SIAS

Transport Model for Scotland 2014 (TMfS14)

Transport Scotland

TMfS14 National Road Model Development Report

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TMFS14 ROAD MODEL DEVELOPMENT

Description:	**National Road Model Development Report**
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TMFS14 ROAD MODEL DEVELOPMENT

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1 INTRODUCTION

1.1 Background

Transport Scotland plays a key role in the assessment of proposed changes to land use and transport networks across Scotland. As part of the planning process, Transport Scotland offers the use of its strategic transport and land use appraisal tools to assess the social, economic, operational, and environmental impacts of different land use options and transport interventions.

These appraisal tools include National integrated land use and transport models which cover the whole of Scotland. These National models include both the Transport Model for Scotland (TMfS) and the Transport, Economic, and Land-use Model of Scotland (TELMoS) which are both developed and maintained under Transport Scotland's Land Use and Transport Integration in Scotland service (LATIS).

For more information regarding the LATIS service and the National Transport and Land Use Models, please visit the LATIS website: www.transport.gov.scot/latis

Transport Scotland requested the development of TMfS14 which is calibrated to transport and land use conditions observed during 2014, with this model being an update of the previous TMfS12. The TMfS14 development was to consider:

> *During the development of TMfS12 a number of additional data sources became available or were identified as missing, technical challenges were encountered, enhancements proposed and other models developed.*
>
> *TMfS shall incorporate the new data, technical updates and potentially the proposed enhancements. This model shall also have the specific objective of being suitable for supporting the Outline Business Case for improvements on the Inverness to Aberdeen transport corridor.*

This model is to be used to prepare a single (baseline) Forecast Scenario for the future years; 2017 – 2037 at five year intervals.

1.2 Introduction

In summer 2012 SIAS Limited (SIAS) was appointed as a nominated consultant within the Multiple Framework Agreement (MFA) for the Transport Planning, Modelling and Audit Services, Lot 1: Commission for the Maintenance and Enhancement of TMfS, which encompasses the maintenance and enhancement of the existing LATIS models.

The Transport Model for Scotland (TMfS12) was a "light touch" refresh of TMfS07 to 2012 conditions undertaken by SIAS throughout the first half of 2013. TMfS12 and its associated primary forecasts were circulated to all LATIS Framework Participants in the summer of 2013 for use on various applications. The primary focus of TMfS12 was its future application on the A9 Dualling between Perth and Inverness and therefore any updates to the model will also apply to this corridor.

In December 2014 SIAS provided Transport Scotland with an updated programme for the development of TMfS12A, an updated version of TMfS12 utilising the 2011 census travel to work data which had become available from the National Records for Scotland. Following this, Transport Scotland agreed that the demand model structure needs to change to include the ports and other zone disaggregation opportunities would also be included to take advantage of this change to the demand model.

Further TMfS12A scoping discussions took place which concluded on 28 May 2015, where Transport Scotland (TS) requested that SIAS update TMfS12 to create TMfS14. The scope of the TMfS14 update changed throughout the model development period due to delivery timescale constraints. The scope of this TMfS14 model development contains the following elements *(SIAS Ref. 78104,TMfS14 Specification Note, June 2016)*:

- Updating TMfS12 to a 2014 base year, thus creating TMfS14
- Establishing TMfS14/TELMoS14 requirements and features
- Incorporating 2011 census travel to work data
- Data collection, collation and assimilation
- Homogenising the zone system between the demand and assignment models
- Establishing a range of forecast scenarios for TMfS14/TELMoS14
- Calibration, validation and realism testing of the demand model
- Calibration and validation of the road and PT assignment models
- Updating the TMfS14 Trip End Model
- Preparing a release version of TMfS14
- Engagement with the LATIS Lot 3 participant David Simmonds Consultancy (Development, Update and Application of the Transport Economic Land-Use Model of Scotland (TELMoS)
- Preparation of updated technical and support documentation

This Report describes the development, calibration, and validation of the TMfS14 National Road Model and is one of a series of documents describing the development, calibration, and validation of the TMfS12 models, as follows:

- TMfS14 National Road Model Development Report
- TMfS14 National Public Transport Model Development Report
- TMfS14 Demand Model Development Report
- TMfS14 Forecasting Report

1.3 Structure of this Report

The structure of the remainder of this Report is as follows:

- Section 2 details the proposed uses of the model and key model design considerations
- Section 3 details the Model Standards
- Section 4 discusses the Key Features of the Model
- Section 5 summarises the Calibration and validation Data
- Section 6 and 7 discusses the Network and Trip Matrix Development
- Section 8, 9, and 10 discuss the Network, Route Choice and Trip matrix Calibration and Validation
- Section 11 summarises the Assignment Calibration and Validation
- Section 12 contains a Summary of the Model Development, Standards Proposed, and the Fitness for Purpose

2 PROPOSED USES OF THE MODEL AND KEY DESIGN CONSIDERATIONS

The *TMfS14 National Road Model* forms part of the overall TMfS14 model hierarchy, which is shown in Figure 2.1. It is a strategic model which has been prepared with a level of detail commensurate with appraising national policy and strategic land-use and transport interventions and providing a key source of transport supply and demand data.

TMfS14 will also form the starting point for the development of any Sub-Area and Regional models; providing assistance in preparation of model structure, input to base year development and providing a source of forecast travel demand.

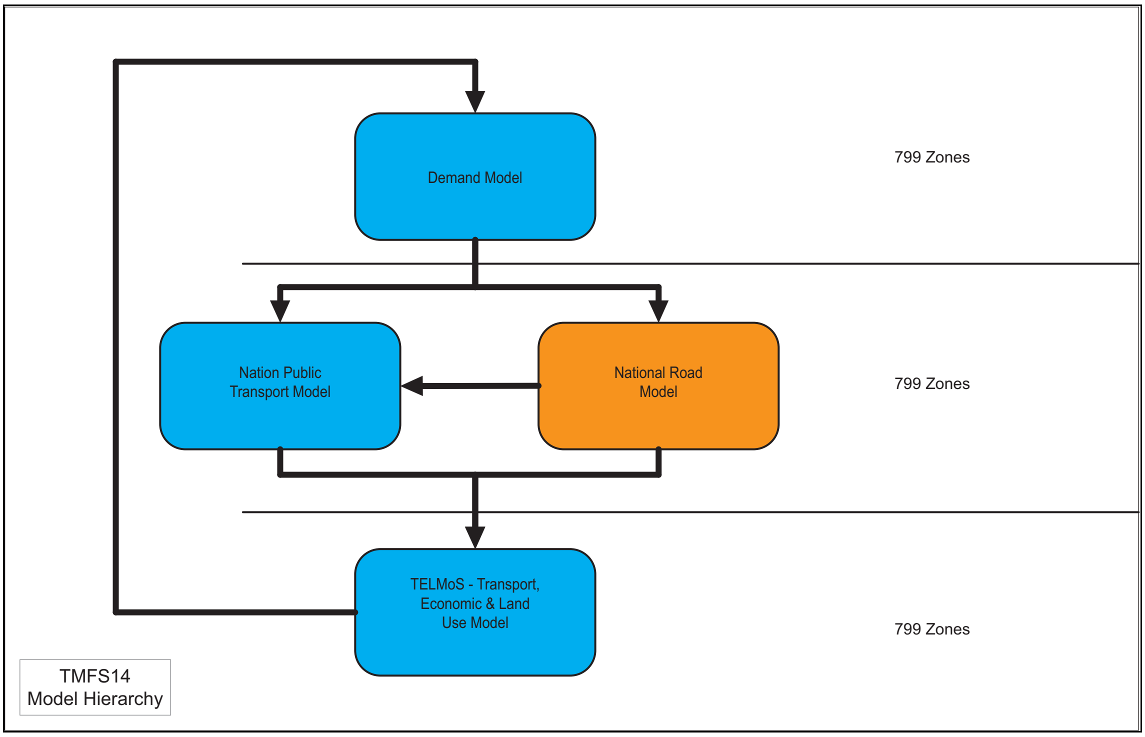

Figure 2.1 : TMfS14 Model Structure, National Road Model Interaction

A set of primary forecast scenarios were developed for the years 2017, 2022, 2027, 2032, and 2037. Further detail can be found in the TMfS14 Forecasting Report.

TMfS14 v1.0 has been developed using the GIS-based software packages MapInfo, QGIS, and Citilabs CUBE Voyager software version 6.1.1.

3 MODEL STANDARDS

3.1 Calibration and Validation Criteria and Acceptability Guidelines

The calibration and validation of TMfS14 has taken cognisance of the scope of the model development as outlined in Section 1.2 and the aims and objectives of TMfS14 and TMfS12. Where relevant, effort and reporting have focused on specific corridors, e.g. Perth to Inverness and Inverness to Aberdeen.

The calibration and validation process to demonstrate the 'goodness of fit' of the National Road Model against observed data (be that calibration data and\or validation data) makes use of a high volume of observed data from a wide range of data sources. Given the very nature of the model, the data sources available can have significant variation in both quantity and quality and by geographical area. Furthermore, some data is time series data, i.e. collected over a long period of time (e.g. Automatic Traffic Count data) and some data is collected on a single day

Throughout this Report, reference is made to *WebTAG Unit M3.1* guidance for Highway Assignment Modelling. It is recognised that this guidance is not directly appropriate for a model of the size and strategic nature of the National Road Model, i.e. the guidance was written predominantly for smaller road models built for specific scheme appraisal, covering road assignment only and covering a geographical area commensurate with the sphere of influence of the scheme being appraised. Ideally, for the purpose of such a model, observed data would be collected in a time frame close to the base year of the model to ensure consistency. Although the observed data used in the development of the National Road Model does not meet these criteria and the model itself is far larger, more strategic and different in specification to that which formed the basis of the guidance within *WebTAG, Unit M3-1* is nonetheless the only official UK guidance that is currently available for road assignment models.

Given the scale of models Unit M3-1 was intended for, the guidance limits contained within it are considered overly stringent for a model as large as TMfS, however, in line with best practice and the principals outlines in Unit M3-1, the calibration and validation process for TMfS makes efforts to balance a goodness of fit between all observed data sources and the resultant base model assignment.

When comparing modelled flows against observed flows, focussing on either absolute differences or percentage differences alone can be misleading when there is a wide range of observed flows. For example, a difference of 50 PCUs is more significant on a link with an observed flow of 100 PCUS than on one with 1,000 PCUs, while a 10% discrepancy on an observed flow of 100 vehicles is less important than a 10% mismatch on an observed flow of 1,000 PCUs.

To avoid this difficulty, a standard summary statistic known as the GEH statistic is used. This statistic is designed to focus attention on significant absolute differences at low flows and significant percentage differences at high flows.

$$GEH = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$

where

GEH is the GEH statistic

M is the Modelled Flow

C is the Observed Flow

The criteria and acceptability guidelines as set in TAG Unit M3.1 are presented in Table 3.1 - Table 3.3.

Table 3.1 : Screenline Flow Validation Criterion and Acceptability Guideline (Table 1 Unit M3-1)

Criteria	Acceptibility Guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines

Table 3.2 : Link Flow and Turning Movement Validation Criteria and Acceptability Guidelines (Table 2 Unit M3-1)

Criteria	Description of Criteria	Acceptability Guideline
1	Individual Flows within 100 veh/h of counts for flows less than 700 veh/h	> 85% of cases
	Individual Flows within 15% of counts for flows from 700 to 2700 veh/h	> 85% of cases
	Individual Flows within 400 veh/h of counts for flows more than 2700 veh/h	> 85% of cases
2	GEH <5 for individual flows	> 85% of cases

Table 3.3 : Journey Time Validation criterion and Acceptability Guideline Criteria (Table 3 Unit M3-1)

Criteria	Acceptability Guideline
Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher than 15%)	> 85% of cases

3.2 Convergence Criteria and Standards

The convergence Criteria and Standards as set out in Unit M3-1 are provided in Table 3.4

Table 3.4 : Summary of Convergence Measures and Base model Acceptable Values (Table 4 Unit M3-1)

Measure of Convergence	Base Model Acceptable Values
Delta and %GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flows change (P)<1%	Four consecutive interations greater than 98%
Percentage of links with flows change (P2)<1%	Four consecutive interations greater than 98%

3.3 Significance of Matrix Estimation Changes

The criteria by which the significance of the changes brought about by matrix estimation may be judged are given in Table 3.5.

Table 3.5 : Significance of Matrix Estimation Changes (Table 5 Unit M3-1)

Measure	Significance Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02, Intercept near zero and R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99 and 1.01, Intercept near zero and R^2 in excess of 0.98
Sector to sector level matrices	Differences within 5%

4 KEY FEATURES OF THE MODEL

In this update the TMfS14 road network is largely based upon the TMfS12 network, however, it was reviewed against the Ordnance Survey OpenData Meridian GIS layer, local knowledge, and Google Maps. In addition, schemes constructed between 2007 and 2014 that have been represented as forecast schemes in previous versions of TMfS were reviewed against as-built drawings or equivalent information and included in TMfS14 as appropriate.

TMfS14 includes all Scottish Motorways and A-Roads, many strategically-important Scottish B-Roads, a 'skeletal' representation of the road network in England and Wales and ferry crossings around Scotland.

This section covers the following aspects of the model:

- Geographical Coverage
- Zoning System
- Network Structure
- Time Periods
- User Classes

4.1 Geographical Coverage

The TMfS14 Road Model geographical coverage is similar to TMfS12 and is highlighted in Figure 4.1.

