

# SEStran Regional Model

## Highway Model Development Report

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# Summary

# 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 whole of the South East Scotland Transport Partnership (SEStran) area, covering the Local Authorities of East Lothian, Midlothian and Scottish Borders.
- 1.1.3 This Report builds on the foundations developed within the FRC Model Development Report, presenting the development assumptions and the calibration and validation results of the SEStran Base SATURN Model.

## 1.2 Model Overview

- 1.2.1 The SEStran Model base year is 2007. The model uses 'average peak hour' traffic matrices, defined as:

- AM Peak = 0.38 times the 07:00 to 10:00 traffic;
- Inter Peak = 1/6 of the 10:00 to 16:00 traffic; and
- PM Peak = 0.38 times the 16:00 to 19:00 traffic.

- 1.2.2 The model includes five user classes, as follows:

- Car In Work;
- Car Non Work Commuters;
- Car Non Work Others;
- LGV; and
- HGV.

- 1.2.3 Bus traffic on the network is modelled using fixed pre-load flows. The bus routes and frequency were imported from the SEStran PT Voyager Model.
- 1.2.4 The SATURN version used to develop the model was 10.8.17. This remains consistent with the version of SATURN used for the FRC Model.

## 1.3 Report Structure

- 1.3.1 Following this introductory chapter, the Report consists of the following chapters:

- Chapter 2 outlines the Network Development;
- Chapter 3 outlines the Matrix Development;
- Chapter 4 provides an overview of the Assignment Model assumptions;
- Chapter 5 provides the model Calibration results;
- Chapter 6 provides the model Validation results; and
- Chapter 7 presents our Conclusions and Recommendations.

## 2 Model Development

### 2.1 Introduction

- 2.1.1 The SEStran SATURN Model covers an area that extends from the Firth of Tay to the Scottish Border with England and from the East coast to Stirling. The model coverage is shown in Figure 2.1.



Figure 2.1 SEStran Model Area

- 2.1.2 The TMfS:07 network was used as the base for the development of the SEStran SATURN Model network. Additional road links were added where necessary in order to achieve a



## 2 Model Development

more detailed representation of the traffic movements through the study area. All A class roads and a number of key B class roads are included.

2.1.3 The SEStran SATURN Model network is divided into two regions:

- the 'simulation' network, where all the road junctions have been explicitly modelled; and
- the 'buffer' network, where only the links attributes have been coded (ie there is no junction modelling).

2.1.4 The model primarily consists of simulation network, with parts of The City of Edinburgh (mainly within the City Bypass) representing the only areas of buffer network within the model. The extent of the buffer network is shown in Figure 2.2, with all other areas within the model coverage being simulation network.

2.1.5 This type of network structure makes it possible not only to model in detail the areas which are key to the scheme being assessed, but also to take into account possible implications on the traffic flow in the study area as a whole.

