Forth Replacement Crossing Model

Transport Scotland

Model Development Audit – Final Report

SIAS Limited

TAFRC\71029
March 2009

FORTH REPLACEMENT CROSSING MODEL

Description: **Model Development Audit – Final Report**

Date: **12 March 2009**

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FORTH REPLACEMENT CROSSING MODEL

CONTENTS :

FORTH REPLACEMENT CROSSING MODEL

TABLES :

1 FORTH REPLACEMENT CROSSING MODEL DEVELOPMENT AUDIT

1.1 Introduction

1.1.1 SIAS Limited (SIAS) was requested, as the Traffic and Transport Advisor and Auditor (TTAA) to Transport Scotland, to undertake a review of the development of the Forth Replacement Crossing Model that was created during the Forth Replacement Crossing (FRC) study. The Forth Replacement Crossing Model is a multi-modal regional model developed to operate within the overall Transport Model for Scotland 07 (TMfS07) hierarchy.

1.1.2 The Forth Replacement Crossing Model contains three main components:

- Roads assignment model (SATURN Model)
- Public Transport (PT) assignment model (CUBE Voyager Model)
- Demand model (CUBE Voyager Model)

1.1.3 This audit involves a review of the model development, calibration and validation documentation associated with each of the above elements. Additionally, the roads and PT assignment model networks have been reviewed.

1.2 Audit Process

1.2.1 The audit process involved an iterative procedure whereby information and documentation was received by the TTAA, following which a series of Audit Notes was published to outline the TTAA's initial audit findings and requests for additional information or clarification. MVA subsequently responded to the Audit Notes and their commentary and additional information has been taken into account in publishing the final audit findings presented in this Report.

1.3 Acknowledgements

1.3.1 The TTAA wishes to acknowledge the assistance and cooperation of both MVA and Transport Scotland in providing the information and input necessary for the audit process.

2 SATURN ROADS ASSIGNMENT MODEL

2.1 Introduction

2.1.1 The SATURN model was being developed as the roads assignment element of the multi-modal Forth Replacement Crossing Model to be applied in the FRC study. In order to facilitate an accelerated work timeframe, MVA developed an initial draft AM peak SATURN model in September 2008 with an ancillary forecasting mechanism. The TTAA undertook a review of the draft AM Peak model and presented findings separately in Audit Note *AN-FRC-2* (Ref. 70451, 29 October 2008) and in Final Audit Note *FAN-FRC-2* (Ref. 70755, 19 January 2009).

2.1.2 Subsequently, a finalised SATURN model for the AM, inter and PM peaks was developed by MVA and the initial audit findings on this were presented in Audit Note *AN-FRC-6* (Ref. 70788, 29 January 2009). A subsequent response to *AN-FRC-6* was received from MVA and the finalised model, taking into account MVA's response is the subject of this Audit Report.

2.1.3 The TTAA received the following information from MVA for use in the audit process:

- AM Peak Model (FRC_AM_Base_V3), Inter Peak Model (FRC_IP_Base_V2) and PM Peak Model (FRC_PM_Base_V2)
- *Forth Replacement Crossing Support - SATURN Model Development Report* (Issue 2, MVA Ref. C37135/00, 11 November 2008)
- *Audit Response Note to AN-FRC-2: Review of Saturn Model Development* (MVA Ref. C37135, 10 December 2008)
- Zoning system in GIS format
- *Audit Response Note to AN-FRC-6: Forth Regional Saturn Model Development* (MVA Ref. C37135/11 18 February 2009)
- *Technical Note 1 : Distribution of Forth Road Bridge Northbound Trips* (MVA Ref. C37135/00, 2 February 2009)
- *Technical Note 2 : Distribution of Forth Road Bridge Northbound Trips* (MVA Ref. C37135/11, 16 February 2009)

2.1.4 This chapter relates to the audit of the Base network and zoning system based on the review of the above information. The Report generally follows the format of MVA's *Model Development Report*, while also providing commentary on the network, zoning system and other information provided where appropriate.

2.2 Introduction to SATURN Model development

Background

2.2.1 In providing modelling support and advice to Transport Scotland for their Forth Replacement Crossing Team, MVA developed a sub-area model of TMfS07 centred on the Forth Crossing area. The sub-area model was developed in SATURN (Road model) and Cube Voyager (PT model and Demand model).

2.2.2 The Forth Replacement Crossing SATURN model was developed to represent a 2007 Base year with average peak hour assigned flows defined as follows:

- AM Peak (0.38 * 07:00 - 10:00, assigned as 08:00 - 09:00)
- Inter Peak (1/6th of 10:00 - 16:00, assigned as an average Inter Peak hour)
- PM Peak (0.38 * 16:00 - 19:00, assigned as 17:00 - 18:00)

2.2.3 The user classes represented in the model are as follows:

- Car In Work
- Car Non Work Commuters
- Car Non Work Others
- LGV
- HGV

2.2.4 Bus flows are imported from the Forth Replacement Crossing PT Voyager Model and represented as fixed preloaded flows in the Forth Replacement Crossing SATURN model.

2.2.5 The specification of the Forth Replacement Crossing SATURN model in terms of its time periods, user class disaggregation and the PT service coding is generally consistent with TMfS07 and is considered appropriate by the TTAA.

2.3 Network Development

Introduction

2.3.1 The Forth Replacement Crossing Model was developed as a sub-area of TMfS07 and extends from the south side of the Firth of Tay to the south of Edinburgh and from the East of Edinburgh to Stirling. The network was developed using the TMfS07 network as a start point and adding detail as necessary. The model is divided into a simulation (junctions modelled) and buffer area (no junctions modelled). The simulation area covers the Forth crossings at Stirling, Kincardine, the Forth Road Bridge and all major routes and urban areas in close proximity to the estuarial crossings. Overall the TTAA is content with the coverage of the Forth Replacement Crossing SATURN model and the defined simulation and buffer areas**.**

Buffer Area Coding

2.3.2 The buffer network detail is the same as that for TMfS07, with free-flow speed and distance values in the buffer area being extracted from the TMfS07 network. No junctions are modelled in the buffer area, however, flow-delay curves are applied to provide a capacity constraint mechanism. The flow-delay curves and parameters are consistent with those adopted for TMfS07. The TTAA is satisfied that this approach to coding the buffer network is appropriate.

Simulation Area Coding

2.3.3 The simulation area was coded using the TMfS07 network as a start point with detail added as appropriate. Free-flow speeds and distances were extracted from TMfS07 for existing links. Newly added link lengths were derived using GIS with speeds defined by link type. Flow-delay relationships were applied to motorway links, while the urban links were subject to junction modelling.

2.3.4 The junction coding used the 'Boddy Method', which is intended to ensure consistency and appropriateness of capacity coding across the network. Roundabouts were coded using the TRL ARCADY formulae, while standard geometric parameters were specified. The layout and detail of junctions was derived from aerial photography.

2.3.5 The traffic signal coding was generally inherited from TMfS05A, as time constraints prevented the delivery of up to date signal timings from the relevant local authorities. For new signal junctions not included in TMfS05A the timings were estimated by MVA. Information provided shows that 22 junctions had their timings estimated.

2.3.6 In total the simulation network contains:

- 1,345 priority junctions
- 95 traffic signals
- 160 roundabouts
- 212 external nodes

2.3.7 This indicates that almost a quarter of the signal junctions in the model are operating with estimated signal timings. While this situation is less than ideal, it is difficult to see what could otherwise have been done in the absence of the signal timing information. The TTAA requested clarification from MVA regarding whether any checks had been undertaken to ensure that the delays modelled at the 22 junctions with estimated signal timings were within expected limits. MVA confirmed that such checks had not been undertaken, but acknowledged the potential benefits of doing so. A suggested approach and outline resource estimate for undertaking such analysis was provided by MVA to Transport Scotland on 18 December 2008. Transport Scotland subsequently decided not to pursue such analysis.

2.3.8 The TTAA is generally content with the methodology adopted for coding the simulation area of the network. **Potential users should, however, note the number of signal junction for which timings have been estimated. This should be borne in mind when interpreting model outputs and consideration should be given to collecting up to date signal information for verification or adjustment of the signal timings at these junctions for relevant applications of the model**.

Geo-rectification

2.3.9 The TMfS07 network used as the start point for coding the Forth Replacement Crossing Model was itself geo-rectified as it was developed from the Ordnance Survey Integrated Transport Network (ITN) layer. This ensures a geographically accurate network representation of the link centrelines and the junction locations, which is useful for subsequent environmental assessment. In the simulation area of the Forth Replacement Crossing network it was necessary in some cases to adjust the node positioning for small roundabouts and complex signal junctions.

2.3.10 The ITN layer structure results in all roundabouts being represented as a series of one-way links connected by a series of give-way junctions. For larger and/or signalised junctions this structure works well, but is less effective for small roundabouts. MVA adopted the method whereby any roundabout which had one or more dual carriageway approaches were modelled as a series of give way junctions, while all roundabouts with only single carriageway approaches were modelled as a single node.

2.3.11 Similarly, at complex signal junctions the ITN layer can represent these using an inordinately large number of links and nodes. In reality, while this more complex structure reflects the road layout well the junction is often controlled by a single signal controller. To better model these in SATURN, MVA has simplified the network structure to enable all the permissible turning movements to be controlled by a single signalised node while attempting to minimise the deviation from the ITN layer centerline.

2.3.12 Overall the TTAA is satisfied that this approach to coding is appropriate.

Forth Bridge and Kincardine Bridge Modelling

2.3.13 The Forth Replacement Crossing Base model replicates the conditions present in 2007 and includes a £1 charge for cars and LGVs and £2 charge for HGVs on the Forth Bridge link in the northbound direction.

2.3.14 Analysis undertaken by MVA showed that traffic flows in the Kincardine Bridge area have not changed significantly as a result of the road works and traffic management measures introduced between November 2006 and November 2008. The Kincardine Bridge area has, therefore, been modelled to represent the conditions that were in place before the beginning of the road works.

2.3.15 The TTAA is satisfied that the representation of the Forth Bridge and Kincardine Bridge in the Forth Replacement Crossing SATURN model is appropriate.

Bus Pre-Load

2.3.16 Bus traffic on the network was modelled using fixed pre-load flows using information from the Forth Replacement Crossing PT Voyager Model. All the traffic in the SATURN model is expressed in Passenger car Units (PCUs) using separate PCU factors by vehicle type. For buses a PCU factor of 2.2 is used.

2.3.17 The TTAA undertook checks of the pre-load flows across the Forth Road Bridge against actual bus flows according to websites of service operators obtained in January 2009. Table 2.1 shows that the modelled pre-load flows are lower than those scheduled.

Table 2.1 : Modelled Preload Flow Comparison

	Forth Road Bridge Northbound			**Forth Road Bridge Southbound**		
	Scheduled (vehs/hr)	Scheduled (pcus/hr)	Modelled (pcus/hr)	Scheduled (vehs/hr)	Scheduled (pcus/hr)	Modelled (pcus/hr)
AM Peak	12	26	18	16	35	20
Inter Peak	15	33	26	12	26	24
PM Peak	17	37	26	12	26	15

Note: scheduled services based on information obtained from Ferrytoll Leaflet for buses and service operator's websites

2.3.18 On balance, the TTAA acknowledges that the pre-load flows in the study area are generally small and this should have an immaterial effect on the overall traffic assignment. Nevertheless, this issue was investigated by MVA who subsequently commented as follows:

> *In the PT model bus frequencies were based on the service pattern over the relevant 3-hour peak and 6-hour Inter Peak periods, resulting in non-integer bus frequencies (e.g. frequency of 0.33 buses per hour). In SATURN, however, each bus service pre-load can only be coded as an integer number of vehicles per hour. The resulting rounding leads to the discrepancies identified…*
>
> *We agree with the TTAA's assessment…that the impact of this loss of bus-preload on the overall traffic assignment is insignificant. However, if a decision is taken to adjust the FRCM Base Year model, it would be possible to work round this SATURN limitation by amending the bus pre-load process to import bus frequencies in tenths of vehicles per hour, with a Bus PCU factor of 0.22*

2.3.19 The TTAA is content that the overall impact of this matter is likely to be small for the general application of the Forth Replacement Crossing Model. **Given that it is a relatively straightforward issue to resolve the TTAA would recommend that this is done at the most convenient opportunity (i.e. in developing a Base+ or Do-Minimum network or at the next model upgrade)**.

2.4 SATURN Network and Zoning System

Introduction

2.4.1 The TTAA undertook a series of checks on the Forth Replacement Crossing SATURN network to ensure that it was coded appropriately. In general, the detailed checks concentrated on examining the AM peak network. Subsequently, a consistency check was undertaken to compare consistency in coded network details across the inter and PM peak networks.

Connectivity and Physical Layout of the Network

2.4.2 The layout of the SATURN network was compared with digital mapping (using MapInfo) in order to determine whether the network, concentrating on the major roads in the area (A90, M9, M8, M876, M80, M90), was representative of the actual road outline. It was found that the basic layout of the network was very similar to the maps in almost all areas. Furthermore, any issues highlighted in the audit of the draft AM peak SATURN network had been addressed in the final version of the Forth Replacement Crossing SATURN model.

2.4.3 The TTAA is satisfied that the skeletal network layout is appropriately represented.

Network Speeds

2.4.4 Using SATURN, a list of all the links and their associated free flow speeds was produced in order to assess if there were any outliers or obvious errors in link speed coding. Table 2.2 shows the number of links coded by each speed limit in the final AM Peak model network.

Table 2.2 : Number of Links by Coded Speed Limit

FRC_AM_Base_V3	
Coded Speed (kph)	**Number of Links**
32	38
34	105
44	1
45	345
46	2
47	379
48	2,664
50	619
54	15
58	126
60	2
64	474
72	10
75	4
78	51
80	75
82	152
90	701
96	375
101	5
104	9
105	17
108	178
111	119
Total	**6,466**

2.4.5 In the final AM Peak model, the coded free flow speeds have been amended to range from 32kph (20mph) to 111kph (70mph), which is generally consistent with the current range of speed limits across the Forth Replacement Crossing Model area. It is evident that there are several speeds (e.g. 40kph, 50kph and 104kph, etc.) that are only applied to a very small number of links. MVA has clarified that these individual speeds represent the free flow speeds assumed in the various speed-flow curves used in the model.

2.4.6 A further check was carried out on the link speeds along the major routes (A90, M9, M8, M876, M80, M90) to ensure that the coded speeds were consistent and accurate along these routes. The TTAA found that coded speeds on major routes all appeared to have consistent and accurate coded speeds.

2.4.7 The TTAA is generally content with the coded speeds across the Forth Replacement Crossing SATURN network. **Given the proliferation of differing free-flow coded speeds and the relatively sparse use of some values, the TTAA would recommend a rationalisation of the speed limit coding in any future upgrade of the model. This should adopt some easily followed guideline (e.g. using speed limits) in order to provide consistency in how the network is coded and should ideally be undertaken consistently between the Forth Replacement Crossing Model and TMfS07**.

Network Link Lengths

2.4.8 The TTAA undertook a check on the network link lengths on the final AM Peak model. This was done by comparing the coded link lengths with the 'crow-fly' distance between the two points based on the coordinates of the nodes. The calculated lengths were compared to the coded lengths using the GEH statistic. It is recognised by the TTAA that this is not a precise method for identifying the differences, nevertheless, it was considered appropriate in the circumstances to attempt to identify any potentially large discrepancies.

