Transport Model for Scotland

SEDD

Model Development Audit – Final Report

64047

SIAS Limited

September 2005

TRANSPORT MODEL FOR SCOTLAND

Description:

Model Development Audit – Final Report

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30 September 2005

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1 INTRODUCTION

1.1 Purpose of Report

1.1.1 SIAS was commissioned under the Traffic and Transportation Planning Advisor and Auditor Commission to undertake an audit of the transport model development work associated with the Transport Model for Scotland (TMfS). TMfS was developed by MVA on behalf of the Scottish Executive as a strategic, multi-modal model to supersede previous generations of the Central Scotland Transport Model 3 (CSTM3, CSTM3A etc.).

1.1.2 The audit has focused largely on reviewing the documentation produced by MVA for the different elements of the model development and a review of the highway and public transport (PT) networks. Additionally an iterative process of queries and responses between the auditor and auditee was adopted before the audit findings were published. The audit was divided into a number of discrete sections relevant to different aspects of model development. In each case, this ultimately led to audit findings being published in a series of documents termed Audit Notes (ANs). This report presents the findings relating to all aspects which have been audited and effectively distils the findings from each of the ANs into a single document.

1.1.3 It should be noted that SIAS, in the role of auditor, is referred to as the TTAA throughout the remainder of this document.

1.2 Audit Guidance

1.2.1 It should be borne in mind when reading this document that the TTAA assumes that all potential users of TMfS have sufficient technical knowledge of the transport modelling concepts and software packages pertinent to the application of TMfS. Where insufficient detail is available from the supporting TMfS model development documentation or this Audit Report, it is further assumed that users will refer to the model development and support team for the necessary advice.

1.2.2 It is also assumed that any user of the model will undertake a thorough, study specific review of TMfS within their intended study area to establish its localised strengths and weaknesses and overall fitness for purpose prior to application. This review process should also continue throughout the model application to verify the robustness of the model outputs in forecast mode.

1.2.3 Continuing users of CSTM3 and CSTM3A should also take cognisance of the differences and enhancements which have been introduced during the development of TMfS.

1.3 Report Structure

1.3.1 Following this introductory chapter the individual elements of the audit are presented as follows:

- Chapter 2 - Highway Network and Zoning System (AN1-1)
- Chapter 3 - Highway Assignment Model Development and Validation (AN2-1)
- Chapter 4 - Public Transport Network and Services (AN5-1)
- Chapter 5 - Public Transport Assignment Model Development and Validation (AN6-1)
- Chapter 6 - Demand Model (AN9-1)
- Chapter 7 - Park and Ride Model (AN10-1)

1.4 Acknowledgements

1.4.1 The TTAA wishes to acknowledge the assistance of MVA and the Scottish Executive in supplying the necessary information during the course of this audit.

2 HIGHWAY NETWORK AND ZONING SYSTEM

2.1 Introduction

2.1.1 This chapter presents the TTAA's findings based on information supplied by MVA relating to TMfS Audit Task 1 : Review updated network and zoning system.

2.1.2 The TTAA produced Audit Inquiry Note, AIN1-1 (TTAA ref. 57053) to raise specific data requests and/or queries regarding this audit task. MVA responded by providing the appropriate information in various formats as requested along with Information Note No. AIN1-1_1_AR and Information Note No. A27_AN1-1b_AR. The findings in this chapter are based on a review of the specific information supplied in response to AIN1-1 and on the basis of various discussions with MVA during the audit process.

2.1.3 All requested files were made available through the TMfS website www.tmfs.org.uk.

2.2 Skeletal Network Description

2.2.1 MVA provided the TTAA with a copy of the TMfS network in TRIPS format, which enabled an analysis of the skeletal detail of the network. Given that the general network description, in terms of overall coverage, for CSTM3A was considered acceptable, the TTAA concentrated on the areas of network where TMfS differs from CSTM3A.

2.2.2 The major areas of change in the skeletal network description between TMfS and CSTM3A are concentrated around Aberdeen with the incorporation of the Aberdeen Sub Area model (ASAM). There have been minor changes to the network in East Lothian, Dunfermline and west of Glasgow. The TTAA consider that the additional level of skeletal network detail modelled in TMfS is satisfactory.

2.3 Zoning System

2.3.1 MVA provided the TTAA with a copy of the revised TMfS zoning system in MapInfo format. The TTAA holds copies of the CSTM3 and CSTM3A zoning systems in MapInfo format which enabled comparisons to be made between TMfS and CSTM3/3A. This information was reviewed by the TTAA to examine the suitability of the updated zoning system adopted in TMfS.

2.3.2 MVA also informed the TTAA that the TMfS zoning system had been changed to coincide with the current Census output area boundaries. Additionally, the more refined zoning system has been applied within the ASAM, West Lothian, North Lanarkshire and North Berwick areas. A number of zones within the TMfS zoning system have been consolidated in Edinburgh and Glasgow city centres.

2.3.3 The TTAA acknowledges that the new zoning system provides a number of advantages and is appropriate for TMfS.

2.4 Scope of Skeletal Network Coding Audit

2.4.1 In reviewing the TMfS network coverage, the areas where coding differences were evident between CSTM3A and TMfS have been outlined by the TTAA. Whilst many of these issues were relatively minor, others were considered to be potentially more significant and an examination of the coding logic was therefore undertaken by the TTAA.

2.4.2 It should be noted that some issues identified during the network coding audit required recoding within the TMfS Base network. Where this was the case, MVA has developed a “Base Plus” network which is effectively the calibrated and validated TMfS network incorporating appropriate changes, including those identified during the audit process.

2.5 Periodic Differences

2.5.1 It was found that TMFS AM and PM Peak Networks were identical. Differences in the capacity values were found between the AM (and PM) and Off Peak TMFS networks with regard to link capacity. The AM and PM networks showed an increased link capacity of 600 vehicles per hour on 10 links in North Aberdeen, a decrease of 200 vehicles per hour on 2 links in South Aberdeen, a decrease of 400 vehicles per hour on 17 links in Aberdeen city centre and a decrease of 600 vehicles per hour on one link in Glasgow and one link in Aberdeen city centre when compared with Off Peak networks.

2.5.2 MVA has subsequently confirmed that these temporal variations are included to reflect peak specific bus lanes at these locations. The TTAA is therefore satisfied that these variations are acceptable.

2.6 Additional Network Checks

2.6.1 The TTAA undertook a further series of checks on the logic and accuracy of the network coding within TMfS taking cognisance of previous checks undertaken as part of the CSTM3, CSTCS and ASAM audits. The review of each element is provided below.

2.6.2 The TTAA undertook a series of logic checks on the coding of the skeletal network to ensure that it is representative of the road network. The elements of the skeletal coding that have been checked are:

- Link Type
- Jurisdiction Code
- Capacity Indicator
- Link Lengths

Link Type

2.6.3 The link type coding within TMfS was checked to ensure that the appropriate types were represented in the network. The TMfS link types are listed in Table 2.1. It is acknowledged that the link types have been rationalised (from CSTM3A) to match with the Scottish Transport Statistics.

Table 2.1 : TMfS Link Type Coding

Type	Description	Examples in TMfS
1	Motorway	M8 Between Glasgow and Edinburgh
2	Motorway Slip	Junction 6 of M74 at Hamilton
3	Trunk A Non Built Up	A96 Between Aberdeen and Elgin
4	Trunk A Built Up	A82 at Inverness
5	Non Trunk A Non Built Up	A923 Between Dundee and Blairgowrie
6	Non Trunk A Built Up	A814 at Clydebank
7	Minor Non Built Up	B6456 North East of Galashiels
8	Minor Built Up	B7081 from Irvine
9	Banned HGV	Queen's Drive at Palace of Holyrood, Edinburgh
10	Bus Only	Princes St Eastbound, Edinburgh
22	Zone Centroid	

2.6.4 The following anomaly was detected as a result of this check. The slip roads on the grade separated junction of the A737 and the A761 have been coded as motorway slip roads. The junction is an intersection of A-Class roads and has been coded so. Figure 2.1 shows the anomaly with the motorway links highlighted in red. This anomaly will have little impact on model operation, however, this issue was subsequently acknowledged by MVA who agreed to amend this in the Base Plus network.

Figure 2.1 : TMfS - A737/A761 Junction

2.6.5 Overall the TTAA is satisfied that the link type coding within TMfS is appropriate. However, it should be noted that the TMfS link capacity coding which has been applied throughout the network is tabulated in Table 2.4 of the Highway Cal/Val Report. The TTAA is of the opinion that the link capacities for link type 5 to 8 are below what is expected. Further commentary on this matter is provided in Chapter 3 of this report.

Jurisdiction Code

2.6.6 The jurisdiction code for the TMfS network was checked to ensure the appropriate codes were correct. The TTAA identified errors with Jurisdiction code 5 which is for the Edinburgh area but includes a significant number of zone connectors throughout the model. A similar error occurs for jurisdiction code 6 which is West Lothian and includes links in Aberdeen.

2.6.7 It was also found that TMFS had 5 out of 21236 links with differing jurisdiction code for the two directions on the same link. These issues have no impact on model operation but could have some localised implications for analysis (e.g. analysis by Jurisdiction Code). Again, these issues were acknowledged by MVA who agreed to amend these matters in the Base Plus network.

Capacity Indicator

2.6.8 The TTAA has undertaken selective checks to ensure that appropriate speed/flow curves have been applied. The TTAA is satisfied that this is the case.

Link Lengths

2.6.9 The TTAA undertook a series of logic checks on the coding of individual link lengths as well as the cumulative link length along a series of routes. The individual coded link lengths were compared against link lengths which were calculated by the TTAA based on the grid references in the TMfS highway network node co-ordinates file. The potential limitations and inaccuracies of using calculated distances based on node co-ordinate positions in these checks are acknowledged by the TTAA. Nevertheless, this provided a useful and manageable means of undertaking link length range and logic checks on a network wide basis. The vast majority of coded and calculated link lengths compared reasonably well within acceptable error limits. However, there were a few errors which were significant in terms of the discrepancy between coded, calculated values and true distance. The calculated lengths have been compared to the coded links lengths using the GEH statistic.

2.6.10 It was found that TMFS had 195 links with a GEH > 10. CSTM3A had 373 links with GEH >10. This would indicate that the distances used in the TMFS model were more accurate than the ones used in the CSTM3A model, i.e. they have been amended.

2.6.11 Links with a GEH > 20, for TMFS and GEH > 20, for CSTM3A, i.e. links which looked to incorporate large errors, were extracted for further analysis. Links from TMFS with a GEH > 20 were all found to be representative links on the periphery of the model, hence, these errors are unlikely to have any notable impact on model operation.

2.6.12 It was found that TMFS had 1 out the 21236 links with differing link distance for the two directions on the same link. Zone feeder 1093 – 42471 contained an error and was found to be 100m longer in one direction resulting in an extra 6 seconds of travel time for all trips inbound to zone 1093. Whilst this is not a significant error it should still be noted by potential users of TMfS.

2.6.13 The TTAA also undertook a series of checks to ensure the accuracy of coded cumulative link lengths for various routes within the network. Overall, the TTAA was satisfied that the coded route lengths were within acceptable limits of accuracy for TMfS.

2.6.14 The cumulative link length along a series of routes was checked by comparing the coded link length, the sum of the calculated link length using the coordinates and the true route distance using an OS map. Each route was checked in both directions. The ten key routes analysed were:

- Glasgow to Edinburgh
- Glasgow to Carlisle
- Glasgow to Inverness
- Glasgow to Dumfries
- Glasgow to Dundee
- Edinburgh to Carlisle
- Edinburgh to Dumfries
- Edinburgh to Aberdeen
- Aberdeen to Inverness
- Edinburgh to Newcastle

2.6.15 The results of the analysis are shown in Table 2.2.

Table 2.2: Route Analysis Summary

Route		Actual Distance	Forward Direction	Absolute Difference	% Difference	Reverse Direction	Absolute Difference	% Difference
1	Glasgow - Edinburgh	62.5	64.27	1.77	3%	61.99	-0.51	-1%
2	Glasgow - Carlisle	140.5	137.74	-2.76	-2%	137.45	-3.05	-2%
3	Glasgow - Inverness	260	257.34	-2.66	-1%	256.18	-3.82	-1%
4	Glasgow - Dumfries	110	106.08	-3.92	-4%	105.08	-4.92	-5%
5	Glasgow - Dundee	120	118.2	-1.8	-2%	117.02	-2.98	-3%
6	Edinburgh - Carlisle	144	143.06	-0.94	-1%	143.1	-0.9	-1%
7	Edinburgh - Dumfries	113	110.35	-2.65	-2%	110.35	-2.65	-2%
8	Edinburgh - Aberdeen	180.5	178.21	-2.29	-1%	177.6	-2.9	-2%
9	Aberdeen - Inverness	157	154.43	-2.57	-2%	154.45	-2.55	-2%
10	Edinburgh - Newcastle	169	169.71	0.71	0%	169.02	0.02	0%

2.6.16 The TTAA is satisfied that the comparison of the link length coding and the true distance measure from an OS map on these routes is within acceptable limits. It should be noted that there is a noticeable difference in the directional distance for the Glasgow to Edinburgh route. This can occur because the route distance is calculated using a different set of links for each direction. This route has been checked between the M8, Junction 15 and the M8 Junction 1 following the route of the M8/A8. The comparison using the link length calculated from the coordinates demonstrates that the network is geographically accurate on the above routes.

2.7 Junction Coding

2.7.1 The TTAA undertook a series of checks on the junction coding within the TMfS network. A small selection of significant junctions/interchanges at key locations on the strategic network was chosen and audited. Care was taken to ensure that the selection was a sample of junctions across the network and not biased to a specific area. It is recognised by the TTAA that the sample of junctions chosen is small relative to the total number of modelled junctions within TMfS. However, given the general, strategic scope of TMfS, the TTAA considered that examining the accuracy of the coding at a selection of the key strategic junctions and interchanges was the most manageable and appropriate way of establishing the reliability of the junction coding with respect to the overall scope of TMfS development.

2.7.2 The aspects of the junctions that were interrogated are as follows:

- Number of approaching lanes
- Link capacities
- Turn Capacities

2.7.3 Table 2.3 shows the junctions that were checked and the results of the checks.

Table 2.3: Junction Coding Observations

Junction	Comments
M73/M74 Interchange	Link Capacities are very high - M74(N) to M73(N) (is 3600 should be 1800) - M74(S) to A74 (is 3600 should be 1800) - M74(S) to M73(N) (is 4800 should be 3600) - A74 to M74(N) (is 3600 should be 1800) - A74 to M74(S) (is 3600 should be 1800) - M73(N) & M74(S) (is 9600 should be approx. 6000 taking account of weaving)
M8/A720 Hermiston Gait Interchange	Number of Approaching Lanes and Link Capacities are incorrect - Hermiston Gait Approach (both circulating and approach coded as 3 lanes should be 4 lanes) - A720(S) (Approach is coded as 3 lanes should be 4 lanes) - Missing free flow lane from Hermiston Gait to A720/A70 is missing
M9/A8 Newbridge Roundabout	Number of Approaching Lanes and Link Capacities are incorrect - A89 Approach (approach is coded as 3 lanes and has the link capacity of one lane it should be 2 lanes)
M9/M876 Interchange	Link Capacities appear incorrect - M9(E) to M876 (is 3600 should be 1800)
M9/A9 Keir Roundabout	Link Capacities appear incorrect - B8033 Stirling Road (is 2000 should be 3600) - Approach from the West (is 1000 should be 1600)
A90/A956 Charleston Interchange	Coded Correctly
A90/A923 Dundee	All slip road and circulating link capacities are incorrect (is 1600 should be 3200)
M8/A737 St James Interchange	Link Capacities are incorrect - A726 Barnsford Road (is 3200 should be 1800)
M74 Junction 5, Raith Interchange	Link Capacities Low between Mini-roundabout from Hamilton and A725 roundabout (is 2000 should be 3600) Main Interchange Coded Correctly

2.7.4 The junction coding anomalies identified in the above table were subsequently acknowledged by MVA who agreed to incorporate the appropriate amendments in the Base Plus network. The one exception to this is the coding of the free-flow lane from Hermiston Gait to the A720/A70 which was omitted by MVA due to *"…the geographical coverage of zone 102 from the census area. This zone straddles the rail line covering Edinburgh Park and Hermiston Gait. The inclusion of the free-flow lane would have given trips from Edinburgh Park an unrealistically easy route out of that area and was therefore omitted"*.

2.7.5 The TTAA acknowledges this rationale for exclusion of the free-flow link, nevertheless, potential users of TMfS should be aware of this issue when conducting analysis of TMfS assigned flows in this area, particularly in future years.

2.7.6 From the above table showing the coding at major intersections it can be seen that although nine junctions were selected eight of them demonstrate apparent coding anomalies. In addition the following junctions have turn capacities and/or signals coded which constrain the demand where the demand is surprisingly low:

- M8/A720 Hermiston Gait Approach (turn capacity 200vph, flow 200vph)
- M9/A8 Newbridge Roundabout A89 Approach (turn capacity 776pcuph, flow 760pcuph)
- M9/A8 Newbridge Roundabout A8(E) Approach (turn capacity 776pcuph, flow 790pcuph)
- M9/A8 Newbridge Roundabout M8(S) Approach (turn capacity 283pcuph, flow 244pcuph)
- M9/A8 Newbridge Roundabout M9(N) Approach (turn capacity 362pcuph, flow 331pcuph)

2.7.7 The TTAA has concerns that these apparently unrealistic junction turning capacity values may have an impact on both the validation of the model and more particularly, the application of the model in forecast years. MVA has commented on these turning capacities as follows:

- *"M8/A720 Hermiston Gait approach has a low capacity due to the geographical coverage of zone 102 from the census area. This zone straddles the rail line covering Edinburgh Park and Hermiston Gait. The green time was therefore reduced to help curtail an unrealistically easy route out of that area. The correct route is via Gogar Roundabout but without this alteration the traffic from zone 102 would simply route out through Hermiston Gait without going through Gogar"*
- *"M9/A8 Newbridge Roundabout approaches – The modelled junction coded for Newbridge Roundabout reflect the base conditions as known at the time. Updated green times were not available and therefore existing CSTM coding was used. However, no counter-intuitive delays are apparent from the assignment"*

2.7.8 Again, the TTAA acknowledges the rationale for these coded turning capacity values. However, whilst they may have resulted in acceptable Base model conditions, any artificial constraint will be passed on to the future year assignments which may provide an unrealistic assignment in the affected area.

2.7.9 The TTAA also undertook network coding checks using the documentation from the CSTM and CSTM3A audits undertaken by SIAS Ltd as well as the KWAM audit undertaken by Faber Maunsel. It was found that all the major coding issues raised in these audits have been resolved in the TMfS networks.

2.7.10 The TTAA considers that, in light of the above coding issues the junction coding particularly on the strategic network should be thoroughly reviewed prior to the widespread application of TMfS. This could be a relatively inexpensive task which would enhance the integrity of the network without significantly affecting the assignment in the base year. Furthermore, this would enhance the confidence in the network's ability to predict costs robustly in future years.

3 HIGHWAY ASSIGNMENT MODEL DEVELOPMENT AND VALIDATION

3.1 Background

3.1.1 This chapter presents the TTAA's findings based on information supplied by MVA relating to TMfS Audit Tasks 2, 3 & 4 : Review Highway Assignment Model Development/Trip Matrix Development/Validation. The TTAA will use the acronym HAM to refer to the TMfS Highway Assignment Model throughout this chapter.

3.1.2 The TTAA produced Audit Inquiry Notes AIN2-1, AIN3-1 & AIN4-1 (TTAA ref. 60151, 60149 & 60150) to raise specific data requests and/or queries regarding this audit task. MVA responded by providing the "TMfS HAM Calibration and Validation – Draft Final Report, Issue 5, December 2005". Additional information was made available through the TMfS website www.tmfs.org.uk along with Information Note No. IN_AN2-1b_MB_AR_NT.

3.1.3 The findings in this chapter are based on a review of the specific information supplied in response to AIN2-1/3-1/4-1 and on the basis of various discussions with MVA during the audit process. The TTAA's comments regarding the TMfS HAM are listed in the following sections of this chapter. The section headings correspond with the chapter headings from MVA's HAM Calibration and Validation – Draft Final Report.

3.2 Introduction

3.2.1 The introductory chapter of MVA's report initially sets out the background and context of the HAM development and the key objectives of TMfS. The TTAA has no substantive comments on this aspect of MVA's report. The TMfS modelled area is depicted in Figure 1.1 of MVA's report and appears consistent with the extended model area. More detailed comments on the TMfS highway network coverage and coding are provided in Chapter 2 of this report.

3.3 Network Development

3.3.1 The various changes made to the TMfS network to update this from the previous CSTM3A 2000 network are outlined in this chapter. The TTAA's findings from the review of each process are outlined as follows.

Link Type Changes

3.3.2 Historically there were a total of 32 differing link types used in the network definition for CSTM3. The link type specification is used solely for analytical purposes and has no impact on the HAM operation (other than HGV Banned and Bus only link types). Consequently, the opportunity was taken during the TMfS development to rationalise the link type descriptions with those of the Scottish Transport Statistics to enable more meaningful analytical outputs from TMfS. The TTAA considers this to be a practical enhancement from an analytical point of view.

3.3.3 The TTAA notes that the section of the West Approach Road in Edinburgh east of Morrison Link has been coded as "Banned HGV" (TMfS link type 9) in both directions. The HGV ban (1.5 tonne limit except for buses) on the West Approach Road does not in fact come into place until the section directly to the west of Morrison Link. The TTAA acknowledges that there are "Alternative route for light vehicle" advisory signs on both Princes Street and Morrison Link, however, there are no signed HGV restrictions on either Lothian Road or Morrison Link which can legally prevent HGVs from accessing the West Approach Road between Lothian Road and Morrison link in either direction. Apart from this minor local anomaly, which should be amended in due course, the TTAA is satisfied that the link type coding adopted is appropriate for TMfS.

Link Capacity Changes

3.3.4 A generic set of link capacities was devised for TMfS to attempt to even out any inconsistencies inherited from historic donor models such as EATM and SITM. The TMfS link types and generic capacities are shown in Table 3.1 below.

Table 3.1 : TMfS Link Types and Generic Capacities

TMfS Link Type	Description	Capacity (PCUs/lane)
1	Motorway	2400
2	Motorway Slips	1800
3	Trunk A road >40mph	1800
4	Trunk A road <40mph	1800
5	Non-Trunk A road >40mph	1600
6	Non-Trunk A road <40mph	1600
7	Minor road >40mph	1000
8	Minor road <40mph	800
9	Banned HGV	Misc
10	Bus Only	Misc
22	Zone Centroid Connector	N/A

3.3.5 It is acknowledged by the TTAA that, following application of the generic capacities by link type, a manual review was undertaken to alter specific link types which will differ from a generic approach. This review was based on local knowledge and observed flow data. This is considered to be good practice, nevertheless, in the TTAA's view, many of the changes implemented are relatively minor capacity increases (typically 200 PCUs/lane). The TTAA is of the opinion that, overall the link capacities for link type 5 to 8 are below what is expected. The rationale for the link capacities adopted by MVA is predominantly taken from DMRB Volume 5 Section 1 Part 3 (TA 46/97 and TA 79/99).

3.3.6 The TTAA considers these appropriate references for deriving generic capacities, however, the values expressed in MVA's documentation refer to PCUs per lane per hour, whilst the values in DMRB refer to vehicles per hour. As an example, a link of type 5 with a capacity of 1600 PCUs/lane would have an overall capacity of approximately 1520 vehicles per lane per hour, assuming an HGV percentage of 5%. The TTAA considers this to be lower than would be expected in many cases, particularly given some of the allocation of link types in some areas (e.g. A8, A90 etc.).

3.3.7 With regard to which links in the network have been allocated which link types, the TTAA is generally satisfied that the link types (particularly types 1 to 4) have been appropriately allocated in TMfS. Nevertheless, with this form of generic coding, some detail from the donor models may have been diluted and/or link capacities altered to potentially unrealistic values. The TTAA is content that link types 1 to 4 and 22 are satisfactory but has the following comments on other link types:

Link Types 5 & 6 – Non-Trunk A roads >40mph & <40mph : Capacity = 1600 PCUs/lane

3.3.8 The following bulleted list gives examples of links coded as types 5 & 6 in TMfS:

- A8 Newbridge to Gogar
- A90 Barnton to Inverkeithing
- A71 west of Edinburgh
- A8011 Central Way Cumbernauld

- A899 Livingston
- Parts of A73 Airdrie to Cumbernauld
- A814 Clydeside Expressway Glasgow

3.3.9 The TTAA considers that whilst the label of "Non-Trunk A road" is appropriate in most cases, the generic per lane capacity is not truly representative of the differing road types. It is particularly considered that the capacities coded for the A8, A90 and A814 are underestimating the capacity for these link types as, for the most part, they are dual carriageway roads with closed central reservations.

3.3.10 MVA has subsequently acknowledged that in the case of the A90 and the A814, *"…the base coding may be slightly low for forecasting"* and that *"An amendment to this capacity would not affect the base calibration and validation"*.

