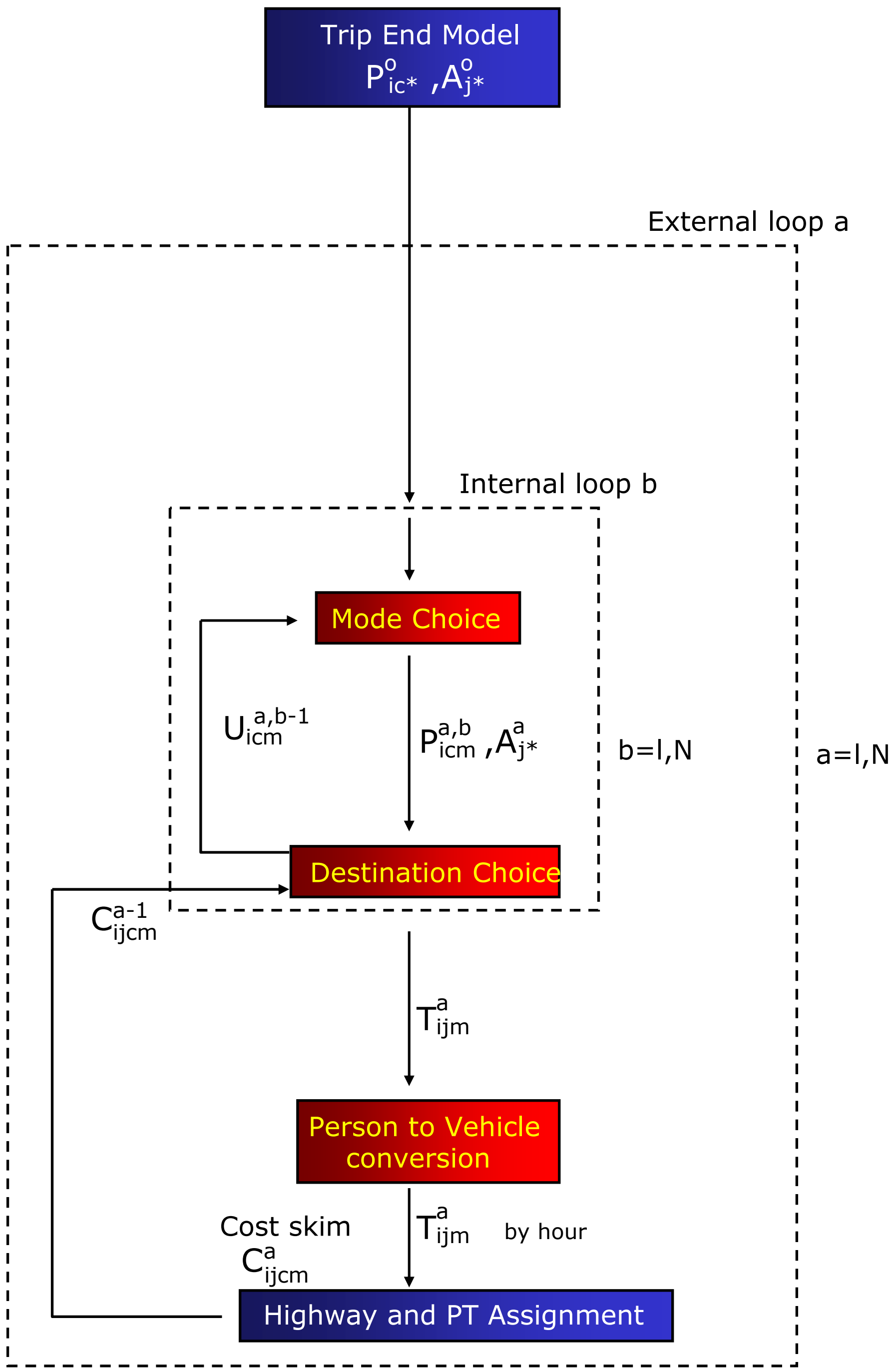
Figure 2: Iterative Demand/Supply Balancing

- This figure outlines how demand and supply are balanced. The process is fairly conventional and essentially consists of a feedback of generalised costs from the assignment models to the distribution, mode split and trip frequency components of the demand model.

- Two loops are shown in this figure, the inner loop ‘b’ and the outer loop ‘a’. The inner loop is necessary because even with fixed costs from the assignment models, the logsum composite utilities which are input to the mode choice component depend on the distribution of trips by mode. Therefore, this process requires to be balanced prior to initiating the outer loop.

- The outer loop is the more conventional iterative process in which the generalised costs of travel are varied through the assignment models and fed back into the demand model.

- As standard, 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.



Key:
C^{a}_{ijcm} - generalised cost skim for cell ij, car availability c, mode m, external loop a
$U^{a,b}_{icm}$ - logsum composite utility for zone i, car availability c, external loop a, internal loop b

= **Internal Process** = **Internal File** = **External Process/File**

Figure 2: Iterative Demand/Supply Balancing

Figure 3 : Trip Production Model for Home-Based Trips from Home

- This model requires the following inputs:

  - base year car ownership by zone;
  - base year planning data by zone;
  - forecast year planning data by zone;
  - forecast year car ownership by zone; and
  - base year person trip productions by mode, car availability, time period and journey purpose.

- The base and forecast year car ownership and planning data are produced by the Trip End and Land Use Model of Scotland (TELMOS). The data consists of persons in 88 categories defined by car ownership and household/person characteristics. These are the 88 categories as used in the National Trip End Model (NTEM).

- Synthetic trip ends are calculated for base and future years by applying the NTEM trip rates to the planning data. These synthetic trip ends are then combined to form growth factors which are applied to the base year trip productions. This process is applied separately for each trip purpose.

- The outputs of the process are trip productions by mode, car availability, time period and journey purpose.

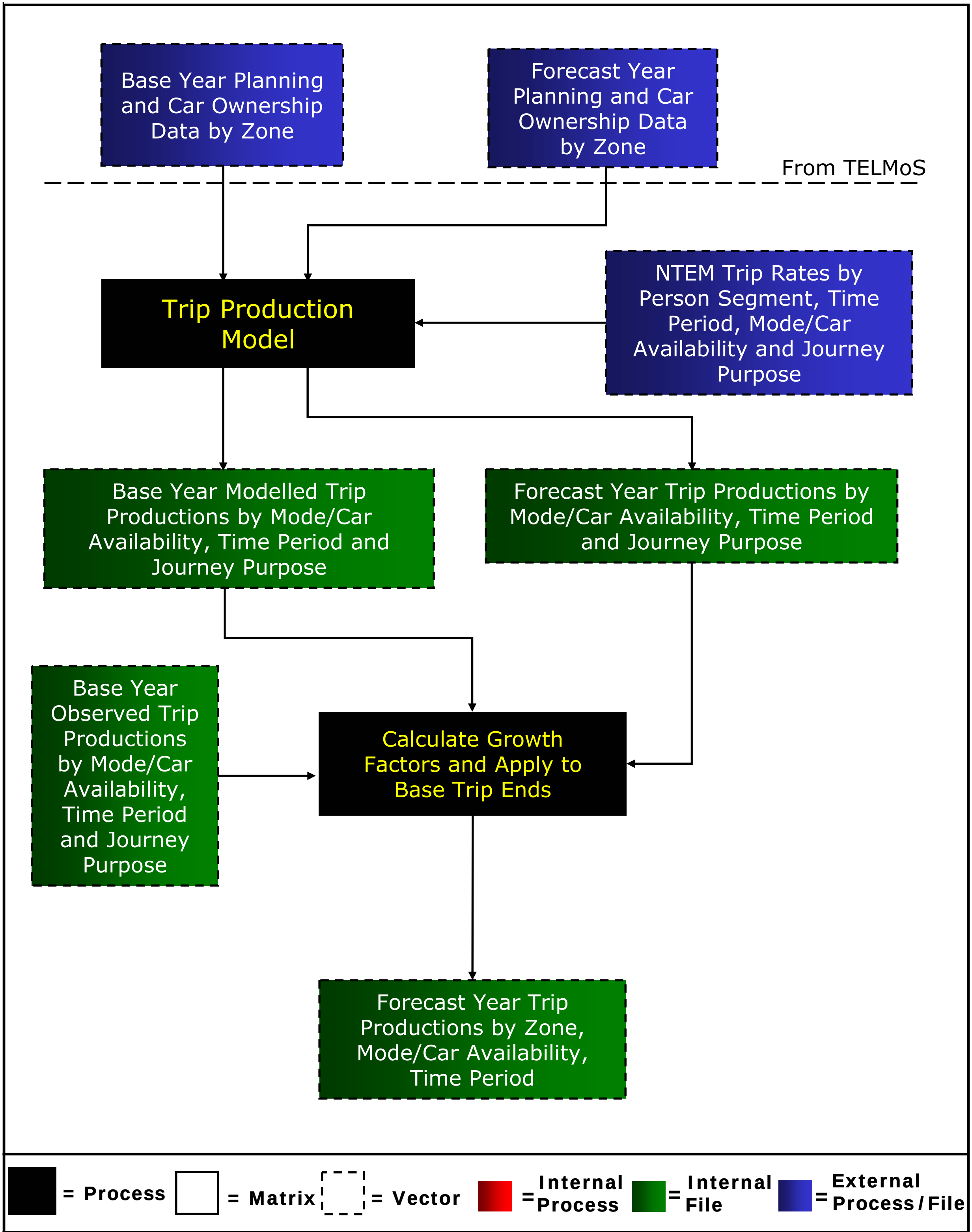


Figure 3:Trip Production Model for Home-Based Trips from Home

Figure 4: Trip Attraction Model for Home-Based Trips from Home

- This model produces the trip attractions (for doubly constrained models) and attraction factors (for singly constrained models). It takes as input:
  - base year employment data by zone;
  - forecast year employment data by zone;
  - base year person trip attractions/attraction factors by time period and journey purpose.
- The base and forecast year employment data are produced by the Trip End and Land Use Model of Scotland (TELMOS). The data consists of employment by zone in the standard industry categories as used in the National Trip End Model (NTEM).
- Synthetic trip attractions are calculated for base and future years by applying the NTEM attraction parameters to the employment data. These synthetic trip attractions are then combined to form growth factors which are applied to the base year trip attractions. This process is applied separately for each trip purpose.
- The outputs of the process are trip attractions/attraction factors by time period and journey purpose for from-home purposes.

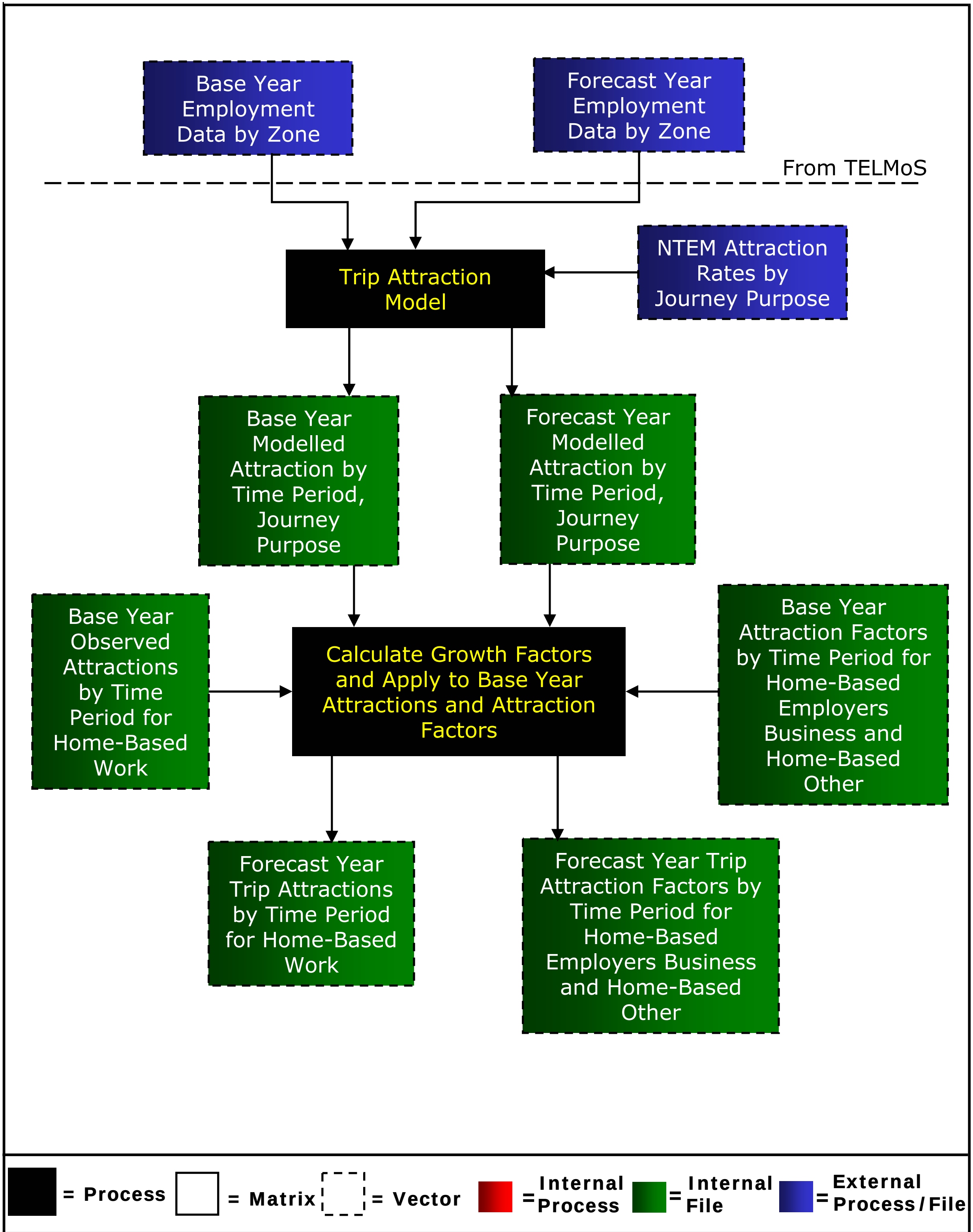


Figure 4:Trip Attraction Model for Home-Based Trips from Home

Figure 5: 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;
  – non-home-based trip rates derived from analysis of the Scottish Household Survey.

- The trip rates are multiplied by the trip attractions to give the trip origins and destinations by mode, car availability, journey purpose and time period.

