SEStran Regional Model

Demand Model Development Report

Report for SEStran / Transport Scotland

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Transport Model for Scotland

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Document Approval

Primary Author:	Chris Robinson
Other Author(s):	Chris Cullen
Reviewer(s):	Scott Leitham
Formatted by:	

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Summary

This report summarises the development of the SEStran Region Demand Model and the subsequent 'realism' testing of the Model.

The report gives an overview of the Model and describes the matrix development and each of the choice models in detail. The calibration of the Park and Ride station choice module is also described in this report.

Model realism testing is described in detail in the report, and the implied model elasticities are compared with expected values. The report concludes with a description of the trip end modelling and forecasting procedures.

1 Introduction

1.1 Background

1.1.1 In March 2008 MVA Consultancy were commissioned by Transport Scotland to provide modelling support and advice for the Forth Replacement Crossing Team. As part of this project we developed a sub-area model of TMfS:07 centred on the Forth Crossing area. The sub-area model was developed in SATURN (Road model) and Cube Voyager (PT model and Demand model). In March 2009 we were asked by Transport Scotland to improve the match between the modelled and observed trip distribution pattern across the Forth Road Bridge Northbound in the AM Peak.

1.1.2 In August 2009, the model was further extended to encompass the South East Scotland Transport Partnership (SEStran) area, covering the Local Authorities of East Lothian, Midlothian and Scottish Borders.

1.2 Development of SEStran Model

1.2.1 This report describes the procedure undertaken to develop the Demand Model element of the SEStran Model.

1.2.2 The Demand Model is based on the Forth Regional (FRC) Demand Model, with some modifications and enhancements. It is the same in structure as the TMfS:07 National Demand Model.

1.3 Structure of Report

1.3.1 Following this introductory Chapter, this report includes the following chapters:

- Chapter 2 which provides an overview of the model structure;
- Chapter 3 which describes the development of the trip and cost matrices used in the model calibration;
- Chapter 4 which describes the mode and destination choice calibration stage;
- Chapter 5 which gives a description of the Park and Ride station choice;
- Chapter 6 which describes the procedures for the creation of return trips and non home-based trips;
- Chapter 7 which covers the other choice models that are included with the model;
- Chapter 8 which covers model realism testing;
- Chapter 9 which explains the trip end modelling within the Forth Model;
- Chapter 10 which describes the forecasting procedures; and
- Chapter 11 which contains the conclusions.

2 Model Overview

2.1 Model Structure

2.1.1 The SEStran Demand Model is a 'four-stage' demand model, which incorporates the stages/choices listed below. Traditional elements of a four-stage model are denoted in bold:

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

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

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

- trip productions and attractions;
- generalised costs of travel by highway and public transport modes from the base-year assignment models;
- park and ride site files; and
- calibrated model parameters.

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

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

2.2 Zone System

2.2.1 The zone system within the SEStran Regional Model is a disaggregation of the TMfS:07 National Model zone system (ie SEStran Regional Model zones are sub-divisions of TMfS:07 National Model zones). A portion of the zone system from the Edinburgh area can be seen in Figure 2.1 below. The dark black lines show the National Model zones, and the red lines show the SEStran Regional Model zones. This figure demonstrates the more disaggregate nature of the Regional Model.

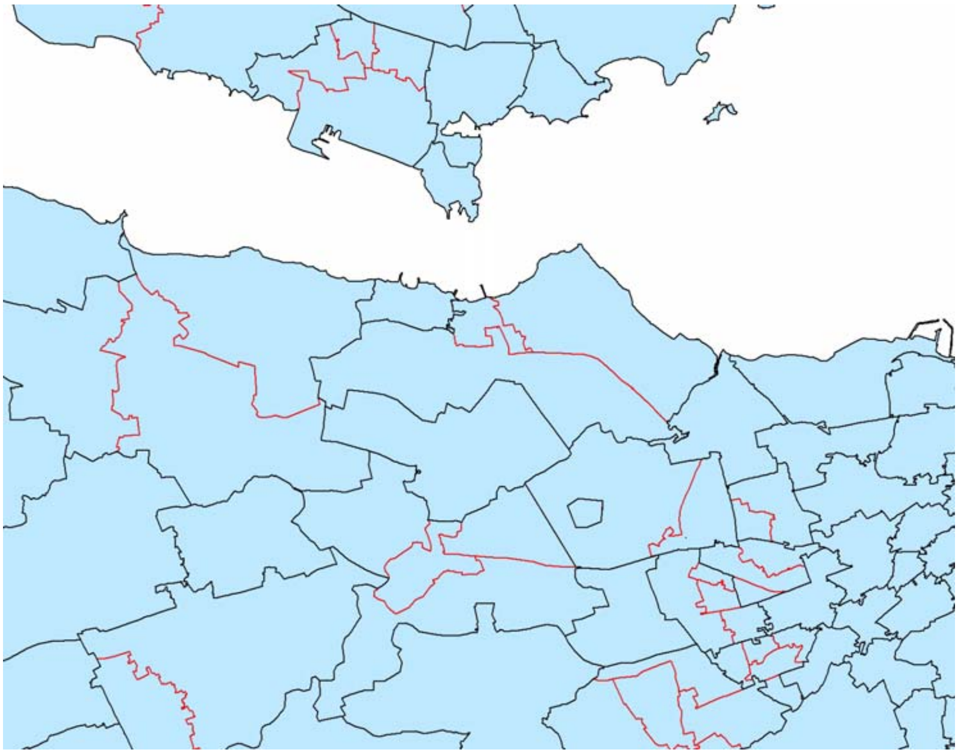

Figure 2.1 SEStran Regional Model Zone System

2.2.2 In total, there are 470 zones, of which those numbered 1 to 335 are internal study area zones. The next 36 zones (336 through 371) represent route zones in the buffer network. The final 99 zones represent Park and Ride zones as well as blank zones for future Park and Ride sites to be modelled.