2.4.9 It was found that the Forth Replacement Crossing model had 289 links with GEH > 10 and 5,147 with GEH < 10. A sample of the links with the highest GEH (greater than 20) was selected and the reasons for the discrepancy between modelled and 'crow-fly' distance examined. Of this sample it was found that the majority of these links were either buffer links on the periphery of the model or links connected to zones, as such, the discrepancy between coded and 'crow-fly' is much less important. Furthermore, it was noted that link length discrepancies identified during the review of the draft AM peak network had been rectified in the final network.

2.4.10 In order to get a further idea of the accuracy of coded link lengths eight major routes were identified. These focused on the Forth Road crossings and their coded length was compared to the actual length of the routes using online mapping. Each route was checked in both directions. The eight key routes analysed were:

- Falkirk to Queensferry
- Edinburgh to Queensferry
- Livingston to Queensferry
- Queensferry to Inverkeithing
- Inverkeithing to Dunfermline
- Inverkeithing to Kirkcaldy
- Inverkeithing to Kinross
- Falkirk to Dunfermline (via Kincardine Bridge)

2.4.11 The results of the analysis for the final AM Peak Model are show in Table 2.3.

Table 2.3 : Route Analysis Summary

Routes	Actual Distance (m)	Modelled Distance (m)	Absolute Difference	% Difference
Falkirk - Queensferry	32,500	31,931	-569	-1.75%
Queensferry - Falrirk	31,700	31,136	-564	-1.78%
Edinburgh - Queensferry	6,800	6,844	44	0.65%
Queensferry - Edinburgh	6,900	6,882	-18	-0.26%
Livingston - Queensferry	16,400	16,372	-28	-0.17%
Queensferry - Livingston	15,800	16,035	235	1.49%
Queensferry - Inverkeithing	5,800	5,855	55	0.95%
Inverkeithing - Queensferry	5,800	5,592	-208	-3.59%
Inverkeithing - Dunfermline	5,400	5,431	31	0.57%
Dunfermline - Inverkeithing	5,800	5,885	85	1.47%
Inverkeithing - Kirkcaldy	19,800	19,403	-397	-2.01%
Kirkcaldy - Inverkeithing	19,500	19,567	67	0.34%
Inverkeithing - Kinross	20,600	20,364	-236	-1.15%
Kinross - Inverkeithing	20,700	20,724	24	0.12%
Falkirk - Dunfermline via Kincardine Bridge	22,700	22,588	-112	-0.49%
Dunfermline - Falkirk via Kincardine Bridge	23,400	23,336	-64	-0.27%

2.4.12 In the review of the final AM Peak Model, the TTAA was satisfied that the comparison of coded and actual distance fell within acceptable limits and that any issues identified from the review of the draft model had been rectified.

Routeing Review

2.4.13 The TTAA undertook a sanity check of the AM Peak assignment model to establish the logic and robustness of routes between specified origins/destinations north and south of the Firth of Forth (i.e. via the Forth Road Bridge and Kincardine Bridge and surrounding strategic network). Origins/destinations based on the following locations were assessed and the results of this analysis are shown in Table 2.4.

- Zone 134 Dunfermline
- Zone 150 Kinross
- Zone 147 Cowdenbeath
- Zone 164 Kirkcaldy
- Zone 48 Grangemouth
- Zone 200 Livingston
- Zone 21 Edinburgh Airport
- Zone 22 Cramond, Edinburgh

Table 2.4 : Routeing Analysis

Origin \ Dest	Stirling	Dunfermline	Kinross	Cowdenbeath	Kirkcaldy	Grangemouth	Livingston	Edinburgh Airport	Cramond
Stirling	–	✓	✓	× (1.)	× (1.)	✓	✓	✓	× (2.)
Dunfermline	✓	–	✓	✓	✓	✓	✓	✓	✓
Kinross	✓	✓	–	× (3.)	× (4.)	✓	✓	✓	✓
Cowdenbeath	× (1.)	✓	× (3.)	–	✓	✓	✓	✓	✓
Kirkcaldy	× (1.)	✓	× (3.)	✓	–	✓	✓	✓	✓
Grangemouth	✓	✓	✓	✓	✓	–	× (6.)	✓	× (2.)
Livingston	× (5.)	✓	✓	✓	✓	× (5.)	–	× (9.)	× (9.)
Edinburgh Airport	✓	✓	✓	✓	✓	✓	✓	–	× (10.)
Cramond	✓	✓	✓	✓	✓	✓	× (7.)	× (8.)	–

1. Localised routeing via A913/A914 rather than using A-class roads throughout the route
2. Local routeing via South Queensferry local streets (B924)
3. Not routeing via M90/A92; uses A92, B996 and A909 instead
4. Not routeing via M90/A92; uses B roads instead (e.g. B996, B9097 etc.)
5. No routes to M9 via M8/A89/A801, all via B8046
6. M8/A89/A801 from M9 not well used, almost all via B8046
7. Many routeing on A90 then minor roads via Kirkliston/M9 Spur to Newbridge. Only 4% via Maybury & A8; none via A720 to Hermiston Gait then M8, the signposted route from Gogar
8. Some routeing off/on A8 via RBS Gogarburn junction
9. Too much using A89 to Newbridge. This route is preferred over the M8
10. 1% of trips on this movement route from Barnton to Craigiehall then back along A90 to Barnton before accessing Cramond

2.4.14 The routeing checks show that assigned paths between the vast majority of the specified locations are reasonable and, in particular, that the main paths for cross Forth trips are in-line with expectations. The TTAA has identified a few localised routeing issues on some routes in Table 2.4. Generally, these relate to localised routeing issues and they are unlikely to have a significant impact on the Forth Replacement Crossing Model outputs. **Nevertheless, users of the Forth Replacement Crossing model should take cognisance of these localised routeing issues when interpreting the model outputs. It is recommended that action should be taken to address these matters at the next upgrade of the Forth Replacement Crossing Model or for any application where these localised routeing issues could influence the model results for the scheme or scenario being tested**.

Speed Flow Curves

2.4.15 There are 46 speed flow curves coded into the model. A basic logic check was carried out by selecting ten links in the buffer network and comparing the speeds on this link with the speed flow curve. The specified speed flow curves of these links were found to be consistent with the intended operation of the model.

Junction Coding

2.4.16 The TTAA undertook a series of checks on the junction coding of the SATURN model. A selection of significant junctions/interchanges, with a focus on the Forth crossings, was examined. The aspects of the junctions that were interrogated are as follows:

- Number of lanes
- Number of turning lanes
- Turn Capacities

2.4.17 Some observations were made regarding coding errors in the draft AM peak models. On reviewing the final AM Peak Model, it was found that all but two of the issues identified in the draft model had been rectified. MVA has subsequently responded to these issues stating that:

> *We will amend the coding to reflect our understanding of the lane arrangements on the A8 eastbound approach to Gogar (i.e. 2 lanes approaching the diverge (1 for the left diverge and for the straight ahead towards the underpass), both widening to 2 lanes immediately downstream of the diverge, with the left diverge then widening to 3 lanes on the approach to roundabout and the underpass dropping a lane again prior to the merge to the east of Gogar; and*
>
> *We will amend the coding to reflect our understanding of the lane arrangements on the A8 westbound approach to Gogar (i.e. 2 lanes approaching the diverge (1 for the left diverge and for the straight ahead towards the underpass), both widening to 2 lanes immediately downstream of the diverge, with the left diverge then widening to 3 lanes on the approach to roundabout and the underpass dropping a lane again prior to the merge to the west of Gogar*

2.4.18 Overall, the TTAA is content that the issues identified have been satisfactorily rectified in the network and supports MVA's proposed approach to addressing the two minor outstanding coding issues.

2.4.19 Furthermore, the TTAA undertook checks on a selection of additional junctions to ensure that the capacities had been coded appropriately. The full list of junctions checked is:

- Barnton - A90
- Hermiston Gait
- M8 J2
- A90/A8000
- A90/A904
- M90 J1
- M90 J3 - Halbeath
- A823/A823(M)
- A823/A907
- M9/M876 J7
- A876/A985
- M9 J8
- M9 J9

2.4.20 It was found that all of these junctions were found to be satisfactorily coded in the final AM peak SATURN network. Based on the above, the TTAA is satisfied that the selected junctions were appropriately represented in the network.

Periodic Differences

2.4.21 The TTAA undertook a review of the final AM, Inter Peak (IP) and PM models to establish if the respective peak models had been coded in a consistent manner. A review of the simulation network showed the number of junctions modelled and number of links connected to each junction for all the peak models to be identical. Table 2.5 show the number of junctions modelled in the Forth Replacement Crossing Model.

Table 2.5 : Simulation Network Nodes by Junction Type

Junction Type	No. Junctions Modelled
External Nodes	217
Priority Junctions	1,389
Traffic Signals	95
Dummy Nodes	14
Roundabout with U-turn	163
Total	**1,878**

2.4.22 In addition to the above, the TTAA undertook more detailed checks of the junction coding in terms of the junction layout, saturation flow and signal staging and timing at selected nodes to establish the consistency of periodic models. Table 2.6 showed that no inconsistencies were noted in the review.

Table 2.6 : Checking of Junction Coding Consistencies at Selected Nodes

Selected Nodes	Node Type	Comments
Barnton - A90 (Node 4045)	Signal	PM Peak green time different
Hermiston Gait (Node 8439)	Signal	coding same for all periods
M8 J2 (Node 8066)	Priority	coding same for all periods
A90/A8000 (Node 60772)	Priority	coding same for all periods
A90/A904 (Node 8192)	Signal	IP and PM Peak green time different
M90 J1 (Node 34381)	Priority	coding same for all periods
M90 J3 – Halbeath (Node 34453)	Signal	coding same for all periods
A823/A823(M) (Node 34270)	Priority	coding same for all periods
A823/A907 (Node 34059)	Signal	coding same for all periods
M9/M876 J7 (Node 26373)	Priority	coding same for all periods
A876/A985 (Node 4007)	Signal	IP and PM Peak green time different
M9 J8 (Node 26230)	Priority	coding same for all periods
M9 J9 (Node 31525)	Priority	coding same for all periods

2.4.23 A review of the buffer network was also undertaken, which showed the number of links and coding details of all the peak models were identical. Based on the above checks, the TTAA is generally content that the individual peak models have been coded in an appropriately consistent manner.

2.5 Matrix Development

Zone System

2.5.1 The Forth Replacement Crossing Model zoning system was supplied as a shape file and this has been compared against the TMfS07 zoning system and the full datazone set. The Forth Replacement Crossing model zoning system is more detailed than that of TMfS07 as would be expected and has 259 zones in the internal area (i.e. excluding the 40 route zones at the model boundary).

2.5.2 The Forth Replacement Crossing zoning system was developed using the TMfS07 zoning system as a start point and in all cases the Forth Replacement Crossing zones either directly replicate a single TMfS07 zone or groups of Forth Replacement Crossing zones combined make up a single TMfS07 zone. There are no cases where a Forth Replacement Crossing zone boundary crosses a TMfS07 boundary and in this case the model is entirely consistent with the parent model TMfS07.

2.5.3 The comparison of the Forth Replacement Crossing and TMfS07 zones shows that 146 Forth Replacement Crossing zones directly correspond with a single TMfS07 zone, while the remaining 113 Forth Replacement Crossing zones form portions of larger TMfS07 zones. The zones, which have been disaggregated to smaller Forth Replacement Crossing zones, generally represent areas where there is likely to be some differential in land use within different parts of the larger TMfS zone or where the full TMfS zone does not represent the area concerned in adequate detail for the purposes of the FRC study.

2.5.4 The zones have been split using datazones to form the boundaries and this is again consistent with the approach adopted for TMfS07. Consequently, in all but a small number of cases, the Forth Replacement Crossing zone is representative of a group of smaller datazones. In a total of 13 cases (Zones 14, 16, 21, 23, 24, 28, 32, 38, 39, 86, 103, 125 and 163) the Forth Replacement Crossing zones do not match entirely with datazone boundaries. On examination this is where the datazones generally cover a relatively large geographical area and these have been split to better represent the local areas for the purpose of the FRC study.

2.5.5 Overall the TTAA is satisfied that the zoning system adopted for the Forth Replacement Crossing SATURN model is appropriate for a strategic, regional model and is appropriately consistent with the national model TMfS07. Should more detailed analysis of specific aspects of the Forth scheme be required during, say, a *Design Manual for Roads and Bridges* (*DMRB*) (Highways Agency) Stage 3 assessment it may be appropriate to consider refinement of certain elements of the zoning system or, alternatively, to use a more detailed local model for such analysis.

Prior Matrix Development

2.5.6 Prior matrices were produced for the matrix calibration process by cordoning the corresponding sub-area of the TMfS07 highway matrices. The TMfS07 roads model assignment matrices were developed primarily using 2001 Census Journey to Work and Roadside Interview Survey data. A high level overview of the TMfS07 trip matrix development is presented in MVA's *TMfS07 National Road Model Development Report* (Issue 3, 30 January 2009). The TTAA has reviewed this information and is generally content that the high level description of the data and its intended use is appropriate. **However, it should be noted that at the time of writing the audit of the TMfS07 National Road Model remains ongoing and a more detailed examination of the TMfS07 trip matrices and their robustness will be undertaken in due course**.

2.5.7 Notwithstanding the above, the TTAA concurs that a cordon matrix from TMfS07 provides an appropriate start point for the development and refinement of the Forth Replacement Crossing trip matrices.

2.5.8 The Forth Replacement Crossing assignment matrices are hourly matrices created by taking proportions of the corresponding time period demand matrices (AM and PM proportion = 0.38, IP proportion = 0.667). The TTAA requested clarification from MVA regarding the source of the AM and PM peak hour factors applied to extract the peak hour from the peak period matrices to which the following response was received:

> *The peak-hour SATURN models are calculated as 0.38 of the corresponding demand in the corresponding peak periods. The period to peak-hour factors used were derived from earlier analysis of a range of RSI data collected prior to 2005 at a variety of sites throughout Scotland. From this analysis sector-specific period to peak-hour factors were calculated. This analysis identified the appropriate peak hours for each RSI location. The sectors used were Glasgow, Edinburgh and Elsewhere. The resulting period to hour matrix of factors was multiplied by a matrix of travel demand representing each period.*

The matrix totals from these resultant matrices where then divided by the total number of trips in each period to derive a single flow-weighted average period to hour factor for each time period

2.5.9 Given that a large amount of the RSI data in the TMfS database was collected prior to 2005 this approach to calculating peak hour factors is considered appropriate by the TTAA.

Matrix Estimation

2.5.10 The Forth Replacement Crossing SATURN matrices were refined using matrix estimation (ME) to improve the fit between modelled and observed flows. The individual user class matrices were aggregated into a single matrix before undertaking ME with the final, refined matrices subsequently being disaggregated back to the five user classes using cell by cell factors.

2.5.11 The ME process was undertaken using aggregate screenline counts as targets, rather than individual link counts. The counts were aggregated into a total of seventeen screenlines across the Forth Replacement Crossing study area.

2.5.12 MVA presented the total difference (in PCUs) between the prior and final matrices for each peak. This demonstrated that the overall matrix totals following ME had only increased by a relatively small amount (up to 3%). The trip length distribution before and after ME is also presented in Appendix C of MVA's Report and this suggests that the distribution was not changed significantly during the ME process. In particular, the shorter trip lengths (<10km) remain stable with the most significant changes occurring on the medium to longer trip lengths.

2.5.13 This analysis provides some evidence that the impact of ME has been relatively small at the global level across the matrix which accords with expectations. The Report does not provide further detail on the ME process and the TTAA requested details of:

- The constraints applied in the ME process
- Checks undertaken on the prior and final matrices on a sector or zonal basis

2.5.14 MVA responded to say that:

Records 6 Combined Constraints' were included in the SATME2 control file. No other constraints were applied

2.5.15 The TTAA considers that it is generally good working practice to include constraints within the ME process and is satisfied that such constraints have been applied. **The level of detail provided regarding the constraints is, however, limited and the TTAA would recommend that future model development reports should provide more detail of the specific constraints adopted in the ME process, perhaps in an appendix**.