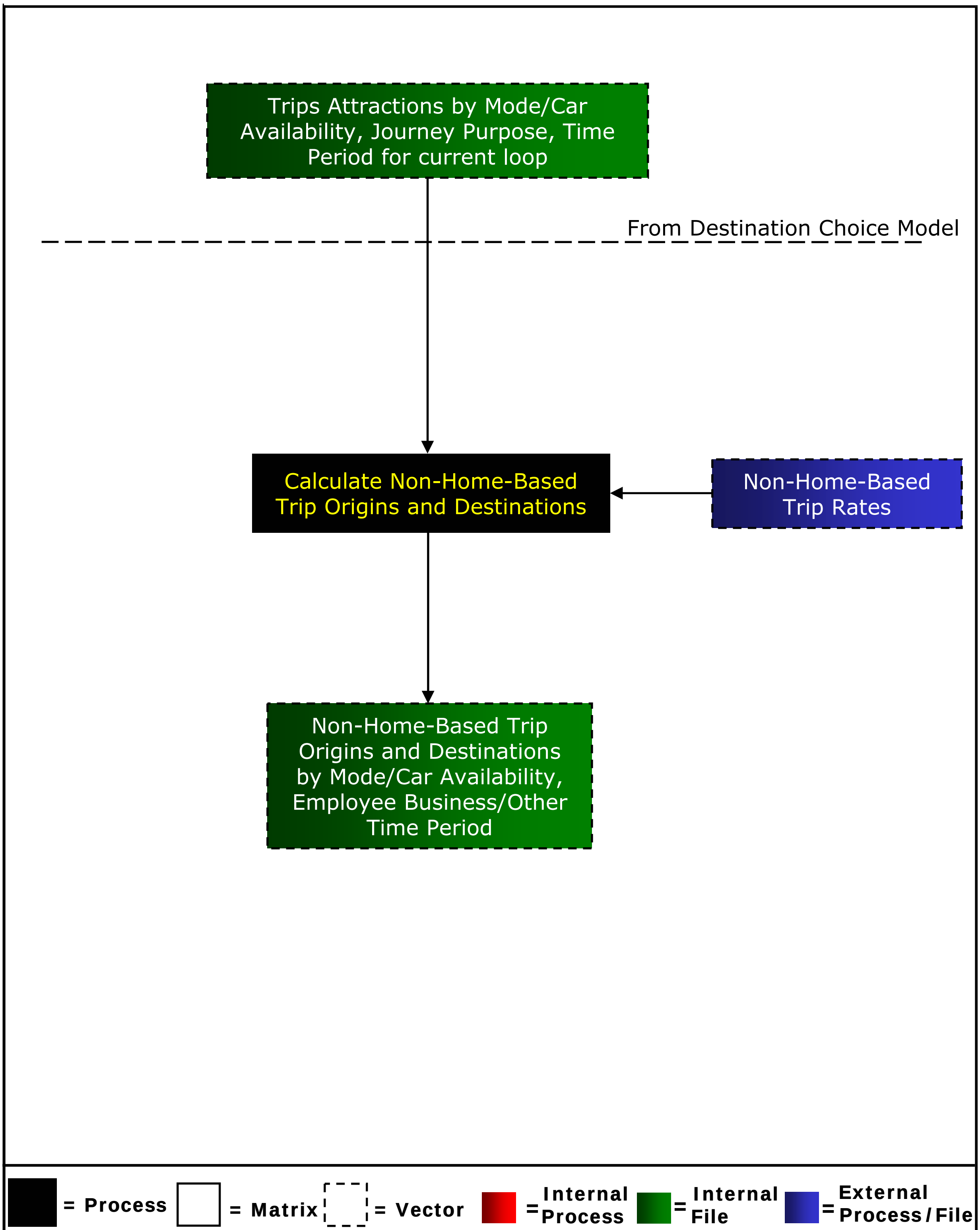


Figure 5:Trip End Model for Non-Home-Based Purposes

Figure 6: Calculation of Logsum Composite Utility for Input to the Trip Frequency Model

- This process takes as input the logsum composite utilities 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 the formulation is based on the mode choice model.

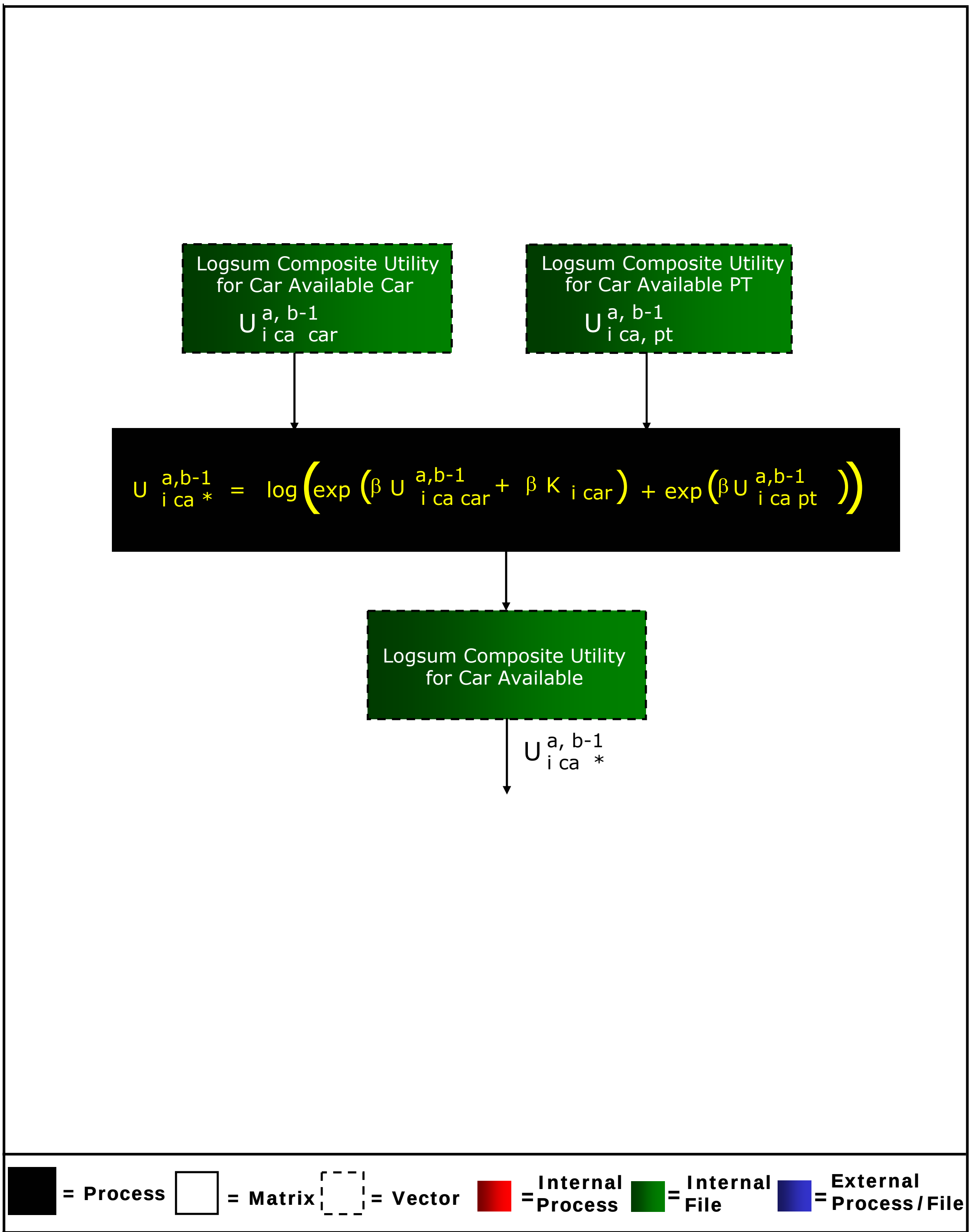


Figure 6: Calculation of Logsum Composite Utility for Input into Trip Frequency Model

Figure 7: Trip Frequency Choice for Home-Based Purposes - Car Available Persons

- 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 for the base year, by zone;
  - logsum composite utility for all modes for the forecast year, by zone; and
  - trip productions for all modes for car available persons.

- The trip productions are adjusted using a straightforward elasticity model, which is based on the assumption that the unadjusted trip ends from the trip end model are compatible with reference case generalised costs of travel.

- The logsum composite utilities are calculated as shown in Figure 7. 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 mode choice model as shown in Figure 10.

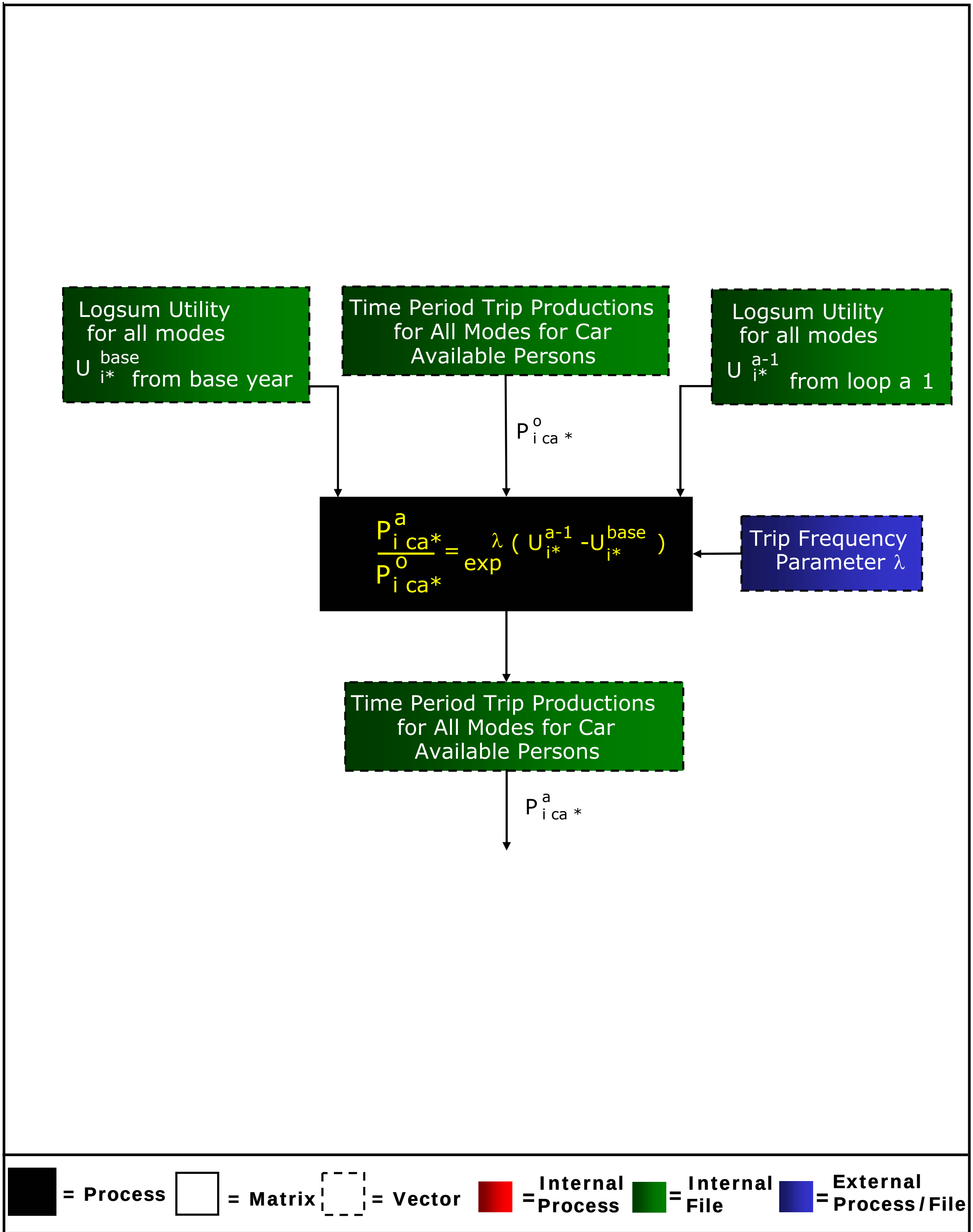


Figure 7: Trip Frequency Choice for Home-Based Purposes – Car Available Persons

Figure 8: Trip Frequency Choice from Home-Based Purposes – Non–Car Available Persons

- 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 Public Transport for the base year, by zone;
  - logsum composite utility for Public Transport for the forecast year, by zone; and
  - trip productions for Public Transport for non-car available persons.

- The trip productions are adjusted using an elasticity model, which is based on the assumption that the unadjusted trip ends from the trip end model are compatible with base year generalised costs of travel.

- The process is applied separately for each home-based trip purpose. The outputs of the process are person trip productions by time period for public transport for non-car available persons. These form the inputs to the mode choice model as shown in Figure 9.

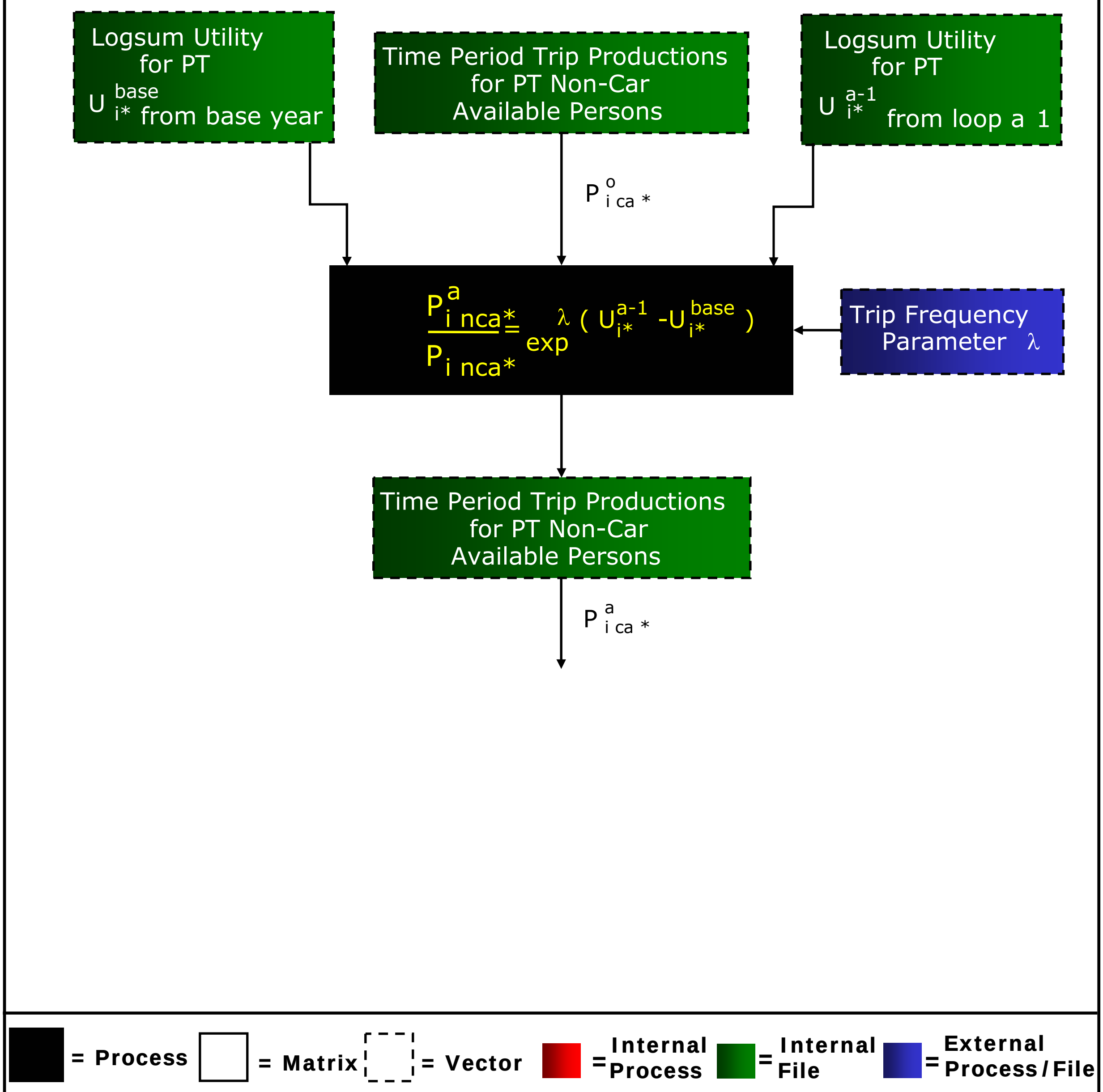


Figure 8: Trip Frequency Choice for Home-Based Purposes – Non-Car Available Persons

Figure 9: 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 effectively 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. In the case of car available persons the output utilities are used as input to both the mode choice and frequency choice processes. For non-car available there is no mode choice but the utilities are input to the frequency choice process.

