GBATS4M Model Update

METROWEST Highway Model Local Model Validation Report

Prepared for

West of England Authorities

08 October 2015

CH2MHILL®

1 The Square
Temple Quay
Bristol
BS1 6DG

Document History

GBATS4M Model Update

METROWEST Highway Model LMVR

West of England Authorities

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
1.0	17.10.2014	Initial Draft Report	Pete Knightbridge		
1.1	14.4.2015	Draft Report	Pete Knightbridge	Katherine Williams	Chris Bushell
1.2	08.10.2015	Final Report	Pete Knightbridge	Katherine Williams	Chris Bushell

Contents

Section **Page**

Figures

Tables

SECTION 1

Introduction

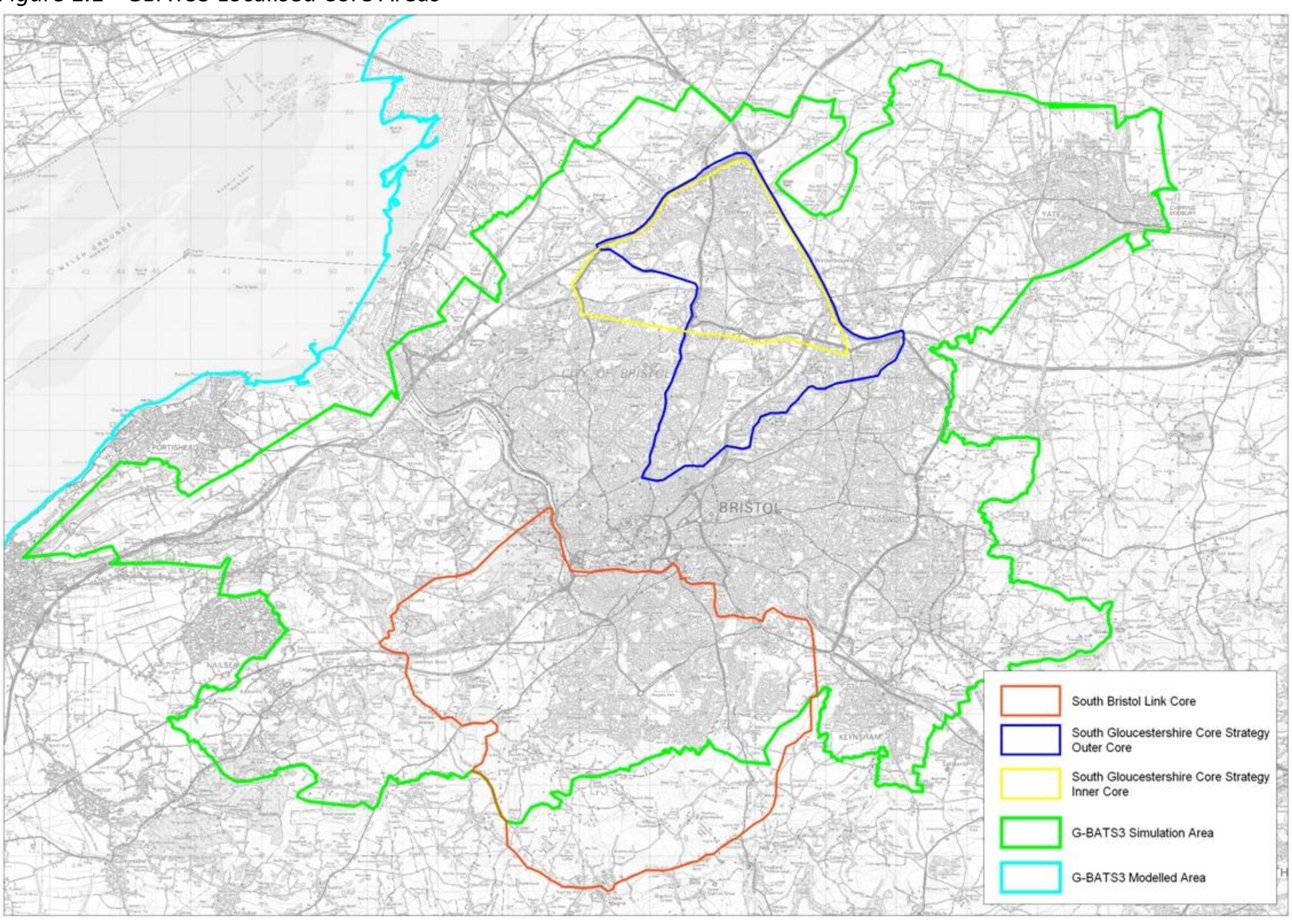
1.1 Background

This report has been prepared by CH2M Hill as part of their commission to update the Greater Bristol Area Transport Study (GBATS) modelling suite for Bristol City Council (BCC), on behalf of the West of England authorities.

The updated GBATS model has been specified to be suitable for assessing the MetroWest major scheme Phases 1 and 2. The Bristol Area Traffic Study (BATS) model was originally built and validated to a base year of 2001. Since then it has been updated to BATS2 as a part of the Greater Bristol Bus Network study in 2004 and further updated to the GBATS3 strategic model with a base year of 2006. The GBATS3 model was used as the starting point for four localised studies. In each case the model was updated, recalibrated and revalidated with the local study area core as its focus. Figure 1.1 shows the core areas of the localised models. The four studies are below:

- Ashton Vale to Temple Meads Rapid Transit (AVTM, 2006 Base year, 580 active zones);
- Northern Fringe to Hengrove Package (NFHP, 2009, 584);
- South Bristol Link (SBL, 2009 & 2012, 616); and
- South Gloucestershire Core Strategy (SGCS, 2011, 591).

Figure 1.1 - GBATS3 Localised Core Areas



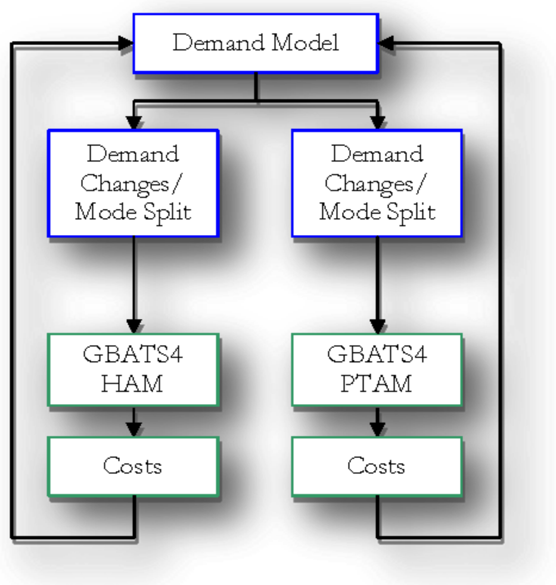
The updated model is called the GBATS4 Metro Model (GBATS4M). The GBATS4M model consists of:

- A Highway Assignment Model representing vehicle based movements across the Greater Bristol area for a 2013 autumn weekday morning peak hour (08:00-09:00), an average inter-peak hour (10:00-16:00) and an evening peak hour (17:00-18:00);
- A Public Transport (PT) Assignment Model representing bus and rail based movements across the same area and time periods; and
- A five-stage multi-modal incremental Variable Demand Model (VDM) that forecasts changes in trip frequency and choice of main mode, time period of travel, destination, and sub-mode choice, in response to changes in generalised costs across the 12-hour period (07:00 – 19:00).

The GBATS4M highway model is closely integrated with the GBATS4M PT model. The two models use different software packages (SATURN and EMME, respectively) but are identical in terms of road network structure, and zone system. The bus routes and frequencies in the PT model are used in the highway model.

The GBATS4M highway model is fully integrated within the GBATS4M VDM. The GBATS4M highway model provides highway transport costs to the GBATS4M VDM which, in turn, provides trip matrices for the GBATS4M highway model. The relationship between the elements of the modelling system is shown in Figure 1.2.

Figure 1.2 - GBATS4M Modelling Suite



1.2 Report Structure

This model development report consists of the following sections, after the Introduction:

- Section 2 – Model Usage and Design Considerations;
- Section 3 – Model Standards, Criteria and Acceptability Guidelines;
- Section 4 – Key Features of the model;
- Section 5 – Survey Data;
- Section 6 – Network Development;
- Section 7 – Trip Matrix Development;
- Section 8 – Network Calibration and Validation;
- Section 9 – Trip Matrix Calibration and Validation;
- Section 10 – Assignment Calibration and Validation and
- Section 11 – Conclusion

SECTION 2

Model Usage and Design Considerations

2.1 MetroWest

The GBATS4M modelling suite provides a tool with which to test the ability of future transport proposals to support forecast travel demand. At a general level this includes:

- Investigation of new development proposals; and
- Longer-term strategic planning of the transport network.

The specific purpose of the model is for assessing the MetroWest major scheme Phases 1 and 2. Figure 2.1 shows a schematic of the MetroWest scheme. The primary focus of GBATS4M highway model is the MetroWest scheme corridors.

2.2 Potential Further Uses

The GBATS4M modelling suite could (with further validation if necessary) also be used to forecast and assess a range of alternative potential interventions. While not a definitive list, the following future year schemes could potentially be assessed:

- Bristol Arena
- Temple Circus Roundabout / Redcliffe Way;
- Temple Quarter Enterprise Zone;
- Central Area Action Plan;
- Changes to bus operations;
- Park and Ride schemes;
- North Fringe VISSIM interface;
- Strategic wider area schemes; and
- Major development proposals in the wider urban area.

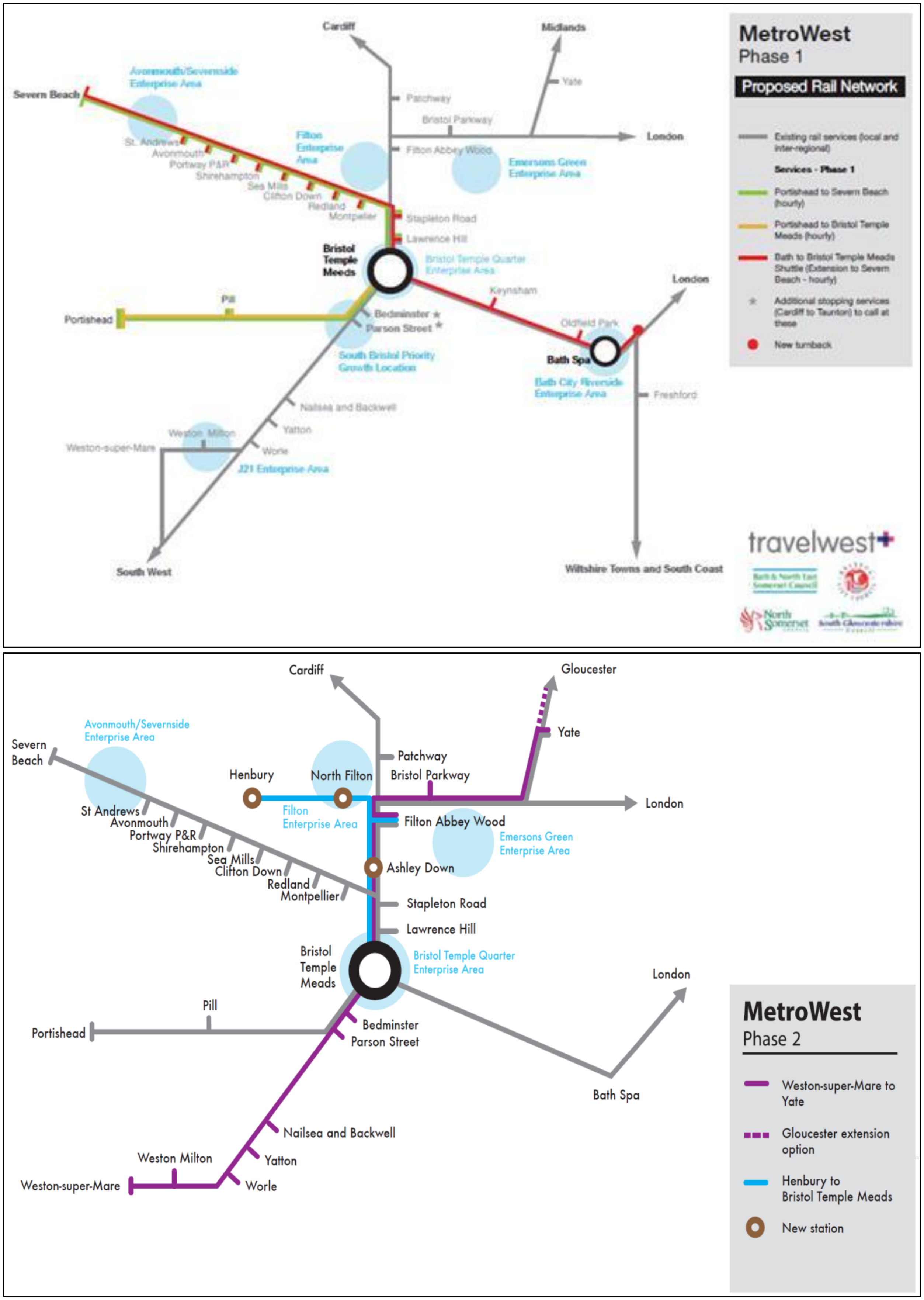
2.3 Model Design Considerations

The principal objective of the GBATS4M highway model is to represent travel conditions on the highway network for the appraisal of the MetroWest scheme and should therefore provide:

- changes in the travel cost between the base year and forecast years for input to the GBATS4M VDM;
- changes in traffic flows along the MetroWest corridors for input to the appraisal; and
- changes in wider area travel costs for input to the economic appraisal.

The GBATS4M highway model is a SATURN model updated from the most recent versions of the GBATS3 highway model (South Bristol Link, 2012 and SGCS, 2011). In order to improve the model validation the focus has been to update the trip matrices and network along the routes most likely to be most affected by MetroWest. To facilitate this, a programme of traffic counts and trip pattern surveys were undertaken around Bristol. Where available, reliable existing survey data was also utilised. Details are provided in section 5.

Figure 2.1 - Metro Corridors



SECTION 3

Model Standards, Criteria and Acceptability Guidelines

3.1 Overview

The model has been designed and developed using the UK Department for Transport (DfT) Transport Analysis Guidance (TAG). The current, relevant guidance is DfT TAG UNIT M3.1 Highway Assignment Modelling, January 2014. Referenced throughout this report as: 'TAG M3.1'.

3.2 Validation Criteria and Acceptability Guidelines

Highway model validation acceptability guidelines are specified in TAG M3.1. However, TAG M3.1 states if these guidelines are not meet this does not necessarily mean the model is not 'fit for purpose', or indeed if they are met that the model is automatically deemed so. If these criteria cannot be fully met, the importance of the relevant locations to overall model validation and assessment of proposed schemes should be reviewed to ensure the model is still fit for purpose. Further, TAG M3.1 states if necessary the impact of matrix estimation should be reduced so that they do not become significant, and a lower standard of validation reported.

The validation criteria and acceptability guidelines as specified in TAG M3.1 are shown in Table 3.1 below. The observed flow and screenline flow criteria are applied to "all vehicles" and "cars/LGVs".

Table 3.1 - DMRB Acceptability Guidelines

Criteria and Measure		Acceptability Guideline	
Flow Difference Criteria			
1	Total screenline flows (normally > 5 links) to be within +/- 5%	All (or nearly all) screenlines	
2	Observed (individual) link flow < 700vph	Modelled flow within +/- 100vph	> 85% of links
	Observed (individual) link flow 700 to 2700vph	Modelled flow within +/- 15%	> 85% of links
	Observed (individual) link flow > 2700vph	Modelled flow within +/- 400vph	> 85% of links
GEH Criteria			
3	GEH statistic for individual link flows <5		> 85% of links
Journey Time Validation			
4	Modelled times along routes should be within 15% (or 1 minute, if higher)		> 85% of links

The GEH statistic, included in Table 3.1, is used as an indicator of the extent to which the modelled flows match the corresponding observed flows. This is recommended in the guidelines contained in TAG M3.1 and is defined as:

$$GEH = \sqrt{\frac{(M - C)^2}{0.5(M + C)}}$$

Where:

M = modelled flow; and

C = observed flow.

3.3 Convergence Criteria and Standards

SATURN is specifically designed to model congested networks which contain alternative routes between zones. The software uses algorithms which seek to achieve Wardrop's First Principle of Traffic Equilibrium and provides the following (TAG M3.1) recommended convergence indicators:

- The percentage of links on which flows or costs change by less than a fixed percentage between successive iterations;
- The difference between the costs along the chosen routes and those along the minimum cost routes, summed across the whole network, and expressed as a percentage of the minimum costs, usually known as 'Delta' or the '%GAP'.

To ensure a satisfactory model convergence, TAG M3.1 recommends the criteria shown in Table 3.2.

Table 3.2- TAG M3.1 Convergence Criteria

Criteria and Measure	Type	Acceptable values
Delta and %GAP	Proximity	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P) < 1% or Percentage of links with cost change (P2) < 1%	Stability	Four consecutive iterations greater than 98%

TAG M3.1 (section 3.3.6 and 3.3.7) states the following:
"The percentages of links with small flow or cost changes both provide pragmatic views of the stability of the assignment, rather than the degree of convergence. The measures are necessary but not sufficient indicators of convergence. It is recommended that, in addition to satisfying the true convergence measures described below, assignment model iterations should continue until at least four successive values of 'P' or 'P2' in excess of 98% have been obtained. If this cannot be achieved, especially in a future year assignment, this may be an indication of instability caused by the level of traffic demand being higher than can be absorbed by the network capacity. "

"The Delta statistic or %GAP is a truer measure of convergence. Delta values generally decrease towards a minimum value as the number of iterations increases but will not do so monotonically….Delta should be used as the first choice measure of assignment convergence. "

The terminating criteria for the assignment-simulation iterative procedure used in the model are based on the %GAP criteria, with further checks on the "stability" criteria.

3.4 Trip Matrix Changes

The development of 'prior' matrices, using OD survey data for city centre trips and the use of the source highway models (SBL and SGCS) 'prior' matrices, has been undertaken. TAG M3.1 recommends that the changes brought about by matrix estimation should be carefully monitored by the following means:

- scatter plots of matrix zonal cell values, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R2 values);
- scatter plots of zonal trip ends, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R2 values);

- trip length distributions, prior to and post matrix estimation, with means and standard deviations; and
- sector to sector level matrices, prior to and post matrix estimation, with absolute and percentage changes.

The changes brought about by matrix estimation should not be significant. The criteria by which the significance of the changes brought about by matrix estimation may be judged are given in Table 3.3.

Table 3.3 - TAG M3.1 Significance of Matrix Estimation changes

Criteria and Measure	**Significance Criteria**
Matrix zonal cell levels	Slope within 0.98<Slope<1.02 , Intercept near zero , R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99<Slope<1.01, Intercept near zero , R^2 in excess of 0.98
Trip length distributions	Means within 5% , Standard deviations within 5%
Sector to sector level matrices	Differences within 5%

SECTION 4

Key Features of the Model

4.1 Source Models

The GBATS3 SBL 2012 model was the main source model used as a starting point for the initial parameters and majority network area of GBATS4M highway model. The SGCS 2011 model network and zone structure was used as the primary source for the North Fringe area of GBATS4M highway model by merging the two models.