Link Type 7 – Minor roads >40mph : Capacity = 1000 PCUs/lane

3.3.11 This link type is coded mainly towards the edges of the main urban areas or in suburban and rural areas of the model. The application of the link type is considered to be representative in TMfS, however, the generic capacity of 1000 PCUs/lane is considered to be very conservative for links of this nature in some areas. For example, the B969 around Glenrothes is coded with this link type, as is the connection between Gogar Roundabout and Edinburgh Park/Gyle Centre as are many rural links in Ayrshire and the Borders. Again, it is considered that the generic per lane capacity is not truly representative of the differing road types.

Link Type 8 – Minor roads <40mph : Capacity = 800 PCUs/lane

3.3.12 This link type has been mainly applied in urban and suburban areas to represent connector, access or residential links. Again, the application of the "Minor road" label is has been appropriately applied in most cases, however, the capacity of 800 PCUs/lane is considered very conservative in some areas. The following list provides examples of links coded as type 8:

- Stewartfield Way East Kilbride
- Cathcart Road Glasgow
- Various links in all major urban centres in the model
- Queen Street Edinburgh City Centre
- Hanover Street Edinburgh City Centre

3.3.13 It is clear that each of the above links performs a different function within its locality and that a uniform capacity is unlikely to be truly representative of the actual capacity in each case. Additionally, a value of 800 PCUs/lane is exceptionally low for some, if not all of these locations. It is also evident that where any local adjustments have been applied, these are generally conservative. For example, the link capacity of Queen Street (Edinburgh) westbound is coded as 1000 PCU/hr along its entire length. Whilst the TTAA recognises there are a number of constraints (bus lanes, parking etc.) the capacity coded is prohibitively low. It is further recognised by the TTAA that in a number of cases, junctions will be coded on these links and the capacity will be controlled by the junction rather than the link coding, hence, the impact of the low coded link capacity will be negligible in such cases. Nevertheless, in cases where the link does not directly lead into a modelled junction, the coded link capacity will be relevant to the calculated speed used in the assignment.

3.3.14 The TTAA acknowledges the rationalisation of the link types to match the Scottish Transport Statistics link types was introduced as a means of providing comparable analytical outputs. However, the associated generic link type capacities applied are considered by the TTAA to be conservative and in some cases unrepresentative of actual conditions, albeit that a manual review process was undertaken by MVA to alter the capacity on specific links. Link types 5 to 8 are considered to have very low capacities with types 7 and 8 being extremely conservative.

3.3.15 The TTAA considers that whilst the chosen generic capacities, and the manual adjustments applied may represent a reasonable strategic, global road hierarchy within TMfS for the base year, this may have an influence on the model operation in future years. The issue is unlikely to have materially affected the overall level of base year calibration/validation and may also be relatively minor in respect of large scale, wide area policy/intervention testing in TMfS. Nevertheless, users of the model can reasonably expect to require robust outputs within more localised areas of the model. Whilst the impact cannot be quantified in this audit, the TTAA considers the link capacity coding may influence the robustness and realism of predicted model flows within more localised areas of the model, particularly in areas with a lower density of modelled junctions.

3.3.16 It is recognised that TMfS is primarily a tool to be applied in strategic transport assessments, nevertheless, it will often be the only readily available model for a particular application in a particular area. Consequently, potential users of TMfS should be made aware of the extent to which the generic coding has influenced the coded link capacities in TMfS, particularly when considering an application of TMfS which is likely to require analysis at a local level.

3.3.17 The TTAA therefore considers that a full review of the coded capacities for link types 5 to 8 should be undertaken and appropriate amendments incorporated in the Base Plus networks. The TTAA concurs with MVA's advice that such capacity changes are unlikely to materially affect the base calibration and validation and they are therefore relatively "safe" updates to include in the Base Plus network. It may also be relevant during this review to introduce some additional sub-division of link types to better reflect the true characteristics of differing roads within each link type (e.g. urban/suburban/rural, single/dual carriageway etc.).

Speed/Flow Curve Definition

3.3.18 The TTAA analysed the capacity indices and speed/flow curve definition (ref. Chapter 2) and was satisfied that these had been defined appropriately for TMfS.

Link Distance Checks

3.3.19 The TTAA provided more detailed commentary on this matter in Chapter 2. It is considered that the link distances are generally coded appropriately for TMfS.

Link Connectivity Checks

3.3.20 The TTAA has supplemented MVA's checks by examining the network in MapInfo GIS and considers the connectivity to be appropriate.

Updating Modelled Junctions

3.3.21 A comprehensive junction survey was undertaken in August 2003 to provide updated TMfS junction layout details for the model area. This covered all areas of the network except those covered by ASAM and by the GCC SATURN model. The survey data was then used to code junctions using generic assumptions on capacities for signal/priority junctions and geometry for roundabouts. The generic capacities and geometric details quoted in MVA's report are in line with expected values, consequently this approach is considered appropriate for TMfS.

3.3.22 The review of junction coding undertaken for the ASAM audit demonstrated that the coding within that area of the model was satisfactory. This has been inherited within TMfS and the TTAA is therefore content that the coding in this area remains appropriately accurate. The TTAA has not examined the latest version of the GCC SATURN Model and consequently cannot comment on the detail of the junction coding within that model.

3.3.23 A full, detailed review of junction coding within the remainder of the TMfS model area was not feasible within the scope of this model development audit. Nevertheless, a sample of major junctions was examined. More detailed comments on the TTAA's review of the TMfS junction coding are provided in Chapter 1.

3.3.24 A diagrammatic representation of the extent of modelled junctions within TMfS is presented in Appendix A of MVA's report. Whilst a detailed, network wide, junction by junction review has not been undertaken by the TTAA, it is considered that the overall extent of junction coding is appropriate for TMfS.

3.4 Trip Matrix Development

3.4.1 The various aspects of the highway trip matrix development are outlined in Chapter 3 of MVA's report. A number of processes were involved in the development of the TMfS HAM trip matrices including:

- addition of CSTM3A RSI data
- conversion of CSTM3A matrix to TMfS zoning system
- addition of ASAM trip matrix
- addition of TMfS RSI data
- matrix smoothing
- matrix estimation

3.4.2 The TTAA's findings based on a review of the HAM trip matrix development information are provided as follows.

Change in Zoning System

3.4.3 The TMfS zoning system has been rationalised to be consistent with the 2001 census output area boundaries. This has a number of advantages including simplifying the provision of planning data for the model and integration with the land use model. From the strategic model perspective this change is desirable and appropriate for TMfS.

Matrix Data

3.4.4 The following existing trip matrix data sources were used in the TMfS matrix development:

- CSTM3A prior highway matrices
- ASAM prior highway matrices

3.4.5 The CSTM3A prior matrices were developed using the following data sources:

- CSTM3 2001 forecast matrix
- Glasgow SATURN model matrix
- A80 traffic model matrix
- CSTCS RSI data

3.4.6 The CSTM3A prior matrices were subject to an audit during the CSTCS and readers are referred to the Central Scotland Transport Corridor Studies – Transport Model Development – Final Audit Report, July 2002 for full details of the audit of these matrices.

3.4.7 Additionally, the ASAM matrices were audited following their development and readers are referred to the Aberdeen Sub Area Model – Transport Model Development – Final Audit Report, July 2004 for detailed findings.

3.4.8 Notwithstanding any findings presented in the above audit reports, these matrices were appropriate sources to utilise for the TMfS HAM trip matrix development.

RSI Data

3.4.9 A total of 155 RSI sites provided observed data for inclusion within the TMfS HAM trip matrices. A summary of the datasets is shown in Table 3.2 below.

Table 3.2 : TMfS RSI Datasets

Dataset	Supplier	Date of Collection
ASAM RSI	Babtie & SIAS	Autumn 2001
CSTM3 RSI	SIAS & Oscar Faber	Summer 1997
CSTM3A RSI	Babtie	Autumn 2000
	SIAS	1999
	Oscar Faber	Autumn 1998
GCC SATURN RSI	Babtie	May 2002
Fife RSI	SIAS	Autumn 2002
Dundee & Perth	Babtie	Autumn 2002
M74 & M9	Babtie	Autumn 2002
Glasgow Area	Babtie	Autumn 2002
Edinburgh Airport	Babtie	Autumn 2002
Edinburgh 1	Babtie	Autumn 2002
Edinburgh 2	Oscar Faber	April 1999
New Stirling Sites	SIAS	March 2002
Dunfermline	SIAS	Autumn 2001
New TMfS Sites	Babtie	June 2003
Ayrshire	Oscar Faber	September 1999/March 2000
SITM RSI	Jacobs	2002

3.4.10 The above datasets are all considered appropriate for the TMfS trip matrix development.

3.4.11 MVA also undertook logic checks as follows:

- review of sample factors
- review of missing time period data
- review of logic of OD movements

3.4.12 A small number of records were identified where the sample factor was considered to be high. It was MVA's judgement that such instances were rare and that no remedial action should be taken to account for this. This issue mainly affected the Ayrshire RSI sites and some of the CSTM3 RSI sites. It is acknowledged in MVA's report that this will lead to high numbers of trips being allocated to a few single OD movements, thereby affecting the underlying trip pattern.

3.4.13 Additionally, some sites were shown to have missing time periods (e.g. Site 13 for the M74 dataset which was suspended between 0830 and 0930). In such instances, data was taken from a different hour within the same time period (e.g. 0730-0830) and the sample factor recalculated using count data for the hour where the RSI trip record was missing.

3.4.14 Finally, MapInfo was used to determine whether the resulting origins and destinations for each RSI location and direction were intuitively correct. Any apparently counter-intuitive movements were discarded from the matrix development and the matrix expansion factors recalculated. MVA describe the number of apparently illogical movements as *"few"*.

3.4.15 The TTAA is content that the principles adopted in screening the RSI data for anomalies and the action taken to be appropriate for TMfS. It should be noted that there is no quantitative information presented in MVA's report which enables the extent and magnitude of such adjustments to be established. The TTAA therefore cannot comment on the degree to which any RSI adjustments applied by MVA during the screening process may have affected the underlying observed trip pattern.

Prior Matrix Development

3.4.16 The TMfS prior matrices were developed by a process involving three main stages which can be broadly described as follows:

- combine CSTM3A and ASAM prior (to matrix estimation) matrices and expand to TMfS zoning system
- build RSI matrices and incorporate within the above matrices
- undertake "matrix smoothing" process to generate TMfS pre-MVESTM matrix

3.4.17 The CSTM3A and ASAM prior matrices were converted to the TMfS zoning system based on factoring to geographical areas. This was subject to a manual checking procedure to ensure that large zones in sparsely populated areas were not unduly allocated significant numbers of trips. The matrices were then subject to disaggregation into four user classes (car in-work, car non-work, LGV and OGV) using factors derived from the CSTM3A and ASAM RSI databases. In principle, the TTAA considers this procedure appropriate.

3.4.18 The RSI data was then incorporated in the matrix by creating 23 RSI screenlines and 35 RSI sectors. Additionally, the observed RSI movements internal to the ASAM area were used to replace the CSTM3A data in this area of the matrix. The ASAM RSI data for other movements (i.e. Aberdeen City to everywhere except Aberdeenshire area) was then collated onto a single screenline.

3.4.19 Observed RSI matrices were then created for all "fully observed" movements and used to replace the equivalent cells in the CSTM3A matrix. MVA independently supplied the TTAA with a graphical representation of the RSI screenlines and a definition of the movements considered to be "fully observed" in 35x35 sector format. Additionally, 35x35 sector matrices were also supplied for each stage of the prior matrix development.

3.4.20 It is noted by MVA that the movement between Edinburgh and Glasgow is not fully observed due to incomplete screenlines around both Edinburgh and Glasgow. The TTAA fully acknowledges the difficulties of collecting RSI data, particularly on the trunk road and motorway network. MVA has provided details which indicate that the proportion of trips between Edinburgh and Glasgow has remained reasonably consistent between the CSTM3A and TMfS trip matrices, which is encouraging to note. Nevertheless, given that these are the two major conurbations within TMfS, the lack of full observations for trips between these cities should be noted as a significant omission from the TMfS RSI database.

3.4.21 There were also instances where a movement could be theoretically considered as "fully observed" across a screenline but no such movements were captured by the RSI surveys. In this instance, the CSTM3A equivalent cell in the matrix was replaced with a zero. This was mainly evident for movements from Dundee to Ayrshire, Dumfries, Galloway/Scottish Borders. These movements were then subject to the "matrix smoothing" process to ensure all cells had a value of greater than zero.

3.4.22 The "Smoothed" matrix was created via a gravity model process utilising the unsmoothed matrices and highway costs for car in-work and car non-work purposes. The smoothed and unsmoothed matrices were then combined to create the pre-estimation matrix by combining 10% of the smoothed matrix with 90% of the unsmoothed matrix.

3.4.23 The smoothed matrices are presented in a 14 sector format in Tables 3.3, 3.6 and 3.9 of MVA's report. The TTAA has examined these to establish the scale of any infilled/adjusted movements using this smoothing process. The matrices are also presented at various stages of the development process in Appendix E of MVA's report in 14 sector format. This was subsequently augmented by the 35x35 sector breakdown of these trip matrices for each stage of the development process. The TTAA has the following comments on the review of all of those matrices for all processes up to and including matrix smoothing:

- Addition of the ASAM RSI data resulted in increased intra-sector 12 (i.e. ASAM area) trips (only) as expected in the 14 sector matrices. The 35 sector breakdown confirms that this trip increase corresponds to the sectors for Aberdeen City and Aberdeenshire
- It is noted that the incorporation of the ASAM and TMfS RSI data has resulted in increased trip totals for the North East, Fife and Ayrshire sectors as expected
- The addition of the TMfS RSI data results in a number of significant trip reductions on sector to sector movements (implying that the original CSTM3A matrices greatly overestimated such movements). This is particularly true for individual movements between Lothian and Edinburgh and between Glasgow and Strathclyde. This also appears to be the general trend for total movements to and from Edinburgh, Lothian, Glasgow, Strathclyde, Perthshire and Dundee. This is due to the incorporation of the TMfS RSI data providing fully observed trip patterns for movements between Lothian and Edinburgh, between Glasgow and Strathclyde and between Perth/Dundee and all areas, which were previously not present in CSTM3A
- The addition of the TMfS RSI data has altered trip totals only in cells defined by MVA as fully observed, as expected
- The most significant changes as a result of matrix smoothing are on the intra and inter Glasgow and Strathclyde sectors. Examination of the changes at the 35x35 sector level demonstrate that matrix smoothing has only altered 1 sector to sector movement by a "significant" ($\geq$ 100 PCUs & $\geq$ 15%) amount and this movement is unobserved

3.4.24 Having reviewed the trip matrices supplied, the TTAA is generally content that the changes incorporated at each stage of the prior matrix development were appropriate for TMfS.

Matrix Estimation

3.4.25 A process of matrix refinement was applied using matrix estimation to attempt to improve the fit between the trip matrix/assignment and observations. The data used in this process was the prior matrix, trip end data, assignment paths and traffic counts. Confidence levels were applied to specific movements in the matrix estimation process with the TMfS RSI data having the highest confidence, the ASAM/CSTM3A RSI data having slightly lower confidence (due to being older) and other areas of the matrix the lowest confidence.

3.4.26 The trip end data was given a lower confidence than that of the matrix as the confidence in the total zonal productions and attractions was considered to be low. The TTAA is content that this approach is intuitive. It should be noted, however, that no details of the actual confidence levels applied to each dataset in the matrix estimation process have been documented.

3.4.27 The paths used in the matrix estimation procedure were created during successive iterations between the matrix estimation and the highway assignment. The count information used in the estimation process was that collected for the RSIs, grouped into appropriate screenlines as depicted in Appendix D of MVA's report.

3.4.28 Details of the changes to the trip matrices following the matrix estimation procedure are provided in Tables 3.4, 3.7 and 3.10 and in Appendix E of MVA's report. The TTAA has the following observations on the outputs from the matrix estimation procedure:

- Trips between Edinburgh and Fife (both directions) have been subject to significant reductions (anything between -16% and -36% change in each time period) following matrix estimation. The RSI screenline locations, however, suggest that such movements would be fully observed
- Trips from Edinburgh to Lothian have been subject to significant change (+20%) in the AM peak. The RSI screenline locations, however, suggest that such movements would be fully (or substantially) observed
- Glasgow to Strathclyde trips in all time periods have been subject to significant changes (+2919, +1920 and +2032 for AM, IP and PM respectively)
- Other inter-sector movements which experience significant changes include Strathclyde to Central (AM & IP), Strathclyde to Ayr (AM & PM), Fife to Lothian (PM), Central to Lothian (IP), Lothian to Strathclyde (PM), Glasgow to Central (PM), Central to Strathclyde (PM) and Dundee to Perth (PM)
- Intra-North East sector trips have altered significantly in the inter and PM peaks despite this data being directly inherited from ASAM

3.4.29 MVA also supplied the post matrix estimation matrices in 35x35 sector format to enable a direct comparison with the prior matrices. The TTAA used this information to establish which sectors of the matrix were adjusted during matrix estimation and whether they were fully observed or not. The main objective of this exercise was to establish whether the most significant changes in both absolute and percentage terms resulting from matrix estimation have occurred in unobserved cells of the matrix, as would be expected.

3.4.30 The TTAA therefore established two criteria for defining "significant" changes on a sector movement as follows:

- Criterion 1 : Changes ≥ 100 PCUs and ≥ 15%
- Criterion 2 : Changes ≥ 200 PCUs and ≥ 15%

3.4.31 The following series of tables shows the sector movements (in 35x35 sector matrix format) which meet each of the above criteria. The shaded areas of the tables show movements which were defined as fully observed by MVA with all other cells being unobserved. The cells marked with *** depict the sector to sector movements where the changes resulting from matrix estimation match the criteria outlined above. Table 3.3 to 3.5 reflect criterion 1 whilst Tables 3.6 to 3.8 reflect criterion 2. The locations of the sectors are loosely described in Table 3.3.

Table 3.3 : AM Peak Matrix Estimation Changes ≥ 100 PCUs and ≥ 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
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8																																				West Central Fife
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28																													***							Dumfires & Galloway
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30	***														***						***											***	***		External (Scotland)
31																																				Aberdeenshire
32																																				Aberdeen City
33													***																		***					Falkirk
34									***		***							***	***		***									***							East Dunbartonshire
35														***	***																			***		South Lanarkshire

Table 3.4 : Inter Peak Matrix Estimation Changes ≥ 100 PCUs and ≥ 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
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Table 3.5 : PM Peak Matrix Estimation Changes ≥ 100 PCUs and ≥ 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
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Table 3.6 : AM Peak Matrix Estimation Changes ≥ 200 PCUs and ≥ 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
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Table 3.7 : Inter Peak Matrix Estimation Changes > 200 PCUs and > 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
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Table 3.8 : PM Peak Matrix Estimation Changes > 200 PCUs and > 15% (All vehicles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
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3.4.32 It is acknowledged that a certain amount of significant changes in the sector to sector movements would be expected to arise from the matrix estimation procedure for movements which were not fully observed. Examination of Tables 3.3 to 3.8 demonstrates that this is the case for a relatively small number of the unobserved movements as the majority of unshaded cells do not show significant changes. Those unshaded cells which do show significant changes are, however, anticipated and are considered as acceptable changes due to the matrix estimation procedure.

3.4.33 The evidence in Tables 3.3 to 3.8 also demonstrates that the majority of observed movements (shaded cells) have not been subject to significant changes during the matrix estimation process. This is encouraging and demonstrates that, for the most part, good working practice has been adopted when undertaking the matrix estimation procedure.

3.4.34 It is also evident, however, that in a number of cases, the matrix estimation procedure has adjusted observed sector to sector movements by significant amounts. Approximately the same number of fully observed and unobserved sector to sector movements have been subject to significant changes during matrix estimation. These changes on fully observed movements are considered contrary to good working practice as the underlying, observed trip levels have been adjusted during matrix estimation. It is encouraging to note that these significant changes to observed movements are only evident in a limited number of cases, hence, the majority of the underlying observations have been maintained.

3.4.35 From Tables 3.6 to 3.8, the observed movements which have been subject to the most significant changes are as follows:

- Fife to Edinburgh and Aberdeenshire
- Edinburgh to Lothian & Borders
- Stirling to Falkirk and North Lanarkshire
- South Lanarkshire to North Lanarkshire, Glasgow and South Lanarkshire
- North Lanarkshire to South Lanarkshire and Glasgow
- Inverclyde to East Dunbartonshire
- Renfrewshire to Inverclyde and External (Scotland)
- East Renfrewshire to Inverclyde
- Falkirk to Stirling
- Glasgow to South Lanarkshire

3.4.36 Overall, the TTAA is satisfied that the changes to unobserved movements during matrix estimation are acceptable and that the majority of fully observed movements have not been significantly altered by the matrix estimation process for TMfS. The TTAA does, however, have concerns over the significant changes which have occurred on a limited number of fully observed movements. Therefore, whilst the matrix estimation process may have resulted in a better fit between modelled and observed flows, this has been at the expense of eroding the quality of the underlying, observed elements of the matrix for a limited number of movements.

3.5 Assignment Model Development

3.5.1 The assignment procedure for TMfS is a volume averaged capacity restraint assignment based on All or Nothing (AoN) paths at each iteration. This is similar to that adopted for CSTM3A with the following exceptions:

- Four user classes are assigned in TMfS (Car in-work, car non-work, LGV and OGV) compared with two in CSTM3A (light and heavy)
- The assignment adopts the Davis method which allows for the modelling of tolls during the main assignment as opposed to developing a separate tolling model such as that for CSTM3

3.5.2 The TTAA's findings on the assignment model development are outlined as follows.

Assignment Procedure

3.5.3 The assignment procedure operates in an iterative manner assigning trips to AoN paths for *n* iterations until a predetermined convergence level is achieved. The flows are averaged over all paths and iterations to produce a volume averaged assignment upon model convergence.

3.5.4 This procedure is most appropriate for congested urban situations where multi-routeing is evident based on changing travel costs due to congestion. It is rightly pointed out by MVA in §4.2.3 that *"..an uncongested rural area will tend to give mono-routeing results because the low level of traffic compared with capacity and the reduced routeing choices, and so the best paths on the first iteration will stay best throughout assignment"*. This point was also raised during the audits of CSTM3 and CSTM3A and should be noted by users of TMfS for any assessment which involves examination of flows in rural areas.

3.5.5 The TTAA is content that the volume averaged capacity restraint assignment method adopted for TMfS is appropriate.

Cost versus Time Assignment Method

3.5.6 This new assignment methodology has been incorporated within TMfS to enable tolling tests to be undertaken without the requirement to develop a separate tolling model. The methodology adopted is based on the paper titled "Cost versus Time Equilibrium over a Network" by Fabien Leurent in the European Journal of Operational Research. The principle of this method is that the willingness to pay tolls is varied between iterations by randomly sampling from a distribution that represents the whole population. The principle of this is similar to a stochastic user equilibrium process.

3.5.7 The advantage of this method is that it negates the requirement to further disaggregate the assignment to represent differing willingness to pay bands, as was undertaken for Tolling CSTM3. A single, consistent version of the model is therefore used for all applications whether concerned with tolling or not. The TTAA acknowledges the advantages of the adopted assignment methodology in this regard.

3.5.8 The HAM convergence procedure for TMfS consequently requires to consider the tolling element of the generalised cost. At the time of calibrating the model, this convergence check was not in place, hence, the model was run for a fixed number of iterations assumed to be sufficient to achieve convergence. The fixed number of iterations were 80 for the AM and PM and 40 for the inter peak.

3.5.9 Overall, the TTAA is content that the CvT assignment technique is an appropriate one to use for TMfS and has obvious advantages compared with the previous separate version of Tolling CSTM3. The principles of the methodology outlined in section 4.3 of MVA's report are considered to be acceptable. MVA also supplied the TTAA with details of the distributions from which the willingness to pay for each user class was randomly sampled. The TTAA is content that the distributions and the resulting random sample values are acceptable.

3.5.10 It should also be noted that if the principles of the CvT assignment method (i.e. the Davis method) via a stochastic equilibrium assignment were applied to travel time costs, then this could be used to address the issues associated with mono-routeing on inter-urban routes (e.g. A68/A1 etc.). Consideration should be given to this issue for future developments of TMfS.

Model Convergence

3.5.11 Post-calibration of the TMfS HAM, a convergence criteria was adopted which considered the toll parameter within the generalised cost formulation. Consequently, tolling costs were added to the time and distance network costs to obtain the total costs on an iteration by iteration basis. A normalised regression statistic is then calculated which relates the cost in the current iteration to the total network cost.

3.5.12 The HAM is considered to have converged when the regression statistic is less than or equal to 0.01 on 3 successive iterations. The resulting, post-calibration TMfS HAM base year convergence using this methodology was achieved as follows:

- AM peak – 75 iterations
- Inter-peak – 33 iterations
- PM peak – 74 iterations

3.5.13 This is considered to be in the expected range for a model the scale of TMfS and with the level of user class disaggregation inherent within the model. It is noted that the convergence takes approximately twice the number of iterations compared with CSTM3A in the congested AM and PM peaks, but this is expected due to the addition of the stochastic, random sampling incorporated within the assignment procedure as well as the extended model area, the greater user class disaggregation and the addition of more observed data.