2.5.16 MVA further supplied analysis showing the trip matrices aggregated to a 25 sector system pre and post the ME process. The TTAA undertook analysis of this to establish the changes on a sector to sector basis and in particular to establish whether any significant changes had been introduced to the matrices during the ME process. A 'significant' change was classified as any value which changed by more than 200 PCUs and 15% in the ME process.

2.5.17 It is encouraging to note that in the vast majority of sectors the change in the matrices resulting from the ME process was relatively small in absolute terms. There are only 2, 3 and 3 cases in the AM, inter and PM peaks where the change was classified as significant. In all of these cases the change was either only slightly over the significance threshold and/or involved movements to/from sector 24, which is a very large sector covering the southern and western external model area. The TTAA is satisfied that the impacts of the ME process are generally of the expected order of magnitude at a sector level.

2.5.18 The TTAA undertook an independent analysis of the trip length distribution for the AM Peak model. The results showed some differences between that reported in the Appendix C of the *Model Development Report*, in particular that there was a higher concentration of trips travelling below 6km than shown in MVA's Report. MVA has examined this issue and noted that the 0 - 1km band was not included in the analysis in the Report, which will be updated to include this information in the final version in due course.

2.5.19 In addition, TTAA notes that the demand matrices contain significant numbers of OD movements with small fractions of a trip (i.e. < 1 PCU). A broad analysis of the peak models undertaken suggests about 20% of trips or about 80% of OD movements fall into this category. The TTAA requested some further commentary on this matter from MVA, who responded as follows:

> *These small non-zero cells are a consequence of the process used to create the initial demand matrices from the TMfS:07 model. The numbers effectively represent the probability of a given OD trip, rather than observed numbers of actual trips passing RSI sites etc. NB our checks suggest that the SATURN matrix estimation had little effect on the number of cells containing small non-zero entries.*
>
> *The only risk we can foresee with this is if a user applies a process which truncates or rounds individual OD demands to integer values. (Calculations based on trip-ends (i.e. the sum across a row or column of the demand matrix) will be unaffected, while calculations based on link-flows will avoid the problems normally associated with the use of 'clumpy' demand matrices*

2.5.20 The TTAA acknowledges MVA's commentary on the matter and recognises that these fractions of trips will not be an issue in terms of modelling aggregate link and junction flows, however, users of the model should note that the travel demand patterns reflected at an individual OD level will in many cases be less realistic than at a more aggregate sector level, particularly where the fractions on individual OD movements are extremely small. In the majority of cases when using the SATURN model outputs this is unlikely to be a significant issue. **However, the TTAA suggests that users of the model should take note of this issue when applying the model for any detailed OD specific analysis or for local area cordoning, particularly when subsequently using cordoned outputs in a microsimulation model**.

2.6 Assignment Model Development

Assignment Procedure

2.6.1 An equilibrium assignment procedure using the Frank-Wolfe algorithm was adopted for the Forth Replacement Crossing SATURN model. The SATURN assignment iterates between the assignment and junction simulation stages until a predefined convergence level is reached. The TTAA is content that the assignment procedure is consistent with expectations for a model of this nature.

Generalised Cost Parameters

2.6.2 Generalised cost parameters were calculated using WebTAG guidance from February 2007 and these were presented in Table 4.1 of MVA's Report. The values shown in Table 4.1 of the Report are broadly comparable with the values of time in WebTAG unit 3.5.6 and their relative scale and magnitude appears to be consistent with previous versions of TMfS.

2.6.3 The toll parameters are also listed in §4.2.2 of the Report as having been derived from previous TMfS based analysis. The parameters used to convert tolls from pence to generalised minutes are listed and again, these appear to be of a relative scale and magnitude that is comparable with previous versions of TMfS.

2.6.4 Some further information on the generalised cost coefficient derivation is provided in Appendix C of the *Forth Replacement Crossing Demand Model Development Report* (Issue 2, December 2008). In response to a request from the TTAA, MVA provided the spreadsheets showing the calculation of the generalised cost coefficients. The TTAA's review of this demonstrated that the calculations followed the expected methodology and are considered appropriate. The TTAA does, however, note one minor inconsistency in the fuel costs adopted from Scot-TAG Table 9.18. The appropriate 2007 resource cost figures have been used, but the duty figures for 2005 (43.6) have been used instead of the values for 2007 (42.7). The TTAA acknowledges that this issue may be partly attributable to a slight inconsistency between the values published in the current guidance documents (Ref. WebTAG Unit 3.5.6, Table 11 and ScotTAG Section 9.5.18, Table 9.18). **This will have a trivial impact on the resulting parameters and the TTAA is content that this can be addressed during the next upgrade of the Forth Replacement Crossing Model**

Convergence

2.6.5 The convergence criteria adopted for the Forth Replacement Crossing SATURN model indicate that convergence is reached if 99% of link flows change by less than 2% between iterations. The final '% GAP' values for the Forth Replacement Crossing SATURN model range between 0.014% and 0.07%, which is an acceptable level of convergence for a model of this scale and nature.

2.7 Calibration

Traffic Count Data

2.7.1 The Forth Replacement Crossing calibration process made use of traffic count data at 118 locations combined into a series of 17 screenlines. The data was from sources including:

- Scottish Road Traffic Database (SRTDb)
- Local Authority Traffic Counts
- Traffic Counts used for the TMfS05 Calibration/Validation
- FRC Survey Traffic Counts

2.7.2 The traffic counts were factored to a common 2007 base year when necessary. The TTAA noted that the Report does not identify how much of the data pertains to each of the above sources and/or which of the count sites provided data that was older than the 2007 base year. MVA subsequently supplied this information independently to the TTAA, which shows that the vast majority of the count data pertains to 2007 and 2008 (80%) with most of the remaining counts being from 2005 (14%) and 2006 (3%). There are only two sites where data older than this was used, on the A823 north of Dunfermline and the A907 west of Dunfermline where only 2001 data was available. The TTAA is satisfied that the vast majority of traffic count data used in the model development can be considered up to date. **The TTAA would recommend that the table showing the date of the observed traffic counts be included in the final report in due course**.

2.7.3 MVA also highlights in §5.1.2 of the Report 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*

2.7.4 While this situation is less than ideal the appropriate remedial action was taken by MVA. Nevertheless, the local A71 calibration results should be interpreted with this fact in mind.

2.7.5 The 17 calibration screenlines are presented in Figure 5.1 of MVA's Report. The screenlines cover all existing crossings over the Forth, the major motorway and A class roads in the study area (M90, M9, M8, A90, A9, A92, etc.) and some other routes in the study area. In general terms the screenline coverage is considered appropriate.

2.7.6 It is worthy of note that while the Kincardine and Forth Road Bridges are covered by a screenline each there is no screenline that cuts the key links in the immediate vicinity north and south of each crossing. It is difficult to establish from the screenline analysis alone how well the assignment/distribution of traffic on the key approaches to the bridges is reflected in the model (e.g. split between the A90, A8000 south of the Forth Bridge, split between M9 and M876 south of Kincardine Bridge, etc.). The TTAA requested clarification from MVA regarding what analysis had been undertaken to ensure that the appropriate distribution of trips had been modelled across each of the key Forth crossings, with particular reference to the Forth Road Bridge itself. MVA confirmed that such checks had not been undertaken, but was subsequently requested by Transport Scotland to undertake some analysis.

Distribution of Trips Crossing the Forth Road Bridge Northbound

2.7.7 MVA produced the Note *Distribution of Forth Road Bridge Northbound Trips* (First draft 2 February 2009; Final version 18 February 2009). MVA identified that the only reliable observed data for undertaking this analysis related to the Forth Road Bridge and was for the northbound direction only. While survey data is available around the Kincardine Bridge, MVA has identified a number of inconsistencies that would make comparison to this data challenging.

2.7.8 The comparison presented by MVA showed the modelled and observed trip distribution for northbound trips across the Forth Road Bridge using a 25 sector system. The TTAA's analysis of this information identified the following observations:

- The modelled distribution of origins shows a significant underestimate in the central Edinburgh area with a significant overestimate in the 'West Lothian M8 Corridor' sector in the AM and Inter Peaks
- There is also a significant overestimate of origins in the 'Elsewhere (west and south)' sector in the AM peak
- The modelled distribution of origins is generally better in the PM peak
- The modelled distribution of destinations is generally more representative of the observations in each time period although there is a significant overestimate of trips to the 'Elsewhere (north)' sector, particularly in the AM and Inter Peaks and to a lesser extent in the PM peak

2.7.9 The main implications of this analysis are that the origins of trips heading to the Forth Road Bridge in the AM and Inter Peaks will be too heavily focused on routes from the west (i.e. M8 and A89 via Newbridge/M9 spur) with a corresponding underestimate on routes from the east (e.g. Gogar/A8 or A90 Queensferry Road/Barnton). Furthermore, the destinations of trips appear to demonstrate that too many longer distance, through trips are predicted to travel through to the 'Elsewhere (north)' sector rather than destinating somewhere in Fife itself (i.e. there are generally too many trips on the M90 towards Perth and beyond and not enough using the M90 junction exits and local roads to access the Fife sectors, with the exception of Glenrothes).

2.7.10 MVA's note provides a factual statement regarding the comparison of the modelled and observed trip distribution across the Forth Road Bridge and, indeed, identifies the issues highlighted by the TTAA, however, no statement is provided regarding the implications of these discrepancies with respect to the Base model and any future year forecasting. While it is difficult to draw firm and detailed conclusions on the implications of this issue, the TTAA has considered the potential implication within the context of the Forth Replacement Crossing study and also for more general application of the model.

2.7.11 In the context of applying the model in the FRC study, at the highest, Strategic Level the issue is unlikely to be highly significant as the overall volumes crossing the Forth Road Bridge have been shown to be well represented in the model. At the next level down where the model may be applied to undertaking scheme assessments, comparing alternatives, refining the preferred scheme etc. (i.e. generally considering things in more detail) the issue could have more apparent implications, which could include:

- Influence on economic assessment results for ranking of options (e.g. there could be a bias towards an option with a particular junction strategy/configuration if this favoured movements to/from West Lothian and the west).
- Influence on absolute economic assessment values. Related to above, but probably a less significant issue.
- Influence on the rerouteing/mode/destination choices (as there is a bias towards trips between Fife and West Lothian which don't have good PT coverage. This would further bias towards rerouteing and destination choice responses, which are already the most sensitive in the model structure).
- Influence on flows used for environmental/accident assessment and scheme design (i.e. absolute flows on specific links could be significantly over or underestimated because of the mismatch in the distribution).
- Influence on motorway/slip road flows in Fife. There is an overestimate of through trips as opposed to trip destinating in Fife which may bias flows towards the M90 mainline and underestimate the joining/leaving flows. This is likely to be more of an issue for detailed operational assessment and examination of detailed measures such as ITS proposals.

2.7.12 The significance of any these issues in the context of the FRC study is very difficult to conclude in this audit and is most likely to depend on the details of each specific application of the model.

2.7.13 For application of the model outwith the FRC study, as a general Strategic model covering the area then the issue is also unlikely to be highly significant in relation to the overall higher level forecasting process. The points raised in relation to the application of the model in the FRC study remain relevant to general application where more detailed analysis and scrutiny of outputs is significant.

2.7.14 One of the key points to consider for general application is the bias towards trips between West Lothian/West and Fife and the corresponding underestimate between Edinburgh and Fife. Again, if looking at individual flows in detail then there could be an influence on flows on key links and at key junctions on the trunk road network (e.g. bias towards M8 west/Claylands/Newbridge/M9 route and an underestimate on routes from the east Gogar/A8, Barnton/A90, etc.).

2.7.15 The key issue to consider is not necessarily the flows in the base model but the assignment/traffic flow response in any model application. Any scheme/policy which could change flows on these routes would need to be looked at in detail to ensure that the modelled response was intuitively correct and that the predicted flows at these key locations were plausible. This is likely to be more of an issue if assessing the operation of key junctions like Newbridge, Gogar, Barnton, etc. The overestimate of through trips in Fife could similarly have an influence if looking at operational assessment along the M90 corridor.

2.7.16 Again, it is difficult to conclude within this audit how these issues may affect specific applications without knowing the details of the intended applications, however, it is reasonable to conclude that the affected movements are related to key locations/routes in the model so this could well be a relevant issue for many applications of the model. **The TTAA would recommend that ideally additional model development work should be undertaken to refine the distribution of trips across the Forth Road Bridge prior to the widespread application of the Forth Replacement Crossing Model. In the absence of such additional development work the TTAA would strongly recommend that users of the model take cognisance of the issues highlighted in this section of the Report both prior to applying the model and subsequently when interpreting its outputs**.

2.7.17 MVA also undertook a comparison of the modelled versus observed journey lengths for the internal to internal movements in the Forth Replacement Crossing Model matrices (presented in the 2 February 2009 version of the Note *Distribution of Forth Road Bridge Northbound Trips* only). This demonstrated that the general pattern of trip length was similar between modelled and observed in most cases. It is evident that there is a slight overestimate of shorter trip lengths (≤20km) in the AM peak, which is offset by an underestimate of medium distance trips (20km – 30km). This pattern is reversed in the PM peak, where the medium distance trips are overestimated and the shorter distance trips overestimated.

2.7.18 It should be borne in mind that this analysis excludes any trips that begin or end at an external route zone, which is likely to represent a substantial portion of the trips in the overall Forth Replacement Crossing Model trip matrices.

Screenline Calibration

2.7.19 The modelled to observed comparisons for total screenline flows are presented in Tables 5.1 to 5.3 of MVA's Report. These demonstrate that the GEH values for the screenlines show a very good match in all time periods. The maximum GEH values are 3.42, 4.06 and 1.25 for the AM, Inter and PM peaks, while the majority of GEH values are less than 1 in all periods.

2.7.20 Effectively, the calibration in terms of total flows across screenlines meets the *DMRB* acceptability criteria in that regard.

2.8 Validation

Link Count Validation

2.8.1 MVA has presented the link count validation using the individual link flows that comprise each of the 17 screenlines used in the model calibration process. This has been considered by MVA as validation rather than calibration since the ME process used the total screenline flows as the target values.

2.8.2 The TTAA acknowledges that this comparison is extremely useful and necessary for the Forth Replacement Crossing Model, however, it should be borne in mind that the individual link flows are not truly independent of the calibration screenline flows, as they were combined to create the screenlines in the first place; by the strictest interpretation of the terminology in *DMRB*, these link flow counts should be considered as calibration rather than validation as they are not truly independent. **The reader should bear this fact in mind when interpreting the link count validation as presented in MVA's Report**.

2.8.3 Notwithstanding the above the analysis of the validation comparisons demonstrates that:

- 61%, 60% and 58% of individual links show a GEH of less than 5 in the AM, inter and PM peaks
- The flows on the Kincardine and Forth Road Bridges match well with observations in all time periods

- Approximately 72%, 74% and 79% of individual links show a GEH of less than 7 in the AM, inter and PM peaks
- Approximately 88%, 92% and 90% of individual links show a GEH of less than 10 in the AM, inter and PM peaks
- While the screenline total values are well calibrated the individual link flow comparisons comprising each screenline are generally much more variable

2.8.4 Individual link flow comparisons on screenlines are shown to be more variable where flows are overestimated on some links with this being counter-balanced across the screenline by underestimates on others. With respect to individual link flows the ideal *DMRB* target of 85% of GEH values <5 is not achieved, however, this is not particularly unusual in wider area models. Approximately 60%, >70% and 90% of the GEH values are less than 5, 7 and 10 in each time period, which provides some reassurance that the majority of the individual link flow comparisons are within reasonable limits.