The source models have been used as a starting point since they have been developed using TAG-compliant processes and successfully supported schemes through statutory processes which have been open to public scrutiny.

4.2 Modelling software

The GBATS4M highway model uses SATURN version 11.2.05 whilst both VDM and PT model use INRO EMME 4.11

4.3 Base Year

The GBATS4M modelling system has a 2013 base year and represents the travel conditions for a typical October weekday.

4.4 Model Network Area

The GBATS4M highway model area retains the same/similar geographical coverage as the GBATS3 source model, i.e. the ‘simulation’ (detailed) network extends to cover the Bristol urban area, roughly to the boundary of the West of England Partnership (WEP). Outside this area a ‘buffer’ network and zone system is used to cover the rest of the UK.

The focus of the improvements for the GBATS4M was primarily the corridors most likely to be impacted by MetroWest, the central area and key radial routes. This included a review / update of all bus routes and bus priority measures in the central area and radial routes approaching the centre. The red line in Figure 4.1 shows the area considered to be the central area in this regard. This corresponds to the middle cordon, used for data collection purposes as referred to in section 5.

Figure 4.2 shows the wider model area, including the extents of both the simulation and buffer network.

Figure 4.1 - GBATS4M Highway Model Central Modelled Area

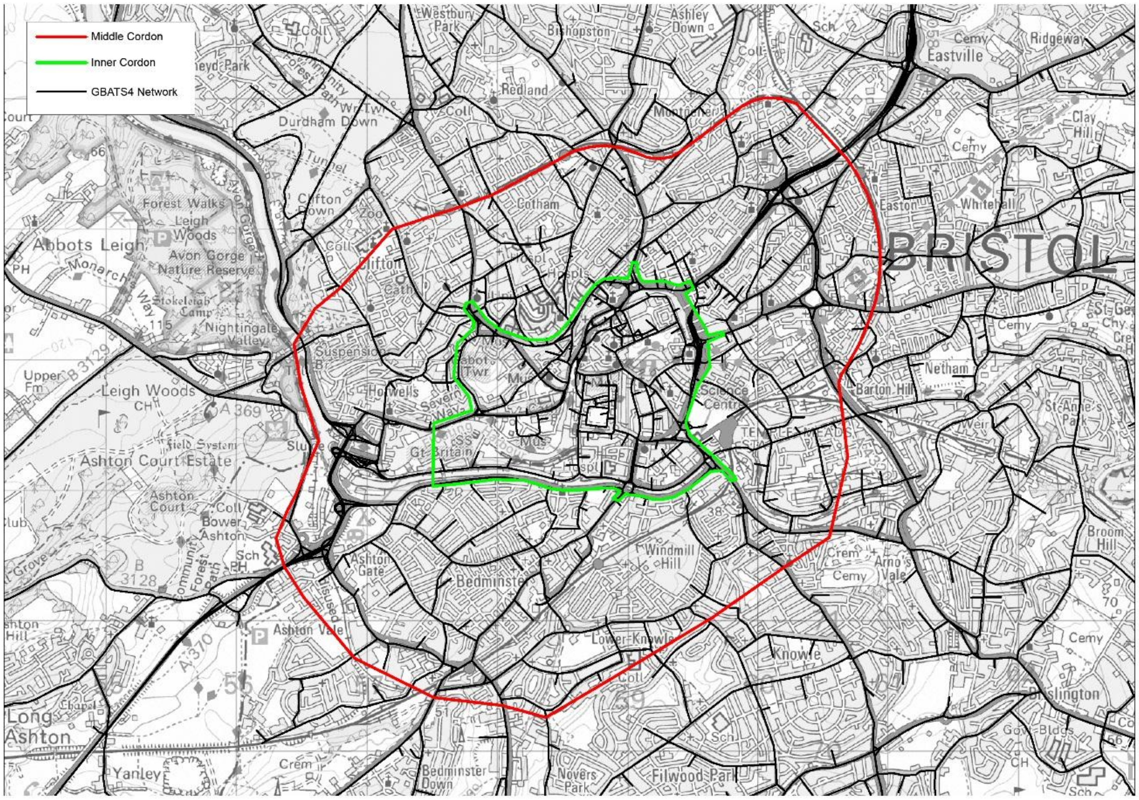
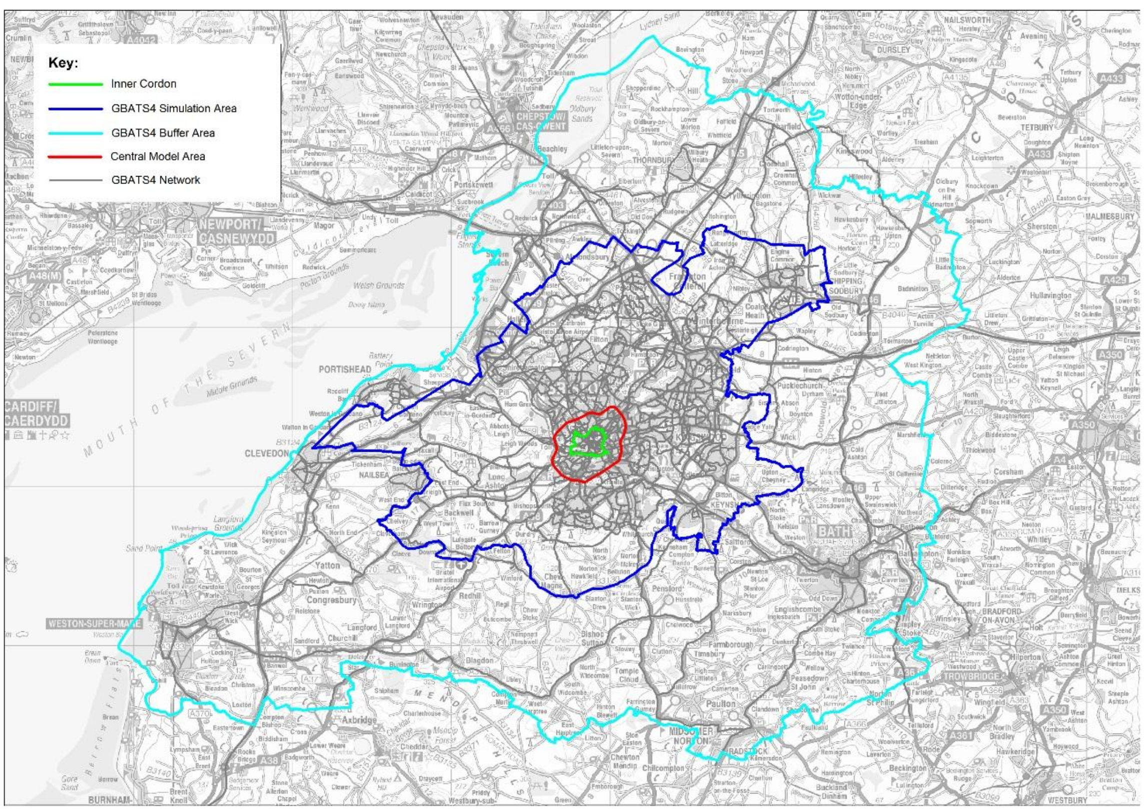


Figure 4.2 - GBATS4M Highway Model Fully Modelled Area



4.5 Time Periods

The GBATS4M highway model is based on trip making patterns on a typical October weekday in 2013. Data relating to other times was normalised to match this date.

Following a review of local traffic count data, the three modelled time periods have been retained from the source model as follows:

- AM peak, representing hourly traffic flow between 08:00 and 09:00;
- Inter peak, representing average hourly traffic flow between 10:00 and 16:00; and
- PM peak, representing hourly traffic flow between 17:00 and 18:00.

4.6 Pre Peak Queuing

For SATURN to adequately represent network performance in congested urban conditions, information on the amount of traffic queuing in the network at the start of the modelled hour is needed. The PASSQ option in SATURN enables this feature and requires information about queuing from the previous hour.

The PASSQ option has been used for the AM and PM peak models and has been derived from factoring the matrix for the relevant peak to represent the previous model hour; 07:00-08:00 for the AM peak and 16:00-17:00 for the PM peak. Initial factors have been developed based on averages of representative counts across the model area. PASSQ flows/queues passed to the peak have been checked to ensure they are not higher than observed flows for the peak hour. The pre-peak counts for both the AM and PM were sufficiently close to the peak hour, that 100% of the peak traffic was used in the pre-peak hours.

4.7 Zoning System

The GBATS4M highway model zone system and network structure exactly matches that of the PT model.

The GBATS4M modelling suite zoning system comprises 650 zones covering the whole of Great Britain. A detailed zoning system was developed to represent the Greater Bristol Urban area and its surroundings. This is shown in Figure 4.3 and 4.4.

Figure 4.3 - GBATS4M Central Model Area Zones

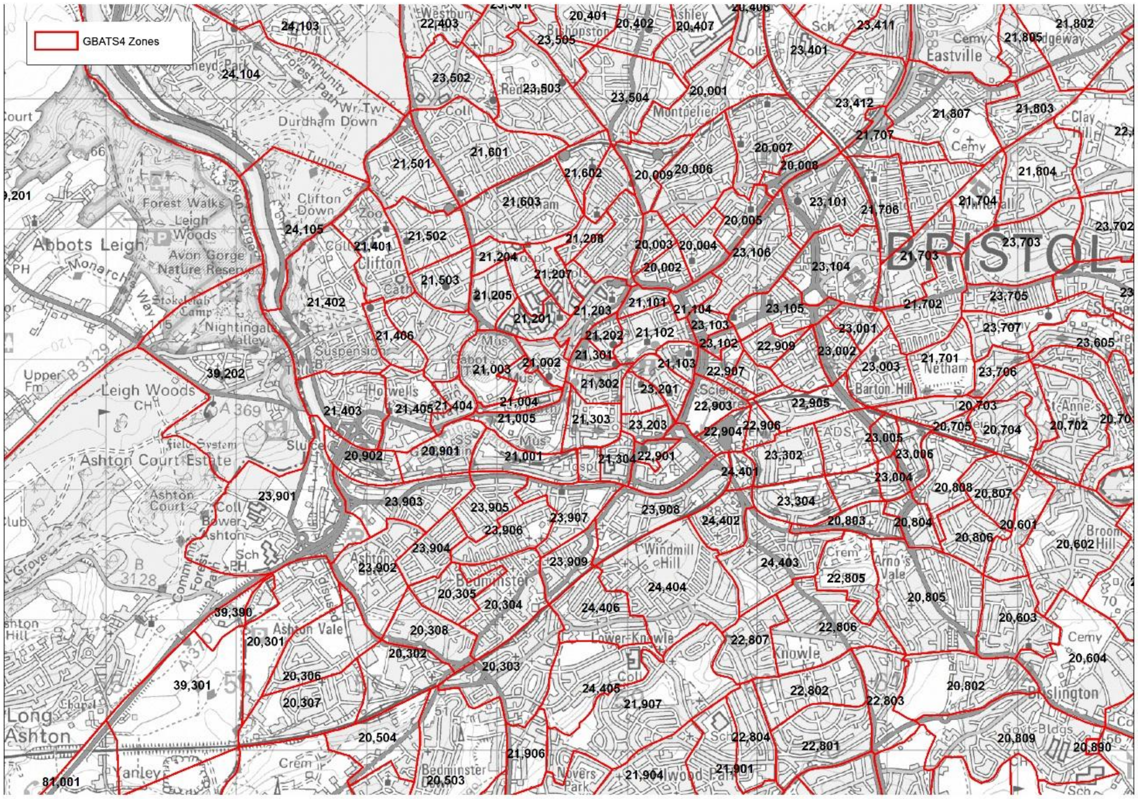
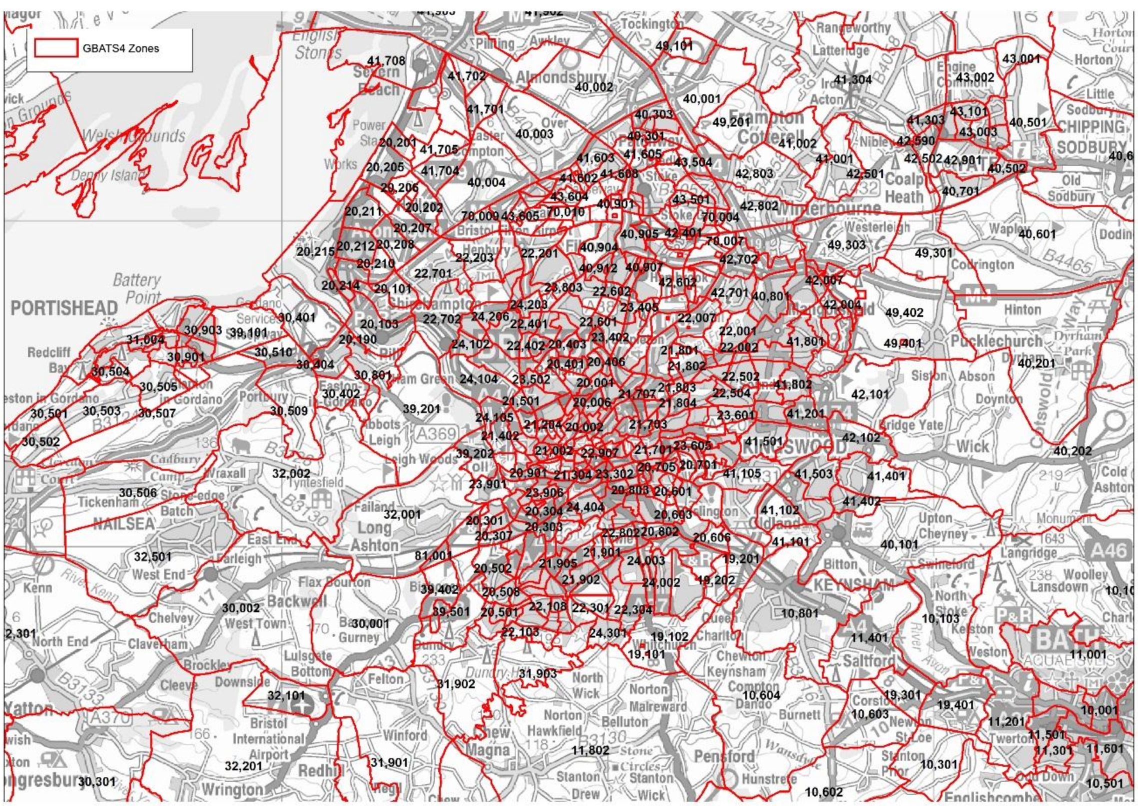


Figure 4.4 - GBATS4M Wider Model Area Zones



4.8 Signal Timings

Signal timings and staging were inherited from the GBATS3 models, thorough checks were undertaken to correct any anomalies along the MetroWest corridors and key junctions, such as the Hambrook interchange, using local knowledge, past experience and traffic flow data.

4.9 User Classes

The development of the GBATS4M highway model matrices initially incorporated two user classes, namely cars / light goods vehicles and heavy goods vehicles. PCU factors for the different classes in GBATS4M highway model are shown in Table 4.1.

Following validation of the two-user class model, the matrices were segmented to six user classes as follows for use in forecasting:

- Car, Non-business (low Income);
- Car, Non-business (medium Income);
- Car, Non-business (high Income);
- Car business;
- Light Goods Vehicles; and
- Heavy Goods Vehicles (HGVs).

TAG M3.1, App D, provides two PCU values for HGVs: 2.5 PCUs for motorways and all-purpose dual carriageways or 2.0 PCUs for all other road types. SATURN only allows for one value to be used within the model. It is assumed that the motorway network around the Bristol conurbation influences the distribution of through trips on the local road network so the higher value has been used throughout.

Table 4.1 - Vehicle to PCU Factors

Type	Car/LGV	HGV	Bus
Equivalent PCUs	1.0	2.5	3.0

4.10 Assignment Methodology

The GBATS4M highway model uses SATURN assignment software. 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 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 choice of convergence algorithm used for the final GBATS4M assignment is detailed in the separate note: "GBATS4M Assignment Methodologies TN1 September 2014".

4.11 Representation of Car Parks

The highway model does not represent car parks explicitly. There is a fine zoning system within the central area, which covers some car parks. The trip matrix is based on ultimate origin or destination zone rather than the zone in which the vehicle is parked. As a result there are no associated car parking charges and parking capacities modelled within the highway model. However, average parking charges are reflected in the VDM, and hence reflected in the GBATS4M mode split and destination choice calculations.

4.12 Generalised Cost and Parameter Values

The generalised cost functions described in TAG M3.1 for trip routeing in the model are applied with parameters derived from TAG A1.3 (May 2014) "*User and provider impacts*" and the WebTAG Databook, May 2014. This relates travel costs to a combination of travel time and the cost per kilometre in terms of vehicle operating and maintenance. The value of time varies by purpose (either working or non-working time), vehicle type and occupancy levels. Similarly, operating and maintenance costs are journey purpose and vehicle dependent and vary by speed.

The speed assumed in the derivation of the generalised cost parameters is the average network speed in the source model.

All monetary values are calculated at 2013 prices.

4.12.1 Values of Time

Perceived values are used throughout. Note that, in the case of HGVs, and cars and LGVs in work time, the perceived and resource values are the same. The process is summarised below:

- equivalent 2013 values were calculated by applying the specified growth in working and non-working values of time, set at 2010 values, (Table A1.3.2 in the Databook) together with the change in prices using the RPI index;
- the relative proportions of Car Non-work for 'Other' and 'Commuting' were calculated from the RSI surveys;
- the equivalent values for vehicles were calculated by applying the occupancies obtained from the 2013 RSI surveys;
- HGV travel was assumed to be in work time with the split between OGV1 and OGV2 recorded from the RSI surveys; and
- The values were converted from £ per hour to p/min.

4.12.2 Vehicle Operating Costs

Vehicle Operating Costs were calculated using TAG A1.3 (May 2014) and defined separately for fuel and non-fuel elements before being combined for the use in the SATURN assignment. Non-fuel costs were only taken into consideration by travellers in work-time.

Fuel Costs

The consumption of fuel, adjusted by the fuel efficiency factors, was multiplied by the cost per litre to provide the cost per km in the model base year (2013), using the formula below from TAG A1.3.

$$L = (a + b.v + c.v^2 + d.v^3) / v$$

Where: L = consumption, expressed in litres per kilometre;
v = average speed in kilometres per hour; and
a, b, c, d are parameters defined for each vehicle category.

Fuel duty was included in the calculations as a perceived cost as businesses are not able to reclaim it. However, VAT was excluded because businesses are able to recover it. For non-work purposes, the perceived cost of the fuel Vehicle Operating Cost was the market price. LGV fuel costs were derived using the same work/non-work proportions used to calculate their average Value of Time.

Non-Fuel Costs

The non-fuel cost element was derived using the formula set out in TAG A1.3 and was a function of average network speed.

$$C = a_1 + b_1/v$$

Where: C = cost in pence per kilometre travelled;
a_1 is a parameter for distance related to costs defined for each vehicle category
b_1 is a parameter for vehicle capital saving defined for each vehicle category (only for work vehicles)
v = average link speed in kilometres per hour;

The cost was calculated using the same average network speeds from the source model and the fuel costs converted from 2010 to 2013 prices. No further adjustments were required as the non-fuel costs were assumed to remain constant, in real terms, over time. As noted above, the non-fuel cost element was only included for work trips.