2.2.3 As with the National Model, each zone only contains at most one train station. It should also be noted that the zone system is completely consistent with Local Authority area boundaries.

2.3 Journey Purposes and Time Periods

2.3.1 The Demand Model contains six journey purposes:

- ***Home-Based Work* (HBW)** – travelling 'from home' to work (and back again) – a typical commuting journey (note – this travel purpose does not take place in employer's time);
- ***Home-Based* Other (HBO)** – travelling 'from home' to a non work-related location such as shopping or leisure;

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

2.3.2 **In addition**, the Demand Model uses four household types:

- **C0** – zero car household (everyone from these is considered to be captive to PT);
- **C11** – 1 car, 1 adult household;
- **C12** – 1 car, 2+ adult household; and
- **C2+** – 2+ car household**.**

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

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

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

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

- AM peak period 0700 - 1000;
- AM peak hour (for assignment modelling) 0800 - 0900;

  (calculated as 0.38 of AM Peak Period Demand)

- 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.

  (calculated as 0.36 of PM Peak Period Demand)

2.4 Generalised Costs

2.4.1 The generalised cost coefficients for the base-year highway assignment model were calculated based on the most up-to-date version of TAG Unit 3.5.6 available at the time of model development (January 2010). The highways generalised cost equation by user class is *GC = a x distance + b x time + c x toll*, where *a, b* and *c* are the parameters.

Table 2.1 Highways Assignment Model Coefficients for Base-year

Mode	Time	Distance	Toll
Cars In-Work	1.0	0.2336	0.0503
Cars Commute	1.0	0.5342	0.1448
Cars Other	1.0	0.3902	0.1448
LGV	1.0	0.6824	0.0225
OGV	1.0	2.1988	0.0225

2.4.2 The base-year generalised cost coefficients for the Public Transport Assignment Model are summarised in Table 2.2. This table also shows the other relevant parameters for the Public Transport Model.

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Table 2.2 Public Transport Assignment Model Parameters

Model Parameter	Value/Factor
Parameter:	
In vehicle times – bus	1.05
.... - rail	1.0
Walk Time Factor	1.6
Minimum Wait Time	0 mins
Maximum Wait Time	60 mins
Boarding Penalty	5 mins
Transfer Penalty	
- rail to rail	5 mins
- bus to bus	10 mins
- bus to rail/underground and vice versa	10 mins
Value of time:	
- in work	21.58 £/hr
- non work	5.11 £/hr

2.4.3 The value of time is used to convert public transport fares into units of generalised time. The values, as in the case of the Highways Assignment Model, were taken from the most up-to-date version of TAG (Unit 3.5.6) available at the time of model development and are in 2007 prices and values.

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

2.5 Parking Charges

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

- Edinburgh;
- Stirling; and
- Dunfermline.

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

2.6 Highway and Public Transport Assignment Models

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

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

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

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

2.7 Trip Ends

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

2.7.2 Forecasting for SEStran Model Trip Ends comes from growth forecasts passed down from the TMfS:07 National Model. This is done to ensure consistency between the SEStran Region model and TMfS:07.

2.7.3 Unlike in previous versions of TMfS, there is much better correlation between the base levels of demand and the base-year planning data. This is a result of using planning data and census matrix tools data to create the initial base-year demand matrices.

2.8 Demand Model Parameters

2.8.1 The demand model parameters control the sensitivity of the various choice processes and also, to some extent, the fit of the model to base-year data.

2.8.2 The base-year demand model parameters include distribution model sensitivity parameters, mode choice scaling factors and mode specific constants. The base model also contains Park and Ride model parameters.

2.8.3 The sensitivity parameter values have been calculated specifically for this model using local data.

2.8.4 These parameters have then been subjected to realism testing as defined by the Variable Demand Model (VADMA) guidance in WebTAG; the implied sensitivities of the model have then been compared to the standard published values.

3 Matrix Development

3.1 Overview

3.1.1 The principal sources of data required for the calibration of the Demand Model were as follows:

- census travel-to-work data;
- planning data from TELMoS;
- TEMPRO trip rates;
- generalised costs of travel from the assignment models, journey purpose, mode and time period;
- roadside interview data;
- public transport survey data;
- National Rail Travel Survey data (NRTS); and
- Park and Ride Site Survey data.

3.1.2 The above data sources were used to build the TMfS:07 National Model matrices. The various data sources have been 'growthed' up from their collection years to a consistent base-year of 2007.