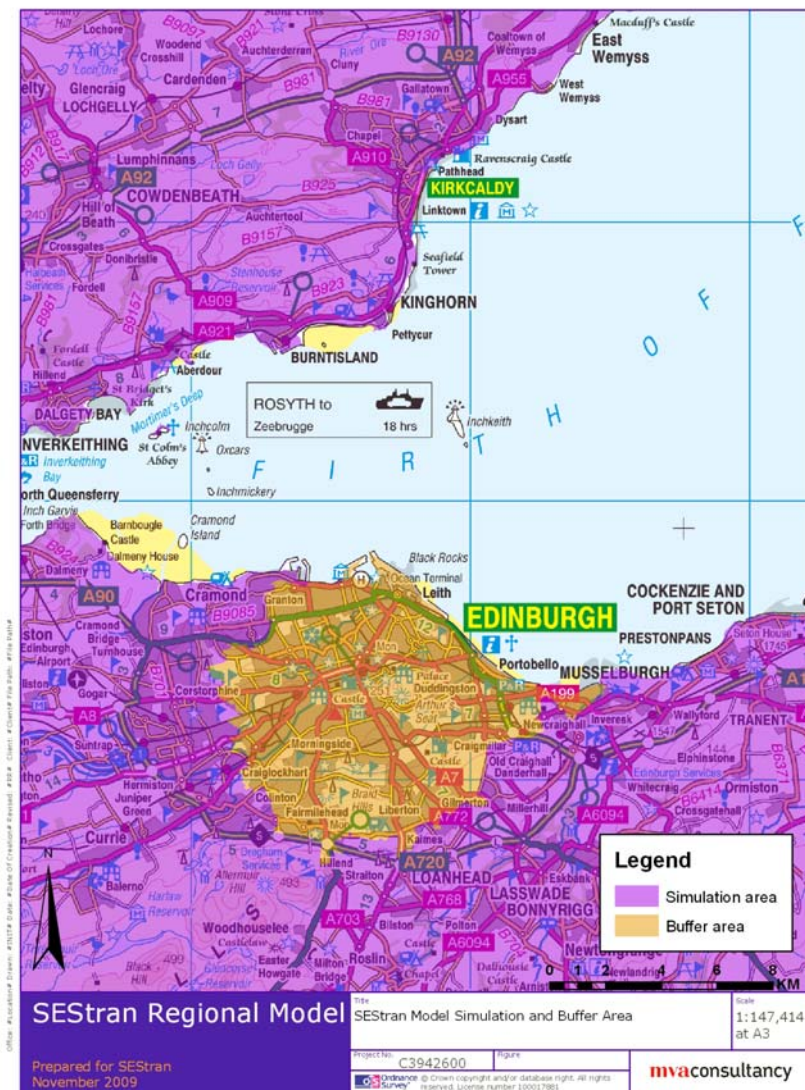


Figure 2.2 SEStran Regional Model Buffer and Simulation Area

## 2 Model Development

- 2.1.6 A twin network replicating the SATURN network structure was built in GIS. In the GIS network the links have accurate geographical representation, ie the links are curved and follow the road centreline alignment available from the Ordnance Survey Integrated Transport Network (ITN). The GIS network was used to calculate accurate distances for all the links in the model. The GIS network can also be used for traffic-based environmental analysis.
- 2.1.7 The SEStran model is essentially an expansion of the preceding FRC model to encompass the Scottish Borders, East Lothian and Midlothian. Using GIS packages, the physical connectivity of the model was automatically produced, with Digital mapping used to enhance junction information.

### 2.2 Buffer Area Coding

- 2.2.1 The buffer network of the SEStran SATURN Model was based on the TMfS:07 model. The same level of detail was maintained; however the TMfS:07 network structure was simplified as a number of intermediate nodes were removed. The link distances were calculated using GIS.
- 2.2.2 Within the buffer network no junction modelling is included. Capacity-restraint is modelled through the use of link-based flow-delay curves whereby the travel time on a link is assumed to be a function of the flow on that link. The flow delay relationships within the SEStran network were modelled using the same updated flow-delay curve parameters used for the TMfS:07 model. Where necessary an additional flow-delay curve was introduced after consultation with DMRB guidelines.
- 2.2.3 Appendix A, at the end of this Report, provides a list of the flow-delay curves definitions and parameters.

### 2.3 Simulation Area Coding

#### Link Coding

- 2.3.1 For the Simulation area, the TMfS:07 network was used as starting point for the coding; additional detail was then added to achieve a level of representation similar to the one used in TMfS:05A.
- 2.3.2 Free-flow speed values were extracted from the TMfS:07 network where available. The speed values for the new links were inferred based upon the type of road and the location (urban, rural) and ITIS speed data was used to supplement this process. Link distances were calculated using the GIS network. Within the modelled area extended for SEStran, where roads pass through small settlements, short links were coded to represent this, together with a 30mph limit.
- 2.3.3 Unlike the previous FRC model, flow delay relationships were coded on all links where the distance is greater than 250m within the Simulation area. This is an enhancement and permits more accurate modelling of the flow delay relationship on all Simulation links, particularly in rural areas. Overall delay is a combination of the link travel time and time taken to negotiate network junctions.

- 2.3.4 For commonality and consistency, the same flow delay relationships used for Buffer network links were used for the Simulation links.

### Junction Coding

- 2.3.5 The junctions in the SEStran model were coded according to the template set out by David Boddy, in his note 'The calculation of Saturation Flows for SATURN'. This method provides a satisfactory representation of junction capacity, whilst ensuring consistency throughout the network and consistency between coding undertaken by different modellers. This method of coding also makes it possible to perform a series of quality checks on the model network.
- 2.3.6 The roundabout junctions were coded using TRL ARCADY formulae to calculate the saturation flow, average controlling, and average GAP values. Standard values of lane width, flare length, radius, diameter and intersection angle were used for the calculations.
- 2.3.7 The junction layout details regarding the number of lanes for each approach and the lane allocation were derived from aerial digital photography and site visits.