Assignment Parameters

The resulting assignment parameters are summarised below in Table 4.2.

Table 4.2 - Generalised User Class - Value of Time and Distance

User Class	AM Peak		Inter Peak		PM Peak	
	Time (PPM)	Distance (PPK)	Time (PPM)	Distance (PPK)	Time (PPM)	Distance (PPK)
Car - Non Business Low Income	9.28	8.28	12.98	8.18	11.75	8.33
Car - Non Business Medium Income	12.95	8.28	16.38	8.18	15.25	8.33
Car - Non Business High Income	18.27	8.28	20.70	8.18	19.90	8.33
Car - Business	49.25	13.22	49.25	13.12	49.25	13.27
LGV	19.27	18.40	19.27	18.29	19.27	18.49
HGV	22.70	37.27	22.70	37.25	22.70	37.36

Note: All values in pence (2013 prices)

SECTION 5

Survey Data

5.1 Overview

The highway model matrix development included the use of new (2013) roadside interview (RSI) and count data. The model calibration and validation was undertaken using two types of survey data, namely traffic counts and journey times.

Traffic counts were required for expanding new RSI data, calibrating trip matrices and validating the model. Journey times were required for calibrating cruise speeds and validating the model.

Traffic count data was provided by local authorities and the Highways Agency (now Highways England) data from the TRADS website. Count data was available in a number of forms including:

- Manual classified counts (MCC);
- Temporary automatic traffic counts (ATC) on non-trunk/motorway roads;
- Permanent ATCs on non-trunk/motorway roads;
- Traffic signals (UTC);
- Junction turning counts; and
- TRADS counts on motorways.

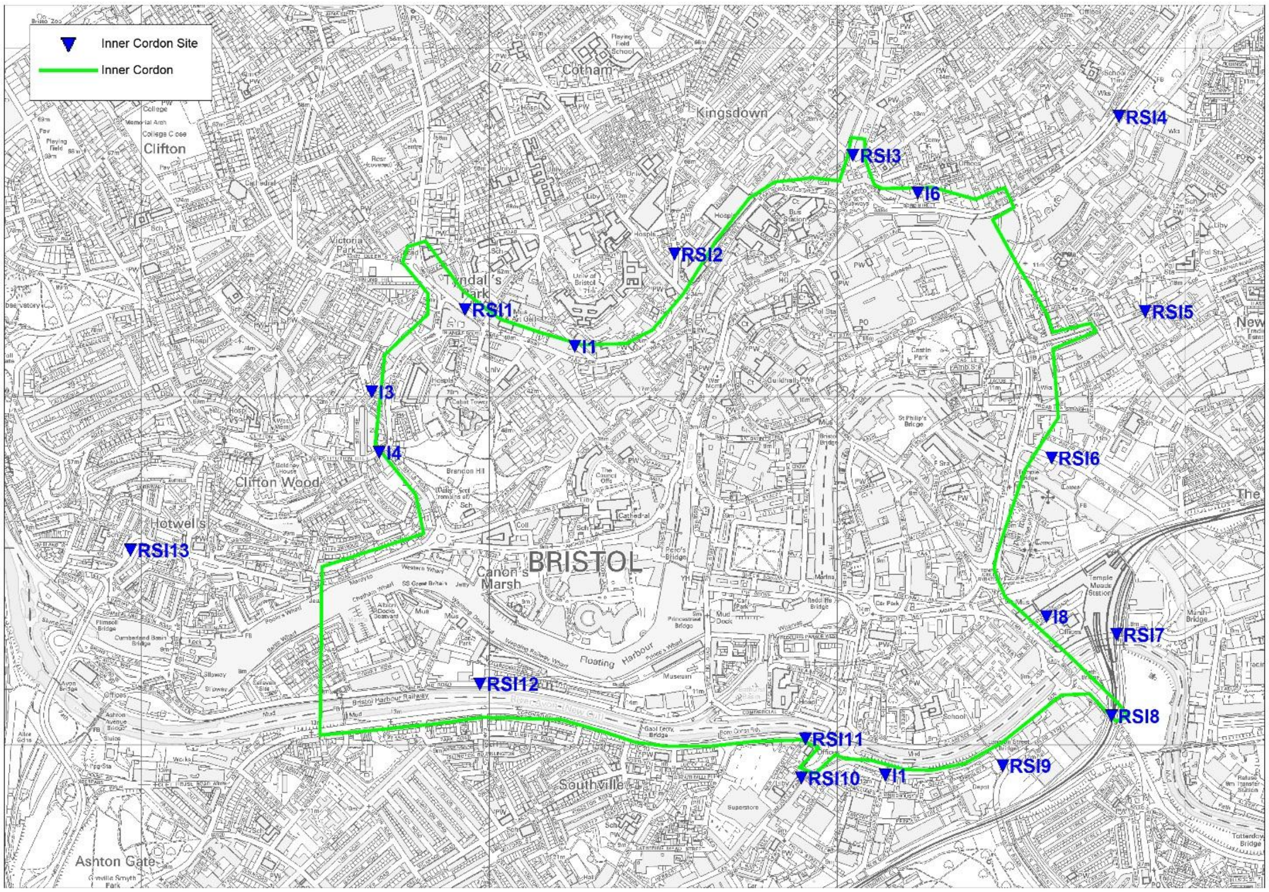
Observed Journey time data was examined using Trafficmaster™ journey time data supplied to the local authorities by the Department for Transport. Trafficmaster™ journey time data uses anonymised data for a large volume of vehicle types (cars, light and heavy vehicles) specially equipped with GPS devices. These devices record speed and location information which is collated, digitally mapped and matched to the Integrated Transport Network (ITN) layer. Any link that has been traversed by a Trafficmaster™ vehicle within each 15 minute time period within the day has a Trafficmaster record™. Separate records are created for each vehicle class.

Further details of surveys are reported in the 'GBATS4 Model Update - Report of Surveys and Existing Data Review'.

5.2 Roadside Interview Sites

A series of RSI surveys, which form the inner cordon of the GBATS4M highway model, were undertaken. They provided accurate origin/destination data for trips entering/exiting the city centre area. Figure 5.1 shows the location of the RSI sites (labelled RSI'n'), which cover the busiest routes across the inner cordon, and other locations. Minor roads were not covered by RSI surveys (labelled as I'n').

Figure 5.1 - City Centre RSI Locations



Sample Size and Logic Checks

The Design Manual for Roads and Bridges (DMRB) Volume 5, Section 1, Part 4, 'Traffic surveys by Roadside Interview'. Annex 8 contains advice on the sample size required to give results to a sufficient level of accuracy. The equation used to calculate the sample size required is as follows:

$$q = \frac{P\,(1-P)\,Q^3}{(E/1.96)^2\,(Q-1) + P\,(1-P)\,Q^2}$$

Where:
q = Sample size
P = Proportion of vehicles with a particular attribute
Q = Total traffic flow
E = Level of accuracy (expressed as a no. of vehicles)

The above equation requires an estimate to be made for the number of trips being made to a particular zone (P). Annex 8 states that "When data is being collected for a large multi-zoned modal, it is impossible to calculate this for every O-D pair for each RSI site as the origins and destinations are not yet known. Once a survey site has been established it is best practice to collect as much data as reasonably practical."

A total of 10007 surveys were conducted/received. Of these 9027 (90%) were flagged by the survey company as being "valid" while 980 were flagged as "invalid". Reasons for survey records being flagged as invalid include round trips, partial completion, complete refusal or illogical movements (where a stated trip origin or destination does not appear to match with the interview point). More detailed checks were then carried out during matrix development to assess whether any of the "invalid" survey records could be utilized and double checking the surveys deemed "valid". After this process 8324 (83%) were seen as "valid" trips to be used for updating the matrix.

The "valid" trips were determined by geocoding each RSI origin and destination record to a zone number based on its Ordinance Survey Grid Reference appended to it. Checks were undertaken to ensure that all characteristics of a trip fell within predefined ranges, such as specified ranges for vehicle type definition, occupancy and trip purpose. Logic checks were also undertaken and to assist in this process the 650 zone system was redefined as 22 sectors.

Full details of the sample rates achieved for each site and vehicle type are shown in the 'GBATS4 Model Update - Report of Surveys and Existing Data Review'.

5.3 Traffic Counts on Cordons and Screenlines

A wide range of traffic counts, forming a number of calibration and validation screenlines and cordons, across the area were conducted. Screenlines and cordons were selected to capture all the major trip movements. The screenlines were designed to be sufficiently long to show the quality of the matrix and the cordons were intended to be suitably 'watertight' and include all main roads in the network that intersect them.

The calibration screenlines were the inner cordon, South, East, North West Inner, River and Railway sections of the city as shown in Figure 5.2.

The validation screenlines were the Outer, Middle and North West Outer and North East cordons as shown in Figure 5.3.

Any data not collected in October 2013 was adjusted using the using factors described in the next section. Tables and figures summarise the count locations as follows:

- Tables 5.1 and 5.2 provide details of the various counts used for calibration and validation.
- Figure 5.2 shows the location of all Calibration traffic count sites.
- Figure 5.3 shows the location of all Validation traffic count sites.

Further details of Highways Agency TRADS count sites (from October 2013), Wider Area and Central area sites can be found in **Appendix A**.

Table 5.1 - Calibration Traffic Count Data

	Ref No.	Source	Road	Location	Available Data	Date
Inner Cordon	RSI1	CH2M	A4018 Whiteladies Road	south of Queens Avenue	MCC/ATC	9/10/2013
	I5	CH2M	Woodland Rd	north of Park Row	ATC	22/06/2013
	RSI2	CH2M	Horfield Road	south of St Michaels Hill	MCC/ATC	11/10/2013
	RSI3	CH2M	A38 North Road	north of St James Barton roundabout	MCC/ATC	9/10/2013
	I6	CH2M	York Street	north of A4044 Newfoundland St	ATC	19/06/2013
	RSI4	CH2M	A4032 Newfoundland Street	at gyratory signals	MCC/ATC	9/10/2013
	RSI5	CH2M	A420 Old Market Street	east of Old market roundabout	MCC/ATC	9/10/2013
	RSI6	CH2M	Avon Street	east of Temple Way	MCC/ATC	9/10/2013
	I8	CH2M	Station Approach Rd	in/out of Temple Meads	ATC	19/06/2013
	RSI7	CH2M	Feeder Road	north of Bath Bridge roundabout	MCC/ATC	9/10/2013
	RSI8	CH2M	A4 Bath Road	south of Bath Bridge roundabout	MCC/ATC	11/10/2013
	RSI9	CH2M	St Lukes Road	south of railway	MCC/ATC	9/10/2013
	I1_I2	CH2M	Whitehouse Street/Spring Street	south of A370 York Rd	ATC	18/06/2013
	RSI10	CH2M	Bedminster Parade	south of Bedminster Bridge	MCC/ATC	9/10/2013
	RSI11	CH2M	A370 Coronation Road	west of Bedminster Bridge	MCC/ATC	9/10/2013
	RSI12	CH2M	Cumberland Road	west of Bedminster Bridge	MCC/ATC	9/10/2013
	RSI13	CH2M	Hotwell Road	west of Jacobs Well roundabout	MCC/ATC	15/10/2013
	I4	CH2M	Constitution Hill	west of Jacob's Wells Rd	ATC	19/06/2013
	I3	CH2M	Lower Clifton Hill (one way)	west of Jacob's Wells Rd	ATC	19/06/2013
East Screenline	E1	SGC	A4174	east of Bristol Rd	ATC	3/06/2013
	E2	CH2M	Downend Rd	west of Stanbury Av	ATC	6/03/2014
	E3	CH2M	Staplehill Rd	west of Lewington Rd	ATC	19/03/2014
	E4	CH2M	Lodge Hill	west of Cotteral Av	ATC	1/03/2014
	E5	CH2M	Two Mile Hill Rd	west of New Queens Way	ATC	1/03/2014
	E6	CH2M	Nags Head Hill	south of Nicholas Lane	ATC	1/03/2014
	E7	BCC	Crews Hole Road	north of Troopers Hill Road	MCC	29/03/2011
	E9	BCC	Bath Rd	east of Ironmould Lane	ATC	23/07/2012
Noth West InnerScreenline	NWI2	BCC	Shirehampton Rd	south of Kings Weston Rd	ATC_perm, MCC	24/07/2011
	NWI3	CH2M	Henbury Rd	south of Hyland Grove	ATC	1/03/2014
	NWI4	BCC	A4018 Passage Rd	south of Eastover Close	ATC_perm	10/07/2011
	NWI5		Grey Stoke Av	south of Concorde Drive	MCC	15/02/2011
	NWI7	CH2M	Southmead Rd	south of Charis Av	ATC	1/03/2014
	NWI8	BCC	Kellaway Av	south of Abbotts Way	ATC_perm, MCC	23/10/2011
	NWI9		Gloucester Rd	south of Wellington Hill	MCC	21/03/2011
	NWI10	CH2M	Muller Rd	north of Stottbury Rd	ATC	1/03/2014
	NWI11	CH2M	Coldhabour Lane	north of M32	ATC	1/03/2014
	NWI12	SGC	Filton Rd	west of M32	ATC_perm, MCC	30/09/2013
	NWI13	SGC	Hambrook Rd	north of Curtis Lane	ATC	30/09/2013
	NWI14	SGC	Winterbourne Rd	west of Old Gloucester Rd	ATC_perm, MCC	25/02/2013
	NWI15	TRADS	M4	J20-J19	TRADS	2014

	Ref No.	Source	Road	Location	Available Data	Date
South Screenline	S1	CH2M	Bridgewater Rd	north of Winford Grove	ATC	1/03/2014
	S2	BCC	Bishopsworth Rd	btw Wrington Close	ATC_perm	3/02/2012
	S3	CH2M	St Peters Rise	south of Headley Park	ATC	27/03/2014
	S4	CH2M	Hengrove Way	east of Cater Rd	ATC	19/03/2014
	S5	CH2M	Hawkfield Rd	south of Baiscoes Av	ATC	6/03/2014
	S6	CH2M	Whitchurch Lane	south of Hawkfield Way	ATC	19/03/2014
	S7	BCC	Bamfield	north of Oatfields Av	MCC	3/02/2011
	S8	CH2M	Wells Rd	north of Hengrove Lane	ATC	19/03/2014
	S9	CH2M	Bath Rd	south of A4174	ATC	19/03/2014
	S10	CH2M	School Road	south of Allison Rd	ATC	6/03/2014
	S11	BCC	Allison Rd	btw Allison Av	MCC	13/01/2010
River Screenline	R1	TRADS	M5	J18-J19	TRADS	2013
	R3	CH2M	A3029 Brunel Way (N)	south of Bennett Way	MCC	20/06/2013
	R4	BCC	A3029 Brunel Way (S)	north of Jessops underpass	MCC	13/10/2011
	R5	BCC	Princes Street Bridge	south of The Grove	MCC	23/11/2011
	R6	CH2M	Bedminster Bridge	north of Bedminster Parade	MCC	26/06/2013
	R7	CH2M	Redcliffe Way	east of Welsh Back	MCC	26/06/2013
	R8	BCC	Bristol Bridge, Victoria Street	south of Baldwin Street	MCC	24/11/2011
	R9	BCC	Passager Street	north of Temple Back	MCC	04/11/2011
	R10	BCC	Temple Way	north of Temple Back	MCC	04/11/2011
	R11	CH2M	Bath Bridge	south of Temple Gate	MCC	27/06/2013
	R12	CH2M	Avon Street	north of Feeder Road	ATC	19/06/2013
	R13	BCC	Albert Road	north of A4 Bath Road	MCC	25/11/2011
	R15	CH2M	St Phillips Causeway	north of Whitby Road	MCC	25/06/2013
	R16	BCC	Marsh Lane	north of Feeder Road	MCC	17/02/2011
	R17	BCC	Nethan Road	north of Feeder Road	MCC	13/07/2009
	R18	BCC	Feeder Road	north of Whitby Road	MCC	17/11/2011
Railway Screenline	RW1	CH2M	A4176 Portway	south of Roman Way	MCC	20/06/2013
	RW5	CH2M	Clifton Down	west of Pembroke Road	ATC	19/06/2013
	RW22	CH2M	Kingsland Road	south of Day's Rd	ATC	19/06/2013
	RW2	CH2M	Avon Street	east of New Kingsley Road	ATC	9/10/2013
	RW26	CH2M	B3021 St Johns Lane	south of A38 Sheene Road	ATC	18/06/2013
	RW27	BCC	A38 Parsons Street	south of A38 West Street	MCC	20/10/2010
	RW28	BCC	A38 Bedminster Down Road	south of A3029 Winterstoke Road	MCC	17/06/2009
	RW30	CH2M	Whitby Road	south of Feeder Road	ATC	19/06/2013
	RW34	SGC	A4174	north of A4 Keynsham By-Pass	ATC	23/01/2012
	RW35	CH2M	A4175 Keynsham Road	between The Ave and Chandos Rd	ATC	19/06/2013
	RW36	CH2M	Muller Road	Shaldon Rd and Petherbridge Way	ATC	18/06/2013
	RW37	BCC	Lockleaze Road		MCC	23/09/2009
	RW38	CH2M	Bonnington Walk	east of Wordsworth Rd	ATC	19/06/2013
	RW39	SGC	A4174 Station Road	east of Filton Avenue	ATC	30/09/2013
	RW40	SGC	Gipsy Patch Lane	west of Station Road	ATC	30/09/2013
	RW41	SGC	A38 Gloucester Road	south of Stoke Lane	MCC	6/12/2013
	RW42	TRADS	M5	J16-J17	TRADS	2014
	M5J19	CH2M	M5J19	All Movements	FURNESS	1/04/2013