- The sensitivity parameters (ɑ) shown in this figure are the same sensitivity parameters used in the destination choice process.

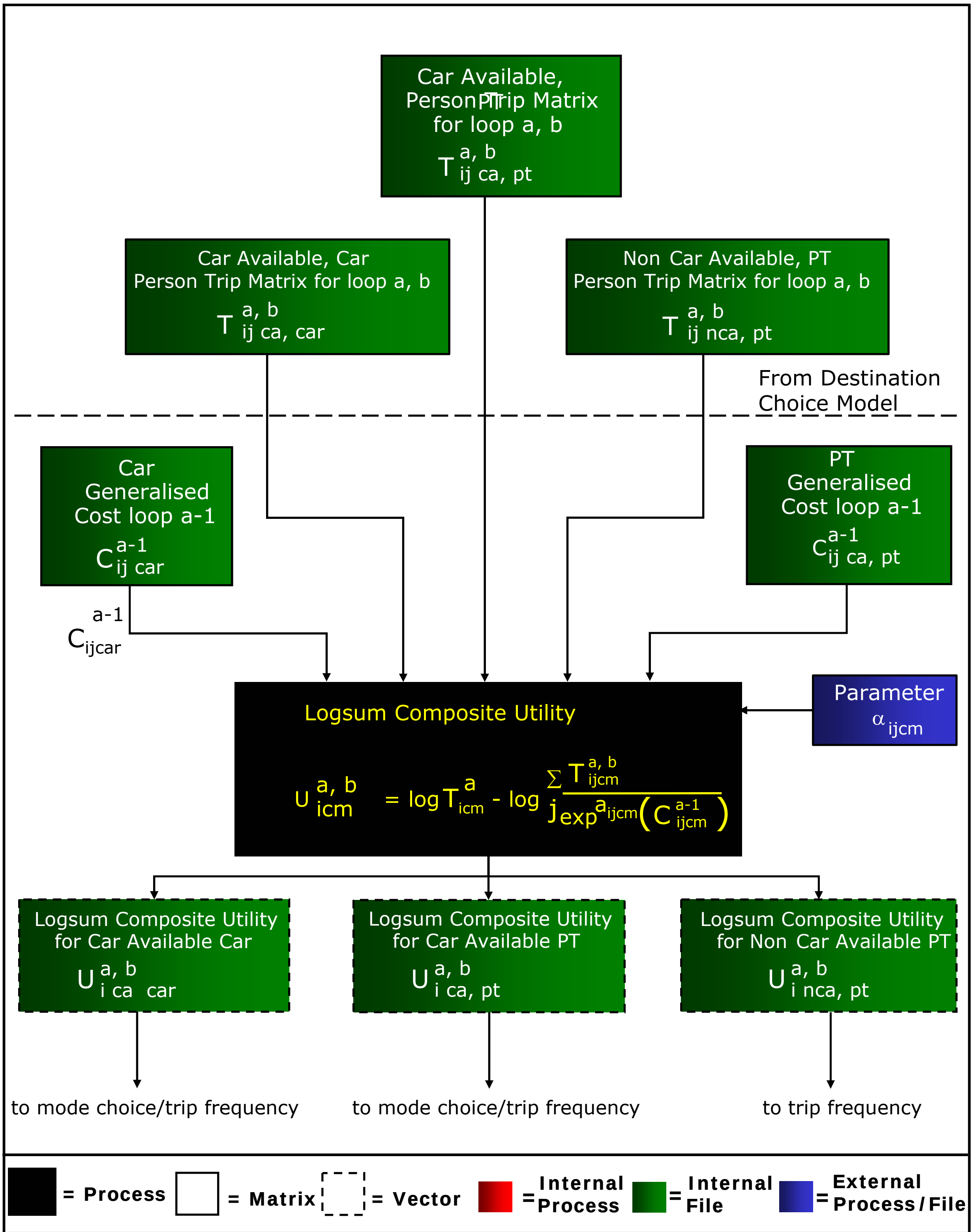


Figure 9: Calculation of Logsum Composite Utility for input to Mode Choice

Figure 10: 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 person trip productions by time period are the outputs of the process described in Figure 3.

- The calculation of the logsum composite utilities is undertaken using the process described in Figure 9.

- There are two types of parameter input.

- (1) The scaling factors (β) which control the sensitivity of the mode choice process.

- (2) 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 11.

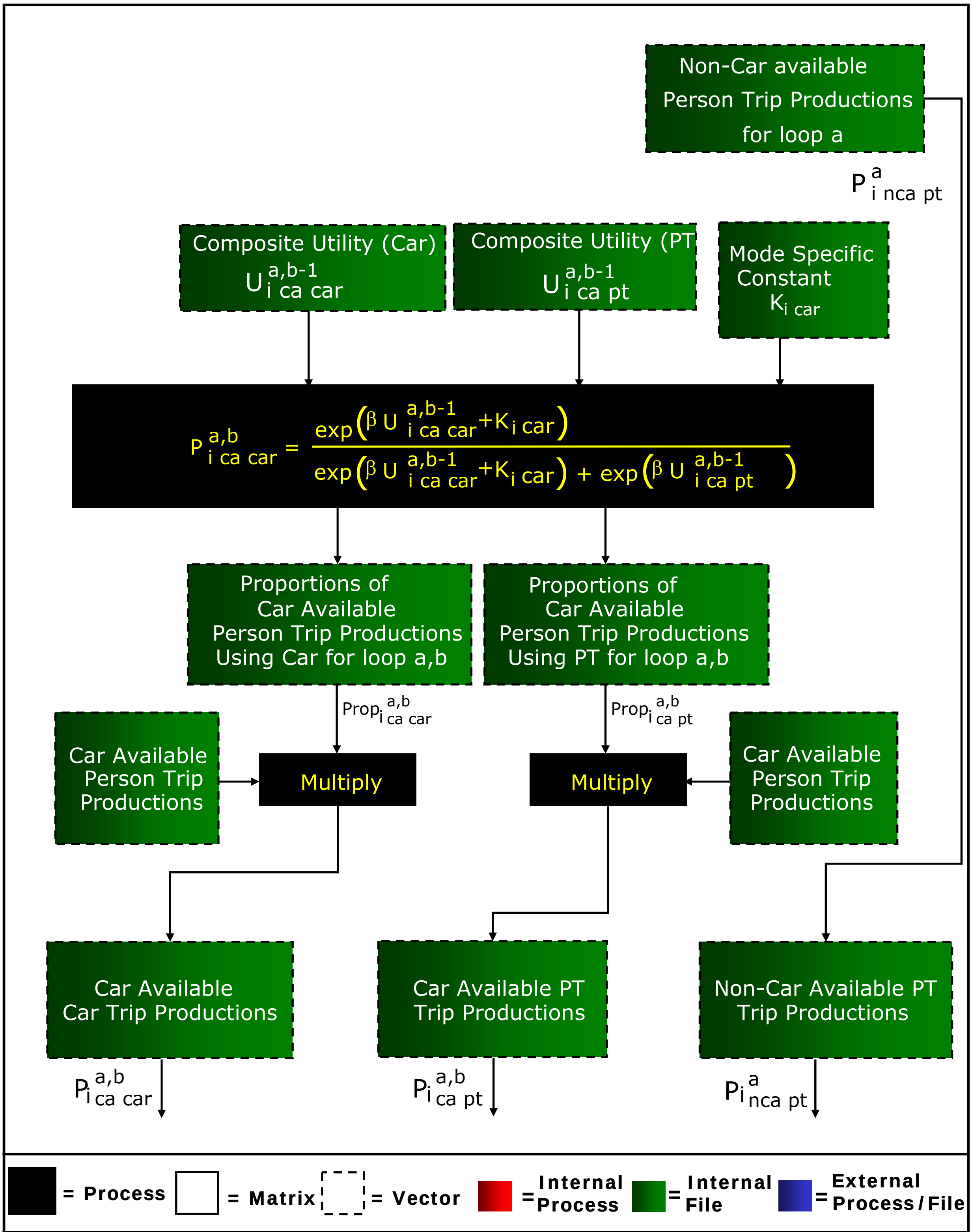


Figure 10: Mode Choice

Figure 11: Destination Choice

- This is the destination choice model for from-home purposes, which takes as inputs:
  - trip productions for car and public transport by car available and non-car available where appropriate;
  - 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 in effect the traditional gravity model process applied in a doubly constrained manner for from-home to work 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.
- There is also a facility to input k-factors in order to ensure a 'fit' to a base pattern of trips; similar to the sensitivity parameters, these are applied by trip purpose and mode.
- 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 described in Figure 13.

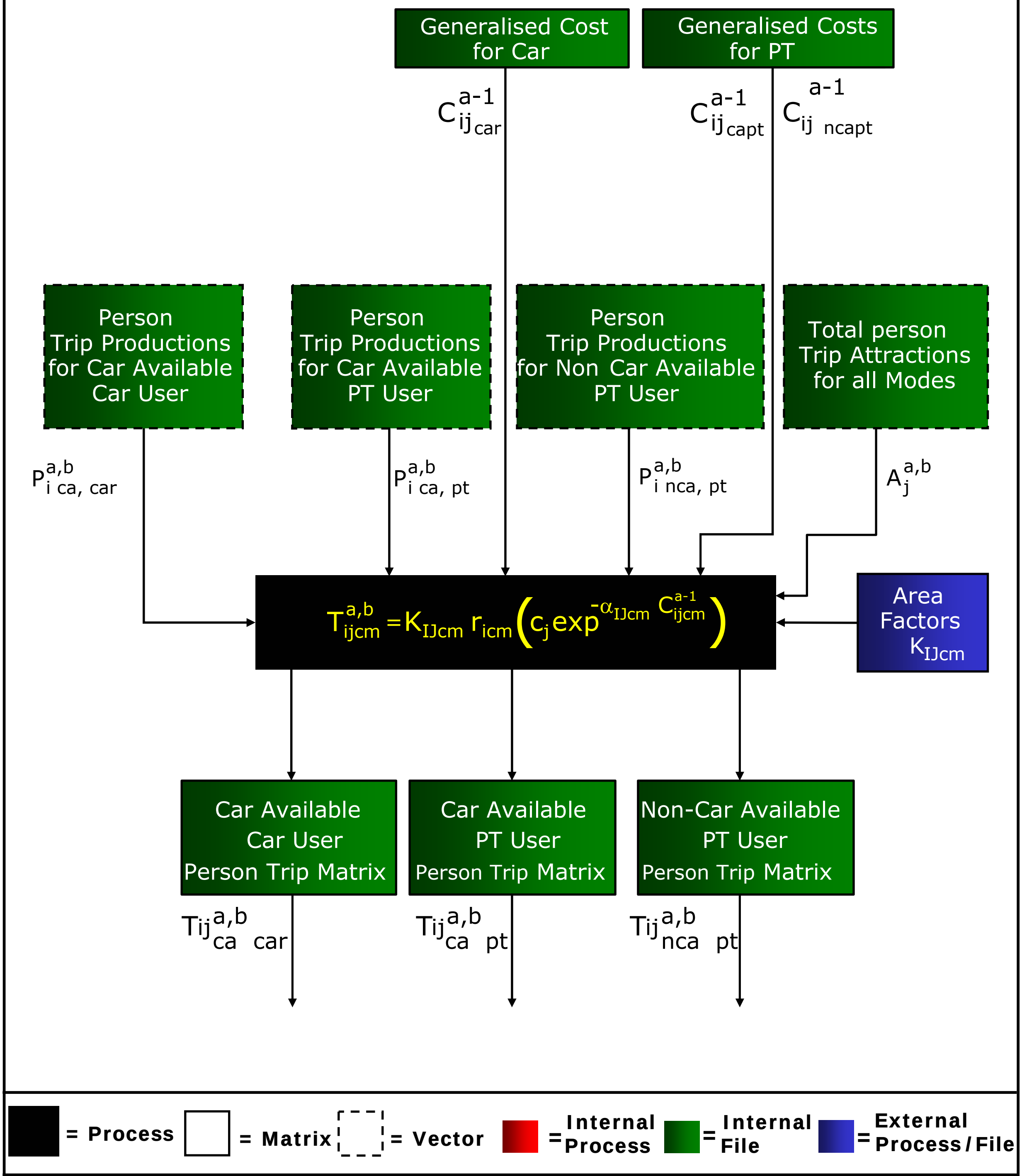


Figure 11: Destination Choice

Figure 12: 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 from-home matrix cells to give to-home matrices by mode, car availability, journey purpose and time period.

