Transport Model for Scotland TMfS14 Upgrade

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1 Introduction

This paper follows on from the presentation given to the LATIS user group in November 2014 which set out the development of TMFS12 and the proposed development of TMfS12A which became TMfS14. This paper sets out the information used, the various methodologies and the results of the TMfS14 Base model development.

SYSTRA and Peter Davidson Consultancy Ltd collaborated successfully throughout the previous LATIS commission, successfully delivering both TMfS12 and TMfS14.

2 Background

2.1 Introduction to TMfS14

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 tools include the Transport Model for Scotland (TMfS) which is 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.transportscotland.gov.uk/latis).

2.2 Scope of the model update

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.*
> *TMfS14 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 and two Alternative Forecast Scenarios for the future years; 2017 – 2037 at five year intervals.

This paper covers the development, calibration, and validation of the TMfS14 National Road Model which is reported in a series of documents describing the development, calibration, and validation of the TMfS14 models, as follows:

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

2.3 Instructions to authors

This paper is written by Rob Culley of Peter Davidson Consultancy Ltd and Malcolm Neil of SYSTRA. Rob is a principal consultant and experienced project manager with 19 years' transport planning and modelling experience with PDC. Since joining PDC in 1997, he has been building and applying statistical transport models, developing modelling software tools, applying and undertaking fundamental research in transport planning. He has been responsible for developing the Consultancy's transport modelling software (Visual-tm) and is project director for the development of Visual Choice, the Consultancy's Choice Modelling software.

Malcolm is an Associate in SYSTRA's Edinburgh office with over 23 years' experience of traffic and transportation planning in the private sector, central and local government. Malcolm has extensive local knowledge and significant experience in a broad range of studies undertaken throughout the UK. Malcolm has been the project manager in a variety of traffic and transportation projects including wide area traffic models, major junction improvements, traffic management, structure plan and local plan assessments and public consultation exercises.

3 Development of Base Year Network and Zone System

3.1 Introduction

The TMfS14 zone system, shown in Figure 1, unlike TMfS12, is now consistent across the model hierarchy at 799 zones, comprising:

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

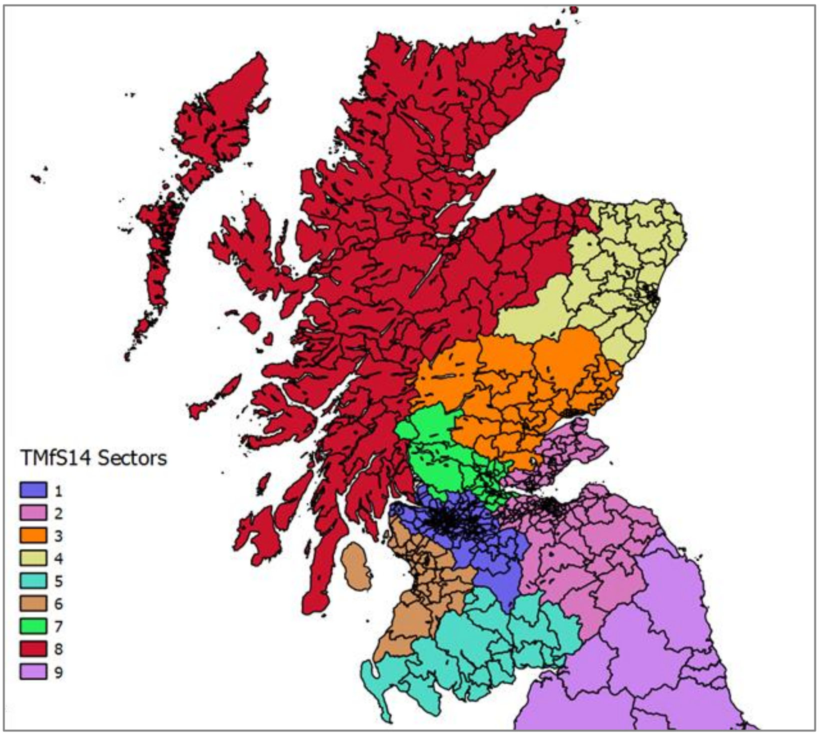

Figure 1: TMfS14 Zone System

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

- Utilise TMfS12 zone system as a starting point
- 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
- Disaggregate zones to account for specific ports
- 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)

4 Data Sources

4.1 Road Model

4.1.1 2011 Census Travel to Work Data

2011 Census Travel to Work data from the National Records of Scotland and 2012/13 Scottish Household Survey data from The Scottish Government was provided for this study under special licence. The Census Travel to Work data contains person trip information for Full Time Students and the working population. The Census data is considered representative of a 24hr weekday sample and each trip equates to a car travel to work trip.

4.1.2 Scottish Household Survey (SHS) 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 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 than 10 trips (35% more than 5 trips).

The resulting factors were applied to the census records which produced peak period census journey to work matrices.

4.1.3 Roadside Interviews

Thirty-Eight Roadside Interview (RSI) count sites dated between 2007 and 2015 were used in the TMfS14 matrix development as shown in Figure 2.