Table 5.2 - Validation Traffic Count Data

	Ref No.	Source	Road	Location	Available Data	Date
Outer Cordon	O1	NS	A38 Bridgewater Road	south of Kings Head Lane	ATC	2013
	O2	NS	A370 Long Ashton Bypass	south of B3128	ATC	2013
	O3	NS	B3128 Ashton Road	east of Long Ashton Rd	ATC	2013
	O4	CH2M	A369 Clanage Road	north of Kennel Lodge Road	ATC	01/03/2014
	O5	NS	B3129 Clifton Suspension Bridge	Leigh Woods	ATC	25/09/2013
	O6	CH2M	A4 Portway	west of Sylvan Way	ATC	19/03/2014
	O7	BCC	B4054 Shirehampton Road	east of Penpole Lane	MCC	28/11/2011
	O8	CH2M	Kings Weston Lane	north of Campbells Farm Drive	ATC	01/03/2014
	O9	CH2M	Hallen Road	north of Marissal Road	ATC	01/03/2014
	O10	SGC	A4018 Cribbs Causeway	west of Hollywood Lane	ATC	27/05/2013
	O11	SGC	Merlin Road	south of Highwood Lane	ATC	30/09/2013
	O12	SGC	Highwood Lane	east of Merlin Road	ATC	04/11/2013
	O13	SGC	A38 Gloucester Rd	north of Bradley Stoke Way	ATC	30/09/2013
	O14	SGC	B4427 Old Gloucester Road	north of Trench Lane	ATC	26/08/2013
	O15	SGC	B4057 Beacon Lane	east of M4	ATC	30/09/2013
	O16	TRADS	M32	M4 - M32 J1	TRADS	October 2013
	O17	SGC	B4058 Bristol Road	east of Old Gloucester Road	ATC	30/09/2013
	O18	SGC	A432 Badminton Road	north of Cuckoo Lane	ATC	30/09/2013
	O19	SGC	Westerleigh Road	south of M4	ATC	30/09/2013
	O20	SGC	Shortwood Road	east of Siston Lane	ATC	30/09/2013
	O21	SGC	A420 London Rd	east of Nashcombe Hill	ATC	26/08/2013
	O22	SGC	A431 Bath Road	east of A4175 Cherry Garden	ATC	30/09/2013
	O23	B&NES	A4 Bath Road	east of Keynsham By-Pass	ATC	2013
	O24	B&NES	B3116 Wellsway	south of Courtenay Rd	ATC	2013
	O25	B&NES	A37 Bristol Road	south of Norton Lane, Whitchurch	ATC	2013
	O26	CH2M	Queens Rd	south of Bearbridge Road	ATC	05/03/2014
Middle cordon	M2	CH2M	A4176 Portway	south of Bridge Valley Road	ATC	18/06/2013
	M4	BCC	College Road	south of Clifton Down	MCC	20/06/2011
	M5	CH2M	Pembroke Road	south of Clifton Down	MCC	19/06/2013
	M7	BCC	Whiteladies Road	north of Cotham Hill	MCC	17/06/2011
	M8	BCC	Hampton Road	north of Waverley Road	MCC	17/06/2011
	M9	BCC	Redland Grove	south of South Road	MCC	17/06/2011
	M10	BCC	Redland Road	south of Zetland Road	MCC	23/06/2011
	M11	CH2M	A38 Cheltenham Road	north of Cotham Brow	ATC	18/06/2013
	M12	CH2M	North Road	north of Cheltenham Rd	ATC	14/03/2014
	RW14	BCC	Ashley Hill	south of Hurlington Road	MCC	27/06/2011
	MM12	BCC	Glenfrome Road	Railway Line	MCC	27/06/2011
	M13	BCC	M32	north of Jct 3	MCC	21/06/2011
	M14	BCC	Stapleton Road	south of Berwick Road	MCC	14/06/2011
	M15	BCC	Easton Road	west of Whitehall Road	MCC	16/06/2011
	M16	CH2M	A420 Lawrence Hill	east of Croydon St	ATC	19/06/2013
	M17	BCC	Ducie Road	North of Morton Street	ATC	11/09/2011
	M18	CH2M	Barrow Road	south of Lincoln St	ATC	19/06/2013
	M19	CH2M	A4320 St Phillips Causeway	south of Day's Rd	ATC	19/06/2013
	M20	BCC	Feeder Road	west of St Phillips Causeway	MCC	24/06/2011
	M21	BCC	Albert Road	west of St Phillips Causeway	MCC	30/06/2011
	M22	BCC	Bath Road	east of Park Street	MCC	13/06/2011
	M23	BCC	Wells Road	south of School Road	MCC	13/06/2011
	MM23	CH2M	Redcatch Road	north of Axbridge Road	MCC	27/06/2013
	M24	CH2M	Wedmore Vale	north of Glynn Vale	ATC	18/06/2013
	M25	BCC	Novers Hill	South of Parson Street	MCC	16/02/2010
	M26	CH2M	A4174 Hartcliffe Way	south of Parson St	ATC	18/06/2013
	M27	CH2M	A38 Bedminster Down Road	north of Bishopsworth Rd	ATC	18/06/2013
	M28	CH2M	South Liberty Lane	west of Nelson St	ATC	18/06/2013
	M29	CH2M	Ashton Drive	near rail bridge	ATC	18/06/2013
	M30	CH2M	A370 Ashton Road	east of B3128 merge	ATC	18/06/2013
NorthWest Outer	NWO1	TRADS	M5	J17-18a	TRADS	2012
	NWO2	SGC	A4018 Cribbs Causeway	s/o The Laurels	ATC	3/06/2013
	NWO4	SGC	Gloucester Rd North	south of Filton Avenue	ATC-perm	30/09/2013
	NWO5	SGC	Great Stoke Way	north of Filton Rd	ATC-perm	30/09/2013
	NWO6	TRADS	M32	M32 J1 Within	TRADS	October 2013
	NWO7	CH2M	Bristol Rd	north of A4174	ATC	06/03/2014
Northeast Screenline	NE1	CH2M	Frenchay park Rd	east of Ham Lane	ATC	01/03/2014
	NE2	BCC	Blackberry Hill	east of Small Lane	MCC	15/03/2011
	NE3	BCC	Fishponds Road	west of Alcove Rd	MCC	19/01/2011
	NE4	BCC	Berkley Rd	south of Lodge Causeway	ATC	16/10/2011
	NE5	CH2M	Charlton Road	south of King Johns Rd	ATC	01/03/2014
	NE6	CH2M	Lodge Rd	south of Britton Gardens	ATC	01/03/2014
	NE7	CH2M	Downend Rd	north of Cross St	ATC	01/03/2014
	NE8	CH2M	Syston Way	west of Northend Rd	ATC	06/03/2014
	NE9	CH2M	Lees Hill	south of High View Road	ATC	06/03/2014
	NE10	CH2M	Pound Rd	south of High View Road	ATC	06/03/2014
	NE12	SGC	Station Rd	south of Chiphouse Rd	ATC Temp	01/03/2014

Figure 5.2- Calibration Traffic Count Sites

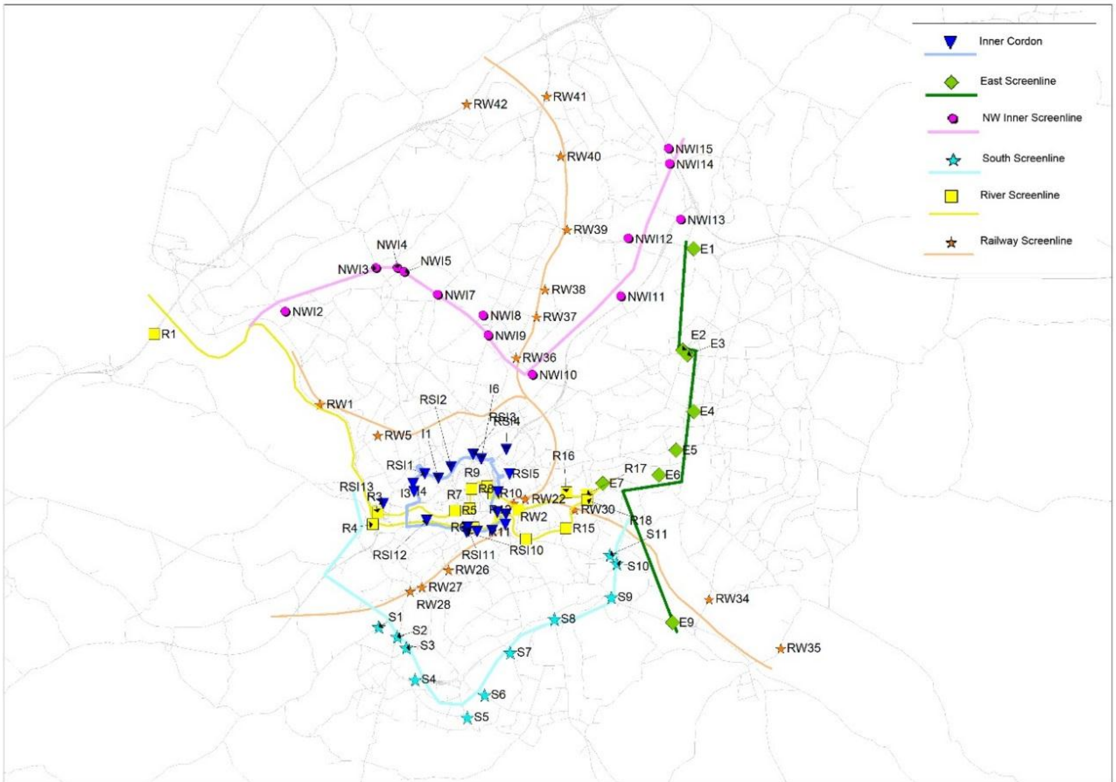
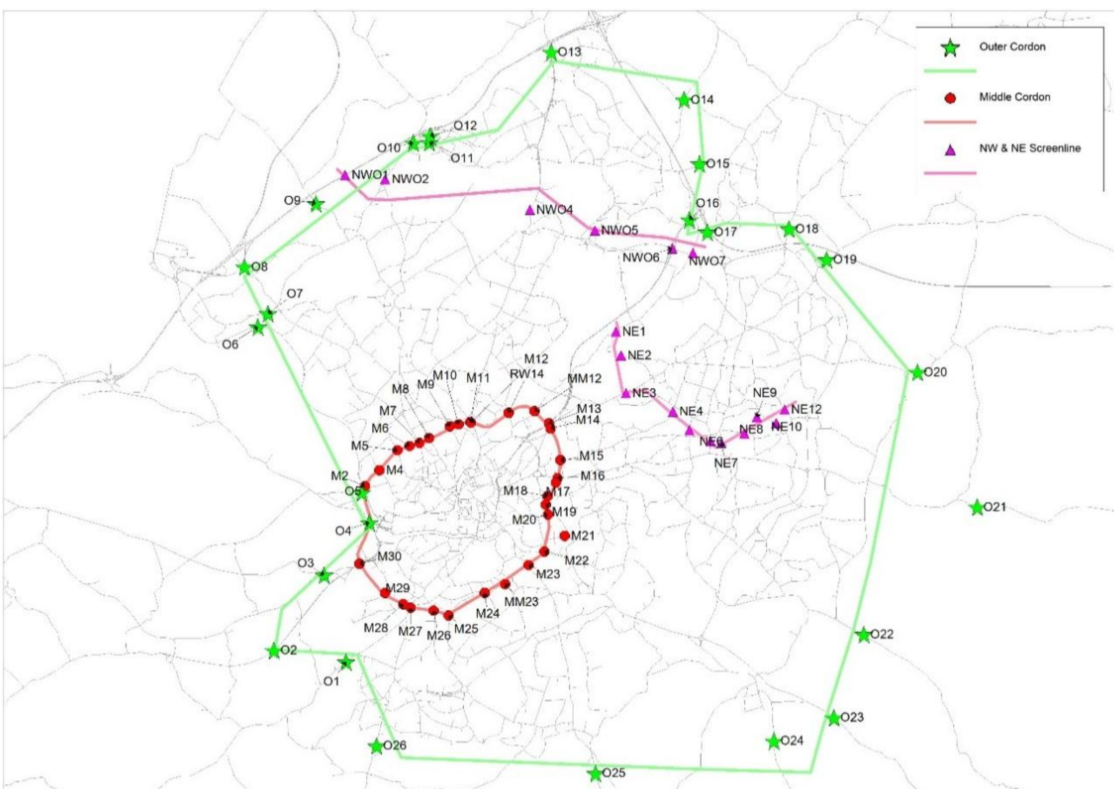


Figure 5.3- Validation Traffic Count Sites



5.4 Data Processing

The model represents a typical weekday in October 2013. The traffic data used in the model was collected over a range of different sources (see Tables 5.1 and 5.2). Therefore, factors were needed to account for monthly variations, as shown in Table 5.3.

Table 5.3 – Monthly Traffic Flow Factors

Site	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
883	Temple Way Underpass	11391	11410	11613	11946	11990	12124	12125	11947	11681	11342	11091	11171
886	Brunel Way	12055	12605	12395	12390	12570	12397	12363	12192	12410	12396	12336	12234
20702071	A4320 Easton Way	16105	16931	17082	16996	16776	16617	16850	16064	17002	17501	17417	17144
32033204	A4174 Avon Ring Road	11214	11676	12029	12464	12960	12998	14936	14738	14757	14497	13704	12066
40000044	A4018 Queen's Road	12930	16293	17393	18226	18311	18153	17877	17505	17769	17882	17430	16671
50000002	A4174 Callington Road	7271	7505	7908	7105	7229	7299	7333	7484	7090	7031	7128	7205
80000179	A4018 Park Street	4966	5180	5286	5358	5352	5333	5312	5111	5302	5377	5252	5296
80000200	A4320 St Philips C'way	8356	7395	8874	8517	8539	8513	8732	8493	8854	9148	8746	8685
80000330	A4 Anchor Road	6322	6678	6796	6731	6743	6672	6709	6766	6667	6679	6765	6722
80000403	A4162 Sylvan Way	4696	4927	5717	5923	5917	5805	5765	5490	5752	5841	5935	5827
80003010	Kings Weston Ln	2023	2144	2216	2303	2303	2313	2240	2244	2298	2270	2234	2132
Total		97330	102744	107310	107961	108690	108225	110243	108034	109580	109964	108037	105153
Factor		**1.13**	**1.07**	**1.02**	**1.02**	**1.01**	**1.02**	**1.00**	**1.02**	**1.00**	**1.00**	**1.02**	**1.05**

Local annual data collected (located in South Gloucestershire, as BCC data was not available) suggested that growth was relatively flat between 2009 (generally the oldest available data) and 2013, as shown in Table 5.4. Therefore no annual adjustment factors were applied.

Table 5.4 - Annual Traffic Flow Factors

Year	South Glos Counts	Index	% Change from 2013
2009	289240	132	0.990
2010	288658	131	0.991
2011	288055	131	0.992
2012	286865	131	0.996
2013	285479	130	1.000

5.5 Journey Time Surveys

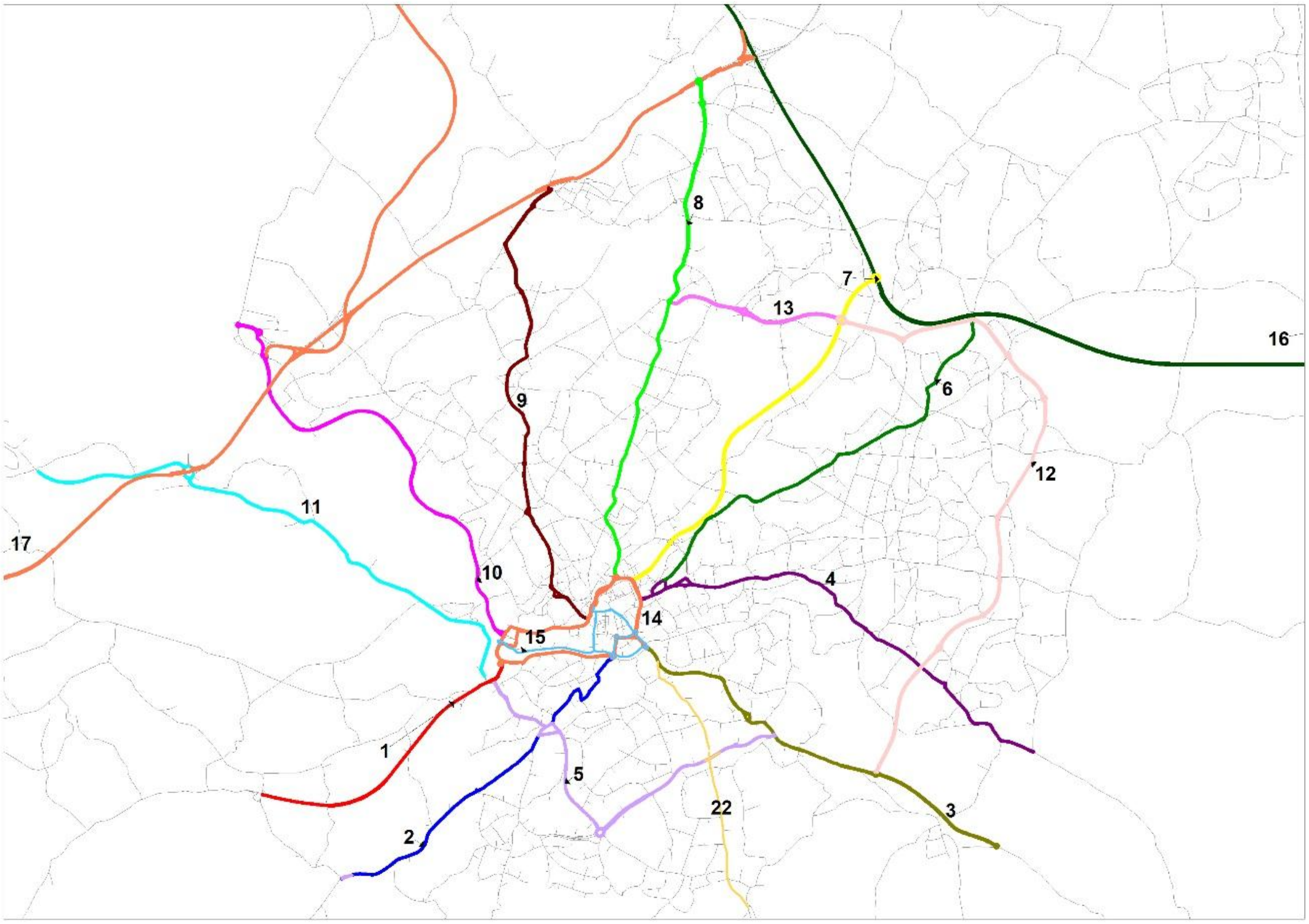
Observed Journey time data was examined using Trafficmaster™ journey time data supplied to the local authorities by the Department for Transport. TAG M3.1 recommends that *"journey time routes should cover as wide a range of route types as possible and cover the Fully Modelled Area as evenly as possible. For models developed for the appraisal of specific interventions, routes should include those from which it is expected traffic will be affected by the scheme, as well as covering the scheme itself as appropriate."*

TAG M3.1 underlines the importance of setting accurate cruise speeds. Although not a specific TAG requirement, Trafficmaster™ journey time data was used to check model cruise times. The cruise speed by link type was estimated by calculating the between-junction link speed on all links during the 7am to 7pm period. During this period, the highest average speed (in 15 minute intervals) recorded for each link was considered to be a reasonable approximation of link cruise time; which in the highway model is the link journey time, excluding junction delay.

The journey time routes are shown in Figure 5.4.

The journey time data used represents mean values from all weekdays in October 2013, filtered to exclude school holidays. During this time period the main road through Barrow Gurney was shut due to repairs to a water main. This had a substantial impact on travel times through both routes 1 and 2. Therefore May 2013 data was used as an alternative for these routes during the morning and evening peaks.

Figure 5.4 - GBATS4M Highway Model Journey Time Survey Routes



5.6 Accuracy of Journey Time Surveys

Table 5.5 summarises the number of runs undertaken for each route by time period, and the resulting standard deviation and accuracy. The accuracy values are a measure of the variability of the journey time surveys and were calculated following the advice given in DMRB guidance (Volume 13, Section 1, Part 5, Chapter 11 'Economic Assessment of Road Schemes').

$$m = \frac{\sum X_i}{n} \qquad s = \sqrt{\frac{\sum (X_i - m)^2}{n-1}} \qquad a = t.\frac{s}{m.\sqrt{n}}$$

Where :

n = the number of observations of journey time

m = the estimate of true mean journey time

s = the estimate of the standard deviation of true mean journey time

t = t-distribution, which depends on (n-1) number of degrees of freedom, and the confidence level (95%)

a = accuracy

The guidance recommends that, as a general rule, it should be realistic to aim for an accuracy of ±10% in the estimate of observed journey time on the existing route, at the 95% confidence level. On individual links the level of accuracy need not be so great.