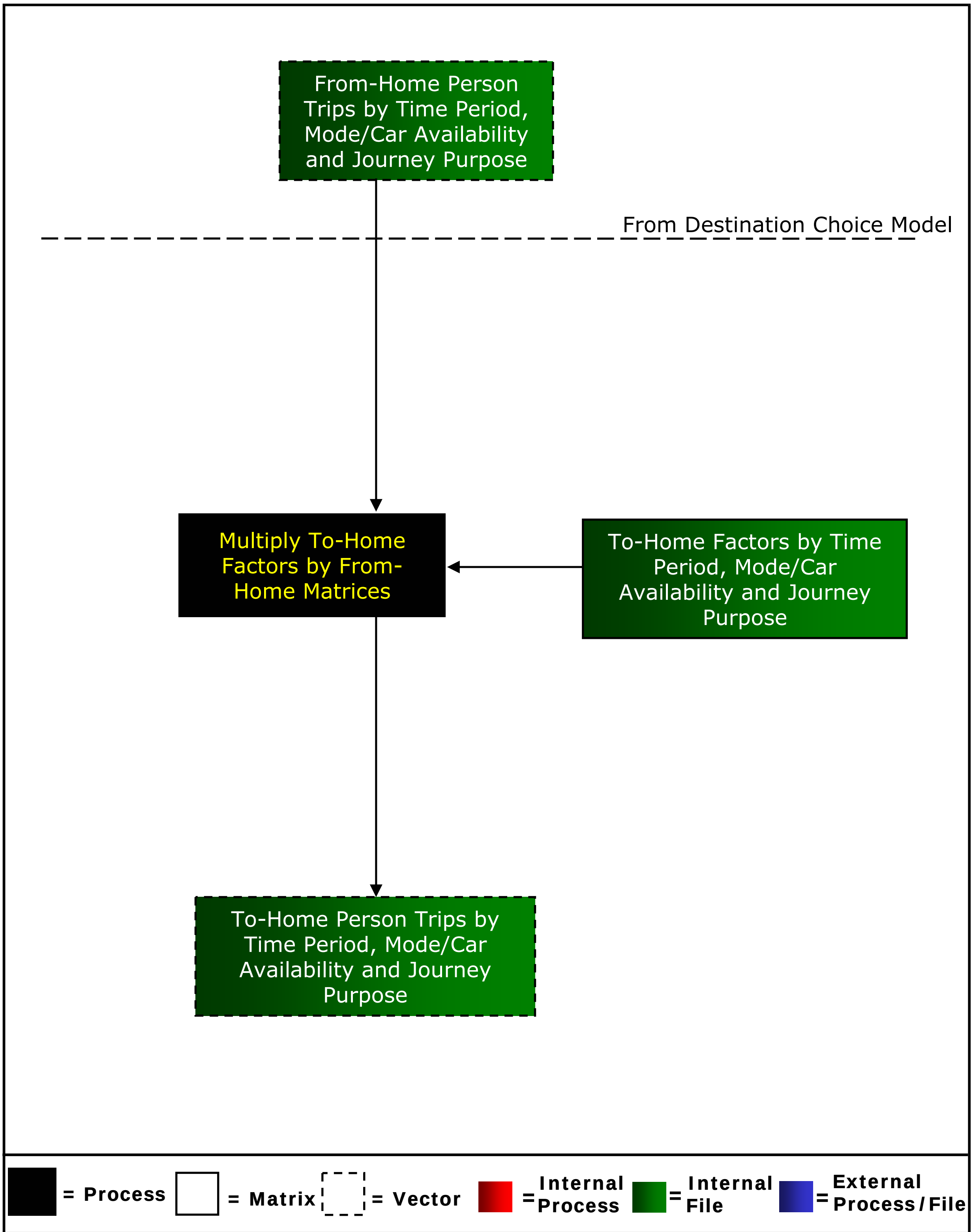


Figure 12: Creation of To-Home Matrices

Figure 13: 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 11 and 12, 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.

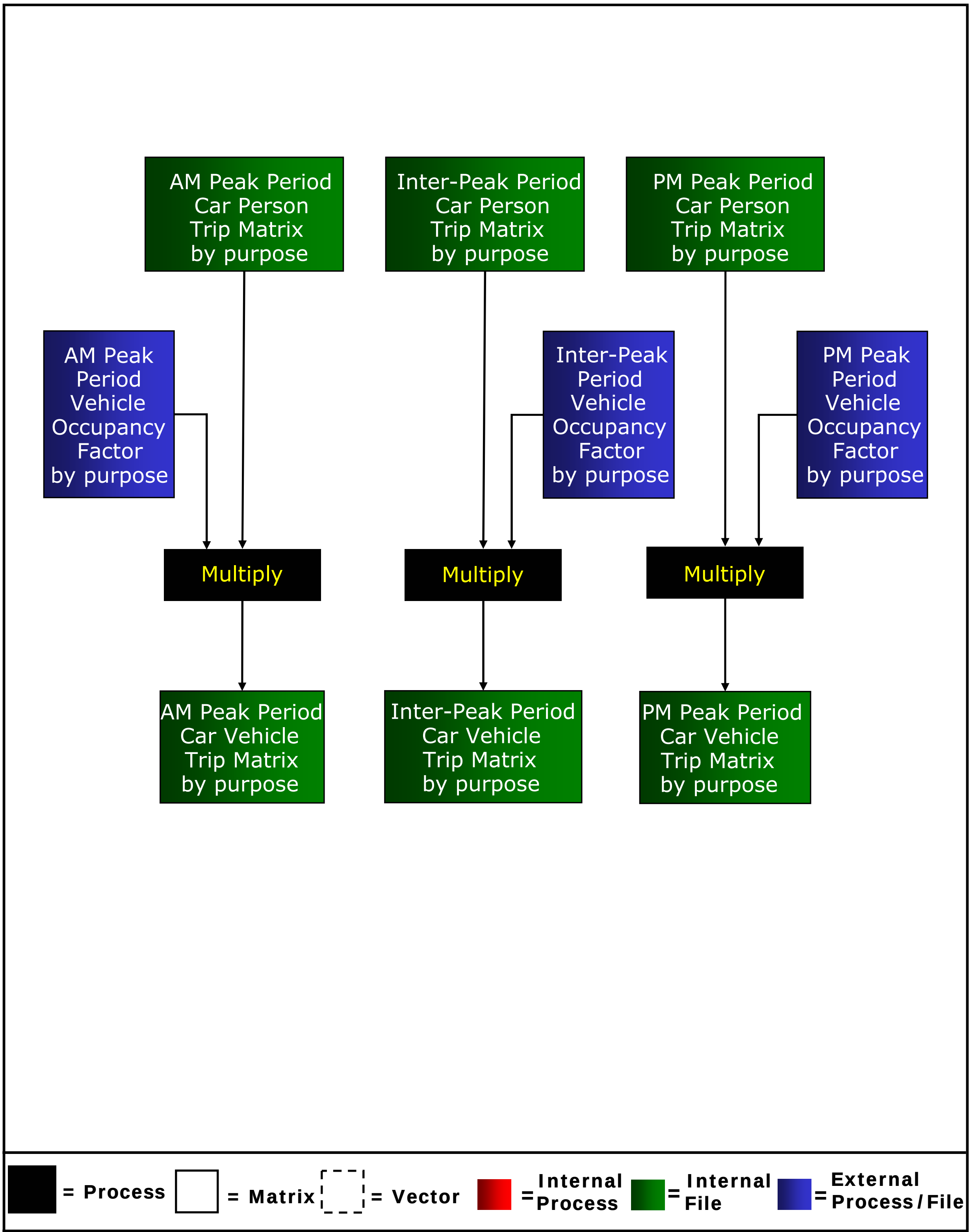


Figure 13: Person to Vehicle Conversion for Car Trips

Figure 14: Peak Spreading

- Peak Spreading is applied to the Morning Peak car time period matrices only. It takes as input:

  - base year generalised cost for car for Morning Peak;
  - forecast year generalised cost for car for Morning Peak for current model loop; and
  - morning peak period trip matrix for car.

- The process is carried out for all trip purposes combined. The base year period to hour factors for car trips in the Morning Peak are modified in the peak spreading model to reflect the relative change in generalised cost between the base and future years.

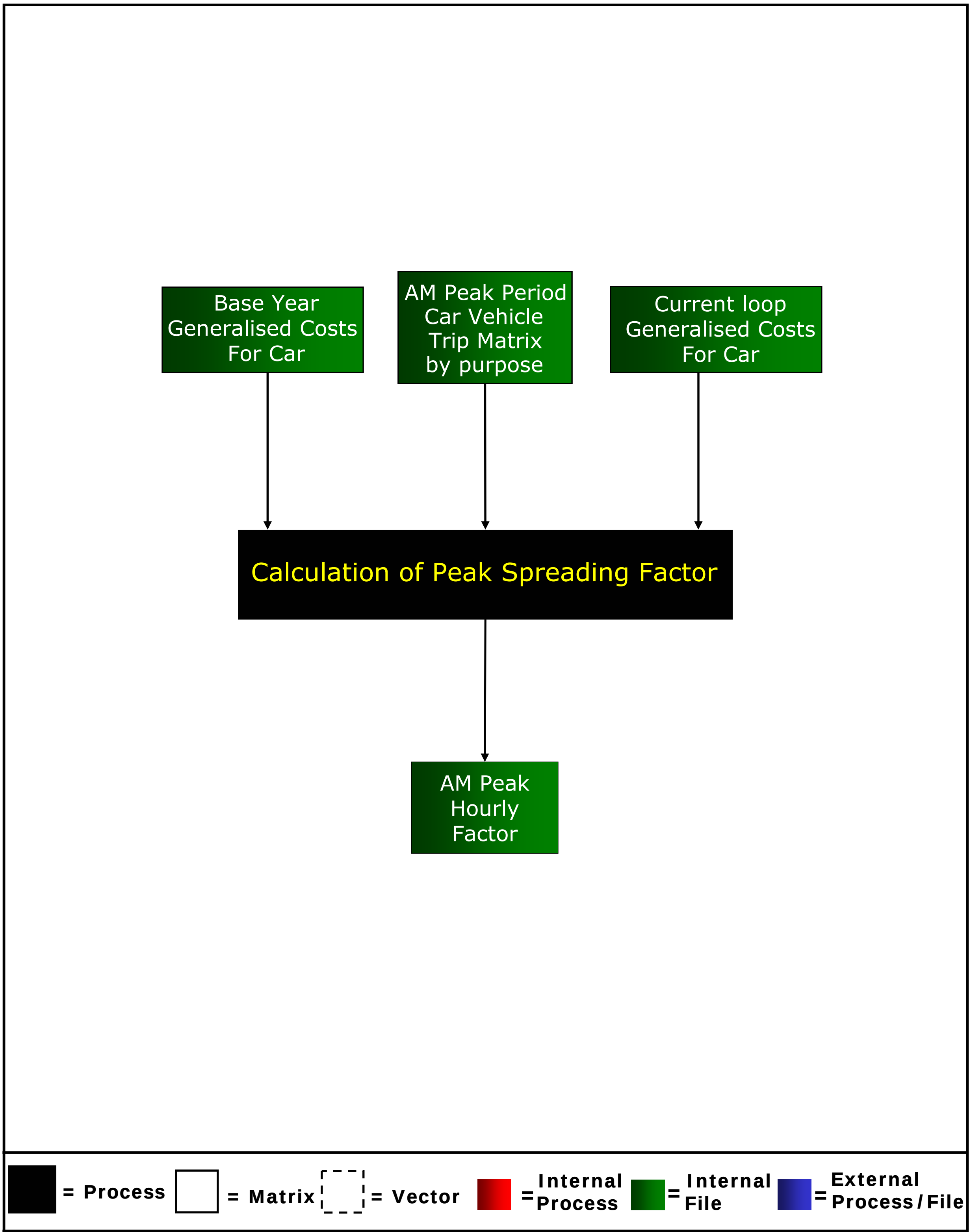


Figure 14: Peak Spreading

Figure 15: 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 at district level.

- The process is carried out for all trip purposes combined. The Inter-Peak and PM Peak factors will generally remain the same in all forecasting situations. The AM Peak factors for car are derived from the peak spreading model.