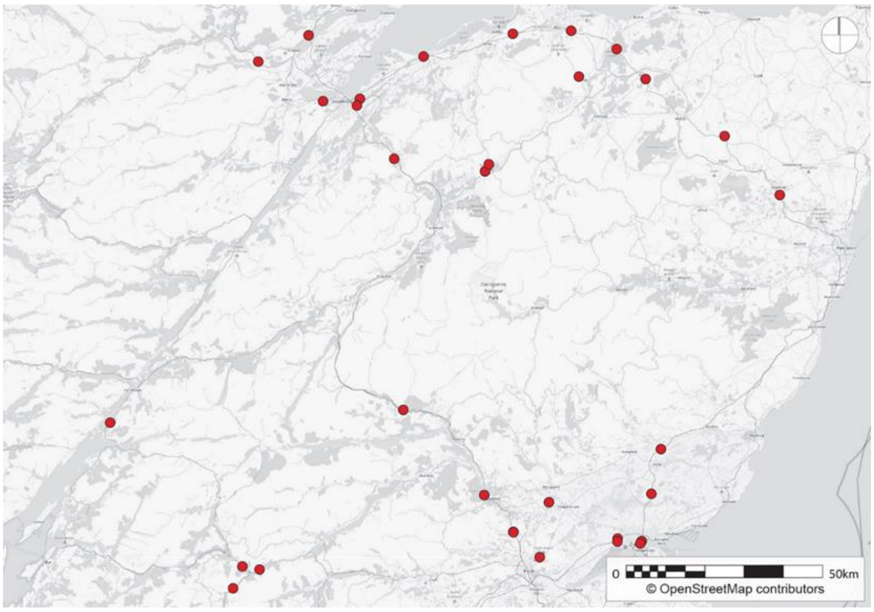

Figure 2: Road Side Interview Count Sites

4.1.4 Traffic Counts for Calibration

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

4.1.5 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)

4.1.6 Journey Time Data

The (TMfS12) reported observed 2012 INRIX journey time data for the validation of TMfS14. 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.

4.1.7 Public Transport Model

Observed public transport data collected between 2012 and 2015 for the Inverness to Aberdeen and Perth to Inverness corridors for both bus and rail was processed and used in the development of TMfS14.

5 Development of Base Year Matrices

5.1 Road Model

Following the creation of the SHS 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 Ltd, 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.

5.1.1 Road Side Interview Data Processing

Each RSI dataset was 'cleaned' at source to remove or correct records whose origins and destinations appeared illogical. 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.

Where site/day trip did not have an equivalent "reverse" direction trip, a dataset for the return direction was synthesised from the "forward" data. The following rules were adopted when generating the reverse trip times:

- Car In-Work (CIW) Home origin 07:00 - 10:00, + 9hr, else + 3hr
- CIW Home destination 16:00 - 19:00, - 9hr, else - 3hr
- Car Non-Work Commute (CNWC) 07:00 - 10:00, + 9hr
- CNWC 16:00 - 19:00, - 9hr
- CNWC 10:00 - 16:00, no change
- Car Non-Work Other (CNWO) no change
- Light Goods Vehicles (LGV) no change
- Heavy Goods Vehicles (HGV) no change

Following the processing of the RSI data all sites were combined with TMfS prior matrices by user class.

5.2 Public Transport Model

5.2.1 Introduction

This section describes the development of the TMfS14 'prior' Public Transport matrices which feed into the calibration 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 bus and rail Inter-Urban survey data for the Perth to Inverness and Inverness to Aberdeen corridors

The methodology adopted for developing the TMfS14 Public Transport matrices involved using the TMfS07 public transport matrices as a starting point and updating them with the above data.

The application of the 2011 Census Travel to Work and SHS data is similar to the Road Model matrix development.

The peak period census matrices adjusted to represent each peak hour by applying the TMfS14 peak hour to peak period factors which are:

- AM Peak 2.222
- Inter Peak 1/6
- PM Peak 2.273

The remainder of the process was consistent with the Road Model matrix development.

6 Update of Base Year Demand Model

6.1 Introduction

The key changes to the TMfS14 demand model were as shown as follows:

- Additional Park & Ride sites added to the model
- Updated base year trip ends, re-basing the trip end model to a 2014 base year
- Mode and destination choice models re-estimated using household travel survey data and the observed matrices
- Updated vehicle occupancy inputs for 2014
- New incremental matrices to compensate for differences between the validated matrices and the synthesized base matrices
- Elasticity calculations for realism testing