3.1.3 The process involved pairing up matrices in each zone system and where a zone was the same in both systems, transferring the trips to and from that zone wholesale. Where the zones didn't match up correctly (due to the finer disaggregation of the SEStran zone system) a proportion was taken such that trips going to the zone were in proportion with the employment crossover, while for trips from the zone population formed the basis of the conversion.

3.1.4 The demand (and assignment model) matrices for the SEStran regional model are based on two previous sources: TMfS:07 and FRC. Firstly a set of sub-area matrices where created from TMfS:07 which were then merged with FRC matrices such that where a zone to zone trip existed in FRC that value was kept.

3.1.5 Subsequent to this matrix estimation was undertaken on the non-FRC zones in order to calibrate to the current user year. The reasoning behind this was that FRC already had calibrated and validated matrices for a large proportion of the modelled area and it was deemed useful to incorporate it into the SEStran regional model.

4 Destination and Mode Choice Calibration

4.1 Overview

4.1.1 In the SEStran Region Model, destination choice is more sensitive than mode choice. This model structure has been implied by the relevant numerical interrogation of the base data.

4.1.2 For the SEStran Region Model, ALOGIT software has been used to calibrate the mode and destination choice parameters. ALOGIT was also used to test the different model structures.

4.1.3 This chapter covers data processing, model specification and model estimation. Separate parameters have been calculated by time period, car availability segment, mode and purpose.

4.2 Data

4.2.1 The model has 335 (demand model works on internal model zones only) zones generating a demand matrix, incorporating 112,225 origin-destination movements for each segment. For each movement we have data describing the:

- volume of car trips;
- volume of public transport trips;
- volume of park and ride trips;
- generalised cost of travel by car (minutes);
- generalised cost of travel by public transport (minutes); and
- generalised cost of travel by park and ride (minutes).

4.2.2 These sources of data then form the inputs to the calibration process in ALOGIT.

4.3 Data Inspection

4.3.1 The data used in the model shows a strong positive relationship between the generalised cost of travel (in minutes) and journey distance. It also shows a decrease in the PT mode share at greater distances.

4.3.2 The distribution of trips by journey length shows, as expected, a distribution that is negatively skewed, with a peak volume between 0 and 5km and a long tail.

4.3.3 This exploration of the data shows plausible patterns and trends in travel demand and travel costs. The analysis suggests that the data provides a good foundation on which to develop mode and destination choice models.

4.4 Modelling Estimation

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

$$V_j = \beta_0 IntraZonal + \beta_{m1} \ln(C_{ijm}) + \beta_{m2} C_{ijm} + ASC_j$$

Where

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

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

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

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

β_0 is the parameter for the intra-zonal term.

4.4.2 The choice model is equivalent to a doubly constrained gravity model and the logarithmic transformation of generalised costs being equivalent to a constant elasticity approach.

4.4.3 Because the choice-set is large (777 mode and destination combinations), the direct estimation of a full set of 777 alternative specific constants is difficult using conventional maximum likelihood methods. It is therefore necessary to adopt an approach known as "contraction mapping" (Berry, 1994). The approach exploits the fact that, for a given scaling coefficient-vector, there exists a unique set of ASCs, such that the predicted shares equal the actual shares. The estimation of scaling coefficients and ASCs is achieved via an iterative process as follows:

- use ALOGIT to estimate scaling coefficients with ASCs equal to zero;
- forecast market shares for each choice alternative using the model estimated;
- estimate a new set of ASCs, based on the following formula:

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

Where,

ASC - is the base ASC value

ASC` - is the new ASC value

S_A - is the actual share

S_F - is the forecast share;

- re-estimate scaling coefficients in ALOGIT with ASCs set equal to ASC'; and
- iterate steps above until convergence is reached.

4.4.4 The ALOGIT process also estimates a θ value for mode choice.

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

4.5 Model Results

Mode Choice

4.5.1 Table 4.1 below shows the mode choice parameters calculated by ALOGIT for the Forth Area. The parameters are all within the expected range between 0 and 1 and are all positive in sign.

Table 4.1 Mode Choice Parameters

	Segment	AM	IP
Home-Based Employer's Business	C11C	0.45	0.45
	C12	0.78	0.61
	C2	0.90	0.26
	C0	0.00	0.00
Home-Based Other	C11C	0.99	0.53
	C12	0.44	0.92
	C2	0.50	0.53
	C0	0.00	0.00
Home-Based Work	C11C	0.68	0.90
	C12	0.65	0.84
	C2	0.29	0.79
	C0	0.00	0.00

Destination Choice

4.5.2 Table 4.2 below shows the destination choice parameters applied to the log of the generalised cost term in the utility function, while Table 4.3 gives the parameters for the generalised cost only term. These parameters are all of the correct sign.