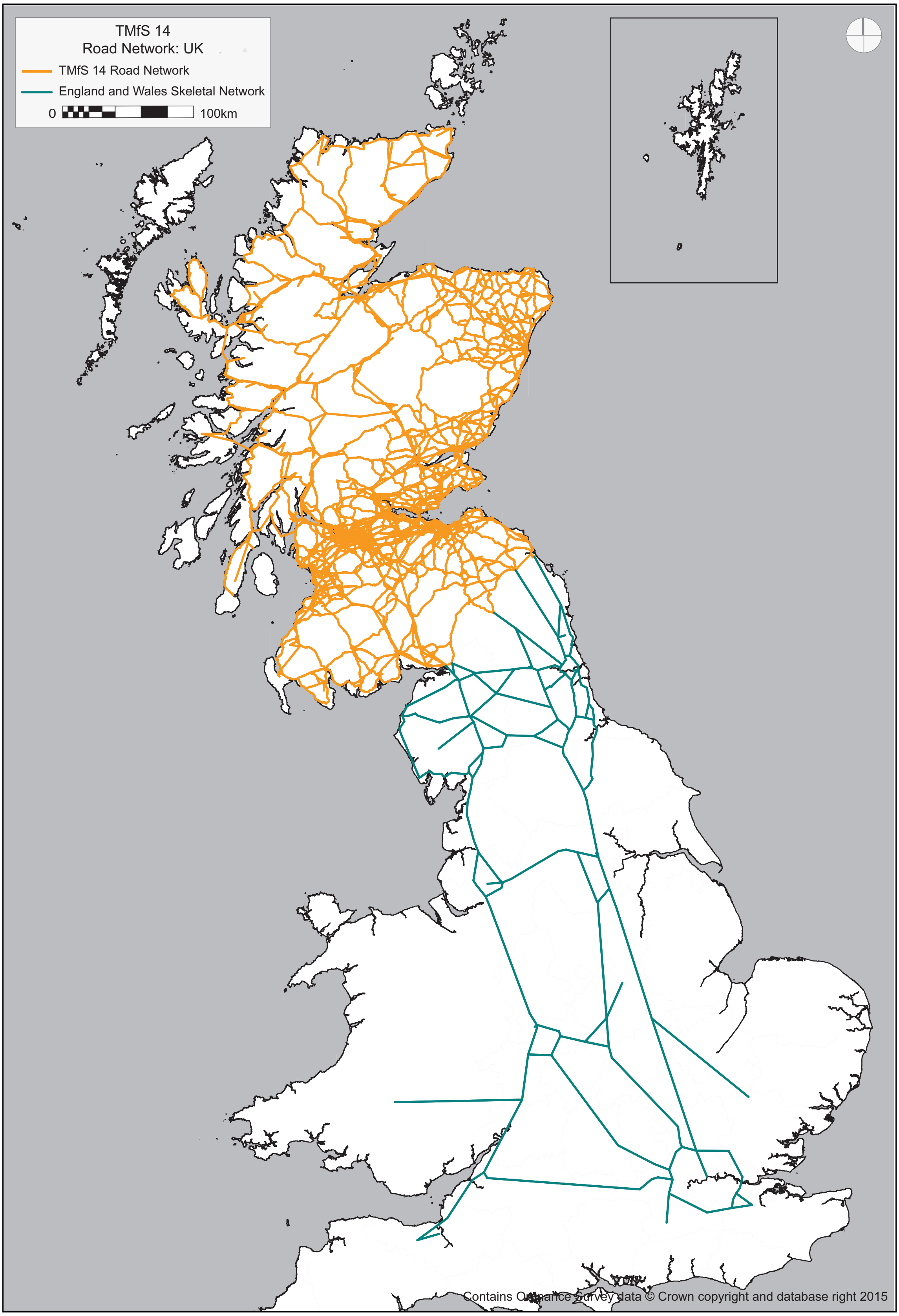

Figure 4.1 : TMfS14 Road Network and Geographical Coverage

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Figure 4.2 highlights the TMfS14 Road Model geographical coverage for Scotland.

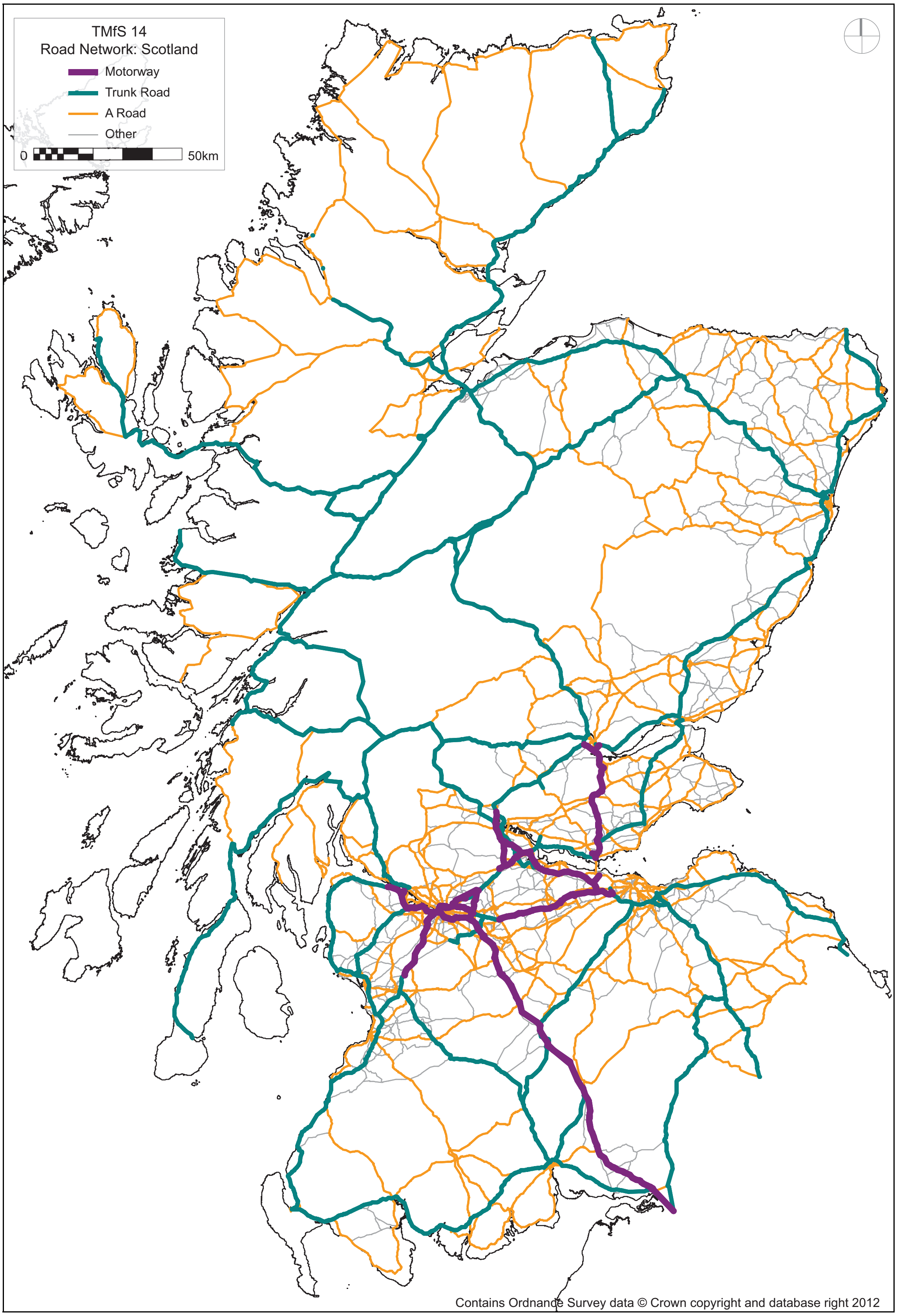

Figure 4.2 : TMfS14 Road Network and Geographical Coverage, Scotland

Figure 4.3 highlights the TMfS14 Road Model geographical coverage for the Central Belt.

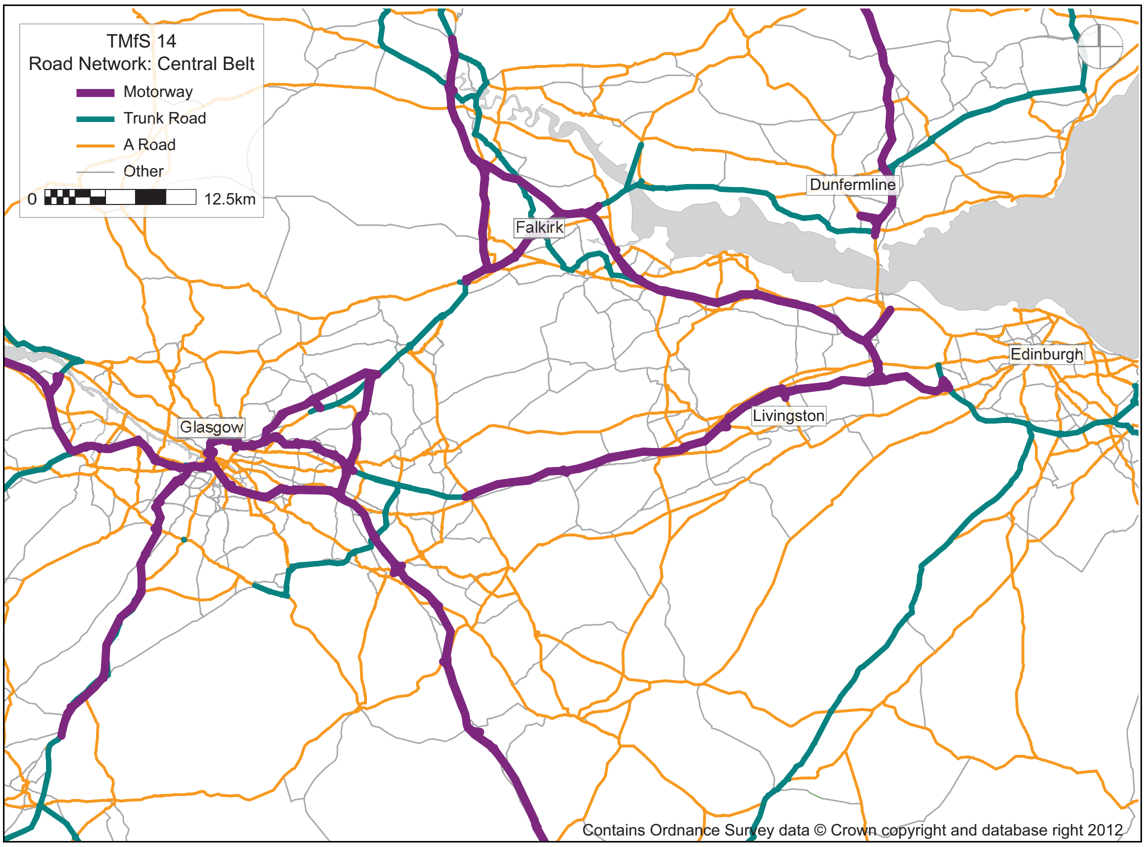

Figure 4.3 : TMfS14 Road Network and Geographical Coverage, Central Belt

Figure 4.4 highlights the TMfS14 Road Model geographical coverage for the A9 and A96 corridors.

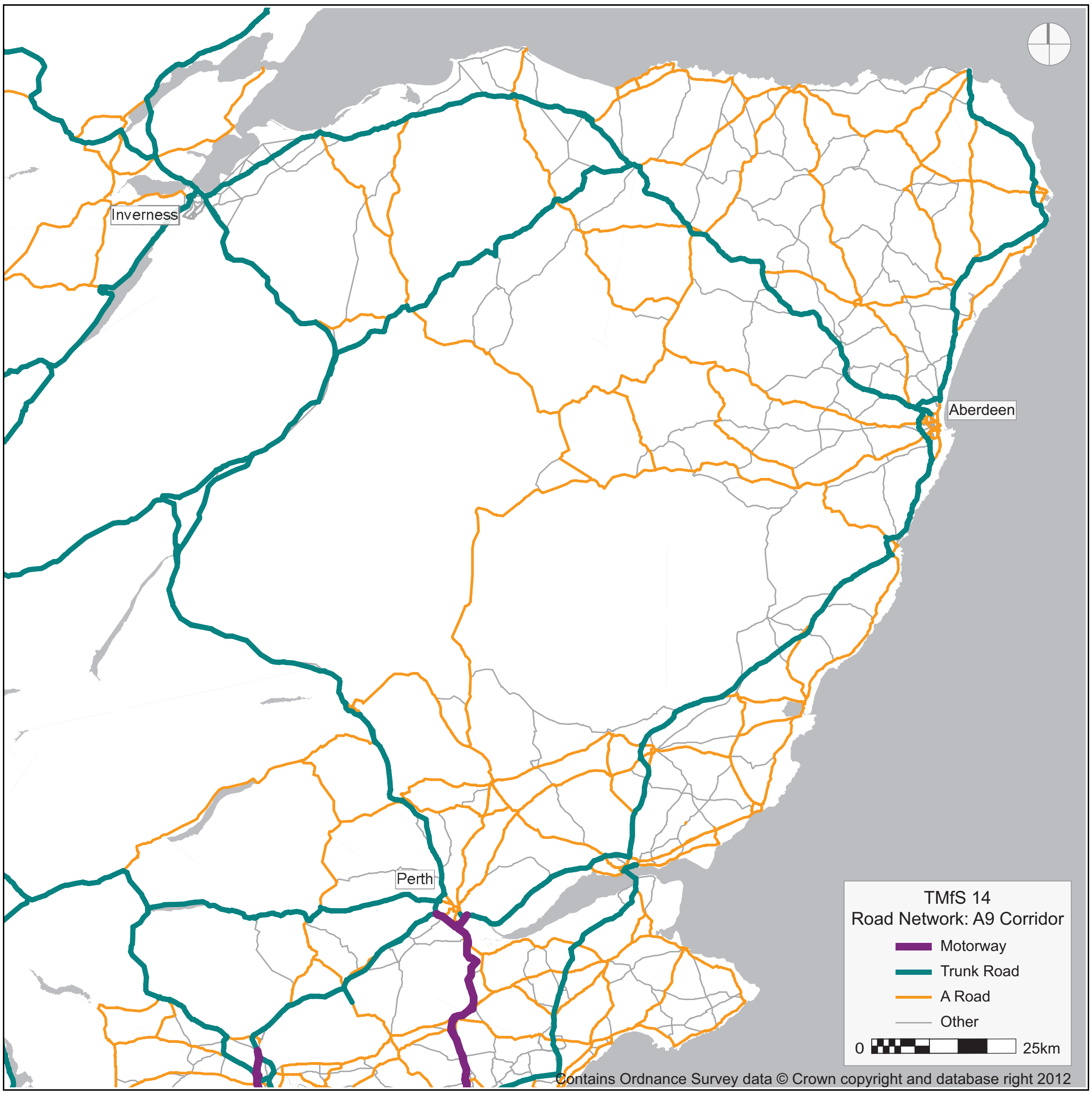

Figure 4.4 : TMfS14 Road Network and Geographical Coverage, A9/A96 Corridors

4.2 Zoning System

The TMfS14 zone system is consistent across the model hierarchy at 799 zones. This is to improve consistency between different elements of the TMfS14 suite.

The TMfS14 national model consists of 799 zones, comprising;

- 774 internal zones
- Four Airport Zones
- Five Key Port Zones
- 16 'External' zones covering England and Wales

Previous model audits and input data requirements were taken into consideration and TMfS14 zoning created. Key enhancements are as follows:

- Update to Census 2011 geography
- Census data zone and local authority boundary compliant
- Operate a unified zoning system (i.e. Demand Model, Assignment Model and the Land-Use model are to use the same system)
- Further disaggregation in Scotland, particularly in the Aberdeen-Inverness corridor
- For improved ferry representation, split the group of islands of Rum, Canna, Eigg, and Muck away from the mainland
- Further Disaggregation in England splitting into Regions, but also to keep boundaries consistent with Census Travel to Work Boundaries
- Ensure that only one Rail station is present per zone (with the exception of Conon Bridge)

It was an oversight that Conon Bridge was not included in its own zone and it could not be retrospectively included due to the delivery timescales. Its exclusion is not considered detrimental to the quality of the model considering its intended application.

Discussions with Transport Scotland, its land-use consultants, the study team and the LATIS Lot 2 consultant leading on the A9 application concluded in agreement that a number of TMfS07 zones should be disaggregated. This disaggregation was undertaken for the development of the TMfS12 assignment models, however, this was reviewed as the TMfS14 zone system is derived from 2011 census whereas the TMfS07/12 zone system was derived from the 2001 census. These are shown in Appendix A (A.2 – A.4).