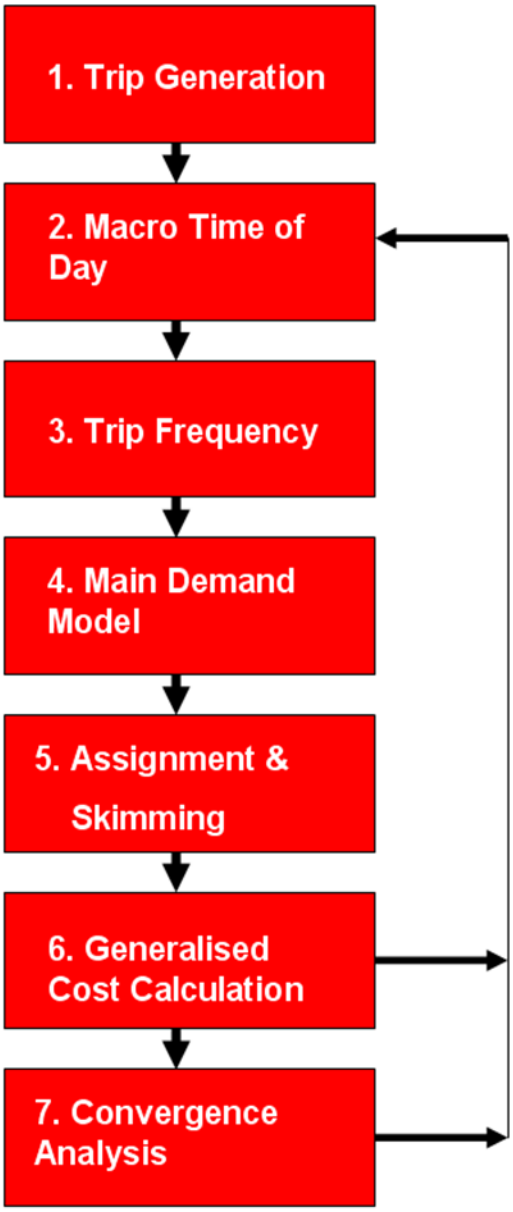

Figure 3. Demand Model Structure

The main inputs to the TMfS14 Demand Model were:

- Updated trip ends from the trip end model
- 2014 demographic data from TELMOS
- New base year generalised cost matrices for highway and public transport modes
- Highway and public transport networks
- Park & ride site files
- Validated base year trip matrices for the three main car journey purposes described below and for goods vehicles
- Incremental matrices
- Model parameters

Several updates were carried out within the changes for TMfS14. Among these: the model zone system was updated from 720 to 799 zones, the P&R model was updated to include additional sites, the base year trip end model was rebased to 2014 and adjusted to work with new data formats, mode and destination choice models were re-estimated and the incremental matrices were updated.
Further detail on the trip end model, mode and destination choice re-estimation and incremental matrices is provided as follows. Later, we describe the realism testing that was carried out with the updated model.

The Park & Ride was found not to converge and the base transfer time parameters and other aspects were adjusted to improve this.

The TMfS14 Demand Model includes a Long Distance Model that was developed for the TMfS12 update and on which a paper was presented at the 2014 STAR Conference (Ref 5).

6.2 Updating the trip end model base year

The trip end model was rebased to 2014. With the zone system extended from 720 zones in TMfS12 to 799 zones in TMfS14, the trip end model was also updated to use inputs and produce outputs with 799 zones.

The trip rates applied were also updated to use the NTEM 6.2 dataset (Ref. 1) and were applied by area type, although it was found that in practice the specific elements extracted from the NTEM dataset for use in TMfS14 had not changed from those applied in TMfS12.

Previous versions of TMfS applied the NTEM trip rates for a single area type to all of the model zones whereas the updated TMfS14 applied the different rates according to the NTEM area types for model zones. This means that rather than assuming that all of the modelled zones related to one of NTEM's area types, each zone was assigned a different area type; this allowed the trip end model to reflect differences in trip making between suburban and rural zones, for example.

New annual airport growth factors based on Department for Transport aviation forecasts were put in (Ref. 2).

The trip end model used data derived from the base and future year land use model outputs to factor up the base year trip ends. We produced a set of base year trip ends split by purpose and time period from the 2014 observed matrices. The trip ends needed to be split by household car availability, which was not available in the observed matrices, so the household car availability split in the TMfS12 base year trip ends was applied to the 2014 trip ends.

The trip end model was updated with additional changes to handle the change in the format of the demographic input files from TELMOS, to take account of the increased number of zones and to aggregate over income bands.

The 2014 land use data was then used in both the base and scenario inputs for the base year trip end model run as an initial test. The resulting output trip ends were identical to the inputs. Additional checks were then carried out using TELMOS data for a 2037 forecast year, confirming that the trip end model was working correctly.

6.3 Estimation of new mode and destination choice coefficients

6.3.1 Scope of update

The remit of the update was to re-estimate and update the coefficients rather than changing the model structure, which effectively has mode choice above destination choice in the hierarchy of responses.

It is, however, worth noting at this point that the estimations carried out appeared generally to support the view that destination choice is more sensitive than mode choice and should, thus, be beneath mode choice in the hierarchy.

6.3.2 Methodology

Using the revealed preference information contained in the base year highway and PT trip matrices and network skims, the Visual Choice software package allowed the estimation of various model coefficients via discrete choice methodology.

There were various approaches available for estimation, and a number of constraints which needed to be taken into account. For example, use of a multinomial logit structure in the estimations would have been computationally quicker and easier than estimating a nested logit, but would not have produced scaling coefficients with the rigour that simultaneous nested logit model estimation would. For the TMfS14 estimations a nested logit structure was used (with destination choice under mode choice) in order to obtain scaling coefficients, cost, log-cost, and intra-zonal coefficients. Nested choice models can be estimated by estimating each nest individually as multinomial logit, calculating the logsums and passing them up to the next level up in the hierarchy, however, it is much better and more robust to estimate both nest levels simultaneously. This is more difficult, has unknown convergence and longer run times.

TMfS incorporates distinct coefficients for different household types, which have different car-ownership levels, however, the estimation dataset, being based on the observed matrices, was not split by car availability level so separate estimations for 1 car, 2 car households, etc. could not be carried out. Instead the data was grouped to an all car available level and the estimations had to be carried out at this aggregate level.