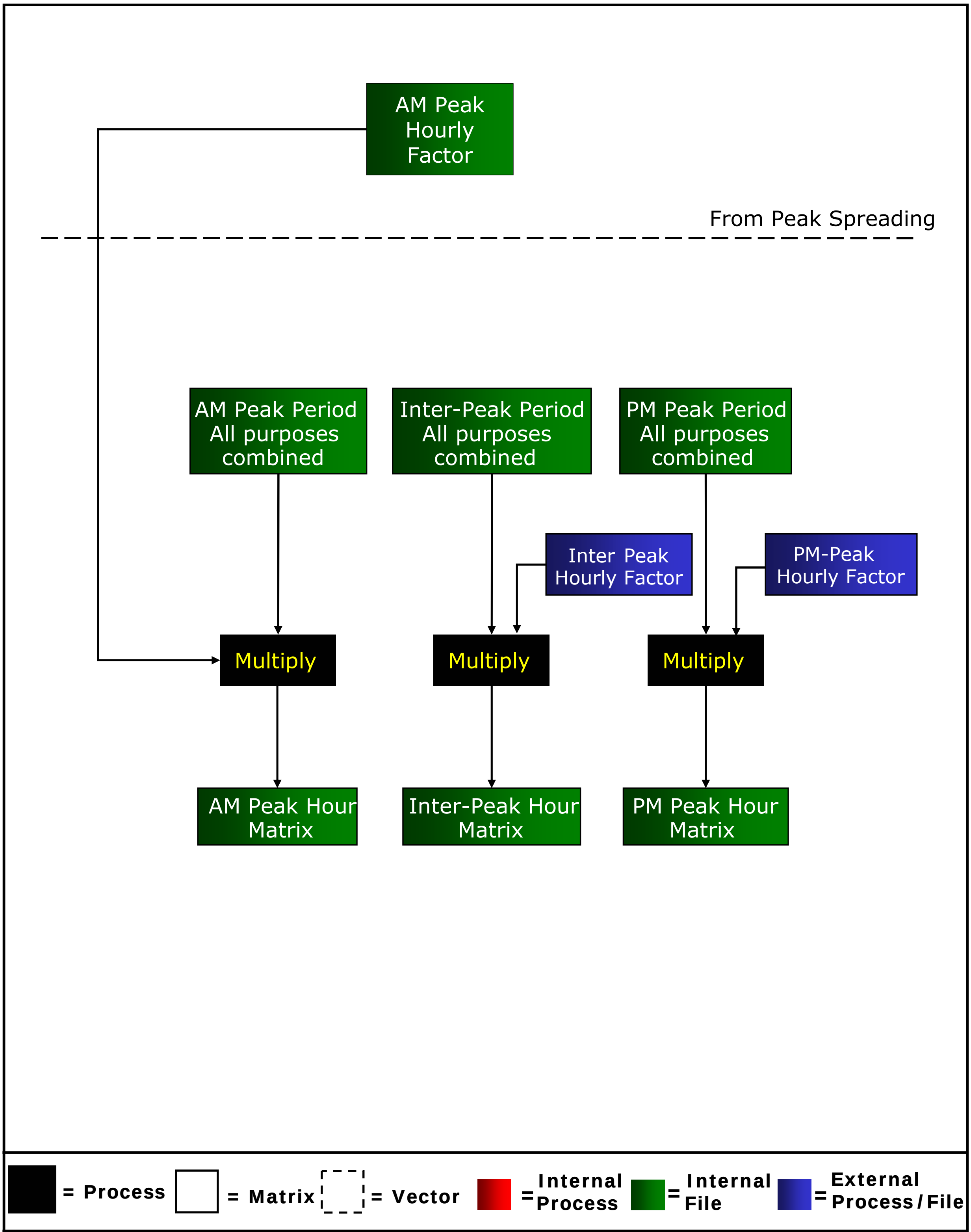


Figure 15: Hourly Matrix Creation for car and pt

Figure 16: Incremental Adjustments

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

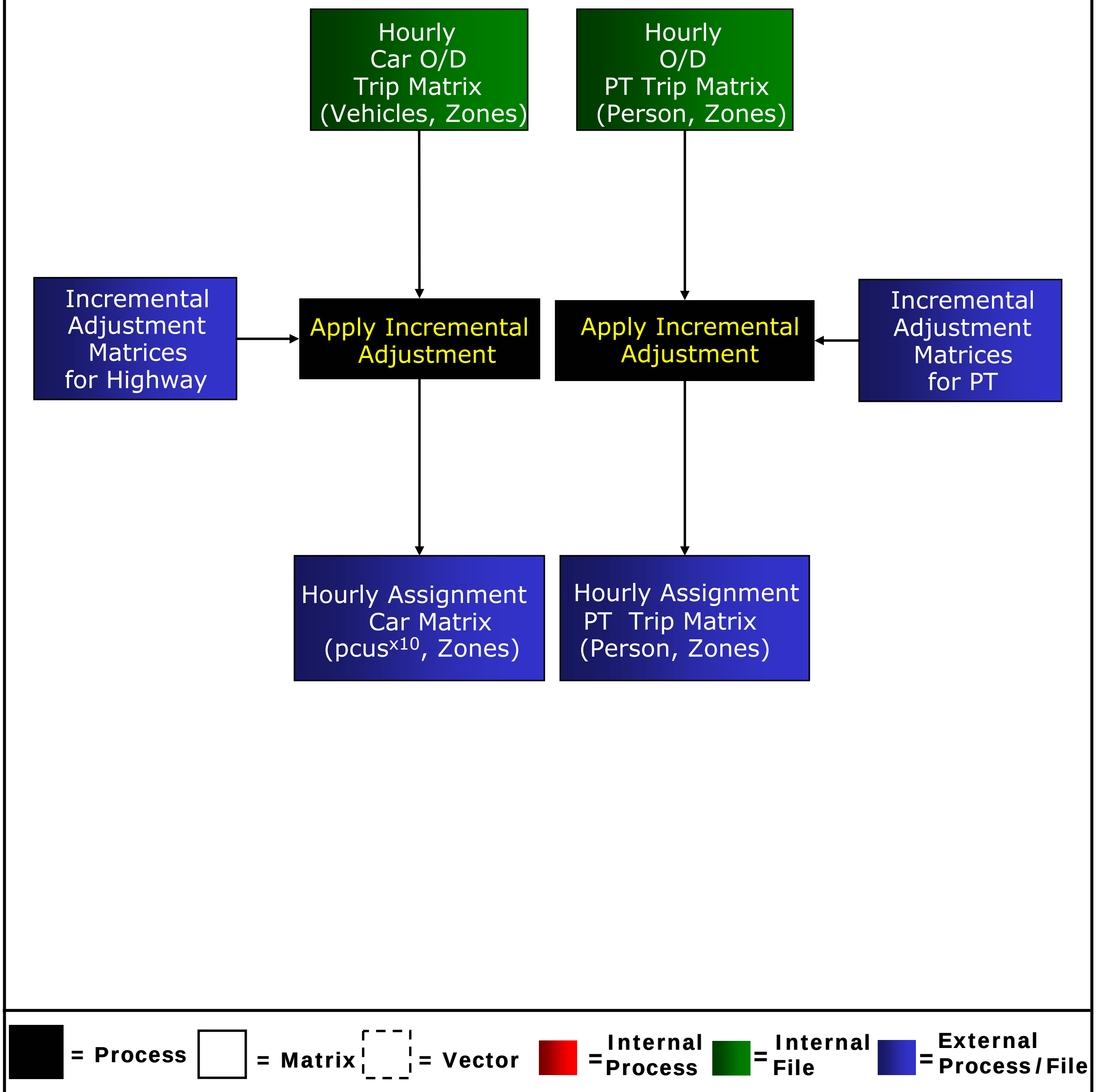


Figure 16: Incremental Adjustment

Figure 17: Highway Assignment

- This is a conventional capacity restrained equilibrium multi-class assignment procedure. There are four user classes:

  1. car In-Work;
  2. car Non-Work;
  3. light goods vehicles; and
  4. other 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.

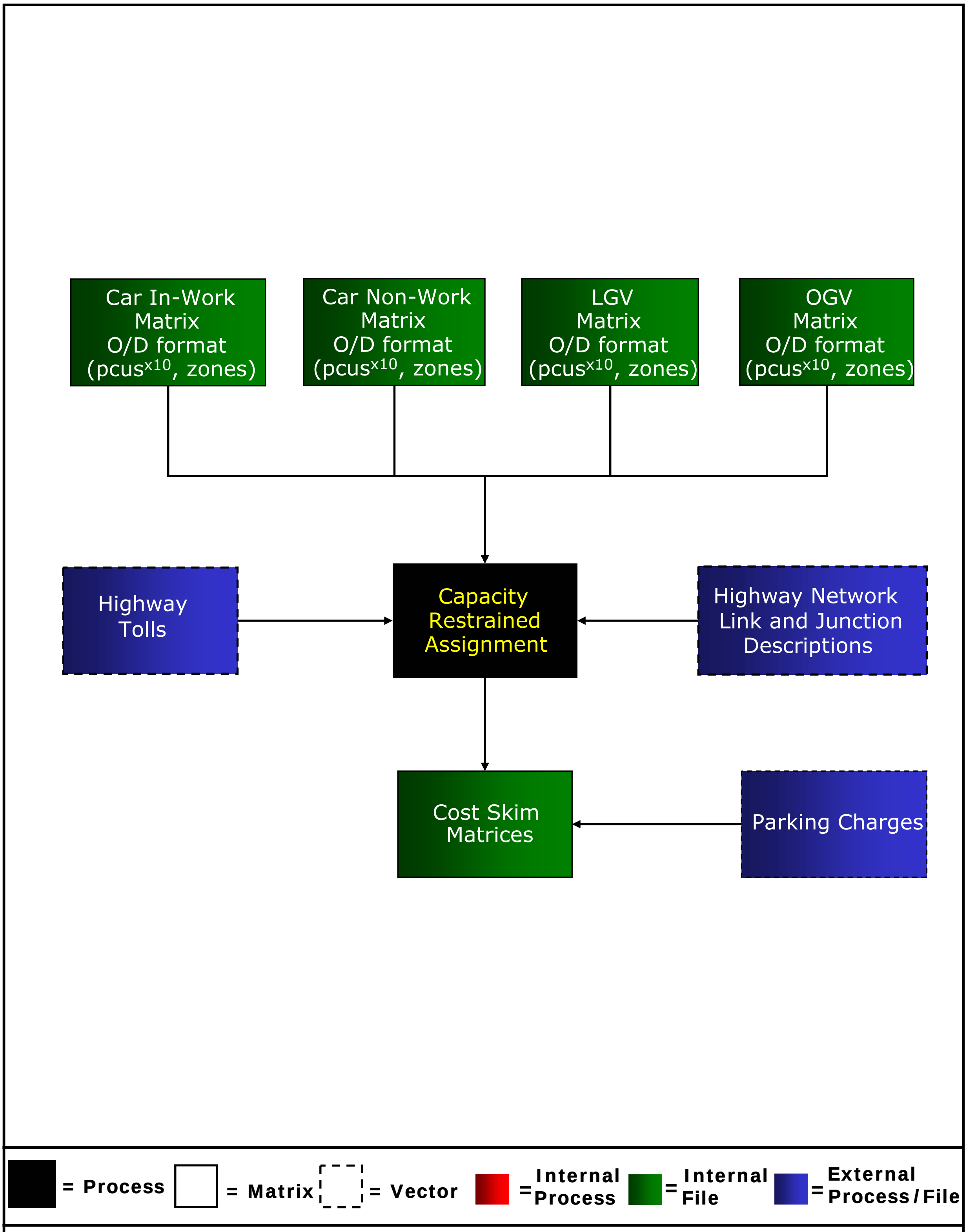


Figure 17: Highway Assignment

Figure 18: Public Transport Passenger Assignment

- This is a standard PT assignment procedure, with sub-mode choice. This has been enhanced from CSTM3 and TMfS:02 to include the effects of crowding. It is standard to skim the PT costs only on the first loop 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.

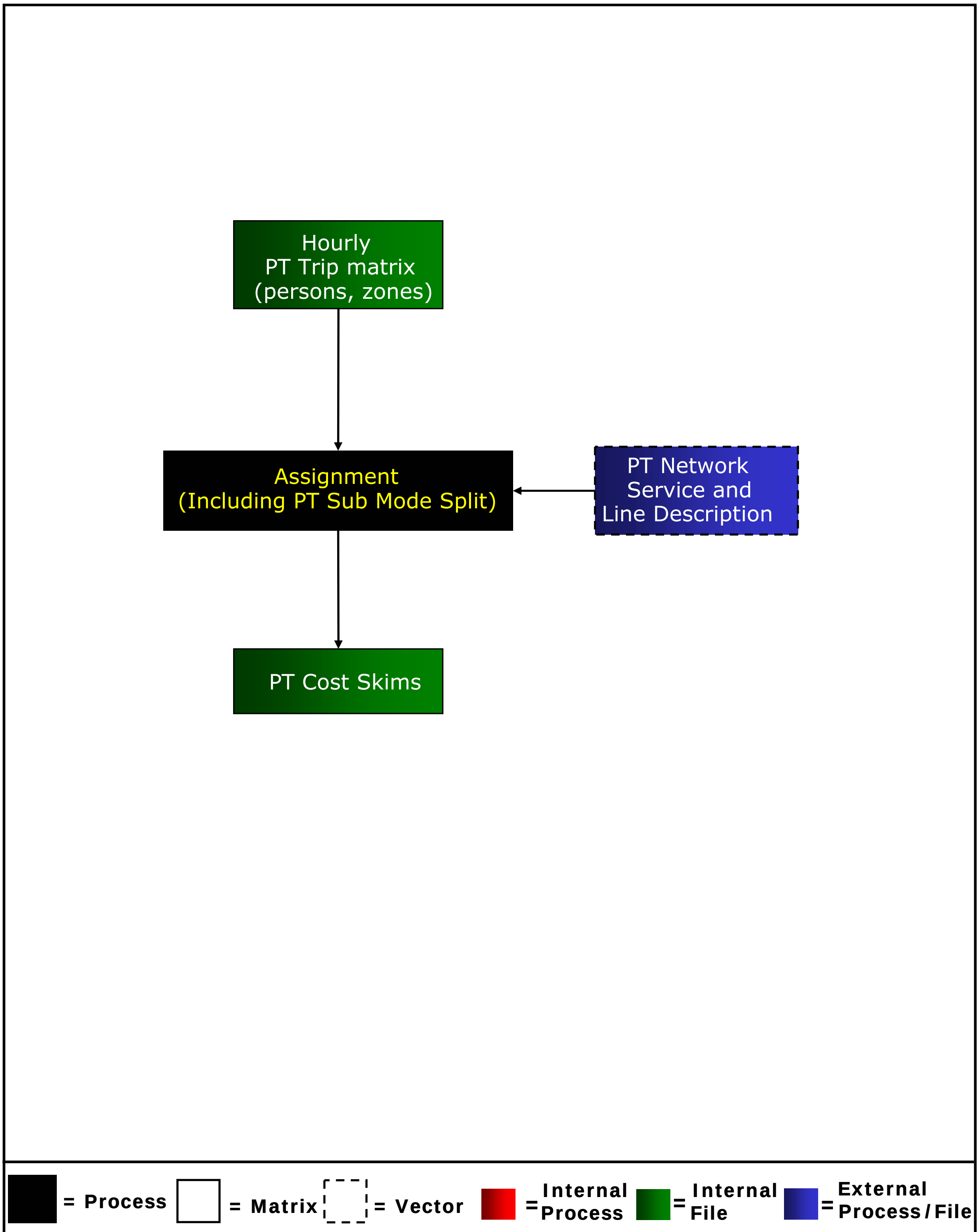


Figure 18: Public Transport Passenger Assignment

Figure 19: Park and Ride Adjustments

- This step makes adjustments to the Assignment Matrices used in the Highway and PT assignment procedures using the costs from these assignments. It adjusts the matrices to represent Park and Ride usage and it creates as output new assignment matrices. The Highway and PT models are reassigned using these new assignment matrices.

- Note: The Park and Ride model is carried out after a full demand model run and it is automatically undertaken as part of the demand model process. Revised travel costs that are produced as a result of this procedure are not fed back into the demand model. However, unlike in TMfS:02, it is no longer an optional part of the framework due to the way in which the Road and PT models were developed. Also note that the process has been recalibrated and additional Park and Ride sites have been included, mainly at train stations since TMfS:02.

