

Model Validation Report
Trans-Pennine South Regional Model

Document Control

Function	Report on the development of the base year model and its performance in replicating observed traffic conditions
Document Title	Model Validation Report
Author	AECOM / Atkins
Owner	
Document Status	

Revision History

Version	Date	Description	Author
1.0 – 1.3		Internal working drafts	AECOM / Atkins
1.4	13/03/17	First client draft	AECOM / Atkins
1.5 – 1.8		Internal working drafts	AECOM / Atkins
1.9	24/03/17	Final client draft	AECOM / Atkins

Reviewer List

Name	Role

Approvals

Name	Signature	Title	Date of Issue	Version

Schedule of Revisions

Revisions issued since publication

Report Issue Number	Revision Date	Paragraphs Amended
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1 Study Overview

1.1 Background to Regional Traffic Models

Highways England have determined that to progress the schemes identified in the Road Investment Strategy (RIS) within the first Road Period (2015-2020), a significant amount of modelling and appraisal work will be required. The 'Traffic Modelling Strategy' developed for Highways England by the Traffic Appraisal, Modelling and Economics (TAME) group identified the creation of five 'regional' models as critical to the future delivery of schemes.

Highways England has let five separate contracts using the Collaborative Delivery Framework (CDF) to consultancy teams to deliver these models. This document relates to the Trans Pennine South (TPS) Model.

1.1.1 Model Purpose and Objectives

The primary purpose of the regional model programme is to assess RIS highway schemes which are major schemes with a cost estimate greater than £10 million.

The scope for development of the regional models identified two potential levels of usage:

- Type A Usage - a scheme will be coded into the new regional model and the model will be capable of producing all the economic and environmental outputs; or
- Type B Usage – For some smaller schemes the model will be used to generate a cordon area to enable the required outputs to be generated.

It has also been noted that there are detailed models of many of the major towns and cities. Where there is strong interaction between the Strategic Road Network (SRN) and the local urban networks consideration should be given to applying the local model which will represent the local urban (highway and public transport) networks in detail.

1.2 Technical Consistency Groups

As part of the governance of the regional models programme, Highways England established the following technical consistency groups:

- Data Consistency;
- Mobile Phone Data / Matrix Development;
- Variable Demand Modelling;
- Network Coding;
- Calibration / Validation; and
- Forecasting.

These groups were tasked with ensuring that all elements of that work stream were undertaken in a consistent manner and to share best practice in order to maximise the value of the experience of the supply chain in delivering this programme.

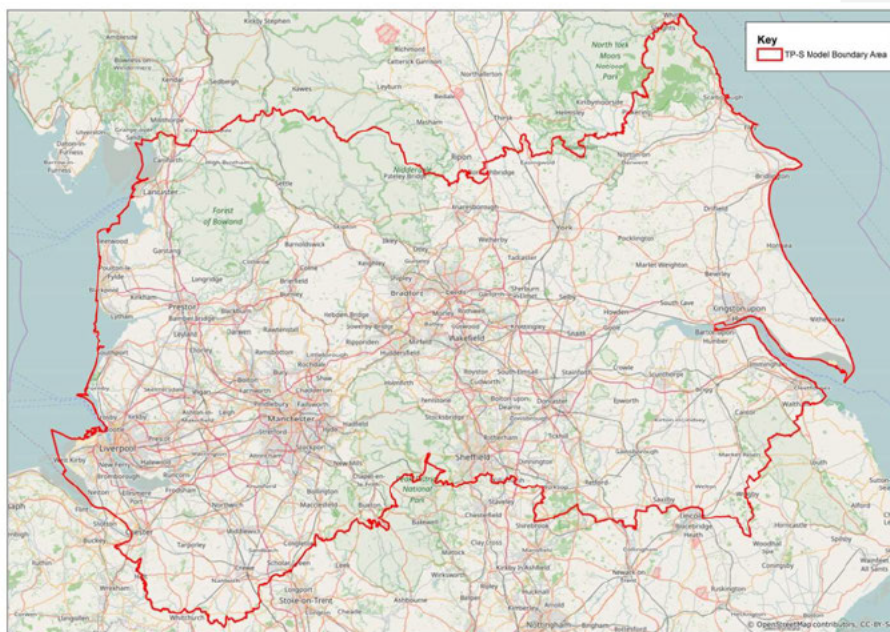
1.3 TransPennine South Regional Traffic Model Area

The Region of Focus (RoF) of the Trans Pennine South Regional Traffic Model is illustrated in Figure 1. The area covers approximately 7,300 square miles and includes 900¹ miles of Strategic Road Network (SRN) with almost 75% of that being motorway.

There are over 50 local authorities within the RoF. The area includes the major metropolitan areas of:

- Merseyside;
- Greater Manchester;
- Leeds; and
- Sheffield.

Figure 1 – Overview of TPS Model Area



1.4 Proposed Schemes

The model will be applied to test policy, programme and major scheme interventions on the SRN represented within its region of focus.

¹ This is a link based figure i.e. total carriageway length would be twice this value.

1.5 Purpose and Structure of Report

The Model Validation Report (MVR) describes how the TPS Model has been built, calibrated and validated. Following this overview, the remainder of the report is structured according to these chapters:

- Chapter 2 – Model Description and Specification;
- Chapter 3 – Model Standards / Objectives;
- Chapter 4 – Summary of Data Collection;
- Chapter 5 – Highway Model Development – Networks;
- Chapter 6 – Highway Model Development – Matrices;
- Chapter 7 – Highway Model Development – Assignment Process;
- Chapter 8 – Highway Model Calibration;
- Chapter 9 – Highway Model Validation;
- Chapter 10 – Variable Demand Model; and
- Chapter 11 – Conclusion and Summary.

A glossary of terms is provided at the end of the main document followed by a series of Appendices which referenced within the main text.

The main data reporting for the RTMs is covered by a 'Dashboard' file that was developed specifically for the RTM programme. This includes all tabulations of model performance and is available as a separate Excel file.

The structure of this document has been agreed with the Regional Traffic Model (RTM) Technical Consistency Group (TCG). Due to the nature of the model, this structure is slightly different to that specified in the standard Highways England Local Model Validation Report (LMVR) Project Control Framework (PCF) Product Description. In order to assist those familiar with that structure, and to ensure consistency of reporting, a checklist is provided at the end of this Chapter ([Table 2](#)) identifying where the various elements of the PCF LMVR can be found.

1.6 Model Versions and Design Freeze Terminology

During the lifetime of the RTM development programme, there has been a requirement to release early versions of the models to allow other Highways England projects to proceed. The terminology adopted to describe these releases is Design Freeze (DF).

The following table summarises which versions have been released.

Table 1 – Model Versions (DFs)

DF	Release Date	Notes
1	02/09/16	First version of base year model outputs.
2	11/11/16	Developed during a six week period where all RTMs undertook further highway calibration to improve the models; TPS changes mainly related to journey time performance.
2a	10/01/17	Correcting an issue with fixed speed coding only.
3a	31/03/17	Changes to external zone centroid coding – no material impact on base year model but relevant for forecasting.

The outputs presented in this document are associated with DF2a and all relevant model files are identified as such. The DF3 files were completed after this document was prepared but show no material difference in terms of model performance to that reported here. Dashboard (spreadsheet) reports of model outputs for DF3 and DF2a have been produced.

1.7 Related Documentation

The MVR is one of four documents produced to report on the development of the TPS RTM. The other three are:

- Model Specification Report (MSR);
- Traffic Data Collection Report (TDCR); and
- Model Forecasting Report (MFR).

Another important document in the context of the model development is the coding manual which was developed by the Network TCG. This document is common to all five RTMs and provides the agreed principles for coding the highway model network. The relevant document is the 'Regional Traffic Models Network Coding Manual', Version 0.7, dated 03 November 2015.

Table 2 – Checklist Against PCF LMVR Requirements

PCF LMVR Reference	Location in this document
1.0 Study Review	
a. Statement of the scheme objectives	Sections 1.1.1 and 1.4
b. Explanation of the purpose of the and the schemes likely to be assessed using the model	
2.0 Model Description / Specification	
a. Description of the demand modelling system.	Section 2.1.1
b. Explanation of how the highway model relates to other components of the demand model	
c. Description of any land use transport interaction models used	None
d. Description and justification of type of highway model used.	Section 2.1.1
e. Description and justification of type of public transport model used	Section 2.1.1
f. Description of how parking, park-and-ride and slow modes are modelled	Section 10.2.5
g. Description, plan and justification of geographical model coverage	Section 1.3
h. Statement of software package and version used	Section 2.1.1, 2.5
3.0 Summary of Data Collection	
a. Outline description of data sources and units - surveys, existing models, national databases	Section 2.4
b. References to the Traffic Data Collection Report	Section 4.1
c. Identification of calibration data	Section 4.6
d. Identification of validation data	Section 4.7
e. Comparison of comparable data from different sources	Section 4.8
4.0 Highway Model – Model Development	
Network	
a. Description of network structure, providing information on the extent of the 'Detailed Study Area' and 'Feeder' network, including a plan/map	Section 2.1 - 2.3, 5.1
b. Description of coding process used to determine link length and node locations	Section 5.2
c. Evidence for assessment of speed limits / road types for use in determining network speeds	Section 5.3.1
d. Location, value and justification of fixed speeds and/or speed-flow curves used on links	Section 5.3.2
e. Description of calculation and assumptions behind junction saturation capacities	Section 5.4.1
f. Description of any network inventory undertaken	Section 5.2.2
g. Description of any junction operation data collected such as signal times and estimates of gaps at roundabouts and priorities	Section 5.4.2
h. Description of modelling assumptions such as values used for queue length per PCU, conversion factors between PCUs and vehicles	Section 7.6
i. Description of modelling of PT services and bus priority measures included in the highway network	Section 5.5

PCF LMVR Reference		Location in this document
j	Description of treatment of Freight Transport	Section 5.6
k	Description of network assumptions relating to representation of Tolls, High Occupancy Vehicles Lanes, Active Traffic Management and Variable Speed Limits	Section 5.7
Matrices		
a	a. Description of zone structure	Section 6.2.4
b	Specification and justification of any demand segmentation within the traffic model	Section 6.2.1
c	Description of data sources including previous study matrices, new RSI data, synthetic matrices	Section 4.3
d	Description of matrix building process including process of adjusting for unobserved directions and unobserved periods, reference to dealing with double counting and substitution of old data with new/more reliable data	Section 6.3
e	Description of any matrix infilling process including the use of synthetic trip matrices / gravity models	Section 6.4- 6.9
f	Description of the matrix estimation process	Section 8.3
g	Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 6.10
Assignment Process		
a	Description of approach used	Section 7.1
b	Description of time slices used and the interaction between time-slices	Section 7.2
c	Definition of assignment costs calculation with reference to generalised cost, VOT and VOC including sensitivity test results and the treatment of different vehicle types and trip purposes	Section 7.4
d	Assignment convergence criteria used	Section 7.5
e	Summary of assignment parameters used by the software	Section 7.6
5.0 Highway Model – Model Calibration		
Network		
a	Evidence of checks of network structure to include: - Graphical review of network structure to identify missing links - Checks of modelled link lengths vs. crow-fly distance - Check model links are two-way where appropriate and one-way links are accurately represented, including slip roads - Check HGV access restriction are represented	Section 8.1
Assignment Process		
a	Evidence of checking that link speeds on the network are realistic	Section 8.2.1
b	Evidence of checks to ensure delay calculations at junctions are operating realistically	Section 8.2.2
Matrices		
a	Identification of counts used in the process	Section 4.6

PCF LMVR Reference		Location in this document
b	Matrix estimation monitoring by comparison of before and after: - link flows against counts - matrix zonal cell values - matrix zonal trip ends - trip length distributions - sector matrices	Section 8.3 and 9.3
c	Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 9.3.109 3.9
6.0 Highway Model – Model Validation		
Network		
a	Analysis of paths	Section 8.1
b	Justification and description of speed-flow curves used for over-capacity formulation	Section 5.2 and 5.3
c	Description of junction coding approach where appropriate	Section 5.4
d	Description of the coding of other network characteristics	Section 5.2 and 5.7
e	Examination and justification of paths used on preliminary assignments	Section 8.1
f	Evidence of ad-hoc network validation checks	Section 8.1
Matrices		
a	Zone plan	Section 9.2.1
b	Distinction between observed and synthesised movements	Section 9.2.2
c	Comparison of modelled zonal demand for key movements against independent data if available	Section 9.2.3
d	Comparison of modelled sector-to-sector demand with any independent screenline counts	Section 9.2.4
e	Plans of zones, sectors and screenlines used in the above comparisons	Section 9.2.5
f	Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 9.2.6
Assignment		
a	List of, and justification for, deviations from any default parameters used in the assignment software	Section 9.3.1
b	Statement / explanation regarding independence of validation data	Section 9.3.39 3.2
c	For each time period and vehicle type as well as totals for (c), (d), (e) and (f): Tabular comparison of modelled flows with observed site and screenline counts	Section 9.3.49 3.3
d	Map-based comparison of modelled flows with observed site and screenline counts	Section 9.3.59 3.4
e	Tabular comparison of modelled and observed journey times	Section 9.3.69 3.5
f	Diagrammatic comparison of modelled and observed journey times	Section 9.3.79 3.6

PCF LMVR Reference	Location in this document
g Statement of convergence stability	Section 9.3.8 9.3.7
h Statement of convergence proximity	
i Discussion of model validation in the context of the wider demand modelling system	Section 9.3.10 9.3.9
j Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 9.3.10 9.3.9
7.0 Variable Demand Model	
Model Development	
a Basis of whether to include variable demand in the model	Section 10.2.1
b Description of variable demand model including incremental or absolute	Section 10.2.2
c Responses included in model including hierarchy of responses	
d Model area and zone size	Section 10.2.3
e Segmentation: Trip and person types	Section 10.2.4
f Forms of Trip Matrices: • Production/Attraction or Origin/Destination • Vehicle Occupancy	
g Representation of public transport supply and demand	Section 10.2.5
h Software used	Section 10.6
Calibration	
a Calibration of variable demand model	Section 10.7
b Choice of model parameters and comparison against published values	Section 10.7.2
c Description of any cost damping mechanisms used	Section 10.8
d Description of model convergence	Section 10.9
e Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 10.10
Validation	
a Realism testing to establish robustness of base model in relation to its use as the 'reference pivot' for subsequent variable demand modelling	Section 10.11.1
b Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 10.12
8.0 Conclusion	
a Conclusion on the robustness of the model to be used for forecasting	Section 11.12
b Discussion of where the model is less robust with statement on how this impacts on the model's performance	Section 11.12
c Discussion of where the model's representation of traffic and travel could be further improved in the future	Section 11.12

2 Model Description and Specification

2.1 Description of the Modelling System

2.1.1 Overview

The original brief for the RTM model programme included a document ('Regional Traffic Modelling Vol 3 Scope', Version 1.0.2 dated 24th April 2015) which set out the high level requirements for the development of the RTMs. The document required that a common model platform would be used for all five regional models and this should be agreed with Consultants following award of the study. It then set out a number of requirements for that platform.

At a very early stage in the project, discussions were therefore held between the five consultancy teams and representatives from TAME to agree the software platform and the general structure of the modelling system.

The key points of agreement were:

- SATURN would be used as the highway assignment tool;
- DIADEM would be used to provide the variable demand responses; and
- Public transport was only to be considered for rail and, for input to the variable demand process, would come from PLANET if available.

PLANET North was available to the TPS team and was therefore used for the provision of the public transport demand.

Furthermore it was agreed that the scope of the model development would be refined by the Technical Consultancy Groups (TCGs) as the programme progressed. All key decisions on the structure or specification of the modelling system have therefore been approved by the appropriate TCG prior to adoption by the RTM modelling teams.

A summary of the key aspects of the agreed modelling system are provided in [Table 3](#).

The demand model operates at the 24 hour level and allows for time period choice between the four periods identified, mode choice between highway and rail for person (non-freight) trips and distribution for person (non-freight) trips.

The assignment model operates for three peak periods.

Table 3 – Model System Overview

	Time Periods	Modes	Vehicle Types	Trip Purposes
Demand Model	AM 07:00 to 10:00	Highway vs Rail	Car	Commuting HBEB ⁽¹⁾ NHBEB ⁽²⁾ HBO ⁽³⁾ NHBO ⁽⁴⁾
	IP 10:00 to 16:00			
	PM 16:00 to 19:00	Highway	LGV HGV	LGV HGV
	OP 19:00 to 07:00			
Assignment Model	Average hour for: AM 07:00 to 10:00	Highway Only	Car	Employers Business
	IP 10:00 to 16:00		LGV	Commuting Other
	PM 16:00 to 19:00		HGV	LGV
				HGV

Notes: (1) Home Based Employers Business
(2) Non Home Based Employers Business
(3) Home Based Other
(4) Non Home Based Other

2.2 Geographical Model Coverage

The geographic scope of the model, as shown earlier in Figure 1, was defined as part of the programme brief. Between them, the five models cover the entirety of the highway network in England.

The TPS model borders the Midlands and Northern RTMs and covers the breadth of the country from East to West within that area. The following counties are contained within this model:

- Cheshire;
- Derbyshire;
- East Riding of Yorkshire;
- Greater Manchester;
- Lancashire;
- Leicestershire;
- Lincolnshire;
- Merseyside;
- North Yorkshire;
- Nottinghamshire;
- South Yorkshire;
- Staffordshire; and
- West Yorkshire.

2.3 Key Features of the Model

Each of the RTMs are considerably bigger than a typical scheme model; they are also required to provide a consistent level of detail across the area of interest rather than focusing on a particular scheme corridor. Whilst the network coverage is extensive, the objective of the programme was to help forecast the

effects of infrastructure and demand changes on the SRN and the level of network detail is thus focused on the SRN.

In accordance with guidelines agreed by the Network Coding TCG, the network was considered in terms of four levels:

- Level 1 – Strategic Road Network (SRN);
 - Roads connected to / parallel with SRN;
 - Roads considered important to RIS scheme appraisal;
- Level 2 – Rural roads that are not connected to SRN;
- Level 3 – Urban areas outside the influence area of RIS and SRN; and
- Level 4 – Roads outside the region of focus.

The coding standard to be applied to each of the four levels was then set out as follows:

- Level 1 – Detailed simulation coding;
- Level 2 – Simulation coding but less detail;
- Level 3 – Dummy nodes / fixed link speeds; and
- Level 4 – Buffer network.

The zonal definition reflects the need to provide a consistent coverage over a wide area whilst recognising that the number of zones will have a direct impact on the run time of the model and therefore its suitability as a practical tool. It was determined at an early stage that a sensible limit would be of the order of 2,000 zones and furthermore, in accordance with standard modelling practice, zonal boundaries should be coincident with official administrative boundaries wherever possible.

In a similar fashion to the network development process, six levels were defined:

- Within 200m of SRN junctions, use LSOA² definition as zone boundary;
- Between 200 and 500m of SRN junctions, use MSOA³ as the boundary;
- For the remainder of the non-urban area of focus (AoF) of the model, use aggregations of MSOA;
- For urban areas where capacity restraint not included in the network structure, utilise NTEM⁴ urban centre definitions to help aggregate;
- Beyond the AoF, an 'adjacent area' of further aggregation was devised, based on a district level grouping of LSOAs; and finally
- For the remaining areas, use groups of districts.

2.4 Overview of Data Used

The key sources of data used in developing the model were:

- Demand Data
 - Mobile Phone (all trips);
 - TrafficMaster (Light Goods Vehicles);
 - GB Freight Model (Heavy Goods Vehicles);
- Traffic Count Data

² LSOA = Lower Super Output Area (Census)

³ MSOA = Middle S Super Output Area (Census)

⁴ NTEM = National Trip End Model

- Bespoke automatic traffic count (ATC);
- Local Authority ATC;
- HATRIS (TRADS) Sites
- Journey Time Data
 - TrafficMaster
- Network Data
 - Integrated Transport Network (ITN);
 - Local Authority and Highways England traffic signal data
 - Existing traffic models

2.5 Software Packages Used

The main software package was SATURN which was used for all the assignments. DIADEM was used for variable demand and a bespoke management interface, HEIDI, was developed by the RTM programme to help support the handling of the considerable number of files involved in the process.

3 Model Standards / Objectives

3.1 Introduction

This chapter summarises the standards adopted for the development of the TPS RTM. The Regional Models required best practice to be adopted across all the model elements in a consistent fashion. To facilitate this process, the data standards associated with the project were discussed and confirmed with the Technical Consistency Groups. Separate guidance was produced by each of the TCGs and these are summarised in this section.

3.2 Count Data Verification Standards

The development of the TPS RTM required the use of a substantial dataset for network and matrix production, as well as traffic counts and journey time data for model calibration and validation. The Data Consistency group examined the standards associated with the processing of data. Guidance was produced which outlines the approaches to the processing and storing of data such that it could be shared between the RTM teams. The guidance considers the suitability of different data sources and outlines the approaches used to process traffic data and the vehicle classifications required for the model.

3.2.1 Volumetric Data Processing

Weekends and bank holidays were removed from the data set so that the remaining data is representative of weekdays only (Monday-Friday). In accordance with the RTM guidance weeks that included bank holidays were excluded for the analysis.

Data were checked for consistency by removing outliers that arise from unusual events (WebTAG unit M1.2, 3.3.37). This was done by checking AM peak period, IP period and PM peak period volumes within a 2* standard deviation tolerance interval of the observed days. Days where volumes fall outside the 2 STD Dev tolerance interval were flagged so that they could be removed for the model calibration/ validation.

Having derived the flows for the period of the observations, a series of factors were derived for day, month and year factors to enable data to be converted to represent March 2015. Day factors were only needed for the limited occasions where one day MCC values were being used for volumetric data. Data were converted to an average weekday. Month factors were needed to convert annual average weekday traffic (AAWT) in the period collected to represent March. Year factors were needed to convert to 2015. It should be noted that in most cases, the pre-2012 data were not used. The factors derived are summarised in the TDCR.

3.2.2 Vehicle Classification Data Processing

The proportion of various vehicle classes was calculated for each model time period and for the entire day for sites where manual classified count (MCC) data

or classified ATC data were available. In accordance with guidance set out by the Data Consistency group, a hierarchical approach was adopted to vehicle classifications (see Table 3).

The approach was to adopt the most robust source of local data where possible. However, where local data were not available then use of regional or national vehicle splits was undertaken.

3.3 Matrix Verification Standards

The OD trip matrices used for the RTMs represent highway demand and are primarily sourced from mobile phone data, provided by Telefonica (O2) UK. Given the timing of the release of the data in relation to other Highways England projects, the data used for the RTMs were referred to as the 'Provisional data'.

The Matrix TCG developed a guidance document that sets out the key considerations for the RTM matrix development. This is partly built on lessons learnt regarding the use and application of mobile phone data for the purpose of OD Matrix Development. This is a new technology and there is no existing guideline at this stage on how to use mobile phone data to produce OD matrices. In fact there is little guidance in WebTAG on matrix building and the merging of different data sources in doing so.

The guidance provides some alternatives for processing the data and introduces an approach to develop demand highway matrices. The approach therefore was to use existing data sources to test and seek to establish at which resolution level (both spatially and demand segments) the mobile phone data set should be used and then from there to make use of other data sets to refine and disaggregate from this point.

A set of verification standards was developed to ensure consistency between the RTMs. In particular, the following key aspects of the provisional mobile phone data were reviewed and verified through comparisons with independent data sources related to (see [Table 5Table-5](#)):

- mode split;
- trip-ends;
- symmetry of the matrix;
- trip rates;
- trip distribution pattern;
- trip length profile;
- trip purpose allocation;
- daily profile of trips; and
- and level of vehicle flows

3.4 Calibration and Validation Criteria

The performance of any transport model is judged against a series of performance criteria. WebTAG unit M3.1 outlines a number of checks that should be undertaken in the calibration and validation stages of model development. The WebTAG unit recommends that performance is assessed against a series of criteria including:

- flows across cordons;
- flows on individual links;

- journey times;
- convergence; and
- impact of matrix estimation.

The Calibration / Validation (Cal/Val) TCG produced guidance on the RTM process which is outlined in Chapter 7. The TCG also discussed the acceptability criteria for screenline, flow and journey time acceptability. The aim was to ensure that the standards applied in the model were fit for its main purpose which was to provide detailed forecasts for the SRN. The reasoning behind the criteria followed an examination of the types of measure being assessed with the distribution of errors. These sources of error derive from errors in the count data that the model flow is tested against and the error in the model. Links are defined as core and non-core which is further explained in the next chapter.

The acceptability criteria established by the CalVal TCG guidance are shown in [Table 6](#)~~Table 6~~. These relate to screenline, flow and journey time performance. In addition, the TCG provided guidance on the use of matrix estimation to improve the performance of the model. This confirmed the tests that should be undertaken in line with WebTAG guidance relative to trip length distributions, mean trip length and sector changes.

Table 4 – Data Consistency TCG Guidance on the Derivation of Vehicle Splits

Vehicle Class	Data Source				
	TRADS Data	DfT ⁵ Count Data Source https://data.gov.uk/dataset/qb-road-traffic-counts	ATC (No vehicle Splits)	MCC with COBA Classification Splits	MCC – Non standard classifications (where there is uncertainty over vehicle types)
HGV ⁶ s	>6.6m length	Total HGV Classification (note there are individual HGV columns and a total HGV column)	Use Local splits (by road type etc.) obtained from MCC or DfT data. If no data available use the national default data by road type (see below)	Use Classification Splits	If unable to split to car/LGV/HGV then combine as total flow and use Local Classification data to split out
Cars and LGV ⁷ combined	<6.6m lengths	NA			
Cars	Use Local MCC splits (e.g. DfT Data) to split between cars and LGV's	Car Classification			
LGV		LGV Classification			
	If local classification data is not available/suitable use the DfT national splits by Road Type: (Table TSGB0706 (TRA0204)) https://www.gov.uk/government/statistical-data-sets/tsqb07				

⁵ DfT = Department for Transport

⁶ HGV = Heavy Goods Vehicle

⁷ LGV = Light Goods Vehicle

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Table 5 – Description of Provisional data Verification Tests and the Indicative Criteria

Test ID	Demand Indicator	Data Check / Comparison	Analysis Approach	Geographic al Level	Indicative Criteria	Purpose of Test / Problems to Identify	See Note	
A	Mode Split (Road vs. Rail)	All day HBW from-home origins and destinations vs. Census JTW 'home' and 'work' locations, for selected corridors with significant rail mode share.	Regression analysis / scatter plots	MSOA	No criteria, comparison of R ² values, look for outliers	Verify removal of rail trips	1	
	Trip-ends	All day HBW from-home origins and to home destinations vs. Census JTW 'home' locations	Regression analysis / scatter plots	Model Zones / LA Districts	R ² ≥ 0.90, slope close to unity and small intercept	Verify usability of the data Spatial accuracy of trip allocation to zones Inform requirements for defining mobile data sectors as aggregations of model zones.	2	
		All day HBW from-home destinations and to-home origins vs. Census JTW 'work' locations						
		All day trip origins and destinations vs. customised NTEM trip-ends, separately for HBW, HBO, and NHB.	Regression analysis / scatter plots	Model Zones				
	Symmetry	From-home vs. to-home (all day, all purposes)	Regression analysis / scatter plots	Model Zones	R ² ≥ 0.95, slope close to unity and small intercept			
		From-home vs. to-home (all day, HBW)						
		All origins vs. all destinations (all day, all purposes)						
		Undertake the symmetry test at sector level			No criteria			
B	Trip Rates	From-home trip rates vs. NTS (county level)	Compare mean values	County	Review against 95% CI of NTS data	Verify overall expansion of data	3, 10	
		Internal distribution of from-home trip rates (calculated at mobile sector level)	Identify main outliers	Model zones or defined Mobile Data Sectors	No criteria	Identify any localised expansion issue, identify outliers	4	
C	Trip Distribution	HBW from-home (all day) vs. census JTW (district level)	Regression analysis / scatter plots	LA Districts	R ² ≥ 0.95, slope close to unity and small intercept	Verify trip pattern	5, 10	

Test ID	Demand Indicator	Data Check / Comparison	Analysis Approach	Geographic Level	Indicative Criteria	Purpose of Test / Problems to Identify	See Note
		Inter-sector trip totals vs. expanded RSI trips (region specific, dependent on data availability) ; RSI sectors large enough to estimate trips with reasonable confidence for fully observed movements	Compare mean values, regression analysis / scatter plots	Defined Aggregate RSI sectors	Review against 95% CI of RSI data	Verify expansion Verify trip pattern	6, 10
D	Trip Length Profile	HBW all day from-home vs. JTW data	Compare distributions and mean values	Defined Mobile Data Sectors	Review against 95% CI of observed data, CR ≥ 0.70	Verify trip length distribution	7, 10
		All day (all purposes, HBW, HBO) vs. NTS data		Defined Mobile Data Sectors			
		HBW/HBO/NHB vs. RSI data (region specific, dependent on data availability – for the same fully observed movements)					
E	Trip Purpose	HBW/HBO/NHB split vs. NTS	Compare proportions, aggregate region and county level	County	No criteria, comparison only, look for material differences	Verify purpose split Investigate inclusion of HBE in HBW matrices	-
F	Daily profile check	Daily profile of trips at an hourly level (05:00 – 20:00, all purposes, from-home) vs. NTS	Compare profiles visually	-	No criteria, comparison only	Verify daily profile	8
G	Vehicle flows	Assigned flows vs. counts across long screenlines (all day level) at 12hr / 24hr level	Compare traffic volume	-	Differences $\leq \pm 20\%$ of observed flows at individual screenlines and $\pm 5\%$ of observed flows across all screenlines	Verify flow pattern and expansion	9

1. The comparison should be undertaken between Provisional data trip-ends and JTW trip-ends (with and without rail trips). If the comparison with JTW without rail trips shows outliers that do not exist when comparison is made with JTW with rail trips, it suggests that some rail trips still exist in the matrices. Comparison of trip ends may best be based on those identified as homes; however, the same conclusion could be made if the correlation of from home destinations between Provisional data and JTW with rail trips is better than JTW without rail trips, for selected 'work' locations in urban areas where a high proportion of rail trips are expected.

2. This analysis should be undertaken for internal zones with an origin (when comparing origins) or destination (when comparing destinations) within RoF only. In the first instance, the analysis should be undertaken at local authority district level, where the criterion is expected to be met, in order to confirm that the data is suitable when aggregated to a certain degree. If the criterion is not met at district level, usability of data should be reviewed. If the criterion is met, the trip-ends should then be compared with JTW and NTEM trip-ends at model zones level. If the criterion is not met for this, model zones should then be conflated to define mobile sectors until the criterion is met (see Figure 3-1).
3. This comparison should be done at county level within RoF. NTS sample size should be used to calculate 95% confidence interval of estimated mean values. In calculating NTS trip rates, similar modes should be used (i.e. car, van, and bus).
4. Trip rates should be calculated at the sector level defined as the outcome of test A, within RoF (at model zone level if test A criteria is met).
5. Initially, this test should be undertaken at district level and for trips started within RoF. Consistent modes from JTW should be used. Intra district trips should be excluded from the comparison initially given under-identification of short trips.
6. This comparison should be undertaken at an aggregate sector level to minimise sampling error in the RSI data. Ideally, the comparison should only be made on RSI observed direction if all interview directions are consistent across cordons / screenlines. The comparison should be made for all trips across all time period, as well as by trip purpose and time period. Allowances might be required to account for differences in vehicle types between the two datasets and any 'holes' in cordon / screenlines.
7. This test should be done for all trips started within the RoF. For NTS, distances greater than about 2 km are recommended to be used for consistency. Coincidence Ratio (CR) of the distribution curves, calculated using the following formula, should be used to assess the correlation between observed and modelled trip length distributions.

$$CR = \frac{\sum_T [\min(PM_T, PO_T)]}{\sum_T [\max(PM_T, PO_T)]}$$

where:

CR is Coincidence Ratio

PM_T is proportion of modelled distribution in interval T

PO_T is proportion of observed distribution in interval T

T is histogram interval of distance

8. This test should compare distribution of trips by start hour with that from NTS at regional level.
9. This comparison should be done at all day level. The screenlines should be long to minimise any routeing / network effect. An average occupancy factor should be assumed to convert people to vehicles. An early version of network would be sufficient for this purpose. It is recommended that screenlines are defined away from town centres to minimise the inconsistency due to the inclusion of buses in the Provisional data.
10. The following can be used to calculate 95% confidence intervals of various estimates:

- Sample mean (to be used for trip rates):

$$x \pm 1.96 \frac{\sigma}{\sqrt{n}}$$

where x is the mean, σ is standard deviation of the sample, and n is the sample size.

- Sample proportion (to be used for trip length distributions):

$$p \pm 1.96 \sqrt{\frac{p(1-p)}{n}}$$

where p is the sample proportion and n is the sample size.

To calculate 95% confidence intervals of the expanded RSI trips, guidelines from ERICA manual and DMRB Volume 12 (the TAM Manual) should be used.

Table 6 – Acceptability Criteria- Regional Model Calibration and Validation

Element	Criteria	Time Period	Vehicle type
Screenlines			
Boundary- Cross boundary between Models	within 5%	All three time periods	All vehicle class separately
Screenlines	within 10%	All three time periods	All vehicle class separately

Element	Criteria	Time Period	Vehicle type
Mini Screenlines- Core routes	To be treated as Ad hoc sites within the dashboard (if individual links then use WebTAG flow criteria)	All three time periods	All vehicle class separately
Mini screenlines – non Core	within 10%	All three time periods	All vehicle class separately
Individual Links			
Core Roads with flows >2700	adopt WebTAG criteria (+/-400)	All three time periods	Car and Total Flow
Core Roads between 2700 and 700	adopt WebTAG criteria (+/-15%)	All three time periods	Car and Total Flow
Core Roads less than 700	adopt WebTAG criteria (+/-100)	All three time periods	Car and Total Flow
Core Roads	use GEH of <5	All three time periods	Car and Total Flow
Non Core Roads with flows >2700-	adopt WebTAG criteria (+/-400)	All three time periods	Car and Total Flow
Non Core Roads between 2700 - 2000	Within +/-15%	All three time periods	Car and Total Flow
Non Core Roads less than 2000-	Within +/-300 vehicles	All three time periods	Car and Total Flow

Element	Criteria	Time Period	Vehicle type
Non Core Roads	Report sliding proportion of GEH values.	All three time periods	Car and Total Flow
Journey Times			
Journey Times Segments	WebTAG criteria within 15% or 1 minute	All three time periods	Total Flow

3.5 Assignment Convergence Criteria Used

The current base year model convergence criteria for use in Highway Assignment models are provided in WebTAG Unit M3.1 as shown in the following table.

Table 7 – Acceptability Criteria - Summary of Convergence Measures

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 flow change <1%	Four consecutive iterations greater than 98%
Percentage of Links with cost change <1%	Four consecutive iterations greater than 98%
Percentage change in total user costs	Four consecutive iterations less than 0.1% (SUE ⁸ only)

3.6 Demand Model Realism Testing and Convergence Criteria

Demand model performance criteria are as set out in WebTAG M2:

- Fuel cost elasticity between -0.25 and -0.35 (WebTAG M2 para 6.4.14)
- Public transport fare elasticity between -0.2 and -0.9 (WebTAG M2 para 6.4.21); and
- Convergence gap of less than -0.1% (WebTAG M2 para 6.3.8).

Reflecting the wide area of the model and the national representation of demand a refinement commissioned to DIADEM as part of the RTM programme included the calculation of a convergence metric for a defined sub-area. For trips with an internal origin an additional convergence metric (a gap of 0.2%) was also adopted to avoid misstatement of convergence from the dominance of relatively stable external demand.

⁸ Stochastic user equilibrium
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4 Summary of Data Collection

4.1 Introduction

The Model Data Collection Report (MDCR) sets out the data requirements for the TPS Model and details how these data are applied.

The MDCR:

- Sets out the need for data, taking into consideration the purpose of the model and its specification for use as Type A or Type B:
 - Type A Usage – a scheme will be coded into the new regional model, and the model will be capable of producing all the economic and environmental outputs; or
 - Type B Usage – for some smaller schemes, the model will be used to generate a cordon area to enable the required outputs to be generated;
- Collates, summarises and reviews available existing data;
- Identifies the need for additional survey data and its contribution to the modelling process;
- Describes the new surveys, data cleaning, expansion and checking procedures; and
- Summarises the outputs from the data collection exercise and surveys.

Table 8 below summarises the data covered in the MDCR.

Table 8 – Summary of All Data Covered in the MDCR

	Data	Source	Purpose
Traffic Count Data	Automatic Traffic Counts	Local Authorities	Flow Calibration/Validation
	Manual Classified Counts	Local Authorities	Flow Calibration/Validation
	TRADS	Highways England	Flow Calibration/Validation
	DfT Traffic Counts	Department for Transport	Vehicle Classifications and Splits
Journey Time Data	Trafficmaster Vehicle Journey Times	Department for Transport	Time Calibration/Validation
Network Data	ITN (Integrated Transport Network)	Department for Transport	Network Coding
	Trafficmaster Vehicle Journey Speeds	Department for Transport	Network Coding for Fixed Speeds in Urban Areas
	Traffic Signal Data	Highways England and Local Authorities	Network Coding
	Existing Traffic Models	Local Authorities	Network Coding where Primary Traffic Signal Data not Supplied
Highway Demand Data	Mobile Phone Data	Jacobs/Telefonica	Matrix Development
	Trafficmaster Origin/Destination Data	Department for Transport	Matrix Development for Light Goods Vehicles
	NTS (National Travel Survey) Data	Department for Transport	Checking/Verification of Mobile Phone Data
	Great Britain Freight Matrices	Department for Transport	Matrix Development for Heavy Goods Vehicles

	Data	Source	Purpose
	Independent Data Sources: 2011 Census (Population) 2011 Census (Journey to Work) - NTS (National Travel Survey) - Roadside Interview Survey Data (existing) - Traffic Counts (existing)	Various, including Office for National Statistics, Department for Transport, Local Authorities	Checking/Verification of Mobile Phone Data
Public Transport Demand Data	PLANET North	Department for Transport	Rail Matrix Development
	National Rail Travel Survey	Department for Transport	Factoring PLANET North Data
	NTS (National Travel Survey)	Department for Transport	Validating National Rail Travel Survey Factors
	NTEM (National Trip End Model)	Department for Transport	Independent Verification of Rail Demand Matrix
	Rail Station Entry/Exit Counts	ORR (Office of Rail and Road)	Factoring and Verification
	MOIRA	ATOC (Association of Train Operating Companies)	Independent Verification of Rail Demand Matrix
	Other (e.g. rail patronage)	Various including Local Authorities/Passenger Transport Executives	Independent Verification of Rail Demand Matrix

4.2 Network Development Data

The TPS network data required can be categorised as follows:

1. Network Geometry;
2. Network traffic features including speed, restricted movements; and
3. Network operating features, including traffic signals.

A number of data sources have been identified within each of these categories. These are summarised in [Table 9](#) below.

Table 9 – Summary of Available Network Data

Category	Data Type	Source	Selection Criteria	Use
Network Geometry	- Link alignment - Other geometric attributes	Integrated Transport Network (ITN)	- Road Route Information Layer – June 2015 - All Motorways, A roads and B roads within the TPS RoF - A number of specific C roads within the TPS RoF	To be used in the production of both simulation and buffer network in SATURN for TPS model
Network Traffic Attributes	- Vehicle travel time - Vehicle speed	DfT Trafficmaster	- Data for all ITN links within the TPS RoF - Weighted average weekday speed from the Trafficmaster observed data.	To be used in calibration and validation of the modelled network
Network Operating Feature	Signal Data	Local Authorities	All signalised junctions on the TPS Strategic Road Network (SRN)	- To be used for accurate representation of junction flow - To add junction delay

4.3 Matrix Development Data

The development of regional matrices was largely driven by the mobile phone data. However, other sources such as census Journey to Work (JTW), National Travel Survey database, and prior demand estimates based on the National Trip End Model (NTEM) were used to augment the mobile phone data. These are summarised in [Table 10](#).

Table 10 – Summary of Available Highway Demand Data

Source	Data Type	Selection Criteria	Use	High Level Summary
DfT	Trafficmaster O-D Data	All data for March 2015 was requested.	Trafficmaster data was used to develop origin-destination matrices for light good vehicles. Matrices were expanded to counts on screenlines.	- Data provides a 2% sample of LGV movements; - Data was expanded to fit flows on screenlines.
	National Travel Survey (NTS) Data	All detailed data between 2002 and 2014 has been requested. From this, the data have been filtered to include the following records: 2012 to 2014; - Weekdays; - TPS model area (at county level).	Analysis of the NTS data was used to check the mobile phone data and to build the synthetic matrices. The data was also been used to: - calculate the trip rates; - summarise the daily profile in hourly intervals; - create trip length profiles. All the analyses have been done separately by trip purpose; - Home based work - Home based other - Non home based	Use of data identified problem areas within the mobile data.
	Base Year Freight Matrices	Base Year Freight Matrices (BYFM) were obtained from the Department for Transport website. This is a fixed format downloadable dataset.	The BYFM data was analysed to create origin-destination matrices for HGV trips. The data was provided for a 2006 base year. Road Traffic forecasts will be used to factor to 2015.	This data set is the primary source of information to develop the HGV matrices

Source	Data Type	Selection Criteria	Use	High Level Summary
	CAA Data	The Civil Aviation Authority (CAA) collate annual data with regards to numbers of trips into and out of all major airports in the UK, and conduct surveys to identify modes of transport for ground access/egress by travellers. This data was provided by DfT Date for 2015 was used.	Data was used to identify numbers of non-work related trips to and from airports within the modelled area	This dataset is used to replace mobile phone data records for air travellers

Source	Data Type	Selection Criteria	Use	High Level Summary
ONS	Census Journey to Work Data	The standard 2011 Census Journey to Work data set was obtained from Office for National Statistics (ONS).	Data was used to remove bus trips from the mobile phone data set and to review home based work trips in the mobile data set	Standard data set used to derive mode shares for analysis of the mobile phone data
3 rd Party	Mobile Phone Data	The data provided, was in person trips between every MSOA in England, Scotland (equivalent thereof) and Wales. Matrices were Monday to Friday averages (based on trips made between the 2nd and 27th March 2015 inclusive) for each hour between 05:00-20:00 hrs and aggregated over the remainder of the day, with trips assigned to each hour based upon the start time of the trip at its origin. Provisional mobile phone data for the whole of the GB mainland in the form of origin-destination (OD) matrices was provided. The initial version was intended to exclude rail trips. Early analysis suggested that the algorithms used by Telefonica to remove rail trips had not been successful and subsequently a revised version of the Provisional data, which included all rail trips, was provided	The mobile phone data have been used to: - calculate the trip rates at MSOA level; - summarise the daily profile in hourly intervals; and - analyse the trip length distribution.	