The four main airport zones (Glasgow, Edinburgh, Prestwick and Aberdeen) have been defined separately from their underlying Data Zones. The airport zones are:

- Edinburgh Airport Zone 709
- Prestwick Airport Zone 710
- Glasgow Airport Zone 711
- Aberdeen Airport Zone 712

Figure 4.5 shows the TMfS14 zone system.

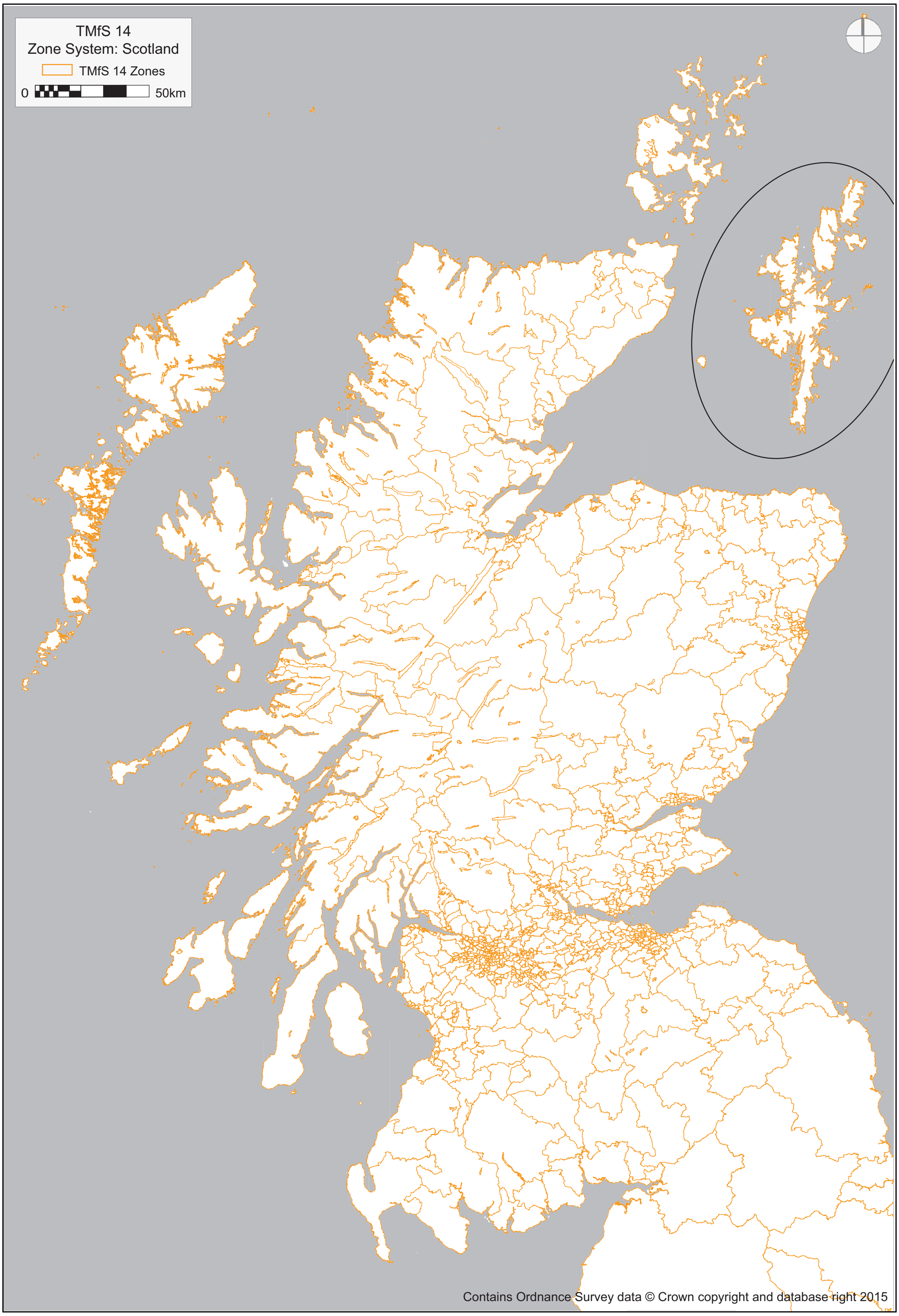

Figure 4.5 : TMfS14 Zone system

Figure 4.6 highlights the zoning in the A9/A96 corridor.

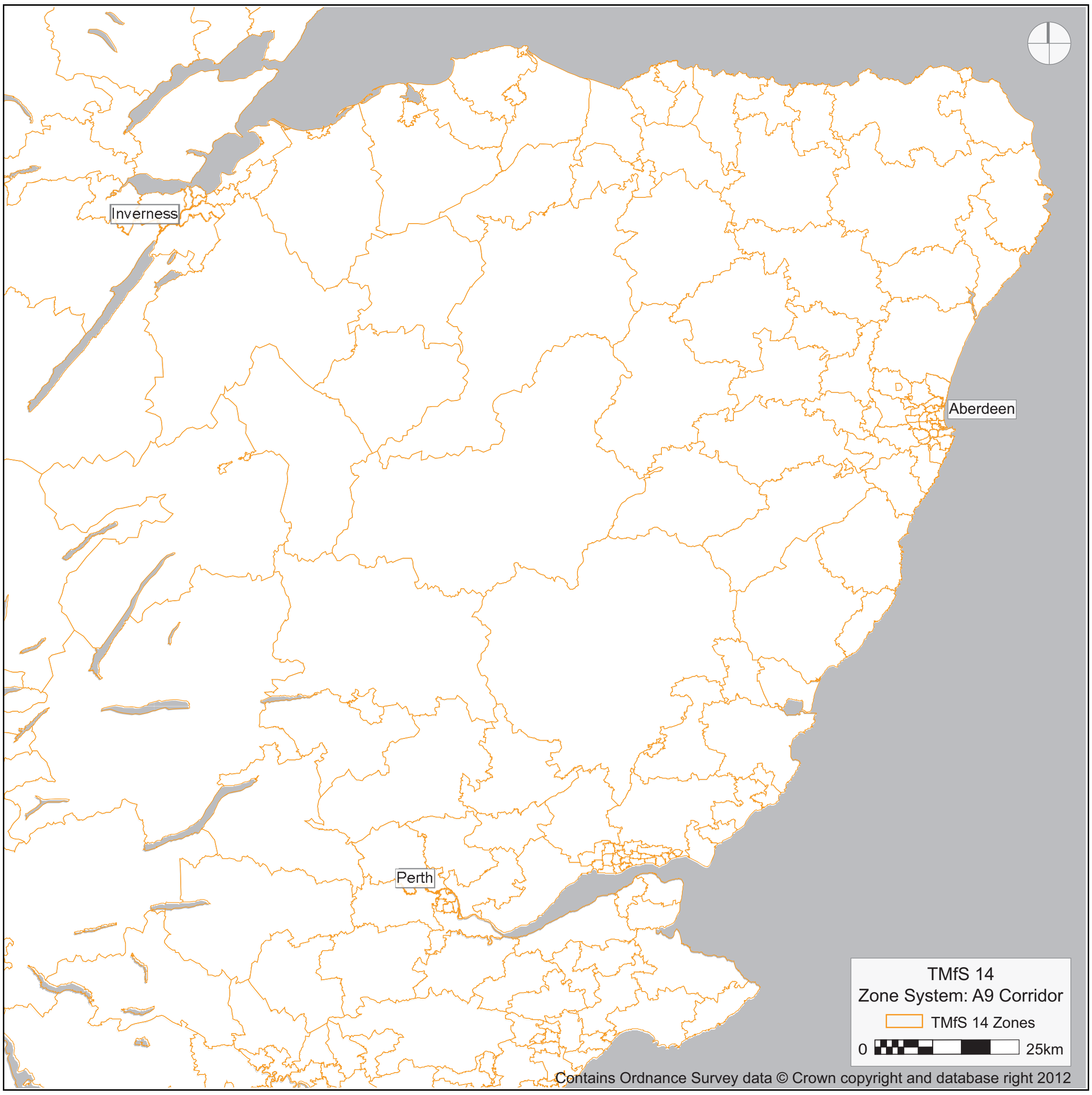

Figure 4.6 : TMfS14 A9/A96 Corridor Zone System

Figure 4.7 highlights the Central Belt zone system more clearly.

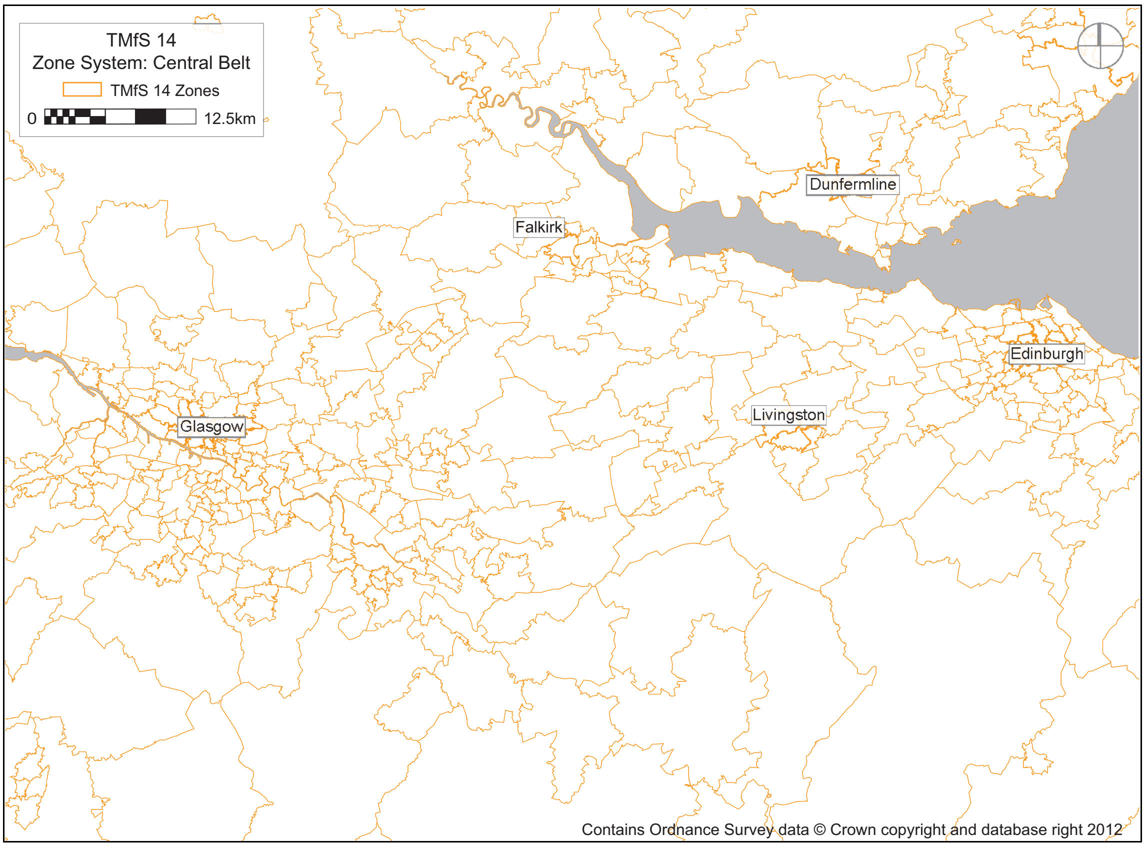

Figure 4.7 : TMfS14 Central Belt Zone System

The TMfS14 zone system is available from Transport Scotland (GIS format) on request. Further technical detail can be obtained in *TMfS14 – Creation of Model Zone System (SIAS, May 2016)* also available on request.

Appendix A reports the number of TMfS14 zones contained within each local authority boundary and the ratio of data zones to TMfS zones for each Local Authority.

4.3 Network Structure

As outlined, TMfS14 includes all Scottish Motorways and A-Roads, several strategically-important Scottish B-Roads and a 'skeletal' representation of the road network in England and Wales. This approach is consistent with that used in TMfS12. Further detail of the network development process can be found in Section 6.

4.4 Time Periods

The model covers three time periods within a 'typical' weekday. These are:

- Average AM Peak Hour between 07:00 – 10:00
- Average Inter Peak Hour (1/6 of 10:00 – 16:00)
- Average PM Peak Hour between 16:00 – 19:00

For the peak time periods, the 'average peak hour' represents the 'peak hour' within the 3hr period. This 'peak hour' was calculated using relevant observed traffic count data collected across Scotland, so represents a 'Scottish Average' peak hour within the relevant time period.

4.5 User Classes

The model includes five user classes:

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

Bus traffic on the network is modelled using fixed pre-load flows. The bus routes are imported from the National Public Transport Model, and were updated to reflect the changes in the Road infrastructure between 2012 and 2014.

4.6 Assignment Model Enhancements

The TMfS14 Road assignment model contains enhancements over its predecessor TMfS12, namely:

- Representing 2014 conditions
- A disaggregated (799) zone system
- Output modelled turn flows
- Refined network which takes account of the TMfS07 and TMfS12 audits

5 CALIBRATION AND VALIDATION DATA

The TMfS14 modelled base year is representative of 2014 transport conditions.

5.1 RSI Counts

The Roadside Interview (RSI) count sites used in the TMfS14 matrix development are shown in Table 5.1.

Table 5.1 : RSI Sites used in TMfS14

Site	Road Name	Location	Direction	Date of Survey
1	A96	A96 Forres to Elgin, Gateside Farm	Eastbound	30 April 2013
2	A941	A941 South of Elgin, near Rothes	Northbound	30 April 2013
3	A96	A96 Elgin to Fochabers	Westbound	30 April 2013
4	A96	A96 Fochabers to Keith	South-Eastbound	17 April 2013
5	A96	A96 Huntly to Keith	North-Westbound	17 April 2013
6	A96	A96 Huntly to A920, near Skares	South-Eastbound	18 April 2013
7	A96	A96 Kintore to Port Elphinstone	Northbound	18 April 2013
8	A9	Bankfoot	Southbound	04 September 2012
9	A9	Calvine	Northbound	06 September 2012
14	A82	Crianlarich	Northbound	02 September 2014
15	A9	Bankfoot	Northbound	03 September 2014
16	A9	Tay Crossing	Southbound	09 September 2014
17	A9	Tomatin	Southbound	09 September 2014
18	A95	Inverallan (Granton on Spey) Roundabout	North-Eastbound	11 September 2014
19	A95	Inverallan (Granton on Spey) Roundabout	Southbound	11 September 2014
20	A95	Inverallan (Granton on Spey) Roundabout	South-Westbound	11 September 2014
21	A96	Barnchurch Road, Smithton	Westbound	16 March 2010
22	B9006	Culloden Road, Westhill, Inverness	South-Westbound	25 November 2009
23	A9	Lay-by Just North of Cromarty Bridge at Ardullie Roundabout	Southbound	11 March 2010
24	A835	A835 Garve	Southbound	18 March 2010
25	A939	A939 Granton On Spey	Northbound	17 March 2010
26	A862	A862 at Bunchrew Campsite	Eastbound	25 November 2009
27	A96	A96 West Side of Nairn (Outside Westerlea	South-Westbound	25 November 2009
28	A93	A93, around 1 mile south of Blairgowrie just to the north of Meikleour Forest	Southbound	28 March 2009
29	A94	A94, north of Scone Airport at the Rait junction	Southbound	28 March 2009
30	A82	A82 Lay-by 2.7 miles South of Crianlarich	Northbound	20 May 2010
31	A82	A82 Lay-by, Opposite Na Birlinn Cemetery, Approx 1.2 miles south of Corrychurrachan Viewing Point	Northbound	27 May 2010
32	A85	A85 W/B - Wide section of road approx 2 miles east of Crianlarich	Westbound	20 May 2010
33	A90	North of Forfar at Parkford	Southbound	29 March 2007
34	A90	South of Forfar at Gallowfauld	Southbound	29 March 2007
35	A90	Dundee Kingsway at Gourdie Croft	Northbound	27 March 2007
36	A85	A85 near Apollo Way	Eastbound	29 March 2007
37	A92	A92 East Dock Street	Eastbound	26 April 2007
38	A90	Tay Bridge	South-Eastbound	25 April 2007

5.2 Traffic Counts for Matrix Estimation

The matrix estimation process for the Road Model base year trip matrix development used a wide variety of data sources to estimate a goodness of fit.