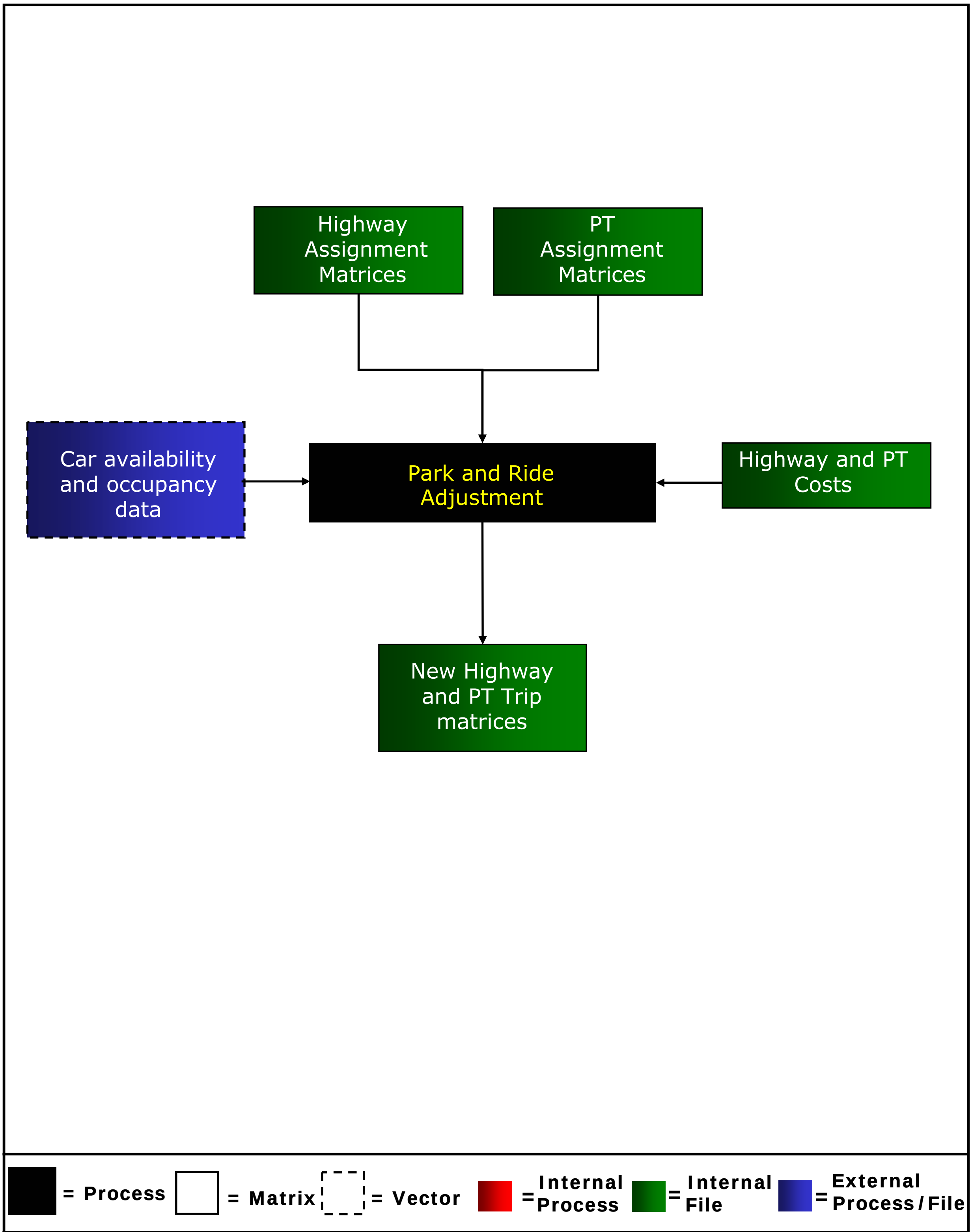


Figure 19: Park and Ride Adjustment

Figure 20: Goods Vehicles Forecasting Process

- This figure shows the goods vehicle forecasting process. It is a growth factor process in which base year matrices at a zonal level by vehicle type (LGV, OGV) and hour are iteratively adjusted using the Furness procedure.

- The forecast trip ends are calculated by applying growth factors to the base year trip ends. The growth factors will be derived from TELMoS for internal zones and based on NRTF for external zones.

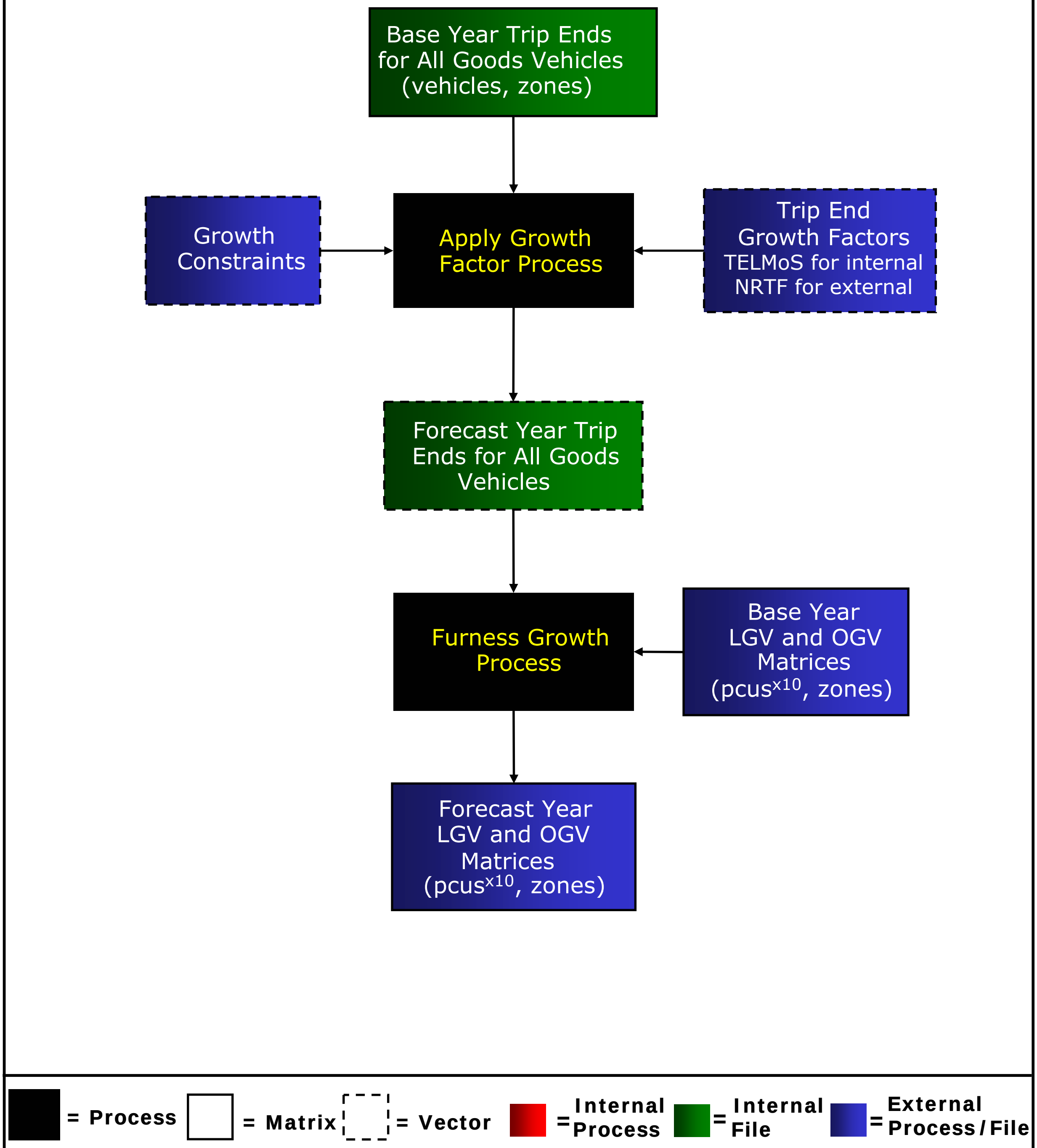


Figure 20: Goods Vehicle Forecasting Process

Appendix B

TMfS Zone to 3 Sector Correspondence

Appendix B

Table B.1 TMfS Zone to Three Sector Correspondence List

TMfS Sector	TMfS Zones	Name
1	1-94, 96-102, 104-162, 169-170, 175-178, 194, 200-201	Edinburgh
2	422-446, 497-498, 575-581, 620-622, 625, 652, 700-706, 730-931, 933-960, 966-970	Glasgow
3	95, 103, 163-168, 171-174, 179-193, 195-199, 202-423, 447-496, 499-574, 582-619, 623-624, 626-651, 653-699, 707-729, 932, 961-965, 972-1096	Rest of Modelled Area
N/A	1097-1100	Airport Zones
N/A	1101-1137	External

Appendix C

Demand Model Cost Coefficients

Appendix C

1 Calculation of public transport and highway base year demand model cost coefficients

1.1 The methodology given in the DfT's Transport Analysis Guidance (TAG) Unit 3.5.6 has been followed. We assign car In-Work and Non-Work separately and therefore cost coefficients are calculated for each. We also do not include goods vehicles elasticity within the demand model and subsequently do not require the calculation of OGV cost coefficients. Therefore, the method of calculation can be followed, but noting that the average speed in the modelled area has been calculated as 59 km/h.

1.2 The Base Year (2005) public transport generalised cost parameters were calculated in accordance with TAG, as follows:

2002 prices

Non-working time (Commuting)

504 p/hr (TAG Table 2 perceived cost)

Non-working time (Other)

446 p/hr (TAG Table 2 perceived cost)

Proportion of commuting and other for Non-Work. These are for average weekday for person distance.

Commuting - 23.9 (TAG Table 7)

Other – 63.5 (TAG Table 7)

Weighted Non-Work Time between Commuting and Other

461.86 p/hr

Multiplied by 2002 to 2005 annual non-work growth rates (TAG Table 3)

2002-2003 - 1.58%

2003-1004 – 1.78%

2004-2005 – 2.57%

= 461.86 x 1.0158 x 1.0178 x 1.0257

489.781 p/hr

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

$$\text{Distance cost parameter} = \frac{\text{fuel cost} + \text{vehicle operating cost}}{\text{value of time per vehicle}/60}$$

$$\text{Toll cost parameter} = \frac{1}{\text{value of time per vehicle}/60}$$

Fuel cost = (cost of petrol × proportion using petrol) +

(cost of diesel × proportion using diesel)

cost of petrol and diesel = consumption × price (excluding VAT)

consumption = $(a + bV + cV^2)$ × change in consumption (Table 13)

where a, b and c are taken from Table 10

and V = average link speed taken as 59 kph

price = (perceived cost (Table11) × growth (Table 14)) + duty (Table 11)

cost of petrol = $\{(0.1617 - 0.0029 \times 59 + 0.00002001 \times 59^2) \times 0.915\}$

$\times \{[(16.5 \times 1.069) + 45.8] * 1.175\}$

= 4.11

[The petrol growth rate is derived from Table 14 of WebTAG 3.5.6, as follows: 1 x (1 + 0.1002) x (1 + 0.0297) x (1 – 0.0562) = 1.069]

cost of diesel = $\{(0.1347 - 0.0022 \times 59 + 0.00001553 \times 59^2) \times 0.921\}$

$\times \{[(18.4 \times 1.036) + 45.8] * 1.175\}$

= 4.14

[The diesel growth rate is derived from Table 14 of WebTAG 3.5.6, as follows: 1 x (1 + 0.0.0715) x (1 + 0.0241) x (1 – 0.0562) = 1.036]

Fuel cost = (4.11 × 0.808) + (4.14 × 0.192)

= 4.11

Vehicle operating cost = 0 for Non-Working time

Value of time per vehicle = v.o.t. per occupant × occupancy

v.o.t. per occupant = 489.78 × 1 (Table 3)

= 489.78

occupancy = {(car occupancy per trip – 1) × growth in passenger occupancy} + 1

passenger occupancy growth = $1 \times (1-0.0059)^3$

= {(1.605 (Table4) – 1) × 0.9824 (Table 6)} + 1

= 1.594

Value of time per vehicle = 489.78 × 1.594 = 780.87

Therefore the car Non-Work time cost parameters are as follows:

Distance cost parameter = **0.3161**

Toll parameter = 1 / (6.24 x 1.0605) = **0.1511**

Where 1.0605 is the growth factor from 2002 to 2005 and 6.24 is the tolling value of time. This is calculated in the same way as in TMfS:02

1.4 Car In-Work time generalised cost parameters were calculated in accordance with TAG, as follows:

Distance cost parameter = $\dfrac{\text{fuel cost} + \text{vehicle operating cost}}{\text{value of time per vehicle}/60}$

Toll cost parameter = $\dfrac{1}{\text{value of time per vehicle}/60}$

Fuel cost = (cost of petrol $\times$ proportion using petrol) +

(cost of diesel $\times$ proportion using diesel

cost of petrol and diesel = consumption $\times$ price (excluding VAT)

consumption = $(a + bV + cV^2) \times$ change in consumption (13)

where a, b and c are taken from Table 10

and V = average link speed taken as 59 kph

price = (perceived cost (Table11) $\times$ growth (Table 14)) + duty (Table 11)

cost of petrol = $\{(0.1617 - 0.0029 \times 59 + 0.00002001 \times 59^2) \times 0.915\}$

$\times \{(16.5 \times 1.069) + 45.8\}$

= 3.50

cost of diesel = $\{(0.1347 - 0.0022 \times 59 + 0.00001553 \times 59^2) \times 0.921\}$

$\times \{(18.4 \times 1.036) + 45.8\}$

= 3.52

Fuel cost = $(3.50 \times 0.808) + (3.52 \times 0.192)$

= 3.50

Vehicle operating cost= (a + b/V)

where a, and b are taken from Table 15

and V = average link speed taken as 59 kph

vehicle operating cost = 4.069 + 111.391 / 59

= 5.96

Value of time per vehicle = v.o.t. per driver +

(v.o.t. per passenger × passenger occupancy)

v.o.t. per driver = 2186 (Table 1) × 1 (Table 3) x 1.0759 (Growth Factor)

= 2352

v.o.t. per passenger = 1566 (Table 1) × 1 (Table 3) x 1.0759 (Growth Factor)

= 1685

passenger occupancy = (car occupancy per trip – 1) ×

growth in passenger occupancy

= (1.2 (Table4) – 1) × 0.9869 (Table 6)

= 0.197

Value of time per vehicle = 2352 + (1685 × 0.2)

=2684

Therefore the car In-Work time cost parameters are as follows:

Distance cost parameter = **0.2114**

Toll parameter = 1 / (17.53 x 1.0759) = **0.0530**

Where 1.0759 is the growth factor from 2002 to 2005 and 17.53 is the tolling value of time. This is calculated in the same way as in TMfS:

Appendix D

Incorporation of Parking Charges into TMfS

Appendix D

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. This has the same generalised cost weighting as for tolls. The average cost per parking stay is different for long stay and short stay. Therefore we need to take into account the proportion of cars with an attraction in central areas which pay to use public spaces. The areas where these charges are applied to are shown in Table D1 below.

Table D.1 Destination zones where parking charges are applied

City	TMfS destination zone
Aberdeen	1068, 1070, 1074
Glasgow	730-739, 742-744
Dunfermline	310
Perth	357
Stirling	254-255
Dundee	402, 405, 413
Edinburgh	1-7, 13-16, 19-24, 26, 28, 122-125, 128-137, 139, 141-142, 162

For the purpose of this process, it is assumed that cars with Private Non Residential (PNR) spaces available and cars doing 'kiss and ride' either to the station or final destination do not pay.

Long Stay Parking

This is appropriate for home based work 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. On this basis therefore we have:

- 15% 'kiss and ride';
- about 45% long stay paying; and
- about 40% PNR.