4.4 Journey Time Validation Data

Trafficmaster data was obtained from the DfT to inform a review of journey times through the network. Data were obtained via a DfT congestion data request, and journey time data were provided nationally for the Regional Model programme.

4.5 Link and Screenline Flow Calibration / Validation Data

The development of the TPS RTM has drawn on existing data sources, complemented by additional traffic count survey data, commissioned specifically for the model development. A number of count data sets have been identified to be of importance to the calibration of the TPS Regional Model and these are summarised in [Table 11Table-44](#).

The data sources highlighted in [Table 11Table-44](#) range from existing local authority automatic and manual traffic counts, Highways England Traffic flow data system (TRADS), Department for Transport (DfT) traffic counts, and existing local models.

The aforementioned traffic flow data is collated in an exhaustive Excel workbook that will act as a primary input for calibration and validation. The workbook contains all relevant information for each count. Further information on this workbook can be found in Section 2.10 and Appendix A1 of the Model Data Collection Report.

The TPS Regional Highway Model is subject to standards set by a series of Technical Consistency Groups (TCGs). In this instance; the Calibration Validation TCG has determined that existing and new traffic count data will be used to the standards agreed with the Data Technical Consistency Group (DCTG).

In summary the key points relating to traffic count data are as follows:

- Traffic count data should be collected in March 2015 where possible;
- Traffic count data should not be older than 2012; and
- An average of ten working days (two weeks) data should be used to calculate averages from the automatic traffic count (ATC) sites.

For additional information on these standards please refer to the Model Data Collection Report, Chapters 1.5 and 2.2.

Relevant data which adhered to the Technical Consistency Group's guidelines as outlined in Section 2.2 in the Model Data Collection Report has been subject to a "sieving process". This process sought to remove outlier counts that may represent anomalous network conditions and is described in Section 2.4.1 of the Data Collection Report.

Regarding vehicle classification, count data have been split by vehicle type (car, LGV, OGV) for use in calibration and validation. On occasions where it was not possible to apply local data to differentiate the vehicle class split, the national factors referring to DfT Traffic Forecasts of 2015 were applied. Further information on vehicle classification can be found in Section 2.4.2 of the Model Data Collection Report.

A number of screenlines and cordons have been identified in accordance with modelling best practice, which will be used to assess the performance of the model. For additional information on screenlines and cordons please refer to Section 2.6 of the Model Data Collection Report.

Table 11 – Summary of Available Traffic Count Data

Source	Data Type	Selection Criteria	Number of Sites	High Level Summary
Local Authorities	Existing Local Authority Automatic and Manual Traffic Count Data	- A GIS plan of site locations; - of two weeks' data for ATCs; - Hourly data for each day of the week; - Vehicle classifications: Motorcycle, Car, LGV, OGV1 and OGV2 (desirable but not essential); - The counts should preferably be from neutral months (see WebTAG Unit M1.2, paragraph 3.3.6); - The age of the data should not be older than 2012; and - The data collected only on A, B and C roads are of interest.	Total: 6,592 - ATC: 3,963 - MTC: 2,222 - Speed: 52 - ANPR: 109 - Undefined Category: 246	142 ATC sites used No MTC, Speed or ANPR sites taken forward for processing at this stage. Potential to revisit if required during calibration / validation.

Source	Data Type	Selection Criteria	Number of Sites	High Level Summary
Highways England	TRADS	- Areas where sites selected: Areas 10, 12, 13, 7 and 14; - Years requested: 2011 to 2015; - Date range: 01 March to 31 March; - Report Type: Period; - Hourly totals.	For 2015: 5,337 sites of which 2,166 sites returned data (40.6%). For 2014: 5,337 sites of which 2,307 sites returned data (43.2%)	Total of 107 sites used 2015: 98 sites 2014: 4 sites 2013: 11 sites 2011: 2 sites
Department for Transport	Department for Transport Traffic Counts	- Data between 2000 to 2014, to determine long term trends; - Data split by user class; and - Annual Average Daily Traffic Flows (AADF), accounting for seasonal variations in the data.	3,636 locations from 2012 to 2014	Initially not intended to be used as a primary source of data. Due to problems encountered with data quality for some counts, only 4 sites were eventually used as an alternative source for traffic flows. The dataset was used as a secondary source of traffic data for vehicle class splits, where required.

Source	Data Type	Selection Criteria	Number of Sites	High Level Summary
Existing Local Models	Data used in development of local traffic models – mixture of ATCs and MCCs	As per Local Authority data	1,599 MCCs; 2,102 ATCs, of which 49 were long term.	No MCC sites were taken forward for processing at this stage. Potential to revisit if required during calibration / validation. 73 ATC sites were used.

4.6 Description of Calibration Data

The various types of traffic count data used to calibrate the Trans Pennine South Regional Model are listed in [Table 11](#) and shall be summarised within this chapter. Additionally, [Figure 2](#) presents a visualisation of the calibration count locations used by the TPS regional model.

The data from the selected sites which met the DTGC's guidance was then processed; firstly by splitting the data across three peak periods of the AM peak (07:00-09:00), the inter peak (10:00-15:00), and the PM peak (16:00-18:00). The processing procedure sought to: count the number of days in which there is suitable data, remove outlying or erroneous data, count the average number of vehicles across the peak periods, find the standard deviation from the mean, count the minimum and maximum vehicles for each peak period, report the dispersion index percentage and vehicle classification splits. Appendix A2 of the Model Data Collection Report expands further upon the data captured by the processing procedure.

Automatic and Manual Traffic Counts

The data sets identified of being of use to the TPS regional model were then filtered through the quality assurance standards outlined in Sections 1.5 and 2.2 of the Model Data Collection Report. In total 245 existing local authority automatic traffic counts were deemed to be appropriate for the purposes of the model. Further data processing outputs regarding vehicle count splits across the peak periods and dispersion index percentages are found in Tables 10 and 11 of the Model Data Collection Report.

Regarding manual traffic counts, there was a very limited coverage which met the required quality criteria. Therefore, it was decided that MCCs would not be taken forward unless necessary. Due to two commissioned ATCs failing along with the lack of availability of other suitable sources of data, two MCC counts were used from previous transport assessments. Please refer to Table 9 of the Model Data Collection Report for more information.

New Data Collection

Based on the agreed screenline and cordon definition, and the availability of existing data, a gap analysis was undertaken to identify those locations where data collection was required.

A further 331 sites were required to be surveyed. The scale of the data collection required meant that it was necessary to undertake the work in two phases: the first was in November / December 2015 (216 sites) and the second in February / March 2016 (115 sites). The spatial breakdown of the two data collection phases can be found in Section 2.7 of the Model Data Collection Report. In each case, the data collection avoided any local school holidays and data was collected for a two-week period at an hourly level by direction.

Tables 28-29 of the Model Data Collection Report provide a summary of the processed data counts for the commissioned surveys' data broken down by peak period.

TRADS

TRADS data was requested over a five year period between the 1st of March and the 31st of March. In total; 5,337 sites were included in the request, please refer to Section 2.5.2 of the Model Data Collection Report for additional information on TRADS selection criteria.

A total of 107 TRADS sites were selected for further analysis and processing, a further 28 sites were used to derive the flows for sites which did not have suitable TRADS data. Each derived site is a combination of two TRADS sites to evaluate the required flows generating 14 unique Derived Sites outlined Section 2.5.2 of the Model Data Collection Report.

The TRADS and Derived sites were subject the same processing procedure as the automatic traffic counts outlined above. The results of which are outlined in Tables 18 – 20 in the Model Data Collection Report.

Department for Transport (DfT) Traffic Counts

The DfT holds a large dataset on traffic flows across Great Britain, ranging from flows collected over a single day, through to longer term monitoring. As a result, the accuracy of this dataset is likely to vary by site depending on the availability of count data. Table 6 of the Model Data Collection Report summarises the number of sites available (in 2014) by Local Authority within the TPS Model area.

Due to uncertainty surrounding the duration and accuracy of these counts, initially this dataset has not been used as a primary source of traffic flows. Instead, this dataset has been used to provide vehicle classifications for sites where this has not been available from another source.

While the DfT dataset was not considered as a primary source of traffic flow data, the non-availability of other sources coupled with a bad quality data for a limited number of sites required the use of the DfT dataset as an alternative source for traffic flows. In total there are three sites where DfT data was deemed to be appropriate to use within the TPS model, the flows are presented in Section 2.6 of the Model Data Collection Report.

The three DfT sites selected to be appropriate for data processing were subject to the same procedure as other forms of data used within the model. The classification approaches and vehicle splits that made use of the DfT data are presented in Tables 23 – 25 of the Model Data Collection Report.

Data Health Check – Accuracy of the Model

Considering the nature of this model, a more qualitative data quality grading system was developed to provide a measure of the data's health, accuracy and quality. Each count is scored on a number of categories such as age and vehicle classification system with the final total grading scale ranging from 0-12. A lower score represents a better quality of the count data.

In the Model Data Collection Report Tables 32-37 of the outline the scoring scales for each of the above categories, while Tables 38-40 provide a summary

of the health check scores for each of the data sources across the different peak periods.

It can be deduced from the health check scores in Tables 38-40 that the majority of the counts are of a good quality providing robust sources of traffic flow data. On the other hand while we have not discarded the counts with a worse score due to the limited sources of data available for those locations, their respective flows will be treated with caution during the calibration/validation process. Their effects will be measured against the performance of the respective screenline or cordon as a whole and will be evaluated at that stage on a case by case scenario.

Journey Time Data

The assessment of journey times across the network is an important factor in determining that speeds and associated delay within the model are reflective of existing conditions, and therefore, journey times are used to validate the base model.

It has been agreed by the Data Technical Consistency Group that Trafficmaster data will be used to identify current journey times. Trafficmaster data was obtained from the DfT to inform a review of journey times through the network. Additional information on Trafficmaster data can be found in Section 3.2 of the Model Data Collection Report.

The core requirement for each RTM therefore is to include journey time validation routes covering the:

- Strategic Road Network relevant to each RTM [SRN Routes];
- Main access routes to the SRN [Access Routes]; and
- Key alternative routes to the SRN (e.g. parallel routes) [Alternative Routes].

Eighteen routes have been defined along the SRN, with another seven smaller sections which are not allocated to a specific route, but considered important parts of the SRN (Routes 19 to 25). [Figure 3](#) displays all the SRN journey time routes with the short sections marked by the pink lines. 31 competing routes have been identified within the network.

The RTMs use of DfT's journey time dataset and the correspondence with the ITN-based model networks provides the opportunity for more comprehensive levels of journey time analysis than traditional methods. Typically, Trafficmaster data is used to assess journey times for particular routes, to act as an 'observed' journey time. For a given time period, a median journey time is calculated. A journey time for an individual route is formed by summing average times for each individual link on that route, with the ability to analyse for individual vehicle classes, any combination of vehicle classes or for all vehicles.

The methodology and processes wherein the Trafficmaster data has been processed is presented in Section 3.3.3 and Figure 21 of the Model Data Collection Report. The results of the journey time routes covering the SRN can be found in Table 41 of the Model Data Collection Report.

Figure 2 – TPS Regional Model Calibration Counts

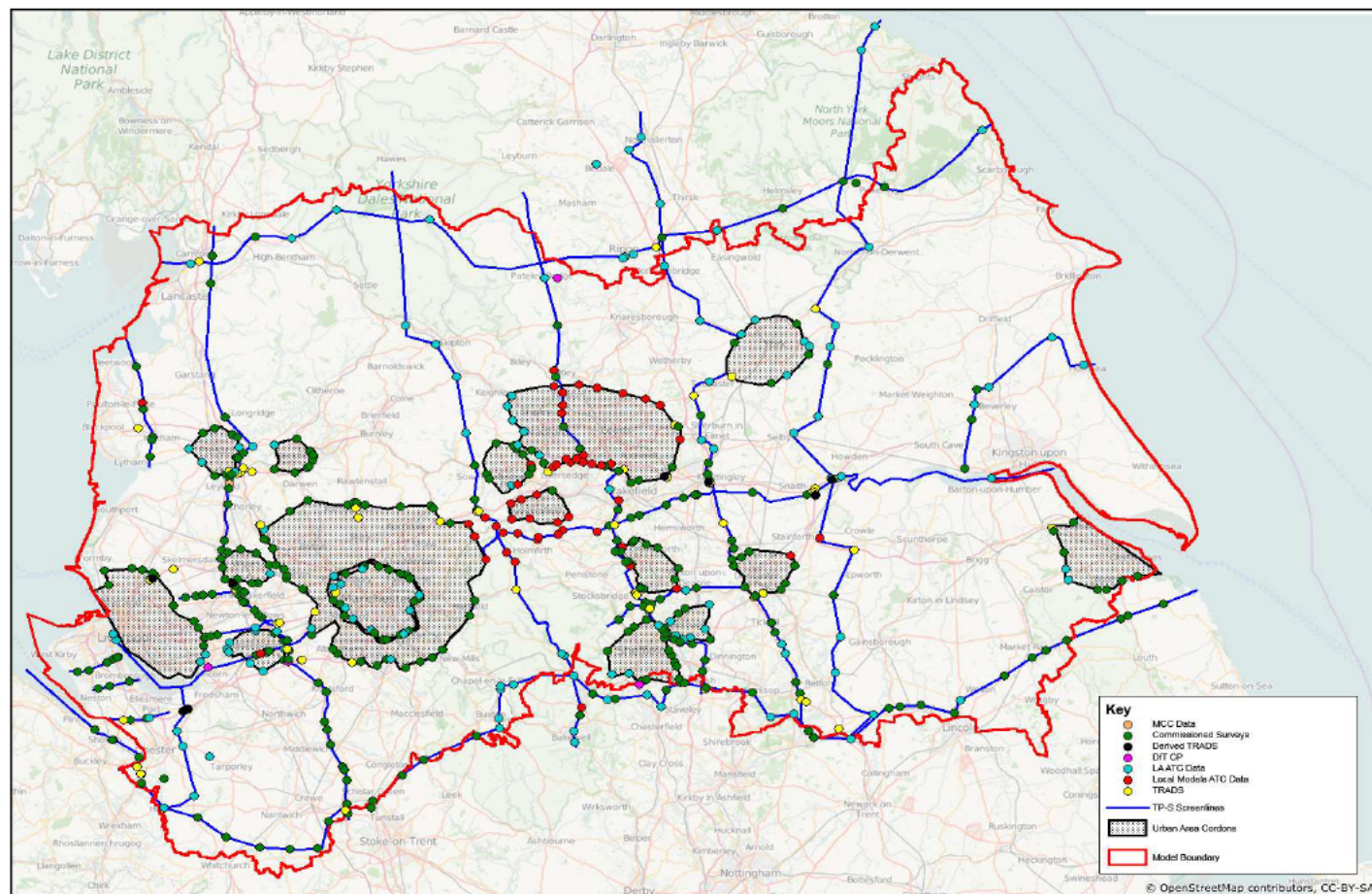
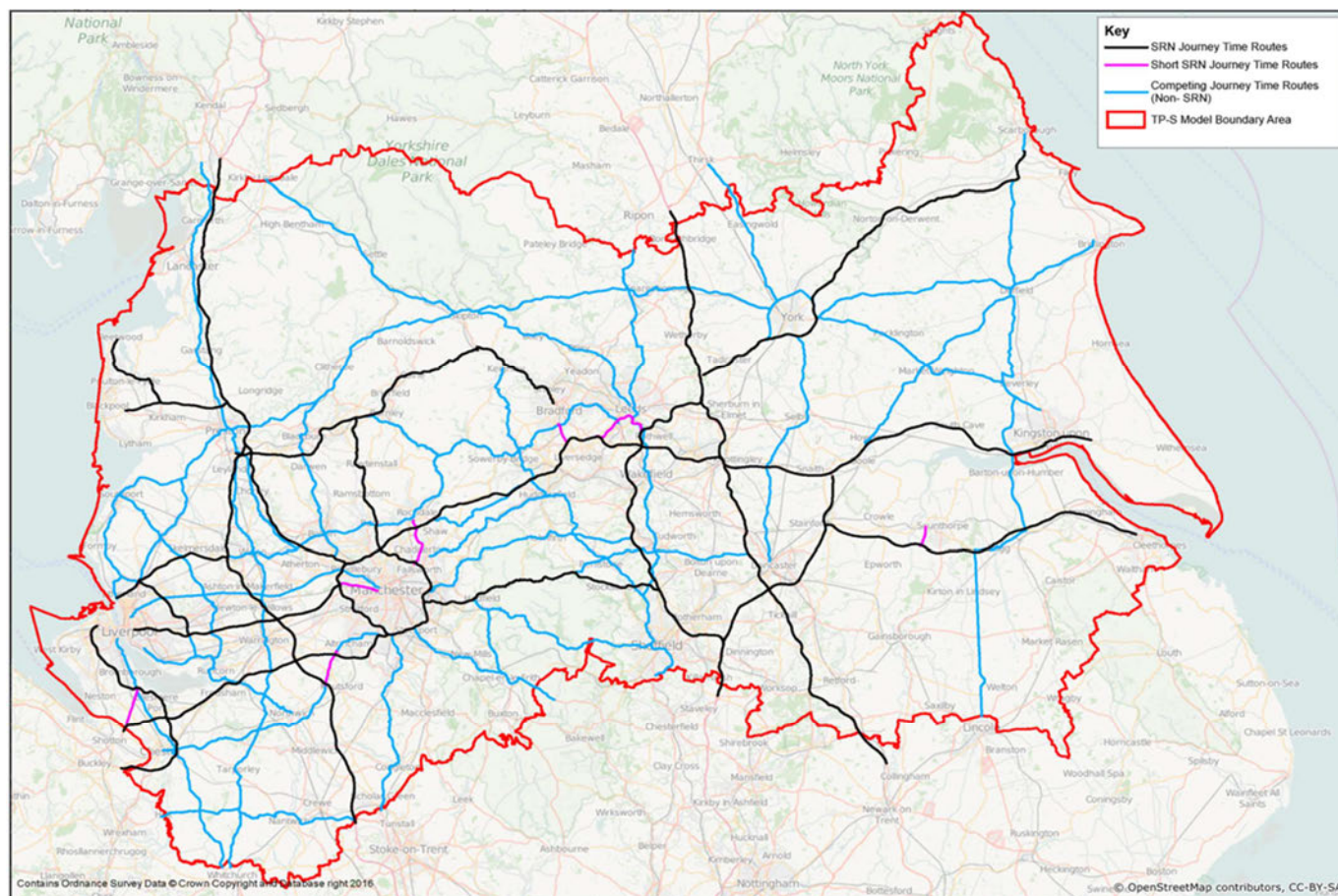


Figure 3 – Journey Time Coverage by Type of Route



4.7 Description of Validation Data

Validation of the TPS Regional Model requires the use of an independent data set to confirm that the model is suitable to accurately represent observed flow conditions. Validation is conducted during the development of a model in order to provide a critical assessment of the ability of the model to robustly reflect the existing traffic conditions. Whilst the validation process requires the comparison of modelled traffic flows and journey times against observed data, this section will primarily focus on the selection of sites for the traffic flow elements on the Strategic Road Network.

During the process of model development a detailed investigation was undertaken to investigate the availability of data to inform the model. This led to the collection of data from a range of sources as previously outlined in [Table 11](#) of this report. A large proportion of these data sets were used to inform the model development, in particular the calibration of the model.

A total of 98 locations have been selected for the model validation process, and is comprised of 207 separate TRADS data sites. It is considered that the sites selected provide an appropriate coverage of the SRN to validate the TPS regional transport model. The sites used for calibration and validation are displayed in [Figure 4](#).

TRADS

The methodology of utilising data from the Highways England TRADS database focused upon the use of 2015 TRADS data, where available. However this approach has required the use of some 2013 and 2014 data to supplement the coverage. Where available, TRADS sites covering the SRN have been selected to provide two-way traffic data. There are some locations where TRADS data is not sufficient for the validation process; for example the information does not cover ten continuous weekdays, therefore these sites have been discounted from the selection.

Motorways

The Highways England TRADS database provides a good coverage of sites along the motorway network within the boundary of the TPS Regional Model. In order to ensure an even spread of validation sites across the model, a location has been selected on every other link on the motorway network. Where a TRADS site has already been utilised within the model calibration process this link has been treated the same as a validation location therefore the adjacent links have not been included in the validation process.

A-Roads

The coverage of TRADS sites for A-roads is restricted to those which form part of the Strategic Road Network (SRN). The coverage is therefore limited to the major A-roads within the TPS model. The frequency of sites is also lower on A-roads than on the motorway network and so an ad hoc approach has been required based on the availability of TRADS data sites and the location of key junctions to provide an appropriate spread of validation sites to give confidence in the accuracy of the model.

Figure 4 – Calibration and Validation Sites across the Trans Pennine South Regional Model

4.8 Comparison of comparable data from different sources

The TPS Regional Model has utilised data from a variety of sources and on occasions this data varies from the base month and year outlined by the Technical Groups. Where traffic count data has been collected outside of the agreed base year (March 2015) modifications were required prior to use within the calibration and validation processes.

Factoring will be applied to reflect:

- Month to month changes / seasonality – factoring to the base model month;
- Annual change in traffic – factoring to the base model year; and
- Vehicle segmentation to represent Car, LGV, and HGV vehicles.

Further information on the factors applied to standardise the data used within the TPS regional model can be found in Section 2.8 of the Model Data Collection Report.

5 Highway Model Development - Networks

5.1 Description of Network Structure

The TPS Regional Traffic Model is a SATURN based highway assignment model covering substantial regions in the north of England. The model represents the highway network within this area, with coverage including all motorways, A roads, B roads and selected minor roads carrying significant volumes of strategic traffic.

The network within the TPS model area has been coded in SATURN in order to enable the interaction of traffic at junctions and the resulting delays and queues to be modelled as accurately as possible. The information required for simulation coding was quite detailed and included:

- the permitted movements at junctions;
- saturation flows and lane usage (including locations of bus lanes);
- traffic signals and settings, including stages, cycle time, green splits, inter-greens and off-sets.

This chapter will:

- discuss the network coverage;
- detail on post processing carried out on initial buffer network before converting it to simulation coding;
- provide details about the network data adopted;
- detail on Saturation flow, signal coding and SFC adopted; and
- discuss about treatment of public transport services.

5.1.1 Initial Buffer Network and Model Boundary

Initial Network

A single SATURN buffer network was supplied by Highways England as starting point for network building for all RTM teams. This buffer SATURN network was developed from the Ordnance Survey (OS) Integrated Transport Network (ITN) Road Route Information (RRI) layer of June 2015 data using ITN2SATURN tool. The SATURN network was created from the individual ITN elements to form basic structure, with majority of the links based on aggregation of existing elements. The network supplied consisted of 60,000 nodes and 126,000 links⁹.

The buffer SATURN network represented following road types:

- Motorways, A-Roads and B Roads in England: and
- Motorways and A-Roads only in Scotland and Wales

⁹ As per 5141063 ITN2SATURN Handover (Draft Final).pdf supplied by Highways England
Trans Pennine South RTM Page 56 Model Validation Report

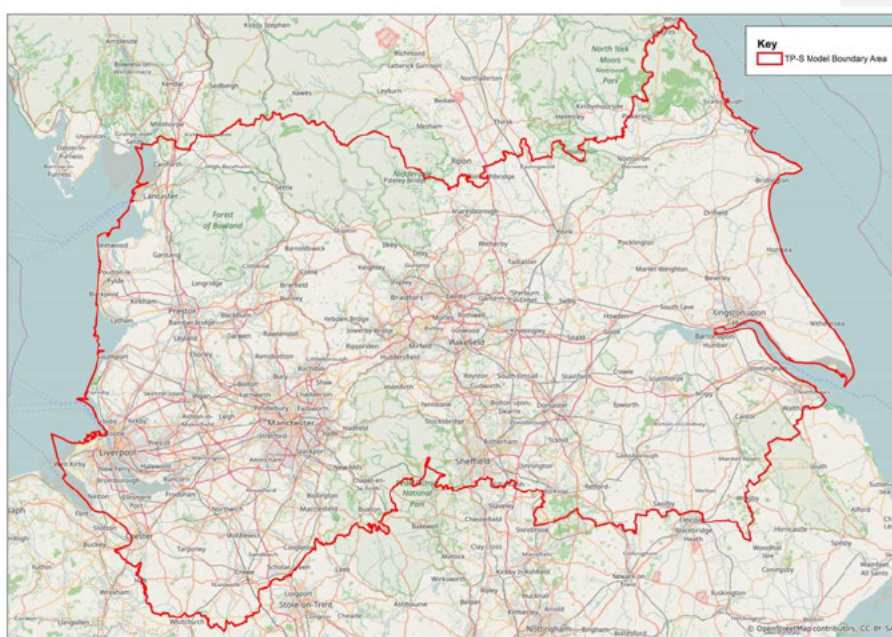
Each local authority area was allocated to a regional model. This provided a structure for numbering nodes, but the boundaries chosen do not always coincide with the model boundaries. Trans-Pennine South Regional Transport Model (TPS RTM) has overlap areas with North RTM and Midlands RTM. A common approach was agreed between both RTM teams to maintain consistent network structure and node numbering. The overlapping areas were allocated to a regional model and coded by the respective team. This coding is included in the TPS model.

Model Boundary

The initial buffer network supplied was for the entire UK, however, for TPS RTM a Region of Focus (RoF) or simulation area was defined which included major metropolitan areas of:

- Merseyside:
- Greater Manchester:
- Leeds: and
- Sheffield

Figure 5 – Region of Focus for TPS RTM



Post Processing of Initial Buffer Network

The initial SATURN buffer network supplied by HE had a considerable amount of detailed network outside the RoF and also at many locations within the RoF ITN2SATURN automated rules were not effective enough to generate the desired network.

Due to difficulties involved in refining the buffer network manually which is also prone to errors, it was re-run through ITN2SATURN tool by providing forced collapse, explode and delete network element lists. Outcome from this has formed a base network to create a start developing simulation coding for the RoF.

5.1.2 Network Categorisation

A basic principal of tiered approach was used for network categorisation by the RTM network coding manual. As per this network has been categorised as follows:

- Area 1 – Strategic Road Network (SRN), Roads connected to / parallel with SRN and roads considered important to RIS scheme appraisal.
- Area 2 – Rural roads that are not connected to SRN.
- Area 3 – Urban areas outside the influence area of RIS schemes and the SRN.
- Area 4 / External – Roads outside the region of focus.

Network coding manual also recommended level network coding required for each network category in terms of junction coding (layout, saturation flow, signal timings, speed & speed flow curves). Above approach was thus followed to classify the highway network in TPS RoF.

5.2 Approach to Network Coding

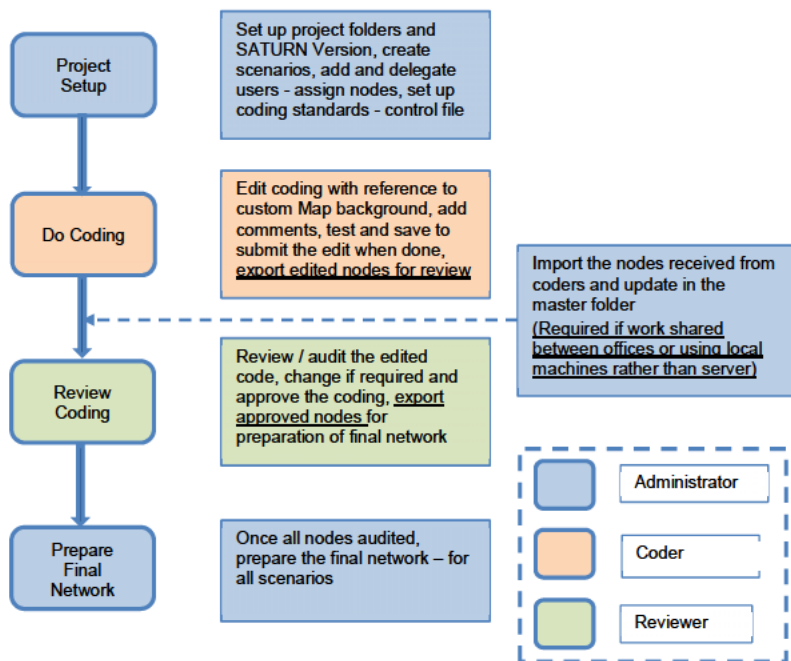
5.2.1 Simulation Network Coding

Before the simulation coding was undertaken, nodes / junctions in RoF were classified into Area 1, Area 2, Area 3 and Area 4 as defined in section 5.1.2 of this report in GIS using various GIS layers like SRN Network, proposed RIS Schemes, 2011 Built-up Area layer from OS.

As recommended by coding manual and Network TCG, it was agreed to code Area 1 in detail, Area 2 to lesser detail, Area 3 as dummy nodes and Area 4 as buffer network. Based on this approach nodes that fall in Area 1 and Area 2 were coded through SATCODER v0.5 tool, which was developed by Atkins SATURN software team and made specifically available for the South East and Trans-Pennine South Regional Traffic models development.

The SATCODER tool requires a dummy simulation network converted from the ITN buffer network. Users were required to input all the required parameters for complete junction using the drop-down menu except the link length, which was already available in buffer network from ITN. Coders were required to code each junction parameter in detail including junction type, lane definition, signal timings, gap value (for roundabout in particular) etc., most can be done by drop-down manual selection without a coder to enter figures manually. [Figure 6](#) shows the process of network coding handled using SATCODER for TPS RTM.

Figure 6 – Simulation Coding Process Using SATCODER



SATCODER has limited custom map background functionality to help the coder and reviewer to verify the junction in detail. Google street view and Bing StreetSide features were used to understand the junction, lane configuration in detail while coding each arm of the node / junction. Coders and reviewers made sure that they are referring to the aerial and street view images are for March 2015 before coding it in SATCODER.

It was recommended by the Network TCG that it would be preferable to create two networks for each time period one without road works and one with roadway works in place. At the first instance highway network without roadway works was coded using SATCODER. Upon first cut full highway network was built from SATCODER, another set of network was created to include the road works using an include file option in SATURN. Further detail on how road works were coded in subsequent sections of the chapter.

5.2.2 Description of any network inventory undertaken

The development of the network has been described above in sections 5.1.1, 5.2.1 and 5.2.3.

5.2.3 Description of coding process used to determine link length and node locations

The base network generated from ITN2SATURN process retained the actual link lengths. The buffer network did not contain any information on link speeds,

number of lanes, etc. Data about link speeds was determined using information from various sources like speed limit boards through Google Street view, Open Street Map speed limit data, national speed limits and Trafficmaster data.

Trafficmaster speeds by time period were utilised for links falling in urban areas and buffer network, where fixed link speed was applied as per the RTM network coding manual¹⁰.

5.3 Network Topology

5.3.1 Evidence for assessment of speed limits / road types for determining network speeds

This has been described above in sections 5.2.1 and 5.2.3.

5.3.2 Location, value and justification of fixed speeds and/or speed-flow curves used

Speed Flow Curves (SFC) were used to represent the relationship between link flow, speed and capacity and, by defining a speed-flow relationship (or 'curve') enables the (observed) decrease in link speeds to be estimated as the overall link flow increases.

As general rule of thumb SFC were applied on all links with greater than 1km length for Area 1, Area 2 nodes and also on all motorway links. SFC prescribed in coding manual section 4.10 were adopted in the TPS model and are set out in [Table 12](#) below.

Table 12 – RTM Speed Flow Curves

SFC Index	Road Type	FF Speed (kph)	Cap Speed (kph)	Capacity (PCUs / hr)	Power
48	Motorway D6M	113	81	13980	2.8
1	Motorway D5M	113	81	11650	2.8
2	Motorway D4M	113	81	9320	2.8
3	Motorway D3M	113	81	6990	2.8
4	Motorway D3M+DHS	100	75	9320	2.8
5	Motorway D2M	113	74	4659	2.8
44	Motorway D3Mworks	80	64	5580	2.6
45	Rural D5AP 70mph	112	80	10497	2.75
46	Rural D5AP 60mph	98	76	10497	2.75
47	Rural D4AP 70mph	112	80	8397	2.75
6	Rural D4AP 60mph	98	76	8397	2.75
7	Rural D4AP 50mph	80	62	8397	2.2
8	Rural D3AP 70mph	112	80	6298	2.75
9	Rural D3AP 60mph	98	76	6298	2.75
10	Rural D3AP 50mph	80	62	6298	2.2
11	Rural D2AP 70mph	112	73	4199	2.75
49	Rural D2AP 60mph	98	76	4199	2.75
12	Rural D2AP 50mph	80	62	4199	2.2
13	Rural D2AP 40mph	64	35	4199	1.6

¹⁰ RTM Network Coding Draft V 08 Final.pdf – supplied by Highways England
Trans Pennine South RTM

SFC Index	Road Type	FF Speed (kph)	Cap Speed (kph)	Capacity (PCUs / hr)	Power
14	Rural WS2 A 10m	93	55	1686	2.15
15	Rural S2A 7.3 new	87	58	1328	1.99
16	Rural S2A 7.3 old	82	53	1328	2.04
17	Rural S2A 40mph	64	35	1328	2.39
18	Rural S2 6.5m	67	45	1010	1.79
19	Rural S2 - slow	54	35	1328	1.53
20	Rural S2 - narrow	82	53	950	2.11
21	Rural S2 slow/nw	54	35	950	1.53
50	Rural AP S3/4	87	58	3400	2
22	Suburban D4	71	35	7080	1.42
23	Suburban D3	71	35	5310	1.42
24	Suburban D2 (slight dev)	75	35	3540	2.56
25	Suburban D2 (typical dev)	71	35	3540	1.42
26	Suburban D2 (heavy dev/40mph)	58	35	3540	0.93
27	Suburban D2 (30mph)	48	30	3540	1.28
28	Suburban S4 (slight dev)	54	25	3400	2
29	Suburban S4 (typical dev)	54	25	2500	2
30	Suburban S2 (50mph)	71	35	1680	1.52
31	Suburban S2 (light dev)	65	25	1680	2.63
32	Suburban S2 (typical dev)	61	25	1680	1.58
33	Suburban S2 (heavy dev)	58	25	1680	1.03
34	Suburban S2 (30mph)	48	25	1680	1.28
35	Urban Non-central 50% dev	48	30	896	2.22
36	Urban Non-central 80% dev	48	25	896	1.49
37	Urban Non central 90% dev	46	25	896	1.25
38	Urban Central INT = 2	37	15	944	1.51
39	Urban Central INT = 4.5	33	15	944	1.19
40	Urban Central INT = 9	28	15	896	0.72
41	Small Town 35% development	63	32	1344	2.91
42	Small Town 60% development	56	30	1344	2.37
43	Small Town 90% development	46	30	1344	1.27
99	Buffer Zone Connectors	70	50	10000	1.39

As recommended by coding manual maximum speed restrictions for HGV's on the highway network was implemented by using CLICKS facility in SATURN for HGV user class.

Apart from this, routing through urban areas is restricted by use of fixed speeds derived from Trafficmaster journey time data by time period. During initial network coding stage for Area 3 nodes, fixed SFC were used by setting free flow speed and speed at capacity same as average speed derived from Trafficmaster data using the method set out in Appendix D of the Coding Manual by time period.

5.4 Junction Data

5.4.1 Junction Saturation Capacities and Other Parameters

As recommended by the Network Technical Consistency Group (TCG), the simulation coding exercise assumed to prepare the network with a standard layout, e.g. standard lane width for all junction types. This was to ensure the network is produced following a consistent approach and reduce human errors in measuring junction geometry. The junction performance would be considered during the calibration and validation stage and the junction coding might be refined accordingly if the geometry inputs have significant impacts on junction performance in terms of delays/blocking back, as well as local traffic routings etc.

For the purpose of simulation coding mean saturation flows for standard lane width were adopted for each junction type. These are listed in the following tables by junction type:

Table 13 – Priority Junction Turn Saturation Flows (PCUs per hour)

Link Type	Approach Lane Type	Turn		
		Left	Ahead	Right
Major Arm	1 lane only	1730	1980	1730
Major Arm	1 lane offside		2060	1750
Major Arm	1 lane opposed right			760
Major Arm	2 lanes inc. nearside	3460	3970	3460
Major Arm	2 lanes offside		4110	3580
Major Arm	2 lanes opposed right			1420
Major Arm	3 lanes inc. nearside	5240	6030	5240
Major Arm	3 lanes offside		6170	5370
Major Arm	4 lanes inc. nearside	7030	8080	7030
Major Arm	4 lanes offside		8220	7150
Give way - no cent reserve	1 lane	770	640	640
Give way - no cent reserve	2 lanes	1440	1190	1190
Give way - with cent reserve	1 lane	770	690	690
Give way - with cent reserve	2 lanes	1440	1270	1270

For priority junction a global GAP value of 2.0 seconds was adopted, this was adjusted at calibration and validation stage for each junction if need be.

Table 14 – Roundabouts - Turn Saturation Flows (PCUs per hour)

Roundabout Type	Approach Lane Type	Turn			
		1 lane	2 lanes	3 lanes	4 lanes
Mini roundabout	any lane	990			
Standard Rbt	1 lane approach	1100	1620	1800	2450
Standard Rbt	2 lanes approach		2200	2760	3000
Standard Rbt	3 lanes approach			3320	3750
Large roundabout	1 lane approach	1830			
Large roundabout	2 lanes approach		3790		
Large roundabout	3 lanes approach			5740	
Large roundabout	4 lanes approach				7700

Table 15 – Roundabouts - GAP Values and Circulation Capacity

Roundabout Type	Circulation Capacity (PCUs per hour)	GAP (seconds)	Circulation Time (seconds)
Mini Roundabout	2050	1.8	5
Std. Roundabout - 1 lane approach 1 lane at stop line	2250	1.6	10
Std. Roundabout - 1 lane approach 2 lanes at stop line	2770	1.3	10
Std. Roundabout - 1 lane approach 3 lanes at stop line	2910	1.2	10
Std. Roundabout - 1 lane approach 4 lanes at stop line	3200	1.1	10
Std. Roundabout - 2 lanes approach 2 lanes at stop line	3780	1.0	15
Std. Roundabout - 2 lanes approach 3 lanes at stop line	4120	0.9	15
Std. Roundabout - 2 lanes approach 4 lanes at stop line	4400	0.8	15
Std. Roundabout - 3 lanes approach 3 lanes at stop line	4680	0.8	17
Std. Roundabout - 3 lanes approach 4 lanes at stop line	5000	0.7	17
Large Roundabout - 1 circulatory lane	1880	1.9	23
Large Roundabout - 2 circulatory lanes	3900	0.9	23
Large Roundabout - 3 circulatory lanes	5920	0.6	23
Large Roundabout - 4 circulatory lanes	7940	0.5	23

Table 16 – Gyratories and Exploded Roundabouts – Priority - Turn Saturation Flows (PCUs per hour)

Link Type	Approach Lane Type	Saturation Flow
Approach arm	1 lane	1250
Approach arm	2 lanes inc. near side	2500
Approach arm	3 lanes inc. near side	3750
Approach arm	4 lanes inc. near side	5000
Circulating arm	1 lane inc. near side	1880
Circulating arm	1 lane offside	2020
Circulating arm	2 lanes inc. near side	3900
Circulating arm	2 lanes offside	4040
Circulating arm	3 lanes inc. near side	5920
Circulating arm	3 lanes offside	6060
Circulating arm	4 lanes inc. near side	7940

Table 17 – Gyratories and Exploded Roundabouts – Signalised - Turn Saturation Flows (PCUs per hour)

Link Type	Approach Lane Type	Saturation Flow
Approach arm	1 lane	1250
Approach arm	2 lanes inc. near side	2500
Approach arm	3 lanes inc. near side	3750
Approach arm	4 lanes inc. near side	5000
Circulating arm	1 lane inc. near side	1880
Circulating arm	1 lane offside	2020
Circulating arm	2 lanes inc. near side	3900
Circulating arm	2 lanes offside	4040
Circulating arm	3 lanes inc. near side	5920
Circulating arm	3 lanes offside	6060
Circulating arm	4 lanes inc. near side	7940

Table 18 – Signalised Junction - Turn Saturation Flows (PCUs per hour)

Link Type	Approach Lane Type	Turn		
		Left	Ahead	Right
Single Lane	1 lane only	1730	1980	1800
Multiple Lane	1 lane offside	1670	2060	1750
Multiple Lane	2 lanes nearside	3460	3970	3610
Multiple Lane	2 lanes offside		4110	3740
Multiple Lane	3 lanes nearside	5240	6030	5480
Multiple Lane	3 lanes offside		6170	5610
Multiple Lane	4 lanes nearside	7030	8080	7350
Multiple Lane	4 lanes offside		8220	7480

The coding manual also recommended the saturation flows to be adopted for motorway main carriageway, slip roads. [Table 19](#) presents the saturation flow values adopted in TPS network model development for motorways and slip roads.

Table 19 – Motorway Main Carriageway and Slip Roads - Turn Saturation Flows (PCUs per hour)

Link Type	Approach Lane Type	Saturation Flow
Motorway mainline	2 lanes inc. nearside	4100
Motorway mainline	2 lanes exc. nearside	4240
Motorway mainline	3 lanes inc. nearside	6220
Motorway mainline	3 lanes exc. nearside	6360
Motorway mainline	4 lanes inc. nearside	8340
Motorway mainline	4 lanes exc. nearside	8480
Motorway mainline	5 lanes inc. nearside	10460
Motorway mainline	5 lanes exc. nearside	10600
Motorway mainline	6 lanes inc. nearside	12580
Motorway mainline	Diverge 1 lane	1930
Motorway mainline	Diverge 2 lanes	3860
Motorway sliplane	1 lane nearside	1930
Motorway sliplane	1 lane offside	2060
Motorway sliplane	2 lanes inc. nearside	3990
Motorway sliplane	2 lanes offside	4140
A Road sliplane	1 lane	1730
A Road sliplane	2 lane	3460

The coding manual also recommended that for Smart Motorway All Lane Running near side saturation flows to be adopted and for standard motorway offside (excluding nearside) saturation flow values to be adopted. During subsequent network TCG meetings, it was agreed to adopt either nearside or offside saturation flows for standard motorways as the difference in saturation flows is small.