A variety of observed traffic count sources made up a series of calibration screenlines. These include:

- The Scottish Roads Traffic Database (SRTDb)
  2014 neutral month, average weekday peak hour data
- Non trunk road 'Gap Plugging' Manual Classified Counts (MCC) counts collected in Spring 2014
- Counts conducted during Road Side Interviews (RSI), as shown in Table 5.1
- Edinburgh Bypass (Straiton) MCC Data, October 2013

5.3 Traffic Counts for Validation

The observed traffic count sources used for the Road model validation are:

- The Scottish Roads Traffic Database (SRTDb)
  2014 neutral month, average weekday peak hour data
- Edinburgh Bypass (Gilmerton) MCC Data (City of Edinburgh Council, October 2013)

5.4 Journey Time Data

The journey time data used for the validation of TMfS14 is the reported observed journey time data reported in the *Transport Model for Scotland 2012 (TMfS12), TMfS12 Road Model Development Report (September 2014)* provided by Transport Scotland.

This data was used because the timescales for the development of TMfS14 did not permit the collection of more up to date data. The 2012 observed journey time data is considered reasonable as no significant changes in travel demand or infrastructure occurred within the period 2012 to 2014.

6 NETWORK DEVELOPMENT

The TMfS14 Road Network is largely based upon the TMfS12 Road Network and includes all Scottish Motorways and A-Roads, many strategically-important Scottish B-Roads, a 'skeletal' representation of the road network in England and Wales and ferry crossings around Scotland.

The TMfS12 Road Network was reviewed against the Ordnance Survey (OS) OpenData Meridian GIS Layer, local knowledge, and Google Maps. This platform provides a geographically accurate representation of Scotland's road network which allows the Road Model outputs to be used directly for noise and air quality analyses. The Road Network consists of 57,420 nodes and 105,203 links and was developed in CUBE Version 6.1.1.

6.1 Node Convention

The following node convention applies to the Road and Public transport networks:

- Road Nodes: 1,000 – 99,999
- Rail Nodes 100,000 – 149,999
- Subway Nodes: 150,000 – 199,999
- Ferry Nodes: 200,000 – 299,999
- Airport Nodes: 300,000 – 399,999

6.2 Attributes for Road Nodes and Network

A number of attributes are allocated to each node and link that make up the road network. Appendix B details the relevant link attributes for the nodes, road links and ferry links.

6.3 Road Link Types and Capacity

The road link-types used in TMfS14 are consistent with TMfS12 and TMfS07 and are in line with those outlined in the *Scottish Transport Statistics Note 24*. This Link-type numbering system enables analysis of model outputs to be easily compared with published statistics. Table 6.1 details road link types and the corresponding default link capacity (PCUs per lane) for inter-urban area links used in the Road Model.

Table 6.1 : TMfS14 Road Link Types & Capacity Per Lane, Inter Urban Links

Link Type	Description	Capacity Per Lane (PCUs)
1	Trunk – Motorway	2,400
2	Trunk – Motorway slips	1,800
3	Trunk A-Roads Non-built up	1,800
5	Non Trunk A-Roads Non-built up	1,600
9	Banned for Heavy Goods Vehicles (HGV)	Dependent on road type
10	Bus only	Dependent on road type
22	Zone-Road Connectors	Unconstrained
22	Zone-Ferry Connectors	Unconstrained
28	Ferry Routes – Banned for HGV	Dependent on ferry size
29	Ferry-Road Connectors	1,000
30	Ferry Routes – Car and HGV allowed	Dependent on ferry size
31	Ferry Routes – Banned for both Car and HGV	Dependent on ferry size

Note: Link Type 22 has an unconstrained capacity meaning congested link speed equals free-flow link speed (50 km/hr).

Table 6.2 details corresponding road link-types and link capacity for links in urban and built up areas.

Table 6.2 : TMfS14 Road Link Types & Total Capacity, Urban/Built-up Links

Link Type	Description	Total Capacity (PCUs)
4	Trunk A-Roads Built up	2,500
6	Non Trunk A-Roads Built up	2,000
7	Minor Roads – Non built up	1,000
8	Minor Roads – Built up	1,500

Considering Table 6.1 it should be noted that outwith the Glasgow City, Edinburgh City, Dundee City and Aberdeen City local authority areas, the following link capacities apply:

- Link Type 4 (Trunk A-Roads Built Up), link capacity is 1,600 PCUs per lane
- Link Type 6 (Non Trunk A-Roads Built Up), link capacity is 1,600 PCUs per lane
- Link Type 7 (Minor Roads – Non built up), link capacity is 1,000 PCUs per lane
- Link Type 8 (Minor Roads – Built up), link capacity is 1,000 PCUs per lane

Considering Table 6.2 the following link capacity adjustments apply through small towns, i.e. when the ‘Urban’ link attribute within the model equals 1:

- Link Type 4 (Trunk A-Roads Built Up), link capacity is 1,600 PCUs per lane
- Link Type 6 (Non Trunk A-Roads Built Up), link capacity is 1,400 PCUs per lane
- Link Type 8 (Minor Roads – Built up), link capacity is 1,000 PCUs per lane

6.4 Capacity on Approach to Rural Roundabouts

As with TMfS07 and TMfS12, there is no explicit junction modelling within the TMfS14 National Road Model. The congestion effects of traffic flow on a road link and/or junction delay at the end of a road link are included in the link-based flow-delay relationships. These relationships take as input the volume/capacity ratio for the road link.

For urban areas, standard road link capacities are applied to each link type. This is generally accepted as a reasonable approach, as we are not necessarily interested in delays for each road link in the network separately, but more that the journey times over a collection of links are realistic.

For Inter-urban roads with relatively long sections between junctions, flow-delay relationships have been applied and are designed to give road link speeds which take account of traffic interactions on the links themselves. They do not allow for the effects of the junctions at the end of these long stretches of inter-urban route. The default assumption is that these junctions are roundabouts and the capacity of the road links have been adjusted accordingly, by applying the following link capacities to the links which approach these junction nodes:

- Single carriageway: 1,400 PCUs per hour
- Dual carriageway: 2,100 PCUs per hour

Further details of the calculations behind this approach to modelling the impacts of rural roundabout junctions are available in *TMfS07 National Road Model Development Report (MVA, 2012)*.

6.5 Speeds on Urban and Rural Roundabouts

The Ordnance Survey (OS) MasterMap Integrated Transport Network (ITN) GIS data, the foundation for the Road Model network, contains a full list of locations for Scotland's roundabouts within the attribute 'NATUREOFRO'.

The default assumptions which have been applied to roundabouts to assist in achieving robust representation of travel times across the network are as follows:

- Urban = 0 (Rural area) = 35km/hr
- Urban = 1 (Small town) = 35km/hr
- Urban = 2 (Sub-urban area) = 35km/hr
- Urban = 3 (Non-central area) = 35km/hr
- Urban = 4 (Central area) = 30km/hr

6.6 TMfS14 Road Network Enhancements

There were no major infrastructure changes identified between 2012 and 2014 as agreed with Transport Scotland. After a general network review, the following schemes were included to maintain consistency with the Central Scotland Transport Model (CSTM):

- A8 Edinburgh Airport Junction
- A68 Dalkeith Bypass
- M8 Eurocentral
- Glasgow East End Regeneration Route Phase 1b
- M74 Completion
- M9 Spur

The TMfS12 Audit highlighted an issue with the coding of the M80 Stepps to Haggs scheme where the section was not upgraded to motorway standard. This scheme was corrected and remains consistent with CSTM coding.

In addition several minor changes were identified against the 2012 ITN layer which were revised as follows;

- Fochabers and Mosstodloch Bypass and Surrounding areas
- Replacement of previous A9 coding with more accurate representation
- M90 Junction 2 Masterton Junction alteration
- A8000// B800 improvements associated with the M9 Spur
- A823 Gleneagles Junction improvements
- A90 Kingsway/A972/A929 Roundabout Removal
- A92 Chapel Junction Overbridge coding alterations
- Forth Road Bridge capacity amendment
- M74 Dumbreck Junction alteration
- Clyde Expressway to M8 Link coding alteration
- Addition of the M8 Heartlands Junction

The Edinburgh Tram opened to the public on 31 May 2014. Although this is within TMfS14 base year, after consideration and consultation with Transport Scotland, it was decided not to include within TMfS14 base year. This was due to the absence of count data at the time of model development.

6.7 Zone Connectivity

Zone connectors were added using the following criteria. Population weighted centroids were obtained from Census 2011 and connected to the most appropriate point of access/egress on the transport network.

The zone centroid lengths have been calculated by considering the zone to be a circle and then calculating the average radial distance of the circle. From the zonal area the zone length can thus be calculated using the following formula:

$$\frac{2}{3}\sqrt{\frac{area}{\pi}}$$

Where the zone centroid length exceeded 5km the centroid length was capped to 5km.

6.8 Pre-Calibration Network Checks

Consistency of network coding is important, and documentation showing the network attributes is shown in Appendix B

Crow-fly distances were compared against the coded link distance and where any significant differences were observed each link was checked to ensure that the coding of the link distance was correct.

Traffic was assigned to the network at the earliest opportunity, to check network connectivity and to ensure that destinations could be reached to trap any coding errors. Minimum cost paths were plotted to ensure that the routeing was intuitive.

The TMfS14 total network distance was compared to the 2014 National Travel Statistics *(Scottish Transport Statistics, Transport Scotland, No. 34, 2015 Edition http://www.transport.gov.scot/report/j415388-07.htm)* and is presented in Table 6.3, which shows that the total network distances are .

Table 6.3 : Total Network Distance (km)

Road Type	STS 2014 Distance (km)	TMfS:14 Road Model Distance (km)	Difference (km)
Motorway (excluding slip roads)	420	416	-4 (-1%)
Motorway (including slip roads)	600	568	-32 (-5.3%)
Trunk A-Roads	2,830	3,013	183 (+6.5%)
TOTAL	3,430	3,581	151 (+4.4%)

Further adjustments were made as part of the network calibration stage as shown in Section 8.

7 TRIP MATRIX DEVELOPMENT

7.1 Introduction

This section describes the development of the TMfS14 'prior' Road matrices which feed into the matrix estimation process and details the following enhancements:

- Update to the non-work commute matrices with 2011 census travel to work data
- Update to all matrix user classes with up to date RSI survey data

The methodology adopted for developing the TMfS14 Road matrices involved using the TMfS07 prior matrices as a starting point and updating them with the above data. The updated prior matrix was, along with traffic count data, used as an input to the matrix estimation process. Technical Notes and supporting data on the methodology were provided to the Auditor to allow a detailed review of the process to be undertaken.

7.2 2011 Census Travel to Work Data

SIAS, on behalf of Transport Scotland, received 2011 Census Travel to Work data from the National Records of Scotland and 2012/13 Scottish Household Survey data from The Scottish Government.

This section sets out the methodology used to split the 2011 Census Travel to Work data into peak periods using the Scottish Household Survey (SHS) data and the process used to combine the Census data with the TMfS07 prior Road Non-Work Commute matrices.

The Census Travel to Work data contains the following person trip information for Full Time Students and the working population:

- Work or study mainly at or from home
- Underground subway metro light rail or tram
- Train
- Bus minibus or coach
- Taxi
- Motorcycle scooter or moped
- Driving a car or van
- Passenger in a car or van
- Bicycle
- On foot
- Other

For the purposes of incorporating the Census data into the Car Non-Work Commute AM/IP/PM matrices the "Driving a car or van" field has been used for both Full Time Students and the working population. "Passenger in a car or van" was not used as it was assumed that they would be in the same vehicle as the "Driving a car or van" category. If this trip type was included it would have required additional vehicle occupancy calculations which the model development timescales did not allow for. The Census data is considered representative of a 24hr weekday sample and each trip equates to a car travel to work trip.

7.3 Scottish Household Survey Data

The SHS data was used to split the 24 hour weekday Census Travel to Work data into the three peak hours modelled in TMfS14, namely the AM, IP, and PM peak. The SHS dataset used in the analysis contains the following relevant fields required for this analysis, namely:

- Main Mode
- Journey Purpose
- Journey Start Time

The SHS data was used to split the 24 hour 2011 Census Travel to Work data into the three peak hours modelled in TMfS14, namely the AM, IP and PM peak. This was achieved by applying a peak period to 24hr factor at the appropriate aggregation level, e.g. at zone or Local Authority (LA) level. An initial review of the SHS data was undertaken to understand what aggregate level was suitable for disaggregating the Census data.

The SHS data was provided in 720 zone format, consistent with TMfS12, because at the time the request was made, the intention for TMfS12A, as it was titled at the time, was to retain the TMfS12 demand model structure, i.e. 720 zones.

The SHS data was processed at the Local Authority (LA) level of aggregation which produced reasonable peak period to 24hr factors, with 25% of all recorded LA to LA movements containing more that 10 trips (35% more than 5 trips).

The Local Authority aggregation was split between Non-Full Time Students & Full Time Students, however, it was noted that the SHS data contained only 94 Full Time Student records observed over the 24hr period, so this could not be used in isolation unless a very aggregate factor was used. For this reason the Non-Full Time Students & Full Time Students datasets were combined to derive the peak period factors.

The SHS records were split into the following time periods:

- Whole Day (00:00 – 24:00)
- AM Period (07:00 – 10:00)
- IP Period (10:00 – 16:00)
- PM Period (16:00 – 19:00)
- The remainder of the Day (1900 – 0700, used as a checking mechanism)

The following rules were applied at LA level and were used to create the proportions of peak period travel relative to the 24hr period:

- If there are trips in the peak period, divide the peak period value by the 24hr value
- If there are no trips in the peak period, apply the lesser of the LA origin or destination peak hour to 24hr factor
- If there are no trips in the 24hr period, apply the lesser of the total (all LAs combined) origin or destination peak period to 24hr factor

If the sum of the AM, IP, and PM factors was greater than 1 then the factors were reduced proportionally so the maximum sum of the AM, IP, and PM factors was less than or equal to the total AM, IP, and PM records divided by the 24hr period records.