Short Stay

This is appropriate for home based other and non-home based other trips with a destination in a city centre. It is assumed that 80% of total trips will pay this charge.

Average Charges

The average charges for each city are shown in Table D.2. These are in 2002 prices as data has not been recollected for TMfS:05. By convention this is halved for input to the Demand Model (i.e. half each allocated to outward and return journey). Note that the generalised cost weighting for tolls includes an allowance for vehicle occupancy.

Table D.2 Average charges by city

	Short Term (HO)	Long Term (HW)
Aberdeen	£1.20	£7.62
Glasgow	£1.59	£5.28
Dunfermline	£0.93	£3.00
Perth	£0.74	£3.71
Stirling	£1.55	£3.41
Dundee	£1.96	£4.16
Edinburgh	£2.90	£8.32

Application

These costs will be added to the base year generalised cost skim matrices after first being multiplied by the Non Work Car Tolling parameter of the generalised cost equation. The costs will only be added to the areas defined in Table D.1. Table D.3 shows the calculated values for addition to the cost matrices. The calculation is shown below for reference (for this calculation the charge must be converted to pence):

Cost = ((charge × proportion paying) × 0.5) × generalised cost toll parameter

Table D.3 Calculation of Long Stay Generalised Cost

City	Short Term Cost	Long Term Cost
Aberdeen	7.69	27.47
Glasgow	10.20	19.03
Dunfermline	5.98	10.82
Perth	4.78	13.38
Stirling	9.93	12.30
Dundee	12.54	14.99
Edinburgh	18.63	30.01

Appendix E

Destination Choice Model Validation

'From Home to Work' AM Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	47244	520	10833	58597
2	446	80857	21873	103177
3	20295	47620	258951	326867
Total	67985	128997	291657	488640

Estimated Trips

	1	2	3	Total
1	47278	519	10795	58591
2	447	80820	21903	103171
3	20323	47597	258977	326897
Total	68048	128936	291676	488659

Difference

	1	2	3	Total
1	34	-1	-38	-5
2	0	-36	30	-6
3	28	-24	26	30
Total	62	-61	18	19

% Difference

	1	2	3	Total
1	0.1%	-0.2%	-0.4%	0.0%
2	0.1%	0.0%	0.1%	0.0%
3	0.1%	-0.1%	0.0%	0.0%
Total	0.1%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.2	0.0	0.4	0.0
2	0.0	0.1	0.2	0.0
3	0.2	0.1	0.1	0.1
Total	0.2	0.2	0.0	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	8920	772	1099	10791
2	12	7188	1147	8348
3	3958	8286	4558	16802
Total	12890	16246	6805	35941

Estimated Trips

	1	2	3	Total
1	8924	772	1096	10791
2	12	7188	1148	8347
3	3959	8283	4557	16800
Total	12895	16243	6801	35938

Difference

	1	2	3	Total
1	4	0	-4	0
2	0	0	0	0
3	1	-2	-1	-2
Total	5	-3	-4	-2

% Difference

	1	2	3	Total
1	0.0%	0.0%	-0.3%	0.0%
2	0.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%	0.0%
Total	0.0%	0.0%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.1	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.1	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	15617	713	1903	18233
2	436	16172	3138	19746
3	4008	8397	5548	17953
Total	20061	25282	10589	55932

Estimated Trips

	1	2	3	Total
1	15625	712	1896	18233
2	436	16171	3138	19745
3	3934	8455	5562	17951
Total	19995	25339	10595	55930

Difference

	1	2	3	Total
1	8	-1	-7	0
2	1	-1	0	0
3	-74	58	13	-2
Total	-65	56	6	-3

% Difference

	1	2	3	Total
1	0.1%	-0.1%	-0.4%	0.0%
2	0.2%	0.0%	0.0%	0.0%
3	-1.8%	0.7%	0.2%	0.0%
Total	-0.3%	0.2%	0.1%	0.0%

GEH

	1	2	3	Total
1	0.1	0.0	0.2	0.0
2	0.0	0.0	0.0	0.0
3	1.2	0.6	0.2	0.0
Total	0.5	0.4	0.1	0.0

'From Home to Employers Business' AM Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	5929	86	1368	7382
2	255	10894	2812	13960
3	2032	5407	21776	29216
Total	8216	16387	25956	50558

Estimated Trips

	1	2	3	Total
1	5930	86	1368	7385
2	254	10889	2811	13954
3	2029	5410	21765	29204
Total	8213	16385	25945	50542

Difference

	1	2	3	Total
1	1	0	1	2
2	0	-5	-1	-6
3	-3	3	-11	-11
Total	-3	-2	-11	-16

% Difference

	1	2	3	Total
1	0.0%	0.2%	0.1%	0.0%
2	-0.2%	0.0%	0.0%	0.0%
3	-0.2%	0.1%	0.0%	0.0%
Total	0.0%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.1
3	0.1	0.0	0.1	0.1
Total	0.0	0.0	0.1	0.1

PT Car Available

Observed Trips

	1	2	3	Total
1	355	50	53	458
2	0	303	62	365
3	166	300	217	683
Total	521	653	331	1506

Estimated Trips

	1	2	3	Total
1	355	50	53	458
2	0	303	62	365
3	167	299	216	683
Total	522	652	331	1506

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	1	-1	0	0
Total	1	0	0	0

% Difference

	1	2	3	Total
1	0.0%	0.1%	0.0%	0.0%
2	0.4%	0.0%	-0.1%	0.0%
3	0.4%	-0.2%	-0.1%	0.0%
Total	0.1%	-0.1%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	658	29	92	779
2	19	716	183	918
3	181	330	272	782
Total	858	1074	547	2479

Estimated Trips

	1	2	3	Total
1	658	29	92	779
2	19	716	183	918
3	179	330	272	782
Total	857	1075	547	2479

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	-1	1	0	0
Total	-2	1	0	0

% Difference

	1	2	3	Total
1	0.0%	0.1%	0.1%	0.0%
2	-0.1%	0.0%	0.0%	0.0%
3	-0.8%	0.3%	0.2%	0.0%
Total	-0.2%	0.1%	0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.1	0.1	0.0	0.0
Total	0.1	0.0	0.0	0.0

'From Home to Other' AM Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	16744	119	4197	21060
2	192	28164	8799	37156
3	6862	14446	95484	116793
Total	23799	42729	108480	175008

Estimated Trips

	1	2	3	Total
1	16755	119	4186	21060
2	193	28160	8798	37151
3	6866	14434	95495	116795
Total	23814	42713	108479	175006

Difference

	1	2	3	Total
1	11	0	-11	0
2	0	-4	-1	-5
3	4	-12	10	2
Total	15	-16	-1	-2

% Difference

	1	2	3	Total
1	0.1%	-0.1%	-0.3%	0.0%
2	0.1%	0.0%	0.0%	0.0%
3	0.1%	-0.1%	0.0%	0.0%
Total	0.1%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.1	0.0	0.2	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.1	0.0	0.0
Total	0.1	0.1	0.0	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	5715	588	738	7041
2	5	4681	796	5482
3	2570	5436	2971	10977
Total	8290	10704	4505	23500

Estimated Trips

	1	2	3	Total
1	5718	587	736	7041
2	5	4679	797	5482
3	2582	5424	2970	10975
Total	8305	10690	4503	23498

Difference

	1	2	3	Total
1	2	-1	-2	0
2	0	-1	1	0
3	12	-12	-1	-2
Total	14	-14	-2	-2

% Difference

	1	2	3	Total
1	0.0%	-0.1%	-0.2%	0.0%
2	0.2%	0.0%	0.1%	0.0%
3	0.5%	-0.2%	0.0%	0.0%
Total	0.2%	-0.1%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.1	0.0
2	0.0	0.0	0.0	0.0
3	0.2	0.2	0.0	0.0
Total	0.2	0.1	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	9959	522	1217	11698
2	356	10631	2397	13384
3	2655	5593	3434	11683
Total	12970	16746	7048	36765

Estimated Trips

	1	2	3	Total
1	9964	521	1213	11698
2	356	10629	2398	13384
3	2619	5622	3441	11682
Total	12939	16772	7052	36763

Difference

	1	2	3	Total
1	5	-1	-4	0
2	1	-2	1	0
3	-36	29	6	-1
Total	-31	26	3	-2

% Difference

	1	2	3	Total
1	0.0%	-0.2%	-0.3%	0.0%
2	0.2%	0.0%	0.0%	0.0%
3	-1.4%	0.5%	0.2%	0.0%
Total	-0.2%	0.2%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.1	0.0
2	0.0	0.0	0.0	0.0
3	0.7	0.4	0.1	0.0
Total	0.3	0.2	0.0	0.0

'Non-home-based Employers Business' AM Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	8435	231	2376	11042
2	182	15935	4157	20274
3	2000	5385	28397	35781
Total	10616	21550	34931	67097

Estimated Trips

	1	2	3	Total
1	8438	230	2370	11038
2	182	15926	4160	20267
3	1999	5384	28390	35773
Total	10618	21540	34920	67078

Difference

	1	2	3	Total
1	3	-1	-7	-4
2	0	-9	2	-7
3	-1	0	-6	-8
Total	2	-10	-11	-19

% Difference

	1	2	3	Total
1	0.0%	-0.2%	-0.3%	0.0%
2	0.1%	-0.1%	0.1%	0.0%
3	-0.1%	0.0%	0.0%	0.0%
Total	0.0%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.1	0.0
2	0.0	0.1	0.0	0.0
3	0.0	0.0	0.0	0.0
Total	0.0	0.1	0.1	0.1

PT Car Available

Observed Trips

	1	2	3	Total
1	95	2	8	105
2	2	62	10	73
3	44	77	20	142
Total	141	141	38	320

Estimated Trips

	1	2	3	Total
1	95	2	8	105
2	2	62	10	73
3	43	79	20	142
Total	140	142	38	320

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	-1	1	0	0
Total	-1	1	0	0

% Difference

	1	2	3	Total
1	0.0%	-0.2%	-0.3%	0.0%
2	0.1%	0.0%	0.1%	0.0%
3	-3.1%	1.6%	0.8%	0.0%
Total	-1.0%	0.9%	0.4%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.2	0.1	0.0	0.0
Total	0.1	0.1	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	169	1	18	189
2	31	167	34	232
3	42	84	38	164
Total	243	253	90	585

Estimated Trips

	1	2	3	Total
1	169	1	18	189
2	31	167	34	232
3	40	86	38	164
Total	241	254	90	585

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	-2	2	1	0
Total	-2	2	0	0

% Difference

	1	2	3	Total
1	0.0%	-0.9%	-0.3%	0.0%
2	0.2%	-0.1%	0.1%	0.0%
3	-5.4%	2.1%	1.3%	0.0%
Total	-0.9%	0.7%	0.5%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.4	0.2	0.1	0.0
Total	0.1	0.1	0.1	0.0

'Non-home-based Other' AM Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	8341	54	2360	10755
2	116	14838	5462	20416
3	1933	4145	39580	45658
Total	10391	19036	47402	76828

Estimated Trips

	1	2	3	Total
1	8350	54	2353	10757
2	116	14829	5469	20414
3	1937	4145	39585	45666
Total	10402	19027	47407	76836

Difference

	1	2	3	Total
1	8	0	-6	2
2	0	-9	6	-2
3	3	0	5	8
Total	12	-9	5	8

% Difference

	1	2	3	Total
1	0.1%	-0.1%	-0.3%	0.0%
2	0.1%	-0.1%	0.1%	0.0%
3	0.2%	0.0%	0.0%	0.0%
Total	0.1%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.1	0.0	0.1	0.0
2	0.0	0.1	0.1	0.0
3	0.1	0.0	0.0	0.0
Total	0.1	0.1	0.0	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	615	46	73	734
2	2	488	95	585
3	272	531	296	1099
Total	888	1066	464	2418

Estimated Trips

	1	2	3	Total
1	615	46	73	734
2	2	488	95	585
3	269	534	296	1099
Total	885	1069	464	2418

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	-4	3	0	0
Total	-3	3	0	0

% Difference

	1	2	3	Total
1	0.0%	-0.2%	-0.3%	0.0%
2	-0.1%	0.0%	0.1%	0.0%
3	-1.3%	0.6%	0.1%	0.0%
Total	-0.4%	0.3%	0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.2	0.1	0.0	0.0
Total	0.1	0.1	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	1096	33	138	1267
2	88	1153	288	1528
3	275	559	356	1190
Total	1459	1745	781	3985

Estimated Trips

	1	2	3	Total
1	1096	33	137	1267
2	88	1152	288	1528
3	268	564	357	1190
Total	1453	1750	782	3985

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	-7	6	2	0
Total	-6	5	1	0

% Difference

	1	2	3	Total
1	0.0%	-0.3%	-0.3%	0.0%
2	0.2%	0.0%	0.0%	0.0%
3	-2.6%	1.0%	0.4%	0.0%
Total	-0.4%	0.3%	0.2%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.4	0.2	0.1	0.0
Total	0.2	0.1	0.0	0.0

'From Home to Work' Inter Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	13473	47	1756	15276
2	193	26275	6018	32486
3	3771	8883	61490	74144
Total	17437	35205	69264	121906

Estimated Trips

	1	2	3	Total
1	13468	47	1763	15278
2	192	26275	6013	32479
3	3736	8894	61516	74146
Total	17395	35216	69292	121903

Difference

	1	2	3	Total
1	-5	0	7	2
2	-2	0	-4	-6
3	-35	11	26	1
Total	-42	11	28	-3

% Difference

	1	2	3	Total
1	0.0%	0.6%	0.4%	0.0%
2	-0.8%	0.0%	-0.1%	0.0%
3	-0.9%	0.1%	0.0%	0.0%
Total	-0.2%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.2	0.0
2	0.1	0.0	0.1	0.0
3	0.6	0.1	0.1	0.0
Total	0.3	0.1	0.1	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	1998	3	295	2296
2	1	1241	505	1747
3	299	504	3096	3899
Total	2298	1748	3896	7942

Estimated Trips

	1	2	3	Total
1	1997	3	295	2296
2	1	1240	506	1747
3	317	499	3081	3898
Total	2316	1743	3882	7941

Difference

	1	2	3	Total
1	0	0	0	0
2	0	-1	1	0
3	18	-4	-15	-1
Total	18	-5	-14	-1

% Difference

	1	2	3	Total
1	0.0%	0.4%	0.1%	0.0%
2	-0.3%	-0.1%	0.1%	0.0%
3	6.1%	-0.9%	-0.5%	0.0%
Total	0.8%	-0.3%	-0.4%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	1.0	0.2	0.3	0.0
Total	0.4	0.1	0.2	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	3756	5	361	4123
2	36	3480	728	4245
3	330	760	3617	4707
Total	4123	4245	4707	13075