3.6 Changes Post Model Application

3.6.1 An early practical application of TMfS was commissioned by the Scottish Executive to review the tolled bridges across Scotland. This work highlighted an over-sensitivity in the route choice to changes in the tolls for the car non-work user class. Remedial action was taken by MVA to address this by changing the stochastic distribution, the highway network and trip matrices.

Car Non-Work Distribution Changes

3.6.2 The distribution of the values of time about the mean used in the CvT assignment was considered to give too wide a range around the mean for car non-work trips. Consequently, the distribution was altered based on information contained in paragraph R13 of the DfT's "Technical Report on Value of Travel Time Savings in the UK" upon which the DfT's guidance on values of time was based. As a result of this distribution change, adjustments to the network and matrices were required to recalibrate the base model.

3.6.3 MVA subsequently provided the TTAA with details of the changes to the CvT distribution for car non-work trips. The TTAA is generally satisfied that the changes appear to be appropriate, however, it is difficult to draw firm conclusions in the absence of details regarding the nature and scale of the network changes incorporated. The fact that such changes were incorporated post model calibration is also considered undesirable. The TTAA would therefore recommend that for future development and calibration of TMfS, sufficient sensitivity testing is built into the model development and calibration work programme to enable such changes to be incorporated into the model prior to finalising the calibration and validation of the HAM.

Network and Matrix Changes

3.6.4 Some adjustments to both the highway networks and trip matrices were applied by MVA to ensure that the change to the stochastic distribution for car non-work trips did not materially affect the base model calibration. MVA provide a limited description of these changes in §5.3.2 and 5.3.3 of their HAM Calibration and Validation report suggesting that the network changes were limited to the areas surrounding the tolled bridges. Furthermore, the matrices were adjusted by manipulating origin/destination movements which utilised the tolled bridges.

3.6.5 Details of the car non-work trip matrix changes were supplied to the TTAA in 14x14 sector format. Analysis of these matrices demonstrates that the changes were concentrated in expected areas likely to be affected by tolled bridges (e.g. trips to/from Fife and Dundee). The magnitude of the changes is also shown to be relatively small and therefore, the TTAA is satisfied that the adjustments incorporated are appropriate for TMfS.

3.6.6 Details of the location and nature of all network changes incorporated have not been supplied, hence, the TTAA cannot draw conclusions regarding the appropriateness of the network adjustments made.

3.7 Highway Model Calibration

3.7.1 The HAM for TMfS was subject to a wide area calibration process by comparing modelled and observed traffic flows at the RSI locations. Comparisons have been undertaken for individual link flows and screenline flows using the GEH statistic. DMRB Vol. 12a, Section 2, Part 4 sets out the highway assignment validation acceptability guidelines (ref. Table 4.2 in above section of DMRB). These guidelines are ideal standards for comparing modelled to observed flows for assignment modelling. These guidelines are replicated in Table 3.9 below.

Table 3.9 : DMRB Assignment Validation Acceptability Guidelines

Criteria and Measures	
<u>Assigned Hourly Flows compared with observed flows</u>	
1. Individual flows within 15% for flows 700-2,700 vph	)
	)
2. Individual flows within 100 vph for flows < 700 vph	) > 85% of cases
	)
3. Individual flows within 400 vph for flows > 2,700 vph	)
4. Total screenline flows (normally > 5 links) to be within 5%	All (or nearly all) screenlines
5. GEH Statistic:	
i) individual flows : GEH < 5	> 85% of cases
ii) screenline (+) totals : GEH < 4	All (or nearly all) screenlines
<u>Modelled Journey Times compared with observed times</u>	
6. Times within 15% (or 1 minute if higher)	> 85% of routes

3.7.2 Rather than adopting the DMRB guidelines, MVA adopted a series of calibration targets which they consider better reflected the model scale and intended purpose. These targets are for link flow and screenline comparisons to meet:

- GEH<5 - 60% of all sites (DMRB guidance is 85%)
- GEH<7 – 80% of all sites
- GEH<10 – 95% of all sites
- GEH<12 – 100% of all sites

3.7.3 These targets are consistent with those adopted for CSTM3/3A and are also considered appropriate for TMfS. The less stringent nature of the adopted calibration targets compared with DMRB guidelines should, however, be noted.

Key Strategic Screenline Flows

3.7.4 Three key strategic screenlines were defined in the TMfS area for the Forth Estuary, the River Clyde and the River Tay. The Forth Estuary screenline covers the Forth Road Bridge, the Kincardine Bridge and the forth crossing at Stirling. The model demonstrates good calibration across the screenline in both directions in all time periods with GEH values all lying in the range between 0.1 and 3.8.

3.7.5 The Clyde strategic screenline covers all river crossings from Albert Bridge in the east to the Erskine Bridge in the west. This screenline demonstrates a generally good level of calibration with four out of six (IP and PM northbound and AM and IP southbound) GEH values of 2.3 or less. The AM peak northbound GEH is 5.3 largely due to a significant overestimate of flow (approx. +1000 PCUs) on the Kingston Bridge. The PM peak southbound GEH is 7.8 which is attributable to a general tendency for modelled flows to be low on the eastern part of the screenline (i.e. between Kinston Bridge and Albert Bridge).

3.7.6 The Tay strategic "screenline" in fact covers only the Tay Bridge, however, the level of calibration is demonstrated to be good in both directions in all time periods with GEH values falling in the range 1.8 to 3.5.

3.7.7 Overall, the strategic screenline calibration comparisons demonstrate a good level of calibration in most cases. Users of TMfS should be aware of the overestimated flow on the Kingston Bridge northbound in the AM peak and for the general tendency for southbound flows across the Clyde screenline in and around Glasgow city centre in the PM peak to be low.

Other Screenline Flows

3.7.8 The other calibration comparisons undertaken have concentrated on what are termed as "key links" and "multi-point" screenlines. The key links covers the major key trunk and principal roads within the TMfS model area. The multi-point screenlines are where groups of individual link flows have been combined to form screenlines. In some cases, the individual key link flows are included in these screenlines.

3.7.9 The TTAA notes that from the diagrams presented in Appendix D and the tables presented in Appendices F to H, it is difficult to establish in some cases exactly which links are included in some screenlines or to which screenline some of the labels refer. Equally, the descriptors in the tables in Appendices F to H are often quite ambiguous for a given link. For example, screenline 80, which appears to cover the M8 directly west of Junction 1 at Hermiston Gait has the link description in the tables of *"City of Edinburgh"*.

3.7.10 This is a general trend for a number of key links in the study area (e.g. "City of Glasgow", "West Lothian" used as descriptors rather than site locations such as "Kingston Bridge" and "M8 between J2 & J3"). There is, for example, no link descriptor in any table which identifies a link as being on the M8. The TTAA considers this a hindrance for any reader of the documentation who wishes to identify the level of validation either on a given key link (or links) or generally within a given area. It is therefore recommended that the tables and screenline graphics be updated to be more explicit in referencing individual links. This information should then be made available either through updated documentation or by adding the relevant tables and GIS files to the User group area of the TMfS website.

3.7.11 The key link flow calibration is demonstrated in Table 3.10 below.

Table 3.10 : Key Link Flow Calibration

Time Period	% of sites with GEH value ≤5	≤7	≤10	≤12	≤15
Target	**60%**	**80%**	**95%**	**100%**	**100%**
AM	60	75	90	95	99
IP	75	89	96	99	100
PM	62	78	92	97	99

3.7.12 The key link flow calibration table demonstrates that the targets are met in almost all cases for the inter-peak model. In the AM and PM peak, the GEH ≤5 target is met with all other targets being narrowly missed. Globally across the network, this demonstrates an acceptable level of calibration to link flows for a model such as TMfS.

3.7.13 The multi-point screenline analysis summary is presented in Table 3.11 below.

Table 3.11 : Multi-Point Screenline Calibration

Time Period	% of sites with GEH value ≤5	≤7	≤10	≤12	≤15
Target	**60%**	**80%**	**95%**	**100%**	**100%**
AM	57	81	94	95	100
IP	78	88	95	98	100
PM	71	79	92	96	99

3.7.14 This demonstrates that the inter peak model meets or almost meets every target whilst the PM peak model meets the ≤5 target and narrowly fails to meet all other targets. The AM peak model fails to meet the ≤5 target and either meets or narrowly fails to meet all other targets. Again, at a global level, the TTAA considers this to be an acceptable level of calibration for TMfS.

3.7.15 MVA provided the TTAA with an independent, more detailed breakdown of the calibration analysis by area. This analysis grouped the various screenlines within each area and compared them against the GEH targets. The areas provided were Edinburgh, Glasgow City Centre/East/West, Forth Estuary, Tayside and Aberdeen. This analysis demonstrated the following points:

- Edinburgh and Tayside demonstrate good calibration in all time periods with virtually all GEH targets being met
- Glasgow city centre and the Forth Estuary demonstrate good calibration in the inter and PM peaks and a slightly lower level of calibration in the AM peak with the GEH ≤5 target being missed in the AM. The GEH ≤7 target is, however, met in the AM demonstrating that the calibration is only slightly outwith the target level
- Glasgow East, Glasgow West and Aberdeen all demonstrate poor calibration in the AM and PM peaks with the GEH ≤5 and GEH ≤7 targets being missed in each of these areas. The inter-peak calibration is acceptable in each of these areas

3.7.16 The global level of calibration for all of the counts used in the TMfS HAM calibration is presented in Table 3.12 below.

Table 3.12 : TMfS Global Link Flow Calibration

Time Period	% of sites with GEH value ≤5	≤7	≤10	≤12	≤15
Target	**60%**	**80%**	**95%**	**100%**	**100%**
AM	60	76	90	95	99
IP	72	85	94	97	99
PM	60	75	89	94	98

3.7.17 This demonstrates that globally, TMfS achieves its most stringent targets in the inter peak and only narrowly fails to meet the less stringent ones in this time period. The global level of AM and PM peak calibration is broadly the same with the most stringent GEH ≤5 target just being met in both cases. All other GEH targets are missed by a relatively small margin for the AM and PM peaks. Overall, the TTAA considers that the inter peak model is well calibrated and that the AM and PM peak models are considered to be more or less acceptable at a global level.

3.7.18 Regionally, the calibration is demonstrated to at its best in Edinburgh and Tayside and generally good in Glasgow city centre and the Forth Estuary for all except the AM peak which is slightly below the target standard. The calibration is shown to be poor in Glasgow East, Glasgow West and Aberdeen for both the critical AM and PM peaks.

Calibration Summary

3.7.19 The TTAA has undertaken an independent check of the TMfS calibration against the various DMRB assignment validation acceptability guidelines (ref. Table 3.9 above). The results of this comparison are presented in Table 3.13 below.

Table 3.13 : TMfS Calibration Compared with DMRB Criteria

Criteria	**AM**	**IP**	**PM**	*DMRB Acceptability Guidelines*
1) Individual flows within 15% for flows 700 – 2,700 vph	61%	80%	63%	*>85%*
2) Individual flows within 100 vph for flows <700 vph	65%	76%	67%	*>85%*
3) Individual flows within 400 vph for flows >2700 vph	70%	78%	74%	*>85%*
4) Total Screenline flows (normally > 5 links) to be within 5% *	16%	18%	25%	*All (or nearly all) screenlines*
5)(i) Individual flows : GEH < 5	60%	72%	60%	*>85%*
5)(ii) Screenline Totals : GEH < 4 *	43%	59%	54%	*All (or nearly all) screenlines*

* Based on all local area screenlines combined

3.7.20 The TTAA recommends that all future model development and calibration reports for TMfS and any derivatives present a table similar to Table 3.13 above which demonstrates the model's level of calibration against all of the DMRB target guidelines. This table could also be expanded to include alternative target levels which may be considered more appropriate for the model in question.

3.7.21 This independent check demonstrates that the model calibration is outwith the DMRB guideline targets in all cases although it is encouraging to note that the number of individual flows approaching the DMRB targets is generally quite high in all time periods (ref. criteria 1, 2, 3 & 5(i)). The model is furthest from meeting the DMRB criteria for screenline flows (ref. criteria 4 and 5(ii)).

3.7.22 Overall, it is not considered surprising that the level of calibration for TMfS is below the ideal DMRB target guidelines given the scale and nature of the model and the stringent targets in DMRB. It is also encouraging that the individual link flow DMRB targets are met in a minimum of 60% of cases for all time periods. The generally lower level of calibration across screenlines should be noted by potential users of TMfS.

3.7.23 The calibration comparisons generally demonstrate that TMfS has achieved an acceptable level of calibration to link flows and screenlines on a global basis across the model. The key link and strategic screenline analysis has also demonstrated a generally acceptable level of calibration, albeit at a level below the ideal DMRB target guidelines and below that achieved for CSTM3A. Users of TMfS should take cognisance of the poor areas of calibration identified, particularly when considering the potential application of the model for schemes in the east or west of Glasgow or in Aberdeenshire.

3.7.24 Given the geographical variation in the level of calibration achieved in TMfS and the difficulties outlined above in readily identifying individual link flow comparisons from the tables and graphics presented, the TTAA considers that a graphical form of presentation of the calibration should be made available to enable prospective users of TMfS to more readily identify and understand the calibration at a local area and individual link level. The information presented should include, but not be restricted to, the following:

- colour coded GEH comparisons (by target bin e.g. $\leq$5, $\leq$7 etc.) for all calibration link flows individually by time period
- as above, but separately for the strategic, key link flow and multi-point screenlines

3.7.25 Again, this should be made available either via updated documentation or (more likely) via the user group area of the TMfS website.

3.8 Validation

3.8.1 Independent validation of the TMfS HAM has been undertaken by comparing modelled and observed journey times, independent traffic counts not use in the calibration and by examining the trip length distribution. A comparison of modelled to observed HGV flows across screenlines has also been undertaken. The various aspects of the independent validation are considered as follows.

Journey Times

3.8.2 Based on the data provided in Appendices K and L of MVA's report, the TTAA has summarised the journey time validation in Table 3.14 below showing how many routes fall within the 95% confidence intervals of the observed sample on an area by area basis. This demonstrates that the majority of modelled journey times are within the 95% confidence interval of the observed sample for each area and in all time periods with the exception of the inter-urban routes in the PM peak. Overall, this is considered to represent an acceptable level of validation to journey times.

Table 3.14: Summary of Journey Time Validation

		Number within 95% CI of observed		
Area	***Number of Routes***	**AM**	**IP**	**PM**
Edinburgh Urban	*14*	13	12	11
Glasgow Urban	*82*	66	62	59
Aberdeen Urban	*4*	4	4	4
Inter-Urban	*14*	11	10	5

3.8.3 From the results in Appendix L (Inter-Urban Journey Time Segments), 76% of journey time segments fall inside the 95% confidence interval in the AM peak, 60% in the Inter Peak and 64% in the PM peak. Again, this is considered to demonstrate an acceptable level of journey time validation for TMfS.

3.8.4 MVA subsequently provided details of the journey time validation comparisons against the DMRB assignment validation acceptability guideline that 85% of modelled journey times should be within 15% of observed (or 1 minute if higher). This is summarised in Table 3.15 below.

Table 3.15 : Journey Time Validation to DMRB Criteria

		Number within 15% (or 1 minute if higher)		
Area	***Number of Routes***	**AM**	**IP**	**PM**
Edinburgh Urban	*14*	64%	86%	57%
Glasgow Urban	*82*	74%	83%	68%
Aberdeen Urban	*4*	75%	75%	50%
Inter-Urban	*14*	100%	100%	86%

3.8.5 The comparison against DMRB criteria demonstrates that the inter-urban routes meet the criteria in all time periods. The Edinburgh Urban routes also meet DMRB criteria in the inter-peak, whilst the Glasgow Urban routes fall only slightly short of the criteria in the inter-peak. Both Edinburgh and Glasgow Urban routes fall short of the DMRB criteria in the AM and PM peaks with the PM peak showing the lowest level of validation. The Aberdeen Urban routes fall short of the DMRB criteria in all time periods with the PM peak showing the lowest level of validation.

3.8.6 Overall, the level of validation to journey times is considered acceptable for a model of the scale and nature of TMfS. Inter-urban journey time validation is shown to be acceptable in all time periods whilst validation in urban areas generally falls short of DMRB criteria during the AM and particularly the PM peak. The majority of modelled journey times fall within the 95% confidence intervals of the observed ranges, therefore the level of validation to journey times is considered acceptable.

Flow Validation

3.8.7 Table 3.16 shows the independent validation results for all screenlines in TMfS.

Table 3.16 : TMfS Validation Summary

% of Screenlines With GEH Value					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	55%	70%	87%	94%	98%
IP	62%	76%	90%	96%	99%
PM	52%	68%	83%	92%	98%

3.8.8 It can be seen that the TMfS validation narrowly fails to meet the targets in both the AM and PM peaks for comparisons with GEH < 5, whereas it meets this target in the Inter Peak. None of the validation statistics meet the target of GEH < 10. Given the nature of TMfS, the TTAA considers this to be an acceptable level of independent validation.

3.8.9 A geographical breakdown of the TMfS independent validation is shown in Table 3.17.

Table 3.17 : TMfS Area Validation

% of Screenlines With GEH Value - Edinburgh					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	70%	80%	90%	90%	100%
IP	60%	70%	100%	100%	100%
PM	60%	80%	90%	100%	100%

% of Screenlines With GEH Value - Glasgow CC					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	55%	64%	73%	82%	91%
IP	45%	73%	91%	100%	100%
PM	9%	18%	27%	64%	100%

% of Screenlines With GEH Value - Glasgow East					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	70%	90%	90%	100%	100%
IP	90%	100%	100%	100%	100%
PM	50%	60%	80%	100%	100%

% of Screenlines With GEH Value - Forth Estuary					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	67%	100%	100%	100%	100%
IP	67%	67%	100%	100%	100%
PM	67%	83%	100%	100%	100%

% of Screenlines With GEH Value - Glasgow West					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	33%	50%	67%	67%	100%
IP	67%	67%	100%	100%	100%
PM	33%	67%	67%	83%	100%

% of Screenlines With GEH Value - Tayside					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	43%	43%	71%	86%	100%
IP	57%	100%	100%	100%	100%
PM	86%	86%	100%	100%	100%

% of Screenlines With GEH Value - Aberdeen					
Time Period	<5	<7	<10	<12	<15
Target	60%	80%	95%	100%	100%
AM	75%	75%	100%	100%	100%
IP	75%	100%	100%	100%	100%
PM	50%	75%	75%	100%	100%

3.8.10 It can be seen that areas such as the Forth Estuary, Edinburgh and Glasgow East demonstrate generally good validation in all time periods. Specific areas of poor validation are the AM and PM peaks for Glasgow West, the AM peak for Tayside, and the inter and PM peaks for Glasgow city centre.

3.8.11 An independent comparison of the TMfS validation against the various DMRB assignment validation acceptability guidelines (ref. Table 3.9 above) has been undertaken by the TTAA. The results of this comparison are presented in Table 3.18.

Table 3.18 : TMfS Validation Compared with DMRB Criteria

Criteria	**AM**	**IP**	**PM**	*DMRB Acceptability Guidelines*
1) Individual flows within 15% for flows 700 – 2,700 vph	63%	61%	55%	>85%
2) Individual flows within 100 vph for flows <700 vph	62%	72%	58%	>85%
3) Individual flows within 400 vph for flows >2700 vph	63%	100%	82%	>85%
4) Total Screenline flows (normally > 5 links) to be within 5%	76%* 56%** 62%***	84%* 66%** 67%***	80%* 57%** 67%***	All (or nearly all) screenlines
5)(i) Individual flows : GEH < 5	55%	62%	52%	>85%
5)(ii) Screenline Totals : GEH < 4 *	52%	54%	41%	All (or nearly all) screenlines

* - Cars in Work
** - Cars Non Work
*** - HGV

3.8.12 The analysis in Table 3.18 demonstrates that the level of independent validation achieved is similar to, and in some cases better than, the level of calibration achieved compared with DMRB guidelines. Furthermore, this provides verification that the HGV flows and the car in-work and non-work flows across screenlines represent a reasonable level of validation for TMfS.

3.8.13 Overall, the TTAA is content that, in light of the generally good level of calibration achieved, the level of global independent validation achieved for TMfS is acceptable. Users of TMfS should take cognisance of the poor areas of validation identified, particularly when considering the potential application of the model for schemes in Glasgow city centre, the west of Glasgow or in Tayside.

3.8.14 Similar to the calibration, the TTAA considers that it would be of benefit to potential users of TMfS for a graphical representation of the validation to be made available to enable prospective users of TMfS to more readily identify and understand the validation at a local area and individual link level. The information presented should include, but not be restricted to, the following:

- Colour coded GEH comparisons (by target bin e.g. $\leq$5, $\leq$7 etc.) for all validation link flows individually by time period
- As above, but separately for the HGV, car in-work and car non-work screenlines
- Details of the journey time validation including comparisons with DMRB acceptability guidelines

3.8.15 Again, this should be made available either via updated documentation or (more likely) via the user group area of the TMfS website.

Trip Length Distribution

3.8.16 The trip length (cost) distributions for each assignment user class and time period are presented in Appendix P of MVA's report. These demonstrate intuitively correct trends with goods vehicles generally having a greater spread of trip costs compared with car trips. It is also encouraging to note that the post-MVESTM trip length distributions do not appear to have altered significantly from the pre-MVESTM distributions. This provides some validation that the matrix estimation procedure has not unduly altered the trip pattern in the matrices (e.g. by unduly satisfying target counts in the estimation procedure by factoring up shorter distance trips).

3.9 Summary of TMfS HAM Calibration/Validation

3.9.1 The TTAA has reviewed the development, calibration and validation of the TMfS HAM. A summary of the main findings is as follows.

Network Development

3.9.2 Generally, the network development in terms of coverage, connectivity, link length coding and speed/flow curve definition is considered acceptable for TMfS. The TTAA does have concerns, particularly for future year applications, regarding the apparently very low capacities coded for many link types within the TMfS study area. This is unlikely to affect some strategic, broad brushed applications, however, it is likely to have an influence when considering analysis of any outputs at a more local level.

Trip Matrix Development

3.9.3 The TMfS trip matrix development has been undertaken using existing trip matrices from CSTM3A supplemented with new RSI data collected for ASAM and TMfS. The matrices were also subject to refinement through matrix estimation. The TTAA is generally content that the appropriate data and processes have been applied in creating the TMFS HAM matrices.

3.9.4 Having reviewed the trip matrices supplied, the TTAA is generally content that the changes incorporated at each stage of the prior matrix development were appropriate for TMfS.

3.9.5 Overall, the TTAA is satisfied that the changes to unobserved movements during matrix estimation are acceptable and that the majority of fully observed movements have not been significantly altered by the matrix estimation process for TMfS. The TTAA does, however, have concerns over the significant changes which have occurred on a limited number of fully observed movements. Therefore, whilst the matrix estimation process may have resulted in a better fit between modelled and observed flows, this has been at the expense of eroding the quality of the underlying, observed elements of the matrix for a limited number of movements.

Assignment Model Development

3.9.6 The TMfS HAM has been developed along similar lines to that of CSTM3A with improvements to include a greater level of user class disaggregation and also the use of a stochastic method for modelling willingness to pay tolls. The TTAA is satisfied that these improvements are appropriate for TMfS. The TTAA is also satisfied that the CvT distributions and the convergence criteria adopted are appropriate for TMfS.

Changes Post Model Application

3.9.7 Some changes were made post-model application to the car non-work stochastic distribution for toll costs and also to the highway networks and matrices. These resulted from evidence of over sensitivity in the modelled response for car non-work trips to changes in bridge tolls over the Forth, Tay and Clyde. The TTAA is satisfied that the changes to the CvT distribution and the extent and magnitude of the matrix adjustments for car non-work trips are acceptable for TMfS.

Details of the local network adjustments made post model application have not been supplied, hence, the TTAA cannot draw conclusions regarding these changes.

Model Calibration

3.9.8 The TMfS HAM has been calibrated to traffic flows at the various RSI sites from which the observed trip matrices were developed. The calibration has considered key strategic screenlines, key link flows, multi-point screenlines as well as all link flow comparisons combined. Additionally, MVA provided the TTAA with a breakdown of the calibration on a geographical basis.

3.9.9 The calibration comparisons generally demonstrate that TMfS has achieved an acceptable level of calibration to link flows and screenlines on a global basis across the model. The key link and strategic screenline analysis has also demonstrated a generally acceptable level of calibration, albeit at a level below the ideal DMRB target guidelines and below that achieved for CSTM3A. Users of TMfS should take cognisance of the poor areas of calibration identified, particularly when considering the potential application of the model for schemes in the east or west of Glasgow or in Aberdeenshire.

Model Validation

3.9.10 The TMfS HAM has been validated to journey time data, count data not used in the model calibration and the trip length distribution. The journey time validation meets DMRB criteria for inter-urban journeys in all time periods whilst the urban journey time validation is generally outwith the DMRB criteria in the AM and particularly the PM periods. The majority of journey times fall within the 95% confidence intervals of the observed samples, hence, overall the journey time validation is considered acceptable for TMfS.