For all observed routes, the mean values are shown to meet TAG M3.1 guidelines and standards.

Table 5.5 - Accuracy of Journey Time Data

Route Description		Mean No. Vehs in Sample (Weighted by Distance)			Standard Deviation			Accuracy (95% Confidence)		
		AM	IP	PM	AM	IP	PM	AM	IP	PM
1	A370 Inbound (Backwell to Ashton Gate)	46	300	18	1.7	1.7	0.5	4.9%	1.8%	2.7%
1	A370 Outbound (Jessop Underpass to Backwell)	27	464	53	1.2	1.8	0.9	5.0%	1.6%	2.4%
2	A38 Inbound (Barrow Gurney to Bedminster Bridge)	44	382	48	1.9	2.2	2.2	3.3%	1.2%	3.4%
2	A38 Outbound (Bedminster Bridge to Barrow Gurney)	39	420	51	1.7	1.4	2.2	4.1%	1.0%	3.8%
3	A4 Inbound (Keynesham to Bath Bridge)	82	673	78	4.4	1.8	2.1	3.1%	0.9%	2.5%
3	A4 Outbound (Bath Bridge to Keynesham)	100	551	70	3.0	0.7	1.9	3.1%	0.4%	2.5%
4	A431 Inbound (Willsbridge to Old Market St)	54	284	44	2.6	0.6	1.6	2.3%	0.3%	2.2%
4	A431 Outbound (Old Market St Jct to Willsbridge)	45	289	48	1.4	0.8	2.0	2.1%	0.4%	2.2%
5	A38 Eastbound (Ashton Gate to Brislington)	92	447	64	4.3	2.2	3.1	3.1%	1.1%	3.0%
5	A38 Westbound (Brislington to Ashton Gate)	72	435	55	3.0	1.8	2.2	3.0%	0.9%	2.7%
6	A432 Inbound (A4174 Badminton Rbt to Old Market St)	48	220	30	3.3	1.7	1.7	2.7%	1.0%	2.7%
6	A432 Outbound (West St to A4174 Badminton Rbt)	28	212	35	2.5	1.6	1.9	3.7%	0.9%	2.5%
7	M32 Inbound (M32 J1 to Cabot Circus)	205	1560	203	2.2	0.7	1.4	2.3%	0.7%	3.0%
7	M32 Outbound (Cabot Circus to M32 J1)	266	1686	222	0.9	0.4	1.0	2.0%	0.5%	2.7%
8	A38 Inbound (M5 J16 to St James Barton Rbt)	70	398	49	3.3	1.8	2.3	2.4%	0.7%	2.2%
8	A38 Outbound (St James Barton Rbt to M5 J16)	57	389	45	2.9	2.5	2.9	2.4%	1.0%	2.5%
9	A4018 Inbound (M5 J17 Cribbs to Clifton Triangle)	75	412	64	3.4	1.5	2.1	2.6%	0.9%	2.3%
9	A4018 Outbound (College Green to M5 J17 Cribbs)	58	417	57	1.6	1.5	1.5	2.3%	0.9%	2.1%
10	A4 Portway Inbound (Avonmouth to Hotwells)	73	475	52	1.7	1.1	1.9	1.9%	0.7%	2.8%
10	A4 Portway Outbound (Hotwells to Avonmouth)	57	452	53	1.0	1.1	0.7	2.1%	0.9%	1.7%
11	A369 Inbound (Portishead to A4 Bristol Gate)	90	459	82	4.2	1.0	1.4	3.6%	0.7%	1.8%
11	A369 Outbound (A4 Bristol Gate to Portishead)	78	497	73	1.2	0.7	1.5	1.6%	0.4%	1.9%
12	A4174 Eastbound (Filton Rbt to A4)	132	990	140	3.7	1.0	3.6	2.3%	0.3%	1.9%
12	A4174 Westbound (A4 to Filton Rbt)	126	898	147	3.8	1.1	3.0	2.1%	0.3%	1.9%
14	City Centre Outer Loop (Clockwise)	63	518	57	3.5	1.6	3.9	2.5%	0.6%	2.5%
14	City Centre Outer Loop (Anti-Clockwise)	67	466	51	3.4	0.7	2.8	2.5%	0.3%	2.5%
15	City Centre Inner Loop (Clockwise)	31	227	33	2.7	1.7	2.6	3.3%	1.1%	3.1%
15	City Centre Inner Loop (Anti-Clockwise)	48	270	34	2.1	1.6	2.4	3.2%	1.4%	4.7%
16	M4 Mainline Eastbound (J22 to J18)	304	1816	300	3.0	0.6	1.6	1.2%	0.1%	0.9%
16	M4 Mainline Westbound (J18 to J22)	264	1901	314	1.9	0.8	1.6	1.1%	0.2%	0.9%
17	M5 Mainline Northbound (J20 to M4)	427	2256	381	0.8	0.7	2.4	0.6%	0.2%	1.4%
17	M5 Mainline Southbound (M4 to J20)	346	2443	352	0.9	0.7	1.5	0.7%	0.2%	1.0%

SECTION 6

Network Development

6.1 Source Networks

As a starting point, the GBATS3 2012 South Bristol Link (SBL) model was the primary source model for the majority of the network area of the GBATS4M highway model. The 2011 SGC Core Strategy Model (CSM) model was used as the primary source for the North Fringe area of the GBATS4M highway model. The two networks were merged and a thorough check of the network was undertaken to ensure that the model coding is representative of the October 2013 Bristol area road network. This included checks as outlined below.

6.2 Link Coding

The network development process involved checking and adjusting the highway network principally along the journey time routes, and other routes where necessary to calibrate the model.

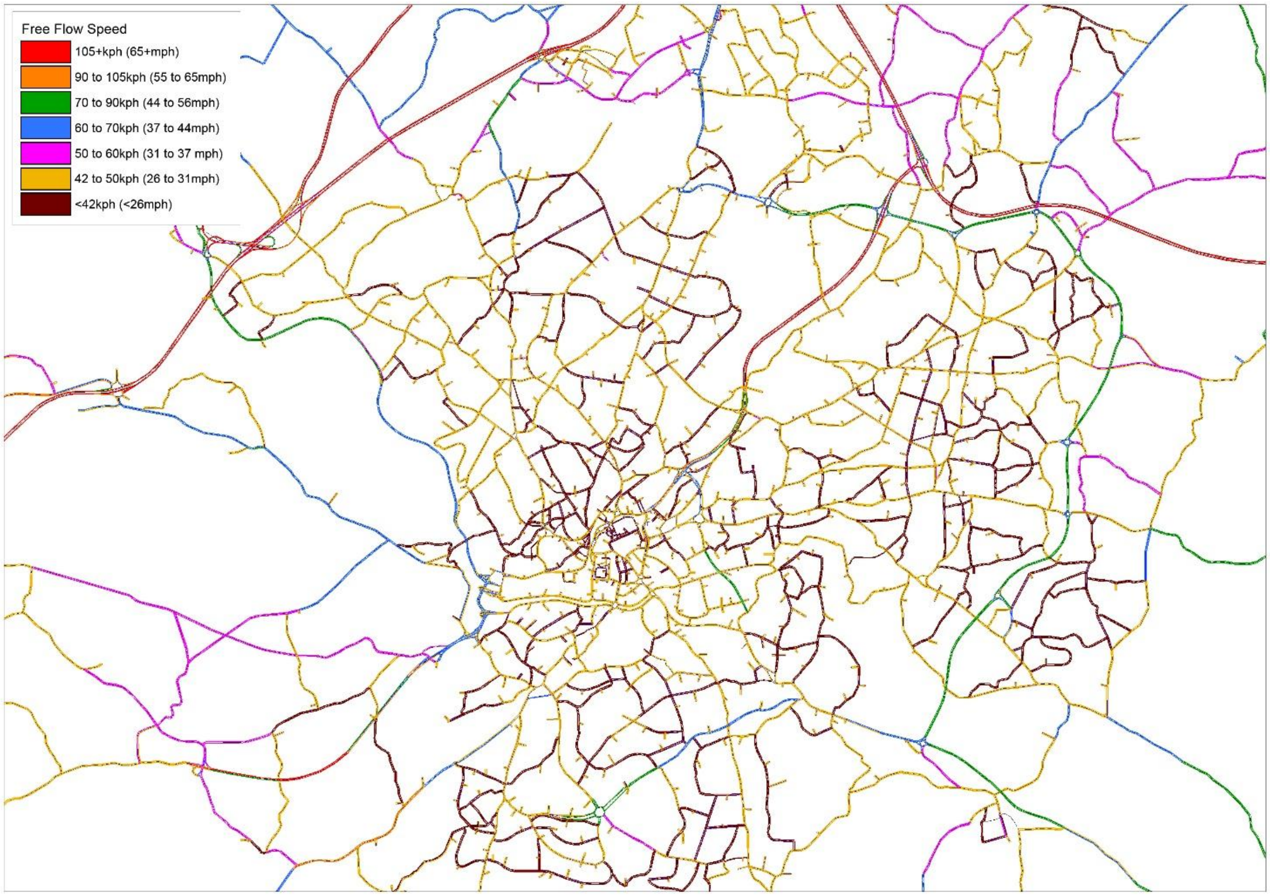
All links in simulated area were allocated distances derived from a detailed GIS based analysis of mapping to provide an estimation of road lengths.

The road classification system and local network speed limits were used to apply free-flow speed limits to individual links in the network. Speed/flow curves on specific links in the simulation area have been included to a) represent interactions on links which are otherwise not directly modelled, such as in busy retail/high street areas which are impacted by on-street parking, bus stops, pedestrians and non-modelled junctions and b) high speed inter-urban roads (i.e roads with a speed limit greater than or equal to 50 mph) which have been defined using the using the standard Cost Benefit Analysis (COBA) speed/flow classification.

The Trafficmaster™ journey time data was used to validate the cruise speed of the inter-peak model (see section 10).

The free flow speeds used in the simulation area are shown in Figure 6.1.

Figure 6.1 - GBATS4M Free Flow Speed



6.3 Junction Coding

The coding of junctions within SATURN requires a range of information. This included the use of web-based imagery and site visits. The following checks were undertaken for all the key nodes within the simulation area, including all nodes on MetroWest corridors, with corrections where required:

- Junction type, layout, lane usage and flare length;
- Junction geometry and turn capacities;
- Signal stages and timings;
- Junction delay, and particularly junctions with highest delay, as identified by the SATURN software.

6.4 Centroid Connectors

The allocation of centroid connectors for internal zones were examined to verify that trips are loading onto the network at locations that are both sensible and realistic. Centroid connectors for external zones were also checked and corrected where required. Internal zones are those in the simulation network and external zones are those in the buffer network.

Summary details of the network coding standards utilised are found in **Appendix B**.

SECTION 7

Trip Matrix Development

7.1 Matrix Development process

The development of GBATS4M 'prior' trip matrices involved new RSI OD survey data for city centre trips and the use of the 2012 SBL model and the 2011 SGC CSM 'prior' matrices. The source model prior matrices were used rather than the validated assignment matrices so that any matrix estimation effects were not incorporated into the new GBATS4 model. The matrix development process for light vehicles was undertaken as described below. Due to the relatively low sample rate for heavy goods vehicles (HGVs) in the 2013 RSI surveys, a check of trip patterns for HGVs for the central area in the source model matrices was undertaken in relation to Trafficmaster™ OD data. This showed a reasonable fit in terms of trip lengths and spatial patterns. Hence no adjustment was made to the OD data for HGVs in the development of prior matrices.

7.2 GBATS3 Matrix Merge

The SBL 2012 model was deemed the most appropriate starting point for the updated GBATS4M Metro Model, however the northern part of the model was out of date as the CSM model of this area had been developed to test schemes to the north of the city. Therefore, the two models needed to be merged, both network and matrices, to fully update the GBATS4M model. The SBL 2012 and CSM 2011 model matrices were merged using the following process:

- Expand SBL and CSM matrices to have a consistent zoning system (650 zones) – (total trips remained the same);
- Expand SBL and CSM networks to have a consistent zoning system (650 zones);
- Assign both models using the updated networks and matrices;
- Undertake a select link on both model assignments for each time period, at each RSI location used in the development of the CSM model, but not used in the SBL model (see Table 7.1 for sites);
- Remove the SBL select link matrices from the SBL prior matrices and replace with the SGCS select link matrices; and
- Assign GBATS3 merged 'prior' matrices to the SBL 2012 network.

Table 7.1 – CSM RSI Locations Used

Site Location	Year
Aztec West	2011
Bradley Stoke Way	2011
Hayes Way	2011
Highwood Lane	2011
Merlin Road	2011
Lysander Road	2011
A38 Gloucester Road	2009
Hatchet Road	2009
B4427 Old Gloucester Road	2009
Great Stoke Way	2009
A432 Badminton Road	2009
A4174 Avon Ring Road	2009
B4057 Beacon Lane	2006

B4058 Bristol Road	2006
A369 Portbury Hundred	2009

7.3 RSI Data

The 2013 RSI data was used to develop an observed matrix of trip movements to/from the city centre, i.e. the part of the matrix based on 2013 fully observed data. It was assumed that the level of vehicular trips with both origin and destination within the inner cordon was not significant.

The RSI data was processed as follows:

- Range and logic checks to determine the data was 'sensible';
- Allocate trips to 'super-zones', defined based on groups of nearby model assignment zones;
- Disaggregate trips to assignment zones within each super-zone based on residential and/or employment demographic data to produce a 'smoothed' distribution of trips within super zones;
- Expand origin/destination trips to the manual classified count (MCC) collected on the day of interview, by time period and vehicle type; and
- Correct to the automatic traffic count (ATC) collected over a two week period, to remove any bias with the day of interview.

The use of a super-zone system, combined with demographic-based trip allocation to assignment zones removed any 'unevenness' (as far as possible) from the RSI data collected.

For example, if a trip was observed at an RSI site between two assignment zones this would be identified as a trip between the super-zones containing these assignment zones. Trips would then be disaggregated back to the assignment zone level pro rata using demographic data for each zone. This effectively smoothed the observed trips across nearby zones. This was undertaken in line with DMRB matrix building guidance; specifically Vol 12 Section 1 Chapter 8 as referenced by TAG M3.1.

The creation of the non-interview direction matrices was undertaken by transposing the AM, Inter-Peak and PM interview direction matrices. The AM transpose was used for the PM non-interview direction and the PM transpose was used for the AM non-interview direction. This meant that the trips seen travelling (interview direction) into the city in one time period travelled back in the other time period, i.e. 'home to work' trips in the AM become 'work to home' trips in the PM. For the inter-peak model it is assumed that trips enter and leave within the same time period. This approach was applied to trips of all purposes. The resulting purpose split for transposed trips in each time period was controlled to the purpose split for observed trips in each time period. The factors required to control the purpose splits were reviewed to ensure best use was made of the observed data.

7.4 Merging RSI Data

Once hourly trip purpose matrices for each site were developed, the RSI data was 'merged' to create observed RSI matrices. To avoid double counting of trips passing through the area enclosed by the inner cordon, interview direction data was used in preference to transposed data.

The hourly observed matrices were then used to replace the OD trips within the source model highway matrices, using the following methodology:

- Undertaken a select link on the GBATS3 merged 'prior' matrices / SBL 2012 network assignment, at each RSI location and output an OD matrix;
- Remove all RSI OD trips from the original matrix; and
- Add the RSI observed matrices to the matrices created in the step above.

The merged observed and updated source model trip matrices then became the initial prior matrices for the model matrix development process.

7.5 Calibration of the Initial Trip Matrices

TAG M3.1 recommends that the 'prior' trip matrix should be validated by comparing total screenline and cordon model flows and counts. If screenline and cordon totals are not within 5%, then remedial action should be considered.

Table 7.2 shows the model screenline output when the initial prior matrices were assigned to the network and the model flows were compared to the count for each screenline and cordon. Where the difference in the total screenline count was greater than 5%, then appropriate OD pairs (which crossed the screenline) were factored to match the observed flow. This iterative process was continued until an appropriate 'prior' matrix was created, which fulfilled the TAG M3.1 criteria. This process did not disaggregate light and heavy vehicles.

Table 7.2 - Initial Trip Matrix Comparison

		AM Peak		Inter Peak		PM Peak	
Screenlines and Cordon	No. Links observed	Observed Total (PCUs)	Initial Matrix vs Obs % Diff	Observed Total (PCUs)	Initial Matrix vs Obs % Diff	Observed Total (PCUs)	Initial Matrix vs Obs % Diff
Calibration Total	163	144,654	-2%	122,397	-5%	149,598	-3%
Inner (In)	19	14,232	-1%	10,216	-6%	11,030	-4%
Inner (Out)	18	10,975	-9%	10,461	-5%	14,527	-6%
East (In)	8	6,612	4%	5,053	1%	5,342	0%
East (Out)	8	4,963	25%	5,456	-1%	7,917	3%
NW Inner (In)	13	13,434	-3%	11,192	-9%	13,488	-8%
NW Inner (Out)	13	12,330	10%	9,984	-6%	13,851	1%
South (In)	11	6,063	11%	5,655	2%	6,321	3%
South (Out)	11	6,042	-1%	5,703	4%	6,835	7%
River (WBSB)	16	18,175	-8%	17,279	-3%	22,218	-3%
River (EBNB)	16	23,640	-4%	17,640	-2%	19,778	-6%
RW (ALL)	30	28,188	-8%	23,759	-12%	28,291	-2%
Validation Total	146	119,970	-7%	93,005	-8%	122,986	-9%
Outer (In)	26	25,522	-5%	16,282	-4%	21,238	-12%
Outer (Out)	26	19,660	-15%	15,827	-5%	24,825	-7%
Middle (In)	30	23,785	-7%	17,425	-8%	19,770	-8%
Middle (Out)	30	18,054	-5%	17,360	-8%	23,120	-8%
NW Outer (In)	6	10,937	-9%	8,744	-3%	12,082	-8%
NW Outer (Out)	6	11,634	0%	9,006	1%	11,666	-1%
NE (In)	11	4,889	-6%	4,215	-30%	5,320	-25%
NE (Out)	11	5,490	-12%	4,147	-35%	4,964	-11%
All	**309**	**264,624**	**-4%**	**215,403**	**-6%**	**272,584**	**-5%**

SECTION 8

Network Calibration and Validation

8.1 Network Calibration

Highway network calibration was undertaken to ensure that the model fully replicated the observed traffic characteristics in terms of speeds, throughputs and delays. This was done by systematically reviewing model assignments and modifying the network parameters to improve the model's fit against observed calibration data. Checks were made to ensure:

- Link speeds on the network are realistic and speed/flow calculations are operating as expected; and
- Delay calculations at junctions are realistic.

Modelled speeds, traffic flows and journey times were compared to observed data. Any significant differences were subsequently reviewed and the network updated accordingly.

A large number of checks were iteratively undertaken, throughout the process, to calibrate the models. This included:

- Reviewing the warnings produced by SATNET;
- Inspecting excessive junction delays to check network coding;
- Monitoring where model flows were too high or low and checking the coding of the principle route and alternate competing routes.