Table 4.2 Destination Choice Parameters (Ln (C))

		Car		PT		P&R
	Segment	AM	IP	AM	IP	AM
Home-Based Employer's Business	C11C	0.00	0.00	0.00	0.00	0.00
	C12	-0.28	-0.40	0.00	-1.34	0.00
	C2	-0.15	-0.10	0.00	-4.05	0.00
	C0	0.00	0.00	0.00	0.00	0.00
Home-Based Other	C11C	-0.03	0.00	-2.31	0.00	-2.21
	C12	0.00	0.00	-1.90	-2.34	-0.94
	C2	0.00	0.00	0.00	-2.74	0.00
	C0	0.00	0.00	-2.26	0.00	0.00
Home-Based Work	C11C	-0.09	-0.06	-0.41	-0.30	-1.36
	C12	-0.08	-0.39	0.00	-0.47	-0.65
	C2	-0.08	-0.14	0.00	-0.50	-0.90
	C0	0.00	0.00	-0.19	0.00	0.00

Table 4.3 Destination Choice Parameters (C)

		Car			PT	P&R
	Segment	AM	IP	AM	IP	AM
Home-Based Employer's Business	C11C	-0.17	-0.07	-0.09	-0.04	-0.06
	C12	-0.17	-0.20	-0.13	-0.03	-0.03
	C2	-0.15	-0.17	-0.06	-0.01	-0.07
	C0	0.00	0.00	-0.14	-0.08	0.00
Home-Based Other	C11C	-0.14	-0.09	0.00	-0.04	0.00
	C12	-0.13	-0.11	0.00	0.00	-0.02
	C2	-0.11	-0.10	-0.04	0.00	-0.07
	C0	0.00	0.00	0.00	-0.01	0.00
Home-Based Work	C11C	-0.11	-0.17	-0.04	-0.07	-0.02
	C12	-0.09	-0.14	-0.04	-0.03	-0.02
	C2	-0.08	-0.13	-0.05	-0.04	-0.02
	C0	0.00	0.00	-0.04	-0.06	0.00

4.5.3 Table 4.4 shows the intra-zonal K Factors for each purpose and segment.

Table 4.4 Intra Zonal K Factors

	Segment	AM	IP
Home-based Employers Business	C11C	0.86	-1.00
	C12	0.31	0.45
	C2	-0.42	0.65
	C0	-0.94	0.42
Home-based Other	C11C	0.07	-1.00
	C12	-0.36	-0.04
	C2	-0.39	0.39
	C0	-1.62	4.13
Home-based Work	C11C	1.14	0.09
	C12	0.94	0.93
	C2	1.04	0.85
	C0	-0.43	-0.32

4.6 Mode Specific Constants

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

$K_{car} = (U_{p\&r} - U_{Car}) + \{(1/ \beta) * \log (P_{Car}/P_{p\&r})$; and

$K_{pt} = (U_{p\&r} - U_{pt}) + \{(1/ \beta) * \log (P_{pt}/P_{p\&r})$

where:

U_{pt} - composite utility for PT;

$U_{p\&r}$ - composite utility for Park and Ride;

U_{Car} - composite utility for Car;

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

P_{Car} - proportion of Car in base;

$P_{p\&r}$ - proportion of Park and Ride in base; and

P_{pt} - proportion of PT in base.

4.6.2 These formulae have been derived from the mode split formulation and are carried out for each journey purpose. Mode choice scaling factors are required to calculate the constants.

5 Park and Ride Station Choice Calibration

5.1 Overview

5.1.1 Park and Ride choice has been included in the main mode choice model. The demand model parameters associated with Park and Ride and their calibration is described in Chapter 4.

5.1.2 After the Mode and Destination Choice stages of the model, Park and Ride site choice is undertaken. The calibration of the site choice is described in the remainder of this chapter.

5.1.3 The Park and Ride module is applied to the 'from home' trips only in the AM time period. The corresponding return trips for the AM trips are assumed to take place during the PM Peak period.

5.1.4 It should be noted that the Park and Ride module only works for those demand segments which have a car available (ie Non Car trips cannot make a Park and Ride trip)

5.2 Methodology

5.2.1 The inputs to the site choice calibration are the Park and Ride generalised costs and Park and Ride site files.

5.2.2 Each site file contains a specification of the site catchment area, which are defined as a list of zones. For the rail-based Park and Ride sites, the possible destinations are all zones within the model, while for the bus-based Park and Ride sites, the possible destinations are all zones which the bus services from these sites serve. For both bus and rail, the possible origins are all sites in the model.

5.2.3 The Generalised Costs are calculated from combinations of the base highway and PT costs. Park and Ride cost matrices are best path cost matrices (regardless of whether a Park and Ride trip uses the minimum cost path). They are built by finding the minimum cost path from each origin to each Park and Ride site by car and then from there to each destination.

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

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

Where:

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

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

C_s is the generalised cost via site s;

TT_s is the transfer time for site s; and

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

5.2.5 The Park and Ride module works separately for each purpose. It calculates Park and Ride demand for Home-Based Work, Home-Based Employers Business and Home-Based other simultaneously. The model then outputs data by site for each purpose.

5.2.6 Those sites which are overcapacity have a cost based on the level over capacity they are, added in on the next iteration of the Park and Ride to represent the extra cost of finding a parking space.

5.2.7 External Park and Ride trips are introduced using add-in matrices. These trips are fixed and are not altered by the demand model.

5.2.8 The Park and Ride module outputs AM /'From-Home' and PM 'to-Home' matrices by purpose and mode. These are then added into the Highway and Public Transport assignment matrices for route choice.