3.9.11 The validation to independent link flows has been presented for individual link flows and for screenlines, as well as supplementary validation of car in-work and non-work and HGV screenlines. The screenline comparisons have also been presented with the same geographical breakdown as per the calibration.

3.9.12 Overall, the TTAA is content that, in light of the generally good level of calibration achieved, the level of global independent validation achieved for TMfS is acceptable. Users of TMfS should take cognisance of the poor areas of validation identified, particularly when considering the potential application of the model for schemes in Glasgow city centre, the west of Glasgow or in Tayside.

3.9.13 The trip length distribution analysis presented also demonstrates intuitively correct trends and do not appear to have been significantly altered during the matrix estimation procedure.

4 PUBLIC TRANSPORT NETWORK AND SERVICES

4.1 Introduction

4.1.1 This chapter presents the TTAA's findings relating to TMfS Audit Task 5 : Public Transport Network and Services. The TTAA produced Audit Inquiry Note, AIN5-1 (TTAA ref. 57055) to raise specific data requests and/or queries regarding this audit task. MVA responded by providing the appropriate information in various formats as requested along with Information Note No. AN5-1b_GP and Information Note No. AIN5-1_1b_GP. The findings in this chapter are based on a review of the specific information supplied in response to AIN5-1 and on the basis of various discussions with MVA during the audit process.

4.2 Public Transport Network

4.2.1 MVA provided the TTAA with a copy of the TMfS network in TRIPS format, which enabled an analysis of the network to be undertaken.

4.2.2 The public transport road network is consistent with the TMfS highway network with the exception of some minor speed and capacity changes due to bus lanes in specific areas. The TTAA is satisfied with these aspects of the public transport network coding.

4.2.3 The TTAA acknowledges that the significant changes to the TMfS public transport network (compared with CSTM3A) are:

- extension in north-east to Aberdeen
- extension of the train line to the new stations at Brunstane and Musselburgh located in the south east of Edinburgh
- services through Glasgow Central station have been split into high and low level service
- an overview of the rail station connectors was also undertaken and any changes made
- the addition of the Renfrew to Yoker foot ferry
- complete review of all public transport services to recode and update to 2002

4.2.4 The extent and coverage of the PT (bus and rail) network is considered to be appropriately representative of the existing network within the main internal TMfS study area.

4.2.5 It is worth noting that the Perth-Inverness (and further north) line is curtailed in Perthshire (around Dunkeld) rather than extending into the external model area. Similarly, Glasgow to Fort William (and onwards to Mallaig in the north) is curtailed at Crianlarich rather than extending into the external model area. The rail spur between Crianlarich and Oban has also been omitted from the PT model network, although bus services do extend to Oban. There are, however, external zone connectors which link into Crianlarich and Dunkeld railway stations, hence, the network connectivity allows patrons to use rail services from these stations.

4.2.6 All main west coast ferry terminals within the main internal model area appear to be served by the relevant PT links (e.g. Gourock, Ardrossan, Stranraer etc.) with the exception of Oban, which has rail links omitted. Given Oban's proximity to the internal/external model boundary (the zone straddles the boundary), this is unlikely to be a significant issue for most applications of TMfS.

4.3 Public Transport Services

4.3.1 The TTAA received a list of all the bus, rail and ferry companies where services have been included in TMfS. In total there are 41 bus companies coded within TMfS. Table 4.1 shows the breakdown of the bus services by Mode type in TMfS.

Table 4.1: TMfS Public Transport Services

Mode	AM Peak	Inter Peak	PM Peak
Urban Bus	470	462	466
Inter-Urban Bus	400	590	371
Rail	139	274	139
Underground	2	2	2
Ferry	2	2	2
Total	**1013**	**1330**	**980**

4.3.2 Table 4.2 shows the breakdown of the bus services by mode type within CSTM3A.

Table 4.2: CSTM3A Public Transport Services

Mode	AM Peak	Inter Peak	PM Peak
Urban Bus	774	1262	762
Inter-Urban Bus	69	149	84
Rail	122	204	114
Underground	2	2	2
Ferry	-	-	-
Total	**967**	**1617**	**962**

4.3.3 The total number of PT services has remained broadly the same between CSTM3A and TMfS in the AM and PM peaks particularly. The inter-peak services have reduced by around 18% between CSTM3A and TMfS although it is unclear from the report as to why this has occurred.

4.3.4 MVA has subsequently confirmed that *"…due to the nature of the model, the public transport services that were coded were aimed towards providing the most strategic routes between the main towns and cities in Scotland…The previous services in CSTM3A included smaller localised services in those areas that are not included in TMfS in as much detail. It must be noted that CSTM3A included more detailed network structure within three corridors and therefore more local services were coded in the inter-peak. In addition, it can be the case that some operators are also running less frequent inter-peak services since the Public Transport coding was last undertaken for CSTM3A"*. The TTAA is therefore satisfied that the changes in the level of inter-peak bus service representation between CSTM3A and TMfS are acceptable.

4.3.5 The most obvious difference between CSTM3A and TMfS is, however, the split between urban and inter-urban bus services. The split has changed from approximately 90% urban, 10% inter-urban for all time periods in CSTM3A to approximately 55% urban, 45% inter-urban for the AM and PM peaks and 44% urban, 56% inter-urban for the interpeak in TMfS.

4.3.6 MVA has subsequently confirmed that *"…the inter-urban services cover the rural services in the model as well as the dedicated inter-urban services such as Edinburgh to Glasgow…inter-urban bus were called so due to the geographic nature of their routes, i.e. they were not exclusively operating within an urban area such as Edinburgh. Although a service may be coded as inter-urban, the public transport model shows that inter-urban services have an intense stopping pattern at the majority of nodes along its path. Local services that operate in and around Edinburgh and Glasgow have been coded as urban buses and operate with an urban fare table. Those services classified as inter-urban are given an inter-urban fare table"*.

4.3.7 The TTAA is satisfied that this definition of urban and inter-urban services is appropriate for TMfS.

4.4 Rail Services

4.4.1 The TTAA reviewed the timetables and route coding of the following Railway services concentrating specifically on the stopping locations and the timetabled stopping times:

- Glasgow - Edinburgh via Falkirk
- Glasgow - Aberdeen / Dyce
- Edinburgh - Aberdeen / Dyce
- Aberdeen - Inverness
- Edinburgh / Glasgow - Falkirk Grahamston / Dunblane / Perth
- Edinburgh - Bathgate
- Edinburgh - Dunfermline - Kirkcaldy – Edinburgh

4.4.2 The TTAA is satisfied that the coding of the above services is acceptable for the purposes of modelling rail travel within TMfS.

4.5 Bus Services

4.5.1 The TTAA reviewed the timetables and route coding of the following Bus services:

- Glasgow – Edinburgh (Citylink)
- Torphin - Newhaven (Service 10, Lothian, Edinburgh)
- Edinburgh Park – Bathgate (First Edinburgh)
- Blairdardie – East Kilbride (Services 16, 16A and 18, First Glasgow)
- Glasgow – Ayr (Stagecoach)
- Perth – Dundee (Citylink)
- Dundee – Aberdeen (Citylink)
- Kilmarnock – Stevenston (First)

4.5.2 The TTAA is satisfied that the coding of the above services is acceptable for the purposes of modelling bus travel within TMfS.

4.6 Bus Operators

4.6.1 The TTAA has reviewed the bus operators contained within TMfS.

4.6.2 A number of bus operators have not been included within TMfS. The exclusion of a number of operators may be due to their location or services provided, e.g. D and E Coaches which is based in the Inverness area (i.e. external model area), and West Coast Motors which provides a largely rural service in Argyll. However, a number of companies (some of which are considered significant) operating within the TMfS modelled area have been omitted, as summarised below. It is the case for a number of these companies, such as Munros of Jedburgh, that their exclusion along with others removes important public transport services from a given area, in this case the south east Borders region (and also links with the north of England). Equally, the First Aberdeen and Strathtay Scottish services cover a significant number of routes intra-Aberdeenshire and intra-Perth/Dundee/Angus respectively which will not be reflected in TMfS.

Table 4.3: Bus Services omitted from TMfS

Company	Area
Alex Wait and Son	East Borders
Bulldog Travel	West Lothian (Livingston, Bathgate etc.)
Earnside Coaches	Perth & Kinross
First Aberdeen	Aberdeen and surrounds
Henderson Travel	Glasgow conurbation
MacEwan Coaches	Edinburgh/Dumfries links, Lanarkshire
Megabus	City links
MacEwan's Coaches	Dumfries area, Edinburgh-Peebles/Dumfries)
Meffans Coaches	Angus and Perth & Kinross
Munro of Jedburgh	South East Borders, links to North England in the east
Perrymans	Berwick Upon Tweed, Eyemouth, Edinburgh
Rowe's Coaches	Ayrshire (Cumnock, Dalmellington etc.)
Shuttle Busses	Ayr, West Coast
Strathtay Scottish	Dundee and Angus
Swans Coaches	South East Borders, links to England in the east
Travel Dundee	Dundee and surrounds
Telford Coaches	Links Borders to England in the west
West Coast Motors	Argyll (Inveraray, Lochgilphead, Campbelltown etc.)

4.6.3 It is acknowledged that changes to public transport operations has occurred between the time the routes were coded and the time the audit was undertaken for example Fife Scottish and Western Scottish services are now run by Stagecoach.

4.6.4 MVA has confirmed that due to network (and zoning) detail in TMfS a number of the services were omitted as it would be difficult to provide a reasonable representation of the services in the model. In particular, the intra-Aberdeen and Strathtay services were affected by the network detail issues and were consequently omitted. Stagecoach inter-urban services to areas outlying Aberdeen (e.g. Ballater, Inverurie etc.) were, however, included in TMfS. Strathtay inter-urban services such as Dundee to Perth via Errol have also been omitted due to network detail, however, Stagecoach and Citylink services have been coded to stop at zone centroids on the main A90, thereby enabling passengers to access inter-urban services on this corridor.

4.6.5 The TTAA acknowledges these reasons for omitting such services and considers them acceptable given the more strategic focus of TMfS. Nevertheless, the TTAA considers that this general lack of detail of bus service representation, particularly in the Tayside and Aberdeen areas should be borne in mind by potential users of TMfS.

4.7 Summary of Public Transport Coding Audit

4.7.1 The main points from the TTAA's review of the TMfS public transport coding are as follows:

- The general coverage of the public transport bus and rail network is acceptable for TMfS. It should be noted that the Perth to Inverness and Glasgow to Fort William lines has been curtailed at Dunkeld and Crianlarich respectively, albeit that zonal connectivity allows passengers to access rail services at Dunkeld and Crianlarich. The Crianlarich to Oban spur has also been omitted. These are unlikely to be significant for most TMfS applications but their omission should be noted
- The TTAA considers the definition of urban and inter-urban buses in TMfS to be acceptable

- The TTAA is generally satisfied that from the sample of rail services checked, the coding is acceptable for TMfS
- The TTAA is generally satisfied that from the sample of bus services checked, the coding is acceptable for TMfS
- The TTAA acknowledges that a number of bus services have been omitted due to network detail prohibiting a realistic representation of these services. This is acceptable given the more strategic focus of TMfS. Nevertheless, the TTAA considers that this general lack of detail of bus service representation, particularly in the Tayside and Aberdeen areas should be borne in mind by potential users of TMfS

5 PUBLIC TRANSPORT ASSIGNMENT MODEL

5.1 Background

5.1.1 This chapter presents the TTAA's findings relating to TMfS Audit Tasks 6, 7 & 8 : Review Public Transport Assignment Model Development/Trip Matrix Development/Validation. The TTAA will use the acronym PTM to refer to the TMfS Public Transport Model throughout this chapter.

5.1.2 The TTAA produced Audit Inquiry Note, AIN6-1 (TTAA ref. 60168) to raise specific data requests and/or queries regarding this audit task. MVA responded by providing the appropriate information in the TMfS "Public Transport Model – Development and Validation Draft Report", Issue 7, 29 October 2004. Additionally, all requested Public Transport (PT) network files were made available through the TMfS website www.tmfs.org.uk. Information Note No AN6-1b_GP_IW_CPv4 was also supplied by MVA. The findings in this chapter are based on a review of the specific information supplied, and on the basis of various discussions with MVA during the audit process.

5.1.3 The TTAA's comments regarding the TMfS PTM are listed in the following sections of this chapter. The section headings correspond with the chapter headings from MVA's Public Transport Model – Development and Validation Draft Report.

5.2 Introduction

5.2.1 The introductory chapter of MVA's report initially sets out the background and overview of the PTM development. The TTAA has no substantive comments on this aspect of MVA's report. An overview of the PT model zoning system, modelled time periods and journey purpose correspondence is also provided. The TTAA is content that these are appropriately described and are suitable for TMfS.

5.3 Public Transport Network Development

5.3.1 The PT network description and coding is also the subject of more detailed discussion in Chapter 4. The comments in this section relate specifically to the information in Chapter 2 of the TMfS PT Model – Development and Validation Draft Report.

Network Data File

5.3.2 The physical PT network is based on that for the Highway Assignment Model (HAM) with the addition of the appropriate heavy rail/underground links and walk connections between rail/underground stations and the highway network. The link type descriptions used in TMfS have altered from those used in CSTM3A. This was undertaken consistently for both the TMfS HAM and PTM to ensure greater consistency with the link types described in the Scottish Transport Statistics.

5.3.3 The only obvious addition to the PTM link types between CSTM3A and TMfS is a specific link type to represent the Renfrew-Yoker foot ferry. The TTAA is satisfied that the link types described in the PTM for TMfS are appropriate.

5.3.4 Notwithstanding the the TTAA's findings regarding the PT network coverage outlined in Chapter 4, the extent and coverage of the skeletal PT (bus and rail) network is considered to be appropriately representative of the existing network within the main internal TMfS study area.

5.3.5 The coding of walk links with a 3mph speed and connections to rail stations of up to 0.8km is considered acceptable for TMfS.

5.3.6 The speed factors applied to the highway network speeds to derive the slower bus speeds were updated from CSTM3A to reflect 2001 travel statistics. The factors of 0.7712 (motorway), 0.7861 (urban roads) and 0.7793 (rural roads) are considered by the TTAA to be of the appropriate order of magnitude to be applicable for TMfS.

Public Transport Lines and Services

5.3.7 The TTAA's findings regarding the details of the PT lines and service coding are presented in Chapter 4 of this report. Some general details of the PT services are provided in Chapter 2 of MVA's report and the TTAA's comments on this information are provided below.

5.3.8 The general inputs such as system information and line descriptions coded for the PT network are essentially the same between CSTM3A and TMfS. In addition to the public transport modes previously coded in CSTM3 and 3A (namely: rail, inter-urban bus, urban bus and underground), TMfS has an additional (fifth) PT mode to represent ferries. In the TMfS base model, this mode solely represents the Renfrew-Yoker foot ferry.

5.3.9 Examination of the number of services coded by PT Company demonstrates that a significant number of changes have been incorporated in TMfS compared with CSTM3A. Most of these are as a result of different PT operators taking over services previously operated by others. Proportionately, the number of services attributed to the major operators (Stagecoach, First Group, Scotrail, Lothian Buses, Arriva etc.) appears to be intuitively correct in TMfS.

5.3.10 The TTAA's findings in Chapter 4 regarding bus services omitted from TMfS should be noted here. Although a number of bus services have been omitted, it is acknowledged that many of them are in areas of the model with coarse network and/or zoning detail. Equally, the PT matrix for many of the movements that these services would facilitate is likely to be less robust than for the major PT movements. Consequently, the omission of these services is unlikely to have a significant effect on the operation of TMfS. Nevertheless, potential users should be aware of the limited PT service coding within these areas of the model (ref. Chapter 4).

5.3.11 Table 2.4 of MVA's report provides a breakdown of the vehicle-kilometres and vehicle-hours on an operator by operator basis for each time period for TMfS. By inspection it is clear that proportionately, the greatest vehicle-kilometres and vehicle-hours are travelled by the major operators (Stagecoach, First Group, Scotrail, Lothian Buses, Arriva etc.) which appears to be intuitively correct for TMfS.

5.4 PT Demand Matrix Development

5.4.1 Chapter 3 of MVA's report presents the PT demand matrix development process and data sources. The main sources of data for the TMfS PT matrices were as follows:

- CSTM3A (2000) PT Matrices
- ASAM PT Matrices
- TMfS bus survey data (June 2003)
- CSTCS rail survey data

5.4.2 The TTAA acknowledges that these data sources are appropriate for the development of the TMfS PT matrices. Further comments on the use of this data and the resulting matrices are provided throughout this section.

Processing PT Survey Data

5.4.3 The new survey data for inclusion in the PT matrix was largely related to bus surveys undertaken by Babtie and Jacobs consultants in June 2003. Additionally, the rail data collected, but not used, for CSTCS was considered appropriate for inclusion. This data was processed by calculating expansion factors, checking for double counting and allocating the movements to the appropriate TMfS zones.

5.4.4 The main bus data comprised interview data and boarding and alighting counts as follows:

- Babtie data taken at count sites in Coatbridge, Kirkintilloch, Wishaw, Dundee, Perth and a single site at Central Way in Cumbernauld
- Babtie on-bus data from Cumbernauld
- Jacobs data taken at count sites in Airdrie, Dumbarton, East Kilbride, Greenock, Hamilton, Motherwell and bus stations at Glasgow Queen Street and Buchanan Street

5.4.5 None of the survey data considered return trips, consequently, these were estimated by reversing the interview origins and destinations and matching these to the appropriate boarding and alighting counts. The data was collected for 0700-1900, from which the peak periods of 0700-1000, 1000-1600 and 1600-1900 were extracted by MVA.

5.4.6 The process for calculating expansion factors is outlined in section 3.5 of MVA's report. This suggests that for each period, site and bus service, the number of boardings was divided by the number of interviews to obtain the expansion factor.

5.4.7 Where no boarding count was available, the count was assumed equal to the number of interviews (i.e. expansion factor = 1) and the boarding counts were corrected in accordance with this process. MVA also provided the TTAA with details of the frequency of such adjustments which are summarised in Table 5.1.

Table 5.1 : Frequency of Corrections due to Missing Count Data

		Forward	**Reverse**
Data Source	**Total No. of Interviews**	**Number of Interviews without counts**	**Number of Interviews without counts**
Babtie On-Bus	612	14	266
Babtie Site	3870	567	1916
Jacobs	8686	2053	2578

5.4.8 This demonstrates that in the interview direction, the number of adjustments was relatively minimal (2%) for the Babtie On-Bus data, moderate (15%) for the Babtie Site data and relatively high (24%) for the Jacobs data. In the non-interview direction, the number of adjustments was high in all cases with 43%, 50% and 30% for the Babtie On-Bus, Babtie Site and Jacobs data respectively. In the absence of count data for these sites, the TTAA considers that the appropriate corrective action was taken by MVA. Nevertheless, the relatively high number of instances where this corrective action was taken, particularly for the non-interview direction should be borne in mind with respect to the overall quality of the underlying data.

5.4.9 In cases where there was no interview data but a boarding count was recorded, the count data was carried forward and contributed to expansion factors at a more aggregate level. Again, the TTAA considers the course of action taken by MVA to be appropriate in the circumstances, although it is unknown how frequently such action was taken.

5.4.10 The calculation of reverse trips was undertaken by reversing the origins and destinations of the "forward" trips and calculating expansion factors to match alighting rather than boarding (as in the case of the "forward" trips) counts. In the absence of more comprehensive data, the TTAA considers that process described for creating reverse trips was appropriate for TMfS. MVA provided the TTAA with summary details of the expansion factors used in creating the matrices. It is encouraging to note that most of the expansion factors were $\leq$5 whilst the vast majority were $\leq$10 suggesting reasonable sample rates were achieved in most cases. The TTAA is therefore content that the expansion factors were generally within expected ranges.

5.4.11 Potential double counting for trips that run between two or more survey sites was also accounted for by MVA. This involved identifying for each forward OD whether the reverse of this OD was present among all other forward ODs. In such instances, the expansion factor for the forward OD was halved. A similar process was applied for the reverse ODs to address all potential double counting issues. MVA provided details which suggest that around one third of the interview records were adjusted by this process reducing the total number of records by around 60% in the forward and reverse directions. The TTAA considers this process to be logical and appropriate for TMfS.

5.4.12 The rail data from the CSTCS surveys covered lines to Glasgow from:

- Aberdeen
- Edinburgh
- Cumbernauld
- Drumgelloch
- Whifflet
- Shotts
- Lanark
- Hamilton Circle

5.4.13 Interviews and counts were taken at all stations on these lines with the notable exceptions of Linlithgow, Polmont and Falkirk High on the Edinburgh/Cumbernauld line. The TTAA considers this to be a significant omission. All interview and count data was recorded in the inbound (to Glasgow) direction with no data recorded in the outbound direction. The information in MVA's report suggests that a complete dataset was obtained for all Aberdeen to Glasgow rail trips. MVA has subsequently confirmed, however, that the dataset was obtained by combining separate, smaller datasets (e.g. ASAM data combined with CSTM3A data). Trip information between Aberdeen and Dundee was obtained from the ASAM model. Rail survey information was available for Stirling Station for Glasgow bound trips whilst rail trips between Dundee, Stirling and Perth were extracted from the CSTM3A matrices. As a general rule CSTM3A data was used in instances where there was a gap in the new survey data.

5.4.14 Expansion factors were calculated for AM peak interviews between 0700 and 0800 and PM peak interviews between 1700 and 1800 and for each inter-peak hour between 1000 and 1600. The records were then factored to match the hourly boarding counts as appropriate. Whilst this approach is considered generally acceptable for TMfS, the TTAA considers that it may have been beneficial in the case of the AM and PM peak periods to factor the interview records (i.e. distribution of trips) for the 3 hour peak periods (0700-1000 and 1600-1900 respectively) to the boarding counts for the peak hours. The process adopted has consequently omitted any interview data collected for the AM period of 0800-1000 and the PM periods of 1600-1700 and 1800-1900.

5.4.15 Reverse journeys were calculated by reversing the origins and destinations of the "forward" trips. However, as no alighting counts were available, the expansion factors from the inbound journey were retained. In the absence of any more appropriate data, the TTAA considers this to be an acceptable approach for creating the reverse journeys. Nevertheless, users of the model should be aware of the assumptions adopted in the processing of this rail data, especially for trips outbound from Glasgow to the east and north.

5.4.16 Overall the TTAA is content that MVA has applied procedures that are appropriate for the processing of the available new PT survey data. Users of TMfS, however, should consider the following issues from the rail data processing:

- no interviews or counts were taken at Linlithgow, Polmont or Falkirk High stations
- no outbound (from Glasgow) interview or counts were carried out, consequently the outbound trips were synthesised by reversing the observed inbound trips
- rail data in the shoulders of the AM and PM peaks (i.e. 0800-1000 in the AM and 1600-1700 & 1800-1900 in the PM) has not been utilised in creating the PT matrices

Initial Matrix Construction and Conversion to TMfS Format

5.4.17 The four main data sources used to create the TMfS PT matrices were converted to the TMfS zoning system (1133 zones) for comparison at an aggregate (sector level). This was undertaken to ensure that the PT trips on an area by area basis could be examined without inherent inaccuracies at an OD level clouding the comparisons.

5.4.18 One of the first steps in the process was for MVA to graphically depict the data sources on an origin zone by zone basis. Figures 3.2 to 3.8 in section 3.11 of MVA's report present the zonal proportion of origins by data source at varying zoom levels for the TMfS network. The main data sources were colour coded as follows:

- CSTM3A (Various data sources for bus and rail) – Red
- ASAM (Autumn 2001 bus and rail data) – Blue
- bus survey data (June 2003) – Green
- CSTCS Rail data (2000) – Yellow

5.4.19 These diagrams clearly demonstrate the following points:

- The extended north eastern area of the model (i.e. the ASAM area) is almost entirely comprised of the new bus and rail data collected for ASAM. Some portions of individual zones are comprised of data from the other 3 data sources, however, very little is inherited from CSTM3A
- The data in the Dundee and Perth area is comprised of the recent bus survey data combined with historic data inherited from CSTM3A. It is assumed that all (or virtually all) rail trips in this area of the model are inherited from CSTM3A
- The data for Edinburgh, Fife and central Scotland (excluding Glasgow) is comprised almost entirely of information inherited from CSTM3A for Rail and Bus modes
- Data for Greater Glasgow is also heavily dominated by information inherited from CSTM3A. This has been complimented with more up to date independent bus and rail data, particularly for movements between Glasgow and outlying areas to the east (e.g. North & South Lanarkshire and also for some movements between Glasgow and Ayrshire

5.4.20 MVA then devised a set of aggregation rules for combining the various data sources for the different sectors of the model. Details of these rules for the AM peak are provided in Appendix A of MVA's report and the TTAA is content that the rules are appropriate given the coverage of the various data sources available for the TMfS PT model development.