All output data for route choice calibration and validation is found in **Appendix D**.

8.2 Route Choice Calibration

Network calibration focuses on adjusting the network to perform to replicate the observed data. However, it is generally not considered a cost effective use of resources to check all modelled routes against travel time data. Therefore, checking of the routes chosen by traffic travelling through the network is used to calibrate the parts of the network not directly observed. In line with TAG M3.1, the selected origins and destinations focused on important centres of population and employment or key intersections. These were chosen so that the routes:

- relate to significant numbers of trips;
- are of significant length or cost (e.g. 20+ minutes);
- pass through areas of interest (e.g. scheme impacted areas);
- include both directions of travel (to sense check differences);
- link different compass areas (e.g. north to south, east to west, etc.); and
- coincide with journey time routes as appropriate.

TAG M3.1 suggests the number of pairs of zones to be examined and displayed should be at least:

Number of OD pairs = $(\text{number of zones})^{0.25}$ x the number of user classes.

There are 650 zones and the model was developed and calibrated using 2 user classes equating to 10 routes (note the model was validated using 6 user classes). The OD routes selected to check are below:

1. Portishead – Bristol City Centre
2. Avonmouth – Bristol City Centre
3. Wales – Bristol City Centre
4. Yate – Bristol City Centre

5. Bath – Bristol City Centre
6. Weston-super-Mare – Bristol City Centre
7. Lawrance Weston – Hanham
8. Stoke Gifford – Bedminster
9. Clifton – Emerson Green
10. Filton - Brislington

8.3 Route Choice Validation

There are no validation criteria or prescribed mechanisms for route choice validation. Therefore, common practice is to provide plots of the trees (the paths from an origin to all destinations) chosen by the model from a number of locations. Routeings were checked in key corridors through and around the city centre to ensure plausible and realistic routeing of traffic, as above.

The following locations (by zone) for plotting trees, include: Wales, Gloucester, Yate, Bath, Weston-super-Mare, Portishead, Pill, Avonmouth, Westbury-on-Trym, Bradley Stoke, Filton, Stoke Gifford, Emersons Green, Fishponds, Kingswood, Brislington, Bedminster, St Phillips, City Centre and Clifton.

All output is found in **Appendix D**. Note: this output is based on the final version of the model, post matrix Estimation, with 6 user classes, see following section.

SECTION 9

Trip Matrix Calibration and Validation

9.1 Prior Trip Matrix

The prior matrix was assigned to the model network to ensure that it produced trip patterns across the network that reasonably replicates the origins and destinations of trips in the model area. This was done by comparing modelled movements to observed independent counts and total screenline flows. This showed that whilst screenline and cordon totals showed a better fit to observed data than assignment of the initial trip matrices, the resulting flows still did not meet the model validation requirements. As such, matrix estimation was applied to the prior trip matrix to improve the matrix calibration.

9.2 Application of Matrix Estimation

The SATURN modules SATME2 and SATPIJA were used for matrix estimation. In combination they attempt to match assigned link flows in the model with observed traffic counts. The matrix estimation process forms part of the calibration process and is designed to modify the origin-destination volumes by reference to the observed traffic counts. Trips are adjusted in the prior matrix to produce the estimated matrix, which is most likely to be consistent with the traffic counts. The equation used may be written as:

$$T_{ij} = t_{ij} \prod aXaP_{ij}a$$

Where:

T_{ij} = the output estimated matrix of OD pairs $_{ij}$; t_{ij} = the prior matrix of OD pairs $_{ij}$;
∏a = the product over all counted links a; Xa = the balancing factor associated with counted link;

$P_{ij}a$ = the fraction of trips from i to j using link a.

Matrix estimation was undertaken on both light and heavy vehicles and was limited to the calibration sites shown in Figure 5.2.

9.3 Changes due to Matrix Estimation

TAG M3.1 advises that it is important that the process of matrix estimation does not significantly alter the characteristics of the prior matrix. The relevant criteria are described in section 3. The checks undertaken are shown as follows:

- Table 9.1 shows the regression analysis;
- Table 9.2 shows the total mean trip length check and;
- Table 9.3 shows the changes comparing the ‘prior’ and ‘final post ME2’ sector matrix totals;
- Figure 9.1 shows the corresponding sector plan.
- Additional output (including scatter plots and trip length distribution checks) is found in **Appendix C**.

An analysis of the output shows that the regression analysis guidance has been met with the exception of the R^2 value for AM cells, which is within rounding error tolerances. The mean trip length changes are well within the criteria. The total matrix change are each within 1% and individual sector changes are generally less than the recommended 5%, with the exception of only a few sectors which are all within 10%, and only marginally higher than 5%.

Table 9.1 - Matrix Estimation (Prior vs Post ME2 matrix) Regression Analysis Summary

Measure	Cells							Trips Ends						
	Criteria	AM		IP		PM		Criteria	AM		IP		PM	
Intercept	near 0	0.005	✓	0.005	✓	0.004	✓	near 0	5.886	✓	3.267	✓	3.483	✓
Slope	0.98<X<1.02	0.98	✓	0.98	✓	0.97	×	0.99<X<1.01	0.99	✓	0.99	✓	0.98	✓
R^2	>0.95	0.947	×	0.960	✓	0.960	✓	>0.98	0.989	✓	0.996	✓	0.993	✓

Table 9.2 - Matrix Estimation (Prior vs Post ME2 matrix) Total Mean Trip Length

Time Period / Criteria	AM Peak			Inter Peak			PM Peak		
	Prior	Final	% Diff	Prior	Final	% Diff	Prior	Final	% Diff
Mean Distance (kms)	23,555	23,555	0.0%	23,467	23,472	0.0%	23,642	23,668	-0.1%
Standard Deviation	26,547	26,547	0.0%	26,432	26,433	0.0%	26,525	26,537	0.0%

Figure 9.1 - GBATS4M Sector Plan

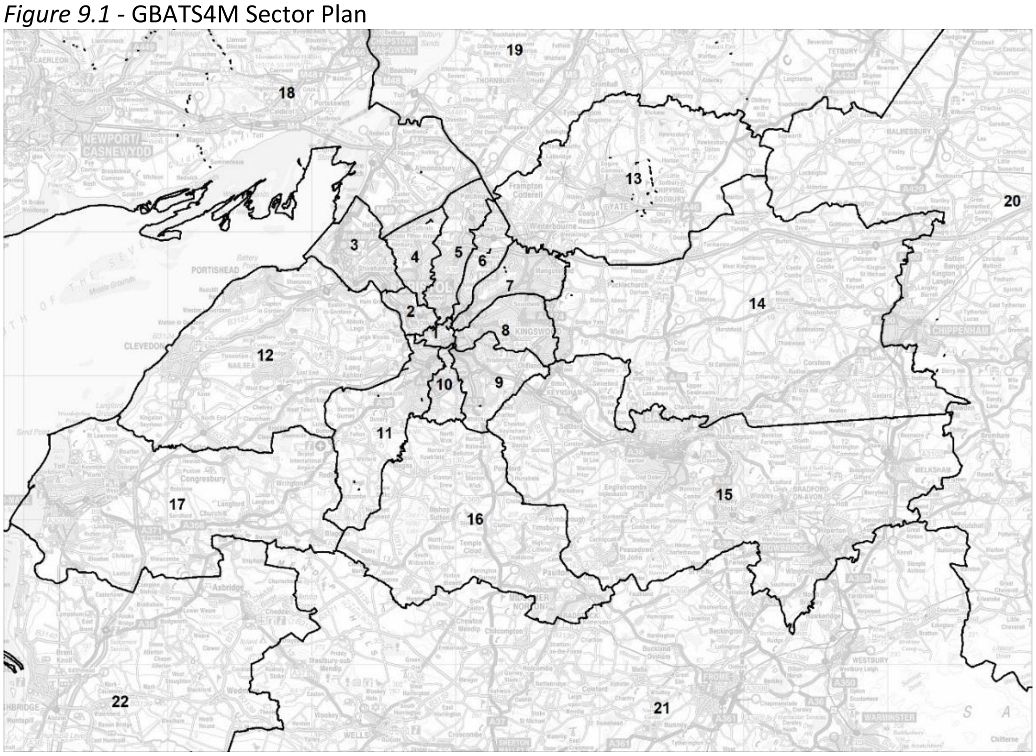


Table 9.3 - Matrix Estimation (Prior vs Post ME2 matrix) Sector Matrix Changes

Time / Sector	AM Peak			Inter Peak			PM Peak		
	Prior (2UC)	ME (6UC)	% Diff	Prior (2UC)	ME (6UC)	% Diff	Prior (2UC)	ME (6UC)	% Diff
1	5239	5211	-1%	6165	6242	1%	7858	7773	-1%
2	4829	4818	0%	4420	4500	2%	4959	4906	-1%
3	5247	5230	0%	4592	4641	1%	4789	4516	-6%
4	4827	4854	1%	5136	5206	1%	6104	5986	-2%
5	11939	12033	1%	10412	10578	2%	12343	12772	3%
6	3578	3589	0%	4708	4730	0%	7386	7182	-3%
7	10164	10169	0%	8316	8201	-1%	8057	8294	3%
8	13569	13499	-1%	10589	10762	2%	12398	12400	0%
9	8281	8274	0%	6536	6710	3%	8386	8622	3%
10	5091	5150	1%	4334	4469	3%	5265	5337	1%
11	7388	7241	-2%	6644	6862	3%	7956	7923	0%
12	8310	8456	2%	4861	5074	4%	7109	7183	1%
13	4833	4843	0%	3362	3390	1%	3612	3485	-3%
14	2935	2935	0%	1781	1806	1%	2152	2161	0%
15	3675	3698	1%	2542	2659	5%	3363	3535	5%
16	1091	1140	5%	1018	1057	4%	1319	1295	-2%
17	4360	4383	1%	3650	3782	4%	4511	4456	-1%
18	4990	4868	-2%	3673	3698	1%	3873	3876	0%
19	7044	7014	0%	4440	4512	2%	5487	5454	-1%
20	3679	3669	0%	3547	3395	-4%	3968	3994	1%
21	2055	2099	2%	1776	1789	1%	1747	1741	0%
22	2436	2457	1%	2581	2499	-3%	2383	2476	4%
Total	**125561**	**125630**	**0%**	**105084**	**106561**	**1%**	**125059**	**125406**	**0%**

9.4 Park and Ride Matrices

There are three park and ride sites in Bristol and each of the sites were surveyed. On bus origin-destination surveys were carried out at Brislington and Portway, Long Ashton was surveyed by BCC in 2013. This obtained OD data to provide both the car and bus leg of the journey. The car leg of the journey was added to the 'post-ME2' matrices for each of the sites.

9.5 Further Trip Matrix Segmentation

The models were developed, matrix estimation undertaken and calibrated using two-user classes. Further matrix segmentation was undertaken to include six user classes, detailed in Section 4. This segmentation was undertaken using income and purpose data obtained in the RSI surveys. The light vehicle user class was firstly split into 3 user classes using the percentage splits in Table 9.4.

Table 9.4 - RSI Light Vehicle User Class Splits

Purpose / Veh Type	AM	IP	PM
Car Non Business	78.6%	69.5%	84.8%
Car Business	8.6%	12.9%	5.1%
LGVs	12.7%	17.6%	10.1%

The Car Non Business trips were then split by income, on a sector basis to account for spatial variation. Table 9.5 shows the income split percentages by sector, based on the following criteria:

- Low (Less than £23,000)
- Medium (Between £23,000 and £46,000)
- High (More than £46,000)

Table 9.5 - RSI Light Vehicle User Class Splits

	Origin End - AM and IP			Destination End - PM			Sector	Origin End - AM and IP			Destination End - PM		
Sector	Low	Med	High	Low	Med	High		Low	Med	High	Low	Med	High
1	25%	42%	34%	28%	40%	32%	11	37%	47%	16%	35%	42%	22%
2	27%	44%	29%	27%	42%	31%	12	19%	43%	38%	32%	48%	20%
3	27%	42%	30%	55%	35%	10%	13	17%	43%	39%	15%	51%	34%
4	21%	46%	33%	38%	44%	18%	14	11%	18%	71%	27%	38%	36%
5	40%	37%	23%	31%	52%	17%	15	30%	41%	29%	19%	46%	35%
6	26%	40%	34%	36%	43%	21%	16	17%	59%	23%	15%	60%	26%
7	33%	43%	24%	31%	51%	18%	17	28%	46%	26%	28%	40%	31%
8	36%	45%	19%	37%	45%	18%	18	22%	36%	43%	19%	50%	31%
9	41%	42%	17%	29%	45%	26%	19	21%	32%	47%	31%	42%	27%
10	35%	53%	12%	35%	47%	19%	20	12%	42%	46%	21%	48%	31%

SECTION 10

Assignment Calibration and Validation

10.1 Overview

The final assignment was undertaken with the final (post ME) matrix and calibrated network, using the processes previously described. Validation checks were made on comparing model cruise time, traffic flow on links and net journey time. The output from the models, compared against observed data, is found in the following section. The final section presents results from model convergence.

10.2 Cruise Times

Output from the Trafficmaster™ journey time database was used to check the cruise time of the inter-peak model. The observed cruise time was estimated by calculating the lowest time (in 15 minute intervals) during the 7am to 7pm period. This was considered to be a reasonably accurate reflection of actual cruise time.

Inter peak model output is shown in Table 10.1. The location of the journey time routes is shown in Figure 5.4. A check of just one time period was undertaken since the coding of model speeds is consistent between time periods. Further this is not a TAG requirement but merely an additional model check to confirm appropriate generation of delays between links and junctions.

62% of modelled routes are within 5% of observed times. 82% of routes are within 10%. All routes are within 15%. The model is therefore considered sufficient to present an accurate representation of observed cruise speeds.

Table 10.1 – Inter-Peak Model Cruise Time Check

Route Description		Dist (km)	Cruise Time (mins)			Av Cruise Speed (kph)
			Obs	Model	% Diff	
1	A370 Inbound (Backwell to Ashton Gate)	9.6	8.1	9.1	12%	71
1	A370 Outbound (Jessop Underpass to Backwell)	9.5	8.6	8.9	4%	67
2	A38 Inbound (Barrow Gurney to Bedminster Bridge)	7.6	11.3	9.8	-13%	40
2	A38 Outbound (Bedminster Bridge to Barrow Gurney)	7.6	9.7	9.9	3%	47
3	A4 Inbound (Keynesham to Bath Bridge)	8.3	11.4	10.6	-6%	44
3	A4 Outbound (Bath Bridge to Keynesham)	8.3	10.4	10.3	-1%	48
4	A431 Inbound (Willsbridge to Old Market St)	9.2	14.6	14.7	1%	38
4	A431 Outbound (Old Market St Jct to Willsbridge)	9.6	13.7	15.3	12%	42
5	A38 Eastbound (Ashton Gate to Brislington)	8.0	12.4	12.6	1%	39
5	A38 Westbound (Brislington to Ashton Gate)	8.6	13.2	13.7	4%	39
6	A432 Inbound (A4174 Badminton Rbt to Old Market St)	9.4	15.2	16.3	8%	37
6	A432 Outbound (West St to A4174 Badminton Rbt)	9.4	15.4	15.7	2%	37
7	M32 Inbound (M32 J1 to Cabot Circus)	6.2	4.9	4.3	-11%	77
7	M32 Outbound (Cabot Circus to M32 J1)	6.0	3.8	3.6	-7%	94
8	A38 Inbound (M5 J16 to St James Barton Rbt)	10.3	16.3	17.0	4%	38
8	A38 Outbound (St James Barton Rbt to M5 J16)	10.3	16.6	16.7	0%	37
9	A4018 Inbound (M5 J17 Cribbs to Clifton Triangle)	8.2	12.3	11.9	-4%	40
9	A4018 Outbound (College Green to M5 J17 Cribbs)	8.2	12.5	12.7	1%	39
#	A4 Portway Inbound (Avonmouth to Hotwells)	9.8	10.8	10.8	0%	55
#	A4 Portway Outbound (Hotwells to Avonmouth)	9.7	9.8	9.6	-2%	59
#	A369 Inbound (Portishead to A4 Bristol Gate)	11.5	11.6	12.1	4%	59
#	A369 Outbound (A4 Bristol Gate to Portishead)	12.8	13.2	13.4	2%	58
#	A4174 Eastbound (Filton Rbt to A4)	17.1	17.3	17.1	-1%	59
#	A4174 Westbound (A4 to Filton Rbt)	17.1	17.6	16.6	-6%	58
#	City Centre Outer Loop (Clockwise)	9.3	17.2	17.0	-1%	32
#	City Centre Outer Loop (Anti-Clockwise)	8.1	14.5	13.9	-4%	34
#	City Centre Inner Loop (Clockwise)	7.0	13.8	14.0	1%	31
#	City Centre Inner Loop (Anti-Clockwise)	3.7	8.0	8.6	7%	28
#	M4 Mainline Eastbound (J22 to J18)	34.5	18.9	18.3	-3%	109
#	M4 Mainline Westbound (J18 to J22)	34.6	18.5	18.4	0%	112
#	M5 Mainline Northbound (J20 to M4)	24.1	14.2	12.7	-10%	102
#	M5 Mainline Southbound (M4 to J20)	24.2	14.0	12.5	-11%	103

	<5%	<10%	<15%
% All routes within x% of observed	62%	82%	100%

10.3 Traffic Flows

Tables 10.2 (AM), 10.3 (IP) and 10.4 (PM) present a summary of the link flow validation on all the cordons and screenlines. The location of the calibration and validation screenlines is shown in Figures 5.2 and 5.3. Detailed individual link outputs are found in **Appendix E**.

The flow validation criteria and acceptability guidelines (as specified in TAG M3.1, see Table 3.1) have been met for all screenline and cordon links in all modelled time periods for both calibration and validated links in relation to checks for "all vehicles". Additional checks have been undertaken for light vehicles (LVs), i.e. cars/LGVs. For LVs the traffic flow criteria has been met for both GEH values and DMRB flow criteria for calibration and validation screenlines for all time periods with the exception of validation screenlines in the AM and PM peaks, which are very close to the criteria, both with a value of 84%. When the model fit is considered as a whole this is deemed to be acceptable since the corresponding value against GEH criteria is 86% and 85% for each peak respectively and the value across all screenlines is 86% for both peaks. All (or nearly all) screenlines are within 5% of the observed data.

Figures 10.1 to 10.3 show the GEH values in graphical form. Note that GEH values have been assigned a negative value where model flow is lower than observed.