The resulting proportions for Road Trips to/from workplace/study are shown in Appendix C.

7.4 Application of SHS factors to Census data

Following the creation of the peak period factors, they were applied to the 24hr Census data to produce the peak period census matrices.

The census matrices were split up by the SHS peak period proportions and adjusted to represent each peak hour by applying the TMfS14 peak hour to peak period factors which are:

- AM Peak 2.555
- Inter Peak 1/6
- PM Peak 2.638

The next factor that was applied to the Census matrices is based upon research undertaken by *Peter Davidson Consultancy Traffic Engineering and Control, Census Matrix Tools Software – An essential data source for transport planning in the UK (February 2006)* which stated that the proportion of census trips made on a typical day was as follows:

- To Work 59.1%
- From Work 54.2%

The final process for producing the TMfS14 prior matrix was identifying where 2011 Census cell values were available and replacing the equivalent TMfS07 prior matrix values with these. The intra-zonal values and cell values that do not have new 2011 Census data remain unchanged from their 2007 values.

The resulting TMfS14 prior matrix was aggregated to Local Authority level and compared to the TMfS07 prior matrix which is underpinned by the 2001 Census data. This growth comparison was compared to the 2001 – 2011 LA to LA Census Travel to Work growth which was independently calculated. Where significant differences between the TMfS14 growth in travel to work were observed, the proportion of census trips made in a day was adjusted so the TMfS14 prior LA growth was more consistent with the 2001-2011 LA to LA Census Travel to Work growth. This was only applied at LA level so the trip distribution within each LA was retained.

This approach of replacing the TMfS07 prior matrices with 2011 Census Travel to Work data was agreed with Transport Scotland, as it was acknowledged that the timescales did not permit investigating and removing the 2001 census data from the TMfS07 prior matrices which would have been the preferred approach.

The resulting TMfS14 prior matrix totals are provided in Table 7.1.

Table 7.1 : Census Output Results

			Road
	AM	**IP**	**PM**
TMfS14 Prior Commute Matrix (without RSIs or observed PT data)	241,056	51,163	226,339
TMfS12 Commute Matrix	222,628	47,452	196,571
TMfS07 Prior Commute Matrix	219,673	46,662	196,006

The matrix totals appear intuitive and are consistent with the growth in Census Travel to Work between 2001 and 2011. The final check was to assign the TMfS14 prior matrices to their respective networks and compare with observed data. This was undertaken and the high level comparisons (i.e. screenline calibration/validation comparisons) were consistent with those obtained using TMfS07 prior matrices. The matrices were therefore considered sufficiently robust to be taken forward and used as prior matrices for the TMfS14 Road Assignment Model.

It should be noted that the TMfS14 Road prior matrix totals shown in Table 7.1 do not include the RSI data collected between 2007 and 2014. This process is described in the following sections.

7.5 Road Side Interview Data Processing

This section details the processing of Roadside Interview (RSI) data collected throughout Scotland for use in the trip matrix development within TMfS14. This dataset includes the RSI data processed for the TMfS12 development. The 34 RSI sites used in TMfS14 Matrix Development are summarised in Table 5.1.

Each RSI dataset was 'cleaned' at source to remove or correct records whose origins and destinations appeared illogical. RSI records were mapped by origin and destination using the coordinates for each recorded postcode. Records with an illogical origin or illogical destination were rejected from the datasets.

The resulting records were then used to derive individual sample rates for the site, by vehicle type (Car, LGV & HGV), by comparing with the surveyed peak period link flow data collected during RSI surveys at each site. Factors were then generated to expand the sampled RSI data for each site to meet the observed link flows, by vehicle type.

For the Car records, the data provided for origin and destination "Purpose" (home, work, etc.) were then used to define the trip purpose for each record. The trip purposes are consistent with TMfS12, namely:

- Car in-Work (CIW)
- Car Non-Work Commute (CNWC)
- Car Non-Work Other (CNWO)

For RSI Sites 1 –9 it was found that the in-work proportions were unrealistically low, so an adjustment was applied using the frequency of trip information where possible. For the 2014 RSI data (Sites 14 – 20) this adjustment was not necessary as the phrasing of the questions had been changed to account for this. For Sites 20 – 38 the adjustment was not possible because there was no frequency information collected.

Where site/day trip did not have an equivalent "reverse" direction trip, a dataset for the return direction was synthesised from the "forward" data. Each trip observed was assumed to have an equivalent opposite or the reverse trip at a later/earlier time dependent on trip purpose/vehicle type.

The following rules were adopted when generating the reverse trip times:

- CIW Home origin 07:00 – 10:00, + 9hr, else + 3hr
- CIW Home destination 16:00 – 19:00, - 9hr, else – 3hr
- CNWC 07:00 – 10:00, + 9hr
- CNWC 16:00 – 19:00, - 9hr
- CNWC 10:00 – 16:00, no change
- CNWO no change
- LGV no change
- HGV no change

The resulting reverse dataset was then expanded in the same manner as the dataset for the surveyed direction.

It was found that in some instances, the interviews did not cover the full AM and PM periods. To account for this data was in-filled from the PM period minus 9hr or from the AM period plus 9hr.

Relevant checks are undertaken throughout the process including:

- For each RSI Site, comparing the sum of the factors by period with the surveyed link count
- Checking the Journey Purpose Splits for each Site and expansion factors used for each user class
- Understand how many rejections occurred for each period by site
- Calculate the interview expansion factors by vehicle type and compare with 2014 Weekday Neutral month traffic counts

Following the processing of the RSI data all sites were combined into observed matrices by user class and assigned to the Road Network to highlight whether the observed travel patterns were being reflected in the highway assignment.

The existing trip data in the prior matrix corresponding with the new RSI sites had to be removed from the TMfS07 prior matrix. To do this the new link locations were defined for each new RSI site, and a select link analysis was undertaken for each site in both directions using the prior matrix assignment. Trips for each RSI site were removed from the TMfS07 prior matrices for each user class and time period.

One potential issue associated with the new RSI data and the select link analysis was that each RSI and select link analysis are independent of each other, so it was possible that trips between specific origins and destinations could travel through more than one site. This potential issue was accounted for by averaging the number of trips where this occurred.

7.6 Matrix Totals

The resulting matrix totals are presented in Table 7.2 to Table 7.4.

Table 7.2 : AM Peak Prior Matrix Totals

AM Peak	Pre-RSI	Post RSI	AM Peak Diff.	%
Car In-Work	27,572	27,819	247	0.9%
Car Non-Work Commute	241,056	239,715	-1,341	-0.6%
Car Non-Work Other	114,146	114,845	699	0.6%
LGV	38,348	39,549	1,201	3.1%
HGV	50,395	52,656	2,261	4.5%
Total	471,517	474,584	3,067	0.7%

Table 7.3 : IP Peak Prior Matrix Totals

IP Peak	Pre-RSI	Post RSI	IP Peak Diff.	%
Car In-Work	18,323	18,737	414	2.3%
Car Non-Work Commute	51,163	51,617	454	0.9%
Car Non-Work Other	203,780	204,716	936	0.5%
LGV	37,842	38,218	376	1.0%
HGV	52,294	53,795	1,501	2.9%
Total	363,402	367,083	3,681	1.0%

Table 7.4 : PM Peak Prior Matrix Totals

PM Peak	Pre-RSI	Post RSI	PM Peak Diff.	%
Car In-Work	27,661	27,835	174	0.6%
Car Non-Work Commute	226,339	224,963	-1,376	-0.6%
Car Non-Work Other	245,257	245,214	-43	0.0%
LGV	32,462	33,645	1,183	3.6%
HGV	38,871	40,553	1,682	4.3%
Total	570,590	572,210	1,620	0.3%

It is noted that the AM and PM periods Can Non-Work Commute matrices reduce when adding in the RSI data. This is due to short distance synthesised data being replaced with longer observed trip data.

8 NETWORK CALIBRATION AND VALIDATION

8.1 Network Calibration

Initial pre-calibration checks were undertaken as outlined in Section 6.8.

As the base network was constructed using a previous version of TMfS, calibration conducted throughout previous versions was inherently taken forward into the TMfS14 network and the following amendments were made:

- A review of the Forth Road Bridge Capacity took place by analysing SRTDb data. As a result of the Analysis the Forth Road Bridge capacity was increased from 3,200 to 4,000 PCU capacity.

After an initial matrix assignment the following changes were also made:

- The M90 Perth to Dundee and the A92 Glenrothes to Dundee speeds were adjusted to better reflect the routeing to west Dundee from the Fife Bridgehead (Forth Road Bridge/Dunfermline) area. This was shown to improve the routeing without having any significant effect on the overall highway assignment.

Section 6.6 of this Report highlighted a correction to the M80 Stepps to Haggs network coding to motorway standard, however, it also became apparent that the A80 Cumbernauld Road (parallel to the M80) should be changed to non-trunk road standard. The alteration to the link type and the resulting reduction in coded capacity were as follows:

- Urban non trunk A-Roads Built up (2,000 PCU capacity) changed to non trunk A-Roads Built up (1,600 PCU capacity)
- Link Type 3 Trunk A-Roads Non-built up (1,800 PCU Capacity per lane) changed to Link Type 5 Non Trunk A-Roads Non-built up (1,600 PCU Capacity per lane)

The Hermiston Gait circulating carriageway was also identified as having been mis-coded and therefore the number of lanes and associated capacity were corrected.

The capacity between M8 J25 (Clyde Tunnel) and M8 J22 (M8/M77) was reviewed and corrected to reflect the actual number of lanes.

8.2 Assignment Procedure

Traffic is assigned to the road network based on a Generalised Cost Function which takes the following form:

GC = a x distance(km) + b x time(min) + c x toll(pence)

where a, b and c are the parameters and GC is expressed in units of time.

Table 8.1 contains the base year Road Model Generalised Cost Function parameters for each of the five user classes. These parameters have been calculated using the November 2014 DfT WebTAG guidance; the current guidance at the time. The methodology and calculations were agreed with TS and provided to the Auditor for review.

Table 8.1 : Base Road Model Generalised Cost Parameters

	Parameter		
User Class	**Time**	**Distance**	**Toll**
Car In-Work	1	0.2763	0.0549
Car Non-Work Commute	1	0.5056	0.1541
Car Non-Work Other	1	0.3746	0.1541
LGV	1	0.7220	0.0246
HGV	1	1.8958	0.0246

The Road Model convergence is calculated using the Method of Successive Averages (MSA) algorithm which finds an equilibrium solution for the assignment procedure. This procedure is consistent with TMfS07.

The regression parameters used for the Road assignment model within TMfS14 are consistent with those used in TMfS07/12 and are as follows:

- NOITR = 10
- TOLERANCE = 0.0001
- NSUCC = 3

The number of iterations required to reach convergence within the TMfS14 Base Year Road Model were:

- Average AM Peak Hour between 07:00 – 10:00 45 iterations
- Average Inter Peak Hour (1/6 of 10:00 – 16:00) 18 iterations
- Average PM Peak Hour between 16:00 – 19:00 58 iterations

8.3 Flow Delay/Speed Relationships

The Flow Delay Relationships used in TMfS14 are consistent with TMfS07/12 and have not been modified as part of the model development.

The relationship between flow and speed is different for different types of road. Each road link has a 'Link Class' attribute. This attribute determines which flow delay relationship is attached to each road link. Appendix D at the end of this report shows the flow delay coefficient values associated with the different Link Classes.

The following Link Classes are used in Urban Areas (with free flow speeds in brackets):

- 1 Urban Central (32 km/hr)
- 2 Urban Non Central – Single (42 km/hr)
- 3 Urban Non Central – Dual (51 km/hr)
- 4 Small Town (44 km/hr)
- 5 Suburban – Single (54 km/hr)
- 6 Suburban – Dual (44 km/hr)
- 7 Urban Motorway (76.8 km/hr)
- 8 Urban Motorway < 70mph (92.8 km/hr)
- 20 Roundabout Urban Central (30 km/hr)
- 22 Urban Dual 50mph (76.8 km/hr)

The following Link Classes are used in both Urban and Rural Areas:

- 9 Ramp at Grade Separation (80 km/hr)
- 21 Roundabout Elsewhere (35 km/hr)

Table 8.2 shows Link Classes which are used in Rural Areas with the free flow speed in Brackets. These values are consistent with TMfS07 & TMfS12.

Table 8.2 : Rural Area Link Classes (Free flow speed in km/hr)

Hilliness	Bendiness	Rural Single – B Road	Rural Single – A Road	Rural Dual	Motorway – 2 lanes	Motorway – 3 lanes
H	H	10 (61)	-	-	-	-
M	H	11 (66.7)	-	-	-	-
M	M	12 (72.4)	-	-	-	-
L	H	-	13 (78.2)	-	-	-
L	M	-	14 (83.9)	16 (105.6)	-	-
L	L	-	15 (89.6)	17 (107.2)	18 (108.8)	19 (110.4)

8.4 Heavy Goods Vehicles' Speed Cap

An enhancement to previous TMfS Road Models is the implementation of Heavy Goods Vehicles' (HGVs) free flow speed cap by link type. The speed caps are national HGV speed limits for HGVs > 7.5 Tonnes (see Table 8.3).

Table 8.3 : HGV Free Flow Speed Cap by Link Type

Link Type	Description	Free Flow Speed (km/hr)
1	Trunk – Motorway	96
2	Trunk – Motorway slips	96
3	Trunk A-Roads Non-built up	64 (80 if Dual)
4	Trunk A-Roads Built up	48
5	Non Trunk A-Roads Nonbuilt	64
6	Non Trunk A-Roads Built up	48
7	Minor Roads – Non built up	48
8	Minor Roads – Built up	48

This added functionality to the Road Model assignment procedure ensures HGVs cannot travel faster than they are legally allowed to in free flow conditions. (Note: Modelled HGVs will travel at the relevant congested link speeds if these are slower than the HGV speed cap).

The HGV speed cap also allows for improved representation of HGV travel costs in the TELMoS land-use model and in economic scheme appraisals.

8.5 Route Choice Calibration and Validation

The accuracy of the assignment is dependent not only on the elements within network Calibration, but also on the realism of the modelled routes. The modelled routes depend on:

- Zone size and zone connector representation
- Accuracy of network coding and representation
- Accuracy of trip matrices

Initial checks on the assignment were undertaken by plotting routes on the network using the cost paths for each user class. This analysis focused on inter-urban journeys and is summarised in Appendix E.

The checks of the routes taken between major cities prior to the assignment are intuitive based upon local knowledge and comparing to on-line sources, e.g. Google Maps. Another route choice calibration check is the assignment of the observed RSI matrices which was undertaken as part of the prior matrix development and is described in Section 7.

Overall the route choice appeared intuitive and the no adjustments were required.