### Traffic Signals

- 2.3.8 Early in the FRC project we sought to get hold of the most up to date traffic signal information from each authority within the Simulation area. The main reasoning was that each council would hold the most up to date information and this in turn would provide a model of higher quality. Unfortunately, the local authorities were unable to provide us with the required data in time for us to progress with the development of the SATURN network.
- 2.3.9 In view of this it was decided to use the data contained in the TMfS:05A model to code the traffic signals in the SEStran network.
- 2.3.10 During the network preparation it was recognised that since the development of TMfS:05 new signalised junctions have become operational. Given the time constraints for the project, a process was devised to estimate the signal phasing and timings for such junctions.
- 2.3.11 This process estimated the following parameters: cycle time, lost time per phase, phase timings and number of phases. Where possible, local knowledge was used to estimate signal timings. On-line digital photography was used to confirm junction geometry. Up-to-date traffic signal timings from the FRC model for the Newbridge junction have been implemented.

### Simulation Network Summary

- 2.3.12 The simulation area includes:

- 2452 priority junctions;
- 135 traffic signals;
- 252 roundabouts; and
- 411 external nodes.

### 2.4 Geo-rectification

- 2.4.1 A GIS version of the model network was prepared and a link was set up to transfer the SATURN outputs to the GIS network. In the GIS network the links have accurate geographical representation, ie the links are curved and follow the road centreline alignment available from the Ordnance Survey Integrated Transport Network (ITN).
- 2.4.2 The modeling of the junctions within the Simulation area required us to introduce some changes to the geographical position of the intersections in two cases:
- small roundabouts; and
  - complex signalised junctions.
- 2.4.3 In order to maintain the ITN network structure, the roundabouts had to be coded in SATURN as a series of one-way links connected by a series of give-way (or signalised) junctions. This system worked well for large roundabouts and for signalised roundabouts; however it did not provide a good representation for small roundabouts. Also, coding all the roundabouts as a series of give-way junctions would significantly increase the junction coding effort. It was therefore decided that all the roundabouts connected to a dual carriageway road (on any of the approaches) would be modelled as a series of give-way junctions. Conversely, all the roundabouts where all the approaches were single carriageway would be modelled as a single node roundabout.
- 2.4.4 A small number of complex signalised junctions also required to be simplified for the network coding. The ITN network represents these junctions using a large number of links and nodes. Although this accurately reflects the road network, this structure does not represent the fact that the junction is actually controlled by one signal controller (with multiple signal heads located at different points on the network). In order to model these junctions correctly the ITN network was modified so that all the necessary turning movements could be controlled by a single node signalised junction. In each case the discrepancy from the actual road centreline was kept to a minimum.

### 2.5 Forth Bridge and Kincardine Bridge Modelling

- 2.5.1 The SEStran Base model replicates the conditions present in 2007. The model therefore includes tolls on the Forth Bridge link in the northbound direction. The charges were set as £1 for cars and LGVs and £2 for HGVs.
- 2.5.2 Road works and traffic management measures had been in place in the Kincardine Bridge area since November 2006 until November 2008. Analysis of SRTDb traffic counts in the area showed that the traffic flows have not significantly changed as a result of the road works. In the SEStran model the Kincardine Bridge area has therefore been modelled to represent the conditions that were in place before the beginning of the road works.

### 2.6 Rat-running improvements

- 2.6.1 As described in Technical Note 4 (entitled 'FRB AM Peak Trip Distribution Improvement', 18 May 2009) the speed of a number of minor roads has been changed in the area west of the A720 by-pass, to scale down the rat-running problems.

## 2 Model Development

2.6.2 The following changes have been implemented:

- speed reduced on minor roads in the area south of the Forth Road Bridge;
- speed reduced on minor roads connecting with the A70, A71 and A8; and
- speed increased on the M8 between junction 1 and 2.

### 2.7 FRC Network Enhancements

2.7.1 During construction of the FRC SATURN network, enhancements were modelled as requested by the Model Development Audit – Final Report. These enhancements have been incorporated into the SEStran model: there locations being Gogar underpass roundabout, Scotstoun A90/A8000 interchange and Ingliston Park and Ride.

### 2.8 Bus Pre-Load

2.8.1 Bus traffic on the network was modelled using fixed pre-load flows. The bus routes and frequencies were imported from the SEStran PT Voyager Model. All the traffic in the SATURN model is expressed in Passenger car Units (PCUs). For consistency the bus flows are also converted into PCUs by the program before they are added to the total flow. The PCU factor used for buses was 2.2.