Site Choice Calibration

5.2.9 Table 5.1 shows the total usage of Park and Ride Sites. The total observed trips is in vehicles. The modelled total is calculated from the period person matrices, but with an average occupancy of 1.2 applied.

Table 5.1 Park and Rite Site Calibration by Local Authority

Local Authority	Total Observed	Total Modelled	Difference	GEH
East Lothian	416	328	-88	4.6
City of Edinburgh	1,482	1,650	168	4.3
West Lothian	1,076	1,088	12	0.4
Falkirk	1,061	1,146	85	2.5
Stirling	719	595	-123	4.8
Fife	2,067	2,048	-18	0.4
Perthshire & Kinross	15	1	-13	4.7
Total	**6,835**	**6,857**	**22**	**0.3**

5.2.10 The table above shows that at an individual site level, the model predictions of Park and Ride use is very close to the observed levels.

5.2.11 For the rail-based Park and Ride sites, the observed data comes from the NRTS. Within this database it was very easy to isolate purely internal to internal trips. The bus-based Park and Ride sites come from survey data, to which site specific factors were applied to get internal only observations.

6 Reverse and Non Home Based Trips

6.1 Overview

6.1.1 The demand works at for 'from home' journey purposes for the AM Peak period and Inter-Peak only. Further factoring procedures are then run to calculate the PM 'from home' trips, 'to home' and non home-based trips. This is the same process as in TMfS national model.

6.1.2 This chapter describes the methodology for these detailed factoring processes.

6.2 Evening Peak Trips

6.2.1 For the Evening Peak, 'from home' trips were generated by factoring the 'from home' trips for the Inter-Peak time period.

6.2.2 We then have:

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

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

6.3 'To Home' Trips

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

- **t** the time period of the *'from home'* trip;
- **p** the journey purpose of the *'from home'* trip;
- **m** the mode of the *'from home'* trip;
- **T** the time period of the *'to home'* trip;
- **P** the journey purpose of the *'to home'* trip; and
- **M** the mode of the *'to home'* trip.

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

6.3.3 The 'to home' trips are calculated from the *'from home'* trips as follows:

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

where:

$T_{ij(to)}^{TMP}$ = *'to home'* person trips from origin *i* to destination *j* in time period **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**; and

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**.

Note that α_{TPM}^{tpm} = 0 for 'from home' time periods later than the 'to home' time period, ie 'to home' trips in the AM Peak for example, cannot be linked to 'from home' trips in the Inter-Peak.

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

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

6.4 Non Home-Based Trips

6.4.1 For non home-based trips, the origins and destinations for the two non home-based purposes (In-Work and Non-Work) were calculated based on the destinations of 'from home' trips and the origins of 'to home' trips. The non home-based Trip Ends were calculated separately by time period.

6.4.2 For non home-based origins:

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

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.

Note that the factors **β** are zero for time periods later than the *non home-based* origins/destinations.

6.4.3 It is unlikely that the total origins will equal the total destinations when applying this process, so the totals will be constrained to an average of the two. Matrices of non home-based trips by mode and time period will be created by applying the Trip Ends to a distribution model using appropriate inter-zonal costs. The calibrated parameters for these distribution models are described in Section 6.5.

6.4.4 The total trips by mode are calculated simply by adding the origin destination matrices together for Public Transport, and weighting by vehicle occupancy for car trips.

6.5 Non Home-based Destination Choice

6.5.1 For the SEStran regional model the non home-based choice parameters have been taken from WEBATG guidance. Note that the median values (in bold) were used in the model and the signs are correct. There are nolog parameters (Ln(C)) included. The Intra-zonal K-factors in all cases were taken as -1.

Table 6.1 Non Home-Based Destination Choice Sensitivity Parameters (C)

Mode	Trip Purpose	Minimum	Median	Maximum	Sample
Car (C)	NE	-0.069	**-0.081**	-0.107	-3
	NO	-0.073	**-0.077**	-0.105	-3
PT (C)	NE	-0.038	**-0.042**	-0.045	-2
	NO	-0.032	**-0.033**	-0.035	-3

7 Other Choice Models

7.1 Overview

7.1.1 As well as the mode and destination choice models within the SEStran Regional model, there are four additional choice models. These are Macro Time of Day Choice, Trip Frequency, High Occupancy Vehicle Modelling and Peak Spreading. Each of these modules is optional within the model structure and can all be turned off or turned on in any combination that suits the purpose of the model run. It should be noted that as standard forecast year Do-Minima and Reference Case test runs are run with Trip Frequency turned on, but the other choice models turned off.

7.2 Trip Frequency Model

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

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

- home-based employers business – 1;
- home-based other – 0.5; and
- home-based work -0.

7.2.3 These parameters reflect the relative frequency of trip making to changes in cost. For example, the Home-based Work Parameter is 0, since people will not go to work more frequently regardless of any changes in costs.

7.3 Macro Time of Day Choice Model

7.3.1 The Macro Time of Day Module sits between the Trip Frequency module and the 'Inner Loops' procedure in the model hierarchy.

7.3.2 Macro Time of Day Choice is applied to the AM 'from home' Trip Ends. As part of the process, a set of residual pre-peak 'from home' trip ends by purpose are produced. These trip ends are then converted into matrices using the base costs. These matrices produce return trips in later time periods. The production of reverse trips will be undertaken in the same way as previously described in Chapter 6, on a cell by cell basis.