One of the options would be to calculate these by hand for all zones in an iterative process. Firstly coefficients would be estimated based on no Alternative-Specific Constants (ASCs fixed at zero), these would be run through the Cube demand model, then a set of ASCs would be calculated to ‘correct’ the modelled share across destinations and modes predicted by the model. These would then be input as fixed ASCs to a new estimation and the process repeated until the estimations are satisfactorily stable or converged. Due to the interaction between running estimations and running Cube, this was a very time consuming approach.

With the nested logit structure and large number of zones, estimation run times were found to be very long. In order to allow overnight runs a sampling approach had to be adopted, working with just one part of the dataset at a time. The estimations were initially run with external (i.e. outside of the estimation software) calculation of 9 ASCs, one for each sector, however, under this approach the estimation process was not converging and the number of ASCs had to be increased to 32 based on division of the zones across local authority boundaries.

We also found that the Park & Ride was not converging and so we took action to try and address that problem and make the model converge (see Section 3.2). The Park & Ride non-convergence exacerbated the problems with run times, and with the non-convergence of the ASCs.

Each of these samples were still substantial sized datasets, and in combination with the sector-level ASCs allowed overnight estimations and 24hr turnarounds for a full iteration of estimation, running the demand model in Cube and calculating a new set of ASCs ready for the next estimation run. We found that iterations 2 and 3 of the 32 sector ASCs appeared to give the best overall set of ASCs so we used iteration 3.

6.3.3 Sample Selection

Samples of the order of about 1,000 records were used, and a set of ten estimations were made from 10 different sets of data for each trip purpose. The resulting coefficients were then averaged across the sampled subsets.

The samples were selected at random according to the following approach for each purpose:

- The master set of all trip records for the purpose in question was created
- The proportion of this dataset required to provide a sample of approximately 1,000 records was determined, i.e. 1 in every n records (e.g. 1 in 40 records)
- Random starting point x within the first n records determined using random number tables
- Records x, x+n, x+2n, x+3n… selected to form the sample
- The process was repeated to get all ten sets of trip records, ensuring that no record was used twice

6.3.4 Utility specification

The parameters included in the estimations were highway generalised cost, the PT generalised cost, two cost damping ln (GeneralisedCost) parameters (one for highway and one for PT), and an intrazonal factor. These are equivalent to the parameters that were used in the destination choice model in TMfS12 so the essential structure was unchanged. In order to improve the estimation of the above coefficients, Alternative Specific Constants (ASCs) were also estimated for each destination sector.

As described earlier, in the initial stages ASCs were calculated for each of the 9 model sectors. Following difficulty achieving convergence with this configuration an alternative set of 32 sub-sectors, based on local authority areas, was used.

Hence the utility functions used were as follows:

$$U_{j.Hwy} = \beta_0 Intra + \beta_1 \ln\left(C_{ij.Hwy}\right) + \beta_2 C_{ij.Hwy} + ASC_{j.Hwy}$$

And

$$U_{j.PT} = \beta_0 Intra + \beta_1 \ln\left(C_{ij.PT}\right) + \beta_2 C_{ij.PT} + ASC_{j.PT}$$

The model was a simultaneously estimated nested logit model, with mode choice above destination choice, producing structural parameters (scalar coefficients applied to each branch of the nest) for highway and public transport. These structural parameters are equivalent to the mode choice spread parameter described in TMfS07.

Table 6.1: AM Mode and Destination Choice Coefficients for Home Based Work

am coefficients	HBW	HBW t-stat
β_0 intrazonal		
C0	0.03261	5
C11	0.69826	5
C12	0.73214	5
C2	0.77836	5
β_1 ln (cost)		
C11C	-0.24344	5
C12C	-0.24445	5
C2C	-0.21956	5
C11P	0	0
C12P	0	0
C2P	0	0
C0P	0	0
β_2 cost		
C11C	-0.06413	27
C12C	-0.05330	27
C2C	-0.05164	27
C11P	-0.02762	29
C12P	-0.02494	29
C2P	-0.02179	29
C0P	-0.03415	29
θ *spread*		
C11	0.63783708	28
C12	0.66539099	28
C2	0.65658193	28

Table 6.1 shows the coefficients obtained for AM Home Based Work trips along with their ‘t’ statistics. The ‘t’ statistic is a measure of the accuracy of the value obtained and is found by dividing the value by its margin of error so a larger ‘t’ statistic indicated a higher degree of accuracy. Any value greater than 2 is normally considered acceptable. The coefficients for the log of generalised cost for public transport trips were found to be positive and/or not statistically significant i.e. with ‘t’ statistics below 2, so these were removed from the utility equations and the estimations rerun. Positive coefficients for elements of cost are somewhat counterintuitive and might lead to the model producing unreasonable outputs under certain circumstances, so it is best practice to remove the parameter from the utility equation and re-estimate. The corresponding log cost coefficients in the model’s input files have thus been set to zero for AM Home Based Work by public transport.

The positive values for the intrazonal movements are, however, acceptable as short journeys such as these are more attractive than longer journeys.

The coefficients are split into different categories of household car availability, which are households with one adult and one car, households with two adult and one car, households with two or more cars and households with no car. This final category is only applicable to public transport trips.

θ is the spread parameter or mode choice scaling factor and should have a value between zero and one. A paper on the sampling methodology was presented at the 2016 ETC Conference (Ref 6).