## 3 Matrix Development

### 3.1 Zone System

- 3.1.1 The SEStran Zone System was divided into 'Internal zones' and 'External zones'. External zones were defined for each link at the edge of the study area to represent the corridors feeding into (and out of) the model. The internal zones were then further segregated into a Simulation area and a Buffer area.
- 3.1.2 The SEStran model inherited the FRC zone system. Within the 'new' areas, ie Midlothian, Scottish Borders and East Lothian, a new zone system was defined and the opportunity was taken to adopt a rather more detailed zone system in these areas. Aggregations of census datazones within TMfS:07 zones were the main means of defining the zone system, combined with natural features such as rivers etc.
- 3.1.3 It should be noted that for this model the buffer area incorporates the Edinburgh city area, as specified in the initial proposal.
- 3.1.4 A key requirement for the internal zone system was consistency with both the Forth Replacement Crossing (FRC) regional model and consequently the national Transport Model for Scotland 2007 (TMfS:07). This allowed easy comparison between the models and was especially useful in matrix formulation.
- 3.1.5 Where a previous TMfS:07 zone split up, the values in the matrix were split proportionally, in line with population for trips coming from the zone and employment for trips entering the zone.
- 3.1.6 Note also that new zones were defined for all park and ride sites across the whole modelled area. This significant enhancement to the FRC model allows a much better spatial representation of park and ride within the model.
- 3.1.7 The SEStran zone system therefore includes:

- 335 internal zones (296 simulation zones, 39 buffer zones)
- 36 external zones
- 99 Park and ride site specific zones (not all used).

- 3.1.8 Zone centroid lengths were calculated by considering the zone to be a circle and then calculating the average radial distance of the circle if all points within it are evenly distributed. This was calculated by weighting the expectation of the average radius by the area, which reduces to the following equation:

$$\frac{2\pi r^3}{3\pi r^2} \text{ which reduces to } \frac{2}{3} \sqrt{\frac{\text{area}}{\pi}} \text{ and can then be calculated from the zonal area.}$$