Table 10.2 – AM Peak Link Flow Validation Summary

Screenlines and Cordon	No. Links	% Links GEH (PCUs)		% links DMRB flow (PCUs)	Observed Total (PCUs)	Model vs Obs Total (PCUs)	Model vs Obs % Diff (PCUs)	% Links GEH (LVs)	% links DMRB Flow (LVs)
		<5	<7					<5	
Calibration total	163	88%	98%	88%	144,654	-1,614	-1%	87%	89%
Inner (In)	19	84%	95%	79%	14,232	384	3%	79%	84%
Inner (Out)	18	94%	100%	83%	10,975	94	1%	83%	94%
East (In)	8	88%	100%	88%	6,612	-142	-2%	75%	75%
East (Out)	8	100%	100%	100%	4,963	-142	-3%	100%	100%
NW Inner (In)	13	92%	100%	85%	13,434	-402	-3%	92%	92%
NW Inner (Out)	13	85%	92%	92%	12,330	238	2%	100%	100%
South (In)	11	91%	91%	82%	6,063	37	1%	91%	91%
South (Out)	11	82%	100%	91%	6,042	55	1%	82%	91%
River (WBSB)	16	81%	100%	81%	18,175	168	1%	75%	69%
River (EBNB)	16	88%	100%	94%	23,640	-869	-4%	88%	88%
RW (ALL)	30	87%	97%	93%	28,188	-1,035	-4%	90%	93%
Validation total	146	92%	98%	88%	119,970	-368	0%	86%	84%
Outer (In)	26	88%	100%	77%	25,522	-463	-2%	81%	73%
Outer (Out)	26	96%	96%	96%	19,660	-170	-1%	96%	88%
Middle (In)	30	93%	93%	87%	23,785	-386	-2%	87%	87%
Middle (Out)	30	90%	100%	90%	18,054	106	1%	87%	90%
NW Outer (In)	6	83%	100%	83%	10,937	730	7%	67%	50%
NW Outer (Out)	6	100%	100%	83%	11,634	-217	-2%	83%	100%
NE (In)	11	91%	100%	91%	4,889	-46	-1%	82%	91%
NE (Out)	11	100%	100%	100%	5,490	79	1%	91%	73%
All	**309**	**90%**	**98%**	**88%**	**264,624**	**-1,982**	**-1%**	**86%**	**86%**

Figure 10.1 - AM Peak Traffic Flow Validation and Calibration Screenlines

Table 10.3 – Inter Peak Link Flow Validation Summary

Screenlines and Cordon	No. Links observed	% Links GEH (PCUs)		% links DMRB Flow (PCUs)	Observed Total (PCUs)	Model vs Obs Total (PCUs)	Model vs Obs % Diff (PCUs)	% Links GEH (LVs)	% links DMRB Flow (LVs)
		<5	<7					<5	
Calibration Total	163	87%	96%	88%	122,397	-3,444	-3%	89%	93%
Inner (In)	19	79%	89%	79%	10,216	-496	-5%	79%	84%
Inner (Out)	18	78%	94%	83%	10,461	-253	-2%	83%	94%
East (In)	8	88%	88%	88%	5,053	-383	-8%	75%	88%
East (Out)	8	88%	100%	100%	5,456	-276	-5%	100%	100%
NW Inner (In)	13	92%	100%	92%	11,192	-185	-2%	100%	100%
NW Inner (Out)	13	100%	100%	100%	9,984	-126	-1%	100%	100%
South (In)	11	100%	100%	100%	5,655	30	1%	91%	91%
South (Out)	11	100%	100%	100%	5,703	47	1%	100%	100%
River (WBSB)	16	88%	88%	88%	17,279	-241	-1%	88%	94%
River (EBNB)	16	75%	100%	75%	17,640	-457	-3%	81%	81%
RW (ALL)	30	83%	97%	87%	23,759	-1,105	-5%	90%	93%
Validation Total	146	90%	99%	89%	93,005	-2,096	-2%	92%	93%
Outer (In)	26	100%	100%	92%	16,282	-856	-5%	100%	96%
Outer (Out)	26	92%	100%	88%	15,827	-356	-2%	92%	92%
Middle (In)	30	80%	97%	80%	17,425	-921	-5%	90%	93%
Middle (Out)	30	87%	100%	93%	17,360	-762	-4%	100%	100%
NW Outer (In)	6	83%	100%	100%	8,744	282	3%	83%	100%
NW Outer (Out)	6	67%	100%	83%	9,006	274	3%	100%	100%
NE (In)	11	100%	100%	91%	4,215	173	4%	73%	64%
NE (Out)	11	100%	100%	91%	4,147	71	2%	82%	91%
All	**309**	**88%**	**97%**	**89%**	**215,403**	**-5,540**	**-3%**	**91%**	**93%**

Figure 10.2 - Inter Peak Traffic Flow Validation and Calibration Screenlines

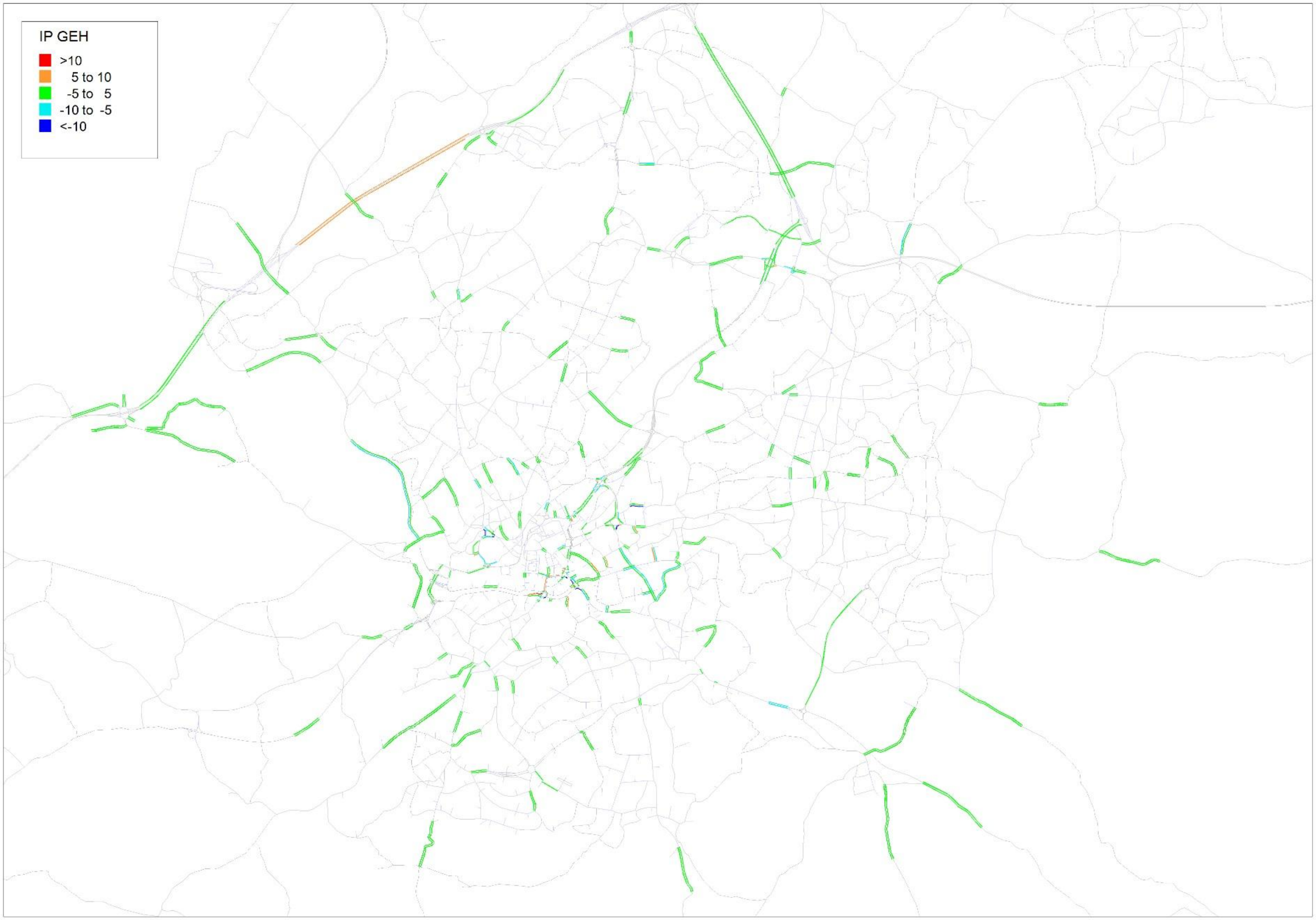


Table 10.4 – PM Peak Link Flow Validation Summary

Screenlines and Cordon	No. Links observed	% Links GEH (PCUs)		% links DMRB Flow (PCUs)	Observed Total (PCUs)	Model vs Obs Total (PCUs)	Model vs Obs % Diff (PCUs)	% Links GEH (LVs)	% links DMRB Flow (LVs)
		<5	<7					<5	
Calibration Total	163	85%	91%	88%	149,598	-311	0%	88%	88%
Inner (In)	19	84%	89%	89%	11,030	65	1%	84%	89%
Inner (Out)	18	67%	78%	78%	14,527	-263	-2%	72%	72%
East (In)	8	100%	100%	100%	5,342	-275	-5%	100%	100%
East (Out)	8	88%	100%	100%	7,917	-225	-3%	100%	100%
NW Inner (In)	13	85%	92%	85%	13,488	-544	-4%	85%	85%
NW Inner (Out)	13	92%	92%	77%	13,851	-254	-2%	92%	92%
South (In)	11	100%	100%	100%	6,321	32	1%	100%	100%
South (Out)	11	82%	82%	82%	6,835	403	6%	82%	73%
River (WBSB)	16	94%	100%	94%	22,218	753	3%	94%	94%
River (EBNB)	16	75%	81%	75%	19,778	455	2%	69%	75%
RW (ALL)	30	87%	97%	93%	28,291	-457	-2%	97%	97%
Validation Total	146	89%	97%	91%	123,001	-1,800	-1%	85%	84%
Outer (In)	26	96%	100%	92%	21,239	-316	-1%	85%	81%
Outer (Out)	26	88%	96%	88%	24,827	-533	-2%	85%	85%
Middle (In)	30	87%	100%	93%	19,779	-470	-2%	90%	90%
Middle (Out)	30	87%	87%	87%	23,123	140	1%	73%	73%
NW Outer (In)	6	67%	100%	83%	12,082	-522	-4%	83%	83%
NW Outer (Out)	6	100%	100%	100%	11,667	228	2%	83%	100%
NE (In)	11	91%	100%	100%	5,320	-189	-4%	91%	100%
NE (Out)	11	91%	100%	91%	4,964	-139	-3%	100%	82%
All	**309**	**87%**	**94%**	**89%**	**272,599**	**-2,111**	**-1%**	**86%**	**86%**

Figure 10.3 - PM Peak Traffic Flow Validation and Calibration Screenlines

10.4 Journey Times

All observed data is from October 2013 (excluding school half term), using output from the Trafficmaster™ journey time database, with the exception of Routes 1 & 2, where local roadworks in Barrow Gurney were underway, hence May 2013 data was utilised. The location of the routes is shown in Figure 5.4. Table 10.5 shows a good model fit to observed journey times in all time periods. **Appendix F** shows distance-time graphs.

Table 10.5 - GBATS4M Net Journey Time (mins) Validation

Route Description		AM Peak			Inter Peak			PM Peak		
		Obs	Model	% Diff	Obs	Model	% Diff	Obs	Model	% Diff
1	A370 Inbound (Backwell to Ashton Gate)	*10.1*	10.5	4%	10.8	9.5	-12%	*9.8*	9.7	-1%
1	A370 Outbound (Jessop Underpass to Backwell)	*9.7*	9.6	-1%	10.3	9.5	-7%	*10.2*	11.7	15%
2	A38 Inbound (Barrow Gurney to Bedminster Bridge)	*17.6*	15.6	-11%	18.2	16.2	-11%	*18.8*	17.3	-8%
2	A38 Outbound (Bedminster Bridge to Barrow Gurney)	*13.6*	14.0	3%	12.7	13.9	9%	*16.6*	18.0	9%
3	A4 Inbound (Keynesham to Bath Bridge)	30.9	26.5	-14%	15.1	16.1	7%	19.2	21.3	11%
3	A4 Outbound (Bath Bridge to Keynesham)	19.2	20.1	5%	14.4	14.9	4%	18.6	20.6	10%
4	A431 Inbound (Willsbridge to Old Market St)	30.7	33.5	9%	20.4	21.2	4%	22.8	22.6	-1%
4	A431 Outbound (Old Market St Jct to Willsbridge)	20.7	23.0	11%	20.9	22.4	7%	25.8	28.6	11%
5	A38 Eastbound (Ashton Gate to Brislington)	29.2	25.1	-14%	18.8	21.4	14%	26.1	29.6	14%
5	A38 Westbound (Brislington to Ashton Gate)	23.3	23.0	-1%	17.9	20.7	16%	21.8	24.6	13%
6	A432 Inbound (A4174 Badminton Rbt to Old Market St)	35.6	34.0	-4%	23.0	25.1	9%	23.6	26.0	10%
6	A432 Outbound (West St to A4174 Badminton Rbt)	26.3	28.8	9%	23.4	26.7	14%	26.0	25.7	-1%
7	M32 Inbound (M32 J1 to Cabot Circus)	13.1	12.5	-5%	5.1	5.7	11%	6.2	6.8	10%
7	M32 Outbound (Cabot Circus to M32 J1)	5.6	5.3	-6%	4.1	4.3	5%	4.8	4.2	-12%
8	A38 Inbound (M5 J16 to St James Barton Rbt)	33.6	36.2	8%	24.7	25.9	5%	30.4	31.2	2%
8	A38 Outbound (St James Barton Rbt to M5 J16)	32.2	31.2	-3%	24.9	24.8	-1%	35.3	29.9	-15%
9	A4018 Inbound (M5 J17 Cribbs to Clifton Triangle)	29.7	21.4	-28%	16.7	16.0	-4%	22.9	19.6	-14%
9	A4018 Outbound (College Green to M5 J17 Cribbs)	18.1	18.4	2%	16.3	17.5	7%	18.9	19.4	3%
10	A4 Portway Inbound (Avonmouth to Hotwells)	20.8	17.5	-16%	13.7	14.4	5%	18.3	18.8	3%
10	A4 Portway Outbound (Hotwells to Avonmouth)	12.0	12.6	5%	10.9	11.6	6%	11.9	12.3	3%
11	A369 Inbound (Portishead to A4 Bristol Gate)	24.2	21.8	-10%	13.2	14.9	13%	16.6	16.4	-1%
11	A369 Outbound (A4 Bristol Gate to Portishead)	16.7	17.6	5%	15.3	16.4	7%	19.0	19.8	4%
12	A4174 Eastbound (Filton Rbt to A4)	28.0	26.4	-5%	22.1	23.5	7%	31.5	27.3	-13%
12	A4174 Westbound (A4 to Filton Rbt)	31.7	36.2	14%	21.1	22.2	5%	26.1	25.3	-3%
14	City Centre Outer Loop (Clockwise)	35.5	34.5	-3%	24.0	27.3	14%	41.5	39.9	-4%
14	City Centre Outer Loop (Anti-Clockwise)	32.2	31.1	-4%	20.3	22.3	10%	32.4	37.6	16%
15	City Centre Inner Loop (Clockwise)	30.5	26.7	-12%	20.9	21.8	4%	29.4	29.1	-1%
15	City Centre Inner Loop (Anti-Clockwise)	19.4	19.5	0%	13.6	14.4	6%	17.9	20.0	11%
16	M4 Mainline Eastbound (J22 to J18)	28.0	24.4	-13%	19.6	19.8	1%	21.0	20.6	-2%
16	M4 Mainline Westbound (J18 to J22)	20.5	20.4	-1%	20.2	20.2	0%	20.9	20.4	-3%
17	M5 Mainline Northbound (J20 to M4)	14.4	14.2	-2%	14.8	13.7	-7%	17.5	14.0	-20%
17	M5 Mainline Southbound (M4 to J20)	14.9	13.4	-10%	14.5	13.3	-8%	14.9	14.0	-6%
% All routes within x% of observed		*10%*	*15%*	*20%*	*10%*	*15%*	*20%*	*10%*	*15%*	*20%*
		69%	**94%**	97%	72%	**97%**	100%	56%	**91%**	100%

10.5 Model Convergence

The convergence for each model period is summarised in Table 10.6 and shows that the three models have achieved TAG M3.1 proximity %GAP criteria (the first choice measure of assignment convergence, see section 3.2). The stability criteria is achieved, based on change in delay (used as a proxy for cost) but has not for flow change. TAG M3.1 states that the convergence criteria must be met for either flow or cost and hence overall the convergence criteria is met.

Table 10.6 - GBATS4M Convergence Summary

Measure		AM Peak		Inter Peak		PM Peak	
No. Loops till termination		16		20		44	
Final 4 Loops Mean	Gap %	0.08	✓	0.01	✓	0.05	✓
	% Flow change (P <1%)	91	×	96	×	96	×
	% Delay change (P2 <1%)	98	✓	100	✓	99	✓

10.6 Stress Test

After achieving a near-fully validated model a ‘stress test’ of the Base AM and PM models was undertaken by increasing the total numbers of trips in the matrices by 30% and reassigning. This revealed some minor network faults which previous checks had not detected. The changes were made and feed back into the iterative model development process.

SECTION 11
Conclusion

11.1 Overview

The model has been validated using the guidance, measures and criteria recommended in TAG M3.1. The following comparisons between modelled and observed data have been reported:

- Total flows for cordons and screenlines;
- Traffic Flows on individual links; and
- Journey times (both cruise and net) for a range of key routes.

The analysis shows that the three models meet the acceptability guidelines:

- Regarding matrix estimation changes;
- For traffic flows on links across the total cordon and screenlines and at the individual calibration, and independent validation sites; and
- For journey times.

All three models achieve acceptable levels of convergence and are stable based on delay/cost.

Stress test confirmed the network is fit for future year testing, in particular the MetroWest Phase 1 and 2 schemes.