6.4 Other Updates

The vehicle occupancy matrices were updated to be in line with the trends from the WebTAG Databook (Ref 3).
New Park & Ride sites with their capacities and costs (where appropriate) were added to the Park & Ride site file with their transfer times set to zero. The Park & Ride model was run for one iteration and the resulting calculated transfer times were set as the base transfer times.

6.5 Park & Ride model update

The inputs to the site choice calibration are the Park & Ride generalised costs and Park & Ride sites. Each site file contains a specification of the site catchment area, which are defined as a list of zones, which in nearly every case are all other zones.

The site file also contains the Car Park Charge (if any) and the number of 'official' car parking spaces. Note the Park & Ride station choice model allows users to park outside the 'official' car parking spaces, as is the reality at a number of stations.

Each Park & Ride site also has a calibrated transfer time, which is added to the generalised costs within the car park choice process and is specified in the site file. The transfer time aims to reflect a variety of attributes of the Park & Ride site (e.g. cleanliness, ease of transfer, security etc.) and is used as a calibration tool. This parameter does not vary with car park occupancy.

The TMfS14 update of the Park and Ride model was primarily the inclusion of thirty nine additional sites along with any changes to the number of parking spaces at each site. The change in the TMfS14 zone system was also incorporated into the park and ride model inputs. The TMfS12 observed park and ride data was not updated as part of the TMfS14 development and no observed data for the additional park and ride sites was available within the timescales of the model development.

7 Calibration, Validation and Realism Tests

7.1 Road Model Calibration

7.1.1 Strategic Screenline Flows

This section presents the calibration results for all strategic screenlines. Table 7.1 provides a summary of the number and proportion of screenlines (both directions) that fall within various % differences compared to the observed count data.

Table 7.1: 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 7.1. 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.

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

Table 7.2 provides a similar summary of the screenline statistics.

Table 7.2: 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%

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 than 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, the criteria set by the WebTAG have been viewed in the past as stringent, especially for large strategic style models such as TMfS14.

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

7.1.2 Individual Calibration Points

Table 7.3 provides a summary of the level of calibration achieved at individual locations for the AM, Inter, and PM Peak time periods.

Table 7.3: 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 7.3 indicates that (across all time periods) between 79% and 83% of individual calibration points record a GEH <5. 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 7.4 – Table 7.6 describe GEH ranges for each time period within which individual count locations by road type fall.

Table 7.4: 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 7.5: 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 7.6: 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 7.4 – Table 7.6 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.

7.2 Road Model Validation

7.2.1 Total PCU Link Count Validation

Table 7.7 contains a summary of the validation comparison between modelled and observed counts.

Table 7.7: 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 7.7 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.

7.3 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 7.8.

Table 7.8: 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 7.8 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.

7.4 Traffic Flow on Scotland's Key Road Bridges

Table 7.9 - 7.11 shows the comparison between observed total PCU traffic counts and modelled total PCU traffic flows crossing Scotland's key road bridges.

Table 7.9: 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 7.10: 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 7.11: 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.

7.5 Journey Time Validation

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 is presented in Table 7.12.

Table 7.12: 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

Table 7.13 shows the number of modelled journey times which are quicker or slower than the observed journey times.

Table 7.13: 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%

7.6 PT Model Validation

7.6.1 Observed Screenline Data Update

The timescales for the development of TMfS14 were condensed and as such there was limited opportunity to collate and incorporate recently collected observed public transport Screenline data. In discussion with Transport Scotland the pragmatic solution for updating the observed public transport flows was to take account of national public transport trends between 2007 and 2014, and apply these to the 2007 dataset.

The national trends were calculated using vehicle kilometres statistics (Scottish Transport Statistics No 33, Table 2.3a: Vehicle kilometres on local bus services by type of service) and Passenger Traffic statistics (Table 7.2 Passenger traffic originating in Scotland: journeys and revenue) from the Scottish Transport Statistics. The trends between 2007 and 2012 were calculated using the above data with the assumption, in agreement with Transport Scotland, that Public Transport usage remained constant between 2012 and 2014. The conclusion from the analysis was a 10 – 20% decrease in bus usage between 2007 and 2014 and a 21 – 36% increase in rail usage. The resulting factors which were applied to the 2007 observed data are presented in Table 7.14.

Table 7.14: Public Transport Growth Factors (2007 – 2014)

Peak/Mode	Bus	Rail
AM/PM Peak	0.9	1.21
Inter Peak	0.8	1.36

7.6.2 Passenger Loading Comparisons

Comparisons have been made between modelled and factored observed passenger flows. It should be noted that the observed data is independent data separate from the data used in matrix development. Table 7.15 provides a summary of the cordon and screenline passenger flow comparisons, Table 7.16 summarises the individual site passenger comparisons for the PT model and Table 7.17 summarises the individual site passenger comparisons where the observed flows are greater than 150 passengers per hour.