### 3 Matrix Development

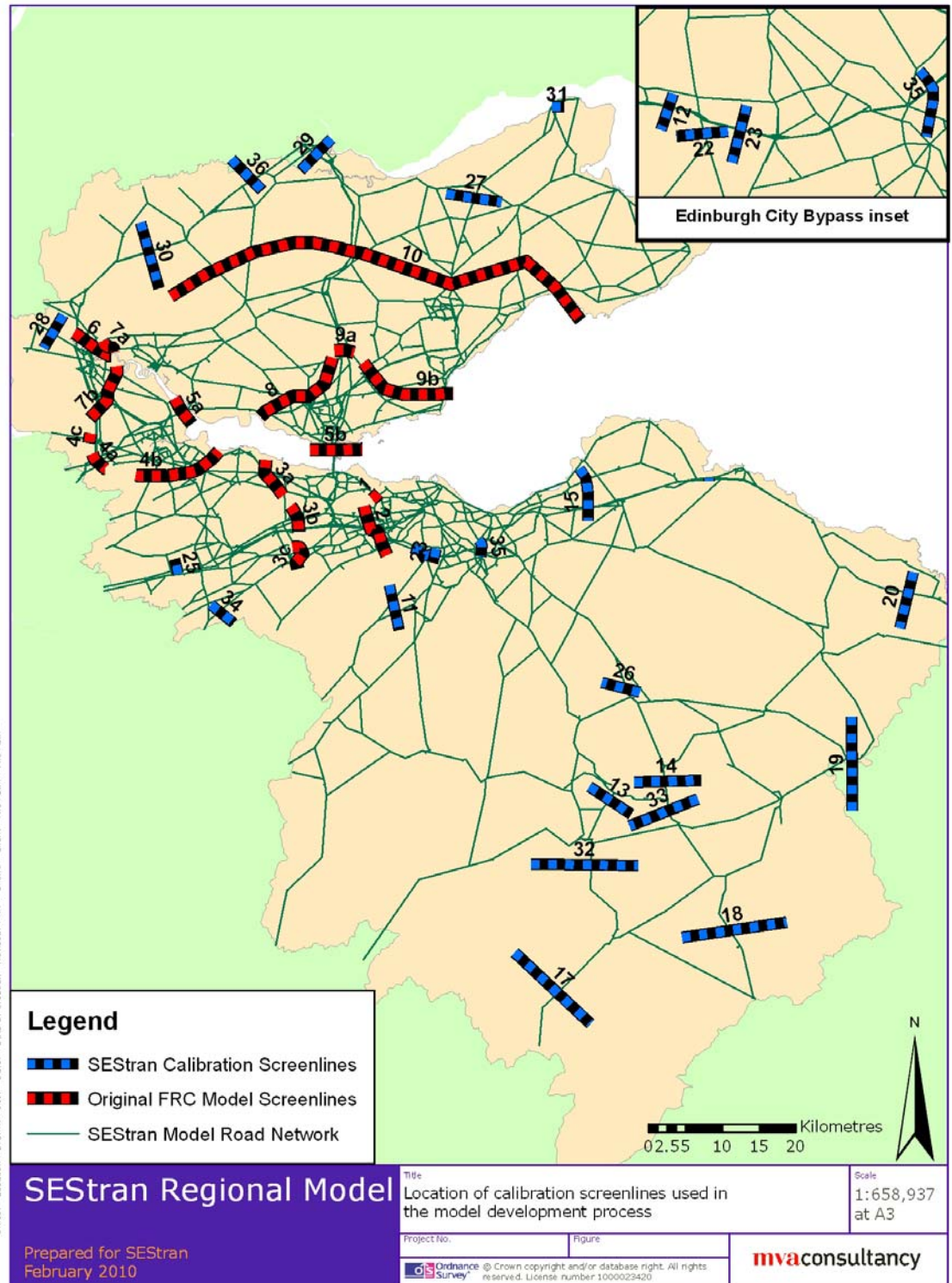
#### 3.2 Prior Matrix Development

- 3.2.1 The prior matrix used to start the matrix calibration process was based on the corresponding sub-areas of the TMFS:07 highway matrices.
- 3.2.2 The assignment matrices are hourly matrices created by taking the following proportions of the corresponding time period demand matrices - AM Period\*0.38, IP\*1/6, PM\*0.38.

#### 3.3 Matrix Estimation

- 3.3.1 Final matrices were produced by Matrix Estimation (ME) using the program SATME2. SATME2 essentially tries to improve the fit between modelled and observed flows by selectively factoring individual cells of the input trip matrix.
- 3.3.2 The five user class matrices were aggregated into one general matrix and this was estimated to reach total target counts. At the end of the estimation the global matrix was re-split into single matrices using cell by cell proportional factors.
- 3.3.3 It is possible, following SATURN 10.5, to combine a set of input counts into a single constraint, such that SATME2 tries to satisfy the sum of all the individual flows. This provides a good method to constrain the estimation process and achieve a more reliable estimation.
- 3.3.4 We made use of this facility and combined our calibration counts into screenlines as shown in Figure 3.1.





**Figure 3.1 Location of calibration screenlines used in the model development process**

3.3.5 The ME procedure was able to achieve a good level of calibration of the screenlines. This is shown in Chapter 5. The analysis of the Trip Length Distribution before and after the ME process showed that the distribution did not significantly change as a result of the estimation. Appendix B shows the Trip Length Distribution analysis for each model period. Appendix C shows a sector to sector comparison of the Post ME matrix against the Prior



### 3 Matrix Development

matrix for each model period, while Appendix D contains an image displaying the sector system used. Table 3.1 shows the matrix totals before and after matrix estimation confirming that the estimation process has not overly distorted the prior matrix.

**Table 3.1 Matrix Totals before and after ME (in PCUs)**

	AM Peak	Inter Peak	PM Peak
Prior Matrix	169,004	130,780	195,186
Final Matrix	170,724	130,679	196,763

## 4 Assignment Model Development

### 4.1 Assignment Procedure

- 4.1.1 The assignment procedure adopted for the SEStran SATURN Model is an Equilibrium Assignment. The Frank-Wolfe Algorithm is used to find the equilibrium solution.
- 4.1.2 The SATURN model combines the assignment stage with a junction simulation stage. The delay information from the simulation is passed back to the assignment stage where a new trip pattern is derived. The process is iterated until convergence is achieved.

### 4.2 Generalised Cost Parameters

- 4.2.1 The calculation of generalised cost parameters was based on WebTAG guidance issued on February 2007. The units of the time parameters and the distance parameter are Pence Per Minute (PPM) and Pence Per Kilometre (PPK) respectively, as required by SATURN. Table 4.1 shows the parameters calculated for each user class.