8.6 Road Model Output Files

The Road Model produces two default output files and three optional output files. The default outputs are:

- Output Road Model Network File (*.net)
  This binary file contains information such as road link traffic flows, congested road speeds, and travel times. This output file is based on the 799 zone assignment.
- Convergence Report File (*.prn)
  This text file summarises the global road network cost for each iteration and convergence level achieved.

The optional outputs are:

- Output Path File (*.pth)
  This binary file contains traffic routeing information for all non-zero origin destination movements (799 zones) for each iteration.
- Output Generalised Cost Skims (*.mat)
  This matrix file contains generalised cost information for each of the five user classes and is fed into the demand model. This file is a 799 zone format, i.e. compatible with the demand model. The file is created only when the demand model is NOT on the last loop.
- Output Time, Distance, Toll and Generalised Cost Skims (*.mat)
  This matrix file contains Time, Distance, Toll and Generalised Cost skims for each of the five user classes and they are combined over ALL iterations. This file is a 799 zone format, i.e. compatible with the demand model.

9 CALIBRATION OF THE NATIONAL ROAD MODEL

9.1 Introduction

The Road Model calibration process makes use of a number of traffic counts organised into screenlines, initial estimates of the trip matrices ('prior matrices') and traveller paths through the transport network. The process brings together this data to estimate the trip matrix from the input data. At the end of the process the 'level of fit' of modelled traffic flows is verified by comparison against available observed data.

A total of 43 screenlines were used in the calibration process (in both directions) and include a total of 435 traffic count sites across all three periods (AM, Interpeak, and PM). Each of the screenlines was made up of a 'set' of road links and thus the screenlines represent an aggregate of a number of traffic counts.

All observed and modelled values in the calibration process are in Total Passenger Car Units (PCUs). The observed values in the calibration process do not consider motorbikes, taxis or buses. Modelled values, however, contain bus pre-load information and this 'mis-match' will potentially have a minor affect on GEH statistics but will not change the overall conclusions presented in this section.

Total screenline results are presented in the following section, with reference to *WebTAG* Unit M3-1 criteria providing a guideline to the overall robustness of modelled total screenline flows.

The discussion presented in Paragraph 1.2 of this Report relating to the aim of the model and the scope of the model development, should also be noted when considering *WebTAG* Unit M3-1 guidance in relation to the calibration of the TMfS14 National Road Model.

9.2 Matrix Estimation Procedure

As part of the calibration process matrix estimation procedures were undertaken using Citilabs CUBE Voyager ANALYST software.

Matrix estimation is a process which is adopted for base year matrix development only. The procedure seeks to modify the prior trip matrices to better match link counts, trip ends, and travel pattern information by user class.

Matrix Estimation was undertaken at Car, Lights and Heavy Vehicle level as recommended by the TMfS12 Audit. Figure 9.1 illustrates the matrix estimation process and interactions with relevant input data.

This procedure was carried out for all three time periods, i.e. AM Peak, Average Inter Peak, and PM Peak.

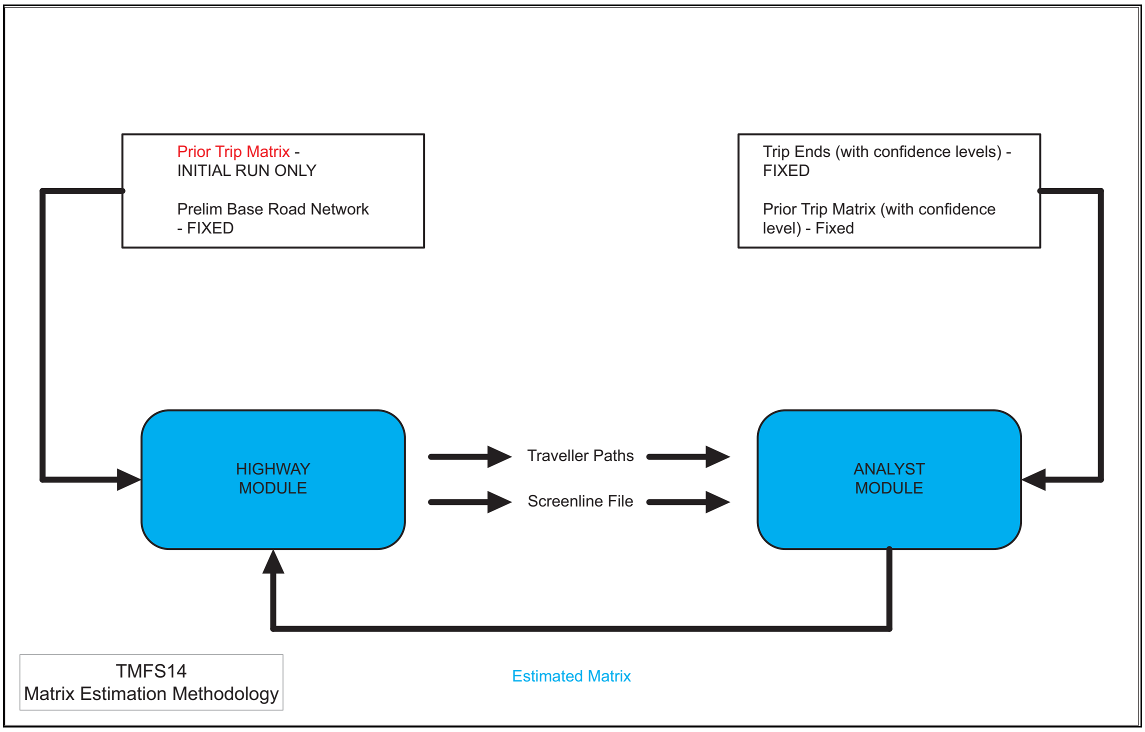

Figure 9.1 : Matrix Estimation Procedure

The matrix estimation process began with an initial road assignment undertaken using the Base Year Road network and the prior demand matrices to create the initial traveller paths. Thereafter, the estimated matrix output from the previous ANALYST run was used to create the next path file and the iteration was then repeated.

The modelled AM and PM Peak periods used the Car Non-Work Commute traveller paths, whereas the Inter Peak period used the Car Non-Work Other (CNWO) traveller paths. This was considered appropriate given the high proportion of trips contained with these travel purposes for each time period.

The traveller paths used in the estimation process were representative of the best traveller paths available after a run of the Road Model with the previous estimated matrix. ANALYST and the Road Assignment Model were run iteratively with successively improving paths being fed into the ANALYST program until a satisfactory estimated matrix was achieved.

Trip end data are the total number of trips travelling to and from each zone in the model. For the purpose of Road Model matrix estimation procedures, the trip end data was extracted from the prior trip matrices and given 30% confidence level for the internal zones, i.e. 1 to 782 inclusive, and 20% for the external zones, i.e. 783 to 799 inclusive.

Confidence levels were considered at the outset which account for the relative confidence of the dataset. The general observations applied to the confidence levels are as follows:

- At least some count sites should have observations made over several days (weeks, etc.) to determine basic levels of variability associated with single observations so strong confidence limits can be associated to them.
- Trip end confidences are unlikely to exceed count confidences, and will usually be less due to observational difficulties; in the case of public transport, the two sets of confidences are more likely to be similar.
- Prior matrix cells are, individually, unlikely to have high confidences even when collected by recent, good surveys because there are so many elements of the matrix. This becomes truer as the number of study area zones increases (due to the difficulty of observing all possible movements adequately).

The resulting confidence levels set within the matrix estimation procedure are as follows:

- Calibration Screenline Aggregate Observed Traffic Counts: 100% – 500%
- Trip End Data: 30% internal zones; 20% external zones
- Prior Matrix: 80% travel pattern

A confidence of 80% in the travel pattern was applied. This high confidence level is appropriate given the quality of the input data used to build the prior matrices.

The trip end and prior matrix files, along with their associated confidence levels, and the screenline files remained ‘fixed’ throughout the procedure; the only variables that changed were the output estimated matrix and the traveller path files.

Initially, focus was given to the calibration of total screenline flows, and once a reasonable match was produced the confidence levels of specific counts were refined to improve the match.

9.3 Demand Matrix Comparisons

The resultant matrices generated from the matrix estimation procedure are compared to the prior matrices and presented in Table 9.1 and in a series of tables in Appendix G. A nine region system was defined for reporting matrix results and this system is illustrated in Figure 9.2..

Table 9.1 : Pre-Post Matrix Estimation Matrix Comparison

	AM	IP	PM
TMfS14 Prior	474,586	367,083	572,210
TMfS14 Post-ME	474,086	364,600	565,275

The following key points of interest were noted from inspection of the sectored matrices:

- The change in the overall matrix totals for all three time period specific matrices from the Prior matrices (before matrix estimation) to the Final matrices (after matrix estimation) is relatively small.
- For all time periods, the largest change in total PCUs is for movements to and from Glasgow.

Analysis of the results was investigated and changes were made to the estimation process to improve the calibration results. The analysis shows that generally where changes in the sectored matrix totals are more than 5% the absolute values are not considered significant. Where sector value changes were greater than the criteria this is not significant in the context of it being a national model and considering the intended application of the model.

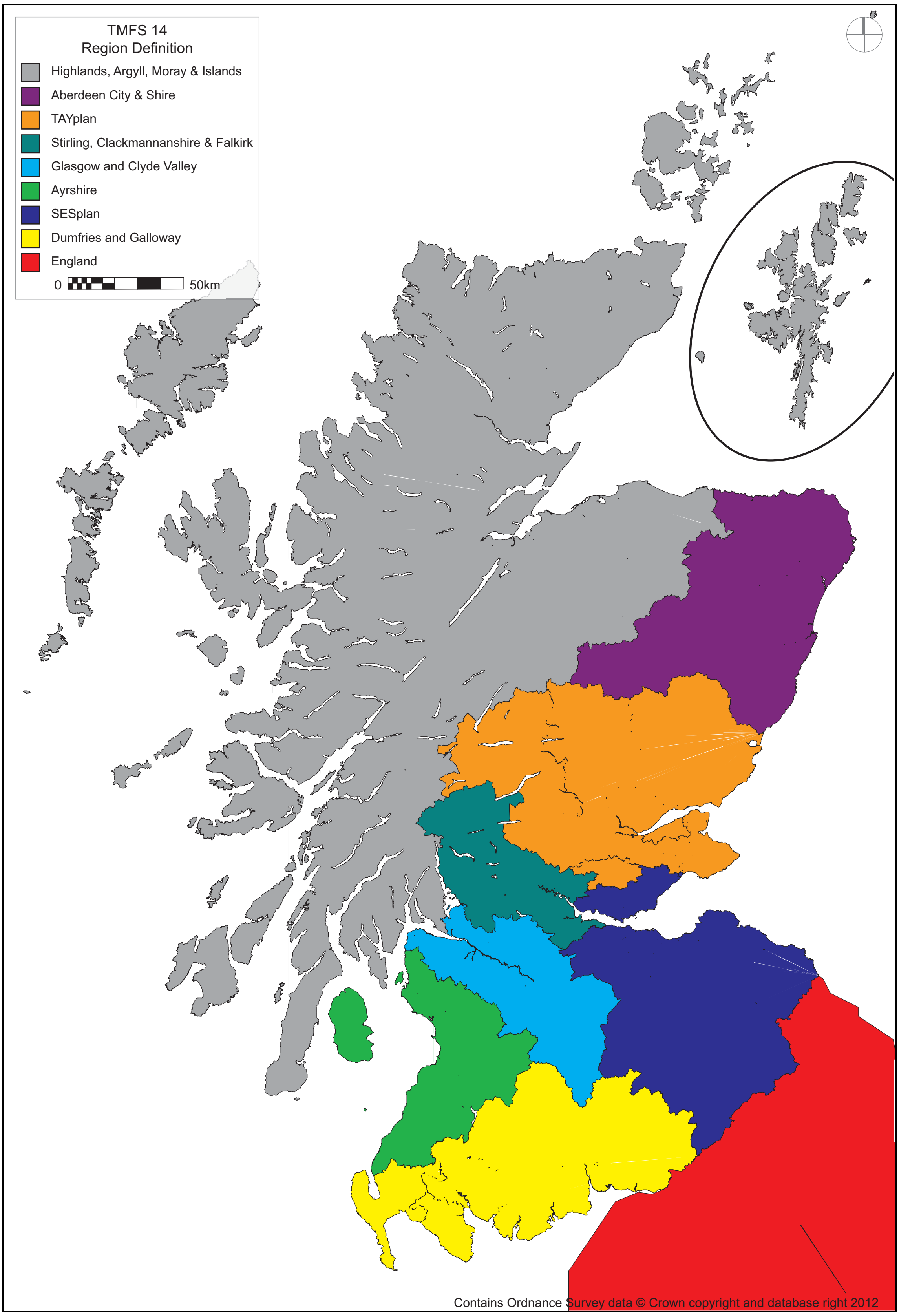

Figure 9.2 : 9 Region Definition Map

9.4 Zonal Cell Values and Trip End Correlation graphs

The significance of the changes brought about by matrix estimation have been considered by assessing the measurements in WebTAG M3-1. The criteria are presented in Table 3.5 and consider trip end and cell value regression calculations comparing pre and post matrix estimation and sector to sector comparisons.

The sector to sector comparisons are shown in Appendix H. In addition to the greater than 5% criteria, values greater than 100 PCUs were also considered for greater transparency.

The trip end and cell value regression calculations are contained in Appendix I. The results show that when considering cars and total vehicles the changes to the matrices are within the recommended tolerances. The LGV and HGV changes are more significant, which is to be expected as the LGV and HGV prior matrices have had limited updates since the TMfS07 prior matrix development.

9.5 Trip Length Distribution Analysis

Analysis of total PCU Trip Length Distribution before and after matrix estimation for each modelled time period is shown in Appendix J

There are six graphs presented for each time period; one which illustrates total PCU trips over a distance of 100km, and five showing total PCU trip lengths in 20km distance bands up to 100km. The 0 – 100km distance band was chosen since between 80% and 85% of total PCU trips for all time periods lie in this distance band.

For each graph there are two trip length distributions shown. The first is the prior assignment matrix (before matrix estimation) and the second is the final assignment matrix (after matrix estimation).

The key conclusion from the trip length distribution analysis is that the changes to the car-based purposes due to the matrix estimation process are particularly small for all three time periods, while the changes are a generally larger for LGV and HGV, as would be expected given the larger changes introduced by matrix estimation in those matrices.

9.6 Matrix Totals

The 2014 Road Base Matrix Totals by User Class are shown in Table 9.2.

Table 9.2 : Road Matrix Totals (PCUs)

Peak	AM Peak	Inter Peak	PM Peak
Car In-Work	28,091	18,807	27,579
Car Non-Work Commute	239,256	52,353	222,618
Car Non-Work Other	115,556	204,439	242,796
LGV	40,492	38,116	33,496
HGV	50,692	50,885	38,785
Total	474,087	364,600	565,274

9.7 Strategic Screenline Total PCU Traffic Flows

This section presents the calibration results for all strategic screenlines.

Table 9.3 provides a summary of the number and proportion of screenlines (both directions) that fall within various % differences compared to the observed count data.