7.3.3 The development of the Macro Time of Day module is described in greater detail in Appendix K.

7.4 Peak Spreading Model

7.4.1 The peak spreading implemented in the model is intended to cover supply-led active peak spreading, where increased congestion forces travellers to change their departure time to avoid the worst congestion.

7.4.2 The TMfS Peak Spreading Model is an incremental logit model that 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.

7.4.3 The module works by using shoulder peak cost skims and comparing them against peak hour costs. 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 are approximated based on the peak hour costs.

7.4.4 The period to hour factors are then calculated by comparing the peak and shoulder peak costs. The period to hour factors in each cell are constrained to not go below 1/3 (ie a completely flat peak period).

7.4.5 The formulation of the Peak Spreading Module is shown in detail in Appendix L.

7.5 High Occupancy Vehicle Choice

7.5.1 The SEStran Regional Demand Model also allows trips to move between single occupancy vehicles and multiple occupancy cars.

7.5.2 The Module sits after the Inner Loops procedure within the Model structure. The Module works on the Home-based Work, Home-based Employers Business trips and Home-based Other trips for the household segments C11, C12 and C2.

7.5.3 The occupancy choice takes the form of a logit model using different generalised costs for Single Occupancy and High Occupancy trips. The person trip proportion of low occupancy for a particular *ij* pair will be:

$$P = \exp(\beta * C_{low})/\{ \exp(\beta * C_{low}) + \exp(\beta * (C_{high} + \partial))\}$$

Where:

C_{low} is the Generalised Cost for Low Occupancy and C_{high} is the Generalised Cost for High Occupancy;

β is a sensitivity parameter for the logit model; and

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

7.5.4 The output of this is 'from home' matrices by purpose and segment for High Occupancy and Single Occupancy. These are then passed through the reverse trip process as before. These are then converted into vehicle OD matrices using High Occupancy Vehicle matrices.

7.5.5 Finally, Highway Assignment is undertaken. If there are specific High Occupancy Vehicle lanes, they need to be coded into the Model as a separate link type. The High Occupancy and Single Occupancy trips are then skimmed separately to be put back into the Demand Model.

7.5.6 A more detailed description of the High Occupancy Vehicle module can be found in Appendix J of this report.

8 Model Realism Tests

8.1 Overview

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

8.2 Introduction

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

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

8.2.2 These tests undertaken to test these responses within the demand model were as follows:

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

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

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

Then the elasticity is then calculated as:

$$e = (\ln(K') - \ln(K)) / (\ln(C') - \ln(C))$$

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

8.3 Results

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

8.3.2 Table 8.1 shows the elasticities with respect to fuel cost implied in the model. The VADMA guidance recommends that elasticities should be in the range -0.1 to -0.4 and most of the results are within that range or just outside it in the case of AM C11 Car. Two values are a little further out, with IP C12 Car (NWC) and IP C11 Car (NWO) giving slight cause for concern but the relative number of trips here should compensate for the issue.

Table 8.1 Fuel Sensitivity Tests

	AM			IP		
Journey Purpose	*C11 Car*	*C12 Car*	*C2 Car*	*C11 Car*	*C12 Car*	*C2 Car*
In-Work	-0.35	-0.36	-0.33	-0.18	-0.23	-0.25
Non-Work Commute	-0.43	-0.43	-0.34	-0.38	-0.53	-0.44
Non-Work Other	-0.40	-0.36	-0.36	-0.57	-0.30	-0.33

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

Table 8.2 Car Generalised Cost Elasticities

	AM			IP		
Journey Purpose	*C11 Car*	*C12 Car*	*C2 Car*	*C11 Car*	*C12 Car*	*C2 Car*
In-Work	-1.76	-1.83	-1.61	-0.83	-1.12	-1.21
Non-Work Commute	-1.19	-1.21	-0.92	-1.05	-1.49	-1.22
Non-Work Other	-1.33	-1.20	-1.18	-1.88	-0.95	-1.05

8.3.4 Table 8.3 shows the elasticities with respect to public transport fares. The VADMA guidance suggests that PT fares elasticities generally lie in the range -0.2 to -0.4, but can be has high as -0.9 for changes over a long period of time. All the model parameters, except some of those for IP IW and AM NWO, lie within these ranges.

Table 8.3 PT Fare Elasticities

	AM			IP		
Journey Purpose	*C11 Car*	*C12 Car*	*C2 Car*	*C11 Car*	*C12 Car*	*C2 Car*
In-Work	-0.05	-0.08	-0.21	-0.07	-0.13	-0.10
Non-Work Commute	-0.31	-0.20	-0.12	-0.38	-0.22	-0.29
Non-Work Other	-0.58	-0.22	-0.30	-0.15	-0.55	-0.38

8.4 Summary

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

8.4.2 The only elasticities which fall outwith the VADMA guidelines are the Employer's Business elasticities to fuel price and PT Fares, which are slightly lower than the recommended range.

9 Trip End Model

9.1 Overview

9.1.1 This chapter details the methodology used to obtain forecast year inputs for the SEStran regional Model from the TMfS:07 National Model.