**Table 4.1 Parameters Calculated for each User Class**

User Class	PPM	PPK
Car In Work	47.15	11.01
Car Non Work Commuters	10.56	5.64
Car Non Work Others	14.46	5.64
LGV	19.04	12.99
HGV	15.93	35.02

- 4.2.2 Toll parameters were derived from previous TMfS-based analysis. The following parameters were used to convert tolls from pence to generalised minutes for each user class:

- Car In Work: 2.37;
- Car Non Work Commuters: 1.53;
- Car Non Work Others: 2.09;
- LGV: 0.43; and
- HGV: 0.36.

### 4.3 Convergence

4.3.1 In SATURN the convergence of the assignment/simulation loops is controlled by the parameters PCNEAR and ISTOP. The loops stop automatically if ISTOP percent of the link flows change by less than PCNEAR percent from one assignment to the next.

4.3.2 For SEStran Model the parameters were set as follows:

- ISTOP= 99; and
- PCNEAR= 2.00.

4.3.3 The final convergence % GAP values obtained were:

- 0.037% for the AM Peak model;
- 0.018% for Inter Peak model; and
- 0.047% for the PM Peak model.

# 5 Calibration

## 5.1 Traffic Count Data

5.1.1 The model was calibrated against the screenlines shown in Figure 3.1. In total 177 traffic counts were used to create the screenlines. The counts were obtained from the following sources:

- SRTDb;
- Local Authority Traffic Counts;
- Traffic Counts used for TMfS05 Calibration/Validation;
- Scottish Borders Council and;
- FRC Survey Traffic Counts.

5.1.2 The traffic counts were factored to the common year 2007 when necessary. Not that the traffic count on the A71 Calder Road which forms part of screenline 2 was surveyed only for the AM Peak period. We requested a full survey to be conducted at this location, however the results arrived too late to be incorporated in the model. The count values for this location for the Inter Peak and PM Peak were therefore synthesised based on the AM peak count.

## 5.2 Screenline Calibration

5.2.1 Tables 5.1 to 5.3 show the results of the calibration for the AM Peak, Inter Peak and PM models respectively. The tables compare the observed and modelled link flows in terms of absolute difference, percentage difference and GEH statistic.

5.2.2 The GEH statistic is designed to be more tolerant of large percentage differences at lower flows than at higher ones and thus it suited to reflect differences over a wide range of flows. The GEH statistic is defined as:

$$\text{GEH} = ((\text{observed} - \text{modelled})^2 / (0.5 * (\text{observed} + \text{modelled})))^{0.5}$$

5.2.3 The summary tables show that the model achieved a good level of calibration on all screenlines for all time periods. Appendix E presents more detailed results in terms of observed and modelled flow for the calibration screenlines.

Table 5.1 Calibration GEH Values

GEH Ranges	AM Peak	Inter Peak	PM Peak
<5	93%	100%	96%
<7	96%	100%	96%
<10	99%	100%	100%

## 6 Validation

### 6.1 Link Count Validation

- 6.1.1 As explained in section 3.3, matrix estimation was carried out by combining the counts into screenlines so that SATME2 worked to satisfy the sum of the flows for each screenline.
- 6.1.2 The individual counts were used to assess the model validation instead. Table 6.1 provides a summary of the validation results for the AM Peak, Inter Peak and PM Peak models. The table shows the number of traffic counts for which the GEH is less than 5, 7 and 10. Note that in extending the FRC model to cover the SEStran area, the objective was to retain the integrity of the original FRC matrix. To this end, travel between the relevant cells of the matrix was frozen during the matrix estimation process.

**Table 6.1 Traffic Counts Validation Summary**

GEH Ranges	AM Peak	Inter Peak	PM Peak	
<5		75%	74%	68%
<7		85%	86%	82%
<10		93%	96%	94%

- 6.1.3 Detailed results of the individual count validation are provided in Appendix F.