Table 7.15: Summary of PT Cal Val, Cordon Screenlines

Mode	AM		IP		PM	
	No.	%	No.	%	No.	%
Bus within 15%	8	57%	5	36%	6	43%
Bus within 25%	9	64%	8	57%	8	57%
Rail within 15%	3	21%	4	29%	6	43%
Rail within 25%	7	50%	8	57%	7	50%
Multi within 15%	8	57%	9	64%	9	64%
Multi within 25%	11	79%	11	79%	13	93%

Table 7.16: Summary of PT Cal Val, Individual Sites

Mode	AM	IP	PM
Bus within 25%	47%	53%	47%
Rail within 25%	55%	62%	47%
Bus and Rail within 25%	50%	56%	47%

Table 7.17: Summary of PT Cal Val, Individual Sites (Greater than 150 Passengers)

Mode	AM	IP	PM
Bus within 25%	27%	46%	34%
Rail within 25%	50%	52%	44%
Bus and Rail within 25%	38%	49%	38%

Overall, it is considered that the key strategic passenger movements are represented appropriately in the TMfS14 Model.

7.6.3 Rail Passenger Boarding/Alighting Comparisons

Table 7.18 provides a summary of the GEH statistics for all the stations in the TMfS14 model. This indicates that the majority of the boarding and alighting comparisons have a GEH of less than five and nearly all have a GEH of less than 10. The validation against these data is considered to be acceptable.

Table 7.18: Boarding Alighting Summary

	AM		IP		PM	
GEH	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Less than 5	61%	59%	73%	69%	64%	62%
Less than 7	76%	71%	85%	83%	77%	75%
Less than 10	86%	84%	94%	94%	90%	89%

7.6.4 Comparison of Timetabled and Modelled Bus Journey Times

As modelled bus journey times are based on assigned road speeds, checks have been made to ensure that modelled bus journey times are representative of timetabled bus journey. A summary of the journey time validation can be seen in Table 7.19.

Table 7.19: Journey Time Validation

		AM		IP		PM	
Within 15% of PT Timetable	Yes	51	50%	53	52%	58	57%
(DMRB Criteria)	No	52	50%	49	48%	43	43%
Within 25% of PT Timetable	Yes	78	76%	75	74%	79	78%
	No	25	24%	27	26%	22	22%

7.6.5 Perth to Inverness and Inverness to Aberdeen Validation

The Public Transport assignments were compared to the observed data on the Perth to Inverness and Inverness to Aberdeen corridors and the comparisons are presented below and the rail boarding and alighting comparisons are presented in Appendix A.

The modelled and observed bus and rail screenline comparisons compare very well, as do the specific rail and bus comparisons given the strategic nature of the model. The modelled boarding/alighting and the departure loadings (i.e. the total volume of passengers on the train as it leaves a station) compare very well with the observed data given the strategic nature of the model.

7.7 Realism Tests

The sensitivity tests were run in accordance with the guidance in the DfT's TAG unit M2 Variable Demand Modelling (January 2014) (Ref. 4), which recommends checking the elasticity of demand with respect to:

- Highway fuel price
- Public transport fares
- Highway journey time

The demand model runs that were undertaken to test these responses were as follows:

- 10% increase in fuel cost
- 10% increase in PT fares
- 10% increase in highway journey times

The rest of the parameters were kept unchanged. External and long distance trips were excluded from the tests and all others were included. For the car fuel cost sensitivity tests, the elasticities were calculated by weighting the trips by distance to get vehicle kilometres. For highway journey time and PT fares, the number of trips were used, as required by WebTAG.

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

The elasticities were calculated using:

$$e = \frac{\ln(k') - \ln(k)}{\ln(C') - \ln(C)}$$

This ensured that the elasticity was a good approximation to the point elasticity at the midpoint of the data.

The calculated elasticities are presented in Table 7.20 and 7.21.

Table 7.20: WebTAG Elasticity Ranges (Table 6.2, TAG Unit M2, January 2014)

Elasticity	High	Low
Average Fuel Cost (kms)	-0.35	-0.25
PT Main Model Fare (trips)	-0.9	-0.2
Car Journey Time (trips)	No Stronger than -2	No Stronger than -2

Table 7.21: WebTAG Elasticity Ranges (Table 6.2, TAG Unit M2, January 2014)

Elasticity test	All trips	A9/A96	Non A9/A96
Average Fuel Cost (kms)	-0.31	-0.35	-0.3
PT Main Model Fare (trips)	-0.05	-0.11	-0.05
Car Journey Time (trips)	-0.55	-0.6	-0.54

The model gives elasticities within this range for the combined purposes, with the elasticities for trips on the A9/A96 corridor, which will typically be longer distance trips, having an elasticity stronger than -0.3 and the non A9/A96 trips having an elasticity just weaker than -0.3 (-0.295).

For car journey time, the guidelines state that the elasticity should be checked “to ensure that the model does not produce very high output elasticities (say stronger than - 2.0”. The modelled elasticities for car journey time are significantly weaker than -2.

WebTAG suggests that the Public Transport fare elasticities should lie between -0.2 and -0.9 for changes over a period longer than a year. The results observed are within this range.

8 Conclusions

SYSTRA and PDC's view is that the National Road Model TMfS14 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.

The Road Model also performs well on journey time validation, providing robust estimates of journey times for almost all journey time validation routes.

The Demand model structure has been defined and implemented for the Base Year. The realism tests undertaken have demonstrated a good overall level of sensitivity. The principal travel purpose of the model, commute trips, has elasticities which fall well within the recommended sensitivity guidelines. Investigation of the elasticities in more detail has shown more variation some of which can be explained by the model structure adopted for this model and it is suggested that this is revisited when the model is next being considered for recalibration.