Estimated Trips

	1	2	3	Total
1	3756	5	362	4123
2	36	3479	729	4244
3	352	754	3601	4706
Total	4144	4238	4692	13073

Difference

	1	2	3	Total
1	0	0	0	0
2	0	-1	1	0
3	22	-6	-16	-1
Total	21	-7	-15	-1

% Difference

	1	2	3	Total
1	0.0%	0.4%	0.1%	0.0%
2	-0.4%	0.0%	0.1%	0.0%
3	6.6%	-0.8%	-0.5%	0.0%
Total	0.5%	-0.2%	-0.3%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	1.2	0.2	0.3	0.0
Total	0.3	0.1	0.2	0.0

'From Home to Employers Business' Inter Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	2725	125	1319	4169
2	205	5773	1977	7955
3	1441	2934	19359	23734
Total	4371	8833	22655	35858

Estimated Trips

	1	2	3	Total
1	2725	126	1319	4169
2	205	5771	1974	7950
3	1438	2935	19350	23724
Total	4368	8832	22643	35843

Difference

	1	2	3	Total
1	0	0	0	0
2	0	-2	-2	-5
3	-3	1	-9	-10
Total	-3	-1	-11	-15

% Difference

	1	2	3	Total
1	0.0%	0.0%	0.0%	0.0%
2	-0.2%	0.0%	-0.1%	-0.1%
3	-0.2%	0.0%	0.0%	0.0%
Total	-0.1%	0.0%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.1	0.1
3	0.1	0.0	0.1	0.1
Total	0.0	0.0	0.1	0.1

PT Car Available

Observed Trips

	1	2	3	Total
1	743	5	109	856
2	0	520	198	718
3	114	194	982	1290
Total	857	718	1290	2864

Estimated Trips

	1	2	3	Total
1	742	5	109	856
2	0	520	198	718
3	114	194	981	1289
Total	857	718	1289	2864

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	1	0	-1	0
Total	1	0	-1	0

% Difference

	1	2	3	Total
1	0.0%	0.1%	0.0%	0.0%
2	-0.5%	0.0%	0.0%	0.0%
3	0.6%	-0.1%	-0.1%	0.0%
Total	0.1%	0.0%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	1429	24	126	1579
2	18	1462	336	1816
3	132	331	1142	1605
Total	1579	1817	1604	5000

Estimated Trips

	1	2	3	Total
1	1429	24	126	1579
2	18	1462	336	1816
3	132	331	1142	1604
Total	1579	1817	1603	5000

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	1	0	-1	0
Total	1	0	-1	0

% Difference

	1	2	3	Total
1	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%
3	0.5%	-0.1%	-0.1%	0.0%
Total	0.0%	0.0%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0

'From Home to Other' Inter Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	53756	217	6215	60188
2	733	104537	22807	128077
3	17160	36957	247738	301855
Total	71649	141711	276761	490120

Estimated Trips

	1	2	3	Total
1	53732	218	6237	60186
2	727	104560	22780	128068
3	16980	36981	247916	301877
Total	71439	141759	276934	490131

Difference

	1	2	3	Total
1	-25	1	22	-2
2	-6	23	-27	-9
3	-180	23	178	22
Total	-210	47	173	11

% Difference

	1	2	3	Total
1	0.0%	0.6%	0.3%	0.0%
2	-0.8%	0.0%	-0.1%	0.0%
3	-1.0%	0.1%	0.1%	0.0%
Total	-0.3%	0.0%	0.1%	0.0%

GEH

	1	2	3	Total
1	0.1	0.1	0.3	0.0
2	0.2	0.1	0.2	0.0
3	1.4	0.1	0.4	0.0
Total	0.8	0.1	0.3	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	9514	4	1483	11001
2	26	5725	2736	8487
3	1491	2781	15678	19950
Total	11031	8510	19897	39438

Estimated Trips

	1	2	3	Total
1	9513	4	1484	11001
2	26	5725	2736	8487
3	1582	2761	15603	19946
Total	11122	8490	19822	39433

Difference

	1	2	3	Total
1	-1	0	1	0
2	0	-1	0	-1
3	92	-20	-75	-4
Total	91	-21	-75	-5

% Difference

	1	2	3	Total
1	0.0%	0.5%	0.0%	0.0%
2	-0.5%	0.0%	0.0%	0.0%
3	6.1%	-0.7%	-0.5%	0.0%
Total	0.8%	-0.2%	-0.4%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	2.3	0.4	0.6	0.0
Total	0.9	0.2	0.5	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	17548	36	1853	19436
2	393	16425	4057	20875
3	1496	4413	17528	23436
Total	19436	20874	23437	63747

Estimated Trips

	1	2	3	Total
1	17546	36	1854	19436
2	391	16427	4056	20874
3	1610	4382	17440	23432
Total	19547	20845	23350	63742

Difference

	1	2	3	Total
1	-1	0	1	0
2	-2	2	0	-1
3	115	-31	-88	-4
Total	111	-29	-88	-5

% Difference

	1	2	3	Total
1	0.0%	0.5%	0.1%	0.0%
2	-0.6%	0.0%	0.0%	0.0%
3	7.7%	-0.7%	-0.5%	0.0%
Total	0.6%	-0.1%	-0.4%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.1	0.0	0.0	0.0
3	2.9	0.5	0.7	0.0
Total	0.8	0.2	0.6	0.0

'Non-home-based Employers Business' Inter Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	23384	1551	9863	34798
2	1467	47374	16972	65813
3	9581	18755	146215	174551
Total	34432	67680	173050	275162

Estimated Trips

	1	2	3	Total
1	23374	1550	9862	34786
2	1467	47358	16971	65796
3	9577	18757	146200	174534
Total	34418	67665	173032	275116

Difference

	1	2	3	Total
1	-10	-1	-1	-12
2	0	-16	-1	-17
3	-3	2	-15	-17
Total	-14	-15	-18	-46

% Difference

	1	2	3	Total
1	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%	0.0%
Total	0.0%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.1	0.0	0.0	0.1
2	0.0	0.1	0.0	0.1
3	0.0	0.0	0.0	0.0
Total	0.1	0.1	0.0	0.1

PT Car Available

Observed Trips

	1	2	3	Total
1	333	16	25	374
2	0	278	43	321
3	44	146	357	547
Total	376	440	425	1242

Estimated Trips

	1	2	3	Total
1	333	16	25	374
2	0	278	43	321
3	45	146	356	547
Total	378	440	424	1242

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	1	-1	-1	0
Total	1	-1	-1	0

% Difference

	1	2	3	Total
1	0.0%	0.0%	0.1%	0.0%
2	24.4%	0.0%	-0.1%	0.0%
3	2.6%	-0.4%	-0.1%	0.0%
Total	0.3%	-0.1%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.1	0.0	0.0	0.0
3	0.2	0.1	0.0	0.0
Total	0.1	0.0	0.0	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	674	5	60	739
2	27	756	220	1003
3	41	110	564	715
Total	743	870	844	2458

Estimated Trips

	1	2	3	Total
1	674	5	60	739
2	27	756	220	1003
3	42	109	564	715
Total	743	870	844	2458

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	1	0	0	0
Total	1	0	0	0

% Difference

	1	2	3	Total
1	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%
3	1.4%	-0.1%	-0.1%	0.0%
Total	0.1%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0

'Non-home-based Other' Inter Peak Period - Sector Comparison

Car

Observed Trips

	1	2	3	Total
1	35808	281	6113	42201
2	305	67660	17229	85194
3	6123	16188	148231	170542
Total	42237	84129	171573	297938

Estimated Trips

	1	2	3	Total
1	35803	281	6115	42200
2	304	67659	17224	85187
3	6112	16188	148249	170549
Total	42219	84128	171588	297935

Difference

	1	2	3	Total
1	-5	0	3	-2
2	-1	-1	-5	-7
3	-11	0	18	6
Total	-17	-1	15	-3

% Difference

	1	2	3	Total
1	0.0%	0.2%	0.0%	0.0%
2	-0.3%	0.0%	0.0%	0.0%
3	-0.2%	0.0%	0.0%	0.0%
Total	0.0%	0.0%	0.0%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.1	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0
Total	0.1	0.0	0.0	0.0

PT Car Available

Observed Trips

	1	2	3	Total
1	2200	108	172	2480
2	1	1840	286	2127
3	286	970	2378	3634
Total	2488	2919	2836	8242

Estimated Trips

	1	2	3	Total
1	2200	108	172	2480
2	1	1840	286	2127
3	297	965	2373	3634
Total	2498	2913	2831	8242

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	10	-5	-5	0
Total	10	-5	-5	0

% Difference

	1	2	3	Total
1	0.0%	0.1%	0.0%	0.0%
2	-0.5%	0.0%	0.1%	0.0%
3	3.6%	-0.6%	-0.2%	0.0%
Total	0.4%	-0.2%	-0.2%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.6	0.2	0.1	0.0
Total	0.2	0.1	0.1	0.0

PT Non-car Available

Observed Trips

	1	2	3	Total
1	4471	35	401	4907
2	174	5015	1463	6652
3	273	728	3747	4749
Total	4919	5778	5611	16308

Estimated Trips

	1	2	3	Total
1	4471	35	402	4907
2	174	5015	1463	6652
3	278	727	3743	4749
Total	4923	5777	5608	16308

Difference

	1	2	3	Total
1	0	0	0	0
2	0	0	0	0
3	5	-1	-4	0
Total	4	-1	-3	0

% Difference

	1	2	3	Total
1	0.0%	0.1%	0.0%	0.0%
2	-0.2%	0.0%	0.0%	0.0%
3	1.8%	-0.2%	-0.1%	0.0%
Total	0.1%	0.0%	-0.1%	0.0%

GEH

	1	2	3	Total
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.3	0.0	0.1	0.0
Total	0.1	0.0	0.0	0.0

Appendix F

Destination Choice K-Factors

Appendix F

Table F.1 HBW Destination Choice K-Factors – Morning Peak

	Sector	1	2	3
HBW:				
Car	**1**	0.815	1.117	2.259
	2	0.864	1.624	0.424
	3	1.657	0.592	1.077
PT NCA	**1**	0.860	7.443	2.145
	2	0.267	0.977	1.257
	3	0.982	0.963	1.096
PT CA	**1**	0.921	2.162	1.677
	2	2.065	0.954	1.267
	3	1.205	0.840	1.171

Table F.2 HBEB Destination Choice K-Factors – Morning Peak

	Sector	1	2	3
HBEB:				
Car	**1**	0.871	1.182	1.766
	2	1.423	1.510	0.212
	3	1.589	0.570	1.242
PT NCA	**1**	0.851	2.343	1.986
	2	0.075	0.950	1.888
	3	1.218	0.767	1.355
PT CA	**1**	0.943	0.694	1.929
	2	2.111	0.899	2.283
	3	1.722	0.652	1.367

Table F.3 HBO Destination Choice K-Factors – Morning Peak

	Sector	1	2	3
HBO:				
Car	**1**	0.978	0.749	1.205
	2	0.121	1.629	0.228
	3	1.314	0.485	1.150
PT NCA	**1**	0.847	6.636	2.249
	2	0.225	0.958	1.570
	3	0.975	0.918	1.233
PT CA	**1**	0.932	1.613	1.608
	2	2.826	0.919	1.616
	3	1.235	0.813	1.265

Table F.4 NHBEB Destination Choice K-Factors – Morning Peak

	Sector	1	2	3
NHBEB:				
Car	**1**	0.905	1.097	1.468
	2	1.172	1.665	0.446
	3	1.367	0.377	1.190
PT NCA	**1**	1.008	1.170	0.905
	2	1.540	1.012	0.882
	3	1.295	1.187	0.446
PT CA	**1**	1.009	0.287	1.098
	2	6.642	0.876	0.922
	3	1.612	1.004	0.646

Table F.5 NHBO Destination Choice K-Factors – Morning Peak

	Sector	1	2	3
NHBO:				
Car	**1**	0.990	0.673	1.096
	2	1.185	1.513	0.340
	3	0.839	0.406	1.199
PT NCA	**1**	0.937	4.279	1.112
	2	0.919	0.995	1.088
	3	1.333	0.973	0.825
PT CA	**1**	1.027	0.779	0.888
	2	7.393	0.933	1.057
	3	1.649	0.865	0.887

Table F.6 HBW Destination Choice K-Factors – Inter-Peak

	Sector	1	2	3
HBW:				
Car	**1**	1.072	0.532	0.670
	2	0.671	1.817	0.285
	3	1.069	0.525	1.131
PT NCA	**1**	0.889	0.750	5.060
	2	0.296	0.787	3.026
	3	0.341	0.202	2.436
PT CA	**1**	0.933	0.631	3.491
	2	3.731	0.904	1.916
	3	0.419	0.257	2.210

Table F.7 HBEB Destination Choice K-Factors – Inter-Peak

	Sector	1	2	3
HBEB:				
Car	**1**	1.291	0.561	0.663
	2	0.626	2.873	0.129
	3	0.788	0.529	1.247
PT NCA	**1**	0.931	0.621	2.106
	2	0.115	0.871	1.938
	3	0.725	0.293	1.850
PT CA	**1**	0.975	1.513	1.273
	2	1.686	0.951	1.352
	3	0.803	0.403	1.704

Table F.8 HBO Destination Choice K-Factors – Inter-Peak

	Sector	1	2	3
HBO:				
Car	**1**	1.080	0.430	0.708
	2	0.248	2.044	0.194
	3	1.121	0.374	1.166
PT NCA	**1**	0.881	0.206	5.163
	2	1.053	0.750	3.434
	3	0.399	0.212	2.408
PT CA	**1**	0.922	1.018	3.712
	2	6.201	0.868	2.195
	3	0.402	0.302	2.177

Table F.9 NHBEB Destination Choice K-Factors – Inter-Peak

	Sector	1	2	3
NHBEB:				
Car	**1**	1.235	0.954	0.620
	2	0.867	2.520	0.335
	3	0.640	0.332	1.296
PT NCA	**1**	0.958	5.355	1.070
	2	0.014	1.064	0.738
	3	0.482	0.726	1.384
PT CA	**1**	0.990	0.675	1.208
	2	2.725	0.945	1.247
	3	0.535	0.372	1.635

Table F.10 NHBO Destination Choice K-Factors – Inter-Peak

	Sector	1	2	3
NHBO:				
Car	**1**	1.016	0.818	0.930
	2	0.689	1.511	0.364
	3	1.041	0.374	1.189
PT NCA	**1**	0.920	21.696	1.832
	2	0.232	0.991	1.161
	3	0.462	0.572	1.700
PT CA	**1**	0.956	2.026	1.816
	2	8.010	0.886	1.879
	3	0.516	0.288	2.003