2.8.5 The various links which exhibit a GEH value of more than 10 are:

- A70, Lanark Road (Screenline 2 eastbound) [AM peak only]
- A71, Calder Road (Screenline 2 westbound) [AM and PM peak]
- B7015 west of the B8046, West Lothian (Screenline 3c westbound) [AM peak only]
- A71 at Calder (Screenline 3c westbound) [AM peak only]
- B8046 Pumpherston Road, south of Millbrae, West Lothian (Screenline 3c westbound) [AM peak only]
- B803 south west of Lionthorn Road, Falkirk (Screenline 4b southbound) [All periods]
- A9, Causewayhead between Dumyat Road and Castle Road, Stirling (Screenline 6 southbound) [AM peak only]
- B998 Hillfoots Road, east of East Link Road, Stirling (Screenline 7a eastbound) [AM peak only]
- B9124 Cowie Road, east of the A91 Stirling (Screenline 7b eastbound) [AM and Inter Peak]
- M9 Bannockburn (Screenline 7b eastbound) [AM peak only]
- A872 between Dunipace and A872/A91 Roundabout, Stirling (Screenline 7b eastbound) [AM peak only]
- B9124 Cowie Road, east of the A91 Stirling (Screenline 7b westbound) [All periods]
- B996 Great North Road, north of Bath Street, Fife (Screenline 9a westbound) [AM peak only]
- B934 North of A823/B934 Junction, Perth & Kinross (Screenline 10 northbound) [AM peak only]
- A70 Lanark Road (Screenline 2 westbound) [Inter Peak only]
- A71 At Calder (Screenline 3c westbound) [Inter Peak only]
- B803 south west of Lionthorn Road, Falkirk (Screenline 4b northbound) [inter and PM peak]
- B810 Polmont (Core 948) (Screenline 4b northbound) [Inter Peak only]
- M9 200m S of Keir Roundabout (Screenline 6 southbound) [inter and PM peak]

- A9 South of Stirling (Screenline 7b eastbound) [Inter Peak only]
- M8 0.25 Mile West A720 Junct (Screenline 2 westbound) [PM peak only]
- A70, Lanark Road (Screenline 2 westbound) [PM peak only]
- A899 east of Galloway Crescent, West Lothian (Screenline 3b eastbound) [PM peak only]
- B8046 Pumpherston Road, south of Millbrae, West Lothian (Screenline 3c eastbound) [PM peak only]
- A803 - Main Street, east of Bo'ness Road, Falkirk (Screenline 4b southbound) [PM peak only]
- A91 (Screenline 6 southbound) [PM peak only]
- M9 Bannockburn (Screenline 7b westbound) [PM peak only]

2.8.6 It is evident that these are predominantly relatively remote from the Forth Road Bridge in particular, which is significant given the intended application of the model, however, it is evident that some significant links such as the M9 and M8 demonstrate poor comparisons.

2.8.7 Overall the link flow validation comparisons demonstrate that the general trends in traffic patterns across screenlines are well represented in the model. With respect to undertaking strategic forecasting and wide area assessments of scheme options the Forth Replacement Crossing Model can therefore be considered as fit for purpose. In general terms the link flow validation, while not meeting *DMRB* standards, is acceptable albeit at the lower end of the acceptable range in terms of individual link flows. **Given the issues highlighted with respect to the more variable validation to individual link flows/parallel routeing issues on screenlines the TTAA would recommend that:**

- **Care should be taken in forecasting to ensure that changes in assignment in the SATURN model accord with reasonable expectations for the option/scenario being tested given the potential parallel routeing issues**
- **The Forth Replacement Crossing SATURN model is considered as a strategic tool to provide forecasts for use in economic, environmental and operational assessments, however, given the more variable link flow validation on a local basis in the model, it is likely that detailed operational assessment would require to be undertaken using a more detailed model (e.g. the FRC microsimulation model), should such a model be suitably well calibrated and validated for that purpose**
- **Any future upgrade of the model should make efforts to improve the validation to individual link flows while maintaining robustness across screenlines as a whole**

Journey Time Validation

2.8.8 Journey time validation was undertaken by comparing modelled and observed journey times along 17 different routes in each direction. The routes cover all the major corridors in the study area as follows:

- Route 1: M8 J3 – Echline (Count on Us survey)
- Route 2: Newbridge – Claylands (Count on Us survey)
- Route 3: Echline – Gogar (Count on Us survey)
- Route 4: M9 J2 – Echline (Count on Us survey)

- Route 5: M90 J3 – Echline (Count on Us survey)
- Route 6: Aberdour – Inverkeithing (Count on Us survey)
- Route 7: Crossgates – M90 J1 (Count on Us survey)
- Route 8: Cairneyhill (N) – M90 J2 (Count on Us survey)
- Route 9: Cairneyhill - M90 J1 (Count on Us survey)
- Route 11: Dundee – Denny (ITIS data)
- Route 12: Edin – Perth via FRB (ITIS data)
- Route 13: Edin – Perth via Stirling (ITIS data)
- Route 14: Edin Bypass – Denny (ITIS data)
- Route 15: Kirkcaldy – Torryburn (ITIS data)
- Route 16: Dunfermline Town Centre (ITIS data)
- Route 17: Stirling Area (ITIS data)
- Route 18: M90/A9000 (M) (ITIS data)

2.8.9 The data comes from specific floating vehicle surveys undertaken by Count on Us using GPS (Routes 1 to 9) and average speed data from ITIS (Routes 11 to 18). The Count on Us surveys were undertaken between 06:00 - 10:00, 11:00 - 14:00 and 15:00 - 19:00, however, for the calibration exercise only data relating to the periods 07:00 - 09:00, 17:00 - 19:00 and 12:00 - 14:00 was used as this was considered to better represent the modelled peaks. The TTAA considers the coverage of the journey time routes to be comprehensive and appropriate for the Forth Replacement Crossing Model development.

2.8.10 In overall terms the journey time validation is good with between 88% and 91% of comparisons meeting the *DMRB* journey time acceptability criteria of modelled times being within 15% of observed. The routes which fail to meet the criteria are:

- Route 2 Clockwise (AM peak +25%)
- Route 2 Anti-clockwise (Inter Peak +15%, PM peak -16%)
- Route 6 Eastbound (Inter Peak -27%)
- Route 6 Westbound (Inter Peak -35%)
- Route 11 Southbound (AM peak -17%)
- Route 11 Northbound (PM peak -15%)
- Route 12 Southbound (AM peak -18%, Inter Peak -20%)
- Route 12 Northbound (PM peak -15%)

2.8.11 Of the ten cases outlined above it is reassuring to note that six of these only fail to meet the *DMRB* criteria by up to 3%, with the remaining four cases showing a more significant difference.

2.8.12 Appendix E of MVA's Report provides a breakdown of the journey time comparisons by route section. In general this shows that many of the routes demonstrate a similar trend in the journey time pattern between modelled and observed times when plotting the cumulative journey time by section. Analysis of this has raised some issues as outlined in Table 2.7.

Table 2.7 : Local Journey Time Variations

Route	Direction	Time Period	Local Modelled JT	Locations	Overall Route Meets *DMRB* ?
2	Clockwise	AM	Slow	Eastbound approach to Gogar & Westbound M8 Hermiston Gait to Newbridge	No
2	Anti-clockwise	IP	Slow	M8 eastbound Claylands to Hermiston Gait	No
2	Anti-clockwise	PM	Fast	A8 Ratho Station to Newbridge	No
3	Northbound	All	Variable	Various over and underestimates along the route	Yes
3	Southbound	All	Variable	Generally variable around Barnton and Maybury	Yes
4	Eastbound	AM	Slow	Higher modelled delay on A904 approach to Echline	Yes
5	Southbound	IP	Fast	Generally quicker throughout	Yes
5	Northbound	AM & PM	Fast	Quicker at Echline onto A90	Yes
6	Eastbound	IP	Fast	Quicker at eastern end of route	No
6	Westbound	IP	Fast	Quicker at eastern end of route	No
11	Northbound	All	Fast	Generally quicker throughout	Yes AM & IP, No PM
11	Southbound	All	Fast	Generally quicker throughout	No AM, Yes, IP & PM
12	Northbound	All	Variable	Various over and underestimates along the route	Yes AM & IP, No PM
12	Southbound	All	Fast	Generally quicker throughout	No AM & IP, Yes PM
13	Eastbound	All	Fast	Generally quicker throughout	Yes
13	Westbound	All	Fast	Generally quicker throughout	Yes
14	Eastbound	All	Fast	Quicker at western end of route	Yes
14	Westbound	IP & PM	Variable	Various over and underestimates on M8	Yes
15	Eastbound	AM	Fast	Quicker at eastern end of route	Yes
17	Eastbound	All	Fast	Slow at eastern end, generally quicker along remainder of route	Yes
17	Westbound	All	Fast	Slow at eastern end, generally quicker along remainder of route	Yes

2.8.13 Given that some of the routes highlighted above are on key approaches to the Forth Road Bridge the TTAA requested some commentary from MVA to further explain the reasons behind these localised differences between the modelled and observed journey times. MVA provided a commentary on each route highlighted in Table 2.7 and these comments are reproduced in Appendix A of this Report. **The TTAA would recommend that users of the model familiarise themselves with the comments in Appendix A and bear these in mind when interpreting outputs from the model. Furthermore, the TTAA would recommend that where possible, action is taken to address these comments during the next upgrade of the model**.

2.8.14 In the specific case of Route 5 northbound, the model is shown to underestimate the delays on the immediate approach to the Forth Road Bridge at Echline. As well as providing the commentary in Appendix A, MVA has also identified a number of issues that point to potential inconsistencies between the modelled situation and the on-street situation when the journey time surveys were undertaken which makes these comparisons inconclusive. On the face of it, with the data presented for the SATURN model development, a full resolution of this issue in the context of this audit is unlikely.

2.8.15 In terms of the likely application of the Forth Replacement Crossing Model it is assumed that it will more or less always be applied looking at future Do-Nothing/Minimum networks (rather than the 2007 Base itself), upon which test schemes would be developed. The Do-Nothing/Minimum networks would require to reflect the current or projected future network conditions, part of which would include the removal of the northbound tolls from the Forth Road Bridge which occurred on 11 February 2008. It is the reflection of this updated situation in the Forth Replacement Crossing SATURN model, in terms of traffic flows and journey times that is arguably more important than its representation in the Base model. The key to this would be reflecting the impact of removing the tolls from the Forth Road Bridge.

2.8.16 **The TTAA would recommend that it would be useful if some attempt is made to examine the modelled situation with the northbound tolls removed and to establish the sensitivity to removing the tolls. This would hopefully demonstrate that the Forth Replacement Crossing SATURN model adequately reflects the prevailing no toll situation on the bridge. It is assumed that more recent flow and journey time data collected by Jacobs during their FRC study would be readily available for such a comparison**.

2.8.17 Notwithstanding the commentary outlined in Appendix A, it is evident that the general level of total journey time validation along the observed routes is good. In the context of a strategic, wide area model this provides reassurance that overall delays and journey times are being reflected to an acceptable level. The issues highlighted above with respect to localised variation in journey time validation and the lower level of validation on some routes (particularly Routes 11 and 12) should be borne in mind when interpreting the outputs from the model.

3 DEMAND MODEL

3.1 Introduction

3.1.1 The demand model was developed in CUBE/Voyager and forms the travel demand response forecasting component of the multi-modal Forth Replacement Crossing Model. The initial audit findings on the demand model were presented in Audit Note *AN-FRC-7* (Ref. 70806, 30 January 2009). A subsequent response to *AN-FRC-7* was received from MVA and this has been taken into account in compiling the findings in this Audit Report.

3.1.2 The TTAA received the following information from MVA for use in the audit process:

- *Forth Replacement Crossing Model – Demand Model Development Report* (Issue 2, December 2008)
- Appendices to *Forth Replacement Crossing Model – Demand Model Development Report*
- *Audit Response Note to AN-FRC-7: Demand Model* (MVA Ref. C37135, 5 February 2009)
- *Information Note : Interface with National Model* (MVA Ref. C3713500, 20 February 2009)

3.1.3 This chapter relates to the audit of the demand model and the supporting model development, calibration and validation documentation. The section headings correspond with the chapter headings from MVA's *Demand Model Development Report*.

3.2 Introduction to Demand Model Development

Background

3.2.1 The background to the model development is set out in the Report and this highlights the fact that the Forth Replacement Crossing Model is a sub-area model of TMfS07, centred on the Forth crossing area with a SATURN roads assignment model and Cube Voyager Public Transport (PT) and demand models. Furthermore, it states that the demand model is based on that for TMfS05A with some modifications and enhancements while it adopts the same in structure as the TMfS07 National Demand Model.

3.2.2 The TTAA acknowledges the advantages of retaining the consistency with TMfS07 particularly for ongoing potential use of the Forth Replacement Crossing Model.

3.3 Demand Model Overview

Model Structure

3.3.1 The Forth Replacement Crossing Model contains a four-stage demand model with the choice structure as follows:

- Trip generation
  - Trip frequency
- Mode choice
- Destination choice
  - Park & Ride station choice
  - High occupancy vehicle choice

- Peak spreading
- Route choice

3.3.2 The TTAA is generally satisfied with the choices incorporated in the demand model. More detailed commentary on individual aspects of the model will be provided in later chapters of this Report.

3.3.3 The demand model operates in an incremental manner calculating changes to the base year road and PT assignment matrices arising through changes in planning data and/or transport costs. Again, the TTAA concurs with the adopted approach.

3.3.4 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 & Ride, site files
- Calibrated model parameters

3.3.5 The data sources used in developing the demand model include:

- 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
- Trip rates from TEMPRO

3.3.6 The TTAA is content that both the inputs to the demand model in forecast mode and the data sources used in development are appropriate.

Zone System

3.3.7 The Forth Replacement Crossing zoning system was developed using the TMfS07 zoning system as a start point and, in all cases, the Forth Replacement Crossing zones either directly replicate a single TMfS07 zone or groups of Forth Replacement Crossing zones combined make up a single TMfS07 zone. There are no cases where a Forth Replacement Crossing zone boundary crosses a TMfS07 boundary and, in this case, the model is entirely consistent with the parent model TMfS07. The demand model operates with the same zoning system as the roads and PT assignment models and each zone contains no more than one train station.

3.3.8 Overall, the TTAA is satisfied that the zoning system adopted for the demand model is appropriate for a strategic, regional model and is appropriately consistent with the national model TMfS07.

Journey Purposes and Time Periods

3.3.9 The six journey purposes contained in the demand model are described in MVA's Report as follows:

- 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 (e.g. 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.
- Home-Based Education (HBS) – travelling 'from home' to an education destination (e.g. school, college etc). These are not part of the main Demand Model, but are added in separately after the mode and destination choice phases.

3.3.10 Additionally, there are four household types represented in the model which act as a proxy for car availability:

- 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
- C2+ – 2+ car household

3.3.11 The five user classes are consistent with the roads assignment model:

- Car – in work time
- Car – in commute time
- Car – in other time (e.g. shopping, leisure, etc.)
- Light goods vehicles
- Heavy good vehicles

3.3.12 A separate demand model operates for each peak period for 'from home' trips only. The 'to home' and 'non-home based' trips are derived by applying factors to the 'from home' trips. The time periods of operation are as follows:

- AM peak period 07:00 – 10:00
- AM peak hour (for assignment modelling) 08:00 – 09:00
(calculated as 0.38 of AM Peak Period Demand)
- Inter Peak period 10:00 – 16:00
- Inter Peak hour (for assignment modelling) 1/6 of 10:00 – 16:00
- PM peak period 16:00 – 19:00
- PM peak hour (for assignment modelling) 17:00 – 18;00
(calculated as 0.38 of PM Peak Period Demand)

3.3.13 In general terms, the TTAA is content with the journey purpose, household type, user class and time period specifications adopted.