Final TMfS Matrices

5.4.21 The final TMfS PT matrices are therefore an update of the existing CSTM3A PT matrices with new survey data in 3 main areas as follows:

- ASAM area (bus and rail data)

- Glasgow and Strathclyde (bus and rail data)
- Dundee and Perth (bus data)

5.4.22 The remainder of the data in the TMfS PT matrices was inherited from the CSTM3A matrices. No additional estimation or adjustment processes were reported as being applied to the PT matrices by MVA. A comparison between the CSTM3A and TMfS matrices is provided by MVA for the matrix totals on a global basis as well as on a 43 district by district and a 14 sector by sector basis. Table 5.2 below shows the global change in the PT matrices between CSTM3A and TMfS.

Table 5.2 : Global PT Matrix Totals for CSTM3A and TMfS

Time Period	CSTM3A Trips	TMfS Trips	Absolute Difference	% Difference
AM Peak Hour	97446	101692	4246	4%
Interpeak hour	63023	68322	5299	8%
PM Peak Hour	98045	103023	4978	5%

5.4.23 The overall change in matrix totals between CSTM3A and TMfS is relatively small (between 4% and 8%) and can largely be attributed to the data within the extended model area for Aberdeen. A breakdown of the AM peak matrix total changes by sector is also provided for the AM peak in Table 3.4 of MVA's report. This also demonstrates increases of 52% (192 trips), 180% (386 trips) and 12% (280 trips) between CSTM3A and TMfS for the Perth, Dundee and Ayrshire areas respectively. All of these changes are considered to be in line with expectations given the updated survey data for these areas.

5.4.24 A noticeable reduction in the PT trips for Glasgow (-3%, -949 trips) and Strathclyde (-9%, -2201 trips) sectors is also evident from Table 3.4. More detailed examination of the sector to sector movements comprising these reductions shows that they are largely as a result of both intra and inter Glasgow and Strathclyde movements reducing in TMfS. It is also evident that a similar trend is present in the PM peak, although less so during the interpeak.

5.4.25 Given the new survey rail and bus survey data around the Glasgow area, changes to the matrices on these sector movements would be expected, although it is perhaps surprising that such reductions in trips result from the introduction of new survey data (given a general pattern of increases in other areas where new survey data was added). The calibration to PT observations for movements in these areas will be examined later in this document.

5.4.26 Appendices B and C of MVA's report provide the detailed breakdown of the TMfS PT matrices by 43 district and 14 sector systems as well as a comparison between CSTM3A and TMfS PT matrices for the 14 sector system. This useful breakdown and comparison was examined by the TTAA and following comments arise:

- the general scale of the PT trip totals (relative to each other) appears to be in line with expectations on a sector by sector basis
- the general tidality of inter-sector movements in most major areas (e.g. Edinburgh to/from Fife/Lothian/Central, Glasgow to/from Strathclyde/Ayrshire/Central, Dundee to/from Perthshire/Fife etc.) appears to be in line with expectations

- The movements between Edinburgh and Glasgow appear to demonstrate no tidality with approximately twice as many trips travelling from Edinburgh to Glasgow compared with the reverse direction in all time periods. This is compounded in TMfS with a 22% reduction (between CSTM3A and TMfS) in the PM peak for trips from Glasgow to Edinburgh. The number of PT trips from Edinburgh to Glasgow in the AM Peak is shown to be approximately twice the total number which make the return journey in the inter and PM peaks combined. Conversely, the number of PT trips from Glasgow to Edinburgh in the AM is approximately half of the total number which make the return journey in the inter and PM peaks combined. The TTAA considers this to be totally contrary to the expected travel pattern between these sectors
- External (north) trips to/from Glasgow demonstrate expected tidality between the AM and PM peaks. However, the magnitude of these external trips to Glasgow in the AM and from Glasgow in the PM is greater than the corresponding movements to Glasgow from Edinburgh in the AM and from Glasgow to Edinburgh in the PM. It is acknowledged that these external movements are inherited from CSTM3A, but the relative magnitude of these trips compared to the Edinburgh-Glasgow movements is considered counter-intuitive by the TTAA

5.4.27 By simple inspection of the TMfS PT matrices it can be concluded that the general scale of the PT trips on a sector by sector basis is in line with expectations with the significant exception of trips between Edinburgh and Glasgow. Furthermore, the general tidality demonstrated between the majority of major sectors is considered to be intuitively correct. Broadly, therefore, the TMfS PT matrices can be considered to provide a reasonable representation of relative levels of PT demand between most major sectors of the model area. The TTAA does, however, have concerns over the representation of trips between Glasgow and Edinburgh.

5.4.28 MVA acknowledges (in Information Note No AN6-1b_GP_IW_CP) that the Edinburgh, Lothian and much of the west side of Glasgow urban area rely more heavily on data from the CSTM3A matrices than other parts of the model where more extensive new data was made available. In terms of rail, the new data was confined largely to intra-urban trips with Glasgow whilst no new survey data was available for the Edinburgh and Lothian area. MVA considers this identifies the priorities for new survey data which would assist in improving the validity of the Glasgow-Edinburgh trips. The TTAA concurs with this view.

5.4.29 The data collection carried out and incorporated within the TMfS PT matrices has enabled improvements (compared with CSTM3A) for some areas of the matrix such as Aberdeen, Dundee, Perth and for some movements around Glasgow, Lanarkshire and Ayrshire. Consequently, the TMfS PT matrices remain heavily linked to CSTM3 as the CSTM3A PT matrices were unchanged from CSTM3. The CSTM3 matrices were themselves considered to be reliable only within the Central Belt with all other areas relatively coarse.

5.4.30 Much of the data used in the development of the CSTM3 PT matrices was collected in 1997 or before, consequently the reliance on this data for the majority of PT movements within the Central Belt for TMfS results in a PT matrix which is largely based on data which is at least 8 years old.

5.4.31 Overall, the TTAA considers that MVA has generally adopted appropriate techniques for processing the PT matrices for TMfS and has made best use of the available data. This has resulted in a TMfS PT matrix which, at a global level, provides a reasonable representation of relative levels of PT demand between most major sectors of the model area with the obvious exception of trips between Glasgow and Edinburgh.

5.4.32 With respect to the quality of the resulting matrices, the TTAA does have concerns that the majority of movements within the Central Belt (Edinburgh, Lothian, Fife, Central and much of Glasgow and Strathclyde) are based on relatively old data collected prior to the development of CSTM3.

5.4.33 MVA concludes in §3.14.7 of their report that *"…the robustness of this matrix is determined by the coverage, age and quality of the survey data available"*. The TTAA concurs with this conclusion.

5.4.34 Given the prominence of CSTM3 data within the TMfS matrices, the TTAA considers that the bounds of applicability of the TMfS PT model are similar to those of CSTM3A. That is that the PT model should be considered appropriate for the assessment of inter-urban public transport schemes and long distance commuting PT schemes. It can be used to test both the effect of faster and more frequent services and a new PT mode. TMfS would be lesser suited to testing wholly urban PT schemes.

5.5 PT Assignment Model

5.5.1 Chapter 4 of MVA's report describes the PTM inputs/outputs, the path building/routeing methodology and the model parameters. The TTAA's detailed comments on the inputs (network, PT services and matrices) have been provided in the preceding sections. The TTAA's findings on the other aspects of the TMfS PT Assignment model are as follows.

Path Building and Loading

5.5.2 The path building and loading procedures described in chapter 4 of MVA's report are identical to those adopted for CSTM3A and as such, are considered appropriate for TMfS.

Assignment Model Parameters

5.5.3 The assignment model parameters (wait times, walk time factors, transfer penalties etc.) listed in Table 4.1 of MVA's report are consistent with those adopted for CSTM3A and are considered appropriate for TMfS. The values of time for in-work and non-work PT trips are updated from CSTM3A using values from TAG Unit 3.5.6 (June 2004). Again, these values are considered appropriate for TMfS.

Fares Model

5.5.4 The fares model adopted for TMfS is slightly more detailed than that adopted for CSTM3A. Both models adopted a similar type of structure with fares based on a boarding charge and distance related fares with interpolation between defined points. The modelled PT fares for TMfS are shown in Table 5.3.

Table 5.3 : TMfS Modelled PT Fares (2003 prices)

Mode	Boarding Fare (pence)	Distance (km)	Total Fare (pence)*
1 Lothian Regional Transport	50	0.00	53
	50	1.60	60
	50	6.40	80
	50	7.20	100
	50	1000.00	100
2 Inter-Urban Bus	160	0.00	160
	160	500.00	2840
	160	1000.00	6040
3 Scotrail	60	0.00	60
	60	10.40	120
	60	46.80	380
	60	91.60	870
	60	183.20	1850
	60	366.40	3810
4 Glasgow Underground	90	0.00	90
	90	1000.00	90
5 Other Rail	90	0.00	95
	90	1.91	110
	90	60.75	560
	90	80.51	800
	90	99.52	1270
	90	152.36	2650
	90	293.97	4950
6 Renfrew Foot Ferry	90	0.00	90
	90	1000.00	90
7 Other Urban Bus	50	0.00	68
	50	10.00	117
	50	20.00	201
	50	30.00	223
	50	40.00	245
	50	50.00	263
	50	1000.00	263

*** Total fare includes boarding fare**

5.5.5 Urban buses have been disaggregated in TMfS to represent Lothian Regional Transport (i.e. Edinburgh and Lothians) fares differently from bus fares in other urban areas. Rail fares were also disaggregated to represent Scotrail fares differently from other rail fares. Furthermore, the number of distance categories within which fares can be interpolated has generally been increased for TMfS. Overall, the TTAA considers that the changes to the PT fares model within TMfS represent an improvement over its predecessor CSTM3A.

5.6 PT Model Validation

5.6.1 The PT assignment model was validated against observations from a number of data sources to establish its goodness of fit to these observations. Passenger flows were compared between modelled and observed and the GEH statistic was used to establish the quality of the model's fit to observations. Comparison between modelled and timetabled PT journey times was also made. The TTAA's findings on the various aspects of the TMfS PT model validation are contained in the following sections.

Data Used in Validation

5.6.2 The main data sources used in the PT model validation were as follows:

- Glasgow bus occupancy data (Glasgow inner and outer cordons and Kilmarnock cordon, 2003). Note: this data was based on estimates of the percentage occupancy of each bus and the number of seats for each bus type
- Edinburgh occupancy data (Edinburgh outer cordon inside A720 City Bypass, 2001). Note: this data was based on estimates of the percentage occupancy of each bus and the number of seats for each bus type
- Glasgow rail data (collected in 2000 for CSTCS). Boarding and alighting data was converted to flows for locations approximating to an outer Glasgow cordon
- MOIRA rail data (2002/2003). Station to station trip information for the top 50 destinations from each of the top 50 origin stations

5.6.3 It is noted by the TTAA that the Edinburgh and Glasgow bus occupancy data is based on estimates of the percentage occupancy of each bus and of the number of seats associated with each bus type. Whilst this methodology may provide reasonable estimates of the passenger numbers, it is undoubtedly prone to discrepancies. MVA suggests that a minimum error of ±10% is applicable to the bus flows with some instances where the error would be up to ±20%. This should be borne in mind when interpreting the PT bus validations.

PT Validation – Cordon Totals

5.6.4 Table 5.1 to 5.4 in MVA's report present the validation summaries for the bus and rail cordon totals for Glasgow and Edinburgh. The Glasgow outer bus cordon demonstrates a trend for TMfS to overestimate passenger flows across the cordon in all time periods except the PM peak. GEH values range between 10 and 25 for the inbound direction and between 6 and 27 for the outbound direction. The inner cordon demonstrates a reasonably good validation for the AM and PM peaks on the inbound direction (GEH of 6 and 4 for the AM and PM peaks respectively). The outbound direction of the inner cordon is less well validated for the AM and PM peaks with GEH values of 9 and 29 respectively. For both the inner and outer cordon, the interpeak validation is poor in both directions with GEH values ranging between 21 and 29.

5.6.5 The Glasgow rail cordon demonstrates an acceptable level of validation for the AM and interpeak hours inbound and for the PM peak hour outbound. The PM inbound and AM and interpeak outbound validation are considered poor.

5.6.6 Combining the bus and rail data for the outer cordon demonstrates a good validation for the AM peak inbound (GEH of 3) and for the PM peak outbound (GEH of 2). The combined validation on the outer cordon for interpeak and PM inbound and for AM and interpeak outbound is considered poor.

5.6.7 The improved validation for the AM peak inbound and PM peak outbound on the outer cordon when combining rail and bus trips is encouraging. It is noted, however, that the combined values comprise an overestimate of bus trips and an underestimate of rail trips in the AM and an underestimate of bus trips and an overestimate of rail trips in the PM. It is unknown to what extent the issues regarding the validation data collection, the quality of the trip matrix, PT assignment model parameters or the PT sub-mode split within TMfS influence the level of validation achieved.

5.6.8 Overall, the validation to PT trips can be considered representative of total PT trips (irrespective of mode) entering Glasgow in the AM peak and leaving Glasgow in the PM peak. It should be noted, however, that whilst the total across the outer cordon for these time period/direction combinations matches well with observations, the level of match at individual count sites comprising the cordon vary considerably with no clear pattern of over or underestimates evident. The level of validation for these movements (across the cordon as a whole) in other time periods is considerably more variable and is generally poor.

5.6.9 For the Edinburgh area, only bus data was available for validation, consequently, an outer bus cordon (approximately following the north side of the A720 City Bypass) was used for validation. There is a general trend for TMfS to underestimate the bus flows across this cordon for all time periods except the AM peak inbound to Edinburgh. GEH values range between 8 and 20 for all time period/direction combinations across this cordon.

5.6.10 This level of validation can be considered as a slight improvement for bus flows compared with Glasgow. The AM and PM peak modelled to observed differences are all within 19% with GEH values of 15 or below. When examining the individual comparisons comprising the screenline, it is evident that there is considerable variation on a site by site basis. There is a general trend for overestimates of bus passenger volumes in the eastern half of the cordon with underestimates generally evident on the western half of the cordon for either direction.

5.6.11 It is difficult to draw firm conclusions regarding the overall PT validation for Edinburgh in the absence of corresponding rail flow comparisons over the cordon. The overall level of validation to bus flows in Edinburgh can be considered to be slightly below acceptable standards. It is unknown to what extent the issues regarding the validation data collection, the quality of the trip matrix, PT assignment model parameters or the PT sub-mode split within TMfS influence the level of validation achieved. It is noted that the matrix updates did not include Edinburgh bus trips due to lack of new origin to destination survey data and count data. The validation made use of limited bus occupancy data although the limited accuracy of this information should be recognised as occupancies were only recorded to the nearest 25%.

PT Validation – Independent Rail Validation

5.6.12 The MOIRA data provided MVA with weekday only passenger totals by origin and destination station. A process of factoring, transposing and allocating stations to districts and subsequently sectors was followed to enable a weekday 14 sector matrix. This was subsequently factored to create AM, inter and PM peak “observed” matrices to be as consistent as possible with those in CSTM3A. The various limitations with the data make it difficult to use for direct comparisons with the CSTM3A PT matrices, hence, this data was used for limited comparisons and for improving the observed Glasgow rail data in some areas.

5.6.13 Examination of the MOIRA data indicated that observed flows for Bishopbriggs were significantly lower than would be expected. This was attributed to some express services not being included in the observed data as the survey only considered boarding and alighting at stations. It was therefore considered necessary to adjust the observed flows using the MOIRA data to take account of such services (e.g. services between Glasgow and Edinburgh, Falkirk and the Lothians). This resulted in an adjustment of a +800 trips in the AM and PM peaks and +200 trips in the interpeak on observations for Edinburgh to Glasgow (and vice versa) movements. The TTAA considers that these adjustments are acceptable within the TMfS PT model development.

5.6.14 The MOIRA data was used to calculate rail flows for a cordon around Glasgow thereby enabling a direct comparison between modelled and observed data. The inbound AM peak validation and the PM peak outbound validation to the MOIRA data for this cordon as a whole is shown to be reasonably good with GEH vales of 9 (-9%) and 8 (+10%) respectively. Again, it should be noted that these good comparisons across the whole cordon are comprised of a series of individual comparisons which vary considerably. Generally, there are significant underestimates of flow in TMfS at Anniesland, Possilpark, Carmyle, Muirend and Corkerhill. These are offset by a significant overestimate at Cardonald and to a lesser extent at Pollokshaws West and Cambuslang.

5.6.15 Again, it is encouraging to note the general trend for inbound AM and outbound PM rail journeys for Glasgow to match reasonably well with observations. The observations are, however, to some extent estimated for each peak hour from the weekday annual passenger data from MOIRA. Hence, it is difficult to draw firm conclusions regarding the robustness of the quality of the rail validation over the Glasgow cordon.

5.6.16 The MOIRA data was further used to validate rail trips between Edinburgh and Glasgow. Trips from Edinburgh to Glasgow are shown to compare well with the MOIRA data in both the AM and PM peak hours. Conversely, Glasgow to Edinburgh trips demonstrate a considerably lower level of validation to the MOIRA data being 32% and 42% lower than observations for the AM and PM peak hours respectively. This inconsistency seriously undermines the credibility of the PT trip matrices for these movements.

5.6.17 It is unknown to what extent the issues regarding the validation data collection, the quality of the trip matrix, PT assignment model parameters or the PT sub-mode split within TMfS influence the level of validation achieved for the Glasgow to Edinburgh rail trips. The TTAA considers it worthy of note, however, that the demand for this movement in the TMfS PT matrices is consistently around half the magnitude of the reverse movement in all time periods.

5.6.18 The information presented leads to the conclusion that Edinburgh to Glasgow rail trips validate well with available observations but that Glasgow to Edinburgh rail trips demonstrate a poor level of validation. It should be noted, however, that the “observed” peak hour data used in the validation comparisons was estimated from MOIRA weekday total data and is therefore subject to a significant degree of interpretation and cannot be considered wholly reliable for this purpose.

PT Validation – Glasgow Underground

5.6.19 MVA states in §5.5.17 that the *“…assigned flows on the Glasgow underground in the previous CSTM3A model were approximately 50% lower than observed flows”*. The basis for this statement is unknown as modelled/observed underground flow comparisons are not provided in the corresponding CSTM3A PT calibration/validation report. Nevertheless, the TMfS and CSTM3A AM and PM peak hour underground flows have been presented in Figures 5.1 to 5.4 of MVA’s report.

5.6.20 These figures demonstrate that in virtually all cases, the passenger flow between underground stations has increased in TMfS compared with CSTM3A. Generally, the increase is substantial on links in the northern half of the loop with TMfS flows at least twice as large as the corresponding CSTM3A flows. For the southern half of the loop the TMfS flows are generally between 1 and 2 times the magnitude of the corresponding CSTM3A flows.

5.6.21 It can therefore be concluded that the TMfS underground flows are generally higher than the corresponding flows in CSTM3A, which were themselves considered to be underestimates of actual flows. It is not possible to conclude how well the TMfS underground flows compare with observations as none are presented.

PT Validation – Timetabled and Modelled Bus Journey Times

5.6.22 Modelled to timetabled bus journey time comparisons were undertaken for 50 services within the TMfS model area. The modelled journey time was compared with the average, maximum and minimum timetabled journey times. For the vast majority of cases, the TMfS modelled journey times are quicker than the timetabled average journey time. This is often the case with models of this nature since the timetabled information does not provide a true reflection of actual travelled times. Equally, 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 TMfS.

5.6.23 The TTAA examined the bus journey time comparisons using the DMRB criteria for comparing modelled to observed journey times for highway based vehicles. That is that the modelled time should be within 15% (or 1 minute if higher) of the observed journey time. Applying this criteria shows that 50%, 40% and 48% of the journey times match within DMRB criteria for the AM, inter and PM peaks respectively. The TTAA considers this to be a generally acceptable level of bus journey time validation for TMfS.

5.6.24 The TTAA would recommend that any users of TMfS for schemes likely to be sensitive to changes in bus journey times should examine the level of bus journey time validation within their area of interest prior to undertaking any assessments.

Summary of PT Validation

5.6.25 The validation of the TMfS PT model is focused primarily on bus and rail flows on cordons around Glasgow and Edinburgh with an independent check on rail trips between Glasgow and Edinburgh. The individual bus and rail cordon validation around Glasgow is of variable quality although the combined bus and rail cordon flows match reasonably well with observations for the AM inbound and PM outbound. There is significant variation in the quality of observed to modelled comparisons for both bus and rail flows at the individual sites comprising the Glasgow cordons. The general level of validation around the Glasgow cordons can be considered to be below generally acceptable standards.

5.6.26 The bus flow validation across the Edinburgh cordon is slightly improved compared with Glasgow when considering total flows across the cordon. When examining the individual comparisons comprising the screenline, it is evident that there is considerable variation on a site by site basis. There is a general trend for overestimates of bus passenger volumes in the eastern half of the Edinburgh cordon with underestimates generally evident on the western half of the cordon for either direction.

5.6.27 It is difficult to draw firm conclusions regarding the overall PT validation for Edinburgh in the absence of corresponding rail flow comparisons over the cordon. The overall level of validation to bus flows in Edinburgh can be considered to be slightly below acceptable standards. It is unknown to what extent the issues regarding the validation data collection, the quality of the trip matrix, PT assignment model parameters or the PT sub-mode split within TMfS influence the level of validation achieved.

5.6.28 Rail trips from Edinburgh to Glasgow are shown to compare well with the MOIRA data in both the AM and PM peak hours. Conversely, Glasgow to Edinburgh trips demonstrate a considerably lower level of validation to the MOIRA data being 32% and 42% lower than observations for the AM and PM peak hours respectively. The TTAA considers it worthy of note, that the demand for this movement in the TMfS PT matrices is consistently around half the magnitude of the reverse movement in all time periods. It should be noted, however, that the “observed” peak hour data used in the validation comparisons was estimated from MOIRA weekday total data and is therefore subject to a significant degree of interpretation and cannot be considered wholly reliable for this purpose.

5.6.29 Glasgow underground flows have increased significantly compared with CSTM3A, particularly on the northern half of the loop. MVA suggested that the CSTM3A underground flows were under representing reality, consequently, the increase for TMfS is considered by MVA to be an improvement. No comparisons with observations have been provided to enable firm conclusions regarding the Glasgow underground validation to be drawn.

5.6.30 The TTAA considers that the bus and rail validation exercise was extremely limited given that it focused almost entirely on Edinburgh and Glasgow with only one cordon outwith this area surrounding Kilmarnock. Whilst it is acknowledged that the validation exercise was largely limited because of independent data availability, the TTAA considers that it would have been of significant merit to undertake a non-independent calibration check over a much wider area using the data from the PT matrix development process. This would have enabled direct comparison between assigned flows and observations over a much wider area including Perth, Dundee and Aberdeen.

5.6.31 The modelled to timetabled bus journey time comparisons undertaken demonstrate that the modelled values are generally faster than the timetables. This is expected for a model of this nature and applying DMRB journey time acceptability criteria demonstrates a reasonable match between modelled and timetabled values for TMfS.

5.7 Summary of TMfS PT Model Development and Validation

5.7.1 The TMfS PTM has been developed to represent the PT network of bus rail and underground services within the Central Belt and stretching north east to Dundee, Angus and Aberdeen. Some detailed comments are provided in the relevant section of this chapter, however, the TTAA is generally content that the PT network coverage and detail is appropriate for TMfS. The omission of a number of significant bus services (particularly First Aberdeen and Strathtay Scottish) from the model should be noted, however, it is acknowledged that the representation of many of these services would have been difficult due to the limited network detail in these areas. It is further acknowledged that longer distance inter-urban services are coded with more frequent stopping patterns which provide compensation for the lack of some of the bus services in TMfS.

5.7.2 The PT demand matrices were developed using historic matrices from CSTM3A augmented with bus and/or rail survey data for Aberdeen, Dundee, Perth, Glasgow and some movements in Ayrshire and Lanarkshire. The TTAA is generally satisfied that the PT survey data has been processed and incorporated within the TMfS PT matrices in an appropriate manner. Some detailed comments are provided in the relevant section of this report.

5.7.3 Whilst improvements in the matrix quality have been made in the areas where new survey data is available, the majority of movements within the TMfS PT matrix have been inherited from CSTM3A. The CSTM3A PT matrix was itself inherited without adjustment from CSTM3. Hence, the vast majority of movements within the TMfS PT matrix are based on data which was collected prior to 1997. Therefore, significant PT generating areas such as Edinburgh, Lothian, Fife, Central and much of Glasgow are represented by old data within the TMfS PT matrix. The TTAA is content that MVA has made the best use of all available data in developing the TMfS PT matrix, however, the implications of the paucity of up to date detailed PT information in a number of key areas of the model must be borne in mind by potential users of TMfS.

5.7.4 By simple inspection of the TMfS PT matrices it can be concluded that the general scale of the PT trips on a sector by sector basis is in line with expectations for most movements, with the significant exception of trips between Edinburgh and Glasgow. Furthermore, the general tidality demonstrated between the majority of major sectors is considered to be intuitively correct, again, with the exception of trips between Edinburgh and Glasgow. Broadly, therefore, the TMfS PT matrices can be considered to provide a reasonable representation of relative levels of PT demand between most major sectors of the model area with the significant exception of movements between Edinburgh and Glasgow. The TTAA's detailed comments on the matrices are contained in section 5.4 of this report.