For more details on saturation flow calculations and recommended values for each junction can found in sections 4.1 to 4.6 of the coding manual.

5.4.2 Junction Operation Data

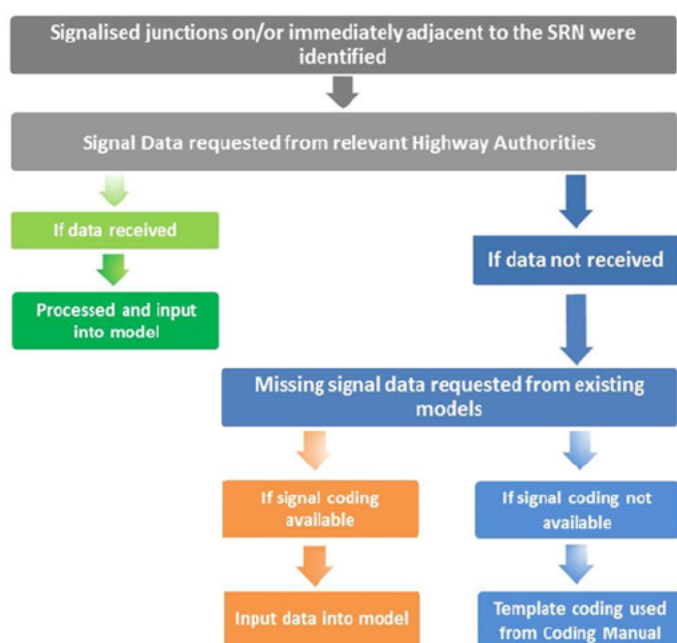
For simulation network coding in RoF global values of 2 seconds and 1 second were adopted for GAP and GAPM values priority junctions and merges.

It was also required to the signalised junctions in detail in Area 1 and Area 2 i.e., signal stages, movements, stage times, etc. Signalised junctions in the RoF were identified and classified as follows:

- SRN = 0 – Other signalised junctions within the study area neither on the SRN junction nor immediately adjacent to an SRN junction;
- SRN = 1 – Signalised junction on the SRN; or
- SRN = 2 – Signalised junction immediately adjacent to an SRN junction.

Given the purpose and size of the model, the number of signals, the length of time required to obtain traffic signal information and the consideration for the programme, signal data was sought from various local authorities only for SRN 1 and SRN 2 categories for inclusion in the SATURN model. For locations where the signal data received it was processed and used for network model building. Locations where signal data were not received either data from existing model or template coding was adopted as prescribed in the coding manual. For SRN 0 category locations template coding was adopted.

Figure 7 – Process for Coding Signalised Junctions on SRN or Junctions Immediate to SRN Junction



5.5 Key Network Specific Assumptions

An average vehicle length of 5.75m has been assumed for queue length per PCU and for flare and tax parameters and a PCU Factor 1 is adopted for Cars and LGV and 2.5 for HGVs.

No PT services or bus priority measures have been included in the highway network

5.6 Treatment of Freight Transport

Freight is represented in the TPS RTM model in the form of Light and Heavy Goods Vehicles (LGV and HGV).

5.7 Roadworks and Other Specific Network Coding

Various assumptions in building the networks are listed below:

- as suggested in the network coding manual section 4.7, any flares longer than 10pcus were coded as an additional lane. Flare lanes were only coded for priority or signalised junctions using FLAREF and FLAREX options available in SATURN;
- no adjustments were made for HOV lanes as these do not form a material part of the network being modelled; and
- in TPS RTM roadway works which were progressing in May / Jun 2015 and were subject to traffic management measure for at least 6 months duration before Jun 2015 were coded. Roadway works information in TPS RTM RoF was obtained from Highways England. [Table 20](#) presents the roadway works considered in the TPS RTM.

Table 20 – List of Modelled Roadway Works

S.No	Roadworks ID	Closure Description
1	RDWS2638	M18 Jct 2-Jct 3 NB Main Line Widening PPP (593) with various lane closures northbound including narrow lanes and 50mph speed restriction.
2	RDWS2639	M18 Jct 2 to Jct 3 PPP carriageway widening works with various lane closures including full closure southbound including narrow lanes and 50mph speed restriction.
3	RDWS2640	M18 Jct 5 PPP Widening of exit slip, localised widening of circulatory, traffic signal control of existing roundabout (3699) with various lane closures and slip road closures, with diversion routes in place.
4	RDWS2816	M18 Technology Upgrade (Pinch Point Scheme) with various lane closures and full carriageway closures southbound. Diversion routes in place.
5	RDWS493	M1 Jct 32 to Jct 35a Managed Motorway Scheme with various lane closures and hardshoulder running southbound including full Jct 35 southbound entry slip road closure, diversion route via M1 to Jct 36 and return to Jct 35.
6	RDWS495	M1 Jct 32 to Jct 35a Managed Motorway Scheme with full closures and various lane closures northbound with diversion routes in place.
7	RDWS6363	Various closures to facilitate the construction of the Heysham to M6 Link road and full reconfiguration of M6 Jct 34
8	RDWS6365	24hr hardshoulder closed southbound for geotechnical investigations. Lane 1 will be closed for 10 days 20th until 31st Oct
9	RDWS6448	M1 Jct 41 (PPP) Carriageway widening & Traffic Signal Installation (3744) with various lane and slip road

S.No	Roadworks ID	Closure Description
		closures on northbound slip roads including lane closures on roundabout.
10	RDWS6523	M62 Jct 30 to Jct 32 HATMS upgrade eastbound with various lane closures for installation of MS4 and upgrading communications network, including narrow lanes and 50mph speed restriction.
11	RDWS6524	M1 Jct 39 to Jct 42 Managed Motorway Scheme with various lane closures southbound, including narrow lanes and 50mph speed restriction. Diversion routes in place for full c/way and slip road closures.
12	RDWS6526	M1 Jct 39 to Jct 42 Managed Motorway Scheme with various lane closures northbound, including narrow lanes and 50mph speed restriction. Diversion routes in place for full c/way and slip road closures.
13	RDWS6527	M1 Jct 39 to Jct 42 Managed Motorway Scheme with various lane closures southbound including hardshoulder running, narrow lanes & 50mph speed restriction. Diversion routes in place.
14	RDWS6530	M1 Jct 39 to Jct 42 Managed Motorway Scheme with various lane closures northbound, including narrow lanes and 50mph speed restriction. Diversion routes in place for full c/way and slip road closures.
15	RDWS6531	M1 Jct 39 to Jct 42 Managed Motorway Scheme with various lane closures southbound, including narrow lanes and 50mph speed restriction. Diversion routes in place for full c/way and slip road closures.
16	RDWS6533	M62 Jct 30 to Jct 32 HATMS upgrade westbound with various lane closures for installation of MS4 and upgrading communications network, including narrow lanes and 50mph speed restriction.
17	RDWS8040	M1 Jct 32 to Jct 35a Managed Motorway Scheme with various lane closures southbound including narrow lanes and 50mph speed restriction. Diversion route in place.
18	RDWS8050	M1 Jct 32 to Jct 35a Managed Motorway Scheme (Central Reserve works) with lane closures southbound for installation of recovery base followed by varioguard in place 24hrs.
19	RDWS8055	M1 Jct 32 to Jct 35a Managed Motorway Scheme with full carriageway closure and various lane closures southbound including various slip road closures, narrow lanes and 50mph speed restriction. Diversion routes in place.
20	RDWS8056	M1 Jct 32 to Jct 35a Managed Motorway Scheme with full carriageway closure and various lane closures northbound including narrow lanes and 50mph speed restriction. Diversion route in place.
21	RDWS8076	M1 Jct 32 to Jct 35a Managed Motorway Scheme with various full carriageway closures and lane closures on M1 southbound link road to M18 northbound. Diversion route via J31 and back.
22	RDWS8077	M1 Jct 32 to Jct 35a Managed Motorway Scheme with full carriageway closures and various lane closures

S.No	Roadworks ID	Closure Description
		northbound including slip road closures and narrow lanes and 50mph speed restriction. Diversion routes in place.
23	RDWS8655	M62 Jct 30 to Jct 32 HATMS upgrade eastbound with various lane closures for installation of MS4 and upgrading communications network, including narrow lanes and 50mph speed restriction.
24	RDWS8664	M62 Jct 30 to Jct 32 HATMS upgrade westbound with various lane closures for installation of MS4 and upgrading communications network, including narrow lanes and 50mph speed restriction.
25	A10RDWKS_2	50MPH Clockwise/Anticlockwise/Eastbound & Westbound
26	A10RDWKS_3	24H - Hard Shoulder closed & Overnight Lane closures clockwise & anticlockwise due to SMART Motorways
27	A10RDWKS_7	24Hours Narrow Lanes - speed limit & Lane one closed – overnight lane closures & some total closures eastbound due to pinch point scheme
28	A10RDWKS_9	24H Lane closures North & Southbound due to Major Scheme
29	A10RDWKS_13	24H Hard Shoulder closed Eastbound and Westbound due to SMART Motorways
30	A10RDWKS_17	24h- Hard shoulder closed Clockwise due to Landslide
31	ADD_SRW_1	Current works have lane 3 closed with hard shoulder running north and southbound with 50mph speed restrictions. Lane 1 and 2 closure north and southbound 2000-0600 hours. Future works will include overnight carriageway and slip road closures
32	ADD_SRW_2	Current works have lane 3 closed north and southbound with hard shoulder running or hard shoulder closure, 50mph speed restrictions, plus verge working 24/7. Lane 2 and 3 closure or lane 1 and 2 closed north and southbound 2000-0600 hours.

5.8 Specific Toll Assumptions

The following tolling locations were identified and toll rates were implemented in SATURN 44444 card for TPS. At locations where different toll rates exist for OGV1 and OGV2 a hybrid toll rate was arrived using a proportion of 40:60 to derive the HGV toll rates.

- Mersey Tunnels (Kingsway & Queensway)
- Humber Bridge
- Dunham Bridge
- Warburton Bridge Rd
- M6 Toll

5.9 Description of the Coding of Other Network Characteristics

All aspects of network coding have been covered in this Chapter.

6 Highway Model Development - Matrices

6.1 Introduction

This chapter discusses the development of the demand matrices for the TPS model. The matrix building process was defined in detail in meetings of the Matrix Building Technical Coordination Group (TCG) and was followed by each of the five models. Since the basis of the models was to be mobile phone generated matrices and given that this remains an emerging technique, at present no single generally accepted method of processing this data has been defined, the TCG provided a forum to consider the experience and findings of all five modelling teams analysing the data and to unite this to define a common process to ensure a consistency of approach between the models. The consistent approach also ensured that there would be minimal discontinuity in the demand matrices between models.

The overall matrix development approach has been documented in the TCG Note "Regional Model Matrix Development: Consistent Approach Towards using Provisional Data" included as Appendix A.

The process was directed by a sequence of specific checks being undertaken to test the data which were used to determine the suitability of the data and to define what further steps should be undertaken to improve the data

The aim of the process developed was to make best use of the mobile data, using other data sets to exclude non-car trips, to infill missing trips and to identify and correct any inherent biases in the dataset. This was carried out drawing on other evidence of:

- person trip rates;
- trip length distribution profiles; and
- trip volumes on long distance screenlines.

The key items of observed travel characteristics being recent records from the National Travel Survey and current traffic count data.

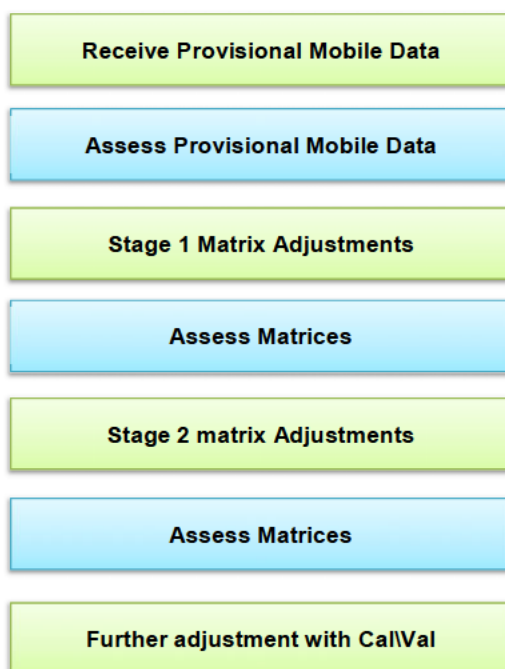
The process evolved through these checks. The final process consisted of three major stages.

- The first stage consisted of cleaning the mobile phone data to ensure that it contained only trips of interest to the model and resolving issues identified in the initial assessment relating to problems in deriving short distance trips from mobile phone data.
- The second stage built on issues identified in the assessment at the end of stage 1 and consisted of refining the data set to ensure that it satisfied the requirements of matching observed data.
- The third stage ran in parallel with the calibration / validation process and was developed to provide consistency in the adjustments made to the matrices in response to issues highlighted during model calibration.

In addition, data were analysed and processed to develop freight matrices for LGV and HGV trips.

The process is outlined in [Figure 8](#) and the results are described in sequence in the subsequent sections.

Figure 8 – Matrix Building Processes



6.2 Highway Matrix Build Specification / Requirements

6.2.1 Trip purpose

Matrices have been developed for light and heavy goods vehicles and for five car based trip purposes:

- Commuting (home based work);
- Home Based Employers' Business;
- Other Home Based;
- Non Home Based Employers' Business; and
- Other Non-Home Based.

6.2.2 Time Periods

Matrices have been developed for three time periods for assignment:

- average AM Peak hour (0700-1000);
- average Inter Peak Hour (1000-1600); and
- average PM Peak Hour (1600-1900).

In addition, for demand modelling matrices were also developed for a full 24 hour day.

6.2.3 User Classes

Five user classes have been output from the process for highway network assignment:

- Car – Commuting;
- Car – Employers' Business;
- Car – other;
- LGV; and
- HGV.

At this stage the matrices are converted from person trips to vehicle trips using the average vehicle occupancy rates discussed in section 6.6.1.

6.2.4 Zone Structure

The original starting zone structure was designed based on MSOAs in accordance with the level at which the mobile phone data was to be provided.

The final zonal definition reflects the need to provide a consistent coverage over a wide area whilst recognising that the number of zones will have a direct impact on the run time of the model and therefore its suitability as a practical tool. It was determined at an early stage that a sensible limit would be of the order of 2,000 zones and furthermore, in accordance with standard modelling practice, zonal boundaries should be coincident with official administrative boundaries wherever possible.

In a similar fashion to the network development process, six levels were defined:

- Within 200m of SRN junctions, use LSOA definition as zone boundary;
- Between 200 and 500m of SRN junctions, use MSOA as the boundary;
- For the remainder of the non-urban area of focus (AoF) of the model, use aggregations of MSOA;
- For urban areas where capacity restraint not included in the network structure, utilise NTEM urban centre definitions to help aggregate;
- Beyond the AoF, an 'adjacent area' of further aggregation was devised, based on a district level grouping of LSOAs; and finally
- For the remaining areas, use groups of districts.

The final zone structure comprised 2,012 zones consisting of:

- 1,849 Simulation Zones; and
- 163 Buffer Zones

The zone plans are provided in Appendix I.

6.3 Approach in using the Provisional Data

6.3.1 Data specification

Mobile phone data records were produced by Telefonica for an average weekday in March 2015. In processing Telefonica allocate each trip origin and destination to a MSOA zone in England and Wales or an Intermediate Zone (IZ) in Scotland. Observed demand is then expanded, using Telefonica's estimate of market share within an area, to the overall population within each MSOA.

The provisional data set was so identified since it was an output from the early data processing carried out by Telefonica for the development of the TIS data system. It was derived more quickly than normally to achieve timescales dictated by the timescales for the Regional Models

Each Regional Model matrix development team were required to define a zoning system, based on groupings MSOAs and IZs for Telefonica to use for provision of the data. This was not necessarily the final model zoning system at this stage. A system of 2499 zones was defined for the TPS model data request which was subsequently rezoned to the final model zoning system.

Telefonica provided separate matrices for each of five trip types:

- Home based work – from home;
- Home based work – to home;
- Home based other – from home;
- Homebased other – to home; and
- Non home based.

Matrices were produced for each hour between 0500 and 1900 and for two overnight time periods 0000-0459 and 2000-2359 for each purpose based on the time of journey start.

6.3.2 Time Periods

Matrices have been developed for three time periods for assignment:

- average AM Peak hour (0700-1000);
- average Inter Peak Hour (1000-1600); and
- average PM Peak Hour (1600-1900).

In addition, for demand modelling matrices were also developed for a full 24 hour day.

6.3.3 User Classes

Five user classes have been output from the process for highway network assignment:

- Car – Commuting;
- Car – Employers' Business;
- Car – other;
- LGV; and
- HGV.

At this stage the matrices are converted from person trips to vehicle trips using the average vehicle occupancy rates discussed in section 6.6.1.

6.3.4 Limitations of the Mobile Phone Data

OD matrices estimated from mobile phone data have certain strengths compared to conventional data sources, which are of particular relevance to the Regional model. The mobile data provides a wider geographical coverage, a higher sample size, captures day to day variability of trips giving potential time and cost savings for data collection and processing.

However this is a relatively new type of data which are not collected exclusively for transport planning. There are key weaknesses and uncertainties associated with OD matrices derived from mobile phone data which include:

- **Definition of a trip** - to translate the mobile data records into trips Telefonica have necessarily defined a number of rules. A trip was defined as beginning when a phone is detected moving from one cell to another and ending when the phone remained within a single cell for at least half an hour. Clearly these rules limit the types of trips that can be identified, limiting the recognition of short distance and short stop over trips and can also register false trip ends if a phone fails to move between cells for 30 minutes on its journey
- **Spatial resolution and data accuracy** - the translation of cell records into zones depends on a perfect linkage between cell locations and MSOAs. It is known that phones can sometimes link to different cells from the same location at times and there is an imperfect match between cells and MSOAs.
- **Identification of short trips** - the identification of trips depends on identifying movement of phones between mobile cells. Trips made entirely within a cell would thus not be identified. In addition short trips of a short duration which do not stay at the destination zone for a sufficiently long time would not be identified as a trip. It is possible in this way that several short trips are chained into a single longer trip.
- **Identification of mode, vehicle type and vehicle occupancy** - Telefonica developed algorithms to identify rail trips and remove these from the dataset, other public transport and freight trips were not distinguished. Trip matrices represent person trips rather than vehicle trips and the technology is unable to produce occupancy rates for trips. This was highlighted by the fact that the first dataset provided by Telefonica purported to have rail trips removed. Initial analysis suggested that this process had not been fully successful and as a result a second complete dataset was provided and rail trips removed as a part of the matrix building process.
- **Identification of trip purpose** - trip purposes are defined in the data set in terms of home/non home and work/non work based trips. The home zone is defined within the process as the location where the phone appears to be overnight on most days and the work zone as the location where the phone appears to remain through most of the working day on most days. Clearly whilst this is realistic for a large majority of trips it will fail to correctly place shift workers and education trips would be identified as work trips.
- **Expansion of mobile data sample** - the mobile sample was expanded by Telefonica to the total population in the MSOA, using the ratio of individual analysed phones to total population. Issues considered were how representative of the total population were the trip records captured and the spatial accuracy of the allocation of phone home locations to MSOA.

Together these limitations informed the development of the processes defined by the TCG. The key problems anticipated with the data were that it might potentially:

- fail to accurately represent short trips due to zonal allocation and identification of the end of a trip;
- misallocate trips between neighbouring zones due to zonal allocation; or
- misrepresent trip purposes due to the definition of trip end purposes.

6.3.5 Initial Data Review

To examine the data received in the light of these expectations an initial set of data checks was undertaken. Full descriptions of the tests are given in Appendix A. A summary of the tests is shown in [Table 21](#).

Table 21 – Data Consistency Tests

Test	Data Check/Comparison	Analysis Approach	Test Criteria
A	Symmetry of origins to destinations	Regression analysis	Comparison of r^2 values ≥ 0.95 and slope close to unity
	All day trip origins and destinations against customised NTEM trip ends	Regression analysis	Comparison of r^2 values ≥ 0.90 and slope close to unity
B	Trip Rates	Compare mean values	Review against NTS data
C	Trip distribution	HBW from home v census	Comparison of r^2 values ≥ 0.95 and slope close to unity
D	Trip Length Profile	Compare distributions and means	Review against 95% CI of observed. CR ≥ 0.70
E	Trip purpose	Compare proportions	No criteria, comparison only. Look for material differences
F	Daily profile check	Compare profiles	No criteria, comparison only
G	Vehicle flows	Compare traffic volumes against counts on long screenlines	Differences $\leq \pm 20\%$ of observed at individual screenlines and $\pm 5\%$ of observed across all screenlines

These tests were designed to examine:

- the accuracy of the technology to identify trip origins and destinations at a zonal level;
- the ability of the technology to identify trips as measured by observed trip rates; and

- the ability of the technology to identify ranges of trips as measured by trip length.

A complete report on the application of these checks to the provisional data as received is provided in Appendix H of the data Collection Report. A summary of the key tests is given below.

Test A - Zonal Allocation -Symmetry

Scatterplots were produced to examine the symmetry between the “from home” matrices and the “to-home” matrices at an MSOA level. The results showed a very high degree of correlation and fit suggesting a consistency between from home origins and to home destinations.

The regression for combined purpose trips is shown in [Figure 9](#) and the correlation by trip purpose in [Table 22](#).

Figure 9 – Symmetry of Mobile Phone Data at MSOA level

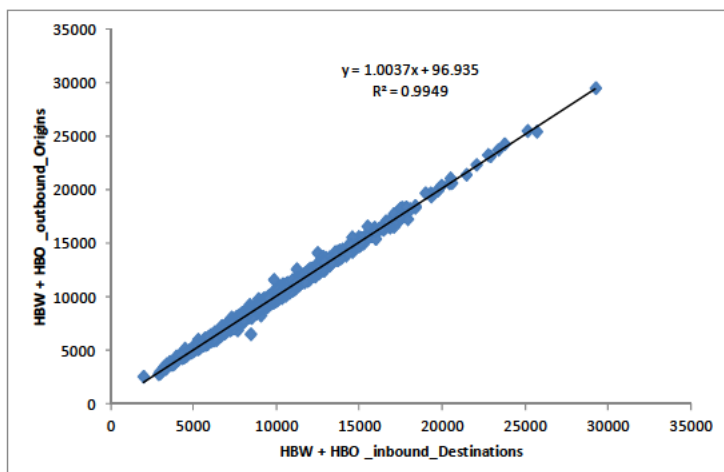


Table 22 – Symmetry of Mobile Phone Data at MSOA Level

	Slope	R ²
Work Trips	1.01	0.99
Non Work Trips	1.01	0.99

It was concluded that the consistency in zonal allocation for trip ends was good.

Test B - Trip Rates

Trip ends were examined by plotting trip ends against resident population at both an MSOA level and at a district level. Correlation statistics are shown in [Table 23](#) for MSOA and [Table 24](#) for District.

Figure 10 – District Level Trip Rates HBW

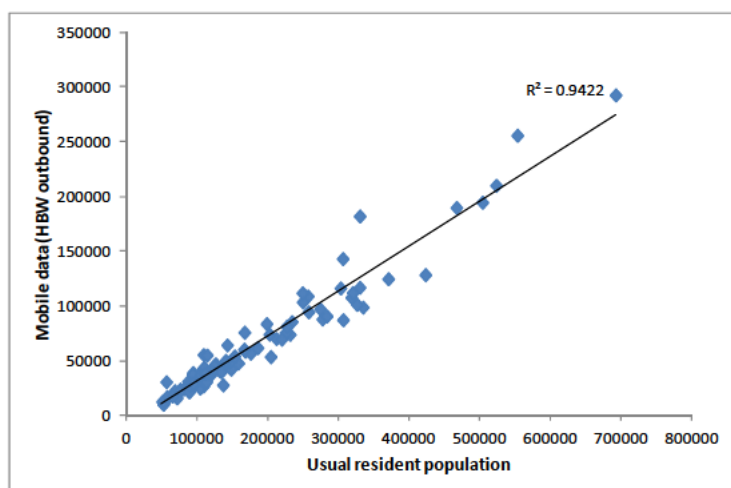


Table 23 – Relationship between Trips and Population at MSOA Level

Category	HBW			HBO		
	R ²	Intercept	Gradient	R ²	Intercept	Gradient
All MSOA	0.409	-181.5	0.381	0.457	-620.2	0.923
Urban	0.391	-2.2	0.346	0.449	-405.7	0.898
Rural	0.303	-92.9	0.277	0.393	-81.8	0.683

Table 24 – Relationship between Trips and Population at District Level

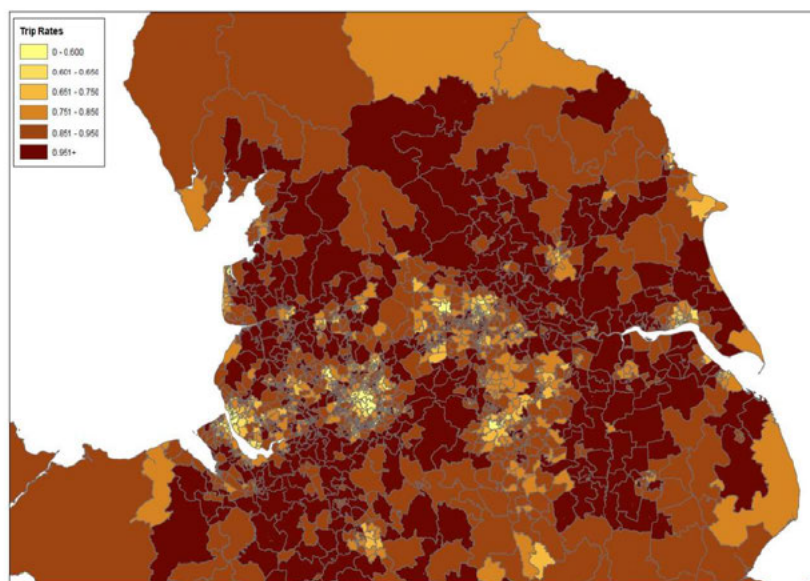
Category	R ²	Gradient
HBW	0.95	0.96
HBO	0.98	0.92
NHBO	0.99	0.80

The comparison between observed trips and population at an MSOA level shows a high degree of scatter however as zones are merged up to district level the relationship is much clearer.

Plotting trip rates in each MSOA shows a reasonably high level of homogeneity between neighbouring MSOAs, a sample is shown in [Figure 11](#).

A similar pattern was observed across the other regional models. Results suggest that the plots demonstrate that the misallocation of homes to MSOAs was minimal; however the detection of short trips may vary between different areas.

Figure 11 – Total Car Based Person Trip Rates per Day (All Purposes Combined at MSOA Level)



A comparison between the implied trip rates in the mobile data and rates from the trip end model were carried out. The results showed that while the mean trip rates were broadly similar, the spread of trip rates in the mobile data was much greater than that seen from NTEM rates applied at the MSOA level within the TPS model area.

The differences are shown in Figure 12 and Figure 13.

The process to account for, and correct, these differences is described in subsequent sections in this chapter (see section 6.5 onwards).

Figure 12 – Trip Rate Comparison (Mobile vs NTEM) HBW Origin Trips (MSOA Level)

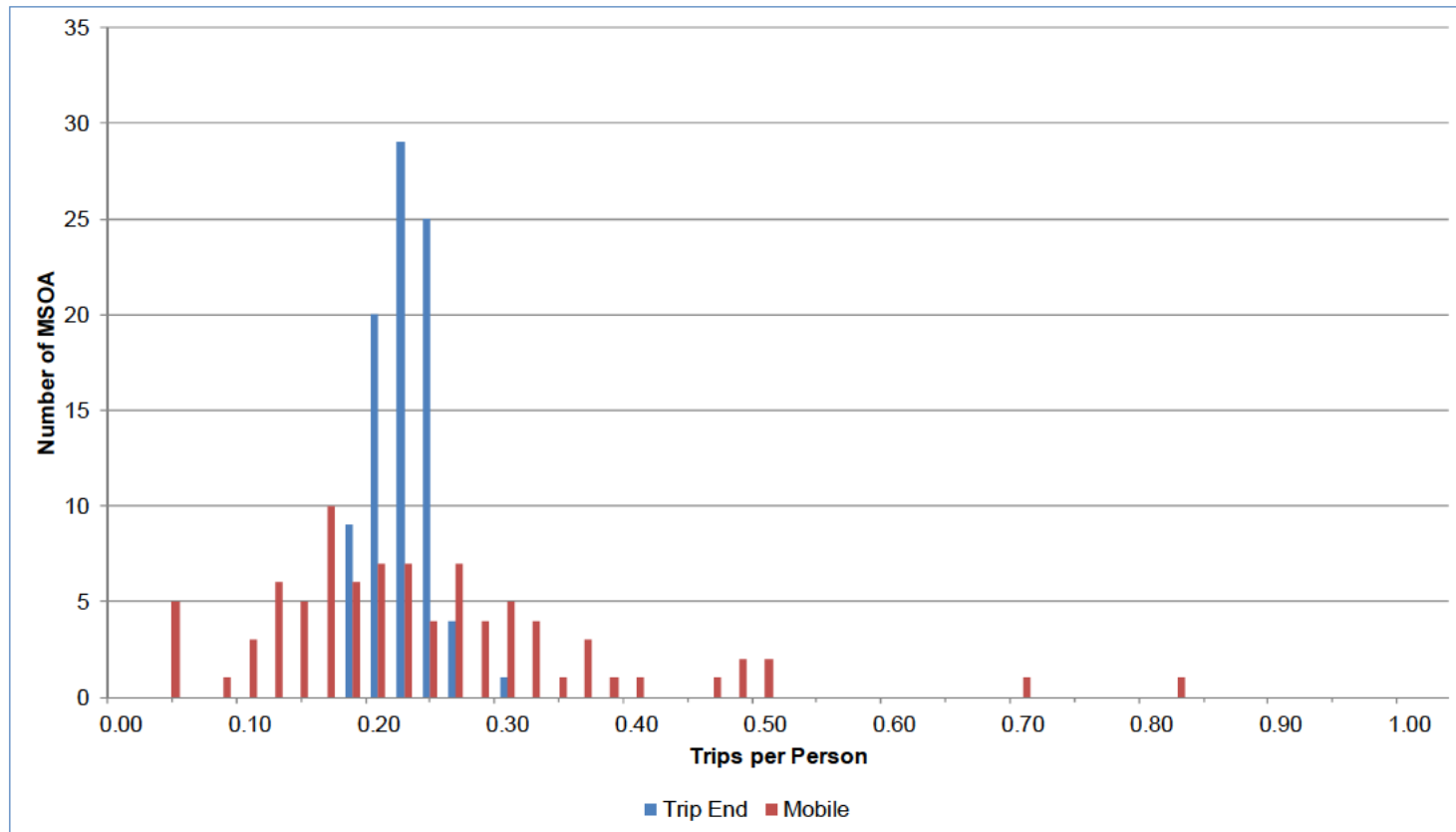
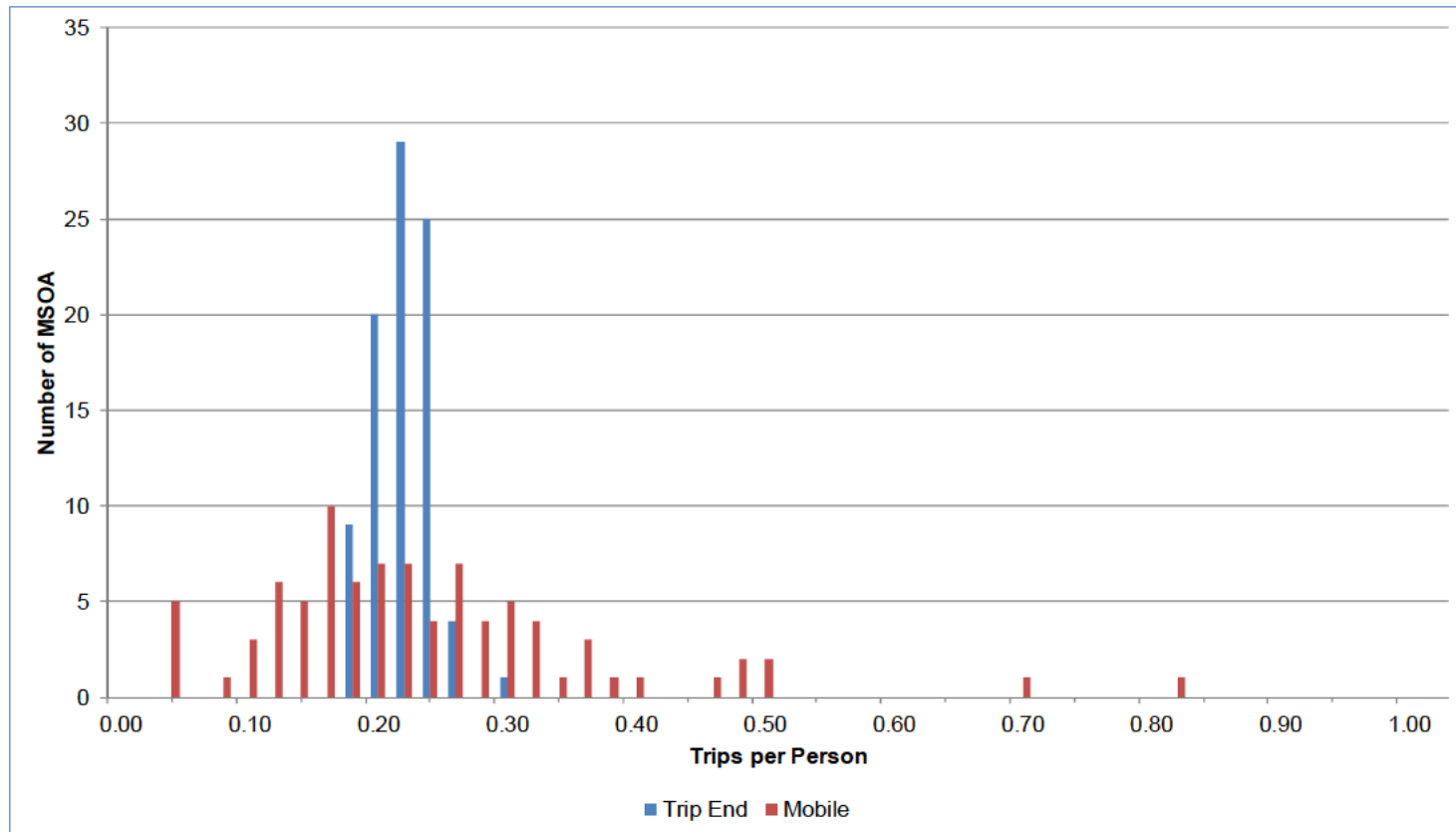


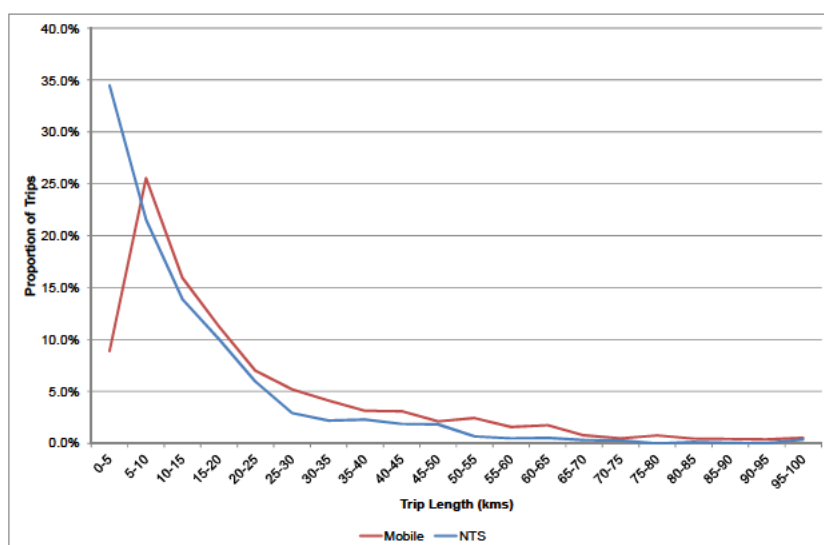
Figure 13 – Trip Rate Comparison (Mobile vs NTEM) HBO Origin Trips (MSOA Level)



Test D - Trip Length Profiles

Figure 14 shows a typical comparison between the trip length profile derived from the NTS data with that derived from the mobile phone data. A consistent finding for all purposes was that the shortest distance trips were under represented within the mobile data set.

Figure 14 – Trip Length Profiles



Test E – Trip Purpose

A comparison was undertaken of the trip purpose split between the provisional data set and independent data from NTS and NTEM 6.2 and is set out in [Table 25](#) below.

The results suggest a small over representation of commute trips and an under representation of non-home based trips.

Table 25 – Purpose Split Comparison

Purpose Split (Internal TPS area)			
Trip Purpose	NTS	Mobile Data	NTEM
HBW_FH	10%	12%	13%
HBW_TH	9%	12%	13%
HBO_FH	27%	30%	31%
HBO_TH	28%	29%	32%
NHB	26%	17%	11%

Test F – Daily Profile Check

The trip start time distribution was reviewed against the profiles derived from NTS. The results showed a greater spreading of work trips into off peak and inter peak periods than observed in the NTS data and a shortfall in HBO trips in the morning peak and inter peak. The latter may be a function of education trips being included within the work dataset.

Figure 15 – Comparison of Phone and NTS Trip Start Times (HBW)

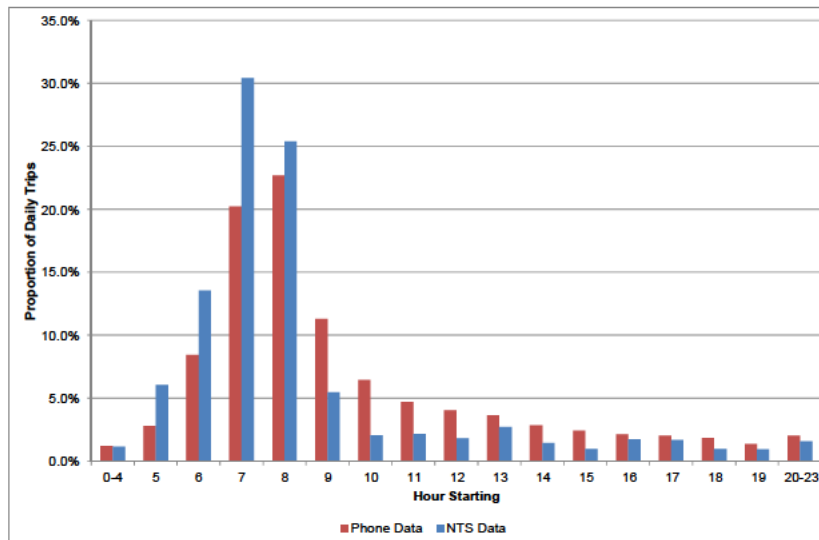
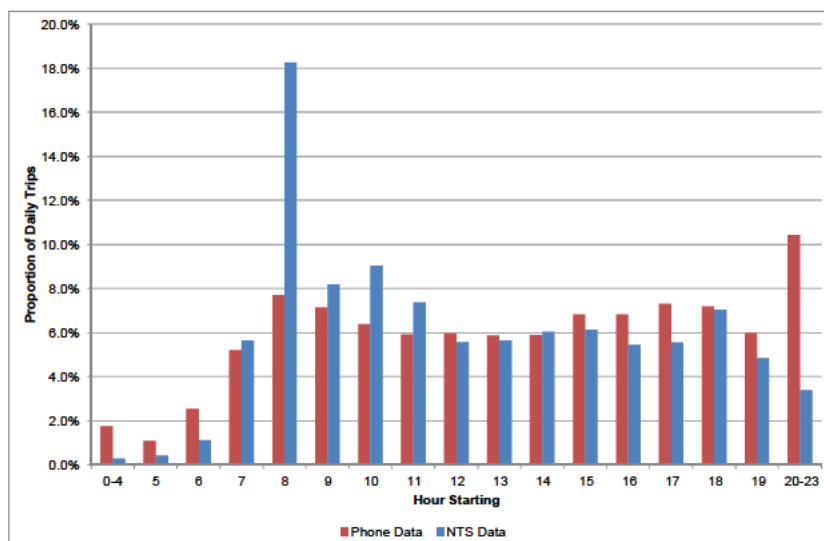


Figure 16 – Comparison of Phone and NTS Trip Start Times (HBO)



Test G – Vehicle Flows

Total demand within the matrix was compared with the demand from count data on long screenlines.

A series of long screenlines across the model area was defined for matrix checks. The complete set of screenlines is shown in Note: This comparison was made at an early stage in the development process and the screenline data contained estimated values. These numbers do not therefore directly compare with tabulations later in this report.

~~Figure 17~~Figure 47. For early stages of matrix development complete data was not available for each screenline, all complete screenlines were used for each test.

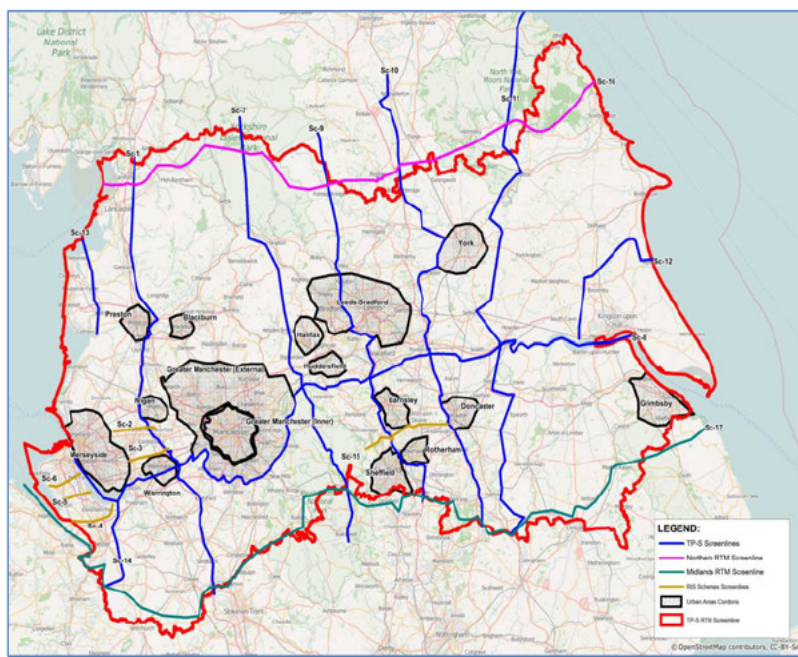
At this point in the process only two screenlines were complete and used in analysis. The results of the comparisons, shown in ~~Table 26~~Table 26, show that the demand in the matrices exceeded the observed flows on screenlines by 25 to 47%.