Generalised Costs

3.3.14 The generalised cost coefficients for the base year roads and PT assignment models were derived using the appropriate values contained in the October 2008 version of TAG Unit 3.5.6. The TTAA has reviewed the calculations underlying these coefficients and is satisfied that they have been appropriately derived. Specific commentary relating to the roads and PT model generalised cost coefficients is provided in the relevant chapters of this Report.

Parking Charges

3.3.15 Parking charges have been introduced by adding costs to the zones in the central areas of Edinburgh, Stirling and Dunfermline. The costs vary by journey purpose to reflect the differing average length of stay by purpose. The costs have been applied using the methodology typically adopted in TMfS which assumes that:

- Long stay parking – 45% of commuting trips will pay this charge
- Short stay parking – 80% of home based other and non home based trips will pay this charge
- Employers business trips pay no parking charge as the cost is deemed not to be perceived
- Average short term and long term parking charges are assumed to apply across all parking sites
- The costs are added to the base year generalised cost skims after applying the appropriate tolling parameter
- The values are applied 50% each to outward and return journeys in the demand model

3.3.16 Overall, the TTAA is content that the approach to reflecting parking charges in the Forth Replacement Crossing Model is appropriate in the context of the FRC study. **Users should, however, note the limited application of parking charges in the model area and the various assumptions adopted. For application of the model outwith the FRC study it may be appropriate to consider revising the methodology for applying parking charges to reflect charges in differing areas of the model and/or differing assumptions with respect to the proportion of each trip purpose paying parking charges**.

3.3.17 In relation to these recommendations MVA has subsequently commented that:

> *MVA agrees with these recommendations. In addition, we would note that the FRCM model currently does not contain the functionality necessary to predict the impacts that significant changes to car parking capacity may have on destination or mode choice.*

Roads and Public Transport Assignment Models

3.3.18 The roads and PT assignment models provide trip and cost matrices in OD format for input to the demand model. The roads model matrices are in PCUs with factors of 1.0 for light vehicles (cars and LGVs), 1.9 for heavy goods vehicles and 2.2 for buses. The roads and PT assignment models are the subject of other chapters in this Report.

Trip Ends

3.3.19 The trip end outputs are by production and attraction, mode, household type, time period and journey purpose. The forecast trip ends are passed down from the TMfS07 National Model to ensure consistency. Further commentary on the forecasting process will be provided in a later chapter of this Report.

Demand Model Parameters

3.3.20 The demand model parameters are specified to control the sensitivity of the various choice processes and to ensure an acceptable fit to the base year data. The base year parameters include distribution model sensitivity parameters, mode choice scaling factors and mode specific constants and Park & Ride model parameters. The sensitivity parameters were derived using local data. The parameters have also been subject to realism testing in accordance with the WebTAG guidance and compared with standard values. Again, further commentary on the derivation and sensitivity testing of the parameters will be provided in later chapters of this Report.

3.4 Matrix Development

Overview

3.4.1 The data sources used in developing and calibrating the demand model included:

- 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)
- Park & Ride Site Survey data

3.4.2 These were the principal data sources used in developing the TMfS07 National Model matrices and where appropriate they were growthed to reflect a consistent 2007 base. The documentation for the roads and PT assignment matrix development process for the TMfS07 National Model was provided separately to the TTAA. The TTAA has reviewed this information and is generally content that the appropriate data sources, the high level description of the data and its intended use is appropriate. Specific commentary relating to the roads and PT assignment model matrices is provided in the relevant chapters of this Report

3.4.3 The Forth Replacement Crossing Model demand matrices were cordoned out from TMfS07 for the relevant sub-area. The TTAA is satisfied that the cordon matrices from TMfS07 are appropriate donor matrices to adopt for the Forth Replacement Crossing Model. Users should note that the zoning system for the Forth Replacement Crossing Model is more refined than that of TMfS07 and in the case of the Forth Replacement Crossing roads assignment model matrices a subsequent matrix refinement was undertaken using matrix estimation. These differences between the Forth Replacement Crossing and TMfS07 matrices should be borne in mind when interpreting outputs between the two models.

3.5 Destination and Mode Choice Calibration

Overview

3.5.1 The Forth Replacement Crossing Model has been defined with a hierarchy in which destination choice is more sensitive than mode choice (i.e. destination choice is lower down the four-stage hierarchy than mode choice). The ALOGIT software was used both to calibrate the mode and destination choice parameters and to test different model structures. MVA states in the *Demand Model Development Report* that the adopted hierarchy has been implied by the relevant numerical interrogation of the base data and the TTAA requested additional information to support this statement.

3.5.2 Information was provided relating to the initial mode choice parameter estimation for AM peak home based work trips using the adopted model structure and an alternative model structure (with mode and destination choice models the other way round). This demonstrated that with the adopted model structure produced a parameter estimate within the correct range while the alternative did not, thereby supporting MVA's statement. The adopted model structure also conforms with the default structure recommended in WebTAG. The TTAA is satisfied that the adopted demand model structure is appropriate for the Forth Replacement Crossing Model.

3.5.3 **The TTAA would, however, recommend that for all future demand model development documentation, a detailed summary of the process followed and analysis undertaken in determining the demand model structure should be provided**.

Data

3.5.4 The demand model operates solely on the internal zones, for which data exists on the volume, distance and generalised cost of car, PT and Park & Ride trips. This information is used as the input to the ALOGIT software used in calibrating the demand model.

Data Inspection

3.5.5 It is stated in Section 4.3 of MVA's Report that:

> *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.*
>
> *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.*
>
> *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.*

3.5.6 The TTAA was independently provided with a summary of this data which relates to the full TMfS study area (*TMfS Model Development Report*, Section 8.2, August 2008) from which these conclusions were drawn. Having reviewed the summary the TTAA concurs with the statements and the conclusion that the data shows plausible patterns and appears to be a sound basis for developing the demand model. It should be noted that the data analysis was based on the full TMfS07 dataset rather than a Forth Replacement Crossing specific subset although this is unlikely to unduly influence the conclusions drawn.

Modelling Estimation

3.5.7 In the model estimation process the utility of each alternative is specified as a function of the generalised cost of travel, a dummy variable to account for intrazonal trips and a full set of alternative specific constants (ASCs). To expedite the process of estimating ASCs a process of 'contraction mapping' was used which uses an iterative approach to gradually refine the ASC estimates until convergence is reached. This is undertaken for each time period, purpose and household segment. The TTAA is satisfied with the adopted approach.

Model Results

3.5.8 The calculated mode choice parameters are demonstrated in Table 4.1 of MVA's Report. These are all between 0 and 1 and are of the expected nature and order of magnitude and are generally in-line with the illustrative parameter values outlined in WebTAG Unit 3.10.3.

3.5.9 The destination choice parameters are outlined in Table 4.2 and 4.3 for the log of the generalised cost and for the generalised cost term respectively. These parameters are all of the correct sign and an initial inspection of the values in Table 4.3 shows that they are generally of a similar scale to the corresponding parameters published for previous TMfS demand model developments. The intra-zonal K factors are outlined in Table 4.4 of MVA's *Demand Model Development Report* .

3.5.10 While it is difficult to comment in detail on the absolute values of the estimated mode and destination choice model parameters the intuitively correct nature and magnitude of the estimated values, and a general similarity with previous TMfS models, provides some reassurance that they have been appropriately derived.

Mode Specific Constants

3.5.11 Mode specific constants have been calculated on a zonal basis to ensure that the synthesised mode split corresponds with that reflected in the base year trip ends. This uses a similar process and formula to that adopted previously in TMfS demand model developments and the TTAA is content with this approach.

3.6 Park & Ride Station Choice Calibration

Overview

3.6.1 The Forth Replacement Crossing Model includes Park & Ride choice in the main mode choice model, unlike previous versions of TMfS which included this as an add-on step prior to the final assignment. The Park & Ride module is applied to 'from home' trips in the AM peak only with all corresponding return trips assumed to take place in the PM peak. Again, this differs slightly from previous versions of TMfS which enabled an element of Inter Peak Park & Ride activity. Given the relatively small Park & Ride demand during the Inter Peak period this is unlikely to be a significant issue for the Forth Replacement Crossing Model.

3.6.2 The Park & Ride module is specific to demand segments/household types which have a car available.

Methodology

3.6.3 The Park & Ride station choice was calibrated using the generalised cost of Park & Ride along with site specific inputs to define the catchment area, cost and parking capacity for each site. Possible destinations for bus based Park & Ride sites are restricted to the locations which the buses serve. For bus and rail Park & Ride sites, all zones in the model are possible origins, while for rail sites all destination zones are also possible.

3.6.4 The overall process for reflecting the Park & Ride costs, parking capacities and transfer penalties is very similar to that adopted for previous versions of TMfS. The main difference is its integration in the mode choice module, rather than acting as an ancillary adjustment process prior to the final assignment. The module operates separately by trip purpose and outputs 'from home' and 'to home' matrices by purpose and mode which are added into the roads and PT assignment matrices.

3.6.5 Overall the TTAA is content with the specified methodology for reflecting Park & Ride in the Forth Replacement Crossing Model.

Site Choice Calibration

3.6.6 The comparison of modelled and observed Park & Ride trips by Local Authority area is provided in Table 5.1 of MVA's Report, while a more detailed breakdown is provided in

Appendix H. The modelled total was calculated for the period person trips using a vehicle occupancy factor of 1.2. Clarification on the source of the occupancy factor was requested from MVA who confirmed that:

> *The average occupancy factor of 1.2 for Park and Ride is a 'guesstimate' based on previous Park and Ride data collection and modelling. It should be noted that this parameter is used only in the calculation of Park and Ride car park utilisation – the adjustments made to public transport demand use person trips, while the Saturn traffic model converts the person trips to vehicles using appropriate vehicle occupancies for each journey purpose.*

3.6.7 The local authority based calibration demonstrates a good overall match between modelled and observed values, with GEH values generally very low and all values less than 5. The site by site breakdown in Appendix H also demonstrates a good match with virtually all GEH values less than 5 (42 out of 44). The two sites with poorer GEH values are Falkirk Grahamston, which slightly overestimates demand and has a GEH of 5.77, and Wester Hailes, which significantly overestimates demand and has a GEH of 10.73. The breakdown on a site by site basis by journey purpose is slightly more variable but still relatively good.

3.6.8 The TTAA is generally content that the level of calibration achieved for Park & Ride sites in the Forth Replacement Crossing Model is acceptable.

3.6.9 MVA notes in §5.2.2 and 5.3.3 that only trips internal to the study area are included in the Park & Ride model. External trips not affected by other choice models are not included in the Park & Ride model, but will have chosen Park & Ride in the TMfS07 National Model instead. Further analysis of the outputs from the TMfS07 National Model Park & Ride module can identify the overall number of trips using Park & Ride sites in the Forth Model area.

3.6.10 The data for rail based Park & Ride sites comes from the recent National Rail Travel Survey, from which internal to internal movements could be readily identified. Bus based Park & Ride data comes from separate surveys to which 'site specific factors' were applied to obtain the internal observations. These site specific factors were defined by calculating the proportion of trips that start or end their journey outside the modelled area from the observed trip matrices. The observed car park occupancy was then factored to only reflect internal movements in the validation process. The four sites at which this was undertaken were Ferrytoll, Ingliston, Hermiston and Springkerse, all of which had calculated internal proportions of between 82% and 95%. The TTAA considers that this is an acceptable simplification to adopt in the Park & Ride validation.

3.7 Reverse and Non-Home-Based Trips

Overview

3.7.1 The demand model operates for the 'from home' journey purposes during the AM and Inter Peak periods only. The calculation of the PM 'from home' and the 'to home' and 'non home based' trips requires a series of factoring processes which are consistent with the TMfS07 National Model

Evening Peak Trips

3.7.2 The evening peak 'from home' trips are derived by a factoring process applied to the 'from home' trips from the Inter Peak period. The factors are derived separately by mode and trip purpose and applied to the corresponding Inter Peak trips.

3.7.3 This process is the same as that adopted in all versions of TMfS and the TTAA considers this appropriate.

To Home Trips

3.7.4 The 'to home' trips for all time periods are derived by applying a series of factors to the 'from home' trips. Separate factors by time period, mode and trip purpose were derived using data from the Scottish Household Survey. This is again the same process as included in previous versions of TMfS, however, it has been expanded to accommodate the greater household car availability segmentation in the TMfS07 National Model and the Forth Replacement Crossing Model. The TTAA is content that the described process is appropriate.

Non Home Based Trips

3.7.5 Separate factors are derived for 'non-home based' trips by time period, trip purpose and mode for both in-work and non-work trips. These factors are then applied to the destinations of the 'from home' trips and the origins of the 'to home' trips to establish the 'non-home based' origins and destinations. The totals are constrained to the average of the total origins and destinations as origins and destinations are unlikely to match in this process.

3.7.6 Matrices of 'non home-based' trips by mode and time period are created by applying a distribution model to the trip ends using appropriate inter-zonal costs. The calibrated parameters for these distribution models are described in the next section of this Report. The total trips by mode are calculated by adding the origin-destination matrices together for Public Transport and weighting by vehicle occupancy for car trips.

3.7.7 Again, this process is the same as that adopted in all versions of TMfS and the TTAA considers this appropriate.

Non Home Based Destination Choice

3.7.8 The sensitivity parameters for the 'non-home based' destination choice were calibrated using the ALOGIT software. The destination choice parameters are outlined in Table 6.1 and 6.2 for the log of the generalised cost and for the generalised cost term. These parameters are all of the correct sign, however, there is little to comment other than to note that the values are generally very small, reflecting a relative insensitivity to destination choice for 'non-home based trips', particularly in the inter and PM peaks. The intra-zonal K factors are outlined in Table 6.3 of MVA's Report.

3.7.9 Overall the TTAA is content with the adopted approach for reflecting the 'non-home based' destination choice is appropriate for the Forth Replacement Crossing Model.

3.8 Other Choice Models

Overview

3.8.1 In addition to the mode and destination choice models the Forth Replacement Crossing demand model also contains models for macro time of day choice, trip frequency, high occupancy vehicle modelling and peak spreading. MVA states in §7.1.1 of the *Demand Model Report* that:

> *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*

3.8.2 The inclusion of trip frequency effects in the hierarchy is in accordance with Variable Demand Modelling Advice (VaDMA) guidance (TAG Unit 3.10.3), where slow modes (walking, cycling etc.) are not reflected in the main mode choice and the TTAA considers this an acceptable approach to adopt for the Forth Replacement Crossing Model.

3.8.3 **Hands-on users should take care to ensure that the appropriate optional choice mechanisms have been invoked for each application of the model**.

Trip Frequency Model

3.8.4 The trip frequency module is a simple logit model of the same form typically adopted in previous versions of TMfS. The adopted parameters have also been inherited from previous versions of TMfS and assume a given level of sensitivity to travel cost by trip purpose and are:

- Home-based employers business – 1
- Home-based other – 0.5
- Home-based work – 0

3.8.5 There is no specific guidance in WebTAG regarding appropriate sensitivity parameters for trip frequency so it is difficult to comment in detail on the appropriateness or otherwise of these parameters. It can be said that it is reasonable to assume that the frequency of 'home based work' (i.e. commuter) trips would be less likely to be sensitive to changes in cost than 'home based other' and 'home based employers business' trips and in that regard the parameters adopted follow a logical sequence.