9.1.2 This is split into two separate sections, namely:

- the creation of the person trip ends for the internal SEStran zones (used as inputs to the main SEStran Main Demand Model); and
- the process used to predict future demand which is not predicted by the SEStran Demand Model (namely trips to/from external zones and the FRM goods vehicle matrices).

9.2 Person Trip Ends to/from Internal SEStran Zones

9.2.1 The methodology for predicting future year SEStran Internal trip-ends using the national model is as follows:

- Trip-ends for the base year and selected forecast year from the national model are allocated to the corresponding SEStran regional model internal zones;
- Where a national model zone contains multiple SEStran regional model zones, the trip-ends are split by user defined proportions;
- Default values of these splitting proportions (based on relevant base-year demographic data) will be provided, but the user will be encuoraged to review these zone-splitting proportions for the future-year to take account of future development which is expected to significantly affect the proportion of trip-making to/from the SEStran zones within a sinhle National Model zone;
- The resulting base and forecast TMfS:07-based trip ends are used to generate zonal growth factors (by purpose and car availability segment) for the SEStran regional zones; and
- These zonal growths are then applied to the corresponding base year SEStran regional model trip-ends, as follows;

F' = **F** * **N'** / **N**.

where:

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F = Base SEStran Model Trip End;

F' = Forecast SEStran Model Trip End;

N = Base National Model Trip End; and

N' = Forecast National Model Trip End.

Note: No growth will be applied if the Base Year National Model trip end for a given FRM zone is zero for the relevant given car-ownership segment and journey purpose.

Note (2): Where any Base Year Forth Model trip end is zero it shall be seeded to allow for growth to be applied.

Note (3): This process is applied to the Education trip ends also, and these are then passed through a furnessing procedure to create the Education Demand Matrices for the Forth Area.

9.3 Trips to/from External zones and the SEStran Goods Vehicle Matrices

9.3.1 The steps above will provide the inputs needed for the SEStran Demand model to predict person-based travel demand with the main SEStran modelled area.

9.3.2 The matrices that need to be created are as follows:

- HGV Demand Matrices;
- LGV Demand Matrices;
- Car Demand to/from External Zones (by journey purpose); and
- Public Transport Demand to/from External Zones (by journey purpose).

9.3.3 These are created from corresponding base and forecast assignment runs of the National Model. These assignments should be consistent with the trip end files used in the main process described in Section 2 above.

9.3.4 The process used to produce these additional future-year SEStran demand matrices is as follows:

- Road Sub-Area matrices for the SEStran area are created from the base year and forecast year National Model Road assignments;
- Where any new links, compared to the 2007 Base National Road Model, cross the Regional model boundary select link matrices are produced and these are added into the sub area matrices;
- These sub area matrices are disaggregated over the smaller sub- zones in the SEStran Model;
- The default zone-splitting will be applied in VOYAGER using a rezoning file, which will apply user-defined splits to the relevant rows and columns. The splitting proportions should be consistent with the corresponding proportions used to split the trip-ends (as described in Section 2 above);

- The rezoned base and forecast year matrices are then be used to create a matrix of growth factors, which are applied to the corresponding SEStran Regional Model base matrices; and
- For the PT model the sub area process is very complicated and time consuming and hence cannot be easily turned into an automatic process. As a result a different methodology is applied, whereby instead of undertaking a sub area analysis, a compression is applied to National Model assignment matrix (external zones only) to convert it to the same zone system (470 zones) as the sub area matrices. Following this the same expansion is applied as to the Highway Model.
- This growth in Road tips is applied as follows (this adds in absolute trips):
  - **F'** = **F** + **N'** – **N**

This growth in PT tips is applied as follows (this uses growth factors as the new PT methodology combines all trips outside the modelled area and not just those that cross the regional model boundary):

- **F'** = **F** * **N'** / **N**.

where:

F = Base SEStran Model Trip Ends;

F' = Forecast SEStran Model Trip Ends;

N = Base National Model Trip Ends; and

N' = Forecast National Model Trip Ends.

Note: No growth will be applied if the Base Year National Model trip end for a given FRM zone is zero for the relevant given car-ownership segment and journey purpose.

Note (2): If N > (F+N') then F' will be set to zero.

9.4 Summary

9.4.1 This methodology is designed to provide a simple but consistent method for predicting future year demand within the SEStran regional model, using relevant outputs from the National TMfS:07/TELMoS:07 model.

10 Forecasting Procedures

10.1 Introduction

10.1.1 The function of the Base-year Demand Model is to:

- demonstrate and validate the model operation and procedures;
- test the sensitivity of model parameters; and
- establish the incremental adjustment matrices.

10.1.2 The forecasting process is designed to provide forecast matrices using an incremental procedure. The Base-year Demand Model structure is designed to operate in an iterative manner to deal with the supply/demand convergence issue. 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 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.

10.2.2 The iterative balancing process is described in more detail in Appendix A. There are two main loops:

- Inner Loops - iterate between the Mode Choice and Distribution Choice Models; and
- External Loops - iterate between Assignment Models and the Mode and Destination Choice Models.

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

10.2.4 The Inner Loops can be run until a converged state is reached. This may vary with the forecast year and economic assumptions and between a Do-Minimum and Do-Something test. Testing has shown that four loops are generally adequate, and the model default is set to this.