This model has also been subject to an audit by the appointed LATIS auditor.

9 References

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3 Department for Transport, WebTAG: TAG data book, November, 2014, (https://www.gov.uk/government/publications/webtag-tag-data-book-november-2014)

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Appendix A

A.1 - A9/A96 PT Screenline Summary

Table A.1: North of Aberdeen (excludes Non ScotRail services) AM

Station/Road Name	ID	Mode	Dir	AM Observed Hour	AM Modelled Hour	Diff	% Diff	GEH
Dyce to Aberdeen	8011	Rail	S	335	210	-125	-37%	7.6
A96 Chapel Of Stoneywood Road	101	Bus	E	95	166	72	75%	6.3
Screenline Total				***430***	***376***	***-54***	***-13%***	***2.7***
Aberdeen to Dyce	8012	Rail	N	160	124	-35	-22%	3.0
A96 Chapel Of Stoneywood Road	102	Bus	W	72	63	-9	-13%	1.2
Screenline Total				***232***	***187***	***-45***	***-19%***	***3.1***

Table A.2: South of Inverness (excludes Non ScotRail services) AM

Station/Road Name	ID	Mode	Dir	AM Observed Hour	AM Modelled Hour	Diff	% Diff	GEH
Inverness to Carrbridge	6032	Rail	S	54	134	80	148%	8.3
A9 B9177 Raigmore Hospital				34	30	-4	-12%	0.7
B9006 Culloden Rd Tesco	203	Bus	S	19	39	20	103%	3.6
Screenline Total				***107***	***202***	***96***	***90%***	***7.7***
Carrbridge to Inverness	6031	Rail	N	74	82	8	11%	0.9
Inverness to Carrbridge				100	59	-42	-41%	4.7
B9006 Culloden Rd Tesco	204	Bus	W	33	69	35	106%	4.9
Screenline Total				***208***	***210***	***2***	***1%***	***0.1***

Table A.1: North of Perth (excludes Non ScotRail services) AM

Station/Road Name	ID	Mode	Dir	AM Observed Hour	AM Modelled Hour	Diff	% Diff	GEH
Dunkeld to Perth		Rail	S	62	162	101	163%	9.5
A912 Dunkeld Road		Bus	S	61	94	33	54%	3.8
Screenline Total				***122***	***256***	***134***	***109%***	***9.7***
Perth to Dunkeld		Rail	N	69	81	11	17%	1.3
A912 Dunkeld Road		Bus	N	13	35	22	163%	4.4
Screenline Total				***83***	***116***	***33***	***40%***	***3.3***