Macro Time of Day Choice Model

3.8.6 A Macro Time of Day Choice (MTODC) mechanism has been included in the Forth Replacement Crossing demand model. This particular choice mechanism is less established in variable demand modelling terms and has been included as an optional module that is not invoked by default. The TTAA concurs with this approach.

3.8.7 The MTODC module has been included before the main mode choice in the model hierarchy, which corresponds with the relevant guidance on the subject (WebTAG Unit 3.10.3, §1.11.17). The model is the same as that adopted in previous versions of TMfS and is applied by journey purpose at the person trip level on the principle that some of the 'from home' trips in the AM peak will move to the pre-AM peak or Inter Peak period. The outputs from the process are 'from home' matrices for the pre-AM peak that also have associated 'to home' and 'non-home based' trips in the other time periods which are derived from the AM peak factors for this.

3.8.8 Overall, the TTAA is satisfied that the defined methodology for dealing with MTODC appears to be logical and conforms with the available guidance on the subject. However, the TTAA notes that during a previous audit of the MTODC module for TMfS05 (Final Audit Note *FAN-6a-2005*, TTAA Ref. 69913, 17 July 2008), MVA had identified some issues with respect to the results output from the module. MVA has subsequently commented further that:

> *Further investigation is ongoing, under the TMfS:07 Model audit and sensitivity test program. The initial results of this appear to suggest that the current implementation produces more intuitive results than previous versions. An information note with results of these findings will be provided to the TTAA in the near future.*

Peak Spreading Model

3.8.9 The Peak Spreading Model adopted for the Forth Replacement Crossing Model is the same as that incorporated in previous versions of TMfS, which is an incremental logit model operating in the AM peak only at the individual matrix cell level. The (unmodelled) shoulder peak costs are estimated for input to the peak spreading model as the additional run time to create these through assignment was considered prohibitive. It is assumed in the peak spreading model that the overall level of demand within the peak period remains unchanged with the model simply altering the ratio of peak to shoulder trips.

3.8.10 The peak spreading model operates on the basis that for each outer loop of the demand model an approximation of the peak spreading supply/demand is established. This is undertaken by simplifying the supply and demand functions to linear approximations. The shoulder peak costs are estimated by reducing converged assignment flows by a percentage representing the average ratio of shoulder to peak flows. The link journey times are then reduced in-line with the reduced flows and costs skimmed from the network. It should be noted that a uniform, rather than cell/area specific reduction factor is applied to the flows. Nevertheless, this provides an acceptable means of estimating supply functions on a cell by cell basis.

3.8.11 An adjustment factor to the average change in costs (between peak and shoulder of peak) can be applied to improve the estimate on a cell by cell basis. A weighting can be applied taking account of the ratio of shoulder to peak flow for the specific cell being considered relative to the average ratio of shoulder to peak flow.

3.8.12 The TTAA is content that the specification of the peak spreading model is acceptable for TMfS.

High Occupancy Vehicle Choice

3.8.13 An optional mechanism, which is not invoked as a default, has been included in the Forth Replacement Crossing demand model to enable trips to move between single and multiple occupancy vehicles. The module operates after the destination choice and before the assignment stage and enables car available 'home based' trips to choose between single and multiple occupancy cars. The mechanism involves a logit model that uses differing generalised costs for single and multiple occupancy vehicles. The outputs from the module are 'from home' matrices by purpose and car availability segment separately for single and multiple occupant cars, which are then subject to the standard factoring processes to create the 'to home', 'non home based' and PM peak trips.

3.8.14 The assignment process then takes place as standard but with the greater disaggregation to reflect the single and multiple occupancy vehicle types. High occupancy vehicle lanes need to be reflected in the assignment model as separate link types to enable the single and multiple occupancy costs to be skimmed separately for feedback to the demand model.

3.8.15 The adopted process is again similar to that included in TMfS05, with some updates to include sensitivity parameters for the logit model based on recent Stated Preference survey work. The TTAA is content that the adopted methodology for including high occupancy vehicle choice is acceptable for the Forth Replacement Crossing Model. It must be borne in mind, however, that such modelling practices remain in their infancy and little reliable guidance and practical experience exists in this regard. **The TTAA would recommend that the HOV module be used only in appropriate circumstances where a specific high occupancy vehicle policy measure requires testing. Furthermore, any application should be subject to appropriate sensitivity testing to verify the robustness and realism of the outputs and potential users should take account of the findings in previous audit notes on the matter (*AN-FRC-1, TTAA* Ref. 70440, 24 October 2008 and Final Audit Note *FAN-7*, Ref. 67846, 23 May 2007)**.

3.9 Model Realism Tests

Overview

3.9.1 Realism testing was undertaken for the Forth Replacement Crossing demand model to ensure that the responses were in-line with expectations and to compare the modelled elasticities with standard published values. This followed the VaDMA guidance outlined in WebTAG Unit 3.10.4.

Introduction

3.9.2 In accordance with the VaDMA guidance, realism tests were undertaken to establish the modelled elasticity of demand with respect to car journey time, car fuel price and public transport fares. The realism tests undertaken were:

- 20% increase in generalised cost (as a proxy for journey times)
- 20% increase in fuel costs
- 20% increase in PT fares

3.9.3 These tests are consistent with those typically undertaken during the development of the TMfS demand model and are considered appropriate by the TTAA.

3.9.4 Additional, more detailed sensitivity tests (e.g. to examine the impact of model parameters on the outcome from a scheme assessment) have not been undertaken at the model development stage, however, MVA has commented that:

> *However, early use of the model may provide evidence regarding the sensitivity of the model to a range of input assumptions.*

3.9.5 **The TTAA would recommend that, ideally, users of the model for scheme appraisals should undertake appropriate sensitivity tests to establish the robustness of the forecasts and resulting conclusions of such appraisals against the uncertainty of the input parameters (WebTAG Unit 3.10.4)**.

Results

3.9.6 The modelled elasticities with respect to fuel cost are shown to lie in the range between -0.224 to -0.333 for 'non work' purposes, which is within the VaDMA recommended range (-0.1 to -0.4). The VaDMA guidance recommends that 'employers business' trips would be expected to have an elasticity value of nearer -0.1 and the corresponding elasticity for 'car in work' trips in the Forth Replacement Crossing Model is shown to range between -0.077 and -0.097. The modelled elasticity is slightly lower than the VaDMA recommended value.

3.9.7 With respect to the elasticity to changes in travel time the VaDMA guidance suggests that the values should typically be much greater than for fuel cost and no more than -0.2 without giving definitive guidance on exact values. The modelled values obtained from the realism test all lie within the range between -0.581 and -0.937 and do not exceed the recommended maximum value; while typically being 2 or more times greater than the corresponding fuel price elasticity values.

3.9.8 The VaDMA guidance for PT fare elasticities suggests that values should generally lie in the range -0.2 to -0.4, but in some cases can be as high as -0.9. The majority of modelled values fall within this range with the exception of some 'in work' (i.e. employers business) elasticities which are shown to be slightly lower than the recommended range.

Summary

3.9.9 MVA summarises in §8.4.1 of the Report that:

> *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*

3.9.10 The TTAA concurs with this and is content that the majority of elasticities have been demonstrated to fall within the recommended ranges. The exceptions to this being the 'employers business' elasticities to fuel price and in most cases the 'employers business' elasticities to PT fares which are slightly lower than the recommended range.

3.10 Trip End Model

Overview

3.10.1 A very brief overview of the trip end model for the Forth Replacement Crossing Model is provided in the Report. A summary of the overview is that:

- The trip end model for the Forth Replacement Crossing uses data from the TMfS07 National Model.
- It operates in an incremental manner calculating the ratio of forecast year to base year synthesised trip ends and applying these to the 'observed' trip ends as the start point for the forecasting process.
- Factors by zone, time period, household car availability segment, purpose and mode are then passed down to the Forth Replacement Crossing Model.
- All Forth Replacement Crossing Model zones within a single TMfS07 zone receive the same growth factor by default. This can be amended if suitable local data/knowledge exists.

3.10.2 A separate Information Note entitled *Interface with National Model* was provided independently to the TTAA. This provides details of the methodology for using the National Model to predict the future year internal trip ends as well as goods vehicle and external trips for the Forth Replacement Crossing Model. The TTAA is generally content that the described trip end forecasting process in the *Demand Model Development Report* and the supporting Information Note appears logical and appropriate for the Forth Replacement Crossing Model.

Trip Attractions and Attraction Factors

3.10.3 A parallel trip attraction process in the TMfS07 Nation Model trip end model calculates trip attractions which are subsequently passed down to the Forth Replacement Crossing Model. These trip attractions are separate for each journey purpose and time period, but are combined by household car availability segment and mode.

3.10.4 The base year trip attractions for 'home based work' represent actual trip ends as they are used as a constraint in the destination choice process. Attraction factors are derived for 'home based employers business' and 'home based other' purposes by successively adjusting the attraction factors and applying the singly constrained model until the trip attractions match those for the base matrices used in the destination choice model calibration.

3.10.5 Again, the TTAA is generally content that the described process is similar to previous versions of TMfS and appears logical and appropriate for the Forth Replacement Crossing Model

3.11 Forecasting Procedures

Introduction

3.11.1 The introduction provides a brief description of the purpose of the Base year demand model and the general application in forecast mode. The TTAA has no comments on this section of the Report.

Overall Operation of the Demand Model

3.11.2 The overall operation of the demand model in forecast mode is essentially the same as previous versions of TMfS. Trip ends are created for the relevant forecast year and economic growth scenario while the various sub-models operate in an iterative manner to create the relevant highway and PT assignment matrices.

3.11.3 There is an iterative inner loop to ensure convergence between the mode and destination choice processes. By default, four inner loops are run before the outer iterative loop between the assignment and demand models is run. The PT costs are fixed after a single external loop of the demand model and by default five external loops are run.

3.11.4 The TTAA is content that the procedures adopted are appropriate for the Forth Replacement Crossing Model. **Users should, however, note the default number of iterations for the inner and outer loops and the fixing of PT costs after a single external demand model loop. While the defaults will be acceptable for general application, changes to these may be required in specific circumstances and this can be readily achieved if necessary**.

The Incremental Forecasting Approach

3.11.5 The Forth Replacement Crossing demand model operates in an incremental manner and therefore produces estimates of the forecast year and base year synthesised trip matrices. Depending on scale of and the difference between the 'observed' and synthesised Base year matrix cell values, the growth is applied to the base year 'observed' matrices either as a factor or as an incremental difference (between the synthesised base and future year trips). This attempts to prevent spurious over or underestimates of growth occurring in the future year assignment matrices.

3.11.6 The TTAA considers this approach to be appropriate for the Forth Replacement Crossing Model.

Model Parameters

3.11.7 The following model parameters are recalculated for forecast model runs:

- Generalised cost coefficients for assignment (WebTAG Unit 3.5.6)
- Occupancy factors to convert from person to vehicle matrices (using WebTAG factors)
- Values of time and vehicle operating costs (WebTAG Unit 3.5.6)

3.11.8 Unlike previous versions of TMfS, the mode specific constants do not need to be recalculated, as the household car availability segregation has been improved in the Forth Replacement Crossing Model.

3.11.9 Overall the TTAA is content with the suggested parameter changes through time for the Forth Replacement Crossing Model.

Highway and Public Transport Cost Matrices

3.11.10 The generalised cost matrices from the base year are used by standard as the start point for the demand model process for a Reference Case, although the user can opt to replace these with future cost matrices if necessary. Similarly, Base or Reference Case generalised cost matrices can be used as the start point for a Variance Case in the Forth Replacement Crossing Model.

3.11.11 The Base-year cost matrices by mode are also required for the calculation of Reference Case mode specific constants. The TTAA concurs with this approach.

Highway and Public Transport Networks

3.11.12 The user is required to code the relevant roads and PT networks for all Reference and Variance Cases using conventional coding methods. Specification of the appropriate reference and variance case networks for highway and PT is the responsibility of the TMfS user who should undertake appropriate checks to ensure consistency between the roads and PT networks.

Education Trips

3.11.13 It is stated in §10.7.1 of MVA's Report that:

> *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*

3.11.14 Additional details of the process for creating the education trips were also provided by MVA who stated:

> *The data in the Census Matrix Tools in Scotland provide estimates of trips from home to education. These demand matrices were converted into a daily matrix, from which period matrices were derived by applying relevant factors from TEMPRO. These matrices are excluded from the destination choice within a given year but are adjusted to reflect changes in the relevant land-use and trip-end data fed into the FRCM demand model (e.g. from the higher-tier TMfS/TELMoS model).*

3.11.15 The TTAA is content that the adopted approach for forecasting education trips is appropriate for the Forth Replacement Crossing Model.

Goods Vehicles

3.11.16 It is stated in §10.8.1 of MVA's Report that:

> *Goods vehicle matrices for the Forth Replacement Crossing 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*

3.11.17 The National model goods vehicle matrices are themselves forecast independently of the demand model process using a combination of the Base year matrices, incremental growth forecasts from TELMoS and NRTF growth for external movements. Again, the TTAA considers this approach to be appropriate for the Forth Replacement Crossing Model. **However, it should be noted that at the time of writing the audit of the TMfS07 National Demand Model and trip matrices remains ongoing and a more detailed examination of these aspects and their robustness will be undertaken in due course**.

External Trips

3.11.18 External trips joining the Forth Replacement Crossing Model network at the buffer zones are derived from sub-area analysis of the TMfS07 National Model. This involves a matrix cordoning process with appropriate factors applied to disaggregate trips to the more detailed Forth Replacement Crossing Model zoning system. The growth derived from the National Model is applied in an incremental to the Base year Forth Replacement Crossing Model trip ends. More detail on this process is provided in MVA's Information Note entitled *Interface with National Model*. The TTAA is satisfied that the approach to forecasting external trip growth is appropriate for the Forth Replacement Crossing Model.

3.12 Summary and Conclusions

Conclusions

3.12.1 MVA concludes in Section 12.1 that the Forth Replacement Crossing demand model has been implemented for the Base year and that realism tests demonstrate acceptable elasticities, particularly for the main travel purposes. It is further commented by MVA that:

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

3.12.2 Notwithstanding the comments made elsewhere in this Report, the TTAA generally concurs with MVA's conclusions and in particular the need to consider the outputs in forecast mode and to undertake sensitivity testing as appropriate when applying the model.

4 PUBLIC TRANSPORT ASSIGNMENT MODEL

4.1 Background

4.1.1 The Public Transport (PT) model was developed in CUBE/Voyager and forms the PT assignment component of the multi-modal Forth Replacement Crossing Model. The initial audit findings on the PT model were presented in Audit Note *AN-FRC-8* (Ref. 70848, 9 February 2009). A subsequent response to *AN-FRC-8* was received from MVA and has been taken into account in compiling the findings in this Audit Report.

4.1.2 The TTAA received the following information from MVA for use in the audit process:

- AM, IP and PM Peak period PT models (BASE_TEST_SF120_SC10)
- *Forth Replacement Crossing – Public Transport Model Development Report* (Issue 1, MVA Ref. C3713500, 14 November 2008)
- *Audit Response Note to AN-FRC-8: Public Transport Model* (MVA Ref. C37135 11, 17 February 2009)

4.1.3 This chapter relates to the audit of the Base PT network and the supporting model development, calibration and validation documentation. The section headings correspond with the chapter headings from MVA's *Public Transport Model Development Report*.