5.7.5 The PT assignment model is similar in specification and the parameters adopted to CSTM3A. Some improvements to the fares model have been incorporated within TMfS leading to a more detailed fares model. Overall, the TTAA is satisfied that the PT assignment model, as specified, is appropriate for TMfS.

5.7.6 The PT model validation for TMfS is limited largely to bus and rail movements over an inner and outer Glasgow cordon and for bus movements over an Edinburgh cordon. The quality of the validation is extremely variable over these cordons, particularly when considering individual validation sites. The total PT (bus and rail) flow inbound across the Glasgow outer cordon in the AM and outbound across the Glasgow outer cordon in the PM peak is shown to validate reasonably well to observations. The individual bus and rail validation which combines to make this comparison, however, shows that high bus flows compensate for low rail flows in the AM and vice versa in the PM.

5.7.7 The Edinburgh bus validation is slightly better than the Glasgow bus validation when considering total cordon flows. The individual sites, however, also demonstrate considerable variation in their level of validation. Generally sites on the eastern part of the cordon demonstrate overestimates whilst sites on the western part of the cordon demonstrate underestimates of bus passenger flow in TMfS. Bus journey time validation was also carried out for selected services and despite TMfS tending to underestimate bus travel times, the validation was considered acceptable for a model of this nature.

5.7.8 It is significant to note that MVA states in §6.2.6 of the PT validation report that *"Following investigations of the problem areas from the above validation, the reliability of much of the count data is viewed as unsatisfactory. The bus validation flows were recorded at the kerbside on a single day and are based on estimates of the occupancy of buses passing various sites. The rail counts are calculated loadings based on single day boarding and alighting data"*. Given this statement, little in the way of firm conclusions can be drawn regarding the level of validation of the PT model for TMfS.

5.7.9 MVA has further commented that *"However, MVA acknowledges that in some areas the validation is below generally acceptable standards. The limited reliability of some of the observed data used for validation purposes is noted. Further survey work for matrix improvement would be recommended in areas where CSTM3A matrix data had not been updated, particularly in Lothian, although it is appreciated that such data is expensive to collect. It is agreed that in the absence of more extensive observed validation data, calibration checks using non-independent data could be undertaken. This could also assist in understanding variation of validation quality within cordons"*.

5.7.10 Ideally, a significant amount of new data would be collected for additional PT matrix development and model validation prior to the application of TMfS. It is extremely unlikely that this will ultimately prove to be the case. Consequently, the TTAA considers that the current level of validation as reported could have significant potential implications for users of TMfS with respect to any scheme where PT demand is sensitive to the network changes.

5.7.11 With this in mind, the TTAA considers that a guidance paper should be prepared to advise potential users of the implications of the various issues discussed in this chapter when applying TMfS. This guidance note should include, but not be restricted to guidance regarding the robustness of the following:

- PT matrices on a sector by sector basis
- PT service coding/coverage on a sector by sector basis
- PT calibration/validation in TMfS on a sector by sector basis

6 DEMAND MODEL

6.1 Background

6.1.1 This chapter presents the TTAA's findings relating to TMfS Audit Task 9 : Review Demand Model.

6.1.2 MVA provided the TTAA with the TMfS "Demand Model Development Draft Final Report", Issue 4, 29 October 2004 and Information Note No AN9-1 dated 28 February 2005. The findings in this chapter are based on a review of the specific information supplied, and on the basis of various discussions with MVA during the audit process.

6.1.3 The TTAA's comments regarding the TMfS Demand Model are listed in the following sections of this chapter. The section headings correspond with the chapter headings from MVA's Demand Model Development Draft Final Report.

6.2 Introduction

6.2.1 MVA's report introduction sets out the background and context to the demand model development as well as defining the TMfS model objectives and illustrating the demand model structure.

6.3 Demand Model Overview

6.3.1 This chapter deals with several aspects of the demand model, its structure, inputs, parameters and application. The TTAA's comments on each aspect are dealt with in turn below.

Demand Model Structure

6.3.2 The TMfS demand model structure is broadly the same as that used for CSTM3A with the main enhancements as follows:

- separate models for AM, inter and PM peak are present, with some linkages between periods
- the trip end, mode and destination choice models are concerned only with "from home" trips
- "to home" trips and "non-home based" trip ends are linked to "from home" trips by a factoring process
- peak spreading is included as part of the main supply demand iterative process, and operates at the matrix cell level rather than uniformly across the matrix

6.3.3 The TTAA considers the above enhancements to be improvements to the demand model structure and operation for TMfS compared with its predecessor CSTM3A. More detailed comments on the individual aspects can be found later in this document.

6.3.4 MVA states in §2.1.3 that *"The order of choices for mode and destination choice remains the same as for CSTM3. That is, destination choice is more sensitive than mode choice. This is determined by the relative sizes of the calibrated parameters for mode and destination choice. Initial testing of the model parameters showed mode choice to have a relatively small sensitivity parameter which indicated a model structure the same as CSTM3. For this reason, the model calibration was carried out based on the assumption of destination choice being more sensitive than mode choice. This was subsequently confirmed by the relative sizes of the calibrated parameters"*.

6.3.5 Given the uncompetitive nature of PT compared to private transport in all but a few situations and the proxy of equating household car ownership to car availability, the relative insensitivity of mode choice is hardly surprising. The TTAA considers that the adopted model structure is a valid option to choose from a range of alternatives and is appropriate for TMfS. Given the timescale for developing TMfS, it is the TTAA's view that ideally it would have been definitively concluded that the adopted model structure is the most appropriate, to the exclusion of all other possibilities, by undertaking a comparison of relative sensitivities of mode and distribution choice for each of the possible model structures. The draft VADMA guidance clearly states (ref. VADMA §23.7) that there is contradictory evidence regarding whether mode or destination choice is more sensitive with the sensitivity of distribution to changes in cost being particularly uncertain. Given this fact, and the significant assumption within the demand model that "car available" trips include all of those which originate from a car owning household the TTAA considers this point particularly pertinent to the TMfS demand model.

6.3.6 In view of the above discussion, the TTAA recommends that all future significant upgrades or enhancements to the model should include for such a comparison (of relative sensitivities of mode and destination choice within alternative order of choice hierarchies) within the demand model development timescale and associated costings.

6.3.7 The demand model operation in forecast mode is designed to synthesise travel demand and apply changes to the base year trip matrices in an incremental manner based on changes in forecast planning data and/or transport network costs. The TTAA is content that this is an appropriate method of operation of the TMfS demand model.

6.3.8 It should be noted due to the demand model's incremental forecasting technique, it will be essential to ensure that the planning data assumptions for the TMfS base year match closely with actual conditions on a zone by zone basis. This will help to ensure that the growth increment between base and future years does not significantly over or underestimate the absolute level of development indicated by the future year planning data. MVA has subsequently stated that a 12 sector comparison with CSTM3A data has been undertaken but this has not been undertaken for the most recent TMfS data. The TTAA would therefore recommend that prior to the widespread application of TMfS such a comparison is undertaken by MVA and a paper presented on this in due course.

6.3.9 The data sources used in preparing the demand model parameters include the HAM and PTM assignment matrices, RSI and PT survey data, cost skims from the HAM and PTM, Scottish Household Survey data and planning data from CSTM3A for 2001. The TTAA is content that these are appropriate data sources to utilise in the demand model development. It should be noted that the 2001 Census data has been omitted. The TTAA presumes that this was due to the data being unavailable at the time of the model calibration.

Zoning System

6.3.10 The zoning system for the TMfS demand model is entirely consistent with that for the HAM and the PTM. Additionally, the demand model is designed to operate on a zonal level rather than at a more aggregate district level, as was the case for CSTM3A. The TTAA is content that this represents an improvement in the demand model operation for TMfS compared with CSTM3A.

6.3.11 Demand model parameters have been devised for a more aggregate 3 sector system which demarcates Glasgow, Edinburgh and the rest of the modelled area from each other. This approach is similar to CSTM3A. The TTAA notes that it may have been an appropriate improvement for TMfS to have devised a more disaggregate sector system based on area characteristics (e.g. rural, major urban etc.) and/or movements where PT estimates were fully observed. Consideration to such a sector system should be given for future developments of TMfS.

Journey Purposes and Time Periods

6.3.12 The demand model contains five journey purposes (HBW, HBO, HBEB, NHBO & NHBEB) and two person types (non-car available & car available) which is similar to CSTM3A. The HAM is further disaggregated into four user classes in TMfS representing cars in-work and non-work separately and LGVs and HGVs separately (compared with two user classes of light and heavy vehicles for CSTM3A). The TTAA considers these appropriate for TMfS.

6.3.13 The demand model has been modified for TMfS to operate separately for each time period. Each periodic demand model operates for "from home" trips only with "to home" and "non home based" trips derived from the outputs of the "from home" models. The time periods for the demand model are:

- AM peak period : 0700-1000 (peak hour for assignment : 0800-0900)
- Inter-peak period : 1000-1600 (peak hour for assignment : $^{1}/_{6}{}^{th}$ of1000-1600)
- PM peak period : 1600-1900 (peak hour for assignment : 1700-1800)

6.3.14 The time periods specified are similar to CSTM3A and are considered appropriate for TMfS.

Generalised Costs

6.3.15 The generalised cost-journey purpose equivalence is reported in Table 2.1 of MVA's report and appears to be consistent with the updated demand model specification for TMfS (i.e. represents "home based" trips only). The corresponding generalised cost coefficients, calculated in accordance with TAG Unit 3.5.6 are provided in Table 2.2 of MVA's report. These are replicated below in Table 6.1.

Table 6.1 : TMfS Generalised Cost Coefficients – HAM Base Year

	Generalised Cost Coefficients		
Mode	**Time**	**Distance**	**Average Toll**
Cars in-work	1.0	0.2332	0.0570
Cars non-work	1.0	0.3575	0.1603
LGV	1.0	0.7433	0.0256
OGV	1.0	2.8617	0.0256

6.3.16 The TTAA notes from the calculations shown in Appendix C, that the distance parameters are correctly calculated in accordance with TAG Unit 3.5.6. The value of time for the toll cost parameter for non-work has, however, been calculated using the methodology from the DfT paper "Advice on Modelling Congestion Charging or Tolling Options for Multi-Modal Studies". The TTAA is content that the calculations have been undertaken correctly, however, the information in Appendix C of MVA's draft report does not make this distinction clear. It is further noted that the Vehicle operating cost = a+b/v part of the GC parameter calculations for car in-work is missing from Appendix C. Although it appears to have been undertaken correctly given the distance cost parameter shown. Given these issues, the TTAA recommends that Appendix C is updated appropriately prior to the publication of the final report.

6.3.17 The PT assignment model coefficients for the base year are provided in Table 2.3 of MVA's report. The parameters (in vehicle times, wait/walk time factors, transfer penalties etc.) are generally similar to CSTM3A. It assumed by the TTAA that the "rail to rail or underground" transfer penalty of 5 minutes implies "rail to rail or underground and vice versa". Hence, any rail to rail (whether overland or underground) transfer penalty is a consistent 5 minutes. Should this be the case, the TTAA is content that the parameter values in Table 2.3 are appropriate for TMfS.

6.3.18 The in-work and non-work values of time for the PT model are also listed in Table 2.3. Furthermore, §2.4.6 suggests that *"The calculation of highways and PT Generalised Cost Coefficients is presented in Appendix C"*. The details in Appendix C do not present any information regarding the in-work value of time for the PT model, as is presented in Table 2.3 (in-work VoT = 1901.24p/hr). The TTAA is content, however, that the values of in-work and non-work VoT for PT are of the correct order of magnitude. Nevertheless, the TTAA recommends that Appendix C is updated appropriately prior to the publication of the final report.

Parking Charges

6.3.19 Parking charges have been included within TMfS by including charges in the central areas of Aberdeen, Glasgow, Edinburgh, Perth, Stirling, Dunfermline and Dundee. The areas covered by the parking charges in TMfS are generally appropriate. It should be noted that the parking coverage in Dundee only encompasses a very small area (3 zones) in the city centre, whilst in Glasgow only parking north of the River Clyde is included (although this represents the majority of significant parking areas for Glasgow).

6.3.20 Details of the parking charges and how these have been applied in TMfS are provided in Appendix D of MVA's report. The parking charges appear to be broadly of the correct order of magnitude for most areas, however, no details of the source of the parking charge information are provided.

6.3.21 It is assumed in TMfS that 45% of home based work trips to each city/town will pay for long stay parking with the remaining 55% (15% kiss and ride and 40% PNR) not paying. 80% of home based other and non-home based trips to each city/town centre are assumed to pay for short stay parking. These proportions were estimated based on data supplied by Aberdeen City Council as part of the ASAM development. Equivalent data for other cities was not available, therefore it should be noted that these assumptions have been applied uniformly for all areas where parking has been included (i.e. Glasgow, Aberdeen, Dunfermline etc. all share the same assumptions).

6.3.22 The parking charges are then allocated 50% each to outward and return journeys and added to the base year generalised cost skim matrices, following application of the non-work car tolling parameter. The parking charges are represented by an average cost per car, which is considered crude but acceptable for TMfS.

6.3.23 Overall, the methodology for applying the parking charges within TMfS follows a logical process which the TTAA considers appropriate for TMfS. Overall, the inclusion of parking charges within the base year TMfS is an improvement over CSTM3A. Potential users should, however, note the limited coverage and of parking charges and uniformity of parking assumptions within the TMfS network with respect to possible applications considering changes to parking charges and/or policies. It is likely that TMfS could only be used to give broad rather than detailed indications of the likely response to changes in parking charge and/or policy.

Highway and PT Assignment Models

6.3.24 The highway and PT assignment models are the subject of separate chapters of this audit report.

Trip Ends

6.3.25 The process used to derive the trip ends for input to the demand model is reviewed in the following section of this chapter.

Demand Model Parameters

6.3.26 Demand model parameters are discussed in more detail elsewhere in this chapter.

Sensitivity Testing

6.3.27 The sensitivity testing undertaken is discussed in more detail elsewhere in this chapter.

Forecasting Procedures

6.3.28 The forecasting procedures are discussed in more detail elsewhere in this chapter.

6.4 Trip and Cost Matrices

6.4.1 Various data sources were used in the calibration of the demand model as follows:

- person trip matrices by journey purpose, mode and time period
- trip productions and attractions by journey purpose, mode and time period
- generalised cost of travel from the assignment model by journey purpose, mode and time period)
- RSI data
- vehicle occupancy and journey purpose breakdowns from CSTM3
- scottish Household Survey data
- planning data

6.4.2 The use of these data sources is discussed in detail in the following sections.

Highway Matrix Development

6.4.3 The methodology adopted to develop the 24 hour person trip matrices from the final highway assignment model is similar to that adopted for CSTM3A, in that it is a mechanistic factoring process. The following points have been identified during the audit process:

- A coarse sectoring system has been utilised for the journey purpose information (Edinburgh, Glasgow and Everywhere else)
- The process inherently assumes that all zone to zone movements in each sector (Edinburgh, Glasgow and Everywhere else) will have the same journey purpose split. Similarly, all inter-sector zone to zone movements will have the same journey purpose split as all other zone to zone movements for the same sector pair. This simplistic assumption is likely to be far from reality for many zone to zone movements. Hence, zoning land use characteristics (e.g. relative levels of employment/population) would have provided a more accurate basis for determining the likely journey purpose composition
- CSTM3A provided the journey purpose split information, which inherited the data from CSTM3, which itself inherited the data from SITM, JIF and CSTM2. This information is therefore at least 10 years old as it pre-dates CSTM3
- The car occupancy factors were derived mainly from analysis of the TMfS RSI database with the exception of intra-Edinburgh and Edinburgh to/from Glasgow trips which were taken from CSTM3A
- The AM and PM period to hour factors (to create hourly matrices for assignment from the period matrices created in the demand model) were derived mainly from analysis of the TMfS RSI database with the exception of intra-Edinburgh and Edinburgh to/from Glasgow trips which were taken from CSTM3A. The inter-peak period to hour factor is 0.166667 for all movements

6.4.4 Given the function and purpose of the TMfS demand model (to provide travel demand growth forecasts rather than absolute travel demand forecasts), these aspects of the matrix development process are considered acceptable within the context of TMfS. It is also acknowledged by the TTAA that there was a lack of consistent data available at a more disaggregate level, hence the approach has made good use of available data sources.

Initial Zonal Trip Ends

6.4.5 The initial trip productions and attractions by journey purpose were developed using data from the TMfS RSI database along with zonal planning data which defined the level of employment and employed persons in each zone. It should be noted that the planning data used was 2001 projection data from CSTM3A as the 2001 census based planning data was not available at the time. The CSTM3A planning data was therefore converted to the TMfS zoning system and was adjudged by MVA to be sufficiently robust for use in the process.

6.4.6 It is acknowledged by MVA that checks have not been made between the 2001 CSTM3A projection planning data used and the 2001 census based data, which has subsequently become available. The TTAA considers that such a check would provide verification of the accuracy of the base planning data within TMfS, thereby providing confidence in the demand model's ability to robustly predict growth increments at a zonal level. The TTAA considers that it would be extremely valuable to undertake this check and report on the findings in advance of the widespread application of TMfS.

6.4.7 Notwithstanding the above, the TTAA considers that in the absence of the 2001 census based planning data, the appropriate planning data source has been used in the creation of the initial zonal trip ends. It is further acknowledged that use of the projected planning data in disaggregating the base year assignment matrices into journey purpose matrices represented an improvement over the procedure adopted for CSTM3A.

6.4.8 The planning data was used to classify individual zones by relating the number of employed persons to the amount of employment. Twelve such classification groups were defined and the productions (P) and attractions (A) from the RSI data were classified in these groups. Trip end parameters (for P&A by time period and journey purpose) were then defined by calculating these directly from the RSI data. Examples of the trip ends and parameters by zone group are provided for the AM and inter-peak periods in MVA's report. The TTAA considers that these have been derived in accordance with the methodology outlined by MVA in the report.

Public Transport Matrix Development

6.4.9 The process for creating person trip matrices by journey purpose and time period for PT trips is similar to that for car trips, although without the need to consider vehicle occupancy. The following points have been identified during the audit process:

- Initial PT journey purpose matrices were not created as no equivalent CTSM3A journey purpose factors for PT were available
- Global period to hour factors (to create hourly matrices for assignment from the period matrices created in the demand model) of 0.498 (AM peak) and 0.166667 (inter-peak) have been applied for PT trips. These factors were inherited from CSTM3A
- Zonal trip end factors for non-home based PT trips are uniformly applied across the TMfS study area as insufficient PT interview data was available to calculate these by planning data group

6.4.10 Similar to the highway matrix development, given the function and purpose of the TMfS demand model (to provide travel demand growth forecasts rather than absolute travel demand forecasts), these aspects of the PT matrix development process are considered acceptable within the context of TMfS.

6.4.11 The PT zonal trip end factors (P & A) for “from home” and “non-home based” trips are provided in Tables 3.19 to 3.21 of MVA’s report. Unlike the corresponding factors for highway trips, the number of trips has not been reported. Consequently, the TTAA cannot confirm that the resulting parameters have been derived appropriately therefore, it is assumed by the TTAA that this is the case.

6.5 Destination Choice Model

6.5.1 The adopted model choice for TMfS implies that destination choice is more sensitive than mode choice. Therefore, the destination choice sensitivity parameters and constants were calculated first as the mode choice calibration relies on outputs from the destination choice model.

6.5.2 Sensitivity parameters were calibrated for each of the five journey purposes, two time periods (AM and inter-peak) and three mode/car available segments (car available car users, car available PT users and non-car available PT users). Separate parameters were calibrated for 4 areas as follows:

- Intra-Edinburgh trips
- Intra-Glasgow trips
- Intra-“remainder of the study area” trips
- All inter-sector trips

6.5.3 The destination choice model is a traditional gravity model using an exponential deterrence function. In forecast mode, the destination choice model will be singly constrained for “from home” to “employer’s business” and “other” trip purposes, thereby enabling trips to change destination based on changes in accessibility. Home based to work trips will be run as doubly constrained to reflect the balance between workers and jobs and to retain consistency with the planning data. For the destination choice model calibration, all purposes were treated as doubly constrained.

6.5.4 The form and processes adopted for the destination choice model are considered appropriate for TMfS.

6.5.5 The destination choice sensitivity parameters for both highway and PT trips in TMfS show a close comparison with those for CSTM3A. It should be noted that the PT sensitivity parameters are uniform across the model area as insufficient data was available to derive these on a sector basis. Notwithstanding the TTAA’s comments regarding the adopted model hierarchy, these parameters are considered acceptable for TMfS.

6.5.6 A series of destination choice constants (K factors) has also been derived for TMfS. These factors ensure that the destination choice model output trip matrices match the input matrices at a 3 sector (Edinburgh, Glasgow and Elsewhere) level. The sector comparison between input and output matrices is presented in Appendix E of MVA’s report, whilst the calibrated K factors are presented in Appendix F. A good match is demonstrated between the input and output matrices and the K factors are broadly comparable with those derived for CSTM3A. The TTAA is therefore content that the distribution model parameters are appropriate for TMfS.

6.5.7 It is noted from the tables in Appendix E that, in the TTAA’s view, the general proportion of PT “car available” trips is very high when compared with the PT “non-car available” trips (e.g. in a number of cases the PT “car available” trips from Edinburgh to Glasgow are greater than the PT “non-car available” trips). This is to a large extent due to nomenclature as PT “car available” trips are simply those which originate from a car owning household rather than trips which genuinely have a car available for the particular journey. The implications of this with respect to the demand model calibration and operation should be borne in mind as it brings into question exactly what the calibrated mode choice parameters are actually reflecting (car ownership and/or PT accessibility or utility). Furthermore, the extent to which the linking of car availability to car ownership affects the sensitivity of the mode choice parameters in relation to the destination choice parameters is unknown.

6.5.8 Also, in the TTAA's view, the number of trips between Edinburgh and Glasgow is considered low for all modes. In addition, the split between car and PT trips on these movements is considered counter-intuitive in some cases. For example, there are 1357 (40%) car trips and 2065 (60%) PT trips from Edinburgh to Glasgow in the AM peak with 1612 (82%) car trips and 345 (18%) PT trips from Glasgow to Edinburgh in the same time period. It is recognised that these values are inherited from the HAM and PTM trip matrices, however, given that the demand model is calibrated to these trip matrices, the possible impact of such counter-intuitive movements on the resulting calibrated demand model parameters should be recognised.

6.5.9 It should be noted that the statistical significance of the destination choice model parameters has not been presented in MVA's report as the software used in calibration does not produce such information. This has consequently not been investigated in this audit.

6.5.10 It should also be noted that the ability of the model to reproduce the observed matrix (at a detailed rather than 3x3 sector level) and the trip length distribution has not been demonstrated in MVA's documentation. This has consequently not been investigated in this audit.

6.6 Mode Choice Model

6.6.1 The mode choice model within TMfS is broadly similar to that for CSTM3A in that it operates at a trip end level for car available trips only. The mode choice model has a logit structure using logsum composite utilities calculated using the inter-zonal costs used by the distribution model. The most obvious difference (from CSTM3A) introduced to the mode choice modelling for TMfS is that the mode choice model does not consider "non home based" trips, as these are factored from the "home based" trips. Overall, the TTAA is content that the adopted mode choice model structure is appropriate for TMfS.

6.6.2 Mode choice sensitivity parameters were derived for the 3 sector system (Edinburgh, Glasgow and Other areas) as insufficient data was available to reliably calculate these on a zonal basis. Again, the TTAA notes that it may have been an appropriate improvement for TMfS to have devised a more disaggregate sector system based on area characteristics (e.g. rural, major urban etc.) and/or movements where PT estimates were fully observed. Consideration to such a sector system should be given for future developments of TMfS. The parameters derived for "home based" trips are presented in Table 5.2 of MVA's report. These are replicated in Table 6.2 below.

Table 6.2 : TMfS Mode Choice Sensitivity Parameters

Mode		Edinburgh	Glasgow	Other
AM Peak				
	HBW	0.937	0.734	0.825
	HBO	0.691	0.704	0.986
	HBEB	0.854	0.707	0.590
Inter Peak				
	HBW	0.289	0.459	0.002
	HBO	0.315	0.384	0.110
	HBEB	0.321	0.243	0.208

6.6.3 The mode choice sensitivity parameters clearly demonstrate that mode choice is more sensitive during the AM peak (as the magnitude of the sensitivity parameters is consistently greater).

Whilst to some extent this may be expected, the relative difference in magnitude of the sensitivity parameters between the AM and inter-peak periods is surprisingly significant. In particular, it is noted that the inter-peak mode choice sensitivity outwith Glasgow and Edinburgh is especially low for all trip purposes, but particularly for HBW trips.

6.6.4 Little commentary is provided in MVA's report regarding these parameters, other than a statement that *"…mode choice is more sensitive in the AM peak…"*. MVA has subsequently commented further that *"The TMfS definition of car availability for a person is that the person comes from a car owning household. This definition was made because car ownership data is widely available in comparison with data on actual car availability for a specific trip. For the inter-peak period it is likely that there is actually less real car availability for a particular car ownership level than for the peak since the household vehicle(s) are more likely to be used for peak hour travel. We would expect therefore that there is less sensitivity to mode choice in the inter-peak period"*.