A.2 - A9/A96 Boarding and alighting comparison

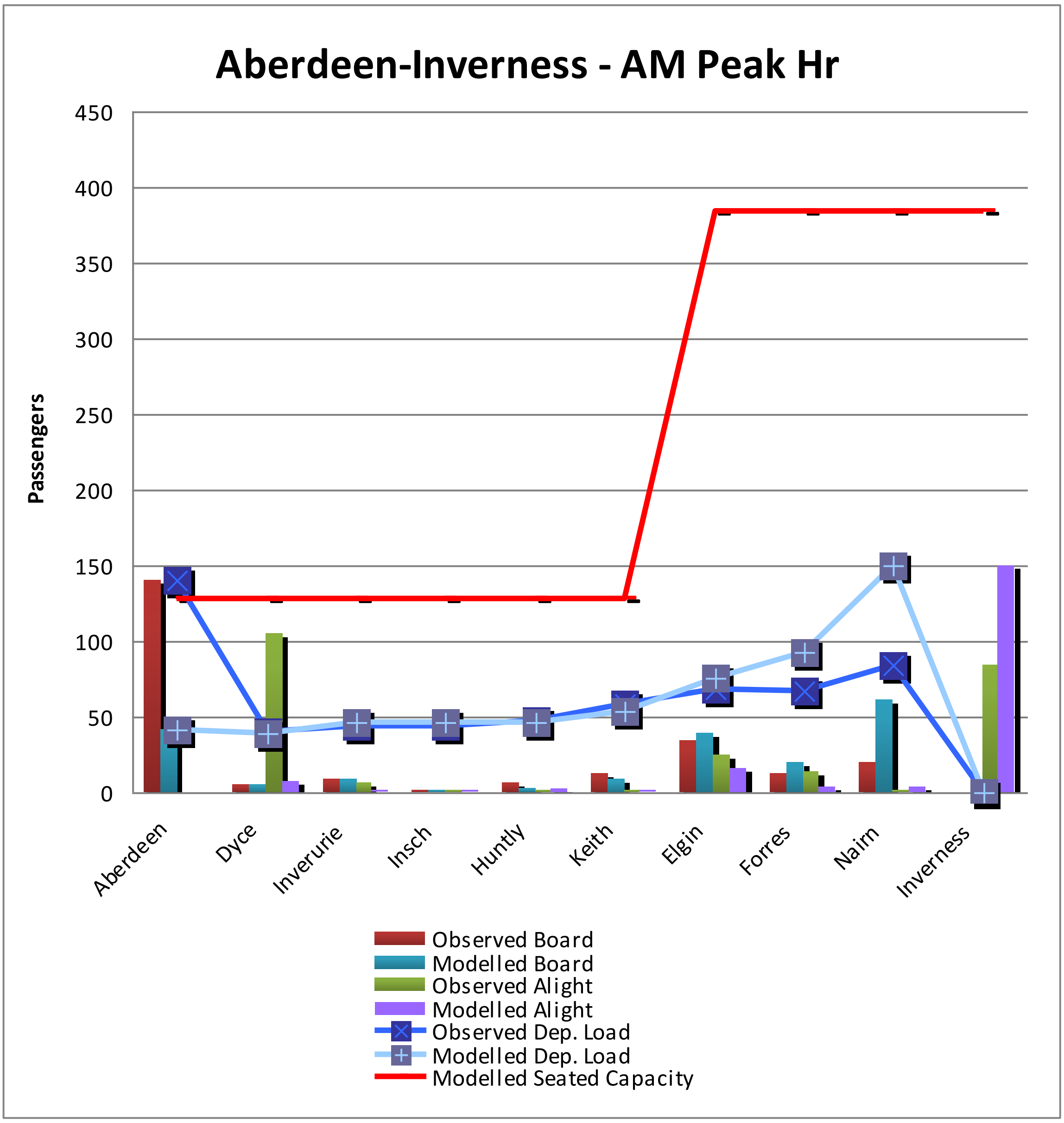

Figure A.1: Rail boarding and Alighting, Aberdeen to Inverness, AM

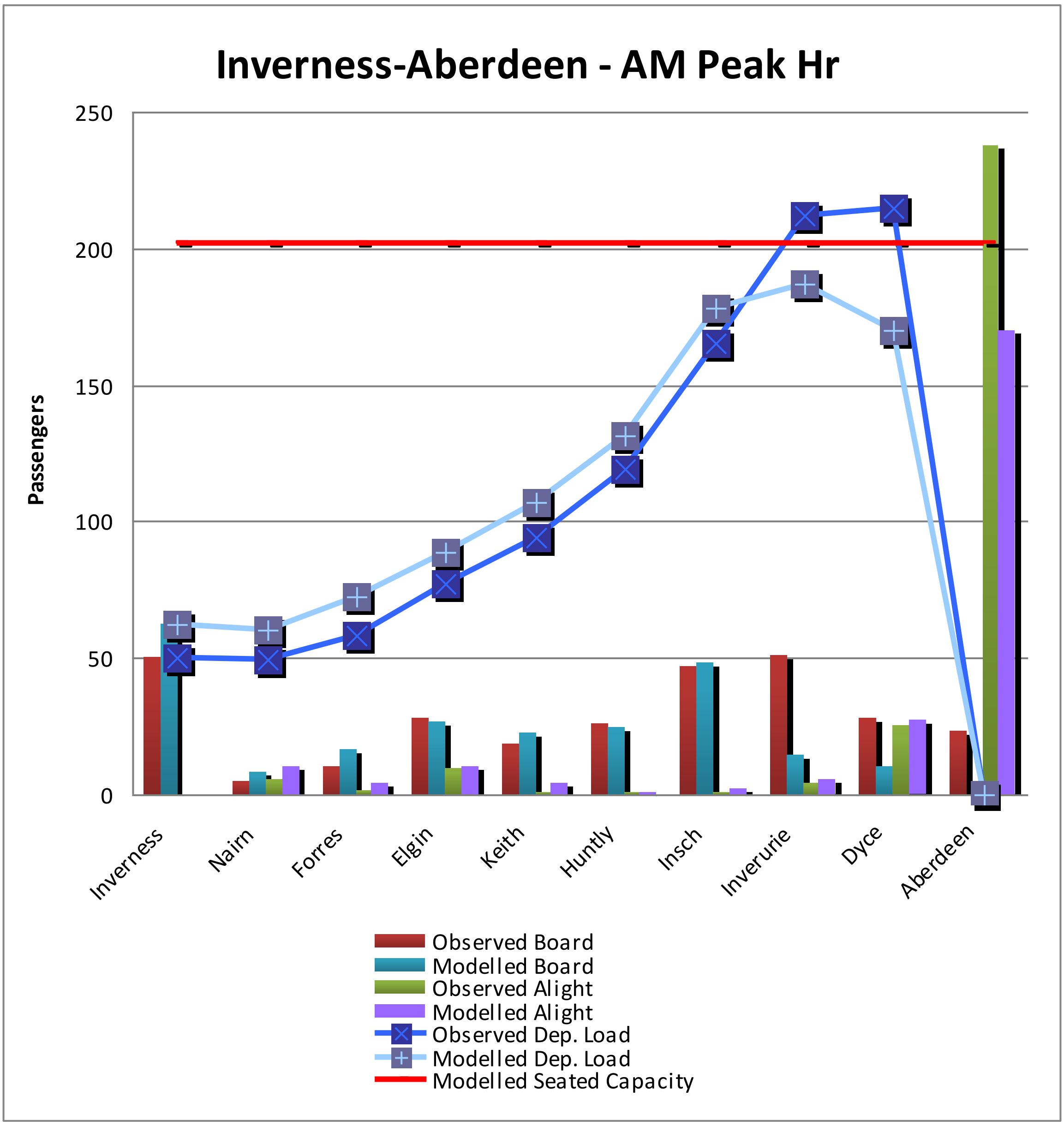

Figure A.1: Rail boarding and Alighting, Inverness to Aberdeen, AM