Table 26 – Comparison of Demand and Counts (12 hour two way all vehicle flow)

Ref	Screenline	Count	Matrix Demand	% difference
16	Northern	86,000	108,000	+25%
7	Pennine	93,000	121,000	+30%
12	Humber	38,000	56,000	+47%

Note: This comparison was made at an early stage in the development process and the screenline data contained estimated values. These numbers do not therefore directly compare with tabulations later in this report.

Figure 17 – Screenlines used for Matrix Checks



6.3.6 Conclusion of Initial Review

Overall the results from the symmetry and trip rate analysis demonstrated that the consistency of allocation to zones was good, and improved at the level of small groups of MSOAs.

The variability of trip rates and the trip length distribution tests show that there is a consistent under reporting of short distance trips within the data, which may vary from area to area in response to the size of the mobile cells.

Allocation to purposes demonstrates an over reporting of work trips and under reporting of non-home based trips.

Thus while the data set may be considered relatively representative of longer distance travel within the study area, there is a need for corrections to the data to allow for:

- issues in mobile data expansion bias;
- processing the data into the appropriate spatial resolution; and
- underestimation of short distance trips.

Other tasks necessary during further processing would be to:

- remove bus and rail trips from the dataset; and
- split between employers business trips and other non-commute trips.

To undertake this matrix processing the mobile phone data was supplemented with a set of synthetic matrices.

The development of the synthetic matrices is discussed in below.

6.4 Synthetic Matrix Build Process

Synthetic matrices were developed using the zone system created for the model.

Synthetic matrices were developed for car trips for each time period for each of five trip purposes:

- Home-based work;
- Home-base employer's business;
- Home-based other;
- Non home-based employer's business; and
- Non home-based other.

The matrices for the home based purposes were also split by from home and to home journey legs. The inputs to the synthetic matrix building process are:

- trip ends (attractions and productions);
- trip cost skims; and
- deterrence function.

Trip Ends

Trip ends for each zone were estimated using the Department for Transport's CTripEnd version 5 database package. This enables the estimation of trip ends for a user defined zoning system using functions calibrated for the National Trip End Model applied to current zonal populations and employment places. Thus the process is consistent with NTEM 6.2 forecasts.

Inputs for CTripEnd version 5 for each zone were derived from the 2014 MSOA level populations statistics Office for National Statistics (ONS) factored to 2015 by extrapolating the observed growth between 2011 and 2014.

Numbers of job places for each zone for 2014 were available from the official labour market statistics database, NOMIS, these were factored to 2015 values using growth at a county level.

Version 5 of CTripEnd is based on the trip rate parameters used in NTEM6.2 calibrated during the 1990s. It is known that trip rates have declined since this period, an issue being addressed in the new NTEM version 7.

It became clear during data processing that trip rates in the CTripEnd data were higher than those observed in the mobile data and count data. Consequently, as an interim measure, NTS data was used to produce correction factors for CTripEnd to reduce trip rates to 2015 levels. A set of factors by purpose and Government Office Region were produced and used to adjust the CTripEnd outputs.

These factors were applied consistently across all Regional models. The process and the factors are documented in the TCG Note "Synthetic Matrix Trip-End Adjustments" in Appendix B.

Trip Cost Skims

Cost skims were derived from a preliminary fixed link speed version of the TPS SATURN network. Link travel times were sourced from 2015 Trafficmaster data. Costs were calculated in terms of generalised minutes generated from the network model using values of time and distance by trip purpose from the current WebTAG data book.

Deterrence Functions

Deterrence functions were calculated for each trip purpose by fitting log-normal functions to observed distributions of trip numbers within each generalised cost band derived from the National Travel Survey (NTS). For this purpose, NTS data were obtained for each district within the TPS model area and to ensure current travel patterns were reflected only the most recent survey records collected during the period 2012 to 2014 were used. Where needed units have been converted to minutes and the parameters expressed in a standard lognormal form.

$$\frac{1}{C_i \sigma \sqrt{2\pi}} \exp\left(\frac{-(\ln C_i - \mu)^2}{2\sigma^2}\right)$$

Where C is the generalised cost
 σ and μ are the fitted distribution parameters

Purpose built software was used to calculate deterrence functions and to fit these to the CTripEnd trip ends and model skimmed costs. The parameters of the functions fitted are shown in [Table 27](#).

Table 27 – Deterrence Function parameters

Purpose	Mu (μ)	Sigma (σ)
HBW	1.9 – 2.2	0.7 – 1.0
HBEB	1.8 – 2.5	0.5 – 1.0
HBO	2.0 – 2.3	0.3 – 0.4
NHBEB	2.0 – 2.4	0.4 – 0.9
NHBO	2.1 – 2.4	0.3 – 0.8

Plots showing a comparison between the observed and fitted trip length distributions for each trip purpose are shown in Appendix C.

6.4.1 Vehicle Occupancy

The mobile data were provided in terms of person trips. For assignment to the network it is necessary to convert the matrices to vehicle trips. This requires an estimate of the number of persons per vehicle.

Occupancy rates were calculated using NTS data for the TCG. Commute and employers' business trips use a fixed occupancy rate whereas the other purpose trips use an occupancy rate that increases with distance travelled.

The process used and the calculated rates are documented in the TCG Note on Vehicle Occupancies included in Appendix D.

6.5 Prior Matrix Development - Stage 1

6.5.1 Overview

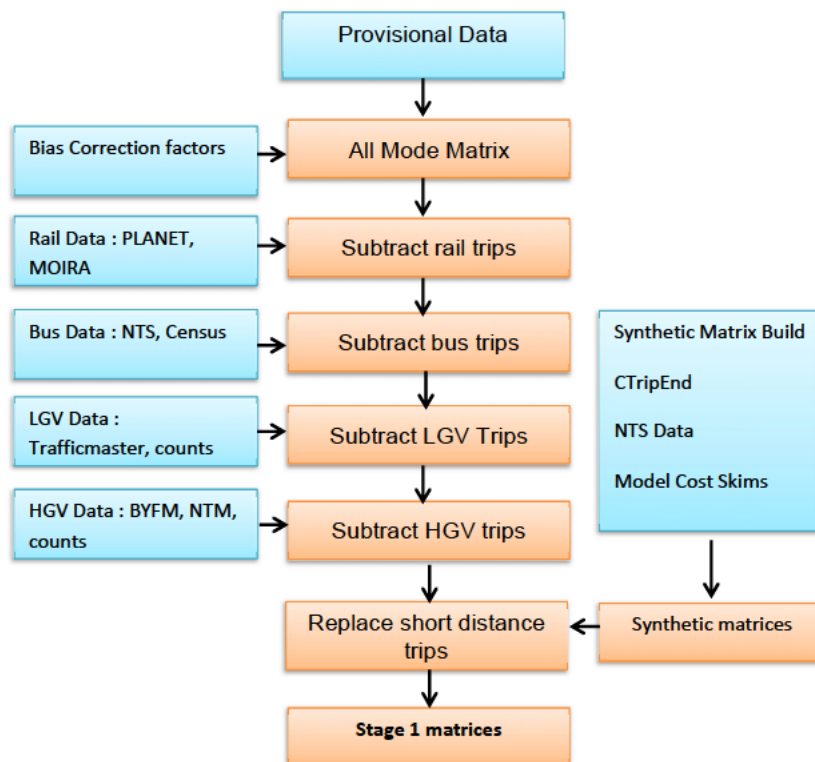
The matrix building process was undertaken in a number of stages with the intention that at the end of each stage the matrices would be reviewed against the criteria outlined in [Table 21](#) above. On the basis of these tests either the matrices would be accepted or further work would be identified to improve the matrices.

The first stage of the matrix development, defined by the TCG, consisted of the sequence of tasks illustrated in [Error! Reference source not found.](#). The objectives of this stage were to:

- isolate car trips within the mobile data set; and
- adjust for biases and other issues identified in the initial review.

These steps were specifically developed to target the specific issues in the expansion of mobile phone samples, identification of mode and identification of short trips discussed in section 6.4.3.

Figure 18 – Stage 1 Matrix Build Process



6.5.2 Bias Correction Factors

A discussion within the TCG revealed that in all five models the mobile data overstated traffic by some 30-40% relative to counts on long screenlines and that in some cases the mobile data trip lengths were longer than suggested by NTS.

This highlighted the potential for sampling bias within the dataset which was investigated for the TCG; the particular bias considered was that trip patterns of mobile phone users in terms of frequency and distance are probably greater than those of the overall population. In particular that phone use is more limited in the very young and the elderly age groups. Two specific sources of bias were considered particularly critical and a common process across all five models was applied to correct for these.

These were:

- trip rate – to correct for the assumption that trips by mobile phone users are representative of the total UK population
- trip length – to correct for differences in trip length distribution between mobile users and the general population

These factors were applied to each of the matrices received from Telefonica, using distances skimmed from the TPS SATURN network, prior to any further processing as set out in [Table 28](#) below.

Table 28 – Bias Correction Factors Applied to Provisional Data

Distance Band (km)	Bias Correction Factor		
	Trip Length	Trip Rate	Total
0-5	1.105	0.936	1.034
5-10	0.959	0.936	0.898
10-15	0.923	0.936	0.864
15-20	0.904	0.936	0.846
20-30	0.889	0.936	0.832
30-40	0.875	0.936	0.819
40-50	0.866	0.936	0.811
50-100	0.856	0.936	0.801
100-300	0.843	0.936	0.789
300+	0.852	0.936	0.797

The calculation of these factors was documented in a Technical Note prepared for the TCG included as Appendix E.

6.5.3 Identification of Rail Trips

Development of rail matrices

Rail demand matrices form an input to the TPS Demand model and were developed for the demand model from the Planet North model and from Moira data. These were produced separately for home based work, home based other and non-home based purposes and disaggregated to the TPS model zoning system.

The process is described in Chapter 10.

Remove Rail Trips from Provisional Data Set

To remove rail trips from the prior mobile phone data these were subtracted from the appropriate trip purpose matrices.

Where the removal of rail trips would leave a negative cell value zones were aggregated to a district level and trips removed were spread over the district.

6.5.4 Identification of Bus Trips

Development of bus matrices

There is no national dataset available to identify the bus trips within the provisional data set. Since the set must include significant numbers of bus trips a method was required to identify and remove these from the dataset.

The most comprehensive data on bus travel is the Census Journey to Work dataset derived from the 2011 census. This dataset provides origin to destination commute trips at an MSOA level. Although absolute numbers within the census data do not directly represent typical daily trips the mode shares have been taken as typical for daily travel. These data were translated into model zones and hourly zone to zone bus matrices were developed for HBW purposes.

There is no similar dataset for trips other than journey to work thus an alternative approach was used for non-work trips.

The National Travel Survey data was used at a district level to estimate the relative mode shares for home base work bus trips to other purpose bus trips within each district and for district to district movements. This provided the expected proportion of district to district trips within the provisional data set that would have been made by bus.

The variability of public transport service provision dictates that within each district trips from some zones or between certain zone pairs will be more likely to use bus than other movements. It was assumed that this variety would be reflected in the journey to work data and so this was used to identify the relative probability of bus use for trips between each zone pair.

Thus individual movements were related to patterns from the census journey to work data, but overall numbers of trips were controlled by National Travel Survey mode shares.

It proved difficult to isolate numbers of longer distance bus trips, and since these are expected to be very low bus demand between any origin – destination pair between two different Government Regions was set to zero.

In this way bus matrices for non-work purposes were produced for each hour of the day.

This analysis provided percentage mode shares for bus for each purpose between each OD pair. These proportions were applied to the overall mobile phone dataset to derive bus OD matrices in terms of person trips.

Removal of Bus Trips from Provisional Data Set

The bus matrices were then subtracted from the provisional data set at a zonal level. Where this was found to create negative cell values zones were merged and the absolute number of trips was removed across the district.

6.5.5 Identification of LGV Trips

Development of Prior LGV matrices

The prior LGV demand matrices were derived from a Trafficmaster data set which was common to all Regional models. The dataset provided details of origin, destination, start time and travel distance for all trips made by Trafficmaster equipped LGVs for a complete month in March 2015. Origins and destinations were given at an MSOA level.

These data were used to create a set of hourly average weekday MSOA to MSOA trip matrices for LGV trips which was shared across all five Regional models. MSOAs were combined as necessary to create matrices at the TPS zoning level. Where disaggregation of MSOAs was required it was based on zonal employment statistics.

This represents a sample matrix since only a small proportion, probably around 2%, of vehicles is equipped. It is believed however that those vehicles represented within the sample might generally be expected to travel greater distances than those not equipped.

To expand the sample to represent a full matrix, all or nothing assignments were carried out for each peak period and the ratio of LGV counts to LGV assigned flows on each long screenline were calculated.

A matrix of the 24 hour Region to Region prior LGV trips developed is given in [Table 51](#)~~Table 54~~. These matrices form the basis of the final LGV matrices derived during matrix estimation within the model calibration stage described in Chapter 8.

Removal of LGV Trips from Provisional Data Set

The resulting LGV matrices were subtracted from the provisional mobile data.

Analysis of the local NTS dataset was carried out to examine the split in trip purpose for LGVs, and trips were removed from the matrices accordingly. The proportion from each matrix is shown in [Table 29](#)~~Table 29~~.

Table 29 – Proportion of LGV Trips removed from each matrix

Purpose	Direction	Proportion of LGV Matrix
Home based work	From Home	19%
	To Home	17%
Home Based Other	From Home	22%
	To Home	23%
Non Home Based		19%

Where the removal of LGV trips would leave a negative cell value zones were aggregated to a district level and trips removed were spread over the district. In all cases the differences were small, however this will have the impact of smoothing the distribution of trip ends for LGV trips, which were drawn from a

small sample; however would underestimate the impact of zones with a large volume of LGV production or attraction. The impact on the SRN is expected to be small. LGV matrices were available at an hourly level and trips were removed from the appropriate hourly matrix.

6.5.6 Identification of HGV Trips

Development of Prior HGV Matrices

Prior HGV trips were generated from the Department for Transport's Base Year Freight Matrix (BYFM) data described in the Data Collection Report.

The matrices are based on a zoning system representing district authority areas and a number of special zones representing ports, airports, major distribution centres and other large attractors of HGV movements.

The district to district matrices were disaggregated to the TPS zoning system in proportion to the numbers of work places in each zone. Special zones were allocated manually to the TPS zone representing the area in which the special zone lies.

The BYFM matrices represent an average 2006 daily flow. The matrix was factored to 2015 on a regional basis using growth rates from the National Transport model. The changes in HGV vehicle kilometres rate calculated between 2006 and 2015 are shown by Government Region in [Table 30](#). The results show an overall decline in HGV traffic between 2006 and 2015, mainly due to the fall in demand during the period 2008 to 2012. Growth factors were applied on the basis of origin zone for each OD pair.

Table 30 – Change in HGV veh km (2006 – 2015)

Region	Change
North East	0%
Yorks & Humber	-11%
East Midlands	-14%
Eastern England	-5%
South East	-4%
London	-14%
South West	-7%
West Midlands	-10%
North West	-9%
England	-8%
Wales	-13%

A single 24 hour HGV matrix was developed from this dataset. The region to region HGV trip matrix is given in [Table 31](#).

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Table 52

Table 52 . This matrix formed the prior matrices for input to the matrix estimation process used during the model calibration stage described in Chapter 8.

Removal of HGV Trips from Provisional Data Set

The HGV matrices were converted to person matrices, using an occupancy value of 1.00, which were then subtracted from the provisional mobile data.

HGV trips were all subtracted from the non-home-based trips matrices. The HGV matrix was a single 24 hour matrix and the mobile data was aggregated to a 24 hour total to remove HGV trips. An average hour HGV matrix was used as the basis for matrix estimation for HGV trips.

Where the removal of HGV trips would leave a negative cell value zones were aggregated to a district level and trips removed were spread over the district. Since the original HGV data were specified at a district level there is no loss of accuracy in this process.

6.5.7 Replacement of short distance trips

The comparison of trip length distributions reported in Section 6.3.5 showed that the provisional data set under represented shorter distance trips. To avoid this problem short distance trips in the provisional data were removed completely and replaced by trips from the synthetic matrices.

From examining the comparisons of NTS and mobile data short distance trips were defined as being those under 7 kilometres in urban areas and 25 kilometres in rural areas. These distances were identified on the basis of comparing trip length distributions to find the point at which the profiles diverged.

The impact on this, in terms of proportions of the remaining matrices that are represented by synthetic data is shown in **Table 31**.

Table 31 – Split Between Synthetic and Provisional Data in Matrices

Purpose	Trip Numbers	Vehicle Kilometres
HBW	40%	14%
HBO	68%	24%
NHB	44%	8%
Total	43%	17%

The results demonstrate that 43% of trips in the matrices are taken from the synthetic matrices, although only 17% of vehicle kilometres on the network are taken from the synthetic matrices. Thus 83% of vehicle kilometres on the highway network are drawn from the mobile phone data set.

This demonstrates that in the assignment the greater proportion of trips on each network link would be drawn from the observed provisional data set and that for the most part assigned trips on the SRN retain the integrity of the mobile phone dataset at this stage in the process.

6.5.8 Time of Day Adjustment

The matrices provided by Telefonica and the Trafficmaster LGV matrices were initially grouped by hour according to the time of the start of the journey. For trips with an origin a long distance from the modelled area the start time would be significantly different to the time the trip arrives in the cordon, thus adjustments were made within the matrices for longer distance trips.

The travel time from each zone to the edge of the modelled area was derived from the model. For trips with a travel time of between half and one and a half hours the matrix trips for each period were replaced by trips from one hour earlier, for travel times of 1.5 – 2.5 hours from two hours earlier and so on.

6.6 Matrix Assessment after Stage 1

This step represented the end of stage 1 of the matrix building process, having removed all non-car based trips from the dataset and corrected for unobserved or inaccurately represented shorter distance trips.

At this stage the comparisons carried out on the original provisional data were repeated to verify the matrices against observed data. This involves an assessment of:

- trip length distribution; and
- trip rates.

Test A – Trip Ends

As an example ~~Figure 19~~[Figure 19](#) shows a comparison between home based work from home total trips generated within each district authority as generated within the synthetic matrices using the CTripEnd process with the equivalent number within the provisional data set. The results show a very high level of correlation between the two, with an R2 statistic of 0.92, however the gradient of the line suggests that the Processed Stage 1 data set overestimates total numbers of trips by around 15%.

~~Table 32~~[Table 32](#) provides the corresponding gradients and correlations for comparisons for all trip purposes, in which all comparisons demonstrate reasonable level of correlation between NTEM and Stage 1 trip ends, which indicates a good fit between population types and trip numbers, but significant and widely fluctuating errors in overall trip numbers.

Figure 19 – Comparison of Stage 1 and NTEM6.2 Trip Ends (origin)

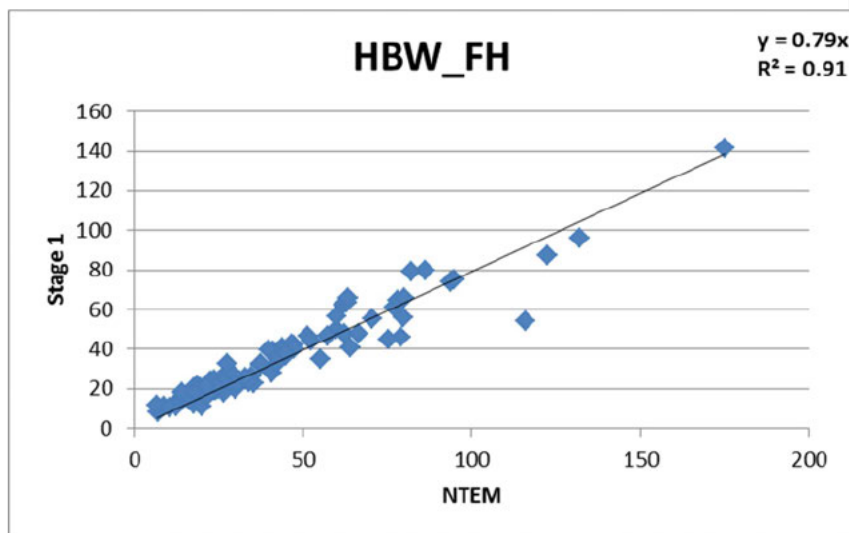


Table 32 – Comparison between NTEM6.2 and Stage 1 data

	Trip Origins		Trip Destinations	
	Gradient	R ²	Gradient	R ²
HBW – (from home)	0.79	0.91	0.74	0.85
HBW – (to home)	0.75	0.85	0.80	0.91
HBO – (from home)	1.15	0.88	1.14	0.88
HBO – (to home)	1.13	0.88	1.13	0.90
NHB	1.36	0.85	1.37	0.84

Test B – Trip Rates

The calculated daily trip rates in the area of focus within the mobile data set with short distance trips replaced were as shown in [Table 33](#). This shows a closer match between the average NTS over the model area and the implied rates for the model.

Table 33 – Comparison of modelled and observed trip rates

	Revised Matrices	NTS	Difference
Home based	1.47	1.52	-5%
Non home based	0.27	0.27	0%

Test D - Trip Length distribution

A comparison between the trip length distribution in the car matrices (following removal of all other modes) before and after the replacement of short distance

trips from the synthetic matrices are shown in Figure 20 to Figure 23. Overlaid on these plots is the trip length distribution obtained from the NTS data. The results show that with the short distance trips replaced the distribution is closer to the NTS; however there is still a tendency to overestimate the numbers of longer distance trips.

Figure 20 – Stage 1 HBW (Urban Trips)

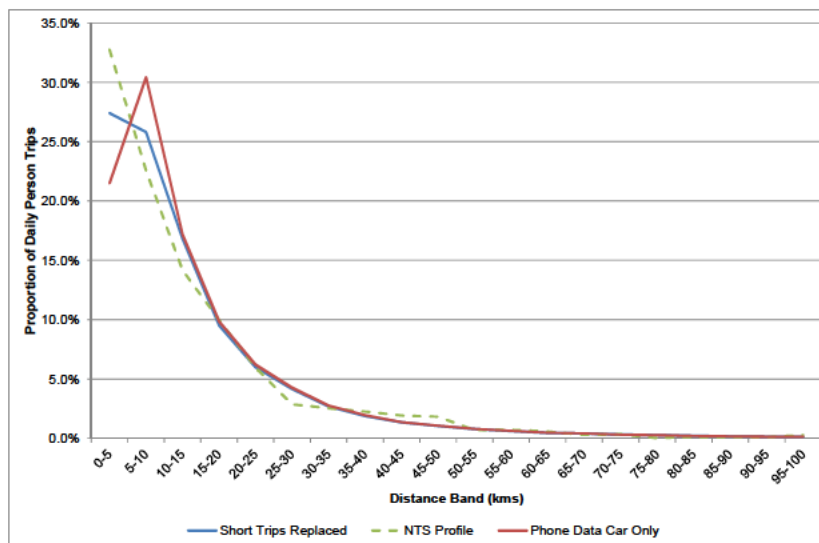


Figure 21 – Stage 1 HBW (Rural Trips)

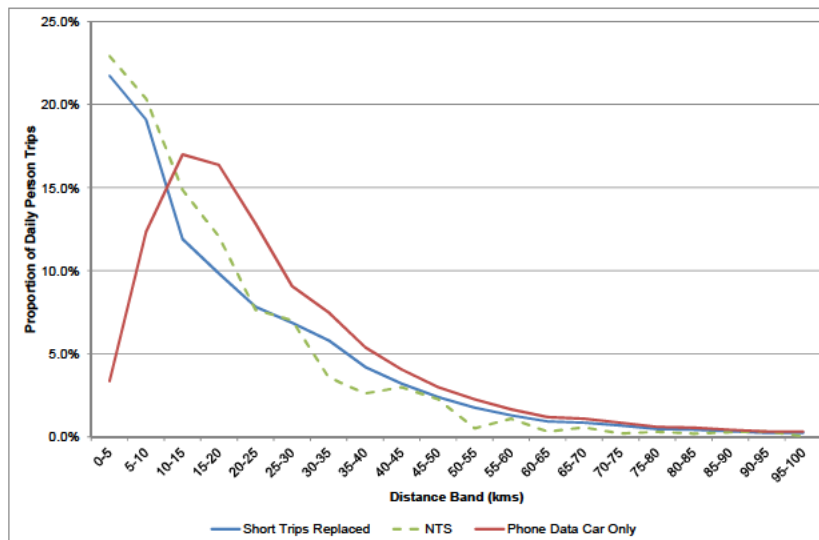


Figure 22 – Stage 1 HBO (Urban Trips)

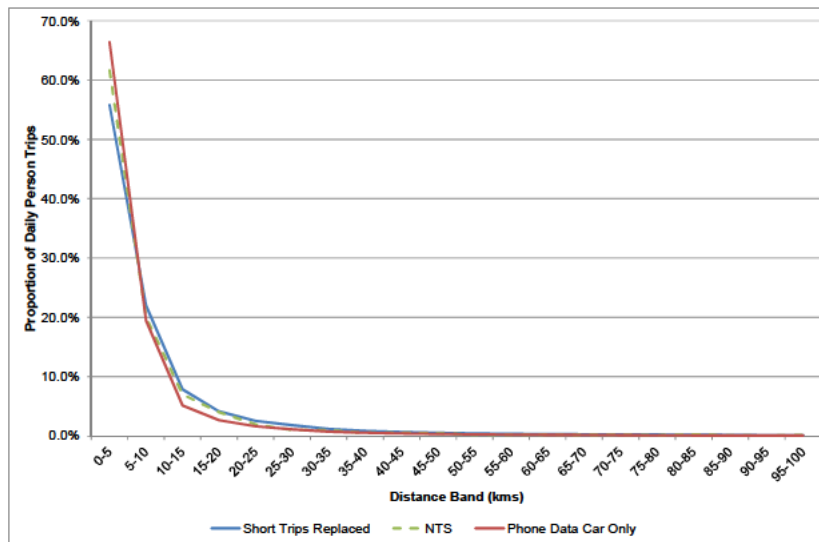
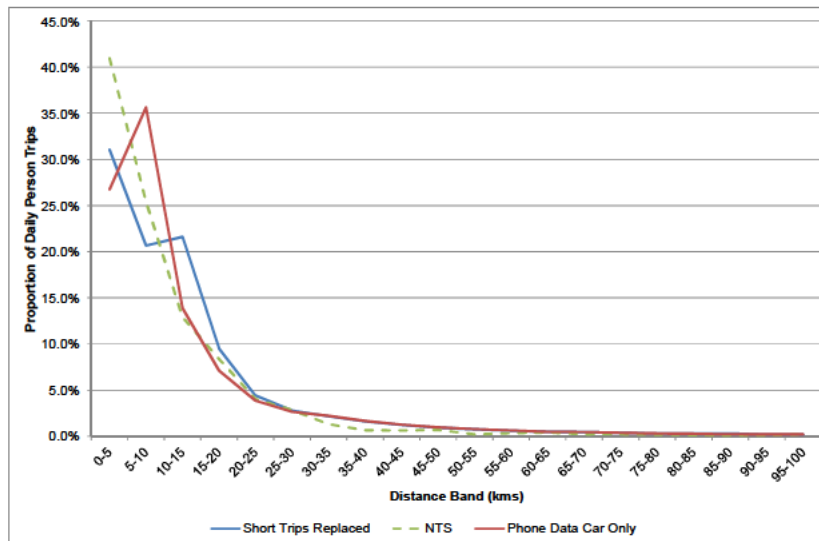


Figure 23 – Stage 1 HBO (Rural Trips)



Test E Trip Purpose

Table 34 and Table 35 show the split between purpose in the stage 1 mobile data set and NTEM data for both the TPS area and nationally.

The results show that the mobile data over estimates trip making overall, although the purpose splits show a similar profile to NTEM.

Table 34 – Comparison between NTEM and Stage 1 Car dataset (TPS Area)

Purpose	Mobile	NTEM	Diff. wrt. NTEM	Purpose Split Mobile	Purpose Split NTEM
HBW_FH	3,016,835	2,308,334	30.7%	12.9%	11.2%
HBW_TH	2,946,210	2,245,876	31.2%	12.6%	10.9%
HBO_FH	6,923,366	6,735,294	2.8%	29.6%	32.7%
HBO_TH	6,907,544	6,772,218	2.0%	29.5%	32.9%
NHB	3,593,211	2,512,365	43.0%	15.4%	12.2%
Total	23,387,167	20,574,088	13.7%	100.0%	100.0%

Table 35 – Comparison between NTEM and Stage 1 Car dataset (National)

Purpose	Mobile	NTEM	Diff. wrt. NTEM	Purpose Split Mobile	Purpose Split NTEM
HBW_FH	12,645,671	11,010,992	14.8%	12.3%	11.3%
HBW_TH	12,229,805	10,643,943	14.9%	11.9%	10.9%
HBO_FH	29,625,660	31,792,314	-6.8%	28.8%	32.5%
HBO_TH	29,514,937	32,093,051	-8.0%	28.7%	32.8%
NHB	18,781,835	12,162,633	54.4%	18.3%	12.4%
Total	102,797,908	97,702,934	5.2%	100.0%	100.0%

Test G - Screenline flow comparison

~~Table 36~~Table 36 shows a comparison between traffic counts and the demand, converted to vehicles, across long screenlines within the modelled area. This shows that the demand in the matrices exceeds the counted traffic by around 30% on average with a range pf 19% to 79%. Flows were obtained by assigning the 24 hour matrices to fixed time network using an all or nothing assignment.

Table 36 – Screenline Flow Comparison After Stage 1 (Cars)

	Screenline	Count	Model	% Difference
1	M6	359,000	496,000	38%
2	Pennine	111,000	159,000	43%
3	Humber / Mersey	382,000	481,000	26%
4	Leeds / Sheffield	374,000	475,000	27%
5	West of York	244,000	346,000	42%
6	East of York	110,000	169,000	54%
7	Humberside	43,000	77,000	79%
8	Fylde Coast	55,000	80,000	46%
9	Mid Cheshire	72,000	93,000	29%
10	Northern Border	98,000	149,000	52%
11	Southern Border	356,000	425,000	19%
	Total	2,204,000	2,950,000	34%

6.6.1 Conclusions

The results demonstrate that the data sets derived from the mobile phone data, once the short trips had been replaced by synthetic trips bear a high level of correlation with the trip end profiles at a district level generated from population, employment and observed trip rates.

The comparison with the major screenlines however demonstrates that the mobile phone data set contains in general too many trips. It shows remaining significant differences between the provisional data at the end of the Stage 1 matrix build process and the observed data. The key issues identified were that:

- assignments demonstrated that the provisional data overstated flows on long screenlines by over 30%;
- the provisional dataset overstated the proportion of long distance trips; and
- the provisional dataset understated observed trip rates

These findings were consistent across all five Regional Models. It was concluded that although the bias corrections had been successful in bringing the modelled demands closer to the NTS observed levels, there remained biases within the data set and that to enable the model to be successfully calibrated that specific structural modifications to the dataset must be made to bring key measures closer to observed values.

6.7 Prior Matrix Development - Stage 2

6.7.1 Overview

To improve the fit between the provisional data and observed travel characteristics the TCG identified further modifications to the dataset. It is acknowledged at this stage that these steps will necessarily distort the mobile phone data set such that it no longer represents pure observed data; however the tests have shown that the data set does not fit other observed data sets so these changes are inevitable.

Two sets of adjustments were applied:

- trip end factoring to match observed trip rates by purpose within each time period; and
- trip matrix factoring to adjust trip length distributions by purpose over the 24 hour period.

The method of application is discussed below.

6.7.2 Adjustment for trip end totals

To correct for the differences, the demand matrices were scaled to match trip rates by purpose and time period from the CTripEnd calculation, modified as described in Section 6.6 to account for observed trip rate changes since the development of the NTEM6.2 process.

Separate factors were applied for each purpose for the three peak periods at a county level to ensure that total productions and attractions of trips reflected the totals within the synthetic matrices.

Through trips with origin and destination outside the core area were left unchanged, these are adjusted in line with the other regional models as discussed in section 6.9.3 below.

6.7.3 Adjustment to Trip Length

To correct for errors by distance factors were applied to the matrices depending on trip length. These factors were derived from the comparisons between Stage 1 matrices and NTS trip length profiles and are shown in [Table 37](#) and [Table 38](#).

Table 37 – Adjustment Factors – Urban Trips

Band (km)	HBW	HBO	NHB
0-10	1.07	0.99	1.24
10-25	0.92	1.12	0.83
25-50	0.96	0.85	0.41
50+	0.83	0.90	0.42

Table 38 – Adjustment Factors – Rural Trips

Band (km)	HBW	HBO	NHB
0-25	1.18	1.04	1.23
25-50	0.69	0.81	0.57
50+	0.45	0.65	0.38

6.8 Matrix Assessment after Stage 2

This step represented the end of stage 2 of the matrix building process.

At this stage the comparisons carried out on the original provisional data and the Stage 1 were repeated to verify the matrices against observed data. This involves an assessment of:

- trip length distribution;
- trip rates; and
- flows on major screenlines.

Test A – Trip Ends

[Figure 24](#) shows a comparison between total trips generated within each district authority as generated within the synthetic matrices using the CTripEnd process with the equivalent number within the Stage 2 data set.

Clearly since the first stage of the adjustment process was to control trip ends to synthetic trip ends at a county level then there should be a high level of fit for these movements.

A comparison of this figure with the equivalent comparison at the end of stage 1 shows that the R^2 statistic has increased to 0.99 and the gradient of the line now suggests that on average the provisional data set matches the CTripEnd values. This demonstrates that the process has been successfully applied and resolved the issue identified at the end of stage 1. It also demonstrates that the results are consistent at a district level within counties.

Table 39 provides the corresponding gradients and correlations for comparisons by trip purpose, in which all comparisons demonstrate a significantly improved correlation between NTEM6.2 and post stage 2 matrices, which indicates a good fit between population types and trip numbers, but errors in overall trip numbers.

Figure 24 – Comparison of Stage 2 and Adjusted NTEM 6.2 Trip Ends (origin)

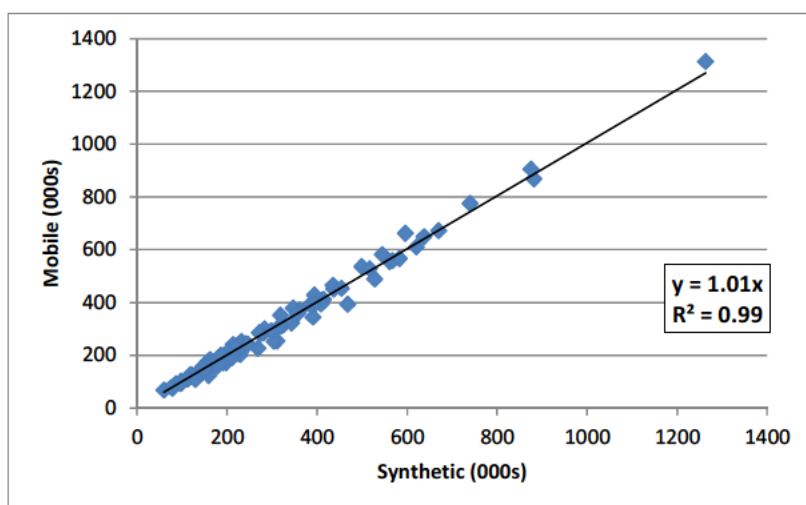


Table 39 – Fit between Adjusted NTEM 6.2 and Stage 2

	Trip Origins		Trip Destinations	
	Gradient	R ²	Gradient	R ²
HBW – (from home)	1.00	1.00	0.93	0.91
HBW – (to home)	0.93	0.92	1.00	1.00
HBO – (from home)	1.00	1.00	1.00	1.00
HBO – (to home)	1.00	0.94	1.00	1.00
NHB	1.00	0.99	0.96	0.97

Test B - Trip Rates

A further comparison was made to compare implied trip rates within the matrices with trip rates calculated from 2012-2014 NTS data. **Table 40** shows a comparison between NTS data at a county level and the trip rates within the matrices. The results suggest that over the region as a whole the matrices match overall trip rates, and at county level there is a high degree of correspondence between the NTS surveys and the matrix values.

Table 40 – Comparison of Matrix and NTS Trip Rates (trips/person/day)

County	Trip Rate (NTS)	Trip Rate (Matrices)
Cheshire	1.87	1.82
Greater Manchester	1.60	1.57
Humberside	1.82	1.65
Lancashire	1.63	1.62
Merseyside	1.43	1.44
North Yorkshire	1.70	1.66
South Yorkshire	1.76	1.65
West Yorkshire	1.71	1.72

Trip rates vary within counties shows the distribution of home based trip rates at a district level comparing NTS rates with the matrices.

Test D - Trip Length distribution

A comparison between the trip length distribution in the adjusted matrices and the trip length distributions calculated from the NTS data is shown in Figure 25 to Figure 28. Since the relationship between NTS and the Stage 2 matrices is largely dependent on the factors applied then the close fit demonstrated by the results shows that the adjustments had the desired effect and brought the distribution within the matrices closer to the NTS observed values.

Figure 25 – Stage 2 HBW (Urban Trips)

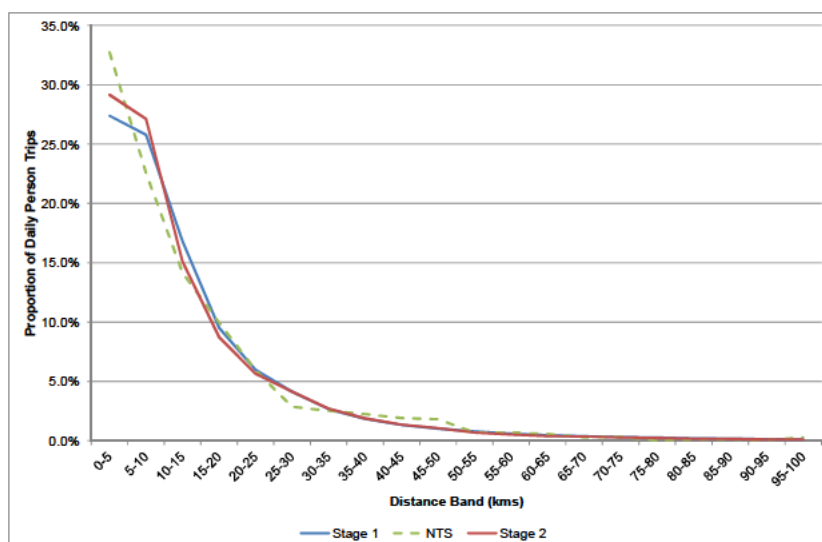


Figure 26 – Stage 2 HBW (Rural Trips)

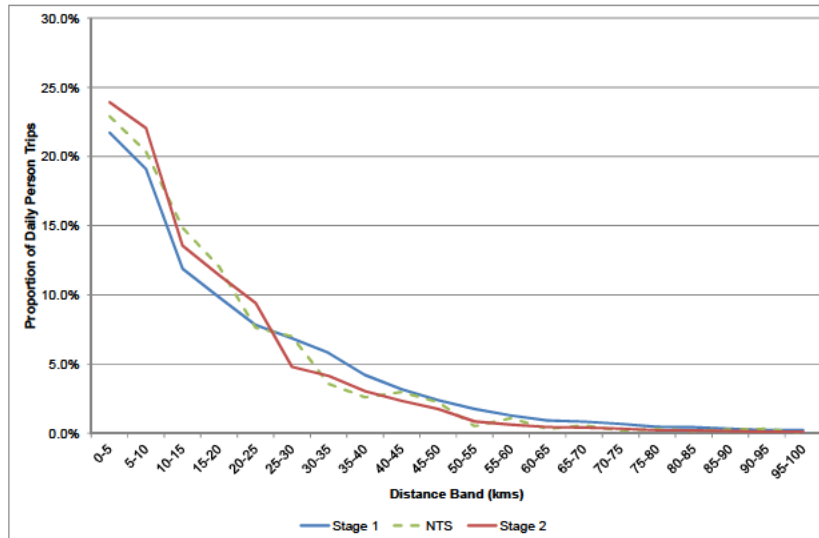


Figure 27 – Stage 2 HBO (Urban Trips)

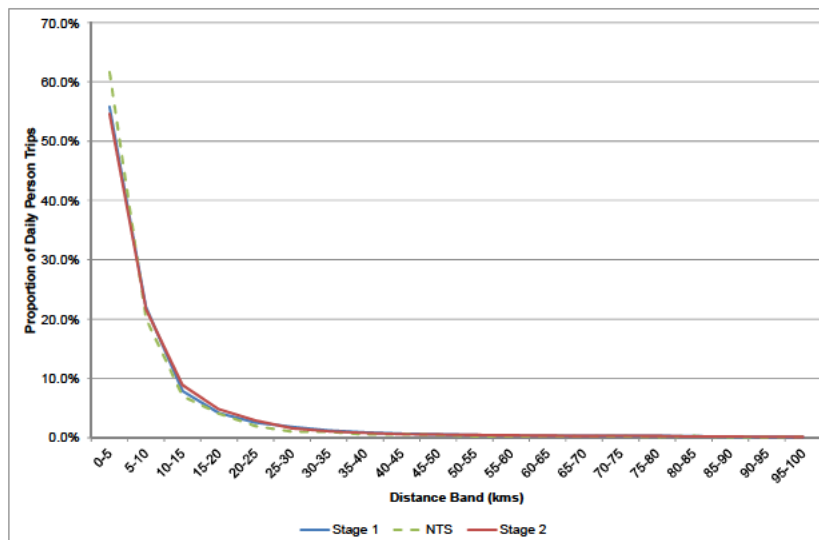
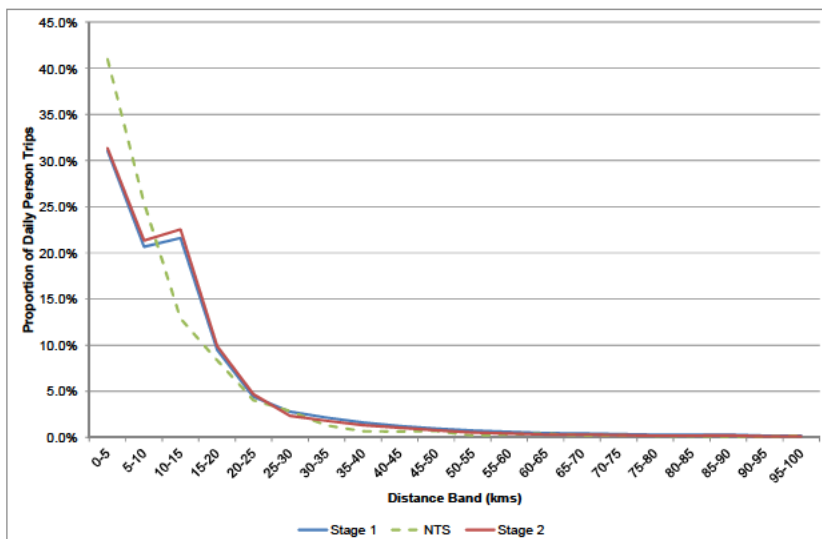


Figure 28 – Stage 2 HBO (Rural Trips)



Test E – Trip Purpose

Table 41 shows a comparison of the trip purpose split in the final matrices against the NTS data for each county within the modelled area.