4.2 Introduction

4.2.1 The introductory chapter initially sets out the background and of the PT model development. The TTAA has no comments on this aspect of the Report.

4.3 Model Dimensions

Model Time Periods

4.3.1 The Forth Replacement Crossing PT model was developed to represent a 2007 Base year with the following time periods:

- AM Peak hour 08:00 - 09:00
- Inter Peak average hour between 10:00 - 16:00
- PM Peak hour 17:00 - 18:00

4.3.2 The AM and PM Peak hour factors have been derived from analysis of the three hour peak period bus occupancy count data and National Rail Travel Survey used in the development of the TMfS07. The Inter Peak hour factor is taken as an average one sixth of the time between 10:00 - 16:00. MVA's analysis has revealed that the peak hour factors for bus and rail to be similar and combined into a single set, as follows, for application to both PT sub models.

- AM Peak hour 0.45
- Inter Peak hour 0.167
- PM Peak Hour 0.44

4.3.3 The TTAA considers the methodology used to obtain the peak hour factors appropriate. The TTAA requested clarification from MVA regarding whether any analysis had been carried out to determine whether the occurrence of the actual peak hours within the Forth Replacement Crossing coincides with the peak hours chosen. MVA provided the following commentary on the matter:

Since the FRCM is likely to need to interface with the TMfS/TELMoS:07 national model, we felt it was desirable to make the manipulations of demand matrices as consistent as possible between the two models. If we had used the profile of public transport trips in the SESTRAN area (as recorded in the SHS Travel Dairy dataset provided to us on 1 October 2007), the corresponding AM and PM factors would have been 0.43 and 0.41 respectively (i.e. slightly lower than the TMfS:07-based values which were used (0.45 and 0.44)

4.3.4 The TTAA is satisfied that the adopted peak hour factors are acceptable and that the retention of consistency with the TMfS07 National Model is appropriate for the Forth Replacement Crossing Model.

User Classes

4.3.5 The user classes represented in the model are as follows:

- In work (IW)
- To/from work (TW)
- Non work (NW)

4.3.6 PT demand matrices were prepared to represent each of the above user classes and these are assigned individually in the PT model. The TTAA considers the user class disaggregation appropriate.

4.4 Public Transport Network

Network Development

4.4.1 The physical PT network is based on the Forth Replacement Crossing SATURN road network with the addition of the TMfS07 rail network. The TTAA carried out an overview check of the PT network and confirms that the extent of the PT (bus and rail) network is considered to be appropriately representative of the existing network in the main FRC study area.

4.4.2 In addition, the TTAA reviewed the coded bus links/lanes in the model and checked against the existing facilities in the area. The TTAA found that the coding of the Bus Links was generally acceptable, with the following exceptions where the following roads do not have bus links coded where they exist:

- South Gyle Broadway
- Bannockburn Road
- Leith Walk
- Lothian Road
- London Road
- The Bridges/South Bridge/South Clark Street
- Morningside/Bruntsfield Corridor
- A90 Queensferry Road

4.4.3 It is unlikely that any of the above would result in any significant impact in the context of the FRC study and the TTAA is content that their omission is negligible in that context. Nevertheless, users of the Forth Replacement Crossing Model should note these omissions when interpreting the model outputs. **The TTAA would recommend that these coding omissions be addressed at the next upgrade of the Forth Replacement Crossing Model**. In the context of the FRC study, it would be possible, with minimum impact, to incorporate these amendments into an updated Base or Do-Minimum model, if necessary. MVA subsequently commented that:

> *We concur with these recommendations and propose to adjust the model to take account of the minor omissions at the earliest opportunity.*

Public Transport Line Data

4.4.4 The PT lines files contain information on service and operational attributes of PT services. The general inputs such as system information and line descriptions coded for the PT network have been adapted from those used for TMfS07, with additional inclusion of local bus services where those were not represented in the TMfS07 national model. The intra-urban and inter-urban lines have been coded to stop at every relevant node on the strategic transport network.

4.4.5 For more detailed PT line files checking, the TTAA undertook a check of selective inter-urban bus services in the model in terms of headways and routeing. These include those services using the Kincardine Bridge or the Forth Road Bridge and other services. The checks showed that the checked services are correctly represented in the model.

4.4.6 The review of services crossing the Kincardine Bridge included:

- Stagecoach Fife Services 78, X26, X27, X24
- First Edinburgh 15

4.4.7 The review of services crossing the Forth Road Bridge included:

- Stagecoach Fife Services 53, 55, 747, X50, X53, X54, X58, X60, X61
- Citylink Services M90, M91, M92

4.4.8 The TTAA is content that bus services crossing the Forth Road Bridge have been correctly represented in the PT model. It should be noted that some minor issues were identified in the audit of the SATURN model relating to the representation of the bus pre-load flows. The reader is referred to Section 2.3 of this Audit Report for further detail.

4.4.9 Other bus services reviewed included:

- Citylink 900 (Edinburgh – Glasgow)
- Lothian 44 (Edinburgh – Musselburgh)

4.4.10 For rail services, the TTAA checked the timetable and route coding of the following rail services (in both directions); this includes those services using the Forth Rail Bridge and the major Edinburgh – Glasgow services:

- Berwick – Aberdeen
- Newcastle – Aberdeen
- Edinburgh – Aberdeen/Dyce
- Edinburgh – Inverness
- Edinburgh – Perth
- Edinburgh – Markinch
- Edinburgh – Cowdenbeath
- Fife Circle
- Edinburgh – Glasgow

4.4.11 The TTAA is satisfied from the sample checked that the coding of rail services is appropriate.

Modes and PT Operators

4.4.12 Six separate modes have been included in the Forth Replacement Crossing PT model, namely:

- Intra-urban bus
- Inter-urban bus
- Rail
- Underground
- Ferry
- Tram

4.4.13 The TTAA notes that the Forth Replacement Crossing modelled area currently contains no underground, ferry or tram services, but these modes have been included for consistency with TMfS07 and for ease of future year coding. Intra-urban buses have been defined as those that operate wholly within the Edinburgh conurbation and the coding of these has been simplified to a representative corridor basis. The TTAA is satisfied with this approach to coding.

4.4.14 Table 3.1 of the PT model development Report provides a summary of the number of PT services by mode. In total, there are 753 bus and rail services coded in the AM Peak, 647 in the Inter Peak and 696 in the PM Peak model. Table 3.2 of the Report provides a breakdown of the number of PT lines by services operator and time period. The operator number matches that assigned in the overarching TMfS07 PT model. The TTAA notes the Forth Replacement Crossing PT model includes all the rail services coded in the TMfS07 PT model even if they operate outwith the Forth Replacement Crossing modelled area, but demand is not be loaded onto those ‘dormant’ services in the model assignment.

4.4.15 The TTAA is generally satisfied with the level of detail in terms of PT services represented in the model and agrees that the PT modes and operators represented in model maintaining consistency with TMfS07 is appropriate.

4.5 Demand Matrix Development

Introduction

4.5.1 The Forth Replacement Crossing PT demand matrices have been developed based on the national TMfS07 matrices and the modelled times and user classes are consistent between the two models.

Zone System

4.5.2 The Forth Replacement Crossing Model has in total 299 zones that are made up by

- 168 internal simulation zones
- 91 internal buffer zones
- 40 external zones

4.5.3 The key part of the Forth Replacement Crossing internal zone system was to be consistent with the TMfS07 zones system. Within the simulation area of the Forth Replacement Crossing internal zones are were refined by disaggregating the TMfS07 zones. The level of disaggregation used was similarly to the TMfS05 model. In the buffer area, the Forth Replacement Crossing zones are identical to the TMfS07 zones. The TTAA is satisfied that the

Forth Replacement Crossing PT zone system maintains consistency with that of TMfS07, which makes future transfer of information between the models more convenient.

Matrix Development

4.5.4 The Model Development Report very broadly describes the steps in creating the Forth Replacement Crossing demand matrices by the three movement types described:

- Internal to Internal – extracted from the TMfS07 model using direct zone equivalence
- Internal to/from External – created based on select link assignment in TMfS07
- External to External – developed through inspection of the TMfS07 matrices at local authority level with movements through the Forth Replacement Crossing area allocated to external route zones

4.5.5 The TTAA notes that the following data sources were used in the TMfS07 PT matrix development.

- *National Rail Travel Survey data*
- *Inter-urban bus passenger survey data*
- *2001 Census journey to work data*
- *Synthesis of some non-commuter trips using planning data*

4.5.6 Slightly more detail on the individual data sources is provided in the *TMfS07 National Public Transport Model Development Report* (Issue 3, 30 January 2009) that was subsequently provided to the TTAA. It is clear that these data sources provide a more comprehensive representation of the PT travel demand patterns throughout Scotland than has previously been available in TMfS. As such, the TTAA is satisfied that the appropriate data sources were used in developing the TMfS07 PT matrices, from which the Forth Replacement Crossing PT matrices have been created. **However, it should be noted that at the time of writing the audit of the TMfS07 National PT Model remains ongoing and a more detailed examination of the TMfS07 trip matrices and their robustness will be undertaken in due course**. The final assignment matrices were prepared by combining the matrices from the three movement types. The matrix totals by user class by time period are presented in Table 4.1 of MVA's Report.

4.5.7 It is unclear from the Report whether any additional refinement or checking procedures were undertaken for the Forth Replacement Crossing PT matrices and the TTAA requested clarification of this from MVA, who responded as follows:

> *Analysis of the Forth demand matrices in parallel with the model calibration indicated that no refinement of the matrices extracted from the national PT model was necessary. We also felt it was desirable as much consistency as possible between the national and regional PT models.*

4.5.8 Given the data sources used and the hierarchical relationship between the National and Regional models the TTAA considers that this approach and the retention of consistency between the TMfS07 and Forth Replacement Crossing Model PT matrices is appropriate.

4.6 Assignment Model

Introduction

4.6.1 The Forth Replacement Crossing Model PT assignment procedure is consistent with that adopted for TMfS07 and includes the modelling of crowding and fares. The TTAA is satisfied with the adopted approach.

Assignment Model Inputs

4.6.2 The model inputs encompass the PT network, PT lines file and hourly assignment matrices as discussed in previous sections of this note. The TTAA is satisfied that these are the appropriate inputs.

Path Building and Loading

4.6.3 The path building and loading procedure includes the modelling of:

- Walk choice
- Service Frequency and Fare Cost
- Alternative Alighting
- Multi-routeing

4.6.4 The TTAA is satisfied that the above variables are considered by the PT loading procedure, but notes from §6.3.5 of the Report that Voyager does not consider Fare Cost in the sub mode split (route enumeration) procedure and this has resulted in some longer journey time, but cheaper fare bus routes being excluded in the trips loading (route evaluation) procedure. The TTAA considers the lack of fare cost consideration in the path building procedure a downgrade compared with the previous TMfS05 PT model capability, but acknowledges this is a current constraint of the Voyager software. The TTAA is also content that this issue has been raised by MVA and has been brought to the attention of software developer. Users of the Forth Replacement Crossing Model should take note of this issue, particularly, if assessing model outputs in relation to any application which is likely to be sensitive with respect to PT sub-mode split.

Crowding

4.6.5 The Forth Replacement Crossing PT model includes the modelling of the effect of crowding in the AM and PM peaks for rail services only. No crowding factors were applied to bus lines due to the ability of bus operators to increase supply to match demand. The model framework allows users to include crowding effects to be modelled on future tram services. The TTAA is generally satisfied that the effects of crowding have been modelled in the PT assignment procedure for the AM and PM peaks, but not the Inter Peak. Implementation of crowding curves, applied to the in-vehicle time component of generalised cost, is considered likely to improve the quality of the modelled forecasts for public transport passenger flows, particularly in corridors of significant competition and for road traffic.

4.6.6 The UK rail standard *Passenger Demand Forecasting Handbook* (PDFH) Non-London Commuting Rail Crowding curve was allocated to rail only for the AM and PM peak periods. The 'crush capacity' was assumed to be 40% above the seated capacity. Passenger and vehicle arrival profiles have been assumed to be level throughout the modelled time periods leaving no allowance for varying demand on services within the peak hours, leading to the potential underestimation of crowding on services where the number of passengers is above the hourly average.

4.6.7 The TTAA notes that above approach for the inclusion of crowding in the TMfS07 is applied without refinement to the Forth Replacement Crossing PT model. Users should note the fact that crowding has been applied on peak hour rail services only. In the PT assignment procedure, where the PT sub-mode split is undertaken at the assignment stage, on corridors with high PT modal competition this could have implications for both the base year sub-mode split and more particularly, when applying the model in forecast mode. While this is unlikely to be an issue in a strategic national model where crowding on buses is unlikely to be an issue, the modelling of bus services in the regional model is more refined and competition between rail and bus and between bus and bus more apparent. **In such circumstances, users should examine the outputs in sufficient detail to ensure that the resultant loading on services conforms with expectations**.

Assignment Model Parameters

4.6.8 Table 4.1 shows the Public Transport Assignment Model Parameters for the Forth Replacement Crossing PT model. The parameters are common to the peak and Inter Peak assignments.

Table 4.1 : Base Year PT Assignment Model Generalised Cost Coefficients

Model Parameter		Value/factor
Parameter		1.0
In vehicle time - bus		1.0
In vehicle time - rail		1.6
Walk time factor		0 mins
Minimum wait time		60 mins
Maximum wait time		5 mins
Boarding penalty		
Transfer penalty		
	- rail to rail	5 mins
	- bus to bus	10 mins
	- bus to rail/underground and vice versa	10 mins
Values of time		
	- in work	£21.05 £/hr
	- non work	£5.11 £/hr

4.6.9 These parameters were defined during the PT model calibration process and through examination of the sub-mode split between bus and rail. The values are generally of the expected order of magnitude and are considered appropriate by the TTAA.

Wait Curves

4.6.10 A single wait curve has been implemented for all PT lines in the Forth Replacement Crossing PT model which does not vary between peak and Inter Peak. The curve is based on perceived values in the PDFH and represents the perceived wait time for a given headway/service frequency. The curve adopts similar values to that used in previous versions of TMfS and is considered appropriate by the TTAA. **Consideration should be given to differentiating the wait curves by peak and Inter Peak in a future upgrade of the model**.

Fares Model

4.6.11 Table 5.4 and Table 5.5 shows the Forth Replacement Crossing modelled fare tables for rail and bus operators respectively. The fares model is consistent with TMfS07.

4.6.12 The fare tables consist of an initial boarding fare and a set of distances and fares that define points on a curve. Modelled fares (in 2007 prices) are calculated based on linear interpolation according to the distance travelled.

4.6.13 The fares tables were derived based on scatter plot analysis of the distance based fares for various bus and rail operators. A line of best fit was then drawn through the scatter plots to define the linear, distance based fare tables for each operator. The TTAA has reviewed the scatter plot analysis and is satisfied that the fare tables adequately represent the actual fares for both rail and bus services.

4.7 Model Validation

Introduction

4.7.1 The validation of the Forth Replacement Crossing PT model and matrices was undertaken through detailed analysis of the following:

- Observed bus and rail passenger count data
- Comparison of timetabled and modelled bus journey times

4.7.2 Comparisons between modelled and observed screenline flows were typically expected to be within 15% as indicated in Appendix E of the Major Scheme Appraisal in Local Transport Plans document. The GEH analysis was also used to assess the flow comparisons. A GEH of 5 and less is considered to be excellent and GEH between 5 and 10 is considered to be acceptable. The TTAA is satisfied with the adopted approach and criteria for the PT model validation.