Table 9.3 : Summary of Total Screenline Percentage Comparison

Bands	AM Total Screenlines	% of total	IP Total Screenlines	% of total	PM Total Screenlines	% of total
+/- 5%	41	57%	39	54%	32	44%
+/- 10%	57	79%	59	82%	59	82%
+/- 15%	71	99%	69	96%	67	93%
> +/- 15%	1	1%	3	4%	5	7%
Total	72	100%	72	100%	72	100%

Table 9.3 illustrates that for total screenlines, 57% of modelled traffic flows in the AM Peak, 54% in the Inter Peak and 44% in the PM Peak lie within 5% of the observed traffic count.

While this level of total screenline calibration does not meet the criteria as specified in the *WebTAG* guidance, as noted previously the criteria set by *WebTAG* are considered very stringent, especially in relation to large strategic style models such as TMfS14.

Using more relaxed criteria, where modelled flows are compared to within +/- 10% of the observed flow, the model produces a more positive comparison, with all time periods recording that over 82% of screenlines fall within this range.

Overall these results are an improvement over previous versions of TMfS: TMfS12 and TMfS07.

Table 9.4 provides a similar summary of screenlines that fall within various GEH statistic bands referred to in Section 3.1.

Table 9.4 : Summary of Total Screenline GEH Statistic

GEH Range	AM Total Screenlines	% of total	IP Total Screenlines	% of total	PM Total Screenlines	% of total
<4	57	79%	58	81%	47	65%
4 - 7	12	17%	7	10%	18	25%
>7	3	4%	7	10%	7	10%
Total	72	100%	72	100%	72	100%

Table 9.4 illustrates that for total screenlines, 79% of modelled traffic flows in the AM Peak, 81% in the Inter Peak and 65% in the PM Peak have a GEH values of less that 4 compared to the observed traffic count.

This level of total screenline calibration is in line with the *WebTAG* guidance which states "Total GEH Statistic: screenline totals GEH < 4 for all (or nearly all) screenlines", however, as noted, the criteria set by the *WebTAG* have been viewed in the past as stringent, especially for large strategic style models such as TMfS14.

Using more relaxed criteria, where modelled flows are compared to within a GEH of less than 7 of the observed flow, the model produces a more positive comparison, with all time periods recording that over 90% of screenlines fall within this range.

Overall these results are comparable with previous versions of TMfS: TMfS12 and TMfS07.

Appendix K contains the detailed breakdown of the calibration screenline comparisons for the AM Peak, Inter Peak, and PM Peak hours respectively.

In summary, 17 out of 108 (16%) screenline comparisons showed a GEH greater than 7. The majority of these are in urban locations within Glasgow (10), Edinburgh (5) and the South West (1) areas. The exception was Screenline 2, Aberdeen Inbound, which covers the A944 and A93 which has a GEH of 7.3 (-15%, 338 PCUs). It is noted observed that the competing route along the A96 has a higher modelled flow than observed (+11%), 339 PCUs) and this should be considered when interpreting any outputs from the model.

A summary of Screenline totals is shown in Appendix K (Figure K.40 – K.45)

9.8 Individual Calibration Points

Each screenline is made up of a 'set' of road links and thus the screenlines represent an aggregate of a number of traffic counts.

The following section discusses how the modelled flows compare to observed traffic count data at individual points along the calibration screenlines. These individual link counts are used to assess the level of calibration in more detail, indicating the robustness of local route choice in the Road Model.

Individual network calibration comparisons of modelled total PCU flows and observed total PCU traffic counts for all 354 sites (both directions considered) are also contained in Appendix K

Table 9.5 provides a summary of the level of calibration achieved at individual locations for the AM, Inter, and PM Peak time periods.

Table 9.5 : Summary of Individual Link Count GEH Statistic

GEH Range	AM Peak No. of Links	% of total	IP Peak No. of Links	% of total	PM Peak No. of Links	% of total
0 - 5	359	83%	361	83%	343	79%
5 - 7	30	7%	43	10%	39	9%
7 - 10	26	6%	16	4%	29	7%
10 - 15	8	2%	9	2%	14	3%
15 +	11	3%	5	1%	9	2%
Total	434	100%	434	100%	434	100%

Table 9.5 indicates that (across all time periods) between 79% and 83% of individual calibration points record a GEH <5. Although this does not fully comply with the specific *WebTAG* criteria, i.e. >85% of individual flows to have a GEH<5, if the range of GEH is extended to <7, 90% of locations in the AM Peak time period, 93% within the Inter Peak and 88% within the PM Peak time period fall within this range.

Therefore, given the scale and strategic nature of TMfS14, the calibration of individual link flow locations indicates that the Road Model is in fact close to matching the level of calibration set by *WebTAG*, particularly within the AM Peak and Inter Peak time periods, even though this level is considered very stringent for a model of this scale.

Overall these results are an improvement over previous versions of TMfS: TMfS12 and TMfS07.

Table 9.6 – Table 9.8 describe GEH ranges for each time period within which individual count locations by road type fall.

Table 9.6 : AM Peak hour GEH Band by Road Type

GEH Range	AM Trunk Roads	% of total	AM Non Trunk Roads	% of total	AM Minor Roads	% of total
0 - 5	188	87%	116	80%	55	77%
5 - 7	15	7%	10	7%	4	6%
7 - 10	10	5%	11	8%	4	6%
10 - 15	2	1%	4	3%	2	3%
15 +	1	0%	4	3%	6	8%
Total	216	100%	145	100%	71	100%

Table 9.7 : Inter Peak hour GEH Band by Road Type

GEH Range	IP Trunk Roads	% of total	IP Non Trunk Roads	% of total	IP Minor Roads	% of total
0 - 5	193	89%	117	81%	51	70%
5 - 7	14	6%	18	12%	11	15%
7 - 10	6	3%	9	6%	1	1%
10 - 15	3	1%	1	1%	5	7%
15 +	0	0%	0	0%	5	7%
Total	216	100%	145	100%	73	100%

Table 9.8 : PM Peak hour GEH Band by Road Type

GEH Range	PM Trunk Roads	% of total	PM Non Trunk Roads	% of total	PM Minor Roads	% of total
0 - 5	179	83%	115	79%	47	66%
5 - 7	19	9%	12	8%	8	11%
7 - 10	12	6%	9	6%	8	11%
10 - 15	4	2%	6	4%	4	6%
15 +	2	1%	3	2%	4	6%
Total	216	100%	145	100%	71	100%

As can be seen from Table 9.6 – Table 9.8 87% in the AM peak, 89% in the Inter Peak and 83% in the PM peak of individual calibration locations on trunk roads (including motorways) exhibit a GEH < 5. Over 92% of all peaks exhibit a GEH < 7 and only 1% of trunk roads in the PM peak exhibit a GEH > 15.

80% in the AM peak, 81% in the Inter Peak and 79% in the PM peak of individual calibration locations on non-trunk A roads exhibit a GEH<5. Between 1 and 6% of individual calibration locations on non-trunk A roads exhibit a GEH>10 and 3% or less exhibit a GEH >15.

77% in the AM peak, 70% in the Inter Peak and 66% in the PM peak of individual calibration locations on minor roads exhibit a GEH<5, however, all peaks show 85% have a GEH < 10.

9.9 Calibration Points by Flow Band

The calibration flow locations have been grouped into the flow bands shown in Table 3.2. This data has been compared to the modelled data for each peak and is presented in Appendix L.

The data demonstrates that almost all of the calibration comparisons are over 95%. The lowest value is 82% which occurs in the Inter Peak 'within 400 Veh > 2,700' flow band criteria, however, there are only 11 sites in this comparison.

9.10 Modelled Flow Observed Count Correlation Analysis

Appendix M presents an analysis of the modelled flows versus observed counts. Graphs are presented showing a correlation between modelled and observed flows for each of the three time periods.

Each graph highlights the Best-fitting Linear Regression Line: Y = θX (where Y is the set of modelled flows and X is the set of observed link-counts), and the corresponding Correlation Coefficient (R^2).

WebTAG guidance states:

> *The correlation coefficient (R) gives some measure of the goodness of model fit and the slope of the best-fit regression line through the origin indicates the extent to which modelled values are over or under estimated.*

The acceptable *WebTAG* criterion are as follows (and noting that a value of 1.0 for both parameters represents a perfect fit and the square root of R^2 gives R):

- (R) acceptable values are above 0.95
- (θ) acceptable values are between 0.9 and 1.1

The comparisons of modelled flows to the observed counts show a good correlation with a similar pattern of results achieved in all modelled time periods. There is a good representation of model fit (R = 0.97) in all time periods and only a very slight tendency towards over-estimation in the AM, Inter, and PM Peak hours (Y = 1.0043X, Y = 1.0315X, Y = 1.0349X).

9.11 Total PCU Traffic Level on Screenlines by Geographical Area

To provide a more aggregate illustration of the level of calibration, the total modelled traffic flows crossing the calibration screenlines were disaggregated by region, area (a disaggregation of region) and local authority area. This analysis is highlighted in Appendix N for each time period.

The tables indicate that the modelled and observed flows compare well at the regional and local authority level with a very slight over-estimation at the national level. The Highland, North–East, and Perth & Kinross areas show minor differences. The largest difference is an over estimation is in the Strathclyde area of up to 32% in the PM peak.

Considering all calibration screenline areas, the net effect is a slight over-estimation (2 – 4%) in total PCU traffic crossing the calibration screenlines. This analysis suggests that the TMfS14 Road Model displays an appropriate level of calibration at the aggregate regional level.

It is recommended that users make a note of the relevant calibration level for their area before applying the model.

9.12 Perth to Inverness and Inverness to Aberdeen Calibration Comparisons

Section 1 of this report refers to the potential application of TMfS14 which includes the assessment of improvements on the Perth to Inverness and Inverness to Aberdeen corridors.

Throughout the model development process specific consideration has been paid to these applications. Appendix O presents a comparison between the modelled and observed calibration flows for the two corridors.

In general the calibration flow comparisons in these areas/corridors compare well against the WebTAG criteria with the exception of a small number of specific locations, e.g. Raigmore Interchange, however, it is recommended that users consider comparisons specific to their areas of interest before interpreting detailed outputs.

9.13 Inter Urban Calibration Comparisons

In this Report summary detailed calibration flow comparisons have been presented. Selected modelled versus observed calibration flow comparisons have been extracted specifically focussing on Inter-Urban Screenlines.

This has been undertaken using the TMfS14 calibration data so contains some gaps, however, it aims to illustrate the robustness of the representation of Inter-Urban travel. These comparisons are presented in Appendix P.

Generally the comparisons compare reasonably well however there are some outliers, namely:

- M9 Edinburgh to Stirling:
  Differences >14% in all peaks (GEH < 11)
- M80 Glasgow to Edinburgh Northbound:
  Differences >8% in all peaks (GEH < 9)

9.14 Road Model Calibration Conclusions

This section outlines the conclusions from the Road Model calibration outlined previously.

9.14.1 Trip Length Distribution

The matrix estimation procedure highlights that the estimated matrix trip length distribution is consistent with the 'prior' matrix in all three modelled time periods, i.e. the calibration process has not significantly altered the observed distance travelled. This provides confidence in the adopted estimation procedure and in the quality of the input data sources.

9.14.2 Total Screenline Flows

The calibration results indicate that the Road Model has achieved a reasonable level of calibration at the aggregate screenline level across all three time periods. Although the model does not meet the (rather stringent) guidelines set by *WebTAG*, the results do suggest that nearly all screenlines lie within or close to a GEH of < 4 with the model indicating that at least 90% of screenlines record a GEH < 7. Given the WebTAG criteria are considered very stringent for a model of the scale and strategic nature of TMfS14, this provides further confidence in the adopted estimation procedure and in the quality of the input data sources.

9.14.3 Individual Calibration Points

At a more detailed level, the Road Model calibration has demonstrated that around 90% of individual calibration points record a GEH < 7, suggesting a relatively close match to the criteria set by the *WebTAG*, particularly within the AM Peak and Inter Peak time periods.

Within the calibration, some outliers have been identified and users should be mindful of these when considering applications of the model.

9.14.4 Traffic Level on Screenlines by Geographical Area

By cross-referencing the calibration analysis by geographical area, the reporting has indicated that the Road Model does not significantly under or over estimate total traffic flows at the aggregate regional level.

9.14.5 Flow/Count Correlation Analysis

There is a good representation of 'model fit' within all three time periods. In addition, there is only a slight tendency towards over-estimation of modelled total PCU values in the AM, Inter, and PM Peak hours. These variations are considered to be within reasonable and acceptable levels for a model of this type.

Overall, the calibration of the TMfS14 Road Model is considered reasonable and appropriate for a model of its scale and strategic nature.

10 VALIDATION OF THE NATIONAL ROAD MODEL

10.1 Validation Introduction

This section analyses the level of validation of the TMfS14 National Road Assignment Model. Validation is the process of checking how well the model compares with available data which is independent of the data used in the calibration process. The following aspects are considered:

- *WebTAG* Link Count Validation Criteria
- Total Traffic Flow Validation
- Goods Vehicle Flow Validation
- Traffic Flows on Scotland's Key Road Bridges
- Journey Time Data
- RSI Journey Length Analysis
- RSI Trip Distribution Analysis

As recommended by WebTAG, a flow screenline is normally formed as part of the Validation process. After reviewing the data coverage available and the strategic nature of the national model, it was concluded in agreement with Transport Scotland that the data collected should be used to create comprehensive calibration screenlines to inform model development. The validation comparisons composed of individual count comparisons throughout the modelled area.

10.2 Total PCU Link Count Validation

Using independent traffic count data (i.e. data that was not used within the model calibration process) the level of Road Model validation was identified. This section describes the validation of the total modelled flows (in total PCUs) using specific/individual points on the road network and summarises the results using the GEH statistic.

Table 10.1 contains a summary of the validation comparison between modelled and observed counts.

Table 10.1 : Summary of Link Flow Validation

GEH Range	AM No. of Links	% of total	IP No. of Links	% of total	PM No. of Links	% of total
0 - 5	136	57%	149	63%	134	57%
5 - 7	38	16%	35	15%	34	14%
7 - 10	35	15%	33	14%	34	14%
10 - 15	22	9%	15	6%	28	12%
15 +	6	3%	5	2%	7	3%
Total	237	100%	237	100%	237	100%

As can be seen from Table 10.1 57% of links in the AM Peak, 63% in the Inter Peak and 57% in the PM Peak have a GEH of less than 5. While these do not meet the *WebTAG* criteria, if the GEH criteria is extended to < 10 then more than 85% of locations meet the criteria in all modelled periods. Some of the validation counts are at locations remote from the calibration screenlines therefore a lower level of compliance may be expected in certain cases.

Appendix Q provides validation statistics and descriptions for each of the locations used in the detailed validation process by the geographical areas North, South-West, South-East, and Central Scotland.

10.3 Validation Points by Flow Band

The validation flow locations have been grouped into the flow bands shown in Table 3.2. This data has been compared to the modelled data for each peak and are presented in Appendix R.

The data demonstrates that all of the validation comparisons are over 75%, which is considered reasonable for a model of this nature.