Table 41 – Comparison between Trip Purpose Breakdown in Stage 2 Matrices and NTS

County	NTS			Stage 2 Matrices		
	HBW	HBO	NHB	HBW	HBO	NHB
Lancashire	20.8%	65.2%	14.1%	21.5%	66.0%	12.5%
Greater Manchester	19.2%	66.5%	14.3%	20.3%	67.9%	11.8%
Cheshire	20.7%	64.4%	14.9%	22.4%	65.1%	12.5%
Merseyside	20.3%	65.5%	14.2%	21.1%	67.9%	11.0%
South Yorkshire	19.5%	66.4%	14.1%	20.1%	68.5%	11.4%
West Yorkshire	18.1%	65.8%	16.1%	18.6%	69.1%	12.3%
East Riding of Yorkshire	22.4%	62.2%	15.4%	19.3%	68.6%	12.1%
North Yorkshire	19.9%	65.8%	14.3%	19.1%	67.5%	13.3%
Lincolnshire	17.7%	66.8%	15.5%	19.9%	68.2%	11.9%

Test G - Screenline flow comparison

Table 42 and Table 43 show a comparison between traffic counts and the demand, across long screenlines within the modelled area. In general the demand in the matrices is much closer to that counted traffic with total demand falling within 2% of the counts within a range of -10% to 22%. Flows were obtained by assigning the 24 hour matrices to fixed time network using an all or nothing assignment.

Table 42 – Screenline Flow Comparison (12 hour)

Ref	Screenline	Count C	Model M	% Diff (M-C)/C
1	M6	512,000	496,000	-3%
7	Pennine	155,000	159,000	3%
8	Humber / Mersey	536,000	514,000	-4%
9	Leeds / Sheffield	527,000	473,000	-10%
10	West of York	348,000	356,000	2%
11	East of York	156,000	177,000	14%
12	Humberside	59,000	72,000	22%
13	Fylde Coast	78,000	74,000	-5%
14	Mid Cheshire	104,000	92,000	-12%
16	Northern Border	135,000	163,000	21%
17	Southern Border	498,000	487,000	-2%
	Total	3,108,000	3,063,000	-1%

Table 43 – Screenline Flow Comparison (by period)

Ref	Screenline	Dir.	No. of Sites	AM Peak	Inter Peak	PM Peak
1	M6	EB	45	-5.4%	-6.0%	-7.5%
		WB	44	9.5%	-2.2%	-4.2%
7	Pennine	EB	20	5.7%	12.0%	-1.8%
		WB	20	-0.9%	2.4%	-5.2%
8	Humber / Mersey	NB	37	7.9%	-9.6%	-3.9%
		SB	36	0.0%	-10.8%	0.1%
9	Leeds / Sheffield	EB	36	1.8%	-13.7%	-8.3%
		WB	35	-12.0%	-13.8%	-11.5%
10	West of York	EB	30	-6.1%	-0.1%	-9.0%
		WB	32	19.3%	9.9%	-0.4%
11	East of York	EB	18	3.4%	13.4%	15.1%
		WB	18	19.8%	9.8%	6.8%
12	Humberside	EB	7	29.2%	-6.8%	12.3%
		WB	7	71.7%	18.6%	39.8%
13	Fylde Coast	EB	7	-0.9%	-13.4%	-13.4%
		WB	7	-2.2%	-1.5%	5.2%

Ref	Screenline	Dir.	No. of Sites	AM Peak	Inter Peak	PM Peak
14	Mid Cheshire	EB	5	-8.0%	-11.5%	-18.2%
		WB	5	-8.2%	-6.1%	-19.6%
16	Northern Border	NB	13	32.2%	16.2%	8.1%
		SB	14	36.0%	28.2%	5.0%
17	Southern Border	NB	54	4.6%	-8.1%	-7.7%
		SB	55	13.2%	-7.9%	2.3%
	Total			5.0%	-2.5%	-2.8%

Green text indicates passes Test G from data consistency check criteria i.e. < +/-20%

Summary

The results demonstrated that the prescribed set of matrix development processes led to a set of matrices that fulfilled the criteria set by the TCG and itemised in [Table 21](#) ~~Table 24~~ above at the outset of the process.

- Trip rates within the matrices are very similar to rates observed in NTS.
- Trip length distributions are very similar to patterns observed in NTS.
- Total flows on long screenlines are very similar to the observed traffic counts.

The matrices output at this stage formed the initial prior matrices for the model calibration.

6.9 Stage 3

6.9.1 Further Adjustment

Following the review of the matrices at the end of stage 2, the Matrix TCG set a final target that further adjustments should be made until individual peak period comparisons should be within 20% on each screenline except for the boundary screenlines, which for TPS was the northern and southern screenlines, which should be within 5% across the screenline.

Further adjustments were made to the matrices on the basis of localised trip rates at a district level. These adjustments were made to improve the fit of demand across the main screenlines, to take account of regional and local variations in trip making rates where appropriate.

6.9.2 Ports and Airports Demand

While the mobile data will include trips to and from airports from travellers carrying UK registered phones, it will exclude foreign registered phones. The Department for Transport's Airport data was used to replace data in the provisional dataset for trips to the five main airports in the model region:

- Manchester;
- Leeds – Bradford;
- Liverpool;
- Humberside; and
- Doncaster.

The data set provided:

- annual patronage for each airport;
- time of day and time of year distribution of demand; and
- mode choice (rail, taxi, park and fly, drop off) for air passengers.

For each of the five airports a single zone was identified as representing the airport. Home based other trips to and from this zone were removed from the matrices and replaced with trips from the CAA dataset. Commuting trips, not included in the CAA dataset were left unchanged.

Taxi and drop off trips were treated as a pair of trips from the home zone to the airport zone and a corresponding return trip. Park and fly trips were treated as single trips, either home to airport or airport to home depending on arrival and departure numbers.

Home ends of trips were derived from the CAA data on district of origin, trips being disaggregated to zones within districts on the basis of population.

No similar data was available for seaports and data was unchanged. It should be noted that the BYFM Freight data included specific zones for each of the major seaports thus goods traffic from ports was represented through this source.

6.9.3 External demands

For completeness within the demand model it is necessary to include trip patterns for all zones within the model including those external to external movements which do not enter the modelled area, for example south east to south west.

The provisional phone data included all these trips within the data set, however much of the subsequent processing did not apply to external to external movements.

To ensure consistency between the Regional Models the TCG took a view that all external to external trips at a Government Region level should be broadly similar between models. So that for external movements not considered within the matrix processing, for the Trans Pennine South model information for other models where these trips had been considered should be used. This applied to movements within and between the following regions:

- Midlands;
- South East; and
- South West.

Trips between these areas were factored so that total trips in these areas were broadly in line with those in calibrated models for the relevant regions.

[Table 51](#)~~Table-54~~ to [Table 53](#)~~Table-53~~ shows a complete matrix of trips between Government Regions.

In addition the symmetry in inter regional trips was reviewed in all models. The test applied was that the numbers of vehicle movements from Government Regional zone internal to the model to each other Region should be symmetrical with the return trips.

This was assessed and confirmed for each of the Regional models.

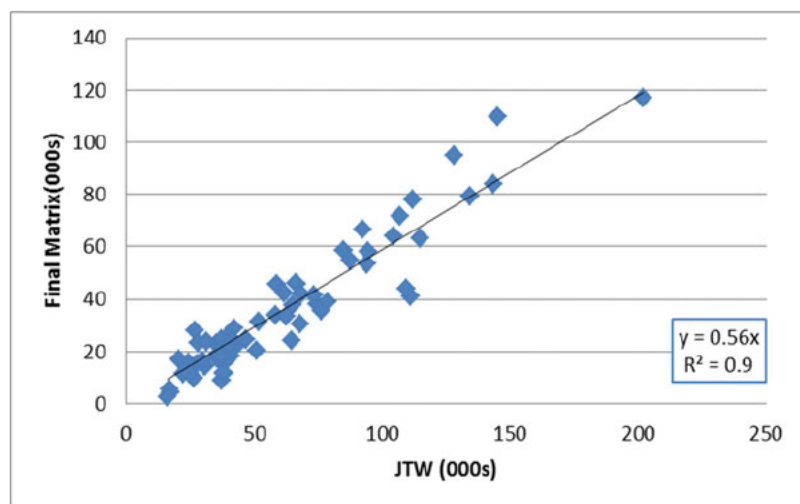
6.9.4 Final Matrix Evaluation

The following section provides a report on the evaluation of the final matrices against the TCG criteria outlined in [Table 21](#) ~~Table 24~~.

Test A

[Figure 29](#) ~~Figure 29~~ shows a comparison between home based work origins in the final matrices against the Journey to Work census data. The comparison shows a correlation statistic of 0.9. The slope being less than 1 reflects the difference in data sets; the matrices represent daily average trips while the census data reflects normal work trips.

Figure 29 – Comparison with Journey To Work Data



Test B trip Rates

[Table 44](#) ~~Table 44~~ shows the final comparison of trip rates at a county level between NTS and the model matrices. [Figure 30](#) ~~Figure 30~~ provides a comparison of final trip rates with the 95% confidence interval for the NTS data.

Table 44 – Trip Rates

	NTS				Model			
	HBW	HBO	NHB	Total	HBW	HBO	NHB	Total
Cheshire	0.39	1.20	0.28	1.87	0.39	1.15	0.22	1.77
Greater Manchester	0.31	1.06	0.23	1.60	0.32	1.08	0.19	1.59
Merseyside	0.29	0.93	0.20	1.43	0.29	0.95	0.15	1.40
Lancashire	0.34	1.06	0.23	1.63	0.34	1.05	0.20	1.59
West Yorkshire	0.31	1.13	0.28	1.71	0.31	1.16	0.21	1.67
South Yorkshire	0.34	1.17	0.25	1.76	0.35	1.21	0.20	1.76
North Yorkshire	0.34	1.12	0.24	1.70	0.31	1.09	0.22	1.61
Humberside	0.41	1.14	0.28	1.82	0.33	1.17	0.21	1.70

Figure 30 – Comparison of Trip Rates

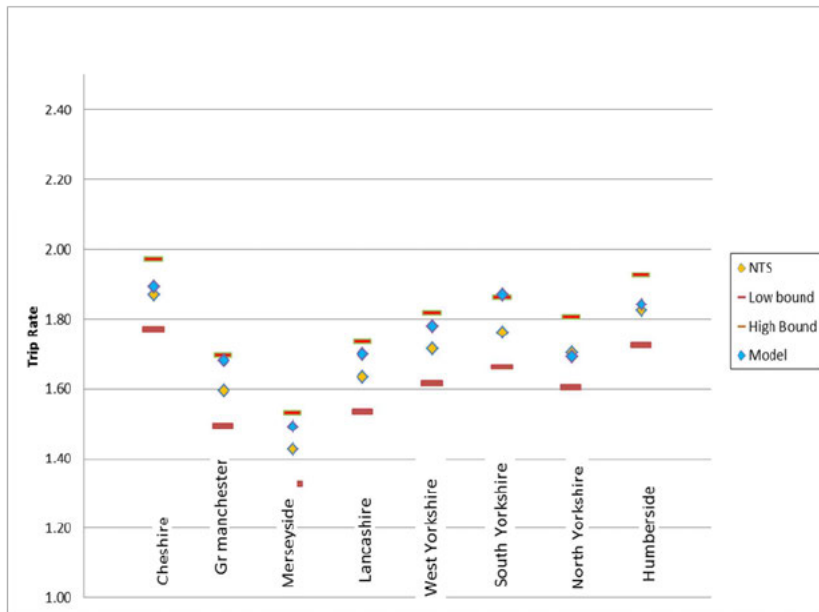


Figure 31 – HBW Urban

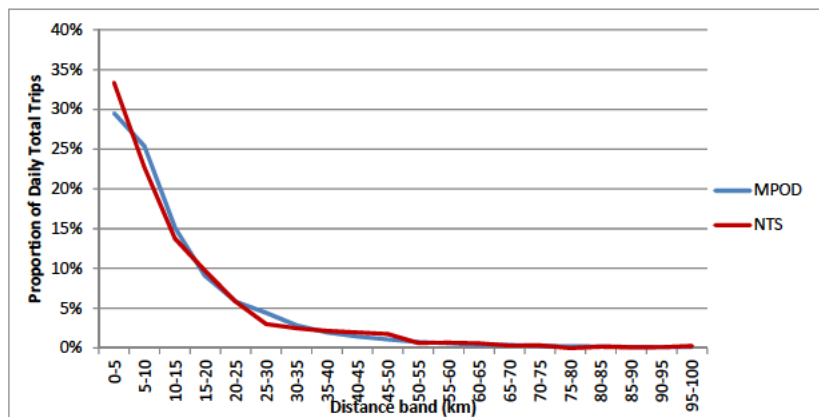


Figure 32 – HBW Rural

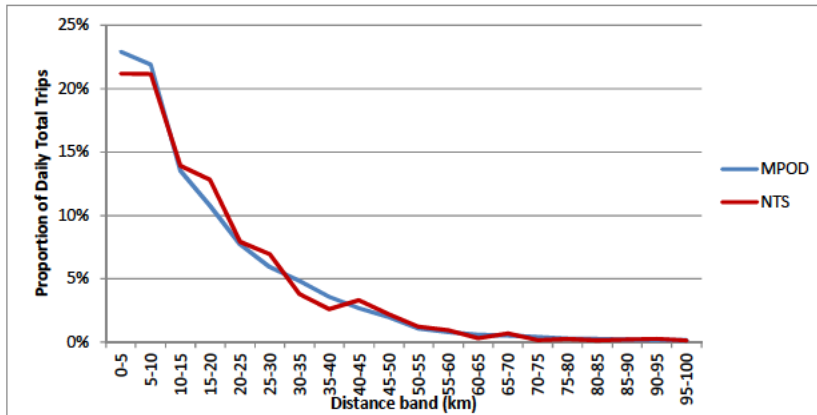


Figure 33 – HBO Urban

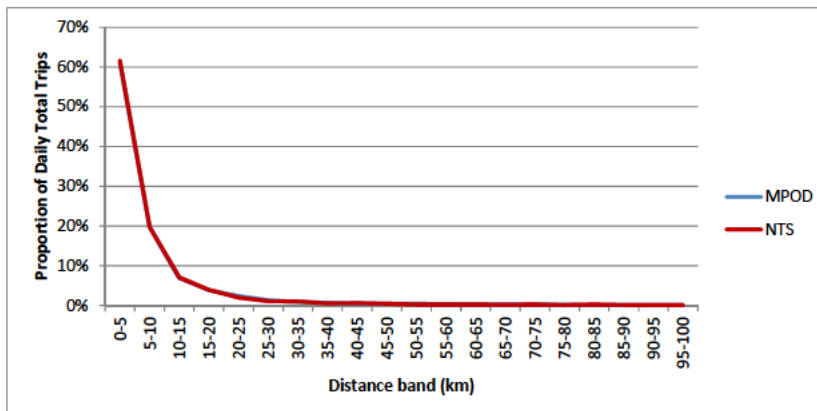


Figure 34 – HBO Rural

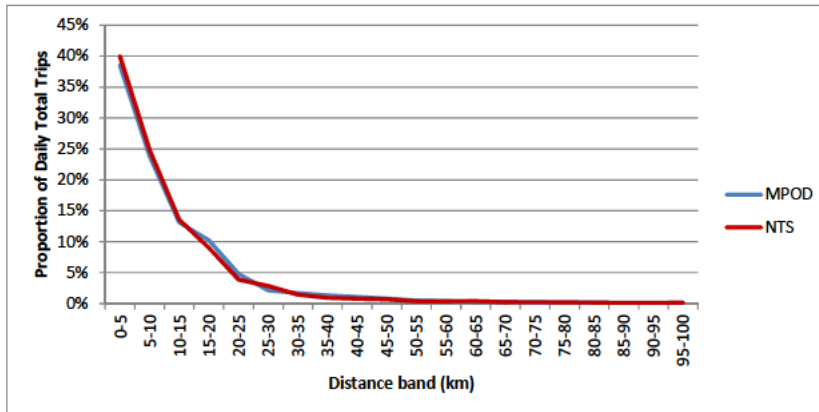


Figure 35 – NHB Urban

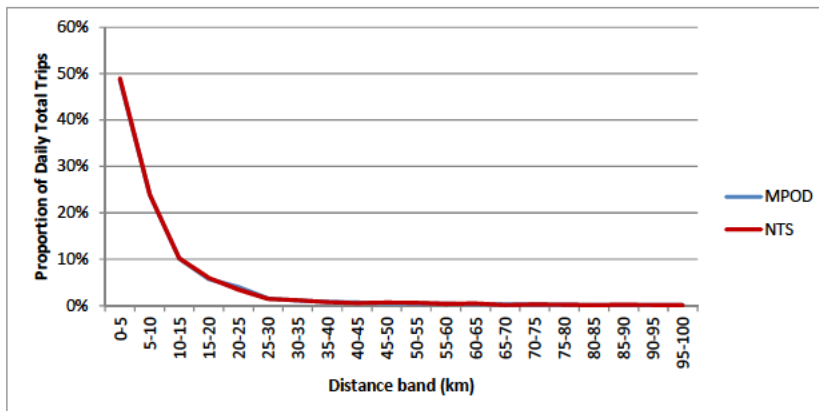
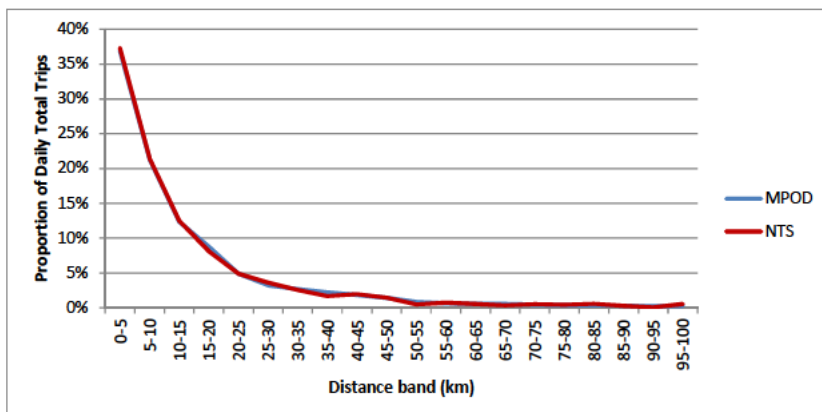


Figure 36 – NHB Rural



Test E – Trip Purpose

Table 45 shows the total number of trips, by purpose, in the final data set. The table shows a high level of correlation in terms of number of trips and purpose breakdown with the NTEM data.

Table 45 – Internal TPS Trip Ends (24 hour)

Purpose	Model	NTEM	Purpose Split Model	Purpose Split NTEM
HBW_FH	2,249,728	2,510,094	12%	13%
HBW_TH	2,085,871	2,426,763	11%	12%
HBO_FH	7,395,560	7,238,920	38%	37%
HBO_TH	7,498,182	7,301,832	39%	37%
NHB	2,696,240	2,754,434	14%	14%
Total	21,925,581	22,232,044		

Test F – Daily profile check

Final matrices were calculated as average peak periods rather than single hours and consequently this analysis is carried out at a time period level. **Table 46** shows a comparison between the final matrices and NTS of the proportions of the daily matrix that fall into each time period and trip purpose.

Table 46 – Daily Profile

Period	Purpose	NTS	Prior
AM	Commute	7%	9%
	Business	3%	2%
	Other	16%	11%
IP	Commute	6%	5%
	Business	6%	4%
	Other	33%	39%
PM	Commute	7%	8%

Period	Purpose	NTS	Prior
	Business	2%	2%
	Other	19%	20%
	Total	100%	100%

The results show that during the AM peak period the prior matrices have a higher proportion of commute trips and lower proportion of other trips than observed in NTS. This is probably due to the misallocation of education trips to commute in the original data, for which some correction has been made during the process.

Test G - Final Screenline Comparisons

Table 47 provides the final comparison of traffic volumes against counts on the main screenlines. The results show that the differences are within $\pm 15\%$ on all screenlines and less than 5% overall.

Table 47 – Screenline Flow Comparison (12 hour All Vehicles)

	Screenline		Count	Model	% Difference
1	M6	EB	300,200	263,700	-12.2%
		WB	297,400	254,200	-14.5%
7	Pennine	EB	72,400	82,600	14.1%
		WB	76,800	82,000	6.8%
8	Humber / Mersey	NB	392,600	364,700	-7.1%
		SB	390,700	351,600	-10.0%
10	West of York	EB	155,200	141,400	-8.9%
		WB	153,800	158,700	3.2%
11	East of York	EB	76,200	73,900	-3.0%
		WB	76,200	76,100	-0.1%
12	Humberside	EB	33,100	36,700	10.9%
		WB	26,300	30,200	14.8%
14	Mid Cheshire	EB	42,900	41,800	-2.6%
		WB	47,800	44,000	-7.9%
16	Northern Border	NB	63,700	61,600	-3.3%
		SB	63,600	61,600	-3.1%
17	Southern Border	NB	244,700	249,800	2.1%
		SB	242,000	246,700	1.9%
	Total		2,755,600	2,621,300	-4.9%

At this stage comparisons were also undertaken by peak period with the TCG setting the criteria that the same level of fit between observed and assigned flows should be achieved. The results for the peak period comparisons are shown in Table 48 to Table 50.

Table 48 – Screenline Flow Comparison By Time Period - Cars

Ref.	Screenline	Dirn.	AM Peak			Inter Peak			PM Peak		
			Count	Model	Diff.	Count	Model	Diff.	Count	Model	Diff.
			C	M	(M-C)/C	C	M	(M-C)/C	C	M	(M-C)/C
1	M6	EB	27,603	24,517	-11.2%	21,302	18,062	-15.2%	29,858	27,251	-8.7%
		WB	27,793	24,178	-13.0%	20,772	17,326	-16.6%	29,799	25,913	-13.0%
7	Pennine	EB	6,523	7,521	15.3%	5,447	6,593	21.0%	6,730	6,841	1.6%
		WB	6,352	7,628	20.1%	5,821	5,816	-0.1%	7,615	8,059	5.8%
8	Humber/Mersey	NB	39,055	37,354	-4.4%	27,392	25,397	-7.3%	37,025	33,424	-9.7%
		SB	33,589	30,344	-9.7%	28,299	24,682	-12.8%	40,044	37,499	-6.4%
10	West Yorkshire	EB	13,970	11,866	-15.1%	10,958	10,501	-4.2%	15,852	14,280	-9.9%
		WB	14,125	14,808	4.8%	11,127	11,577	4.0%	14,889	14,948	0.4%
11	East Yorkshire	EB	6,446	5,428	-15.8%	5,447	5,499	1.0%	8,045	8,196	1.9%
		WB	7,368	8,341	13.2%	5,508	5,360	-2.7%	7,007	6,304	-10.0%
12	Humberside	EB	2,923	3,273	12.0%	2,626	2,825	7.6%	2,858	3,303	15.6%
		WB	2,067	2,380	15.1%	2,017	2,298	13.9%	2,654	3,105	17.0%
14	Mid Cheshire	EB	4,699	4,078	-13.2%	2,713	2,810	3.6%	4,188	4,238	1.2%
		WB	4,883	4,164	-14.7%	2,743	3,058	11.5%	5,549	4,396	-20.8%
16	Northern Boundary	NB	5,038	4,852	-3.7%	5,107	4,817	-5.7%	5,996	6,057	1.0%
		SB	5,312	5,233	-1.5%	5,152	4,932	-4.3%	5,581	5,427	-2.8%
17	Southern Boundary	NB	22,168	23,526	6.1%	18,197	17,862	-1.8%	23,007	24,005	4.3%
		SB	20,026	20,453	2.1%	18,245	18,365	0.7%	24,139	25,050	3.8%
	Total		249,941	239,944	-4.0%	198,874	187,781	-5.6%	270,837	258,295	-4.6%

Table 49 – Screenline Flow Comparison By Time Period - LGV

Ref.	Screenline	Dirn.	AM Peak			Inter Peak			PM Peak		
			Count	Model	Diff.	Count	Model	Diff.	Count	Model	Diff.
			C	M	(M-C)/C	C	M	(M-C)/C	C	M	(M-C)/C
1	M6	EB	3,833	3,583	-6.5%	3,615	3,537	9.5%	3,615	3,537	-2.1%
		WB	3,705	3,845	3.8%	3,775	3,182	4.9%	3,775	3,182	-15.7%
7	Pennine	EB	768	1,140	48.5%	730	923	49.3%	730	923	26.5%
		WB	842	1,206	43.2%	845	1,002	36.8%	845	1,002	18.6%
8	Humber/Mersey	NB	5,021	4,174	-16.9%	4,370	3,904	4.8%	4,370	3,904	-10.7%
		SB	4,477	4,518	0.9%	4,531	3,914	-3.1%	4,531	3,914	-13.6%
10	West Yorkshire	EB	1,935	2,039	5.4%	1,935	1,576	-5.7%	1,935	1,576	-18.6%
		WB	1,948	1,946	-0.1%	1,741	1,987	18.9%	1,741	1,987	14.1%
11	East Yorkshire	EB	834	1,193	43.1%	916	895	18.9%	916	895	-2.2%
		WB	872	1,044	19.7%	833	1,032	35.2%	833	1,032	23.9%
12	Humberside	EB	277	479	73.0%	274	405	28.3%	274	405	47.9%
		WB	190	450	136.8%	191	415	95.0%	191	415	116.8%
14	Mid Cheshire	EB	770	492	-36.2%	559	556	25.1%	559	556	-0.5%
		WB	765	691	-9.7%	841	493	22.2%	841	493	-41.3%
16	Northern Boundary	NB	1,270	1,242	-2.2%	696	712	-0.9%	696	712	2.2%
		SB	1,062	1,050	-1.2%	840	816	-1.5%	840	816	-2.9%
17	Southern Boundary	NB	2,953	3,000	1.6%	2,707	2,876	1.9%	2,707	2,876	6.3%
		SB	2,960	2,966	0.2%	3,040	2,999	0.9%	3,040	2,999	-1.4%
	Total		34,481	35,059	1.7%	32,439	31,223	7.7%	32,439	31,223	-3.7%

Table 50 – Screenline Flow Comparison By Time Period - HGV

Ref.	Screenline	Dirn.	AM Peak			Inter Peak			PM Peak		
			Count	Model	Diff.	Count	Model	Diff.	Count	Model	Diff.
			C	M	(M-C)/C	C	M	(M-C)/C	C	M	(M-C)/C
1	M6	EB	3,030	3,190	5.2%	2,885	2,845	-1.4%	1,977	2,222	12.4%
		WB	3,509	3,260	-7.1%	3,112	2,864	-8.0%	2,301	2,071	-10.0%
7	Pennine	EB	1,201	1,219	1.5%	1,345	1,363	1.4%	882	880	-0.2%
		WB	1,103	909	-17.6%	1,048	1,017	-2.9%	650	679	4.5%
8	Humber/Mersey	NB	4,693	4,808	2.5%	4,603	4,404	-4.3%	3,010	3,023	0.4%
		SB	4,053	3,980	-1.8%	4,026	3,965	-1.5%	3,295	3,446	4.6%
10	West Yorkshire	EB	2,746	2,709	-1.3%	2,647	2,530	-4.4%	1,866	1,766	-5.3%
		WB	2,575	2,447	-4.9%	2,663	2,497	-6.2%	1,860	1,858	-0.1%
11	East Yorkshire	EB	1,487	1,402	-5.8%	1,459	1,402	-3.9%	950	882	-7.1%
		WB	1,369	1,305	-4.7%	1,428	1,345	-5.8%	920	886	-3.7%
12	Humberside	EB	224	223	-0.4%	240	237	-1.5%	174	208	19.7%
		WB	186	172	-7.6%	181	177	-2.1%	123	122	-0.8%
14	Mid Cheshire	EB	667	680	2.0%	527	567	7.6%	350	386	10.3%
		WB	829	885	6.8%	497	468	-5.9%	416	489	17.5%
16	Northern Boundary	NB	1,258	1,288	2.4%	1,075	1,089	1.3%	684	699	2.2%
		SB	1,136	1,154	1.5%	1,234	1,249	1.3%	763	816	6.9%
17	Southern Boundary	NB	3,976	3,929	-1.2%	3,814	3,892	2.1%	2,586	2,584	-0.1%
		SB	3,210	3,235	0.8%	3,273	3,367	2.9%	2,625	2,595	-1.2%
	Total		37,254	36,794	-1.2%	36,056	35,280	-2.2%	25,433	25,613	0.7%

LGV

The results show that LGV volumes over all screenlines the numbers of LGVs are within $\pm 5\%$ of observed totals. There remain some large errors on particular screenlines, particularly the Humberside screenline. In developing LGV matrices local trip rate differences were not assessed.

HGV

The results show that LGV volumes over all screenlines the numbers of LGVs are within $\pm 5\%$ of observed totals, and all screenline comparisons fall within $\pm 20\%$

6.10 Robustness of Matrices and Impacts on Model Performance

Car Trips

Through the three stages of the processing it has been necessary to make significant structural adjustments to the mobile data to account for bias and to remove non car trips. The majority of the adjustment was based on a comparative analysis of OFCOM and NTS data sets, but some was based on empirical factoring of residual bias to reproduce NTS trip length and trip rate evidence, while retaining the origin – destination pattern observed, subject to these constraints.

Overall the outcome then shows reasonable accord with screenline counts – flows within 20%, however there will necessarily be some residual uncertainty.

Analysis shows that short distance trips were not reliably observed in the provisional mobile data and these were replaced throughout with synthetic estimates. While this followed a conversional gravity modelling approach, this was not constrained to any screenline totals as would typically be the case infilling demand for RSI sourced data. While the synthetic process covers nearly half the trips they are the shorter distance trips and thus represent less than 20% of traffic kilometres in the network. By their nature these trips are of relatively minor significance for inter-urban trips on the SRN.

LGV

LGV data has been sourced from Trafficmaster, which provides nationally a small (2%) sample of LGV travel on the highway network. However, by its nature it may be expected that a higher proportion of LGVs using the SRN are fitted with Trafficmaster equipment and consequently the results of the assignments suggested that in terms of vehicles crossing the long screenlines the sample rate was around 9%. For traffic on the SRN expanding these samples to the average counts provides a reasonable starting point for matrix estimation.

HGV

The HGV matrices have been developed using 2006 BYFM matrices and scaling these using growth at a district level between 2006 and 2015. There is no additional data on HGV origin destination movements across the whole of England at a level sufficiently detailed for use in this model.

The HGV matrices can be considered as a suitable starting point for matrix estimation, and should provide a realistic representation of demand on a district to district basis on the SRN, however at a local level there can be little confidence in precise trip origins and destinations. Since HGV traffic comprises around 5% of total demand, and in using the models for examination of predominantly strategic movements it is considered that the HGV matrices represent the best available starting point for further matrix estimation.

Table 51 – LGV Matrices – Government Office Region

	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Scotland	Wales	TOTAL
North East	309,427	1,490	4,949	320	97	44	15	16	6	1,618	21	318,003
North West	1,523	694,860	12,433	4,628	10,013	468	245	601	332	2,131	7,302	734,538
Yorkshire and The Humber	4,942	12,499	472,437	16,353	2,129	904	243	391	161	262	295	510,617
East Midlands	344	4,437	15,295	586,853	25,773	14,905	2,047	8,089	816	80	455	659,095
West Midlands	107	9,278	1,930	25,845	751,402	2,997	1,967	6,500	8,513	113	6,819	815,471
East of England	54	416	852	14,805	3,069	588,554	62,419	26,367	891	16	162	697,604
London	11	192	214	1,716	1,715	60,588	701,040	82,748	1,436	3	196	849,861
South East	22	497	357	8,119	6,470	25,964	84,599	936,806	19,349	11	683	1,082,878
South West	9	301	152	828	8,562	951	1,567	19,354	648,457	7	4,949	685,137
Scotland	1,281	1,431	186	50	82	12	3	10	6	104,045	7	107,112
Wales	25	6,599	272	437	6,545	169	218	693	5,113	17	205,204	225,294
TOTAL	317,746	732,000	509,078	659,957	815,856	695,557	854,363	1,081,575	685,081	108,305	226,093	6,685,609

Table 52 – HGV Matrices – Government Office Region

	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Scotland	Wales	TOTAL
North East	40,557	2,020	3,858	956	682	409	171	401	159	1,278	394	50,885
North West	1,996	102,542	7,832	5,487	6,875	2,173	1,021	2,188	1,396	4,183	3,952	139,645
Yorkshire and The Humber	4,536	9,847	91,698	9,961	3,959	2,781	1,104	2,023	1,071	1,676	762	129,418
East Midlands	903	5,988	8,373	62,870	18,750	9,605	2,391	5,645	1,557	881	1,469	118,429
West Midlands	724	7,129	3,182	19,449	73,407	3,972	2,116	6,736	3,528	1,054	3,727	125,024
East of England	319	1,791	2,125	7,966	3,389	101,966	12,880	14,303	1,526	391	475	147,130
London	122	749	754	1,780	1,426	12,979	58,587	13,847	1,249	159	246	91,897
South East	281	1,847	1,521	4,391	4,948	12,907	12,474	123,690	5,986	439	986	169,471
South West	122	1,293	747	1,419	3,138	1,641	1,559	7,437	72,104	255	2,759	92,475
Scotland	1,119	3,575	1,904	1,194	1,252	649	388	694	324	107,771	263	119,132
Wales	230	4,463	727	1,574	4,177	598	390	1,369	3,507	195	43,402	60,634*
TOTAL	50,909	141,242	122,723	117,045	122,004	149,680	93,080	178,331	92,407	118,283*	58,435	1,244,140

* It should be noted that the HGV trips within Scotland were sourced from a different dataset for the RTM models. The absolute values are not directly comparable with the other elements of the HGV matrix but this is not a concern as it only applies to internal trips within Scotland which are not affected by any other model process.

Table 53 – Car Matrices – Government Office Region

	North East	North West	Yorkshire and The Humber	East Midlands	West Midlands	East of England	London	South East	South West	Scotland	Wales	TOTAL
North East	2,797,448	10,283	50,419	2,878	1,192	748	697	666	327	5,995	189	2,870,843
North West	9,292	7,378,379	67,663	34,608	62,212	2,873	2,069	4,061	2,602	14,684	67,149	7,645,592
Yorkshire and The Humber	50,393	71,942	5,748,693	122,162	10,140	4,799	2,613	3,353	1,543	2,166	1,432	6,019,237
East Midlands	2,648	35,303	136,019	5,119,529	148,987	80,476	9,592	64,231	4,880	890	1,899	5,604,454
West Midlands	1,199	52,581	10,285	147,353	6,543,393	9,964	8,304	28,317	48,093	1,306	33,887	6,884,681
East of England	649	2,913	4,696	81,280	9,108	6,173,839	339,785	144,567	4,587	598	744	6,762,766
London	886	2,831	2,752	9,732	8,276	342,418	4,427,857	476,279	11,805	1,376	2,010	5,286,222
South East	619	3,754	3,029	63,093	28,169	147,453	468,846	9,120,737	108,807	711	3,569	9,948,789
South West	393	3,117	1,609	5,038	50,904	5,150	10,593	113,245	6,758,742	326	33,758	6,982,873
Scotland	6,534	13,535	1,990	872	1,332	488	1,121	717	420	6,300,548	268	6,327,825
Wales	212	63,893	1,370	1,888	32,368	909	1,713	3,942	34,052	185	2,908,876	3,049,408
TOTAL	2,870,273	7,638,531	6,028,526	5,588,432	6,896,081	6,769,117	5,273,190	9,960,115	6,975,857	6,328,784	3,053,782	67,382,689

7 Highway Model Development – Assignment Process

7.1 Approach

SATURN can operate as either a conventional traffic assignment model or as a combined simulation and assignment model in which junction interactions are represented in detail.

SATURN uses the SATALL module to iterate between successive loops of SATASS module (which assigns the user class matrices to the network in accordance with Wardrop's First Principle of Traffic Equilibrium using the Frank-Wolfe algorithm) and SATSIM module (which takes the flows derived by SATASS and calculates the revised flow/delay relationships at each junction within the simulated area) until the resulting travel times and flows do not change significantly (that is, the process has 'converged').

The assignment process starts with SATASS using the free-flow times (without any delays arising from vehicle interactions at the simulated junctions) from the network building program, SATNET. After the first set of path-builds in SATASS, the resulting flows are passed to SATSIM for the turn-based flow/delay curves representing the detailed interactions at each junction to be updated. These revised flow/delay relationships are passed back to SATASS for the travel time and flows to be recalculated. Further details may be found in the SATURN User Manual.

The use of the combined SATASS-SATSIM routine enables the impact of blocking back and downstream flow metering to be robustly assessed.

Wardrop's User Equilibrium is based on the following proposition.

'Traffic arranges itself on congested networks such that the cost of travel on all routes used between each origin-destination pair is equal to the minimum cost of travel and unused routes have equal or greater costs.'

Latest release of SATURN, version 11.3.12U is used for TPS RTM as recommended by coding manual.

7.2 Time Slices

The model hours for TPS RTM represent:

- average AM Peak hour (07:00-10:00);
- average Inter Peak hour (10:00-16:00); and
- average PM Peak hour (16:00-19:00).

7.3 Modelled User Classes

The highway assignment modelled cars and goods vehicles as separate user classes. The car user classes split into the following trip purposes:

- commuting;
- employer's business; and
- other.

Goods vehicles are further classified into light and heavy goods user classes.

7.4 Assignment Costs

Pence per kilometre (PPK) and pence per minute (PPM) values for the TPS RTM I were advised by the Network TCG¹¹ for consistency across the five RTMs.

The route choice within the TP-S RTM modelled using the generalised cost of travel time and vehicle operating costs in accordance with WebTAG guidance. The coefficients for the individual components of generalised costs were calculated using latest values supplied by Highways England. The model base year is 2015 with all monetary values calculated at 2010 prices. The latest research on value of time has been employed in the regional model.

The “Advice on Modelling of Congestion Charging or Tolling Options for Multimodal Studies”, ITEA division January 2002, which is based on the report “The Value of Time on UK roads – 1996” produced by Accent Marketing and Hague Consulting Group, showed that an average factor of 2.3 would be applied to the Databook’s values to include the values that freight operators would be prepared to pay. Since no further analysis has been conducted, it was proposed that the factor of 2.3 used for the purpose of the calculation of the PPM values for HGVs.

[Table 54](#) and [Table 55](#) present the PPM and PPK values adopted in TP-S RTM.

Table 54 – Generalised Cost Parameters – PPM

Vehicle Type	User Class	AM Peak	Inter Peak	PM Peak
Car	Employer Business	29.82	30.56	30.25
	Commuting	20.00	20.32	20.07
	Other	13.80	14.70	14.45
LGV	LGV	21.08	21.08	21.08
HGV	OGV1	49.22	49.22	49.22
	OGV2	49.22	49.22	49.22
	Average OGV	49.22	49.22	49.22

¹¹ NRTM TN06 Generalised Costs_v4.docx – from NRTM
Trans Pennine South RTM

Table 55 – Generalised Cost Parameters – PPK

Vehicle Type	User Class	AM Peak	Inter Peak	PM Peak
Car	Employer Business	12.19	12.19	12.19
	Commuting	5.66	5.66	5.66
	Other	5.66	5.66	5.66
LGV	LGV	12.67	12.67	12.67
HGV	OGV1	30.88	30.88	30.88
	OGV2	56.23	56.23	56.23
	Average OGV	46.09	46.09	46.09

7.5 Assignment Convergence Criteria

Below are assignment convergence criteria which were adopted for the base year model calibration and validation.

ISTOP = 99
 KONSTP = 5
 MASL = 100
 NISTOP = 4
 NITA = 30
 NITA_C = 256
 NITS = 50
 STPGAP = 0.05

7.6 Assignment Parameters

SATURN network assignment parameters were adopted in accordance with Section 3 of the network coding manual and also recommendations by the SATURN software team to the Network TCG. The assignment parameters adopted for TPS RTM are presented in Appendix F.

8 Highway Model Calibration

8.1 Evidence of Network Checks

After initial simulation network was built using the SATCODER, various network checks were carried out as set out by the Network TCG to ensure acceptability of the network. Following tests were carried out on the initial unassigned simulation network. However, the network will be further updated during model calibration and validation process.

Completeness Check

The purpose of this test was to prove that the network produced is structurally complete, including simulation and buffer network. Also the test confirmed that the initial network development process had been undertaken in accordance with the model specification.

SATURN Compilation Tests

The purpose of this test was to ensure that the network (including buffer) compiled in SATURN with the option "WRIGHT = TRUE" without any unacceptable errors. The test also confirmed that the initial network development was successfully built using SATNET.

Prior to this test it was ensured that the networks had been prepared with no FATAL or Semi-Fatal errors. Major warnings and serious warnings were addressed during this acceptance test. Some of these warnings will be addressed during Calibration Validation stage. All other warnings and serious warnings were investigated and remedial measures were undertaken where necessary.