6.6.5 The TTAA acknowledges the logic of this statement, nevertheless the relative difference in sensitivity between peak and inter-peak is considered significant and worthy of note for potential users. The TTAA notes that it may have been an appropriate enhancement for TMfS to have calibrated mode choice parameters separately for 1 and 2+ car owning households. Consideration should be given to this for future development of the TMfS demand model.

6.6.6 It is not possible within this model development audit to draw firm conclusions regarding the appropriateness of the derived mode choice parameters. Such conclusions can only be drawn following comparison with expectations and previous experience when applying the model in predictive mode.

6.6.7 Mode specific constants (similar in function to the destination choice K factors) were also derived for the mode choice model. These constants are used to ensure that the observed base year mode split (at the trip end level) is replicated in the base year model. The process for deriving these constants is considered acceptable for TMfS. The derived mode specific constants are not, however, presented in MVA's report, therefore the TTAA cannot provide any commentary regarding the appropriateness of the constants used.

6.6.8 The mode specific constants are recalculated for forecast years in TMfS. This is intended to reflect the fact that car ownership will increase over time and the assumption that members of the 1+ car ownership segment will be less likely to use PT in the future (all other things remaining equal). On this basis, there is no reason why travel choice behaviour of the 1 car owning household members should vary between base and forecast years. Users of TMfS should therefore take care to ensure that changes in the mode specific constants accord with this expectation. Again, the TTAA notes that it may have been an appropriate enhancement for TMfS to have calibrated mode choice parameters separately for 1 and 2+ car owning households. Consideration should be given to this for future development of the TMfS demand model, although it is recognised by the TTAA that this would lead to an increase in both data requirements and model run times.

6.6.9 It should be noted that the statistical significance of the mode choice model parameters has not been presented in MVA's report and has not been investigated in this audit.

6.7 Reverse Trips and Non-Home Based Trips

6.7.1 The demand models for CSTM3 and CSTM3A operated for a single 24 hour period using a matrix reduction process to convert demand model outputs from the 24 hour period to individual time periods (e.g. AM, inter and PM peaks). "Home based" trips were also allocated to their "from home" and "to home" directions during this process. "Non-home based" trips were also simply considered as a separate journey purpose and were subject to mode choice at the trip end stage, then destination choice.

6.7.2 The TMfS demand model has been altered to operate on an individual time period basis dealing only with “from home” trips separately for the AM, inter and PM peaks. Consequently, a different process to that adopted for CSTM3A was required to derive the “to home” trips, by linking them to the “from home” trips. Furthermore, “non-home based” trips are also linked to “home based” trips in TMfS rather than treating them as a separate journey purpose. The different trip types are handled in the TMfS demand modelling process as follows.

To Home Trips

6.7.3 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.

Evening Peak Trips

6.7.4 The evening peak “from home” trips are derived by a factoring process applied to the “from home” trips from the inter-peak periods. Again, factors are derived separately by mode and trip purpose and applied to the corresponding inter-peak trips.

Non-Home Based Trips

6.7.5 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 respectively. The totals are constrained to the total origins as origins and destinations are unlikely to match in this process.

6.7.6 Overall, the TTAA is content that the principles of the above approach appear to be logical and reasonable for a model such as TMfS, although this is based on the theoretical description provided in the documentation. No numerical information has been presented in MVA’s report to enable confirmation of the appropriateness of the factors applied and the resulting magnitude of the “to home”, “evening peak” and “non-home based” trips. The TTAA therefore cannot draw any conclusions in this audit regarding the magnitude of the reverse and “non-home based” trips.

6.8 Trip End Model

6.8.1 The trip end model for both car and public transport trips in TMfS is a growth factor model based on the DfT National Trip End Model (NTEM). NTEM can be used to produce trip end forecasts by mode and time period for Local Authority districts at a person trip level. TMfS also has an associated land use model (TELMOS) which can output planning data and car ownership data on a zonal basis for a given forecast year.

6.8.2 The TMfS trip end model therefore becomes a relatively simple method of calculating future year trip ends by multiplying vectors of trip rates by the planning data person type vectors for each zone. The trip ends for the forecast year are then divided by those for the base year to create growth factors. The base year trip productions are then multiplied by these factors to create future year trip productions by mode/car availability, time period and journey purpose.

6.8.3 The NTEM based process relates solely to trip productions for “from home” trips. The “to home” and “non-home based” trip ends are created in a separate process.

6.8.4 The trip attraction process involves applying attraction parameters to the number of jobs in each zone. The forecast trip attractions are then divided by the base year attractions to create growth factors to be applied to the base year trip attractions.

6.8.5 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 base other" and "non-home based" 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.

6.8.6 The TTAA is content that these aspects of the TMfS model development are appropriate.

6.9 Peak Spreading and Time Period Choice

6.9.1 The two elements of time of day choice considered in TMfS are as follows:

- peak spreading (i.e. moving from peak to shoulder of the peak, but within the same peak period)
- macro time of day choice (i.e. shifting from AM or PM peak period into the inter-peak or pre-AM peak/post-PM peak periods)

6.9.2 Both of the above aspects are outlined in MVA's report and the TTAA's comments are as follows.

Peak Spreading

6.9.3 The peak spreading model within TMfS has been designed to operate in the AM peak only at the individual matrix cell level. The form of the peak spreading model is an incremental logit model. The shoulder peak costs (not modelled in the HAM) have been 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.

6.9.4 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.

6.9.5 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.

6.9.6 Overall, the TTAA is content that the specification of the peak spreading model is reasonable for TMfS. Furthermore, the application of this on a cell by cell basis, albeit with various assumptions in the process, is considered an improvement over the CSTM3A methodology.

6.9.7 The TTAA would recommend that, prior to the widespread application of TMfS, an advisory paper is produced to demonstrate the scale and relative geographical sensitivity of peak spreading effects under various forecast scenarios.

Macro Time of Day Choice

6.9.8 The macro time of day choice model is intended to model the impact of time period switching in response to road user charging and/or other major network management measures. Consequently, this module will only be invoked for specific scheme or policy tests. This is in accordance with the current DfT guidance on variable demand modelling.

6.9.9 The model will be applied to car trips only on the principle that some of the "from home" trips in the AM peak will move to the pre-AM peak period or the inter-peak period. Similarly, in the PM peak, some of the "to home" trips will move to either the inter or post-PM peak periods. The output from the process will be matrices for the pre-AM peak and post-PM peak. The pre-AM peak "from home" matrix will also have associated "to home" trips in the other time periods which are derived from the AM peak factors for this.

6.9.10 The model is of a similar incremental logit form to the peak spreading model with the main difference being the use of actual time period costs on a cell by cell basis, rather than the approximated method for the peak spreading model.

6.9.11 Overall, the TTAA is satisfied that the defined methodology for dealing with macro time of day choice appears to be logical. Given that the application of macro time of day choice in transport models is in its infancy, the TTAA would expect that any application of this module within TMfS should be supplemented with a range of sensitivity tests. This will enable the model outputs to be interpreted in the full knowledge of TMfS's sensitivity with respect to macro time of day choice for a range of policy or scheme specific tests.

6.10 Model Realism Tests

6.10.1 MVA undertook a series of tests to establish the broad realism of the model outputs in forecast mode. These tests were undertaken in accordance with the DfT draft advice on Variable Demand Modelling (VADMA). The sensitivity tests undertaken to examine the elasticity of demand with respect to:

- car fuel price (20% increase in car fuel price tested)
- PT fares (20% increase in PT fares tested)
- car journey times (20% increase in car journey time tested)

6.10.2 The modelled elasticity in response to each of the above tests was derived on an average basis across the whole TMfS study area and the elasticities compared with the values in §27.7 and §27.8 of the draft VADMA guidance. Each of the sensitivity tests is discussed in turn in the following sections.

Car Fuel Price Elasticity

6.10.3 For this test, the generalised costs were recalculated based on a 20% increase in fuel price and a full demand model run was undertaken. The resulting car matrices were then weighted by a distance matrix to establish the car kilometres. The elasticity was then calculated by comparison with the base case and these are shown in Table 6.3.

Table 6.3 : Fuel Price Elasticities

Journey Purpose	Elasticity Guidance	AM Peak	Inter Peak
In-Work	-0.15 to -0.30	-0.05	-0.09
Non-Work	for all purposes	-0.24	-0.29

6.10.4 The non-work elasticities are within the guideline range, towards the higher end whilst the in-work values are outwith the range. The elasticities are broadly similar to those achieved with CSTM3A, albeit for a considerably more conservative test in TMfS (20% change for TMfS compared with 100% change for CSTM3A). It is intuitively correct that non-work trips would demonstrate a greater sensitivity to changes in fuel price than in-work trips.

PT Fares Elasticity

6.10.5 The same methodology as per the fuel price test was applied in this test with the difference being that a 20% increase in PT fares replaced the 20% increase in fuel price. The resulting elasticities are shown in Table 6.4.

Table 6.4 : PT Fares Elasticities

Journey Purpose	Elasticity Guidance	AM Peak	Inter Peak
All	-0.20 to -0.40	-0.21	-0.13

6.10.6 The AM peak elasticity is demonstrated to be within the guideline range at the lower end whilst the inter-peak falls outwith the range. The elasticities are again broadly similar to those achieved with CSTM3A, albeit for a considerably more conservative test in TMfS (20% change for TMfS compared with 100% change for CSTM3A).

Car Journey Time Elasticity

6.10.7 This test involved skimming generalised costs from the highways network with a factor of 1.2 applied to the time weighting of the generalised cost formula. A single internal loop (no assignment/cost iteration) was run and the output car matrices were weighted by distance. The resulting elasticities are shown in Table 6.5.

Table 6.5 : Car Journey Time Elasticities

Journey Purpose	Elasticity Guidance	AM Peak	Inter Peak
In-Work	-0.15 to -0.70	-0.19	-0.09
Non-Work	for all purposes	-0.37	-0.12

6.10.8 The AM peak elasticities are demonstrated to be within the guideline range towards the lower end whilst the inter-peak elasticities fall outwith the range. The lower sensitivity in the inter-peak is intuitively correct (relative to the AM peak).

Summary of Realism Tests

6.10.9 Overall, the realism tests generally demonstrate morning peak elasticities to be within the range outlined in the draft VADMA guidance but towards the lower end of the range (i.e. relatively insensitive). The inter-peak sensitivities in all but one case (non-work fuel price elasticity) fall outwith the recommended ranges demonstrating very low sensitivity in this time period. The inter-dependence between PM and AM (and to some extent inter-peak) trips in the TMfS demand model would imply a similar level of sensitivity in the PM peak compared with the AM.

6.10.10 It is recognised that the guidelines in VADMA attempt to cover a number of factors such as journey purpose, spatial differences and modal competition which may or may not reflect the specific conditions within TMfS as a whole. Furthermore, the demonstration of non-work trip sensitivity generally being within the guideline range is encouraging, given the predominance of non-work trips within TMfS.

6.10.11 It should be noted, however, that the realism tests have been undertaken at a global level across the TMfS network. Furthermore, the sensitivities across the network as a whole tend to be at the lower end of the VADMA guidance ranges. It follows therefore, that some areas of the model will have much lower sensitivities and other areas much higher. With this in mind, the TTAA considers that prior to the widespread application of TMfS, additional (more localised and focused) realism testing would be beneficial to provide potential users with guidance on the relative elasticity in different areas of the model with respect to issues such as fuel price, PT fare and car journey time changes. More specific measurable outcomes (e.g. mode shift on a sector basis) would assist in the interpretation of these tests and could be used more widely to test other aspects of the modelling process.

6.11 Forecasting Procedures

6.11.1 The general operation of the TMfS demand model in forecast mode is the same, in principal, as CSTM3A. That is that the model is designed to produce forecast matrices to be applied in an incremental manner to the base year matrices. The process relies on model parameters, trip ends and inputs from the highway and public transport assignment models. The differing aspects of the forecasting process are outlined as follows.

Overall Operation of Demand Model

6.11.2 The overall operation of the demand model in forecast mode is essentially the same as CSTM3A. Trip ends are created for the relevant forecast year and economic growth scenario whilst the various sub-models operate in an iterative manner to create the relevant highway and PT assignment matrices. The TTAA is content that the procedures adopted are appropriate for TMfS.

Sequence of Tasks

6.11.3 The sequence of tasks for the demand model differs depending on whether the forecast is for a reference or variance case. In general, the sequence outlined for TMfS appears to follow the same sequence outlined for CSTM3A and is therefore considered appropriate by the TTAA.

The Incremental Forecasting Approach

6.11.4 The TMfS demand model operates in an incremental manner similar to CSTM3A. The model therefore produces estimates of the ratio of forecast year to base year synthesised trip ends and applies these ratios to the base year “observed” trip ends to create the forecast trip ends and consequently the forecast assignment matrices. The TTAA considers this consistent with good working practice and is appropriate for TMfS.

Model Parameters

6.11.5 The mode specific constants and the generalised cost coefficients for assignment are recalculated for forecast years in TMfS (in line with TAG Unit 3.5.6). The TTAA has commented on the mode specific constants earlier in this chapter and is content that the model parameter adjustments are acceptable for TMfS.

Trip Ends

6.11.6 Forecast trip ends in TMfS are created by applying trip rates (by mode, car availability, time period and journey purpose) from NTEM to planning data outputs from TELMOS. The TTAA considers the principle of this approach to be acceptable for TMfS.

6.11.7 It should be noted, however, that TELMOS, its inputs and the realism of its outputs have not been the subject of this audit. The TTAA therefore cannot provide any commentary regarding the appropriateness of the TELMOS outputs for use in the TMfS forecasting process.

Highway and Public Transport Cost Matrices

6.11.8 The generalised cost matrices from the base year are used as the start point for the demand model process for a reference case whilst the reference case generalised cost matrices are used as the start point for a variance case in TMfS. This is similar to the procedure adopted for CSTM3A and is considered appropriate for TMfS.

Highway and Public Transport Networks

6.11.9 The user is required to code the relevant highway and public transport networks for all reference and variance cases using conventional coding methods for TRIPS models. Specification of the appropriate reference and variance case networks for highway and PT is the responsibility of the TMfS user.

Goods Vehicles

6.11.10 Goods vehicle forecasting is not undertaken as part of the standard demand modelling procedure in TMfS. Instead, forecast goods vehicle matrices are created by calculating growth on a cell by cell basis from TELMOS data and applying these to the TMfS base year goods vehicle matrices. External goods vehicle movements are subject to uniform NRTF growth rates. The growth is applied on a factor basis and logic checks are applied on a zone to zone basis to ensure that total zonal growth is consistent with planning data.

6.11.11 The TTAA considers the principle of this methodology acceptable for TMfS and recognises the potential benefits of enabling differential goods vehicle growth on a zone by zone basis within the internal model area.

6.11.12 Again, it should be noted that TELMOS, its inputs and the realism of its outputs have not been the subject of this audit. The TTAA therefore cannot provide any commentary regarding the appropriateness of the goods vehicle data within TELMOS for use in the TMfS forecasting process.

6.11.13 The TTAA considers that prior to the widespread application of TMfS, a supplementary paper providing details of goods vehicle growth from TELMOS should be prepared. This should include details of the differential growth on an area by area basis.

External Trips

6.11.14 External trip growth is handled in the same way in TMfS as it was for CSTM3A. That is that private car trips (in-work and non-work) are subject to uniform NRTF growth rates and PT trips are subject to a uniform growth rate derived from application of the trip end model in the internal model area. The TTAA is content that this methodology is appropriate for TMfS.

6.12 Summary of TMfS Demand model Audit

6.12.1 The main findings from the TTAA's review of the TMfS demand model are outlined below.

Model Overview

6.12.2 The TMfS demand model has been developed as a four stage model operating in an incremental manner in forecast mode. The model structure adopted is one where mode choice precedes destination choice in the model hierarchy. The TTAA considers that this has resulted in a model structure being chosen which is a valid option to choose from a range of alternatives. Given the timescale for developing TMfS, it is the TTAA's view that ideally it would have been definitively concluded that the adopted model structure is the most appropriate, to the exclusion of all other possibilities, by undertaking a comparison of relative sensitivities of mode and distribution choice for each of the possible model structures. In view of this, the TTAA recommends that all future significant upgrades or enhancements to the model should include for such a comparison (of relative sensitivities of mode and destination choice within alternative order of choice hierarchies) within the demand model development timescale and associated costings.

6.12.3 The demand model operates at a zonal level consistent with the highway and PT models which is an enhancement for TMfS. Separate demand models are present for each model time period (with linkages between) whilst the trip end, mode and destination choice models are concerned only with “from home” trips. “To home” and “non-home based” trips are linked to “from home” trips by a factoring process. Peak spreading is now included in the main supply/demand convergence process and operates at the zonal level.

6.12.4 The TTAA is content that the generalised cost derivation for the base year is acceptable for TMfS.

6.12.5 Parking charges have also been included in TMfS for Aberdeen, Edinburgh, Glasgow, Perth, Stirling, Dunfermline and Dundee. These can be used to give broad indications of the likely response to changes in parking charge and/or policy.

Trip and Cost Matrices

6.12.6 These have been derived using various data sources. The TTAA is content that, given the function and purpose of the TMfS demand model (to provide travel demand growth forecasts rather than absolute travel demand forecasts), these aspects of the matrix development process are considered acceptable.

6.12.7 Comparisons have been not been made by MVA between the 2001 CSTM3A projection planning data used in the demand model development and the 2001 census based data, which has subsequently become available. Any significant differences between these datasets at the base level may not be significant when considering base model runs. However, when operating in forecast mode, differences could be extremely significant. For example, if the projected 2001 CSTM3A data contains population and employment data for a given zone which is significantly different to the 2001 census data, this would suggest that existing (i.e. Base year) levels of development are either significantly over or under-represented in the trip ends for this zone in TMfS. Hence, when applying the growth factors calculated from the NTEM/TEMPRO process, the overall increment would therefore be potentially grossly over or underestimated due to the error in the base year trip ends even if the calculated NTEM/TEMPRO growth factor is robust.

6.12.8 Given the above, the TTAA considers that such a check is essential and would provide verification of the accuracy of the base planning data within TMfS, thereby providing confidence in the demand model’s ability to robustly predict growth at a zonal level. The TTAA considers that it is essential to undertake this check and report on the findings in advance of the widespread application of TMfS.

Mode and Destination Choice Model Calibration

6.12.9 Overall, the TTAA is content that the destination choice model has been developed and the relevant parameters calibrated in an appropriate manner for TMfS. Users should, however, note the significant temporal differences evident in the mode choice sensitivity parameters.

Reverse Trips and Non-Home Based Trips

6.12.10 Overall, the TTAA is content that the principles of the approach appear to be logical and reasonable for a model such as TMfS, although this is based solely on the theoretical description provided in the documentation.

Trip End Model

6.12.11 The TTAA is content that this aspect of the TMfS model development is appropriate.

Peak Spreading and Time of Day Choice

6.12.12 Overall, the TTAA is content that the specification of the peak spreading model is reasonable for TMfS. Furthermore, the application of this on a cell by cell basis, albeit with various assumptions in the process, is considered an improvement over the CSTM3A methodology. It is appropriate that the peak spreading model is applied in the AM peak only.

6.12.13 Overall, the TTAA is satisfied that the defined methodology for dealing with macro time of day choice appears to be logical. Given that the application of macro time of day choice in transport models is in its infancy, the TTAA would expect that any application of this module within TMfS should be supplemented with a range of sensitivity tests. This will enable the model outputs to be interpreted in the full knowledge of TMfS's sensitivity with respect to macro time of day choice for a range of policy or scheme specific tests.

Model Realism Tests

6.12.14 Overall, the realism tests generally demonstrate morning peak elasticities to be within the range outlined in the draft VADMA guidance but towards the lower end of the range (i.e. relatively insensitive). The inter-peak sensitivities in all but one case (non-work fuel price elasticity) fall outwith the recommended ranges demonstrating very low sensitivity in this time period. The inter-dependence between PM and AM (and to some extent inter-peak) trips in the TMfS demand model would imply a similar level of sensitivity in the PM peak compared with the AM.

6.12.15 It should be noted, however, that the realism tests have been undertaken at a global level across the TMfS network and that the sensitivities across the network as a whole tend to be at the lower end of the VADMA guidance ranges. The TTAA considers that prior to the widespread application of TMfS, additional (more localised and focused) realism testing would be beneficial to provide potential users with guidance on the relative elasticity in different areas of the model with respect to issues such as fuel price, PT fare and car journey time changes. More specific measurable outcomes (e.g. mode shift on a sector basis) would assist in the interpretation of these tests.

Forecasting Procedures

6.12.16 The forecasting procedures for the TMfS demand model are similar to those for CSTM3A in that an incremental forecasting methodology is applied to base year trip matrices. The main difference in the forecasting process is the estimation of synthetic trip ends and goods vehicle growth using the planning data in TELMOS. The TTAA is satisfied that the principle of this approach is appropriate for TMfS. However, it should be noted that TELMOS, its inputs and the realism of its outputs have not been the subject of this audit. The TTAA therefore cannot provide any commentary regarding the appropriateness of the planning and goods vehicle data within TELMOS for use in the TMfS forecasting process.

7 PARK AND RIDE MODEL

7.1 Background

7.1.1 This chapter presents the TTAA's findings regarding TMfS Audit Task 10 : Review Park and Ride Model.

7.1.2 MVA provided the TTAA with the "TMfS Park and Ride Calibration and Validation Report", Draft Report, Issue 5, 29 February 2005 and with Information Note No AN10-1_JD dated 1st July 2005. The findings in this chapter are based on a review of the specific information supplied, and on the basis of various discussions with MVA during the audit process.

7.1.3 The TTAA's comments regarding the TMfS Park and Ride Model are listed in the following sections of this chapter. The section headings correspond with the chapter headings from the above draft report supplied by MVA.

7.2 Summary

7.2.1 The report summary sets out the contents for the Park and Ride Assignment Model (PARAM) and provides brief conclusions and recommendations. It is concluded in the summary that the *"…model is fit for purpose as a strategic Park and Ride model…"*. Furthermore, it is *"…recommended that the PARAM is only used where Park and Ride is a significant part of the scheme being tested"*. It is also suggested in the summary that *"…users wishing to use TMfS to test specific public transport schemes involving a significant Park and Ride component will extend this calibration of the PARAM…"* as appropriate for the intended application.

7.2.2 The TTAA concurs with these conclusions and recommendations.

7.3 Introduction

7.3.1 The introduction sets out the background and context of the model development as well as the report structure. The Park and Ride modelling procedure for TMfS is based on the procedures developed during the CSTCS for use with CSTM3A. The procedure is therefore an optional "add on" following the main supply/demand convergence to enable the testing of schemes or policies with a significant Park and Ride component. The TTAA considers this an appropriate approach to adopt for TMfS.

7.4 Model Structure

Park and Ride Model Structure

7.4.1 The PARAM uses inputs from various components of TMfS to predict the demand for Park and Ride at user-specified car parks. The primary inputs include:

- highway and PT trip and cost matrices from the HAM and PTM assignments
- car ownership, occupancy and availability data from the Demand model
- parking charge data from the Demand model
- Park and Ride site specific data files

7.4.2 The outputs from the PARAM are amended car and PT demand matrices for subsequent re-assignment and appraisal. Car park occupancies at the end of the AM and inter-peak modelled periods are also output by the PARAM. An automated calculation process is used to control the Park and Ride procedure and manipulate the outputs from the main Park and Ride module to create the relevant demand matrices for assignment. The Park and Ride module is a program called ADJPNR which is discussed in more detail in the next section.

ADJPNR Program

7.4.3 The ADJPNR program is the routine used to estimate the changes to the highway and PT trip matrices to take account of the available Park and Ride sites within the model area. Each Park and Ride site is allocated to the relevant TMfS zone and the potential catchment area (i.e. origins and destinations most likely served by the site) is defined. The program then estimates the cost of driving to each Park and Ride site and travelling to the ultimate destination from there by PT.

7.4.4 The demand for Park and Ride for each site is derived from a logit formula whereby the OD car demand is firstly split by comparing the cost of making the complete journey by car or by Park and Ride via the best (i.e. minimum cost to destination) car park. These costs are then compared with the cost of completing the journey either by car or PT with the proportion choosing to Park and Ride estimated by the logit formula. The car available PT demand is split by comparing the cost of making the complete journey by PT with the cost by Park and Ride via the best (i.e. minimum cost to destination) car park. The separate Park and Ride demands are then distributed between the available car parks using another logit formula.

7.4.5 An iterative process is undertaken whereby available capacity and increased search times at over-capacity car parks are taken into account. The process is considered to have converged when the number of car arrivals is less than or equal to the available spaces at all car parks simultaneously.

7.4.6 Site specific transfer penalties enable the relative attractiveness of each site to be considered. The program can also take account of over-spill parking by adjusting walk time between car and PT as the “nearer” spaces are filled. The output from the process is a set of amended highway and PT matrices which reflect the mode shift to Park and Ride and a summary of the car park occupancy at the end of each time period.