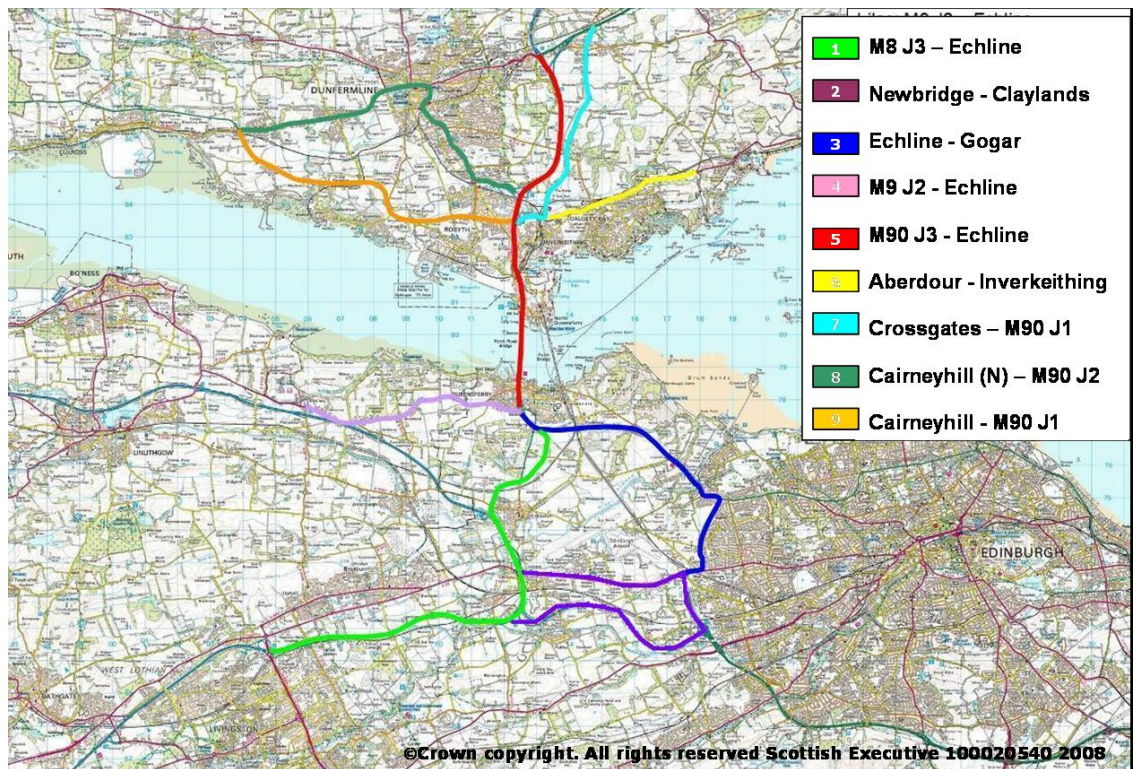
### 6.2 Journey Time Validation

- 6.2.1 The model was validated against two sets of journey time data:

- Journey Time surveys undertaken by Count On Us (COU); and
- Traffic speed and location data provided by ITIS.

#### Journey Time Surveys

- 6.2.2 Count On Us undertook Journey Time surveys for the 9 routes shown in Figure 6.1. Each route was surveyed a minimum of 10 times during each time period utilising GPS technology (floating vehicle method). The defined survey intervals were 0600 to 1000, 1100 to 1400 and 1500 to 1900 for the AM, Inter and PM time periods respectively.
- 6.2.3 Note that no new information was available for the extended modelled area, but the key area of the City Bypass is covered.



**Figure 6.1 Count on Us Journey Time routes**

6.2.4 For the purposes of our calibration exercise only the journey time information which was recorded during the 0700-0900 for the AM peak period and 1700 to 1900 for the PM peak period was utilised, as these intervals correlated better with the modelled time periods. For the Inter Peak we used the data from 1200 to 1400 as a representative sample of the inter-peak conditions.