Network Routing

This test was to check the key routes for all vehicle types in the model area.

As part of network routing test around 219 O-D pairs were identified and checked. The routes shown in the networks were then compared against QGIS route planner. The routing comparisons between SATURN and QGIS are presented in Table G1 of Appendix G.

Link Consistency Test

The purpose of this test was to check that network link types were consistent along a road and in both directions. The test aimed to confirm that the network structure has been developed in accordance with the model specification report.

As part of the link consistency test the type of speed flow curves, capacities and distance coded in the simulation and buffer area were checked. The results of these checks are presented in Appendix G Table G2 for SFC.

A distance check was carried for the links with crow fly distance greater than 500m using the following acceptance criteria:

- If the link length is 30% greater than the crow-fly distance; and
- If the link length is less than 90% of the crow-fly.

The results are presented Appendix G Table G3. This check was carried out for links within RoF area.

8.2 Evidence of Assignment Checks

Once the acceptance checks were completed and findings were fixed, assignments were undertaken with the initial set of prior matrices to identify and fix any further network related issues.

The following checks were undertaken and necessary network related updates were carried out:

- Assignment Convergence;
- Count vs Capacity: check and fix link for count vs capacity;
- Link Outliers: examine and fix links with GEH of greater than 20;
- Node Convergence: examine and fix worst converged nodes; and
- Nodes with significantly large delays (>300 secs).

8.2.1 Link Speed Checks

The link speeds were obtained from Trafficmaster for the fixed speed areas of the network and the SFCs were used to code the remaining parts of the network. A number of assignment checks as set out in section 8.2 have been carried out.

8.2.2 Delay Checks

The delay checks were part of the assignment checks as set out in Section 8.2 above.

8.3 Evidence of Matrix Checks

This is provided in Chapter 6. Matrix estimation was used to improve the fit of the assignment of the prior matrix to the observed count data.

The process by which it was applied was consistent across the five regional models. It is also recognised that with individual regional models there are some points of detail by which each may differ; for example, each regional model will differ in the choice to which individual cell values are allowed to change due to matrix estimation (the XAMAX value).

This process has been detailed in the technical note 'RTM Cal/Val- Use of Matrix Estimation' (dated 12 July 2016) produced by the calibration-validation technical consistency group and reproduced in this report as Appendix H. Rather than repeat long sections of this technical note this section of the MVR provides an overview of the principal features of the matrix estimation process noting where the precise application of matrix estimation to the Trans-Pennine South regional model differs from that presented in the TCG technical note.

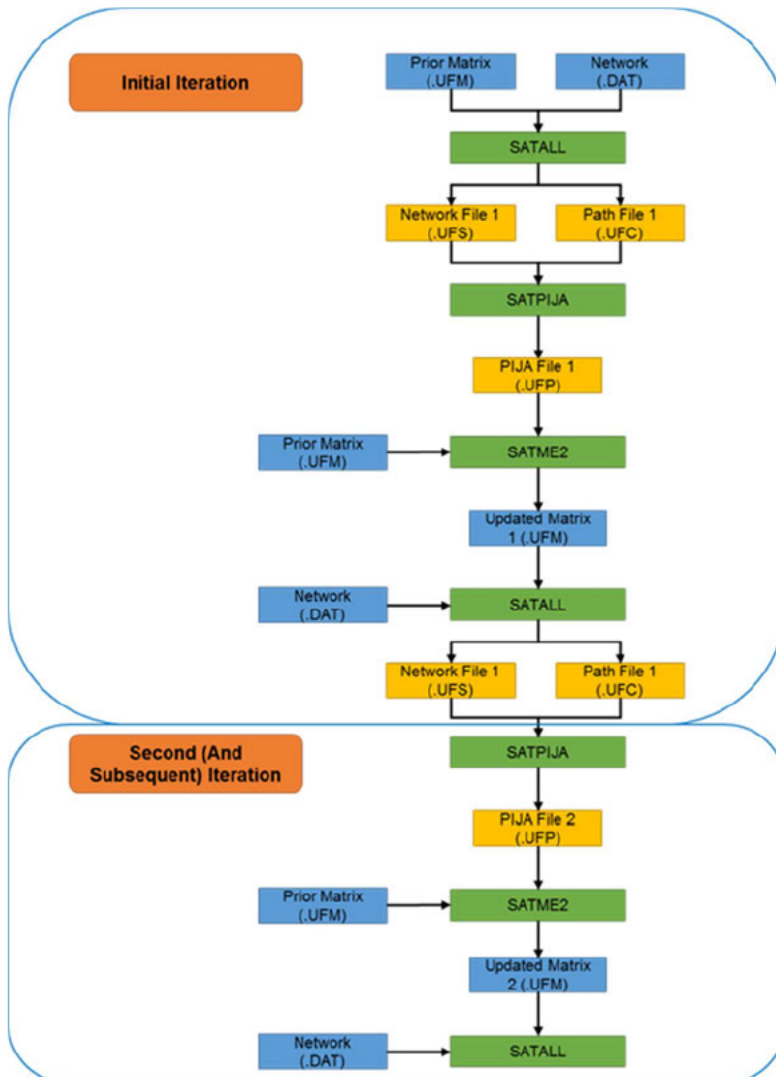
ME Process

The main features of the matrix estimation process were as follows.

- For all user classes matrix estimation is only applied to the prior matrix; it is never the case that matrix estimation is applied to a previously matrix estimated matrix.
- Matrix estimation is applied to all user classes simultaneously. Most importantly it is not the case that the LGV and HGV user classes are imported from a previous model run. This ensures that, for all user classes, the output from the matrix estimation process will be (a) based on the best available information and (b) have been derived on a consistent basis.
- There is an iterative process whereby the post-matrix estimation matrix is assigned back to the model network and then used to generate a new set of PIJA values (the proportion of trips from each origin and destination which use a particular link). It is the case that this process provides a better estimate of the routes taken by traffic, and hence better PIJA values. It needs to be emphasised, however, that the PIJA factors are only ever applied to the prior matrix, as per bullet point one (above) and hence matrix estimation is never performed on a previously matrix estimated matrix.
- Matrix estimation was applied on model links only; no turning count data was used.

The TPS ME Process is presented in Figure 37. The process went through 6 loops.

Figure 37 - Matrix Estimation Process



Use of Mini-screenlines and Strategic Road Network 'Point Counts'

Matrix estimation was undertaken across mini screenlines given the length of the principal 'long screenlines' which in some cases extended across the width of the country. Use of grouped screenlines is consistent with TAG M3.1 where it is recommended that counts should be grouped in order to increase the overall level of confidence.

It is noted that using mini screenlines loses the resolution that is required to improve the individual link performance. Therefore long screenlines were broken up into:

- Mini-screenlines of no more than seven counts on the non-strategic road network. In total there were 163 mini-screenlines which comprised 1,054 individual link counts.
- Strategic road network links represented as separate 'point counts' in order to ensure that each individual strategic road network link was treated with the same priority as a group of counts within a mini-screenlines. In total 108 counts were used on locations where the long screenlines crossed the strategic road network.

Car Vehicle Class

The car vehicle class comprised of the three separate car user classes ('commuting', 'employers business' and 'other'). Because the observed flow information on cars could not differentiate between each user class then proportionate changes applied to each car user class in matrix estimation were the same. It is emphasised that the matrix estimation process maintained the separate car user classes and these were not amalgamated at any stage of the process.

Starting point for matrix estimation is a car matrix where:

- the movements between Government Office regions are within 2 per cent of the values in the other regional models; and
- the boundary screenline flows are within 5 percent of observed values by time period.

In applying matrix estimation a balance has been sought between controlling the impact of matrix estimation and allowing enough scope for matrix estimation to improve the fit of the matrix to observed values. Considerable efforts have been undertaken by the RTM Matrix teams and the TCG in order to develop a consistent approach to matrix development and verification. Consequently matrix estimation has been applied to retain much of the prior matrix, particularly in relation to long distance trips but with greater scope for matrix estimation to be applied to the short distance trips as these are derived from synthetic approaches.

Two runs of matrix estimation were run:

- Unconstrained: The first allowed the full car matrix to be adjusted up to a XAMAX value of 2 (i.e. individual cells could be divided by 2 or multiplied by 2).
- Constrained: The second run applied matrix estimation to only those cells with (a) a distance between zones of less than 20km and (b) that were wholly internal to the model area (internal-internal trips).

The results were analysed and discussed by the project team and the wider TCG and the 'unconstrained' run was deemed to provide the best overall compromise between the competing factors described earlier in this section.

Light Goods and Heavy Goods Vehicle Classes

As outlined earlier the LGV matrix has been developed from the Trafficmaster data. Initial investigations showed that the initial prior matrices performed better than the OGV matrices but have weaknesses. As a result a wider application of matrix estimation was undertaken.

Similarly the HGV matrix, which was derived from the Great Britain Freight Model, was judged to perform poorly and hence a less constrained use of matrix estimation was undertaken.

In both cases the process used was to:

- Develop the prior matrices so that Government Office Region movements were within 5 per cent across models
- Ensure that observed and modelled values across the boundary screenlines with the North and the Midlands regional model were within 5 percent.
- Freeze all movements with an external trip end.
- Do not apply any constraints to movements that were wholly internal to the model area.

HGV and LGV movements were then allowed to move relatively freely with a XAMAX value of 5.

There was no need to 'blend' the LGV or HGV matrices as only a single version of the matrices was run.

Apart from XAMAX the SATME2 convergence criteria of 0.001 was applied in the ME process.

9 Highway Model Validation

9.1 Network

The development of the network has been described in Chapter 5. The work was done in accordance with the RTM Coding Manual.

9.2 Matrices

9.2.1 Zone Plan

A zone plan showing the zoning system for the TP-S is included in Appendix I.

9.2.2 Distinction Between Observed and Synthesised Movements

The basis for the demand matrices has been the observed movements from the Mobile Phone Data set. These have been replaced by synthetic data for shorter distance trips for which the mobile data is considered to be unreliable.

For the purpose of trip replacement, short distance trips were defined as up to 7km in urban areas and up to 25km in rural areas. As a result of this process 43% of trips in the matrices are derived from the synthetic matrices. However since by definition these are short trips only 17% of total vehicle kilometres are derived from synthetic trips. Consequently 83% of traffic on the network is derived from observed data.

9.2.3 Comparison of Modelled Zonal Demand Against Independent Data

Comparisons of numbers of district to district commute trips against Census data are shown in section 6.10.4.

9.2.4 Comparison of Modelled Sector-to-Sector Demand with Any Independent Screenline Counts

All of the available screenlines and cordons have been used in matrix estimation as part of model calibration. As a consequence there are no independent screenline counts available against which to compare sector-to-sector demand.

A sector system has been developed principally to monitor the impact of matrix estimation. This system is based on district and county boundaries and does not fit well with the sector system.

Independent count data is available for 99 single direction counts at sites on the strategic road network, however, any assessment using this data would be route based and could not be used to provide an independent assessment of sector-sector movements.

9.2.5 Plans of Zones, Sectors and Screenlines Used

The cordons and screenlines used are illustrated in [Figure 2](#) earlier in this document.

9.2.6 Robustness of Matrices and Impacts on Model Performance

This has been discussed above under 8.3.3 above.

9.3 Assignment

9.3.1 Model Dashboard

The main data reporting for the RTMs is covered by a 'Dashboard' file that was developed specifically for the RTM programme. This includes all tabulations of model performance and is available as a separate Excel file.

9.3.2 List of Deviations

TPS RTM RoF covers a large amount of area with an extensive network, hence to achieve reasonably converged assignment model the ISTOP value is set to 98 for AM & PM peak models, where ISTOP value of 99 retained for IP. This relaxation is in line with advice provided in the coding manual.

9.3.3 Validation Data Independence

The performance of the base model is measured using a number of criteria which are set out in WebTAG Unit M3.1. Calibration is the adjustment of the inputs to the model (both supply and demand components) in order to improve its capability to represent the characteristics of travel in the modelled area. Whilst calibration is targeted at producing a satisfactory match between modelled and observed journey times and counts, adjustments should only be made where they demonstrably improve the realism of the model. As an example, adjustments of the trip matrices to achieve a match to observed flows should not be at the expense of a pattern of demand that is not realistic.

Validation involves comparing traffic flow and journey time outputs from the model with observed data, using a specific set of performance criteria. These criteria are defined in the WebTAG Unit M3.1. In practice calibration and validation are an iterative process. As each change is made to the model its outputs are tested against the validation criteria.

Independent validation data available for the Trans-Pennine South RTM was as follows.

- Counts of observed flows were for 99 single direction link counts on the strategic road network. These sites were selected where there was at least two junctions between the nearest calibration count location, in accordance with M3.1 para. 4.3.2. Details of these sites is presented in the dashboard, for example, on worksheet 'RTM-FLOWS-AM' rows 1723 to 1821.
- Journey time data for 56 routes (each with two directions) across the study area. Of these 25 routes were on the SRN network and 31 on the local authority road network. Details of these routes can be found in the dashboard at, for example, worksheet 'RTM-JTRoutes-AM'. In turn these routes were sub-divided into sub-sections, referred to as journey time groups'. In total there were 108 groups on the SRN network (each with two

directions) and 93 groups on the local road network. Details of these routes can be found in the dashboard at, for example, worksheet 'RTM-JTGroups-AM'.

The journey time data is only partly independent as:

- the journey time data was used to derive speeds in the fixed speed network; and
- the journey time data was used in model calibration to judge the between modelled and observed journey times and to identify associated issues in the model.

9.3.4 Tabular Comparison of Modelled Flows with Observed Site and Screenline Counts

The dashboard provides a number of comparisons of modelled flows with observed site and screenline counts.

- A comparison of individual sites grouped by direction into mini screenlines is presented, for example, in worksheet RTM-FLOWS-AM. This table includes those sites on the SRN network that were used in validation.
- A summary of each long screenline by direction is presented in worksheet RTM-SCL-AM.
- A summary of each mini screenline by direction is presented in worksheet RTM-MSCL-AM.
- Each individual site by direction is presented in worksheet RTM-LINK-AM

An overall summary of the flow and journey time performance of the model is presented in worksheet RTM-HLS-AM.

Table 56 to Table 58 present the key summary statistics of the comparison of modelled and observed flows for the AM, inter-peak and PM peak respectively. Values are presented for both the prior matrix and the post-ME2 assignments.

Table 56 – Summary Comparison of Modelled and Observed Flows: AM Peak

		No. of Sites or Screenlines	Prior			Post-ME			Definition of Near
			Pass	Near	Fail	Pass	Near	Fail	
Links	GEH < 5	1162	37%	15%	47%	52%	16%	32%	5 < GEH < 7.5
	Flow Criterion		70%	0%	30%	84%	0%	16%	
	GEH or Flow		70%	0%	30%	84%	0%	16%	
Screenlines	Flow Diff. < 5%	69	20%	29%	51%	97%	3%	0%	5% < Flow Diff. < 10%
	GEH < 4		16%	22%	62%	91%	3%	6%	4 < GEH < 7.5
Mini-Screenlines	Flow Criterion	163	40%	0%	60%	94%	0%	6%	
	GEH < 4		30%	21%	49%	90%	7%	3%	4 < GEH < 7.5

Table 57 – Summary Comparison of Modelled and Observed Flows: Inter Peak

		No. of Sites or Screenlines	Prior			Post-ME			Definition of Near
			Pass	Near	Fail	Pass	Near	Fail	
Links	GEH < 5	1162	42%	17%	41%	55%	16%	29%	5 < GEH < 7.5
	Flow Criterion		77%	0%	23%	89%	0%	11%	
	GEH or Flow		77%	0%	23%	89%	0%	11%	
Screenlines	Flow Diff. < 5%	69	22%	19%	59%	96%	3%	1%	5% < Flow Diff. < 10%
	GEH < 4		22%	22%	57%	94%	4%	1%	4 < GEH < 7.5
Mini-Screenlines	Flow Criterion	163	34%	0%	66%	93%	0%	7%	
	GEH < 4		27%	25%	48%	93%	4%	4%	4 < GEH < 7.5

Table 58 – Summary Comparison of Modelled and Observed Flows: PM Peak

		No. of Sites or Screenlines	Prior			Post-ME			Definition of Near
			Pass	Near	Fail	Pass	Near	Fail	
Links	GEH < 5	1162	39%	16%	45%	54%	14%	32%	5 < GEH < 7.5
	Flow Criterion		71%	0%	29%	84%	0%	16%	
	GEH or Flow		71%	0%	29%	84%	0%	16%	
Screenlines	Flow Diff. < 5%	69	32%	20%	48%	96%	4%	0%	5% < Flow Diff. < 10%
	GEH < 4		26%	19%	55%	91%	4%	4%	4 < GEH < 7.5
Mini-Screenlines	Flow Criterion	163	37%	0%	63%	91%	0%	9%	
	GEH < 4		26%	22%	52%	88%	7%	5%	4 < GEH < 7.5

Table 56 illustrates the improvement in the AM peak model performance through the use of matrix estimation. The percentage of individual links passing either the flow or GEH criteria improves from 70% in the prior assignment to 84% in the post-ME assignment. The improvement in the long screenline flows is dramatic with only 20% of long screenlines within modelled flow within 5% of the observed in the prior assignment increasing to 97% in the post-ME assignment. Similarly the improvement in the mini-screenlines is good from 40% achieving the flow criteria in the prior assignment to 94% in the post-ME assignment.

Table 57 illustrates the improvement in the inter-peak model performance through the use of matrix estimation. The percentage of individual links passing either the flow or GEH criteria improves from 77% in the prior assignment to 89% in the post-ME assignment. The improvement in the long screenline flows is from 22% of long screenlines within modelled flow within 5% of the observed in the prior assignment increasing to 96% in the post-ME assignment. Similarly the improvement in the mini-screenlines is from 34% achieving the flow criteria in the prior assignment to 93% in the post-ME assignment.

Table 58 illustrates the improvement in the PM peak model performance through the use of matrix estimation. The percentage of individual links passing either the flow or GEH criteria improves from 71% in the prior assignment to 84% in the post-ME assignment. The improvement in the long screenline flows is from 32% of long screenlines within modelled flow within 5% of the observed in the prior assignment increasing to 96% in the post-ME assignment. Similarly the improvement in the mini-screenlines is from 37% achieving the flow criteria in the prior assignment to 91% in the post-ME assignment.

9.3.5 Map-based Comparison of Modelled Flows with Observed Site and Screenline Counts

Map Based Plots

Map-based comparisons of modelled flows with observed site and screenline counts are available as follows:

- long screenlines;
- mini-screenlines;
- the SRN link counts that are on the long/mini-screenlines; and,
- individual counts that comprise the long/mini-screenlines

These are presented in Appendix J for the prior matrix and Post ME assignments. It should be noted that for the post-ME case all of the count data depicted in the plots has been used in model calibration; no independent data is shown.

A selection of these plots for the Post-ME case is presented in the remainder of this section.

Mini-Screenlines

Figure 38 to Figure 40 present the performance of the mini-screenlines used in model calibration for the Post-ME case for the AM, inter-peak and PM peak cases respectively.

Figure 38 – AM Peak - Post ME - Mini Screenlines

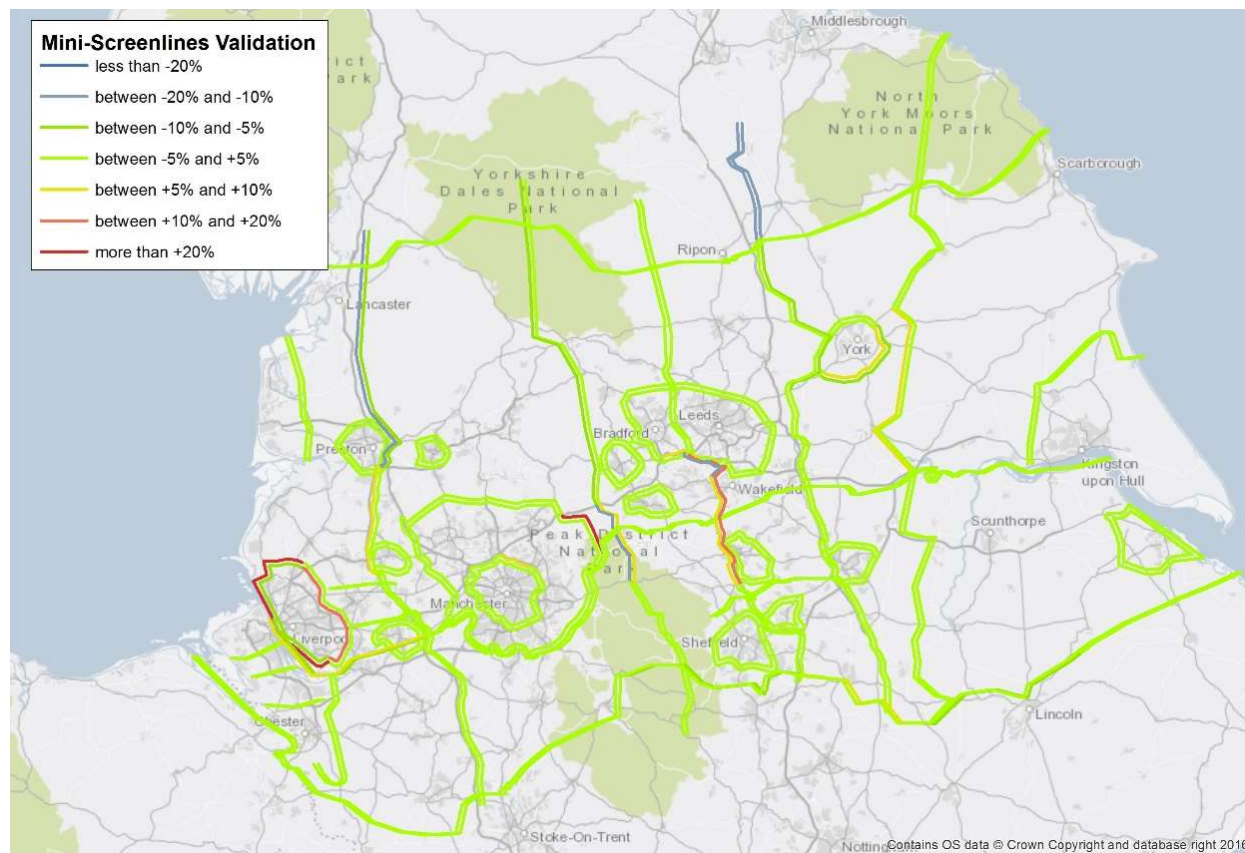


Figure 39 – Inter Peak - Post ME - Mini Screenlines

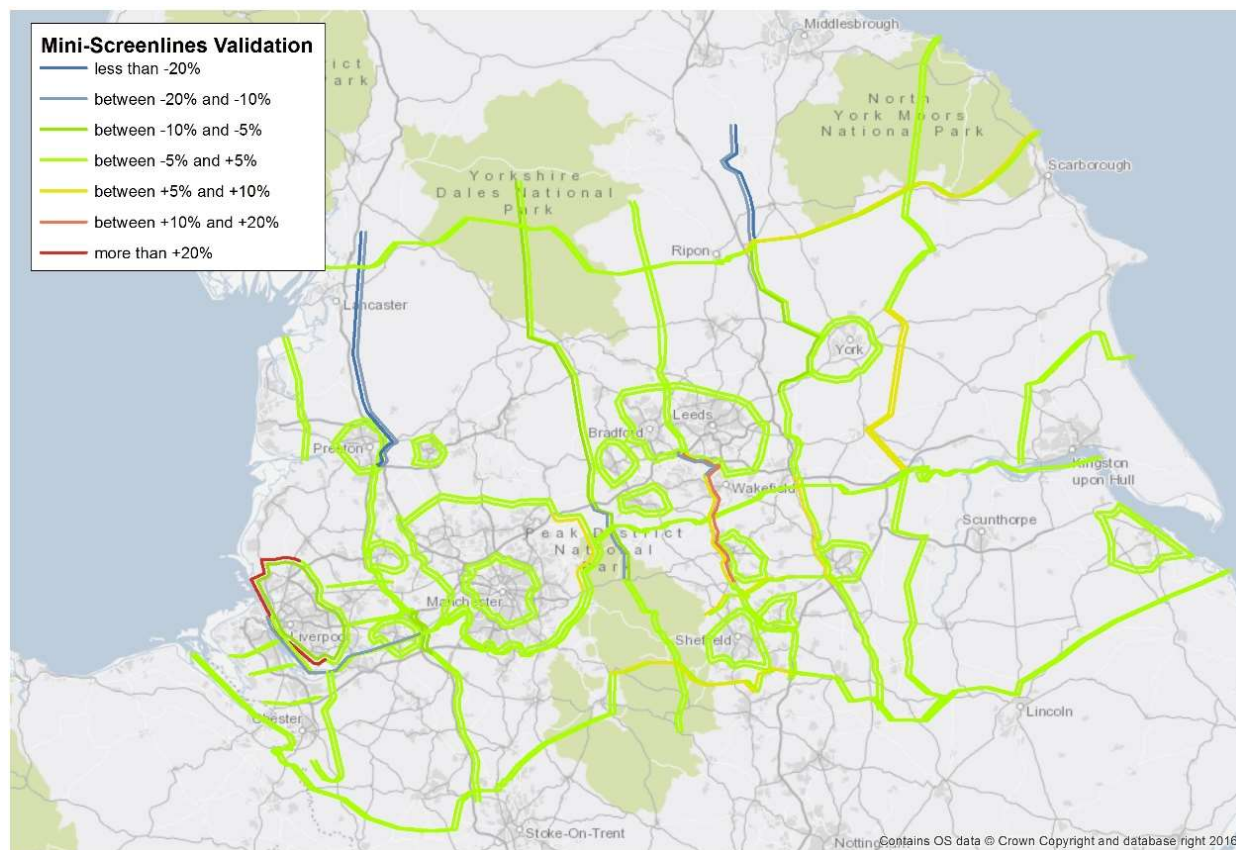


Figure 40 – PM Peak - Post ME - Mini Screenlines

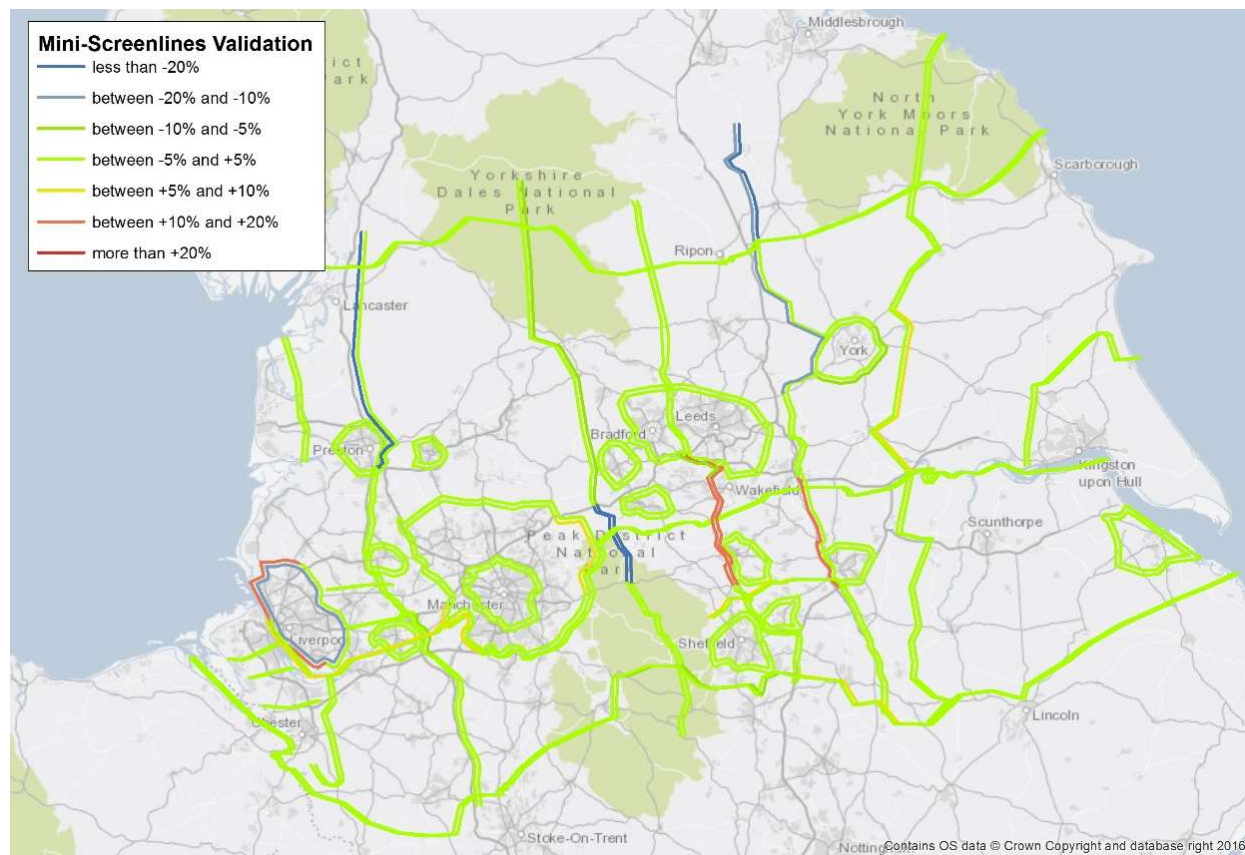


Figure 38 to Figure 40 show that in almost all cases the modelled flow for each mini-screenline is within 10 percent of the observed flow. The plots show that there are some exceptions to this that are common across all three time periods, notably:

- the mini-screenlines that form the Merseyside cordon generally have a modelled total flow that is 'high' (in excess of the observed flow);
- the mini-screenline to the west of the M1 between Barnsley and Wakefield has modelled total flow that is 'high' ;
- the mini-screenline between the A1 and A19 in North Yorkshire has a modelled total flow that is 'low' (less than the observed flow);
- the mini-screenline to the east of the M6 between Preston and Lancaster has a modelled flow that is 'low'; and,
- the trans-Pennine mini-screenline between the A828 and the M62 has a modelled total flow that is 'low'.

These may warrant further consideration when using the model in its current form to test strategies.

Details on the precise numbers of counts within each percentage range band are presented in Section 9.3.3 above.

SRN Links within Mini-Screenlines

Figure 41 to Figure 44 presents the performance of the individual counts on the SRN network that lie on the mini-screenlines used in model calibration for the Post-ME case for the AM, inter-peak and PM peak cases respectively. These links had a greater importance in that they were included as separate constraints within the matrix estimation process and hence a relatively good comparison of modelled and observed flows would be expected.

It should be noted that the plots aim to present a value for each direction; clearly there are instances where the values are 'over plotted' onto each other.

Figure 41 – AM Peak - Post ME - SRN Links on Mini Screenlines

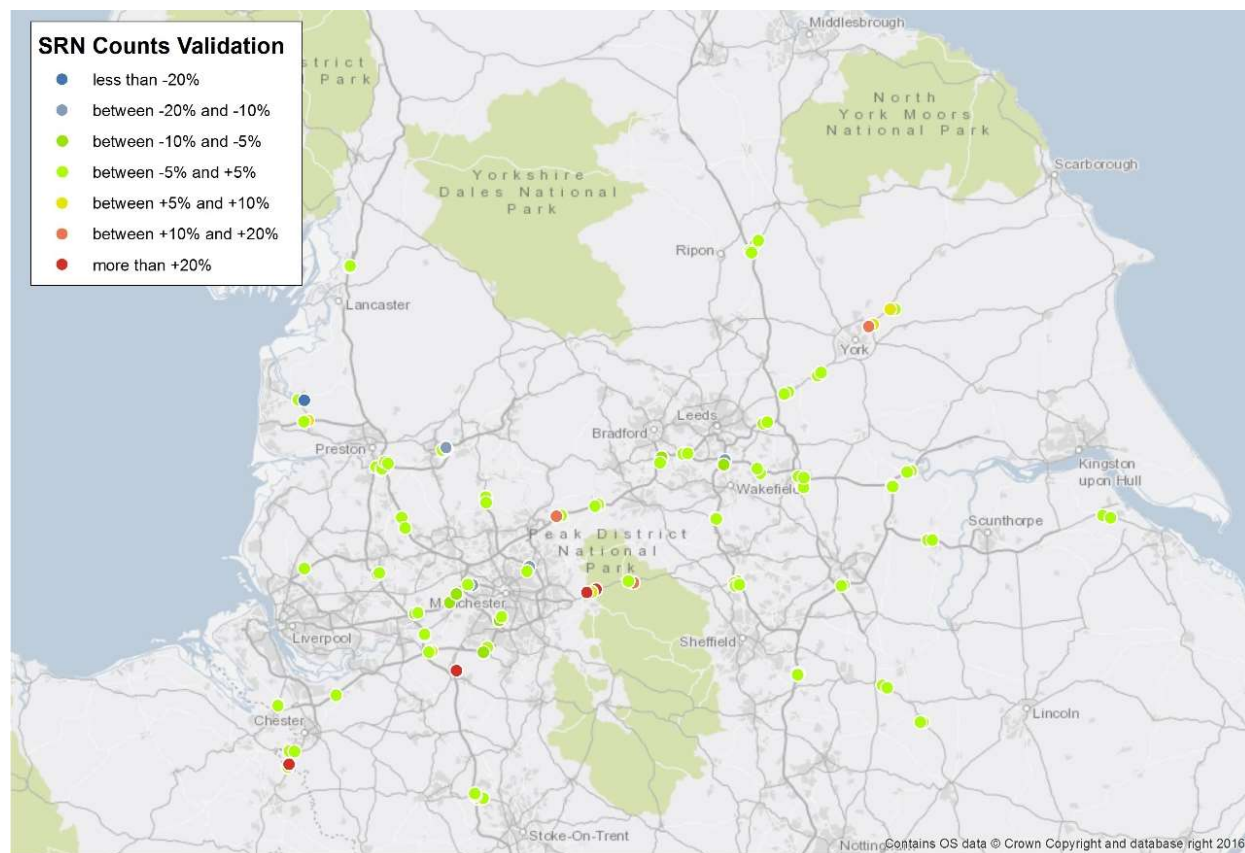


Figure 42 – Inter Peak - Post ME - SRN Links on Mini Screenlines

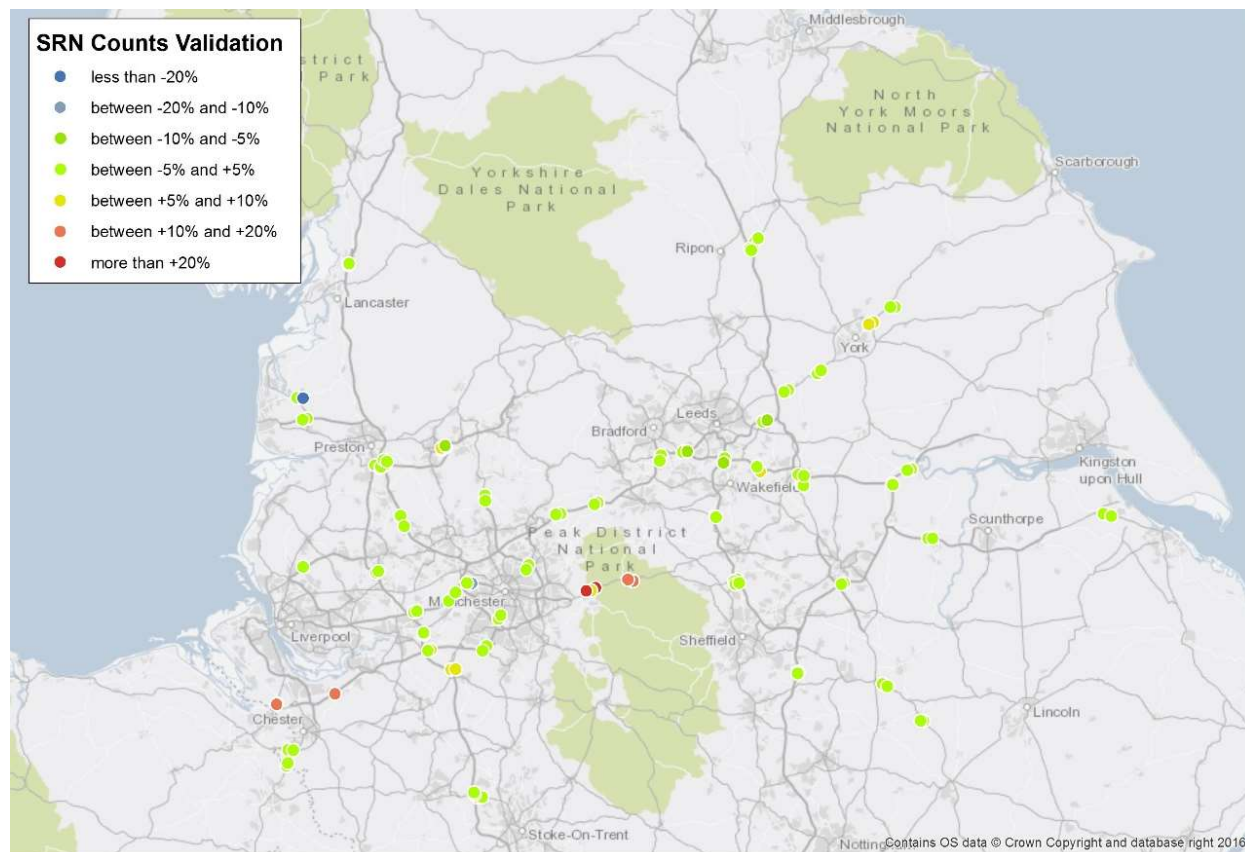
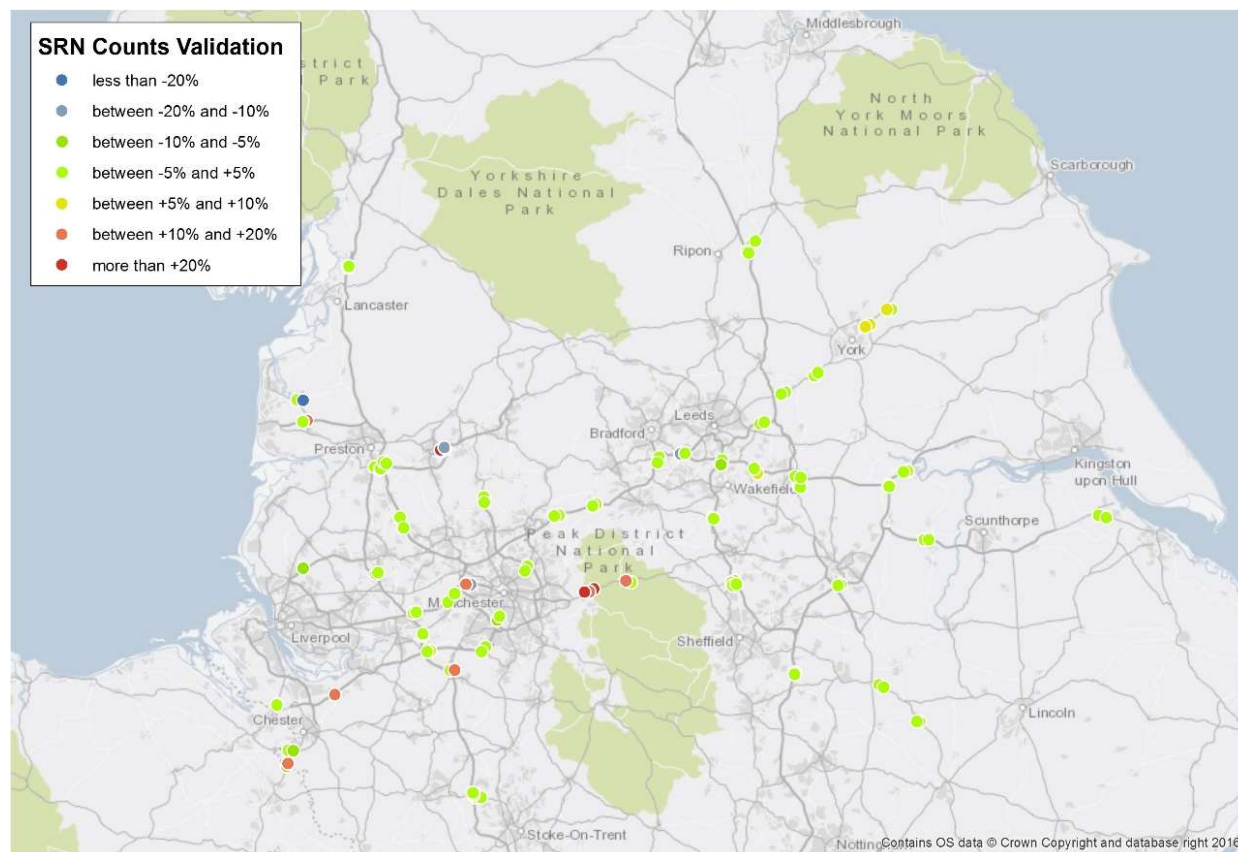


Figure 43 – PM Peak - Post ME - SRN Links on Mini Screenlines



SRN Links on Mini-screenlines

Figure 41 to Figure 43 show that in almost all cases the modelled flow for each SRN count is within 10 percent of the observed flow.

There are some instances where counts are not within 10 percent of the observed flow in more than one time period.

- A series of counts on the A628 trans-Pennine route which have a 'high' modelled flow (in excess of 10 percent greater than the observed) in all three time periods.
- The M56 east of the M53 where the modelled flow is 'high' in the inter-peak and PM peak periods.
- The A585 north of the M55 where the modelled flow is 'low' in all three time periods.

Diagrammatic Plots

In addition diagrammatic represents of the modelled and observed flows have been prepared for the SRN network. These contain all available data for the mainline sections of the SRN and comprise counts which have been used in model calibration, independent counts, and 'observation' counts which have not been used in model calibration but which are not sufficiently remote from a calibration count to be considered as independent.

These plots are also presented in Appendix J.

9.3.6 Tabular Comparison of Modelled and Observed Journey Times

The dashboard provides a number of comparisons of modelled and observed journey times.

- A summary of each of the journey time route by direction is given, for example, in worksheet 'RTM-JTRoutes-AM';
- A summary of each journey time group by direction is given in worksheet 'RTM-JTGroups-AM';
- A summary of each journey time 'chain' of highway model links by direction is given in worksheet 'RTM-JTLinks-AM'. There are a total of 4404 chains of journey time links;

Table 59 presents a summary tabular comparison of modelled and observed journey times for the prior and post-ME assignments.