Observed Data Sources

4.7.3 The PT model validation comparisons have been made against ScotRail count data and TMfS07 bus occupancy surveys.

Passenger Loading Comparison

4.7.4 Comparisons of observed passenger flows against modelled assignments for bus and rail movements have been made for an Edinburgh cordon and a screenline that is described as the Lower Forth Crossing. The cordon includes the following crossing points.

Rail

- South Gyle to Dalmeny
- West of Edinburgh Park
- Wester Hailes to Curriehill
- Brunstane to Newcraighall
- West of Musselburgh

Bus

- A90 (at South Queensferry)
- A8 (West of Edinburgh Airport)
- M8 (at Hermiston Gait Roundabout)
- A71 (at Hermiston House Road)
- A702 (South of City Bypass)
- A701 (South of B702 Junction)
- Lasswade Road (South of City Bypass)
- Gilmerton Road (South of City Bypass)

- A7/A68 (South of Danderhall)
- A1 (South of The Jewel)
- Newcraighall Road (by Clayknowes Crescent)
- A199 (West of B6415 Junction)

4.7.5 The screenline consists of the following crossing points:

- Forth Rail Bridge
- A90 (at South Queensferry)

4.7.6 Tables 6.1 and 6.2 of the Report show the analysis of the Edinburgh cordon flows indicated good validation for all: except the PM inbound direction for bus which has a percentage difference of 20 and a marginally high GEH of 11, and in the IP outbound direction for bus with a percentage difference of 18, but an acceptable GEH of 8. It should noted that analysis of the cordon on an individual site basis (as presented in Appendix B of the Report) indicates that certain individual locations exhibit much higher GEH values than the Cordon as a whole. For example, in the AM inbound direction for bus, the A8 (West of Edinburgh Airport) has a GEH of 11, the A702 (South of City Bypass) and the A701 (South of B702 Junction) both have a GEH of 15.

4.7.7 The TTAA is content that the overall modelled mode split proportions between rail and bus and the peak passenger flow directions appear intuitive in terms of the scale of the assigned volumes. For modelled to observed comparisons of total PT passenger flow for the Edinburgh cordon, MVA's analysis indicated an overall good validation. Further examination of the PT passenger validation by key links is given in Appendix B of the Report. This demonstrates greater variability in the quality of comparisons on individual links with some high GEH values, in particular, in the AM peak period. MVA's Report concludes that:

> *Potential users of the model should, however, bear in mind the variability in the modelled to observed comparisons for individual links, as indicated in Appendix B, when considering potential model application.*

4.7.8 The TTAA concurs with this recommendation.

4.7.9 Tables 6.3 and 6.4 of the Report show the analysis of Lower Forth Crossing flows. The TTAA notes that in the northbound direction, almost all the comparisons have significantly high percentage difference values, but the GEH within an acceptable value of 10. Only one movement, northbound PM for bus, exceeds the GEH value of 10.

4.7.10 More detailed examination of the flow comparisons show some high GEH values with a tendency towards a high percentage difference between modelled against observed values, particularly in the northbound direction. The overall PT (bus plus rail) comparisons are generally slightly better than the individual sub-mode comparisons (i.e. bus and rail separately) with rail generally tending to be higher than observed. Furthermore, it is noted that the modelled flows across the Lower Forth screenline are overall slightly high across the Forth, particularly in the northbound direction. The TTAA considers the Lower Forth Crossing validation to be good southbound and on the limit of acceptability northbound. **In the context of the FRC study, this suggests that close scrutiny should be paid to the responses in terms of PT flows and main mode split in interpreting the model outputs**.

4.7.11 MVA states that modelled rail flows across the modelled network are slightly high relative to competing bus routes and the reason for this was that some bus routes are not being included in the route evaluation in the model because fares were not taken into account in the route enumeration. MVA also mentions that if spread values were increased to include more routes for evaluation, the modelled run times would become prohibitively high. Citilabs, the developer of Voyager, is currently looking at the issue.

4.7.12 The TTAA acknowledges the comment made by MVA regarding the software problem and that steps are being taken to address the issue. **Users of the model should note this issue when interpreting model outputs**.

Passenger Boarding/Alighting Comparisons

4.7.13 The volume of passengers boarding and alighting from ScotRail data at each station has been compared against modelled values and is shown in Appendix C of the MVA Report. The analysis of GEH has been summarised in Table 6.5 of MVA's Report.

4.7.14 At a global level, this demonstrates a good match between modelled and observed boarding/alighting figures. It should be noted that, in the station by station analysis of the comparisons between observed and modelled data, there were some GEH values exceeding 10. The highest GEH values are noted to occur at Haymarket station and, to a lesser extent, at Kirkcaldy throughout the AM, Inter Peak and PM periods.

4.7.15 The TTAA is satisfied that the modelling of individual station boarding and alighting is acceptable at a global level across the model. **Potential users of the Forth Replacement Crossing PT model for more local studies involving assessment of rail passenger volumes should take note of the variability of Haymarket station and Kirkcaldy station boarding and alighting flows**.

Rail Capacities

4.7.16 The PT assignment includes crowding on rail lines in the AM and PM peaks. Information is provided in Appendix D of MVA's Report showing the ratio of passenger loading to seated capacity on the modelled lines.

4.7.17 Analysis of Appendix D shows that there are some services with very high ratios, e.g. Dunblane to Edinburgh (164%), Dundee to Edinburgh (159%) and Inverness to Glasgow (155%), etc. The TTAA notes that the loading ratios are generally higher than those previously modelled in TMf05, e.g. the Dundee to Edinburgh AM peak service in TMfS05 was 118%. The TTAA acknowledges that in the absence of any observations it is difficult to draw any firm conclusions regarding the accuracy of the information presented. The TTAA is content that the effect of crowding is modelled and is shown to occur on services that are expected to be crowded.

Comparison of Timetabled and Modelled Bus Journey Times

4.7.18 As part of the validation process, checks have been made to ensure that modelled bus journey times are representative of timetabled bus journey times.

4.7.19 Modelled to timetabled bus journey time comparisons, as shown in Appendix E of the Report, were undertaken on a sample of services that intends to give a representative geographical spread in the model area. A summary of the journey time validation is presented in Table 6.6 of the Report which showed that over 55% of services have journey times within 15% of PT timetables throughout the AM, IP and PM periods, and over 65% of services have journey time within 25% of PT timetable throughout the modelled periods.

4.7.20 From the analysis undertaken in Appendix E, the TTAA note that the majority of the bus routes crossing the Forth Road Bridge have journey times within 15% of PT timetables in all the peak periods. For the vast majority of the remaining cases the modelled journey times are quicker than the timetabled average journey time. This is often the case with models of this nature, as the timetabled information does not provide a true reflection of actual travelled times.

Furthermore, the TTAA acknowledges that the strategic nature of the model means that network journey times are likely to be under represented through small villages, where services make multiple stops and where local detours into residential areas are not represented in the model.

4.7.21 In consideration of the large variability of bus schedule timetables and constraints of the model, the TTAA is generally satisfied that the modelled bus journey times are appropriately represented.

4.8 Conclusion and Recommendation

Model Development

4.8.1 The Forth Replacement Crossing PT model network has been based on the Forth Replacement Crossing SATURN road network with the addition of TMfS07 rail network. The modelled network includes:

- Road network
- Heavy rail
- Road and rail zone connectors
- Walking connections between rail station and road network

4.8.2 Inter-urban bus and rail services have been coded to a base year of 2007. The PT model zoning system, demand matrices and assignment model procedure is based on the TMfS07.

4.8.3 The TTAA is satisfied that PT model has linkage between the Forth Replacement Crossing SATURN model and the TMfS07 strategic national model and consistency in modelling assumptions is maintenance with these interrelated models.

4.8.4 The TTAA has carried out checks on various aspect of the PT model development, including examination of the physical model network, service line files and documentation. Where appropriate, the TTAA has highlighted issues where they have been identified through the auditing process, although none of model development issues were considered significant to have a large impact on the operation of the PT model

4.8.5 The TTAA is content that development of the Forth Replacement Crossing PT model has been carried out satisfactorily, and maintaining modelling assumptions and data consistent with related TMfS07 and SATURN highway model.

Validation

4.8.6 Validation of modelled passenger flows crossing the Edinburgh Cordon and Lower Forth screenline, and modelled rail passenger boarding and alighting against observed data has been undertaken. These are generally acceptable at an aggregated analysis level.

4.8.7 The TTAA is satisfied that the modelling of cordon flows and individual rail station boarding and alighting is acceptable at a global level across the model. The Lower Forth Crossing validation is considered to be good in the southbound direction and on the limit of acceptability in the northbound direction.

4.8.8 Potential users of the Forth Replacement Crossing PT model for more local studies involving assessment of individual PT link flows and rail station boarding/alighting volumes should take note of the variability of flows at a more detailed level. In the context of the FRC study and for general application of the model, **the TTAA suggests that close scrutiny should be paid to the responses in terms of main mode split, PT flows and PT sub-mode split in interpreting the model outputs.**

4.8.9 Modelled bus journey times are in general quicker than the timetabled journey times. The TTAA is content that the majority of bus routes crossing the Forth Road Bridge have journey times within 15% of PT timetables in all the peak periods. In consideration of the large variability of bus schedule timetables and constraints of the model, the TTAA is generally satisfied that the modelled bus journey times are appropriately represented.

Conclusion and Recommendation

4.8.10 It is stated that the public transport element of the Forth Replacement Crossing model has been successfully developed and is fit for its intended purpose for assigning public transport travel movements in the Forth Crossing area at a strategic level. The TTAA concurs that the model has been successfully developed and is fit for use to assess PT travel movements at a strategic level in the Forth Crossing area**. The application of the model on more regional and local levels, however, will require closer scrutiny and interpretation of the model outputs.**

4.8.11 It is also stated that further model development (and potentially software development) would be required to significantly improve the sub-model split. The TTAA agrees that improving the sub-mode split element of the PT model is crucial to provide a more robust PT assignment procedure.

A APPENDIX A – COMMENTARY ON JOURNEY TIME VALIDATION

Table A.1 : Journey Time Validation Commentary

Route	Direction	Time Period	Local Modelled JT	MVA Comment
2	Clockwise	AM	Slow	Eastbound approach to Gogar - We are aware that the modelled delay at this location is higher than the observed. However, reducing the modelled delay would cause more traffic to switch from the parallel M8 route to the A8 and add to the already-higher than- observed traffic volumes using the A8 instead of the M8 extension to Hermiston Gait. Westbound M8 Hermiston Gait to Newbridge – The slower than observed journeys time along this stretch of road are caused by two factors: the effect of the speed flow curve and the effect of the signalised approach at Newbridge. We have previously tried to code a different type of speed flow curve on this section of road, but found that the resulting speed would be too fast. We could potentially carry out further testing and try to determine a more suitable speed flow curve for this road section. Also, with regards to the effect of the signalised approach, it would be possible to revisit the traffic signal timings at Newbridge and potentially improve the journey validation on this route.
2	Anti-clockwise	IP	Slow	The slower than observed journey times along this stretch of road are due to the effect of the speed flow curve coded. As discussed above for Route 2 Clockwise, this coding could be revisited.
2	Anti-clockwise	PM	Fast	The modelled journey times along this section of roads are faster than the mean observed journey times, however the modelled times are within the observed range limits. Ie the observed range is quite variable.
3	Northbound	All	Variable	AM and IP modelled times actually show a good match with the observed times for most of route sections. There is a discrepancy at the Maybury junction for which we have provided commentary within the previous note 'Audit Response to AN_FRC_2: 'Review of Saturn Model Development", as follows: 'We have previously tried to refine the model to better reflect the observed delays at this location. However, reducing the modelled delay on this A8 approach to Maybury causes more traffic to switch from the parallel M8 route to the A8 and adds to the already-higher-than- observed traffic volumes using the A8 instead of the M8 extension to Hermiston Gait. It would be possible to revisit this and try again to reduce the delay to left-turners only, without creating too many knock-on problems in the model validation in this area. However, since the overall journey-time validation for this route is reasonable, it is not clear if this additional effort is justified.' The PM model shows a similar situation at the Maybury junction. In addition the PM model shows a higher than observed delay on the left turn from the A902 to the A90 at Barton junction. This junction is a give-way junction which appear to work fine in the AM and IP models. It should be noted that the observed times for this route in the PM peak are highly variable.
3	Southbound	All	Variable	The Barton junction is quite complex to model. We have represented the junction using a number of short links. Although these links have been presented separately in the journey time validation analysis this might not be entirely appropriate. In particular link 8563_8458 (which shows an underestimate) and link 8458_4045 (which shows an overestimate) show be considered together. The A902 approach at Maybury junction shows a higher than observed delay. We have previously tried to reduce this delay, but struggled to allocate enough green time to this approach while maintaining reasonable delays at the other approaches.

Table A.2 : Journey Time Validation Commentary Cont…

Route	Direction	Time Period	Local Modelled JT	MVA Comment
4	Eastbound	AM	Slow	The signal timings of the signalised junction controlling the A904 approach to Echline could be revisited to try and improve the validation of this section (the green time for this approach currently coded in the model is only 10 seconds).
5	Southbound	IP	Fast	This route is quicker throughout, but generally by few seconds; the discrepancy between modelled and observed times ranges from 2 to 7 seconds for most of the sections. The three sections where more significant differences occur (53 seconds, 47 seconds and 19 seconds) are controlled by speed flow curves which appear to give reasonable modelled times in the other time periods. Since the overall journey-time validation for this route meets DMRB standard it would not seem justifiable to change the coded speed flow curves.
5	Northbound	AM & PM	Fast	Commentary on Routes 5 Northbound was already provided within the previous note 'Audit Response to AN_FRC_2: 'Review of Saturn Model Development'' , as follows: 'The modelled time for the segment in question is at the lower end of the observed range and it is within the 95% confidence interval about the mean. However, the slip road is currently modelled as an 80kph speed limit – reducing this to 64kph is likely to improve the journey time validation on this link.'
6	Eastbound	IP	Fast	We have examined this section of the route closely, but could not find any errors/inaccuracies in the coding. It is not clear why the IP observed times for this section are so different from the AM and PM peak observed times.
6	Westbound	IP	Fast	As per Route 6 eastbound
11	Northbound	All	Fast	Commentary on Routes 11 and 12 (Northbound and Southbound) was already provided within the previous note 'Audit Response to AN_FRC_2: 'Review of Saturn Model Development'' , as follows: 'We are aware of all four of these issues. We have examined the model closely along these two routes, but could not find anything specifically wrong with either the network coding or the modelled flows NB Since both of these are 'ITIS data' routes we have no information on the range or variability of the relevant journey times.'
11	Southbound	All	Fast	As per Route 11 northbound
12	Northbound	All	Variable	As per Route 11 northbound
12	Southbound	All	Fast	As per Route 11 northbound
13	Eastbound	All	Fast	Routes 13 to 17 - These longer distance routes are generally controlled by the speed flow curves coded on the main Motorway and A road links. We have examined the coding of the speed flow curves and have found it to be consistent and accurate (as indeed has the auditor – see AN-FRC-6 paragraph 4.3.3). As noted above the ITIS data does not provide information on the journey time range or variability. NB We suggest that it would be valuable to do further comparison of conventional journey time survey data and the corresponding ITIS data, to better understand any bias in the ITIS-based estimates of average journey times.
13	Westbound	All	Fast	As per Route 13 eastbound
14	Eastbound	All	Fast	As per Route 13 eastbound
14	Westbound	IP & PM	Variable	As per Route 13 eastbound
15	Eastbound	AM	Fast	As per Route 13 eastbound
17	Eastbound	All	Fast	As per Route 13 eastbound
17	Westbound	All	Fast	As per Route 13 eastbound