10.2.5 The External Loop provides the link between the Assignment Models and the Demand Model. Infrastructure and pricing changes in a future year will change travel costs within the Assignment Models. The resultant converged state assigned travel costs are skimmed and supplied to the Distribution Choice using the same logsum composite utility calculations as for the Mode Choice Model. The sub-models are then run with the revised costs to complete the External Loop.

10.2.6 Due to the change in Park and Ride methodology the SEStran regioanl model differs from its parent in that it must run PT assignment on every loop to produce costs. The Highway Assignment Model is also run for each External Loop.

10.2.7 The External Loop can also be run until a converged state is reached. This would vary with the forecast year and economic assumptions and between a Do-Minimum and Do-Something test. External Loop assignment matrices can be inspected between successive loops to determine whether to select to undertake further External Loops. Tests have shown that six External Loops are sufficient for most applications (and as a result this is the default setting in the model), but the number required will depend on the level of congestion on the Highway network.

10.3 The Incremental Forecasting Approach

10.3.1 The forecasting procedure for the Forth Region Model is designed to operate in a multiplicative incremental manner.

10.3.2 Mode choice and distribution models can require a large number of factors to ensure a close match with observed data. Applying these models to estimate incremental changes from a well-established base situation, removes the reliance on these factors in the forecasting process. The Base-year Matrices are accepted as the best representation of the travel patterns in that year.

10.3.3 The Demand Model is operated to produce matrices for the Base year and Forecast year. We define the Forecast Year matrices in the following way:

$\mathbf{F} = \mathbf{B} + \mathbf{S_f} - \mathbf{S_b}$ (1); or

$\mathbf{F} = \mathbf{B} * \mathbf{S_f} / \mathbf{S_b}$ (2).

Where,

B = base observed trips;

$\mathbf{S_b}$ = base modelled trips;

$\mathbf{S_f}$ = future modelled trips; and

F = future trips.

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Then we define five cases:

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

Case (2) is used in the following circumstances:

- low **B**, high $\mathbf{S_b}$;
- low **B** low $\mathbf{S_b}$; and
- high **B** high $\mathbf{S_b}$.

10.3.4 In this way, the Incremental Matrix remains constant for all applications and the forecast year synthesised trip matrices produced by a forecast run of the Demand Model are adjusted by the Incremental Matrix before assignment.

10.4 Model Parameters

10.4.1 The need to calculate changes to some of the model parameters for a forecast run of the Demand Model is standard. The parameters for which forecast values are required are:

- generalised cost coefficients for highway assignment – these are recalculated in line with TAG Unit 3.5.6;
- occupancy factors to convert from person to vehicle matrices – these are calculated using growth factors from WebTAG; and
- values of time and vehicle operating costs – default values are based on relevant WebTAG (3.5.6) guidance

10.4.2 The mode specific constants calculated for the Base-year are specific to the Base-year distribution of single and multi-car owning households. They remain constant in forecast year as the Trip Ends change relative to the change in household types.

10.5 Highway and Public Transport Cost Matrices

10.5.1 Generalised cost matrices by mode and at a zone level are required as inputs to start the Demand Model process. For the Reference Case, the cost matrices used are those from the Base-year model, but the user can choose to input forecast cost matrices to kick start a demand model run if they so wish.

10.5.2 The Base-year cost matrices by mode are also required for the calculation of Reference Case mode specific constants described above.

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

10.6 Highway and Public Transport Networks

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

10.7 Education Trips

10.7.1 These are passed down from the National Model, using a sub-area analysis process. The base matrices were developed from Census Travel to Work data. They act as an add in.

10.8 Goods Vehicles

10.8.1 Goods vehicle matrices for the Forth Region Model are created as sub-area matrices of the goods vehicle matrices in the TMfS:07 National Model. This will ensure that changes in goods vehicle demand from the National Model level is passed down to the regional model.

10.9 External Trips

10.9.1 External trips, those joining the network at the buffer zones, come from sub-area analysis of the TMfS:07 National Model.

11 Summary and Conclusions

11.1 Conclusions

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

11.1.2 The model structure has been defined and implemented for the Base-year. The realism tests undertaken have demonstrated a good level of sensitivity. The principal travel purpose of the model, commute trips, has elasticities which fall well within the recommended sensitivity guidelines.

11.1.3 We conclude that the Demand Model is therefore 'fit for purpose', ie predicting the main travel responses to changes in future transport provision around the Forth Estuary.

11.1.4 While this report discusses how the model will be applied in forecast model, it does not include consideration of actual 'live' applications of the model in forecast mode. Further experience of these applications gained over time will assist in understanding the sensitivity and performance of the Model.

11.1.5 Testing of the sensitivity of the High Occupancy Vehicle module, Macro Time of Day Choice, Peak Spreading and Trip Frequency modules have also not been discussed in detail in this report. These therefore also require further testing via live applications of the full model.

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For more information visit www.mvaconsultancy.com

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

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

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

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

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

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

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

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

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

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

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

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

Email: info@mvaconsultancy.com

Offices also in
Bangkok, Beijing, Hong Kong, Shenzhen and Singapore

mvaconsultancy