The journey time routes improve to a pass rate of 77% in the AM peak, 76% in the inter-peak and 80% in the PM peak. In comparison the performance of the journey time groups is worse with 65% of groups passing in the AM peak, 71% in the inter-peak and 67% in the PM peak.

Overall the improvement in journey time routes due to matrix estimation is relatively marginal when compared to the improvement in the comparison of modelled and observed flows. The impact of matrix estimation on the overall performance of the journey time groups is negligible with the PM peak deteriorating.

Table 59 – Summary Comparison of Modelled and Observed Journey Times

Time Period		No. of Routes or Sections	Prior			Post-ME		
			Pass ¹	Near ²	Fail	Pass ¹	Near ²	Fail
AM	Routes	112	71%	21%	7%	77%	13%	10%
	Route Sections	302	64%	21%	16%	65%	22%	13%
Inter-Peak	Routes	112	76%	18%	6%	76%	19%	5%
	Route Sections	302	68%	21%	12%	71%	18%	11%
PM	Routes	112	79%	14%	7%	80%	11%	9%
	Route Sections	302	69%	19%	12%	67%	20%	14%

¹ Pass – Journey Time Difference < ±15%

² Near – Journey Time Difference between ±15% and <±25%

9.3.7 Diagrammatic Comparison of Modelled and Observed Journey Times

Figure 44 to Figure 46 present diagrammatic comparisons of modelled and observed journey times for each of the three modelled time periods. The colour coding used in the plots highlights routes where the modelled journey time is less than the observed in blue (i.e. the modelled speed is faster than observed). Conversely where the modelled journey time is greater than the observed the routes are highlighted in red.

Figure 44 – AM Peak – Post-ME – Comparison of Modelled and Observed Journey Time Routes

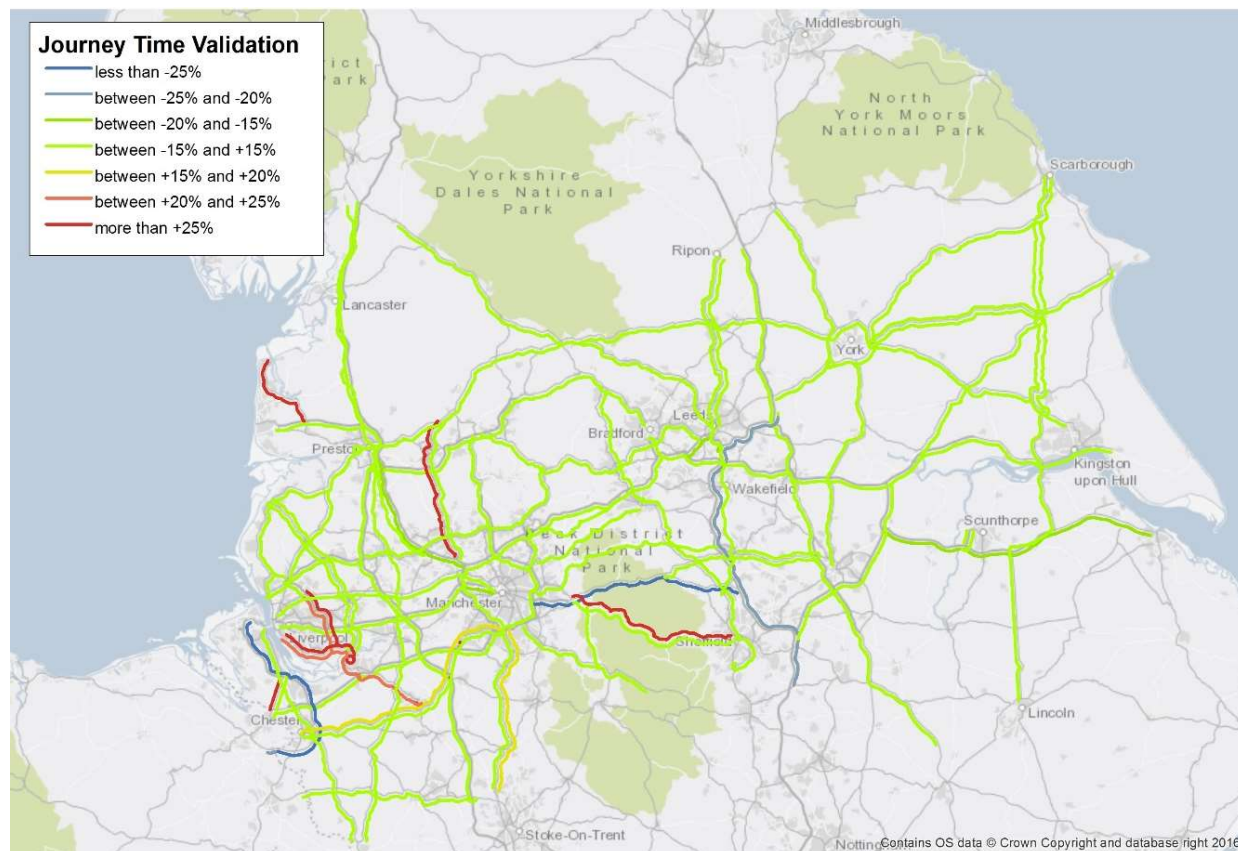


Figure 45 – Inter-peak – Post-ME – Comparison of Modelled and Observed Journey Time Routes

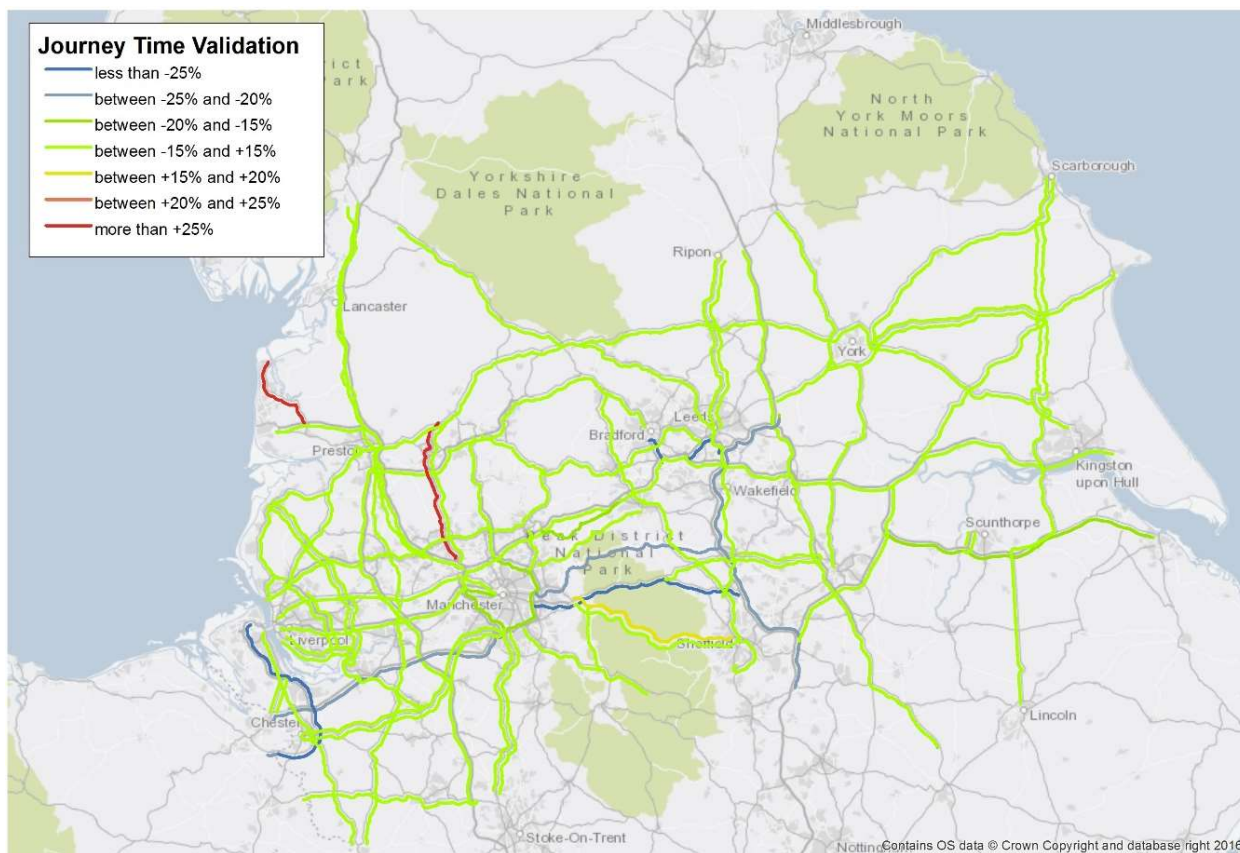
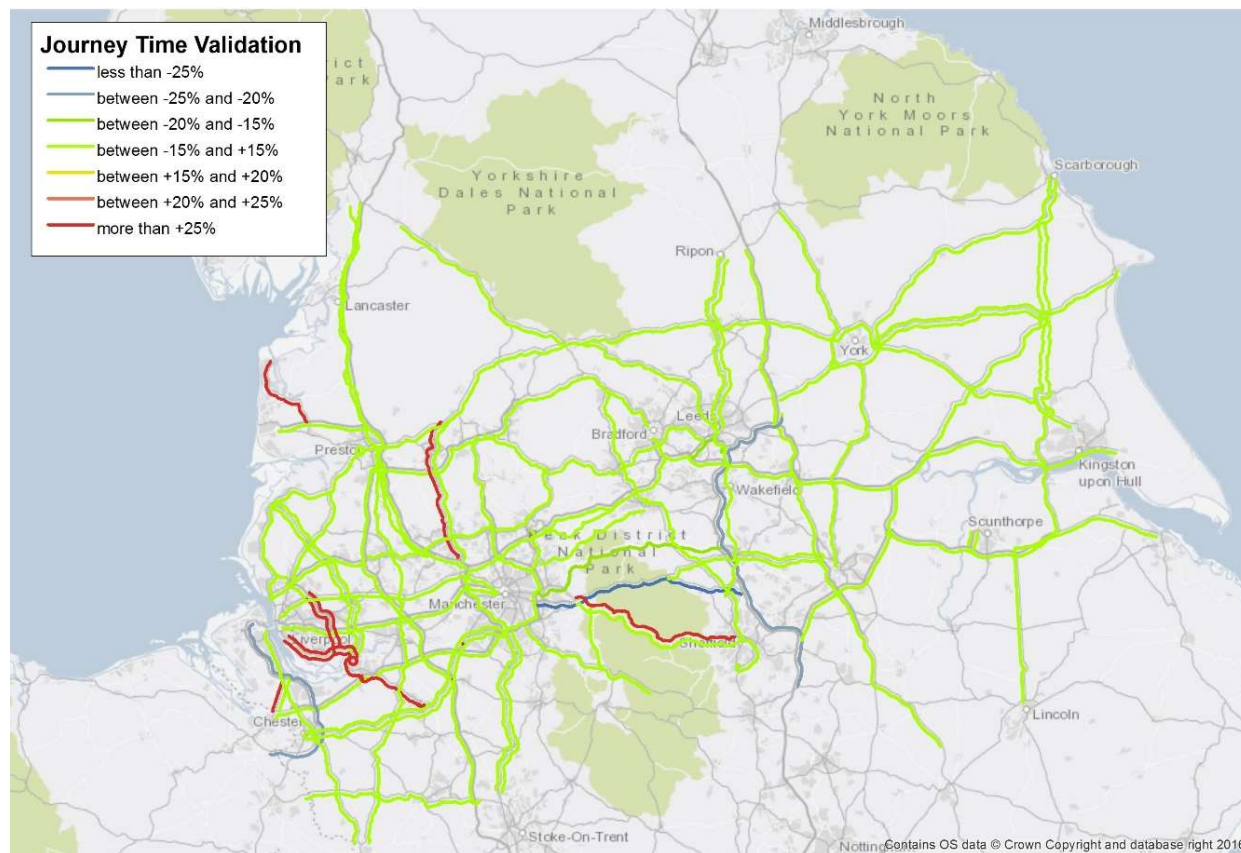


Figure 46 – PM Peak – Post-ME – Comparison of Modelled and Observed Journey Time Routes



The routes that are either 'fast' or 'slow' in more than one time period are as follows.

- The A628 Trans-Pennine route modelled speed is 'faster' than the observed in all three time periods.
- The M1 southbound route between the A1 (Hook Moor in West Yorkshire) and the A57 (Worksop bypass in South Yorkshire) modelled speed is 'faster' than the observed in all three time periods.
- The M53 route around Chester and into the Wirral modelled speed is 'faster' than the observed in all three time periods.
- The M62 west of the M57 (Merseyside), the M57 itself and the A533 Runcorn Bridge all have modelled journey times that are greater than observed (i.e. they are 'slow' in terms of modelled speed).
- The M66/A56 northbound (between the M60 and the M65 near Burnley) has a modelled journey times that greater than observed (it is 'slow' in terms of modelled speed).
- The A57 Snake Pass eastbound is 'slower' than the observed speed in the AM and PM peaks.
- The A585 between the M55 and Fleetwood is 'slower' than the observed speed in all three time periods.

9.3.8 Statement of Convergence Stability and Proximity

The convergence of the highway assignment model is monitored by a series of stability and proximity indicators. ~~Table 60~~ ~~Table 60~~ to ~~Table 62~~ ~~Table 62~~ below provide the final convergence statistics for each time period. As can be seen the % Flow, Delta and %Gap targets have been achieved in each time period and it is therefore considered to be acceptable.

Table 60 – Assignment Convergence Statistics – AM Peak

Iteration	Delta	%Gap	%Flows	%Delays
63	0.0101	0.017%	98.2	98.8
64	0.0084	0.021%	97.7	98.5
65	0.0080	0.022%	98.0	98.7
66	0.0083	0.016%	97.9	98.6

Table 61 – Assignment Convergence Statistics – IP

Iteration	Delta	%Gap	%Flows	%Delays
57	0.0049	0.006%	98.6	99.4
58	0.003	0.006%	99.1	99.4
59	0.0026	0.008%	99.3	99.5
60	0.0033	0.007%	98.9	99.4

Table 62 – Assignment Convergence Statistics – PM Peak

Iteration	Delta	%Gap	%Flows	%Delays
114	0.0093	0.019%	97.7	98.5
115	0.0089	0.018%	97.9	98.8
116	0.0082	0.016%	98.6	98.7
117	0.0077	0.020%	98.8	98.8

9.3.9 Model Validation

The assessment of model validation would normally be limited to observed data that has not been used in model development. In the case of the Trans-Pennine South RTM this would be limited to:

- Traffic flows for the 99 sites on the SRN that have not been used in matrix estimation. Of these the percentage of sites achieving the RTM individual link criteria are 62% for the AM peak, 63% for the inter peak and 62% for the PM peak;
- Journey time data. The results of the analysis of journey time routes is presented in section 9.3.5.
- The assessment of routing between model zones based on judgement and route planning software. This has shown that the route choice in the model is acceptable.

9.3.10 Robustness of Assignment and Impacts on Performance

Robustness as applied to assessing the characteristics of a highway assignment model is a term which is not defined in TAG.

When applied to economic models 'robustness' refers to the assessment of the ability of a model to remain valid in under different assumptions and initial conditions; this definition is of use in judging the 'robustness' of the highway assignment model. On this basis the assessment of robustness has been taken to mean the extent to which the highway assignment would remain essentially 'correct' given the range of accuracy of the inputs.

The development of the model as well as the calibration and validation processes have been informed by the current guidance (WebTAG Unit M3.1) as well as best practice gained from the technical consistency groups of the RTMs.

The various measures by which the highway assignment can be investigated and assessed have been examined in turn in the preceding sections. These measures include:

- assessment of routing between origin-destination pairs;
- assessment of journey time routes;
- comparison of modelled and observed flows for long screenlines, mini-screenlines and individual links;
- convergence of the model; and
- ad hoc inspection of elements such as overcapacity links and turns in the base year

The model generally achieves the guidelines established by the RTM technical consistency group.

10 Variable Demand Model

10.1 Introduction

This Chapter discusses the development, calibration and validation of the Variable Demand Model (VDM) and Public Transport (PT) aspects of the Regional Transport Model's (RTMs).

10.2 Model Development

10.2.1 Basis of whether to include variable demand in the model

A key objective of the RTMs is to provide a multi-modal platform for transport scheme assessment. The scale and spatial coverage of transport schemes to be assessed by the RTMs is significant. Furthermore, many of the schemes to be considered will be in sections of the Strategic Road Network (SRN) that are subject to congestion.

In consequence, a VDM approach has been developed which adheres to WebTAG guidance¹² where appropriate and models the key traveller choices of; route, mode, destination and time of day.

10.2.2 Model Form

In order to ensure consistency between all regional models with respect to approach to VDM, it was agreed (by Highways England) that DfT's DIADEM (Dynamic Integrated Assignment and DEMand Modelling) software would be used.

DIADEM is software designed to enable practitioners to set up variable demand models. It provides a user-friendly method for setting up a multi-stage transport demand model and finding equilibrium between demand and supply, using the SATURN package as the supply model. The process iterates between demand calculations and highway assignments until a converged solution is reached.

DIADEM is also compliant with WebTAG guidance with respect to model form, most notably model hierarchy and incremental nature of the model. The approach makes use of cost changes from incremental differences between base and test scenario operated using a pivot point approach. *Thus the demand model form is incremental rather than absolute.*

¹² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/542504/webtag-unit-m2-variable-demand-modelling-forthcoming-change-november-2016.pdf

DIADEM inputs and outputs are entirely based in text files which have prescribed file names. While DIADEM provides a user interface to control model runs, a bespoke software tool HEIDI (Highways England Integrated Demand Interface) was developed as part of the RTM development programme to:

- control the application of DIADEM;
- enable consistent application of DIADEM across all RTMs;
- to simplify file management;
- organise and implement forecast model runs;
- assemble trip ends;
- undertake multiple model runs; and
- prepare 'template' reporting of VDM runs.

HEIDI is a C#-based Graphical User Interface which interrogates a SQL database containing model inputs and outputs. This approach simplifies the overall model flow, where HEIDI controls DIADEM which in turn controls the SATURN assignments within internal loops of supply/demand calculations until convergence is reached. Further information relating to HEIDI can be found in the HEIDI User Manual as follows:

HighwaysEngland_HEIDI_User_Guide_v4.3_20170214, SYSTRA 14 February 2017

10.2.3 Model area and zone size

The model area is illustrated in Figure 1 with zone plans provided in Appendix I. The zonal dimensions of the model are provided below:

- 1,849 Simulation Zones;
- 163 Buffer Zones; and
- 2,012 Total Zones.

10.2.4 Model Parameters

A wide range of model parameters and inputs to DIADEM have been prepared. Table 63 below contains a list of those applied to the VDM Model.

Table 63 – Demand Model Parameters

Parameter/Setting		Data Source	Notes
Segmentation			
Modelled slices	time	AM 07:00-10:00, IP 10:00-16:00, PM 16:00-19:00 hours, OP 19:00-07:00	AM, IP, PM travel costs derived from average period hour calibrated assignments. OP travel costs derived from uncalibrated assignment of MPD derived OP matrix to IP network to represent free-flow conditions.
Time period factors		AM=3, IP=6, PM=3, OP=12	Simple calculation consistent across all movements and purposes as average period demand is assigned
Assigned classes	User	From assignment models: • Car Employers Business, • Car Commute, • Car Other, • Light Good Vehicles, • Heavy Good Vehicles	
		Segment	Car Available

Parameter/Setting	Data Source		Notes
VDM Segments	Home Based Employers Business	1	Fixed elements relate to 'special zones' which include unique travel patterns that are not subject to VDM response.
	Home Based Commute	2	
	Home Based Other	3	These may be ports or airports where 'Other' (passengers) and Employer's Business may be assumed not to be subject to VDM responses, for example where separate demand modelling has taken place to provide demand inputs.
	Non Home Based Employer's Business	4	
	Non Home Based Other	5	
	Fixed – Employers Business	6	
	Fixed – Commute	7	
	Fixed - Other	8	
	Light Good Vehicles	9	
	Heavy Good Vehicles	10	
Sectors	23 sectors defined for TPS Model. 11 Internal (Counties) and 13 External (country/region).		
Model Parameters			
Model type	Home Based	Incremental PA	

Parameter/Setting	Data Source		Notes
	Non Home Based	Incremental OD	
	Goods	Fixed	
	Special Generators	Fixed	
Model responses and hierarchy	(Macro) Time of Day Choice Mode Choice Distribution		Distribution is singly constrained for Employer's Business and Other, doubly constrained for Commute.
Logit parameters: lambda, theta	Median WebTAG		
Distribution Intra-zonal cost calculation	DIADEM Default values ($\rho=0.5$, minimum cost=5)		
Cost coefficients (VOTs etc.)	WebTAG with distance based VOT		
Cost damping parameters and specification	Damped utility by function of distance		

Parameter/Setting	Data Source		Notes
Occupancy factors	Varies by purpose, travel distance and urban density.		Relationships calibrated from NTS as part of the highway matrix development, with average values aligned to WebTAG.
Demand Matrices			
Road Matrices	Home-based (24hr PA)	Calibrated assignment matrices split using MPOD data and transposed then aggregated to 24-hour using PA Outbound and Return proportions (see below)	
	Non-home-based (hourly OD)	Calibrated assignment matrices split using MPOD data	
	Goods (hourly OD)	Calibrated assignment matrices	
	Special Generators	Calibrated assignment matrices with extraction of demand for specific zones and demand segments	
Public transport	Derived from Planet North (v5) supplemented by MOIRA for longer distance movements		

Parameter/Setting	Data Source		Notes
Cost Matrices			
Reference SATURN UFS files			Extracted from SATURN road assignment.
Rail costs skims for reference and forecast	Base	VISUM Time Skims	Extracted from National Rail network and then compressed to Model zone system.
	Forecast		
Rail fare skims for reference and forecast	Base	distance-based fare function	
	Forecast		
PA Data			
Outbound proportions	Proportions derived from MPOD data, at a 13-sector level, for each Home-Based purpose.		
Return proportions(by time period for each demand segment, sector movement, and mode)	Proportions then merged with whole-model proportions, by purpose, where MPOD data sample was too small to establish proportions reliably		

Parameter/Setting	Data Source	Notes
Tour proportions	Default values provided in DIADEM from NTS were Furnessed, outside of DIADEM, to match the above Outbound and Return proportions derived from MPOD data (see above).	
DIADEM Parameters		
Algorithm	Fixed Step Length (0.5 during base model calibration)	
Convergence	Target GAP of 0.1% for entire model and 0.2% for simulation area	

10.2.5 Representation of public transport supply and demand

It should be noted that the representation of public transport demand varies between the five RTM models, but the approach used to represent public transport supply is common.

A representation of Public Transport (PT) demand and supply data was required for the VDM. With the RTM's focusing on Inter-urban travel, and the need for a proportionate approach to representing PT, it was deemed that rail travel was the main competitor to inter urban car travel and that bus/coach need not be represented. The following approach to representing rail within the VDM was undertaken:

10.3 Derivation of Base Year Public Transport Demand

The process for deriving the base year public transport demand is set out below.

- Extract demand from PLANET: AM peak period (0700-1000), OD matrix, 3 purposes (EB, Commute, Other) by car availability, with car available demand retained for mode choice modelling in the final RTM matrices.
- Factor the three journey purposes in PLANET to the five journey purposes required for the RTMs using National Rail Travel Survey (NRTS) by area classification, splitting out home-based and non-home base demand segments;
- For Home-Based demand calculate factors from NRTS to remove "to home" trips in AM peak period then factor to 24-hour PAs using factors derived from NRTS by purpose and area classification;
- For Non-Home-Based demand factor AM period OD trips to IP, PM, OP and 24 hour using factors derived from NRTS by purpose and sector;
- Factor demands from 2010-11 to 2015 using sectorised Office of Rail and Road (ORR) station usage estimates at a local authority level, resulting in a 13% increase overall.
- Re-zone demand from PLANET to TPS zone system using simple proportion overlap approach.
- Checking output demands against independent data sources such as:
 - Office of the Rail and Road (ORR) station usage estimates;
 - National Transport Model (NTM) rail trip ends (from NTEM); and
 - MOIRA data.

The representation of external demand in PLANET North is negligible, with trips traversing the modelled area or not completed within the 3-hour assignment period not included. The matrices were therefore adjusted to improve the external demand representation, using MOIRA. As part of this analysis it became apparent that PLANET also underestimated trips to/from/within the study area. A matrix of factors was developed at a Local Authority level to improve the match with the MOIRA totals.

Figure 47 shows the comparison of the final TPS matrix trip ends (including Non-Car Available demand) to MOIRA at the Local Authority Level, within the study area. It shows a very strong correlation between the datasets.

Figure 47 – Modified Enhanced TPS Matrix vs MOIRA Boardings and Alightings by LA

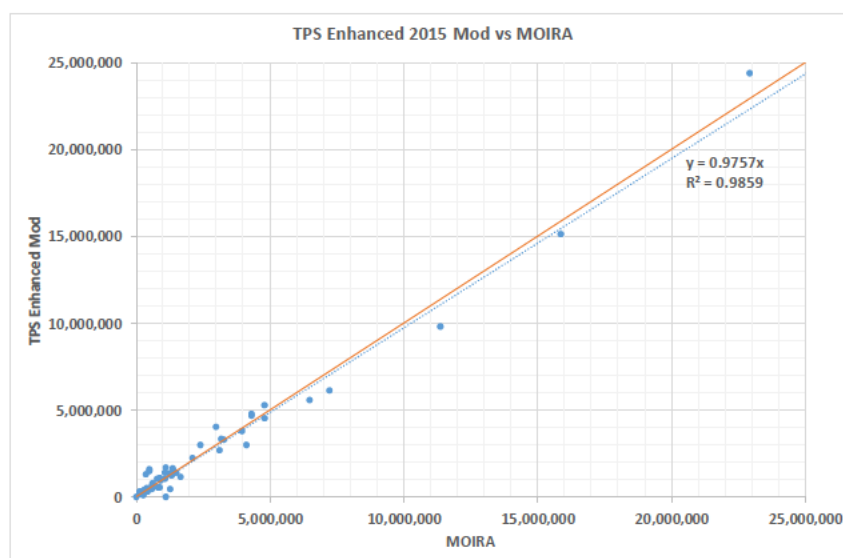


Table 64 summarises the rail derived base year demand by segment, and shows the rail mode share, relative to the highway demand matrices.

Table 64 – Rail Demand and mode share by segment

Demand Segment	24hr	Rail mode share
Home Based Employer Business	171,735	9.3%
Home Based Work	802,488	6.5%
Home Based Other	366,705	2.2%
Non Home Based Employer Business	32,978	1.9%
Non Home Based Other	47,545	0.7%

10.4 Derivation of Base Year Public Transport Supply

A representation of the UK rail network (including Scotland, England and Wales, but excluding Northern Ireland) was prepared using timetable and network data obtained from the Traveline National Dataset, a detailed database of UK rail timetables as well as data from the Association of Train Operating Companies (ATOC). In addition to this the National Public Transport Access Nodes (NaPTAN) provided data on the locations of UK railway stations.

CIF files for April 2016 were downloaded using Basemap Datacutter. These were converted into General Transit Feed Specification (GTFS) format using Basemap TRACC software. These GTFS files were then imported into VISUM, to produce links, nodes, line routes, etc.

The resultant rail network was aligned to a newly developed National Zoning system. This zone system was developed using the finest level of detail from each of the five regional models. A total of 8,049 zones were identified.

After the preparation of the GTFS data and Zone system into VISUM, a number of additional stages were required before cost skims could be produced as follows:

- Connectors were added to connect zones to stop nodes. A filter was placed on the nodes, so as only rail and light rail/underground stop nodes were active. The first iterations of this was:
 - Connectors added to the closest five nodes to the zone centroid, which are less than 1.6km (1 mile) from the centroid with mode set to “walk”. Journey time determined by a walk speed of 3 miles per hour.
 - For zones with less than two connectors after Stage A, connectors were added to the closest Nodes with mode set to “other”. This is to represent a combination of walking, bus and other modes which could be used to reach these railway stations. Journey time determined by assuming a speed of 3 miles per hour for the first mile, then 30 miles per hour for all remaining distance.
- Major rivers and inlets were reviewed to identify possible inappropriate connectors where crossing points are not available. Inappropriate connectors were deleted and, where possible, replacement zone connectors were added.
- The resultant network was assigned a ‘flat’ demand matrix (of 1’s) to identify errors and highlight areas where connectivity was limited or broken.

The skim tool is currently configured to produce skim matrices for Perceived Journey Time (PJT) and In Vehicle Distance (IVD). The perceived generalised journey time for public transport are calculated as follows:

- In-vehicle time (actual from timetable)
- Access/Egress time (from distance based connectors described above)
- Transfer walk time (from distance based connectors at key interchange locations)
- Transfer wait time (from timetable)
- Number of Transfers × 10 minutes

It should be noted that there is no weighting applied to the walk or weight times. Using the VISUM timetable based assignment method there are also no initial wait times included. In general, it’s important to note that the rail skim tool is not intended to be a PT model and is simply a method of extracting comparable PT costs for the demand modelling with a focus on determining change in rail journey times in forecast scenario(s). Therefore, the in-vehicle time is the most important skim component, unless station choice becomes more of a critical aspect, in which case access/egress may also feature more strongly in terms of change.

Some further key features of the rail skim tool:

- Time Periods: The process represents AM Peak (07:00-10:00) only. Following analysis of IP and PM data, it was shown that, although there were differences between the time periods, the effort of preparing three forecast time periods and the context of the RTM’s (with respect to PT representation) suggested that the pragmatic approach is to focus on AM Peak only service representation.
- Journey Purpose: The process is configured to represent an average of all rail journeys regardless of journey purpose. Given the absence of fares, with differences in the value of time by purpose, it is not considered that route choice would vary greatly and segmentation would significantly increase the skim tool run times

- Modes: The following modes are included in the skim tool:
 - Rail
 - Light Rail/Tram (Trams in Sheffield, Manchester, etc. plus Newcastle Metro)
 - London Underground
 - Ferries

For simplicity, all modes are represented with no capacity restraint on services. Buses are not considered in this skim tool.

Walking is considered with regards to connections to, from and between public transport stations. In addition, a proxy "Other" mode is used to represent travellers accessing rail stations by modes such as bus, car, etc. where the average speed is greater than walk.

From the resultant National rail skim, individual regional model skims are derived using demand weighted aggregation.

10.5 Rail Fares

MOIRA was used to derive a distance based fare function. MOIRA contains demand and revenue information between each station pair, split by 'Full', 'Reduced' and 'Season' ticket types. NRTS data were assigned to these ticket types to derive different splits by the RTM journey purposes.

The revenue was divided by the demand between each station pair within the TPS area to derive an average fare for that station pair, for each journey purpose.

A linear distance based fare function was derived for each journey purpose where:

$$\text{Fare} = \text{Intercept} + \text{Distance Factor} * \text{Crow Fly Distance}$$

The parameters derived for each journey purpose are provided in Table 65, along with the R^2 illustrating the goodness of fit of the data. Due to the high degree of scatter, as seen in Figure 2, in the distance and fare relationship, the R^2 values are reasonable, though not particularly strong. This illustrates that real-world fares are not purely a function of distance and different operators, ticket types and regional aspects influence the ticket prices.

Figure 48 – Fares by distance by journey purpose

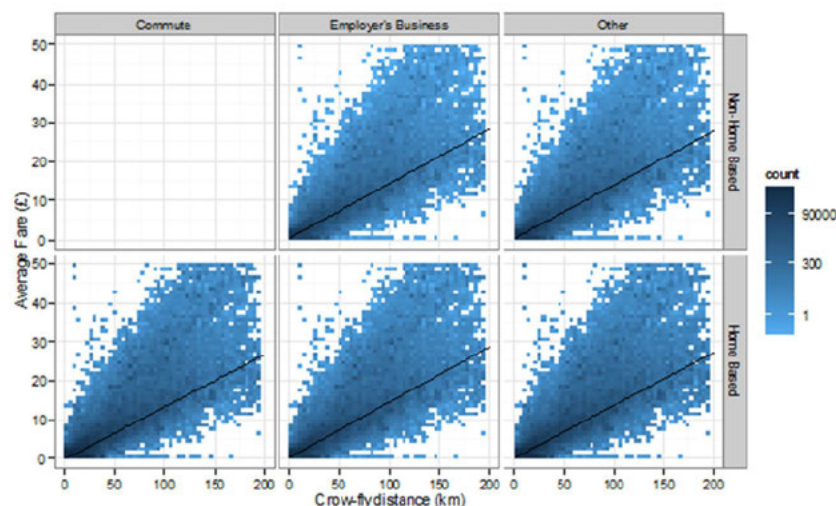


Table 65 – Parameter for Fare Functions by journey purpose (£, 2015)

MOIRA STATIONS WITHIN TPS	INTERCEPT	DISTANCE (KM) FACTOR	R ²
Non-Home-Based Business	0.43	0.14	0.751
Non-Home-Based Leisure	0.29	0.14	0.735
Home-Based Work	-0.06	0.13	0.615
Home-Based Business	0.37	0.14	0.731
Home-Based Leisure	0.19	0.14	0.730

The demand model requires the fares to be specified in a 2010 price base rather than 2015 as output from MOIRA. To adjust the 2015 fares to 2010, the GDP deflator values from the July 2016 WebTAG databook were used to derive an adjustment factor of 0.936.

The fares entered into DIADEM are input by assignment user class and therefore cannot include the distinction between home based and non-home based segments. The home-based fares have been used in the demand model.

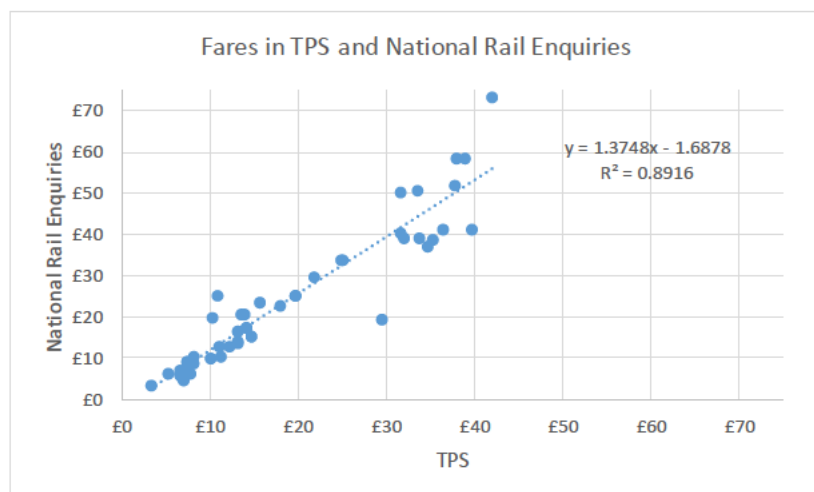
To check that the derived rail supply data were broadly reasonable fares were compared against data extracted from the National Rail website. For the comparison, the un-deflated TPS fares were used as the National Rail fares are in current day prices.

A range of fares were extracted to cover different potential route options. Due to the nature of the rail service provision, multiple route and fare options are available between many locations, particularly for key cities. As the TPS zones are large, station and route choice could materially affect the journey time. The comparisons undertaken used simple averages of available route fares as the purpose was a general order of magnitude check of the TPS rail model supply data.

The comparisons focused on journeys between the key places of Liverpool, Manchester, Sheffield, Leeds, York, Hull, Preston, Crewe, Chester, London, Edinburgh, Glasgow. Data for 52 journeys were extracted from National Rail Enquiries. The data were extracted as return fares divided by 2 to compare against the one-way fare data in the TPS model. Both peak and off peak fares were extracted, but the comparison focused on the off peak data. The comparison indicated that the TPS fares are less than the National Rail Enquiries fares in 85% of cases (44 of 52). As MOIRA data contains season tickets and reduced fares, it is logical that the derived TPS fares are generally lower than the ticket prices shown on National Rail Enquiries. In addition, the fares extracted from National Rail Enquiries were the standard walk-up fares and would typically be higher than the MOIRA data which includes lower cost, advanced fares.

The following chart shows a reasonable correlation between the TPS and National Rail Enquiries fares.

Figure 49 – Comparison of Fares in TPS and National Rail Enquiries



10.6 Software used

The software required to run the VDM comprises:

- SATURN Version 11.3.12
 - Highway Assignment Software
- DIADEM Version 6.3.3
 - VDM Software
- HEIDI Version 4.1
 - C# Graphical User Interface to control DIADEM
- SQL Server 2016 SP1 Express
 - Model Database
- VISUM 15
 - Development of rail skims

10.7 Calibration

10.7.1 Calibration of variable demand model

The source of demand data for highway and rail is, respectively explained in Chapter 6 and Section 9.1.5. These data were assembled for model application and do not provide a structured data source of sufficient standard directly to estimate the demand model coefficients, although the highway matrix development did consider trip distribution, as discussed further below.

Accordingly, the approach taken to determine demand model coefficients and structure followed WebTAG M2¹³ Section 5.6. The research evidence from which the guidance is derived is based on the calibration of a selection of urban models. The main considerations related therefore to extrapolation of this evidence to the relatively long distance range of trips using the Strategic Road Network represented in the RTMs. The estimation of long distance UK travel behaviour most recently undertaken by RAND¹⁴ was limited to trips longer than 50 miles and is not directly applicable. Nevertheless, it demonstrates the same mode/destination choice structure recommended in guidance and the lower generalised cost sensitivity is consistent with guidance on cost damping.

10.7.2 Choice of model parameters and comparison against published values

Model sensitivity parameters

Mode, destination and (macro) time period choices are represented in the demand model. The assumed logit choice parameters have been drawn from Median illustrative values set out in WebTAG unit M2, as summarised in

¹³ An update to WebTAG unit M2 was published for consultation during July 2016 and references are made to this 'draft for consultation'; Hereafter where the draft guidance differs from previous 2014 guidance specific note is made and the section references are distinguished by '(M2-2014)'.

¹⁴ Modelling Longer Distance Demand for Travel Phase 2, Final Report, Scott Wilson Ltd, August 2009.

Table 66~~Table 66~~. The destination parameters give the sensitivities per minute of generalised car time, the mode and time parameters define the sensitivity of these choices *relative* to destination choice. These parameters imply that mode and (macro) time period choices are equally sensitive to changes in generalised car time.

Table 66 – Destination, Mode and Time Period Sensitivity Parameters

Purpose	Car		Rail	
	Destination	Mode	Destination	Mode
Home based work	-0.065	0.68	-0.033	0.68
Home based employer's business	-0.067	0.45	-0.036	0.45
Home based other	-0.090	0.53	-0.036	0.53
Non home based employer's business	-0.081	0.73	-0.042	0.73
Non home based other	-0.077	0.81	-0.033	0.81

Source: WebTAG M2 : Destination- Table 5.1, Mode, – Table 5.2

Demand for non-car available segments is not represented in the variable demand model. Demand from air passengers travelling to/from airports, freight and from selected developments is modelled separately and therefore held fixed within the RTM. The RTM user can decide whether demand for new developments is distinct and should be modelled separately or is to be included (with suitable seeding of reference demand) within the five purposes represented by the VDM.

Car occupancy

In developing the highway trip matrices an analysis was undertaken of NTS data to review car occupancy assumptions reflecting the wide coverage and range of trips represented in the RTMs.

10.7.3 Description of any cost damping mechanisms used

Value of Time

WebTAG M2 Section 3.3.6pp sets out guidance on the variation of values of time with distance using the following formula:

$$VOT_d = VOT \cdot \left(\frac{\max(d, d_c)}{d_0} \right)^{n_c}$$

Where:

d is minimum trip distance, defined from an inter-peak base year highway network assignment (with an allowance for travel distance to access the modelled transport network based on the radius of the zone area),

The approach taken to interpret values of time for the RTM VDMs was applied consistently using national evidence to:

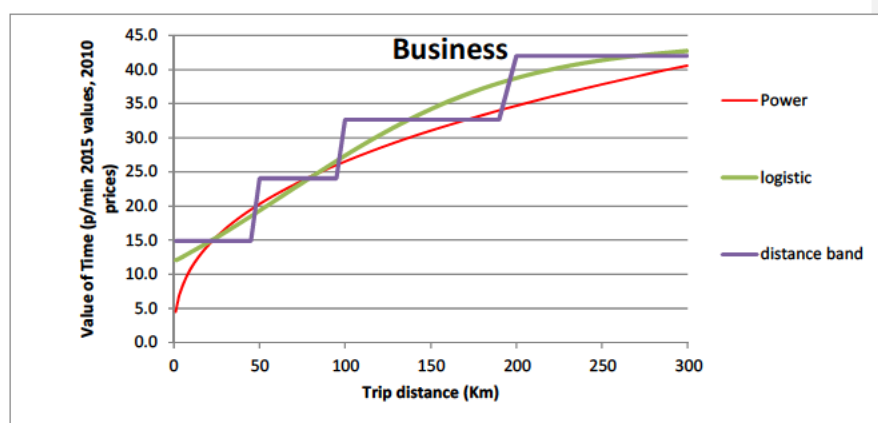
- consider options for a distance cut-off to define d_c
- estimate a value for d_0 using the distance elasticities (η) defined in WebTAG M2 (July 2016 draft) para 3.3.8 that reproduces the average distance weighted values of time set out in the WebTAG data book (July 16, release 1.6, Table A1.3.2), taking 2015 values and 2010 prices.

The DfT have also estimated a logistic value of time for appraisal of employer's business travel time savings (consultation draft guidance July 2016 unit A1-3, section 4.2.9). This option is not currently available in DIADEM and the functional

form is not estimated for non-business purposes. Accordingly, the logistic function was used only for verification purposes.

As illustrated below the material differences between the power and logistic functions (when calibrated to reproduce the same distance weighted average value of time) relate to relatively short distance trips, with the (red) power curve showing lower values of time than the (green) logistic curve for employers' business trips up to about 15 Km. Proportionately the differences are smaller for longer trips over 100Km in length. The purple line comparatively illustrates the average values of time determined by DfT for different distance bands.