6.2.5 Further details of the validation for each sub-section of the routes are provided as Appendix I.

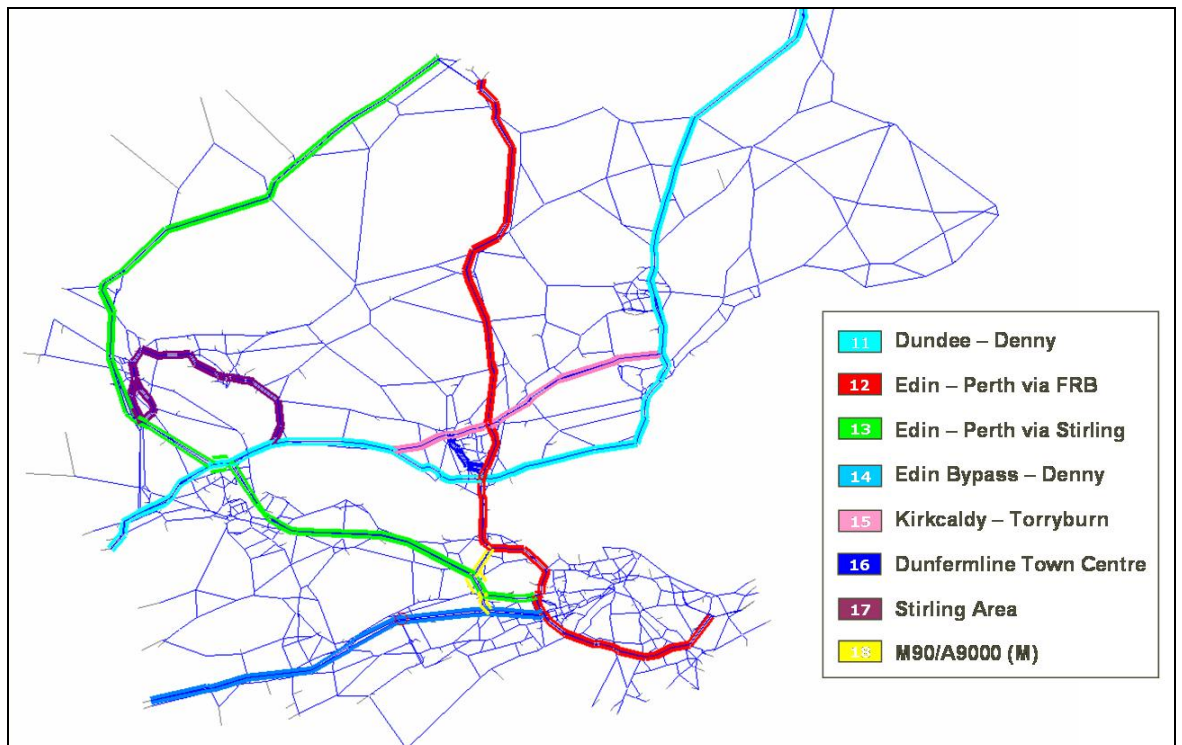
#### **ITIS speed data**

6.2.6 The COU Journey Time survey concentrated on the area around the Forth Road Bridge. In order to assess how well the model replicated observed journey times in other parts of the network, we utilised traffic speed and location data provided by ITIS.

6.2.7 ITIS has developed and operates a system to collect and analyse traffic information using Floating vehicle data (FVD). Using GPS and GSM technology, ITIS collect speed and position information from probe vehicles. The data from the probe vehicles is then aggregated to determine the average speed for a given stretch of road. The entire data set is made up of over 900 million points and is available throughout Great Britain.

6.2.8 The routes for which ITIS data was extrapolated are shown in Figure 6.2.





**Figure 6.2 ITIS Journey Time routes**

### ITIS Data Quality

6.2.9 Two main issues are associated with the quality of the ITIS data:

- a number of links have no data associated with them (12% N=659,900); and
- some other links have low sample sizes in the AM and PM period.

6.2.10 Where there was no data available, 'Speed Plus with NAVTEQ streets' data was used as a rough estimate of speed on a link. 'Speed Plus' provides speeds based upon:

- average off peak times (from 9:00 am – up until 16:00 pm);
- average rush hour times (from 7:00 am – up until 9:00 am & from 16:00 pm – up until 19:00 pm); and
- average night time times (19:00 pm – up until 07:00 am).

6.2.11 Note, speeds are not split by direction of travel and 'rush hour' is not split by am and pm.

6.2.12 A plot showing the locations where 'Speed Plus with NAVTEQ streets' was used to infill ITIS data is included as Appendix I.

6.2.13 We have not been able to obtain estimates of the variability of ITIS observations and therefore cannot estimate 95% confidence intervals (or High/Low ranges) for these IT IS-based speed estimates. However, we feel that the supplemented ITIS dataset provides a reasonable estimate of mean journey time against which to validate the model for routes where no directly-observed journey time surveys have been carried out.



### Summary of JT Validation

**Table 6.2 Summary of Journey Time Route**

Model	Within 15% of Observed Travel Times			
	Yes		No	
AM Peak	31 routes	91% of all routes	3 routes	9 % of all routes
Inter Peak	29 routes	85% of all routes	5 routes	15 % of all routes
PM Peak	29 routes	85% of all routes	5 routes	15 % of all routes

6.2.14 Additional details of the Journey Time validation are provided in Appendix H

# 7 Summary and Conclusions

## 7.1 Conclusions

- 7.1.1 This report has presented the development and the calibration/validation of the SEStran SATURN Base Model.
- 7.1.2 The calibration of the total flows across the screenlines has been shown to be good. The validation of the individual counts has been shown to be acceptable over the entire model and specifically in the area around the Forth Bridge. The validation of the model against observed journey time data is good and provides confidence in the overall robustness of the three separate time-period traffic assignment models.

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