7.4.7 Overall, the TTAA is content that the specification of the ADJPNR program follows a logical sequence and is appropriate for application with TMfS.

Using the PARAM

7.4.8 Application of the PARAM involves three possible steps as follows:

- a fully converged run of TMfS to derive initial trip and cost matrices
- a run of the Park and Ride model to adjust the matrices as appropriate
- re-assignment of the adjusted trip matrices (if considered necessary)

7.4.9 As well as recommending that the PARAM should only be used when Park and Ride is a significant part of the scheme being tested, MVA also recommends that only “major” Park and Ride schemes and/or policies should be evaluated using the PARAM. Given the strategic nature of TMfS, the TTAA concurs with MVA’s recommendations in this regard.

7.4.10 The PARAM has the flexibility to assess a varying number of Park and Ride sites and the competition between them. MVA notes that whilst town/city parking charges are taken into account when considering the attractiveness of such parking areas, the availability and convenience of these spaces is not explicitly taken into account in the PARAM.

7.4.11 MVA further recommends that users of the PARAM:

- collect relevant details at all Park and Ride sites which either compete with, or form part of, the proposed scheme
- calibrate the PARAM to match observed Park and Ride behaviour at these existing locations

- Use the PARAM to predict the Park and Ride component of the proposed scheme, including the impact of competition from existing Park and Ride locations and the abstraction of the new scheme from these existing sites

7.4.12 Again, the TTAA endorses these recommendations and advises that potential users of the PARAM factor these considerations into any timescales and resources required for its application.

7.5 Model Development

7.5.1 The model development involved calibration to establish a set of model parameters which MVA considered represent "initial default" settings with a view to more detailed local calibration being undertaken prior to any detailed application of the PARAM. The TTAA's findings on the model development process are in the following sections.

Locations Used for the Initial Broad-Brush Calibration

7.5.2 The dedicated Park and Ride sites included in the initial broad-brush calibration of the PARAM are as follows:

- Bridge of Don (north Aberdeen)
- Kingswells (west Aberdeen)
- Perth (south-west Perth)
- Ferrytoll (north of Forth Road Bridge)
- Newcraighall (south-east Edinburgh)

7.5.3 The TTAA concurs that these were the appropriate dedicated Park and Ride sites to include within the model calibration. In addition to the dedicated Park and Ride sites, various "informal" Park and Ride sites and/or significant rail stations were also included in the calibration to ensure that appropriate competition within the relevant corridors was considered. The additional sites included in the calibration exercise were as follows:

- Inverkeithing and Kirkcaldy
- North Berwick, Dunbar, Musselburgh, Prestonpans and Wallyford
- Croy, Cumbernauld, Falkirk Grahamston, Falkirk High, Greenfaulds, Larbert, Lenzie, Linlithgow and Polmont

7.5.4 Data was available for each of these sites for use in the calibration process. The TTAA is satisfied that the sites considered in the PARAM calibration area appropriate.

Data Collection

7.5.5 Site specific information was required for each of the Park and Ride sites included within the PARAM. This information includes car park capacity, parking charges, OD catchment area and arrival profile for each car park. The data was collected from Local Authorities, other Park and Ride related projects and from PT operator's websites.

7.5.6 Although all of the calibration data was requested from the Local Authorities, this was not always available and gaps in this information were filled using information from PT operator's websites, data (2002) collected during the development of ASAM and data (2003) from the SITCoS (SESTRANS Integrated Transport Corridors Study) project. MVA states in §3.3.6 that *"…this did result in a slight inconsistency in the base year used for the various calibration sites."*.

7.5.7 MVA has further commented on this matter that *"During the development of the TMfS Park and Ride model, data was requested from Local Authorities with the hope of creating a database* *containing consistent 2002 Base Year Park and Ride Information. However, due to the lack of data collected to date by Local Authorities, creation of a wholly consistent database was not possible. Therefore, information was obtained from other studies even if the dataset was inconsistent with the 2002 model base year.*

7.5.8 *"It was also hoped to obtain survey data that located the origins of users travelling to each Park and Ride site (as was available for some sites as noted). This data would then be used as the main basis for the construction of Park and Ride catchment areas. This information was only available for a very limited number of sites and therefore professional judgement was relied upon to create catchment areas for the majority of Park and Ride sites. Occupancy data was also not available for 3 informal Park and Ride sites within the Edinburgh to Glasgow corridor.*

7.5.9 *"The majority of gaps in the data collected have been filled by information from other (non base) years or general assumptions. Use of this data, assumptions made or remaining gaps in information are not expected to have any significant impact on the calibration of the TMfS Park and Ride model"*.

7.5.10 Overall, the TTAA is content that information from appropriate sources has been used in the development and calibration of the PARAM. Equally, given the limited available data it is acknowledged that professional judgement and use of alternative data sources was acceptable in this context. Users of the PARAM should, however, take cognisance of these issues and MVA's comments regarding lack of local data availability.

Park and Ride Site Parking Data

7.5.11 MVA states in §3.4.1 that *"Occupancy data was available for the majority of car parks included within the PARAM. Where no data existed, it was assumed that the car park was half full at the maximum occupancy. For the Lenzie rail station car park, 100% occupancy was assumed, as the majority of car parks along the Edinburgh to Glasgow line were also full at their maximum occupancy"*.

7.5.12 The TTAA considers these assumptions to be acceptable in the absence of any other information. From the information presented in Table 3.1 of MVA's report, only Perth, Cumbernauld, Greenfaulds and Lenzie occupancy figures were estimated out of a total of 21 sites included within the model. It should be noted, however, that Perth forms one of the dedicated (i.e. significant) Park and Ride sites within the model area and the fact that fully reliable calibration data is unavailable for this site should be borne in mind. It is acknowledged by the TTAA that a limited, independent occupancy survey was undertaken at Perth (outwith the base year) which suggested a reasonable level of calibration at this site was being achieved.

Park and Ride Site Catchment Area

7.5.13 A user defined list of zones representing the likely catchment area of each site is input to the PARAM. The selection of the catchment area zones is a subjective process, however consideration was given to the routes and areas served by the PT services from each site, the road network, unlikelihood of drivers "doubling back" to use the site and the unlikelihood of users subsequently changing to a subsequent PT service.

7.5.14 Graphics depicting the catchment areas for the main Park and Ride sites are provided in Appendix A of MVA's report. Generally, these appear to encapsulate the areas of the network which are most likely to be served by the sites and the TTAA is therefore satisfied that in general, the catchment areas have been appropriately defined.

Creating Highway and PT Demand

7.5.15 The car occupancy sector matrices derived from the TMfS RSI data and used in the demand model development are averaged for input to the PARAM. This data is used to establish the level of car occupancy for new car journeys to Park and Ride sites when shifting from PT in forecast mode.

7.5.16 Existing highway users are assumed to have a car available for access to a Park and Ride site whilst only a proportion of existing PT users are assumed to have this level of car availability, with the proportion depending on the origin zone and the corresponding level of PT car availability calculated for each zone from the TMfS demand model. These assumptions are considered acceptable.

7.5.17 The car ownership matrices for PT users (created by the TMfS demand model) are used in the PARAM to estimate the percentage of PT users who have no car available and removes these from the potential Park and Ride demand. The remaining PT matrix is then reduced by a factor (on a zonal basis derived from base year car ownership census data) to derive the total PT car available demand which has the potential to use Park and Ride.

7.5.18 It is assumed that in-work journeys are excluded from the PARAM process. Hence, the "eligible" PT trips are input to the PARAM along with the "eligible" highway demand, which is further split by HBW long stay parking, HBO short stay parking and PNR.

7.5.19 Overall, the TTAA is satisfied that the process for creating highway and PT demand is logical and appropriate for use in the PARAM.

Creating Cost Matrices

7.5.20 The non-work generalised cost skim for each time period from TMfS is used as input to the PARAM. Town/city centre parking charges for HBW (long stay), HBO (short stay) and PNR trips are then converted to parking charge cost matrices for each journey purpose and combined with the generalised cost skim as appropriate. The TTAA is satisfied that this process is acceptable for the PARAM.

Creating Return Demand Matrices

7.5.21 The ADJPNR program only considers the inbound or from home AM and inter-peak journeys. Return trips are therefore calculated by the PARAM by transposing the AM and inter-peak journeys and adding them to the inter and PM peak demand matrices as appropriate. MVA states in §3.8.1 that *"The process assumes that the proportion of outbound Park and Ride trips which return in the PM peak matches the proportion which travelled inbound during the AM peak"*. The process therefore assumes that of the AM inbound trips, 100% return in the PM time period as they are assumed to consist largely of HBW trips which would return home after 5pm.

7.5.22 The described process is considered logical and appropriate for general application. Users should note the significance of these assumptions regarding return journeys with respect to the intended operation of any Park and Ride proposal testing within the TMfS study area.

7.6 Calibration

7.6.1 The calibration process involved two stages as follows:

- Setting initial global parameters by total usage of each Park and Ride corridor
- Setting site specific parameters by total usage of each Park and Ride site

7.6.2 The PARAM requires an initial LAMBDA value which defines the overall attractiveness of Park and Ride as a mode which was derived from past experience and by matching the modelled to observed occupancy for all sites. Mode constant parameters (defining the attractiveness of switching to Park and Ride) were also derived by matching modelled and observed occupancies in each Park and Ride corridor. An iterative process of refining global and local parameters was undertaken until a satisfactory level of calibration was deemed to have been achieved.

Park and Ride Global Parameters

7.6.3 Initial default catchment areas were defined and a default 10 minute transfer penalty was assumed for each site. The outcome of the global calibration process is shown in Table 7.1.

Table 7.1 : Initial Global Calibration

Park and Ride Corridor	Parking Spaces	Maximum Occupancy (Surveyed)	Maximum Occupancy (Modelled)	Absolute Diff	% Diff
North	1750	706	865	159	23%
Edinburgh to Glasgow	1982	1728	1613	-115	-7%
Edinburgh	739	543	567	24	4%
Fife	1280	960	739	-221	-23%
Total	**5751**	**3937**	**3784**	**-153**	**-4%**

7.6.4 The initial calibration suggested a LAMBDA value of 0.025 and mode constants for highway and PT of 40 minutes and 30 minutes respectively. These setting were then used as the start point for more detailed local calibration. The initial parameters and resulting global calibration are considered acceptable.

Park and Ride Site Specific Parameters

7.6.5 These parameters were defined by calibrating competing Park and Ride sites within each corridor. Catchment areas were enhanced to better match the PT service provision and transfer parameters were amended until calibration to observed occupancies was achieved.

7.6.6 MVA states in §4.3.3 that *"During this review some estimated car park occupancies were altered to match the 'on ground situation…"*. This process was undertaken to ensure that the observed occupancies reflected the actual purpose of motorists using the Park and Ride car parks. Hence, at some informal sites that were surveyed, car parks were used to access local amenities as well as train services. Where such information was recorded, the occupancies were adjusted to exclude these local motorists from the Park and Ride observed occupancy used in calibration. The TTAA considers these adjustments appropriate.

7.6.7 During this stage the global LAMBDA value was reviewed to 0.05 whilst the highway mode constant was changed to 20 minutes (PT remained unchanged). The mechanism for specifying increased walk times from the "far" spaces was also refined. The resultant calibration is outlined in Table 7.2.

Table 7.2 : Calibrated Transfer Parameters and Modelled Occupancies

Park and Ride Site	Car Park Capacity: Car Park (Near)	Car Park Capacity: On Street (Far)	Car Park Capacity: Total Spaces	Transfer Parameter (Near) (Minutes)	Transfer Parameter (Far) (Seconds)	Maximum Daily Occupancy (Observed)	Maximum Daily Occupancy (Modelled)	Occupancy Diff (Absolute)	Occupancy Diff (%)
North									
Bridge of Don	600	0	600	5	10	416	428	12	3%
Kingswells	900	0	900	30	10	142	152	10	7%
Perth	250	0	250	25	10	125	129	4	3%
						683	**709**	**26**	**4%**
Edinburgh to Glasgow									
Croy	160	185	345	5	5	345	345	0	0%
Cumbernauld	85	0	85	20	10	43	43	0	0%
Falkirk Grahamston	340	0	340	1	1	227	99	-128	-56%
Falkirk High	190	71	261	5	5	261	261	0	0%
Greenfaulds	40	0	40	40	10	20	27	7	35%
Larbert	40	105	145	1	1	145	70	-75	-52%
Lenzie	160	0	160	5	5	160	160	0	0%
Linlithgow	100	232	332	1	1	332	308	-24	-7%
Polmont	100	114	214	3	1	214	209	-5	-2%
						1747	**1522**	**-225**	**-13%**
Edinburgh									
Newcraighall	300	0	300	40	10	142	180	38	27%
North Berwick	75	16	91	1	1	91	16	-75	-82%
Dunbar	100	20	120	1	1	120	39	-81	-68%
Musselburgh	35	34	69	20	15	69	69	0	0%
Prestonpans	75	4	79	20	10	80	79	-1	-1%
Wallyford	70	9	79	20	15	79	79	0	0%
						581	**462**	**-119**	**-20%**
Fife									
Ferrytoll	500	0	500	7	10	500	500	0	0%
Inverkeithing	470	0	470	20	10	447	447	0	0%
Kirkcaldy	155	155	310	1	1	101	57	-44	-44%
						1048	**1004**	**-44**	**-4%**
Total						**4059**	**3697**	**-362**	**-9%**

Dedicated Park and Ride Sites
Estimated Occupancy

7.6.8 Overall, it is evident that the modelled to observed occupancy comparisons are good for the dedicated Park and Ride sites at Bridge of Don, Kingswells, Perth, Ferrytoll and Newcraighall. Globally, the level of calibration is also good especially within the North and Fife corridors. The modelled occupancy levels within the Edinburgh and Edinburgh to Glasgow corridors is shown to be generally lower than observed. Further comments on the corridor specific calibration are presented in the following sections.

Calibration of Northern Park and Ride Sites

7.6.9 A low transfer parameter was defined for the Bridge of Don site which resulted in a good match between modelled and observed values. This reflects the maturity of the site which has been in operation for several years. The Kingswells site had only recently opened when the calibration data was collected, which perhaps explains the low occupancy relative to the capacity. A very high transfer parameter was therefore required to match the modelled and observed capacity at this site.

7.6.10 The Perth site is also relatively new and no calibration data was available at the time, however, subsequent site visits have confirmed that the assumed 50% occupancy was reasonable. A high transfer parameter was also required for the Perth site, which resulted in a good comparison between modelled and observed occupancy levels.

7.6.11 Overall, the TTAA considers the calibration of the northern sites to be acceptable. It should be borne in mind that the high transfer parameters for the Kingswells and Perth sites may reflect (amongst other things) the recent opening of these sites. Consequently, the TTAA would recommend that for any application of the PARAM within the vicinity of these sites, additional data be collected and the local parameters be confirmed or recalibrated if appropriate.

Calibration of Park and Ride Sites in the Edinburgh/Glasgow Corridor

7.6.12 The sites in this corridor are all "informal" Park and Ride sites at rail stations. Calibration within the corridor proved difficult for a number of reasons including:

- the large number of competing sites and the overlapping catchment areas
- lack of occupancy data for Cumbernauld, Greenfaulds and Lenzie
- motorists potentially using the Falkirk Grahamston car park for town centre access (in reality)

7.6.13 The PARAM is shown to underestimate the Park and Ride demand in the corridor as a whole, particularly at Falkirk Grahamston. The calibration at the other major sites within the corridor (Croy, Falkirk High, Linlithgow and Polmont) is, however, good and overall, the TTAA considers the calibration in the corridor to be acceptable.

7.6.14 Again, it is noted that the transfer parameters for Cumbernauld and Greenfaulds are high compared with others in the corridor. Due to this and the other issues highlighted by MVA, the TTAA would recommend that for any application of the PARAM within the vicinity of these sites, additional data be collected and the local parameters be confirmed or recalibrated if appropriate.

Calibration of East Edinburgh/East Lothian Park and Ride Sites

7.6.15 Again, the Newcraighall site was recently opened and displays a low observed occupancy, leading to the use of a high transfer parameter to achieve a reasonable match between modelled and observed occupancy values.

7.6.16 The range of transfer parameters used across sites in this corridor is wide, ranging from 1 minute (North Berwick and Dunbar) through 20 minutes (Musselburgh, Prestonpans and Wallyford) to 40 minutes (Newcraighall). MVA states in §4.6.3 that *"It would also be possible to improve calibration in this corridor if it was treated in isolation, rather than as part of the network-wide calibration being attempted here"*.

7.6.17 The TTAA concurs with this view and with this in mind it is recommended that prior to any application of the PARAM within the Edinburgh/East Lothian corridor, additional data be collected and the local parameters be confirmed or recalibrated if appropriate.

Calibration of Fife Park and Ride Sites

7.6.18 Ferrytoll, although recently opened, has good facilities and is well served by PT services. A relatively low transfer parameter enabled a good match between modelled and observed occupancy at the site. The adjacent Inverkeithing site also compares well with observations, albeit with a higher transfer parameter. Kirkcaldy is less well calibrated, but has been given a low transfer parameter and only has a small observed occupancy relative to the other sites.

7.6.19 Overall, the calibration to sites in this corridor is considered acceptable.

Overall Calibration

7.6.20 The TMfS Park and Ride model generally compares well with observed occupancy levels at the five dedicated sites, particularly where reliable data is available. Generally, the calibration is best in the north and Fife whilst the calibration in the Edinburgh to Glasgow and Edinburgh/East Lothian corridors is more variable. Overall, however, the level of calibration is considered acceptable in the strategic sense.

7.6.21 MVA states in §4.8.2 that *"The model fails to match observed values closely at some of the informal Park and Ride sites and would require additional local calibration (and additional data collection) if these locations were to form part of a local scheme assessment"*. The TTAA concurs with this recommendation.

Validation of Matrix Extraction

7.6.22 The Park and Ride usage is calculated by the PARAM by extracting the appropriate trips from the highway and PT matrices. In the 2002 Base year, 48% and 52% of the Park and Ride demand was extracted from the highway and PT matrices respectively. This was compared with a passenger opinion survey from February 2001 at the Ferrytoll site. The survey suggested that 50% of weekday Park and Ride passengers were previously car drivers or passengers and 48% were formerly bus or rail travellers.

7.6.23 This suggests that the corresponding shift from highway and PT using the PARAM is in line with observations at a global level. It is unknown how the model compares with observations on a corridor or site specific basis. Nevertheless, this global similarity between modelled and observed values is encouraging.

7.7 Park and Ride Sensitivity Tests

7.7.1 A series of tests was undertaken, varying in scale and nature, to establish the sensitivity of the PARAM to differing forecast conditions. The various tests are described further in this section.

Test 1 : 2006 Do Nothing Forecast Year

7.7.2 This results in a slight increase in overall Park and Ride demand, although with reductions evident at some sites. Overall, an increase in the Park and Ride demand would be expected in a forecast Do Nothing, due to increased highway only and PT only journey costs. No additional services have been assumed to operate in the forecast year, hence, this may have limited the potential for a more significant increase in Park and Ride trips.

7.7.3 Overall, the result is broadly in line with expectations at a global level. Insufficient detail is provided in the MVA's report to draw more detailed conclusions regarding the outcome of this test.

Test 2 : Additional Parking Spaces at Ferrytoll

7.7.4 The number of spaces at Ferrytoll was assumed to increase from 500 to 1,000 which resulted in an extra 30 cars using Park and Ride facilities across the network compared with the 2006 Do Nothing test. There was an increase in Park and Ride usage at Ferrytoll and a corresponding decrease at Inverkeithing.

7.7.5 Again, the result is broadly in line with expectations at a global level although the overall increase of 30 cars using Park and Ride (compared with the 2006 Do Nothing) does seem to be very small considering the scale of additional parking space provision in the test. Insufficient detail is provided in MVA's report to draw more detailed conclusions regarding the outcome of this test.

Test 3 : Parking Charges Increased

7.7.6 Long stay parking charges were doubled in all city centres within TMfS, although a full demand model run was not undertaken in this case, presumably for reasons of expedience. The outcome of the test was that total usage of Park and Ride increased by approximately 20% (800 vehicles) with the largest increase at sites where parking spaces were readily available. The number of trips shifting from the highway matrix was also shown to increase.

7.7.7 This result is broadly in line with expectations at a global level and is encouraging. Insufficient detail on a corridor and/or site specific basis is provided in MVA's report to draw more detailed conclusions regarding the outcome of this test.

Test 4 : Parking Charges Reduced

7.7.8 Long stay parking charges were halved in all city centres within TMfS, although a full demand model run was not undertaken in this case, again, presumably for reasons of expedience. The outcome of the test was that total usage of Park and Ride reduced by approximately 10% (400 vehicles) with the number of trips shifting from the highway matrix shown to reduce.

7.7.9 This result is broadly in line with expectations at a global level and is encouraging. Insufficient detail on a corridor and/or site specific basis is provided in MVA's report to draw more detailed conclusions regarding the outcome of this test.

Test 5 : Parking Charges Increased Within Edinburgh City Centre

7.7.10 Long and short stay parking charges in Edinburgh were increased by 50% and an additional 500 spaces were created at Ferrytoll. Again, no demand model run was undertaken, presumably for reasons of expedience. This resulted in an increase in Park and Ride trips by approximately 7% (250 vehicles) with the major increases at Ferrytoll and Newcraighall sites.

7.7.11 This outcome is intuitively correct for the test given the inputs, in that increasing parking charges and Park and Ride capacity is likely to result in a greater overall response than increasing Park and Ride capacity alone (ref. Test 2). It is worthy of note that comparing this test with Test 2 indicates that the Park and Ride response seems to be more sensitive to changes in city centre parking charges than to Park and Ride site capacity.

Test 6 : Abolition of Free Private Non Residential (PNR) Parking

7.7.12 This was undertaken by applying the equivalent short stay parking cost to motorists who previously did not pay city centre parking charges. Again, no demand model run was undertaken, presumably for reasons of expedience. The impact of this test was to increase Park and Ride usage by approximately 3% (100 vehicles).

7.7.13 Again, this outcome is intuitively correct for the test. Insufficient detail on a corridor and/or site specific basis is provided in MVA's report to draw more detailed conclusions regarding the outcome of this test.

Test 7 : New Park and Ride Site at Straiton

7.7.14 A new 500 space site was included at Straiton with all spaces assumed as near. No additional, dedicated Park and Ride bus services were assumed to service the site and a full demand model run was not undertaken. Two transfer parameters were tested of 10 minutes and 30 minutes respectively.

7.7.15 The lower transfer parameter resulted in the car park reaching its capacity and a reduction in the usage of the Newcraighall site by approximately 15%. Overall Park and Ride usage increased by approximately 450 vehicles (11%).

7.7.16 The higher transfer parameter resulted in the car park being approximately 65% full (330 spaces occupied) with a reduction in usage at Newcraighall. Overall Park and Ride usage was shown to increase by approximately 300 vehicles (8%).

7.7.17 This result is broadly in line with expectations at a global level and is encouraging.

Summary of Sensitivity Tests

7.7.18 The various sensitivity tests have generally demonstrated an intuitively correct Park and Ride response at a global level. It should be noted that full demand model runs have not been undertaken, which would influence the results to some extent. Additionally, little detail is reported to enable firm conclusions to be drawn other than at a global level.

7.7.19 Overall, the TTAA is satisfied that the results demonstrate responses which are in line with expectations at a global level and considers this encouraging. It is difficult to draw firm conclusions regarding the PARAM's sensitivity of response in the absence of more detailed corridor and/or site specific outputs from the tests.

7.7.20 The outcome from the tests suggest that the PARAM is suitable for application, however, the TTAA would recommend that, if necessary, additional data collection and calibration is undertaken prior to any detailed corridor and/or site specific testing. Additionally, an appropriate set of sensitivity tests should be undertaken for any application of the PARAM to ensure that the likely range in Park and Ride response rather than a single absolute value can be reported for any given application.

7.8 Conclusions and Recommendations

Conclusions

7.8.1 MVA concludes that *"the TMfS Park and Ride model displays a good level of calibration for all dedicated Park and Ride sites. The standard and confidence of calibration rises substantially for sites where reliable information is available"*. The TTAA concurs with this conclusion.

7.8.2 It is further concluded that *"…the model is fit for purpose as a strategic Park and Ride model that can be used, as part of a range of assessment tools to evaluate major schemes and policy decisions. The model database and processes can also be adopted, extended and calibrated for use in more localised assessment of Park and Ride schemes"*. Again, the TTAA concurs with this conclusion.

Recommendations

7.8.3 MVA recommends that *"…the model is used as an initial appraisal of potential major Park and Ride sites or strategies. It is expected that during such appraisal, further more detailed work would be undertaken in the local transport corridor under evaluation. If the Park and Ride model is used as part of a more detailed appraisal, it is recommended that, where necessary, additional Park and Ride data collection is undertaken, which would then form part of the appraisal process"*. Again, the TTAA concurs with these recommendations.

7.8.4 The TTAA would also recommend that an appropriate set of sensitivity tests should be undertaken for any application of the PARAM to ensure that the likely range in Park and Ride response rather than a single absolute value can be reported for any given application.