Figure 50 – Power, Logistic and Distance Band VOT Function Comparison, Business



The argument for imposing a distance cut off relates to the relatively high sensitivity implied for short trips where the power function results in a low value of time¹⁵. The RTMs have zones based on MSOA geography and will not therefore provide reliable trip length estimates for trips substantially less than about 5Km in length. There are also instances where centroid connectors from adjacent zones have been coded on adjacent network links such that the network distance skims are zero or small. Imposing a cut off will help ensure stability of the RTMs when used for forecasting.

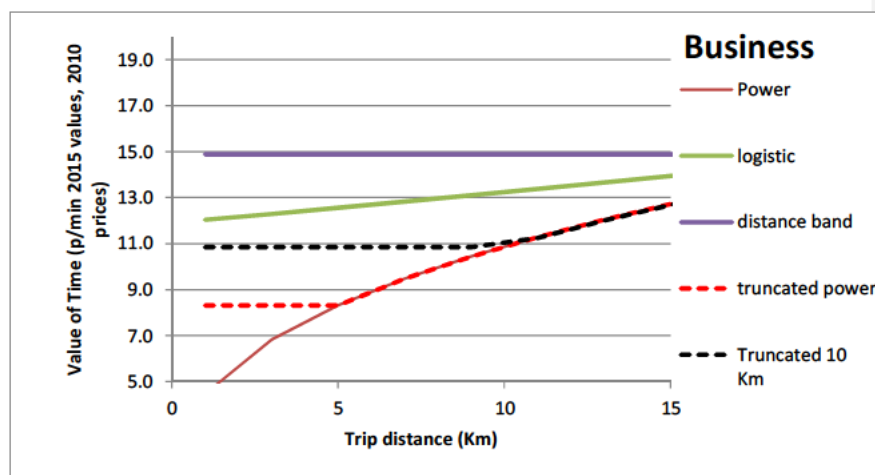
The reasons for recommending the logistic function for appraisal relate to the stability of extrapolation of evidence to very short and very long distance trips, and not whether the logistic or power function fits the observed data better. There are less than 0.3% of business trips recorded in NTS greater than 400Km where the power function has a value of time of about 47p/min, or about 7% larger than the logistic function of 44 p/minute. There are too few extremely long trips to be material for the RTMs and the potential issues about extrapolation concern short trips.

The following figure compares the values of time of short distance trips: the distance banded (purple) and logistic function (green) have higher values than the power function and two variants (dotted lines) where the distance has been

¹⁵ $GC (min) = time(min) + cost(p) / VOT(p/min)$, so lower VOTs give rise to larger generalised cost changes.

truncated at 5 and 10 Km (and the overall value of time calibrated to the same distance weighted average).

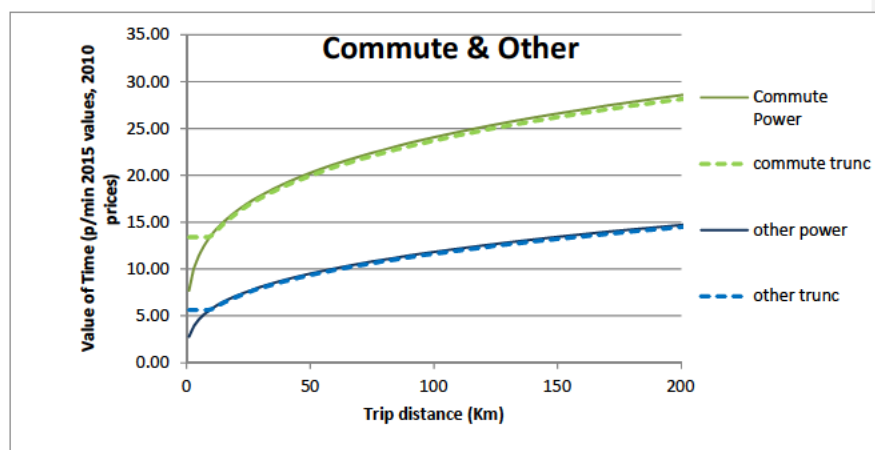
Figure 51 – Power, Logistic and Distance Band VOT Function Comparison, Business, Short Trips



There is limited practical difference imposing a lower bound of 8.3 or 10.9 p/min. A 10Km cut off (d_c) was therefore adopted as an acceptable compromise that better reflects the logistic function.

For reasons of consistency, this same distance cut off assumption was applied for other purposes. The resulting distributions of values of time are illustrated below.

Figure 52 – Power, Logistic and Distance Band VOT Functions, Commute and Other



Separate elasticities are not provided for non-home based purposes, nor is there a substantial difference in trip lengths between home base and non-home based

average trip lengths for business and other purposes. The same value of time distributions have been assumed for the non-home based employers business and non-home based other purposes as for their home-based equivalents.

Estimating D_0 to reproduce distance weighted average values of time yields the following parameters. (Note that the values for D_0 set out here are calibrated to reproduce distance weighted average values of time set out in the WebTAG databook (November 2016 Draft) and are accordingly much larger than would be implied if the functions were calibrated to a trip weighted average value of time.)

Table 67 – Final Value of Time Function Parameters by Purpose

Parameter	Home Based Employers Business -car	Home Based Employers Business - Rail	Home Based Work	Home Based Other
VoT (p/min 2015 values, 2010 prices)	26.38	43.51	17.66	8.06
D_c (Km)	10	10	10	10
D_o (Km)	99.5	165.5	30.5	31.2
η	0.387	0.435	0.248	0.315

10.8 Damping Generalised Cost as a Function of Distance

Work was undertaken to establish synthetic car demand matrices as part of the task to develop prior highway demand matrices (Section 6.5). For this task a lognormal function was adopted to reflect the observed distribution of travel demand with distance. The parameters estimated provide direct evidence on how the sensitivity of demand to generalised cost varies with distance.

The original intent was therefore to maximise consistency and implement the VDM using the same functional form. However, delivery programme constraints together with software implementation issues associated with introducing this function in DIADEM resulted in an alternative approach that adopted a form of cost dampening set out in WebTAG unit M2 (Section 3.3). This approach was verified against the evidence from the highway matrix development. The following paragraphs therefore first briefly introduce the lognormal function and then go on to explain how the lognormal function was used to inform the choice for damping generalised costs in the RTMs.

For the purposes of establishing highway matrices, a number of simplifications were adopted in defining generalised costs: a single value of time and cost per Km were used. The lognormal functional form is not amenable to direct post estimation adjustment to derive parameters consistent with the generalised cost formulation adopted for the VDM. However, limited sensitivity analysis indicated that the effect on the estimated coefficients would be modest.

A second area of concern arose from a review of the iterative procedures applied to establish the synthetic matrices. This confirmed that, while estimated the trip length distribution had adequately converged, the estimated coefficients were not stable between iterations. A pooled estimate of coefficients across all time periods and RTMs was adopted to reduce uncertainty about central coefficient values.

The indicative coefficients and their standard deviations (based on variation between models and time periods) are set out in Table 68 based on the standard log-normal distribution function:

$$\frac{1}{C_i \sigma \sqrt{2\pi}} \exp\left(\frac{-(\ln C_i - \mu)^2}{2\sigma^2}\right)$$

Where:

C is the generalised cost, and

σ and μ are the fitted distribution parameters.

Table 68 – Averaged Lognormal Parameters from all RTM Highway Matrix Syntheses

	HBW		HBEB		HBO	
	μ	σ	μ	σ	μ	σ
mean	2.7	0.70	2.5	0.92	2.21	0.67
(st. dev)	0.43	0.11	0.63	0.22	0.46	0.25

Two common approaches to cost damping are set out in WebTAG:

- varying cost as a function of distance, with common cost damping parameters are set out related to the distance function (WebTAG M2 para 3.3.15); and
- a power function of utility, for which common cost damping assumptions referred (WebTAG M2, para 3.3.18), for which a beta value of 0.75 (centre of range) was assumed and a value for mu estimated to set the mean generalised cost.

A spreadsheet based approach was adopted using NTS trip length distributions, assumed generalised cost distributions and the lognormal, distance based and power based cost dampening alternatives.

The following figures illustrate the forecast change in trip length arising from an increase in fuel cost implied by different distribution functions represented in the spreadsheet. Overall elasticities are summarised in Table XX which covers trips of all lengths. It should be noted that the spreadsheet tool did not include constraints in trip attractions and the purpose was merely to understand the behaviour of different functions, not to indicate or provide a comparison for the individual RTMs. The figures focus on the 20-200 Km trip length that will be of most relevance to the SRN forecast traffic, showing on the left the cumulative proportion of trips against distance and on the right the cumulative trip kilometres against distance, and setting out:

- the NTS trip length distribution (base - black),
- the effect of applying a standard logit function with fixed values of time (dotted),
- a standard logit function with values of time increasing with distance (thin red line),
- logit with value of time increasing with distance using distance based cost damping (thick dark brown line),
- logit with value of time increasing with distance using power based cost damping (thick light brown line), and
- lognormal (thick green line).

Over the distances illustrated the figures indicate little difference between the two cost damping and log-normal functions – the forecast change in trip length distribution to a change in fuel cost appears similar. The figures do however demonstrate substantial and material differences where no cost damping or only a variation in value of time with distance is represented.

The lognormal function behaves differently for short distance trips and the elasticities shown in Table 69 are influenced by that difference. The power function appears to have a more consistent influence on elasticity between business and other purposes whereas the distance based function results in a larger reduction in business related elasticity.

Table 69 – Variation in Implied Fuel Cost Elasticity by Cost Damping Option and Purpose

Functional form	HBW	HBEB	HBO
Standard logit, fixed value of time	-0.59	-0.57	-0.49
Logit, value of time increases with distance	-0.44	-0.39	-0.44
Logit, value of time increases with distance, distance based cost damping	-0.26	-0.13	-0.32
Logit, value of time increases with distance, power function cost damping	-0.25	-0.21	-0.24
Lognormal, value of time increases with distance	-0.33	-0.10	-0.36

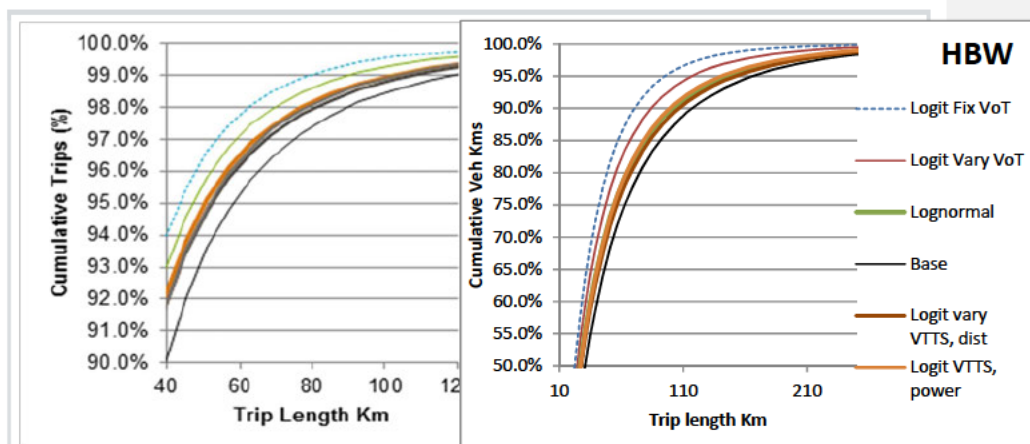


Figure 53 – Illustrative HBW Responsiveness

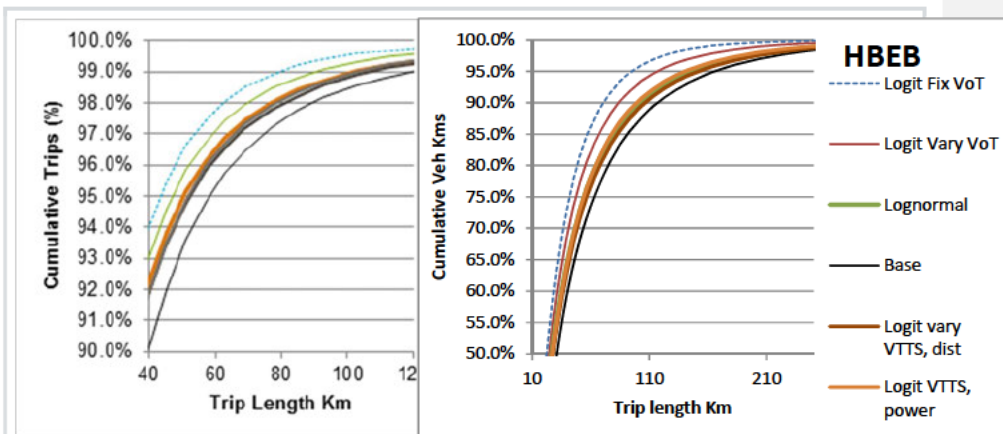


Figure 54 – Illustrative HBEB Responsiveness

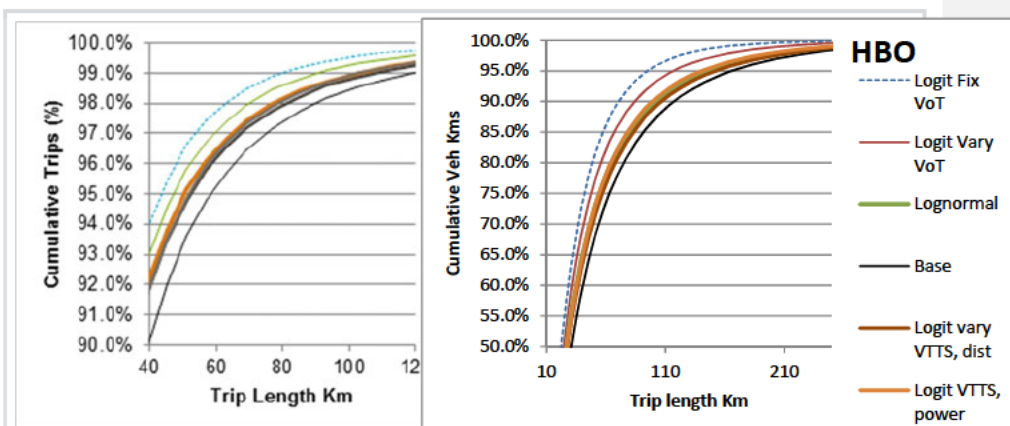


Figure 55 – Illustrative HBO Responsiveness

Both the power based and distance based cost dampening approaches (with an assumption also that values of time increase with distance) result in similar forecasts of the change in trip length distribution for a change in fuel cost. These are similar to the forecasts that arise from the log-normal function using parameters implied from the RTM trip matrix estimation.

Given that the distance based deterrence function appears to result in a more plausible balance between business and non-business fuel price elasticity this form was selected. As previously noted the common assumptions set out in WebTAG were adopted.

$$\hat{G} = \max \left(1, \left(\frac{d}{k} \right)^{-\alpha} \right) G$$

Where G is the generalised cost combining time and monetary cost
 d is the trip distance
 k is a distance cut off, 30Km
 α is a parameter, 0.5

10.9 Model convergence

All variable demand models need to iterate between the demand model and the assignment (or supply) model. This is because the volume of demand affects travel times, which in turn affect the volume of demand and so on.

As in any such modelling system it is important to monitor the convergence of this iterative process. Poor convergence causes noise in the model outputs, which in turn introduces errors into subsequent analyses such as economic appraisal, noise and air quality.

WebTAG requirements for VDM convergence are set out in Section 6.3 of WebTAG Unit M2. This defines the demand/supply gap as the preferred measure of convergence and states that:

'Tests indicate that gap values of less than 0.1% can be achieved in many cases, although in more problematic systems this may be nearer to 0.2%. Where the convergence level, as measured by the %GAP, is over 0.2% remedial steps should be taken to improve the convergence, by increasing the assignment accuracy.'

WebTAG also states that 'ideally the user benefits, as a percentage of network costs, should be at least 10 times the % Gap achieved in the Without-Scheme and With-Scheme scenarios.' However, this relates to economic appraisal and forecasting and cannot be applied to base year realism testing.

One of the new features introduced into version 6 of DIADEM for the RTMs is the ability to calculate the demand/supply gap over a subset of matrix cells. This feature was requested because of a concern that the whole-model gap would be dominated by external zones with very high flows, and may give a misleading picture of convergence within the region of focus (RoF).

The gap calculated over a subset of matrix cells is referred to the 'subarea gap'. The subarea has been defined as all internal to external movements within the RoF.

Based on WebTAG guidance, and on practical experience in terms of what is achievable with the RTMs, the stopping criteria in DIADEM were set as:

- Whole-model gap < 0.1% AND subarea gap < 0.2%.

The gap values achieved during realism testing (discussed in the following section), along with the number of demand-assignment loops required, were as follows:

Table 70 – GAP statistics

	Whole model gap	Subarea gap	Number of loops
Fuel cost realism test	0.06%	0.19%	5
Rail fare realism test	0.06%	0.20%	5

10.10 Model robustness and impact on the model's performance

The focus and associated strength of the RTMs is the representation of highway demand making inter-urban movements. Given this focus inter-urban rail demand is represented. There is no representation of inter-urban coach or air modes, however demand for these modes is focused on specific markets such as airport access and student travel and these were not judged to be of enough importance to be worth explicit representation in the RTMs.

There are simplifications to the highway network using fixed speeds in urban areas, the zones are relatively large with a correspondingly coarse treatment of short (intra-zonal) demand and no representation of travel by active modes, bus or park and ride. The VDM implemented for the RTMs will not therefore provide a reliable basis to forecast the effect of transport interventions on changes intra-urban travel behaviour. The main concerns would be for the appraisal of schemes on the periphery of urban areas where local mode choice or local trip redistribution could affect a material proportion of traffic using the SRN and of relevance therefore for assessing the impact of interventions on or adjacent to the SRN.

With respect to longer distance travel demand, the main focus of the RTMs, care has been taken to implement a model that reflects available evidence representing variations in sensitivity with distance. The approach taken in the RTMs will represent a significant change from existing practice where the sensitivity (fuel cost elasticity) of individual scheme demand models has been constrained to reproduce the same national average value largely irrespective of the nature of travel within the modelled area. While this aligns better with the research evidence available the consequence will be that in using the model there will be some schemes for which the demand modelling responses are larger than would be evident from previous (local) modelling and also others where a smaller demand response will be forecast. This variation in response will require consideration particularly if an approach is taken to develop local models drawing on the RTMs in the assessment of individual schemes.

10.11 Validation

10.11.1 Realism testing

Realism testing has been undertaken for the five RTMs following the guidance set out in Section 6.4 of TAG Unit M2. Specifically, demand elasticities have been calculated using the formula specified in the guidance:

$$e = \frac{\log(T^1) - \log(T^0)}{\log(C^1) - \log(C^0)} \quad (1)$$

where: T^1 and T^0 indicate values of demand in the test and base runs

C' and C^0 indicate levels of cost in the test and base runs

Given that the RTMs are designed to appraise schemes on the strategic highway network, most of the focus in the VDM group discussions has been around the fuel cost kilometrage elasticities. However, the realism of the rail fare elasticities has also been assessed.

Fuel cost elasticities

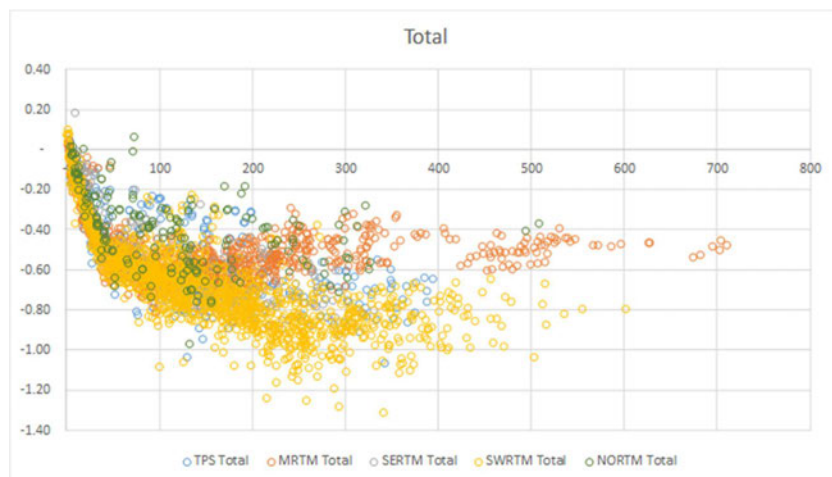
The Section 6.4 TAG unit guidance on fuel cost elasticities is that the overall annual fuel cost elasticity *across purposes* should lie in the range -0.25 to -0.35. Guidance around expected purpose variation is also provided:

- values for business travel expected to be in the region of -0.1
- values for commuting and education expected to be in the region of the -0.3 average
- values for discretionary travel expected to be closer to -0.4.

The research on values of time incorporated into WebTAG databook in 2016 substantially increased the value of time of commuting and reduced for business and other, the effect of which would be expected to bring the business and commuting elasticities close together and increase the elasticity of other travel.

Fuel cost elasticities would be expected to increase with distance, and analysis of the RTMs has confirmed that all five models exhibit a strong variation in elasticity with distance. ~~Figure 56~~Figure-56 scatters, for each region, distance in kilometres and fuel cost elasticity.

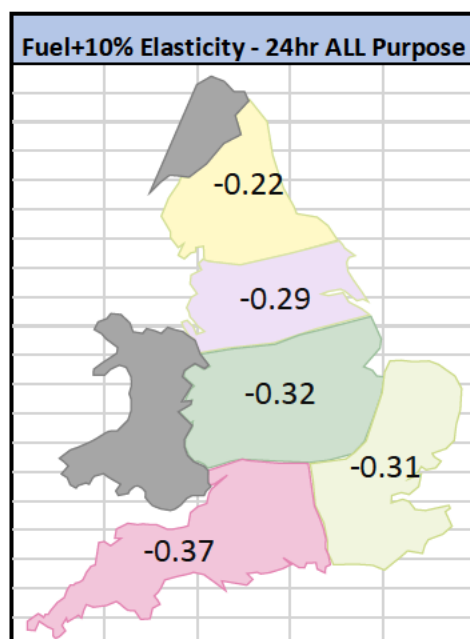
Figure 56 – Variation in fuel cost elasticity with distance



For all five regions there is a strong relationship between fuel cost elasticity and distance, with broadly similar shaped curves that increase rapidly for the first 100km, and level off after 300km. However, there are differences between the regions: in particular, for a given trip distance the elasticities in South West are larger than those for other regions, and those for North smaller and in a few cases positive (reflecting redistribution between short and long trips).

The fuel cost elasticities that have been obtained from the RTM models are also summarised in Figure 57.

Figure 57 – Fuel cost elasticity by region



A simple mean of the five elasticity values is -0.30, and so overall the fuel cost elasticities are in line with current WebTAG guidance. However, there is intra-regional variation, in particular North is lower whereas South West is higher. The evidence on which the WebTAG guidance on elasticities was derived focused on aggregate analysis of national data, with no basis to inform potential variations in different locations.

The fuel cost elasticities for the TPS model are reported for trips originating in the TPS RoF in Table 71 below. Overall the elasticity is central to the TPS evidence from all 5 models and within the range mandated by WebTAG. As would be expected reflecting values of time assumed for the RTMs, the business and commuting elasticities are substantially lower than the other purpose. There are slightly lower elasticities in the peak periods reflecting the constraining effects of network congestion.

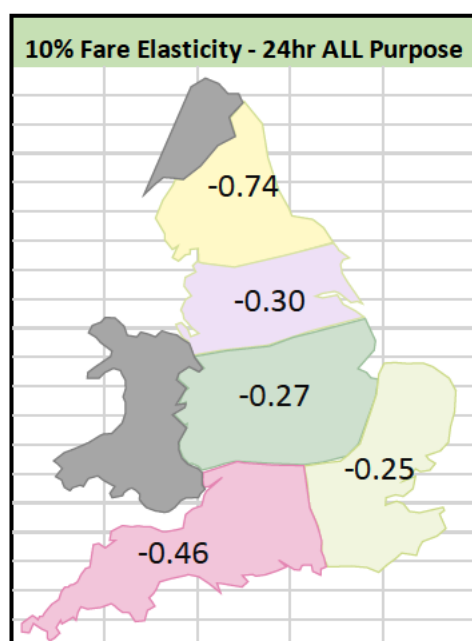
Table 71 – TPS Fuel Cost Elasticities, by Purpose and Time Period

	Employers Business	Home Based Work	Other	Total
AM	-0.18	-0.19	-0.48	-0.25
IP	-0.19	-0.20	-0.49	-0.31
PM	-0.16	-0.17	-0.48	-0.27
OP	-0.26	-0.24	-0.57	-0.37
24 Hours	-0.20	-0.19	-0.50	-0.30

Public transport fare elasticities

WebTAG quotes a public transport fare elasticity range of -0.2 to -0.9, i.e. a relatively wide range of values, based on 2004 TRL work. The following figure summarises the PT fare elasticities obtained in each of the five regional models.

Figure 58 – PT fare elasticity by region



It can be seen that while the values range considerably between regions all of the values lie within the -0.2 to -0.9 range outlined in WebTAG. Table 72 summarised the TPS rail fare elasticities demonstrating credible differential in price sensitivity between the modelled purposes.

Table 72 – TPS Rail Fare Elasticities, by Purpose and Time Period

	Employers Business	Home Based Work	Other	Total
AM	-0.14	-0.17	-0.76	-0.26
IP	-0.15	-0.17	-0.78	-0.48
PM	-0.15	-0.16	-0.81	-0.26
OP	-0.16	-0.17	-0.83	-0.32
24 Hours	-0.15	-0.17	-0.78	-0.29

10.12 Model limitations and robustness

The RTM parameters have been established using WebTAG median evidence and through the application of cost damping following guidance and based on evidence from the highway trip length distributions. Together the five models demonstrate that the sensitivity of the VDM response is consistent with the

research evidence on fuel cost and fare elasticities and thus within the criteria set out in WebTAG.

Analysis of the wide range of trips represented in the RTMs demonstrates variations in sensitivity with other purpose trips being most sensitive to price as would be expected (and in accord with WebTAG. Recommended values of time were updated in the November 2016 databook following research that indicated significantly lower values of time for business travel and higher for home based work travel. Accordingly the RTM elasticities demonstrate higher sensitivity for business and lower for home based work trips than indicated in WebTAG, which has not been updated in respect of this change in evidence on values of time.

The models demonstrate that sensitivity to a proportionate cost change increases with distance – i.e. there are higher elasticities for long distance trips.

The calibration of the models has been at a national level and in consequence there will be variation in sensitivity at a local level that appropriately reflects the detailed variation in local travel patterns. Previous practice to calibrate demand models representing smaller areas to national elasticities will have resulted in some of these variations to be moderated and the outcome of using the RTMs is likely therefore to result in greater variation in demand response between schemes in different locations.

11 Conclusion

11.1 Background to Regional Traffic Models

Highways England have determined that to progress the schemes identified in the Road Investment Strategy (RIS) within the first Road Period (2015-2020), a significant amount of modelling and appraisal work will be required. The 'Traffic Modelling Strategy' developed for Highways England by the Traffic Appraisal, Modelling and Economics (TAME) group identified the creation of five 'regional' models as critical to the future delivery of schemes.

The primary purpose of the regional model programme is to assess RIS highway schemes which are major schemes with a cost estimate greater than £10 million. The models may be used directly (Type A usage), or for smaller schemes to enable more rapid development and calibration of detailed local models (Type B usage). Where there is a strong interaction between the Strategic Road Network (SRN) and the local urban networks consideration should be given to applying the local models

11.2 Technical Consistency Groups

As part of the governance of the regional models programme, Highways England has established the following technical consistency groups:

- Data Consistency;
- Mobile Phone Data / Matrix Development;
- Variable Demand Modelling;
- Network Coding;
- Calibration / Validation; and
- Forecasting.

These groups were tasked with ensuring that all elements of that work stream were undertaken in a consistent manner and to share best practice in order to maximise the value of the experience of the supply chain in delivering this programme.

11.3 TransPennine South Regional Traffic Model Area (TPS RTM)

The Region of Focus (RoF) of the Trans Pennine South Regional Traffic Model is illustrated in **Error! Reference source not found.** The area covers approximately 7,300 square miles and includes 900¹⁶ miles of Strategic Road Network (SRN) with almost 75% of that being motorway.

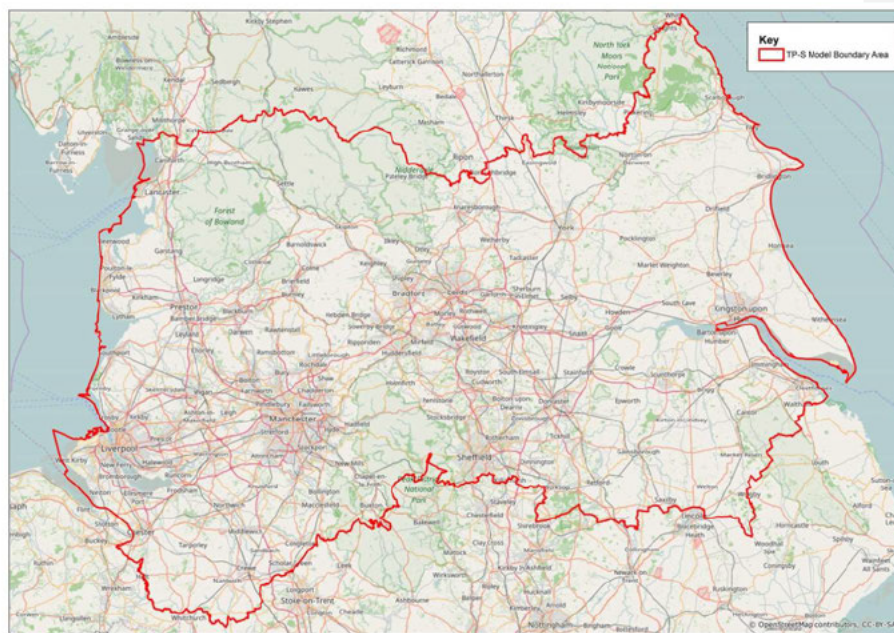
There are over 50 local authorities within the RoF. The area includes the major metropolitan areas of:

- Merseyside;

¹⁶ This is a link based figure i.e. total carriageway length would be twice this value.

- Greater Manchester;
- Leeds; and
- Sheffield.

Figure 59 – Overview of TPS Model Area



11.4 Proposed Schemes

The zonal definition reflects the need to provide a consistent coverage over a wide area whilst recognising that the number of zones will have a direct impact on the run time of the model and therefore its suitability as a practical tool. The TPS model defines some 2000 zones, with detail generally between LSOA and MSOA level near SRN junctions and comprising MSOA or small groups of MSOAs across the rest of the RoF. External zones increase in size with distance from the RoF.

11.5 Description of the Modelling System

The model comprises:

- SATURN as the highway assignment tool;
- DIADEM to provide the variable demand responses managed by a bespoke database interface HEIDI; and
- Public transport generalised costs are derived from a national tool.

A summary of the key aspects of the modelling system are provided in [Table 3Table-3](#). The model base year represents conditions on a typical March 2015 weekday.

Table 73 – Model System Overview

	Time Periods	Modes	Vehicle Types	Trip Purposes
Demand Model	AM 07:00 to 10:00 IP 10:00 to 16:00 PM 16:00 to 19:00 OP 19:00 to 07:00	Highway vs Rail	Car	Commuting HBEB ⁽¹⁾ NHBEB ⁽²⁾ HBO ⁽³⁾ NHBO ⁽⁴⁾
		Highway	LGV HGV	LGV HGV
Assignment Model	Average hour for: AM 07:00 to 10:00 IP 10:00 to 16:00 PM 16:00 to 19:00	Highway Only	Car	Employers Business Commuting Other
			LGV	LGV
			HGV	HGV

Notes:
 (1) Home Based Employers Business
 (2) Non Home Based Employers Business
 (3) Home Based Other
 (4) Non Home Based Other

11.6 Highway Network Scope and Development

The model represents the highway network within the RoF, with coverage including all motorways, A roads, B roads and selected minor roads carrying significant volumes of strategic traffic. The highway network was considered in terms of four levels of detail (Table 74). The overall network structure was sourced from the Ordnance Survey (OS) Integrated Transport Network (ITN) June 2015 mapping data. Signal timing data was sourced from Highways England and Local Authorities and where appropriate their existing models.

Table 74 – Highway Network Detail

Level	Road Types	Model Representation
1	Strategic Road Network (SRN); Roads connected to / parallel with SRN; Roads considered important to RIS scheme appraisal;	Detailed simulation coding
2	Rural roads that are not connected to SRN	Simulation coding but less detail
3	Urban areas outside the influence area of RIS and SRN	Dummy nodes / fixed link speeds
4	Roads outside the region of focus	Buffer network

Junctions that fall in Level 1 and 2 were coded through the SATCODER v0.5 tool, supporting both the standardisation of coding to the coding manual developed by the TCG and the internal verification and audit checking. As recommended by coding manual maximum speed restrictions for HGV's on the highway network was implemented by using CLICKS facility in SATURN for HGV user class. Fixed

speeds through urban and external buffer areas were sourced from Trafficmaster data.

The RoF included some 32 major roadworks (subject to traffic management of more than 6 month duration), which are represented in the base year.

Road tolls were represented at the following locations

- Mersey Tunnels (Kingsway & Queensway)
- Humber Bridge
- Dunham Bridge
- Warburton Bridge Rd
- M6 Toll

Structured verification following best practice set out by the TCG was followed to test and refine the network coding.

11.7 Highway Demand Matrices

The key sources of data used in developing the model were:

- Mobile Phone (all trips) provided by Telefonica (O2) UK; given the timing of the release of the data in relation to other Highways England projects, the data were referred to as the 'Provisional data';
- TrafficMaster (Light Goods Vehicles);
- GB Freight Model (Heavy Goods Vehicles); and
- Air passenger demand data sourced, by DfT, from CAA surveys.

The Matrix TCG developed a guidance document reflecting the innovation in establishing methods to use mobile phone data to produce OD matrices. The structured process incorporated verification checks, both ensuring internal integrity of the data processing and consistency between the RTMs. The aim of the process developed was to make best use of the mobile data, using other data sets to exclude non car trips, to infill missing trips and to identify and correct inherent biases in the dataset.

Analysis of the mobile phone data demonstrated poor representation of short trips and these were replaced by synthetic estimates using a conventional gravity modelling approach. These synthesised matrices reflect (NTS) trip length distributions and trip rate / population variations across the region but not detailed and unobserved local characteristics. While representing about half the demand, these synthesised trips represent 17% of traffic on the network and a smaller proportion of traffic using the SRN which predominantly served long distance travel. The implications are of higher confidence in longer distance demand.

LGV data were sourced from traffic master. This represents data from roundly 2% of the vehicle fleet and there will be appreciable variation in trip rates at zonal level. HGV data were sourced from the DfT's Base Year Freight Model (BYFM), disaggregated to the model zones.

The resulting prior matrices satisfy the verification criteria defined by the TCG demonstrating adequate consistency with census journey to work NTS and traffic count data and with the other RTM matrices.

11.8 Calibration and Verification Data and Standards

The Data TCG examined the standards associated with the processing of data.

Traffic count data were sourced from bespoke ATCs, local authority and HATRIS, with journey time data from Trafficmaster. Data were checked for compliance with age and duration criteria and for consistency by removing outliers that arise from unusual events. Having derived the flows for the period of the observations, a series of factors were derived for day, month and year factors to enable data to be converted to represent March 2015.

The TCGs considered the model purpose and scope in defining the verification standards appropriate to their purpose.

11.9 Highway Network Model Calibration

Matrix estimation was applied to refine the prior matrix using count data. This was based on mini-screenlines.

11.10 Highway Network Model Validation

The performance of any transport model is judged against a series of performance criteria. Drawing on WebTAG unit M3.1, the Cal/Val TCG produced guidance on the RTM standards against a series of criteria including:

- flows across cordons;
- flows on individual links;
- journey times;
- convergence; and
- impact of matrix estimation.

The model performance is tested across a number of cordons and screenlines across the RoF demonstrating acceptable performance against these standards. It should be noted that these are commensurate with the scale of the model and more local and spatially detailed data may be required to refine the model for specific schemes

11.11 Variable Demand Model

A key objective of the RTM's is to provide a multi-modal platform for transport scheme assessment. The scale and spatial coverage of transport schemes to be assessed by the RTM's is significant. Furthermore, many of the schemes to be considered will be in sections of the Strategic Road Network (SRN) that are subject to congestion.

In consequence, a VDM approach has been developed which adheres to WebTAG guidance¹⁷ where appropriate and models the key traveller choices of; route, mode, destination and time of day.

The model was implemented using DIADEM software, together with a bespoke RTM database onmterface tool, HEIDI, better to control and present the demand data.

¹⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/542504/webtag-unit-m2-variable-demand-modelling-forthcoming-change-november-2016.pdf

Rail demand data were sourced from PLANET and MOIRA models, evidence of fares was assembled from industry ticketing data to develop a distance based relationship and journey time data were derived from a national network tool developed for the RTMs.

The demand model was calibrated using evidence from WebTAG together with the trip distribution calibration undertaken in developing the demand matrices. Realism testing demonstrated elasticities that accord with the ranges recommended in UK guidance.

11.12 Model Robustness

The focus and associated strength of the RTMs is the representation of highway demand making inter-urban movements. Given this focus inter-urban rail demand is represented. There is no representation of inter-urban coach or air modes, however demand for these modes is focused on specific markets such as airport access and student travel and these were not judged to be of enough importance to be worth explicit representation in the RTMs.

There are simplifications to the highway network using fixed speeds in urban areas, the zones are relatively large with a correspondingly coarse treatment of short (intra-zonal) demand and no representation of travel by active modes, bus or park and ride. The RTMs will not therefore provide a reliable basis to forecast the effect of transport interventions on changes intra-urban travel behaviour. The main concerns would be for the appraisal of schemes on the periphery of urban areas where local mode choice or local trip redistribution could affect a material proportion of traffic using the SRN and of relevance therefore for assessing the impact of interventions on or adjacent to the SRN. Similarly the RTMs will require augmentation with supplementary spatial detail and associated demand data in considering detailed impacts on local roads near schemes on the SRN.

With respect to longer distance travel demand, the main focus of the RTMs, care has been taken to implement a model that reflects available evidence representing variations in sensitivity with distance. The approach taken in the RTMs will represent a significant change from existing practice where the sensitivity (fuel cost elasticity) of individual scheme demand models has been constrained to reproduce the same national average value largely irrespective of the nature of travel within the modelled area. While this aligns better with the research evidence available the consequence will be that in using the model there will be some schemes for which the demand modelling responses are larger than would be evident from previous (local) modelling and also others where a smaller demand response will be forecast. This variation in response will require consideration particularly if an approach is taken to develop local models drawing on the RTMs in the assessment of individual schemes.

GLOSSARY

AADF	Annual Average Daily Traffic Flows
AAWT	Annual Average Weekday Traffic
ATC	Automatic Traffic Count
ATOC	Association of Train Operating Companies
BYFM	Base Year Freight Matrices
CAA	Civil Aviation Authority
Cal/Val	Calibration / Validation
CDF	Collaborative Delivery Framework
CTripEnd	DfT software providing NTEM compatible trip rates
DF	Design Freeze
DfT	Department for Transport
DIADEM	Variable demand modelling software
FLAREF	Parameter used in SATURN network coding
FLAREX	Parameter used in SATURN network coding
GAP	Parameter used in SATURN network coding
GAPM	Parameter used in SATURN network coding
HBEB	Home Based Employers' Business
HBO	Home Based Other
HBW	Home Based Work (Commuting)
HEIDI	Interface for DIADEM
HGV	Heavy Goods Vehicle
ISTOP	Parameter used to monitor convergence in SATURN
ITN	Integrated Transport Network
IZ	Intermediate Zone (Scottish equivalent of MSOA)
JTW	Journey to Work
KONSTP	Parameter used to monitor convergence in SATURN
LGV	Light Goods Vehicle
LMVR	Local Model Validation Report
LSOA	Lower Super Output Area (Census)
MASL	Parameter used to monitor convergence in SATURN
MCC	Manual Classified Count
ME	Matrix Estimation
MFR	Model Forecasting Report
MOIRA	Rail demand forecasting software
MSOA	Middle Super Output Area (Census)

MSR Model Specification Report

MVR	Model Validation Report
NaPTAN	National Public Transport Access Nodes
NHB	Non Home Based
NHBEB	Non Home Based Employers' Business
NHBO	Non-Home Based Other
NISTOP	Parameter used to monitor convergence in SATURN
NITA	Parameter used to monitor convergence in SATURN
NITA_C	Parameter used to monitor convergence in SATURN
NITS	Parameter used to monitor convergence in SATURN
NOMIS	ONS Labour Market Statistics
NTEM	National Trip End Model
NTS	National Travel Survey
OD	Origin Destination
ONS	Office for National Statistics
ORR	Office of Rail and Road
PCF	Project Control Framework
PCU	Passenger Car Unit
PPK	Pence per kilometre
PPM	Pence per minute
QGIS	GIS software
RIS	Road Investment Strategy
RoF	Region of Focus
RSI	Roadside Interview
RTM	Regional Traffic Model
SATALL	Module within SATURN transport modelling software
SATASS	Module within SATURN transport modelling software
SATCODER	Software to aid network coding in SATURN
SATSIM	Module within SATURN transport modelling software
SATURN	Transport modelling software
SFC	Speed Flow Curves
SRN	Strategic Road Network
STPGAP	Parameter used to monitor convergence in SATURN
SUE	Stochastic user equilibrium

TAME	Traffic Appraisal, Modelling and Economics
TCG	Technical Consistency Group
TDCR	Traffic Data Collection Report
TPS	Trans Pennine South Model
TRADS	Highways England Traffic flow data system
VDM	Variable Demand Model
VISUM	Transport Modelling Software
WebTAG	DfT Advice on Modelling and Appraisal



APPENDIX A
TCG Note – Consistent Approach Towards Using Provisional Data

APPENDIX B
TCG Note – Synthetic Matrix Trip End Adjustments

APPENDIX C

Comparison Between Observed and Synthetic Trip Length Distributions

APPENDIX D
TCG Note – Vehicle Occupancies

APPENDIX E
TCG Note – Calculation of Bias Correction Factors

APPENDIX F

Assignment Parameters

APPENDIX G

Record of Network Checks

APPENDIX H
TCG Note – RTM Calibration / Validation, Use of Matrix Estimation

APPENDIX I

Zone Plans

APPENDIX J
Prior and Post ME Model Performance Plots