10.4 Perth to Inverness and Inverness to Aberdeen Validation Comparisons

Section 1 of this Report refers to the potential application of TMfS14, which includes the assessment of improvements on the Perth to Inverness and Inverness to Aberdeen corridors.

Throughout the model development process specific consideration has been paid to these applications. Appendix S presents a comparison between the modelled and observed validation flows for the two corridors.

In general the validation flow comparisons in these areas/corridors compare well against the general WebTAG criteria, however, it is recommended that users consider comparisons specific to their areas of interest before interpreting detailed outputs.

10.5 Inter Urban Validation Comparisons

Within this Report summary detailed validation flow comparisons have been presented. Selected modelled versus observed validation flow comparisons have been extracted specifically focussing on Inter-Urban Screenlines.

This has been undertaken using the TMfS14 validation data so contains some gaps, however, it aims to illustrate the robustness of the representation of Inter-Urban travel. These comparisons are presented in Appendix T.

Generally, the comparisons compare reasonably well, however, there are some outliers described (as follows) which should be considered when interpreting outputs:

- M9 Edinburgh to Stirling:
  Differences up to 22% (GEH < 13) located M9 between Junction 7 and 8
- M8 Glasgow to Edinburgh:
  Differences of up to 26% (GEH < 13) located on the M8 west of Junction 5

10.6 Goods Vehicle Flow Validation

To determine the level of Goods Vehicles (GV) validation at key strategic network locations, modelled GV flows were compared against observed GV data on individual Motorway and A- Road links. The modelled GV flow is a combination of LGV and HGV flows, which is comparable with the observed dataset.

The observed data was extracted from Transport Scotland's Scottish Road Traffic Database (SRTDb). A summary of the GV validation statistics is described in Table 10.2.

Table 10.2 : Summary of GV Link Flow Validation

GEH Range	AM No. of Links	% of total	IP No. of Links	% of total	PM No. of Links	% of total
0 - 5	150	63%	177	75%	177	75%
5 - 7	41	17%	23	10%	27	11%
7 - 10	28	12%	24	10%	20	8%
10 - 15	10	4%	9	4%	8	3%
15 +	8	3%	4	2%	5	2%
Total	237	100%	237	100%	237	100%

Table 10.2 indicates that around 63%-75% of GV validation links display a GEH of less than 5, with over 80% of links recording a GEH of less than 7 in all time periods.

The previously noted *WebTAG* criteria is not relevant here for the validation of GVs or other subsets of the total modelled traffic, however, for the purpose of presenting the validation against a recognised criteria, *WebTAG* has been used.

Appendix U provides detailed GV validation statistics. There are outliers in the comparisons, however generally the comparisons on the A9 and A96 corridors between Perth and Inverness, and Inverness and Aberdeen compare well at the given locations.

10.7 Traffic Flow on Scotland's Key Road Bridges

This section outlines a comparison between observed total PCU traffic counts and modelled total PCU traffic flows crossing the following key road bridges:

- A9 Kessock Bridge
- A92 Tay Bridge
- M90 Friarton Bridge
- A876 Kincardine Bridge
- A876 Clackmannanshire Bridge
- A90 Forth Road Bridge
- M8 Near to Kingston Bridge
- A898 Erskine Bridge

Table 10.3 - Table 10.5 presents the key road bridge comparison for the AM, Inter, and PM peak periods.

Table 10.3 : AM Peak Hour Key Road Bridge Flow Comparison

Road Bridge	Direction	Total PCU Count	Total PCU Modelled Flow	Diff	% Diff	GEH
A9 Kessock Bridge	NBD	1108	1093	-15	-1%	0.5
	SBD	1667	1793	126	8%	3.0
A92 Tay Bridge	NBD	1026	1140	114	11%	3.5
	SBD	652	695	43	7%	1.7
M90 Friarton Bridge	NBD	1895	1919	24	1%	0.5
	SBD	1403	1390	-13	-1%	0.3
A985 Kincardine Bridge	NBD	739	762	23	3%	0.8
	SBD	712	760	48	7%	1.8
A876 Clackmannanshire Bridge	NBD	829	955	126	15%	4.2
	SBD	1080	955	-125	-12%	3.9
A90 Forth Road Bridge	NBD	3574	3484	-90	-3%	1.5
	SBD	3864	3870	6	0%	0.1
M8 near to Kingston Bridge	NBD	4079	4065	-14	0%	0.2
	SBD	4804	4759	-45	-1%	0.7
A898 Erskine Bridge	NBD	1911	1892	-19	-1%	0.4
	SBD	1866	1927	61	3%	1.4

Table 10.4 : Inter Peak Hour Key Road Bridge Flow Comparison

Road Bridge	Direction	Total PCU Count	Total PCU Modelled Flow	Diff	% Diff	GEH
A9 Kessock Bridge	NBD	1015	1027	12	1%	0.4
	SBD	1037	1127	90	9%	2.7
A92 Tay Bridge	NBD	613	639	26	4%	1.0
	SBD	571	603	32	6%	1.3
M90 Friarton Bridge	NBD	1062	1150	88	8%	2.6
	SBD	1272	1290	18	1%	0.5
A985 Kincardine Bridge	NBD	389	427	38	10%	1.9
	SBD	394	427	33	8%	1.6
A876 Clackmannanshire Bridge	NBD	548	577	29	5%	1.2
	SBD	553	577	24	4%	1.0
A90 Forth Road Bridge	NBD	2314	2297	-17	-1%	0.4
	SBD	2463	2419	-44	-2%	0.9
M8 near to Kingston Bridge	NBD	2870	2887	17	1%	0.3
	SBD	4007	4103	96	2%	1.5
A898 Erskine Bridge	NBD	1176	1257	81	7%	2.3
	SBD	1261	1305	44	3%	1.2

Table 10.5 : PM Peak Hour Key Road Bridge Flow Comparison

Road Bridge	Direction	Total PCU Count	Total PCU Modelled Flow	Diff	% Diff	GEH
A9 Kessock Bridge	NBD	1715	1738	23	1%	0.6
	SBD	1220	1357	137	11%	3.8
A92 Tay Bridge	NBD	848	885	37	4%	1.3
	SBD	1148	1152	4	0%	0.1
M90 Friarton Bridge	NBD	1423	1485	62	4%	1.6
	SBD	1781	1851	70	4%	1.6
A985 Kincardine Bridge	NBD	806	853	47	6%	1.6
	SBD	820	839	19	2%	0.7
A876 Clackmannanshire Bridge	NBD	1101	1015	-86	-8%	2.6
	SBD	846	1015	169	20%	5.5
A90 Forth Road Bridge	NBD	3888	3873	-15	0%	0.2
	SBD	3620	3481	-139	-4%	2.3
M8 near to Kingston Bridge	NBD	3165	3296	131	4%	2.3
	SBD	5582	5821	239	4%	3.2
A898 Erskine Bridge	NBD	1837	1944	107	6%	2.5
	SBD	1929	1983	54	3%	1.2

The results demonstrate that overall the validation is very good with almost all bridges in all periods and in all directions with GEH < 5. The only exception is the Clackmannanshire Bridge in the PM Peak southbound, where the GEH is 5.5.

10.8 Journey Time Validation

To determine the overall robustness of modelled journey times, *WebTAG* criteria and guidelines have been used as a benchmark. The journey time validation criterion and guidelines state: "*modelled journey times to be within 15% (or one minute, if higher) for greater than 85% of routes*".

As part of the validation process, in agreement with Transport Scotland, modelled journey time routes have been compared across 29 routes using the observed journey time data reported in the TMfS12 validation.

A summary of the journey time comparisons are presented in Table 10.6. Further detail for each route is presented in Appendix V.

Table 10.6 : Journey Time Validation Summary

Time Period	Proportion<15% (or 1min, if higher) of Observed Journey Times
AM	87% of all routes
IP	74% of all routes
PM	85% of all routes

Overall the comparison shows that the journey times are meeting the *WebTAG* criteria in the AM and PM. In the Inter peak 74% of modelled journey times are within 15% of observed journey times.

Table 10.7 shows the number of modelled journey times which are quicker or slower than the observed journey times. Overall the modelled journey times are generally quicker than observed journey times. This is not uncommon for a strategic model of this nature which does not encompass detailed junction/incident modelling and the associated delays.

Table 10.7 : Journey Time Additional Analysis

Time Period	Number of Journey Time Quicker than Observed	% of Total	Number of Journey Time Slower than Observed	% of Total
AM	76	73%	28	27%
IP	90	87%	14	13%
PM	73	70%	31	30%

10.9 RSI Trip Distribution Analysis

The trip distributions for the 33 RSI sites presented in Table 5.1 were analysed using the nine sector system highlighted in for all three time periods and for the same user classes. This comparison is presented in Appendix W.

Overall, there is a reasonable match for all sector-to-sector movements across all the RSI sites used in the development of TMfS14.

10.10 RSI Journey Length Analysis

This section outlines a summary of road side interview (RSI) site journey length for all user classes, which have been analysed for the 33 RSI sites used in the development of TMfS14. The analysis has been undertaken for the AM, Inter and PM peak periods.

The distance value has been obtained from the Car Non-Work Commuter distance skim in the AM and PM Peak periods and Car Non-Work Other in the Inter Peak period.

Appendix F provides a summary of the proportion of observed RSI and modelled (derived by undertaking a Select Link Analysis on the link the RSI was collected) trips in each distance band (up to a maximum distance of 500km at 50km increments). A description of the RSI sites is contained in Table 5.1 of this document.

The following key points are noted from this analysis:

- The modelled trip lengths at the majority of sites show a good match to observed RSI data across all three time periods
- The A9 and A96 sites generally show a good comparison between modelled and observed journey lengths across all three time periods
- As expected, for RSI sites close to urban areas (e.g. Barnchurch Road at Inverness, Westhill), the majority of trips travel within the 0 – 50km distance band
- As expected, for RSI sites in more rural areas, trips show a greater spread across the distance bands

The journey length comparisons at each of the RSI sites generally exhibit a reasonable match between modelled and observed journey lengths.

In addition, the distribution of car travel within the distance bands for different RSI sites appears reasonable, i.e. those travelling through an urban RSI site are more likely to be travelling a shorter commute distance compared to a more rural location.

11 SUMMARY OF MODEL DEVELOPMENT, STANDARDS PROPOSED, AND FITNESS FOR PURPOSE

11.1 Summary

The TMfS14 National Road Model has been developed to appraise national transport and planning policy along with strategic land-use and transport interventions. It provides a source of current and forecast national/strategic travel demand and associated demographic information.

This Report has presented and discussed the development and calibration of the TMfS14 National Road Model and has covered the following topics:

- Network and zone system development
- Road Model travel demand matrix development
- Assignment model development

Calibration of the National Road Model including:

- Screenline flow comparison
- Individual calibration points
- Flow band comparisons
- Modelled versus observed flow correlation analysis
- Perth to Inverness and Inverness to Aberdeen comparisons
- Inter Urban flow comparisons

Validation topics which have also been covered include:

- Individual link count validation
- Flow band comparisons
- Goods Vehicle (GV) flow analysis
- Inter Urban flow comparisons
- Perth to Inverness and Inverness to Aberdeen comparisons
- Analysis of traffic flows on Scotland's key road bridges
- Journey Time Validation
- RSI Journey Length and Distribution Analysis

11.2 Conclusions

SIAS's view is that the National Road Model has been successfully developed and is fit for its intended purpose, which is to provide road transport costs as part of an integral process in the National Land Use and Transport Modelling Framework for the purpose of appraising of major strategic transport schemes and policy decisions.

As expected, it should be noted that due to the size, nature, and data used in the model, there are some local variations in the level of calibration and validation achieved by the model and these are discussed in this Report.

As model developers, SIAS is satisfied that the model can be used to provide robust estimates of road-based costs for use in the mode and destination sub-models and the over-arching TELMoS land-use model.

The model can also provide a good starting source of transport supply and demand data for more-detailed sub-area/regional models, provided that relevant checks are carried out on the model's robustness in the relevant specific areas.

Looking at the model development in more detail, the trip length distribution analysis highlights the matrix estimation procedure has not altered the prior trip matrix trip length distribution significantly, providing confirmation in the estimation procedures adopted and the quality of the input data sources.

In addition, the Road Model is considered to be reasonably calibrated at the aggregate screenline level. Although the model does not meet the (stringent and less appropriate for a model of this nature) guidelines set by *WebTAG*, the results demonstrate that over 65% of screenlines lie within or close to the *WebTAG* criteria of a GEH of less than 4 with the model indicating that at least 90% of screenlines record a GEH of less than 7.

At the more detailed individual calibration level, the model also records what is considered to be a very a reasonable/acceptable level of calibration with around 85% of calibration locations across all time periods falling within a GEH of less than 7. Although this statistic does not quite achieve the *WebTAG* criteria, given the scale and strategic nature of TMfS14, its unlikely to meet these levels however they are better than previous versions of TMfS.

More detailed analysis has also indicated that it is the main trunk roads in the model that demonstrate the highest level of calibration.

The Road model also exhibits what is considered to be an acceptable representation of GV flows on key motorway and A-Road links, with around 80% of calibration links displaying a GEH of less than 7.

The Road Model also exhibits a very good representation of traffic flows on Scotland's key road bridges, with nearly all crossings recording a GEH of less than 5 in both directions across all time periods.

The Road Model also performs well on journey time validation, providing robust estimates of journey times for almost all journey time validation routes. The model achieves *WebTAG* criteria for around 85% of these routes in the AM and PM peak and 74% in the Inter peak.

As with all previous versions of the Transport Model for Scotland, all model applications of TMfS14 should be preceded by an appropriate review of the robustness of the model validation in the area/corridor of interest.

The focus of the model application of TMfS14 is supporting the Business Case development of the Inverness to Aberdeen and Perth to Inverness corridor improvements. Where appropriate, modelled versus observed comparisons have been made and compare well which demonstrates that the 2014 Base model update is robust for its intended application.

11.3 Recommendations

When developing the next version of TMfS it is recommended that the Road matrices are developed from the beginning. This would allow the component parts of the matrices which are synthesised to be recreated which use improved data or estimation techniques.

Time could be set aside for data processing in advance of any future model development so that the data is in a form which is ready for use within the model development process. This will reduce the risks to the model development timescale/programme estimates.

It may be beneficial if is recommended that the Road network is georeferenced, e.g. with the Integrated Transport Network (ITN) Layer, for compatibility and ease of integration with large datasets. It can be beneficial if the networks are fully georeferenced when considering journey time information such as INRIX data and when large volumes of output data is required.

More up to date observed Journey time data to be used either as a comparator to the current modelled TMfS14 journey times or for use in the development of the next version of TMfS would benefit the validation of the model.

Cognisance of the forecasting process inputs should be taken during the model development programme to ensure that an agreed specification for the Do Minimum is agreed well in advance of when the forecasting is required. This would reduce risk to the overall delivery programme.

The model development programme should contain a forecasting acceptance phase which considers the emerging Do-Minimum forecasts before they can be considered fit for application. This would ensure that the appropriate checks are undertaken to ensure that the model is responding as it should before being applied.