Appendix A: Other Traffic Count Sites

Figure A1: Highways Agency TRADS Sites and Wider Area counts

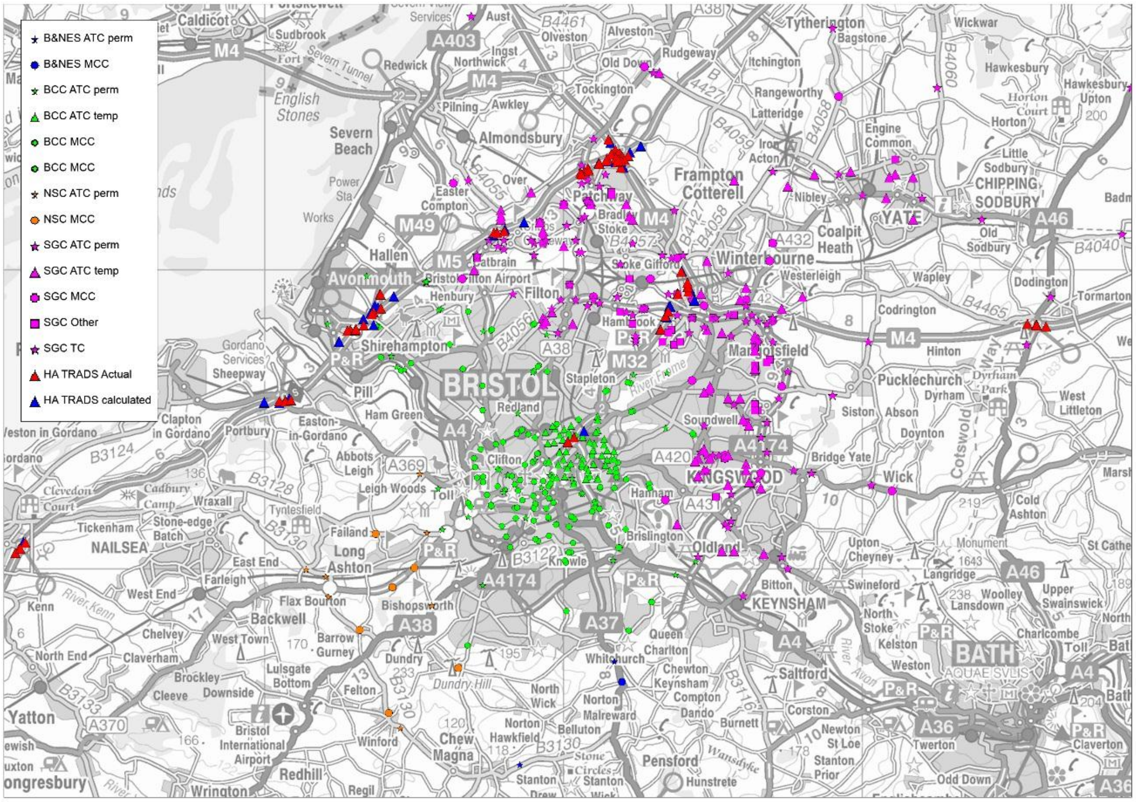
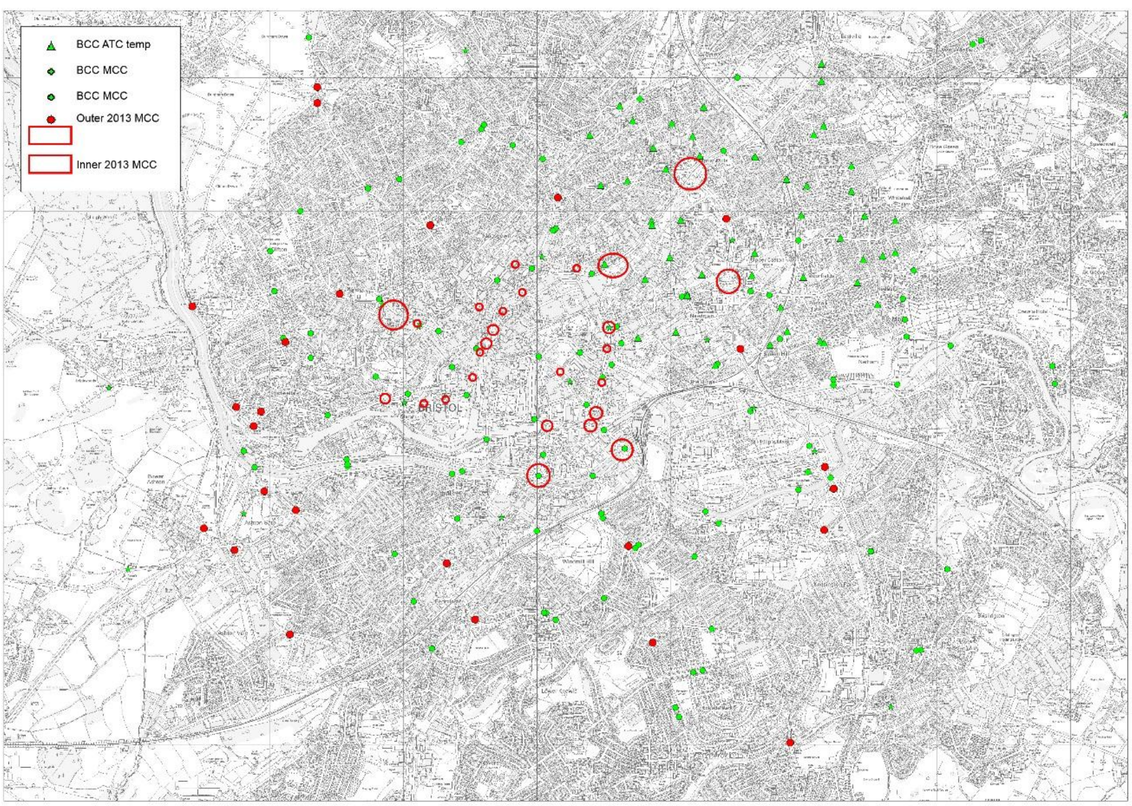


FIGURE A2
Central Area Count Sites



Appendix B: Network Coding Standards

Roundabouts

Roundabouts have entry and circulating saturation flows defined in the SATURN coding. The main factors determining the values of these are entry lane approach width / degree of flaring and the inscribed circle diameter.

TABLE B2

Roundabout saturation flows and GAP

Entry Arm Type	Mini	Small	Medium	Large	Very Large
Inscribed Diameter	~20m	~40m	~60m	~80m	~100m
Single Lane Narrow <3m, No Flare	900	950	1000	N/A	N/A
Single Lane Narrow <3m, Flare To 2 Lanes	1225	1325	1400	N/A	N/A
Single Lane Normal 3.5m, No Flare	1050	1075	1150	1200	1250
Single Lane Normal 3.5m, Flare To 2 Lanes	1475	1550	1625	1700	1800
Dual No Flare	N/A	2325	2400	2475	2525
Dual Flare To 3 Lanes	N/A	2725	2850	2950	3075

Entry Arm Type		Mini	Small	Medium	Large	Very Large
All Single	Cir	1950	2100	2500	N/A	N/A
	Gap	1.8	1.7	1.5	N/A	N/a
Mixed Single/Dual	Cir	N/A	2300	2650	3100	3300
	Gap	N/A	1.6	1.4	1.2	1.1
All Dual But No Flares To 3 Lanes	Cir	N/A	N/A	3550	4200	4500
	GAP	N/A	N/A	1.0	0.9	0.8
All Dual And Flared To 3 Lanes	Cir	N/A	N/A	3850	4500	4800
	GAP	N/A	N/A	0.9	0.8	0.8

Geometry	Mini	Small	Medium	Large	Very Large
Inscribed Diameter	~20m	~40m	~60m	~80m	~100m
Circulation Time (Seconds)	6	11	17	23	28

Signalised Junction Saturation flows

Signalised junctions typically have saturation flows per lane of between 1600 and 2050 depending on the lane width and the turn radii of left/right turns.

TABLE B1

Signalised junction saturation flows

Entry Arm Type	Left Turn	Straight	Right Turn
Single Lane Narrow <3m	1650	1900	1700
Single Lane Normal ~ 3.5m	1750	1950	1800
2 Lanes Narrow <6m	3500	3950	3600
2 Lanes Normal ~7m	3600	4100	3700
3lanes ~10m	N/A	6200	N/A

Priority Junctions

Unopposed Movements:

- Straight ahead 1700 to 1950;
- Left Turn 1650 to 1800;

TABLE B3

Priority junction saturation flows – opposed movements:

Visibility	Right Major	Left Minor	Straight Minor	Right Minor
Poor (<50m)	575	600	500	500
Average (50-120m)	615	625	575	575
Good (120-240m)	675	700	675	675

Gap acceptance at priority junctions is usually of the order of 1.5 to 2.5 seconds depending on the junction geometry.

EMME – SATURN Linkage for Bus Lanes

The coding of bus priority measures within the SATURN network needs to be accessed by EMME3 to ensure that travel time improvements from such measures are incorporated into the mode choice model. The coding of bus priority is based on the 'B-Code' method used in SATURN which allocates lanes on the main carriageway to exclusive bus usage. This method allows the bus lane to be allocated to either adjacent to the kerb or adjacent to the centre line.

Appendix C: Matrix Estimation Checks

FIGURE C1

AM Matrix Zonal Cells Scatterplot

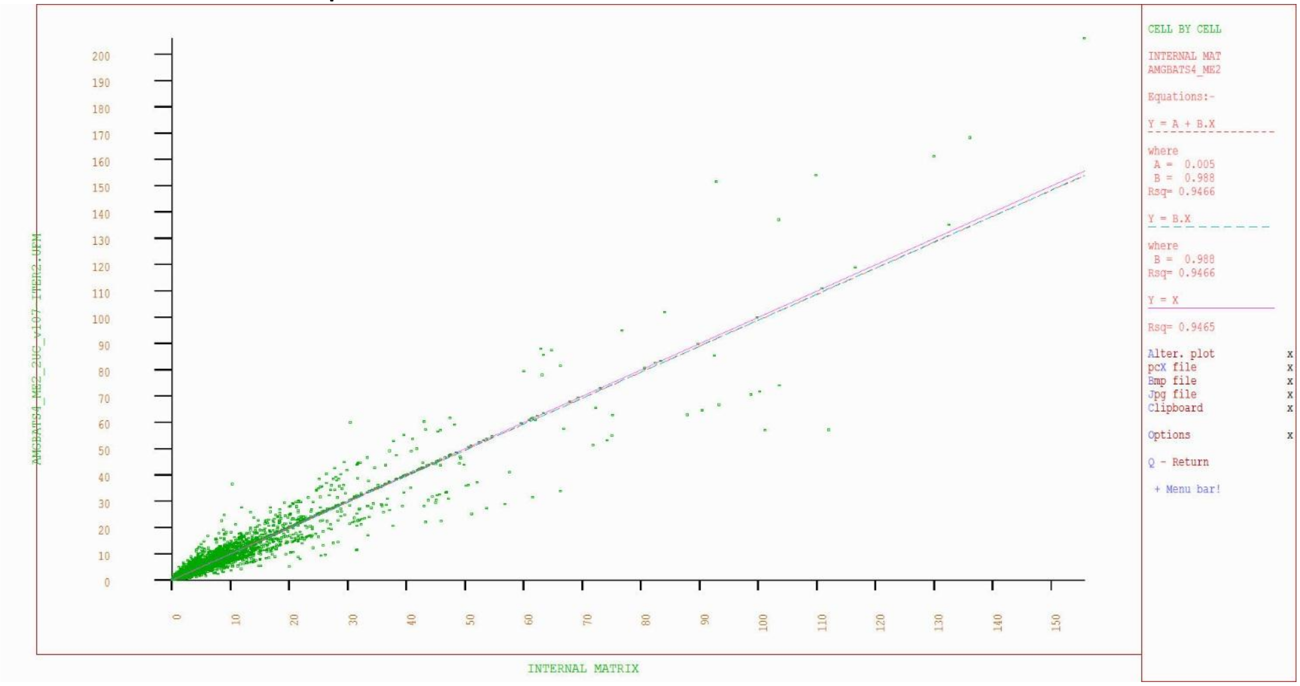


FIGURE C2

AM Matrix Zonal Trip Ends Scatterplot

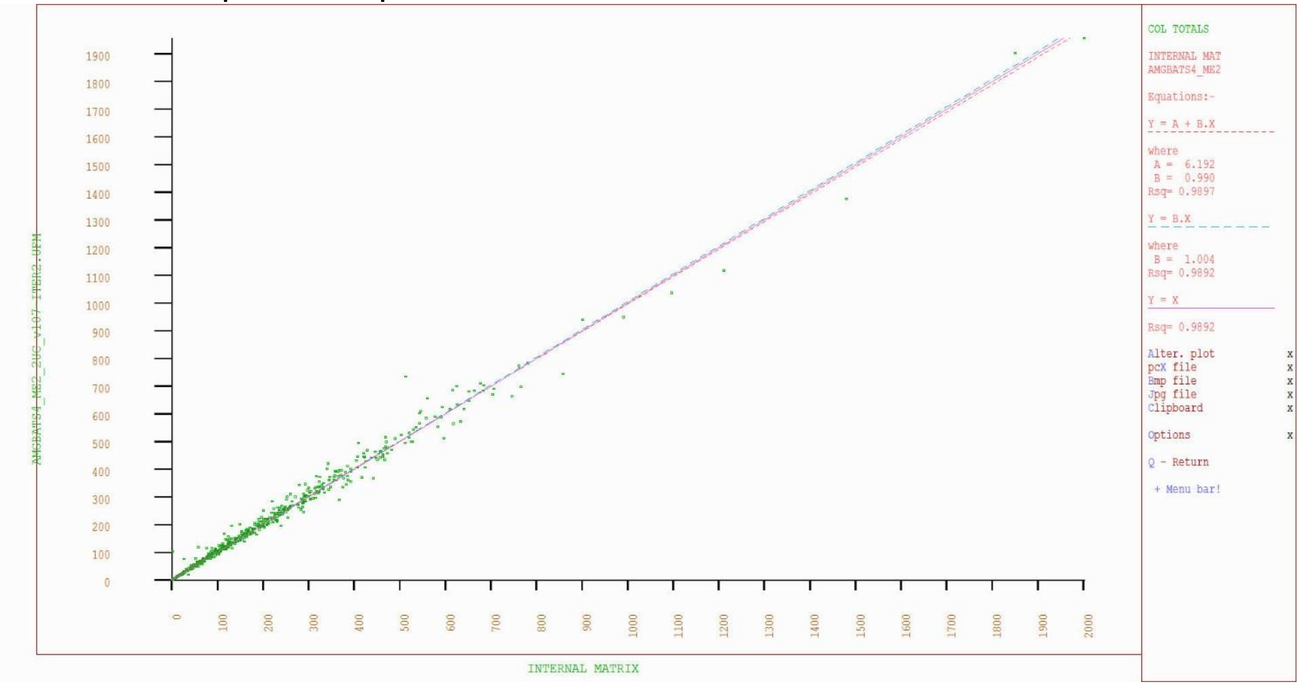


FIGURE C3

IP Matrix Zonal Cells Scatterplot

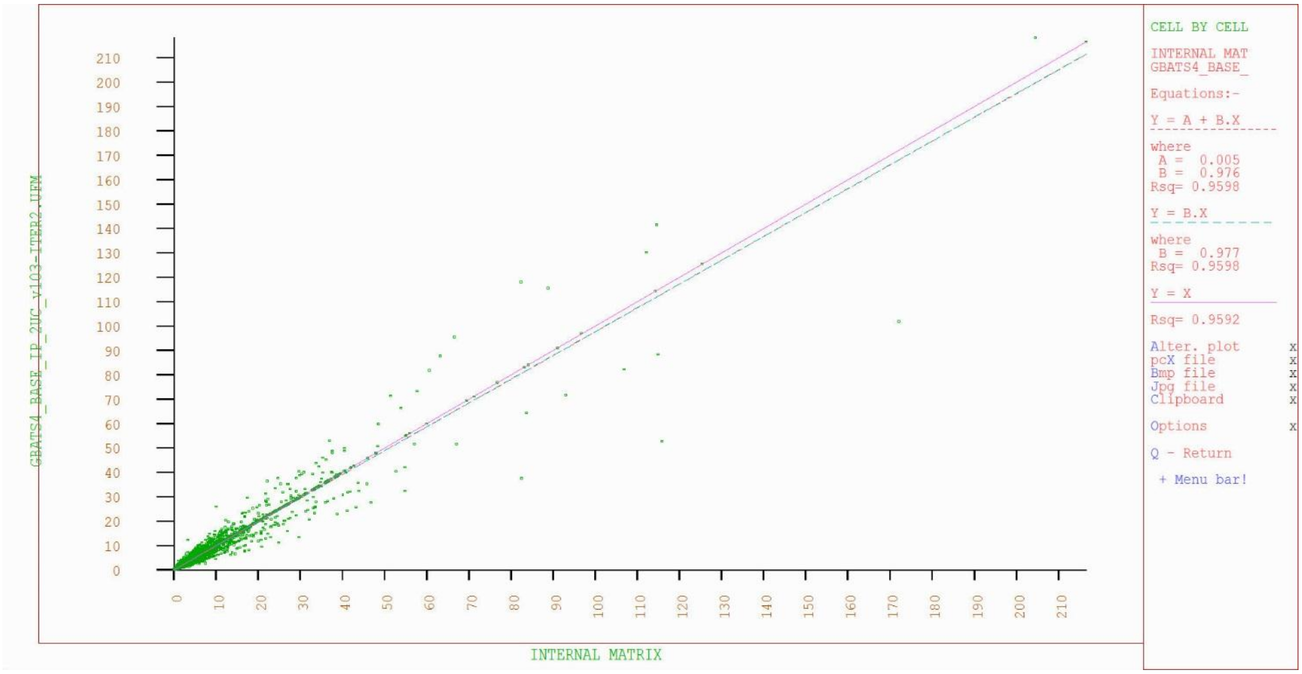


FIGURE C4

IP Matrix Zonal Trip Ends Scatterplot

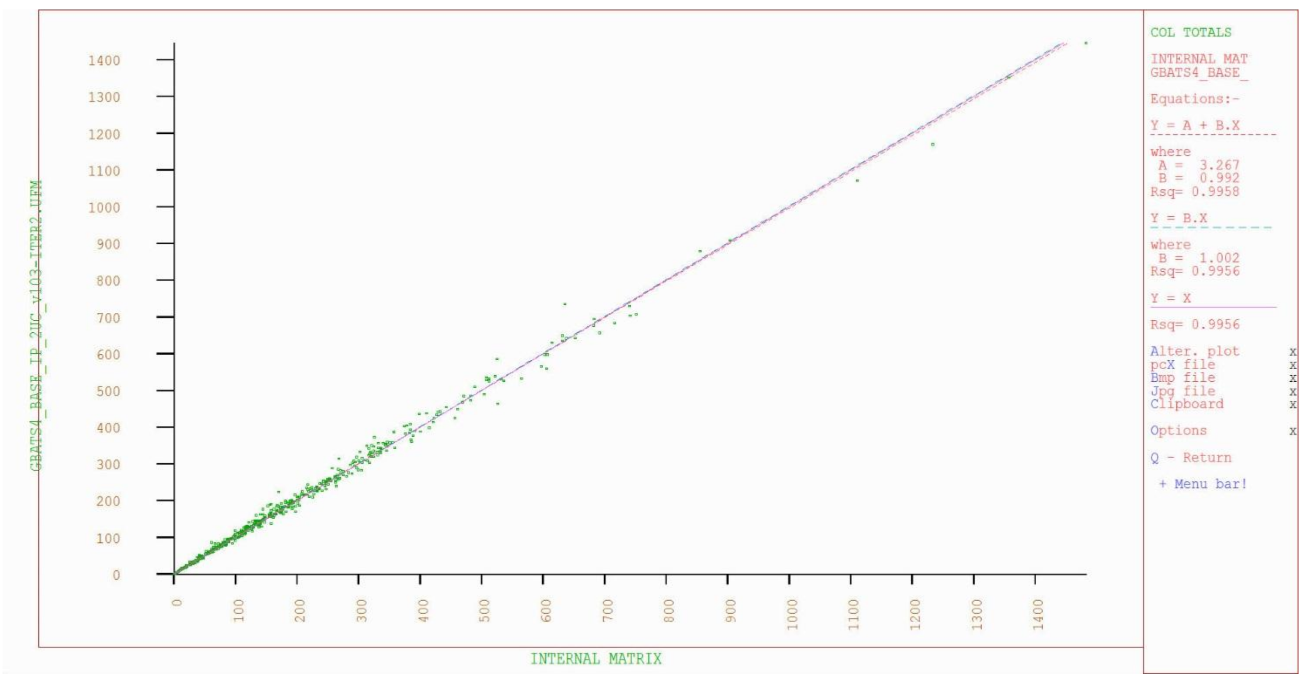


FIGURE C5

PM Matrix Zonal Cells Scatterplot

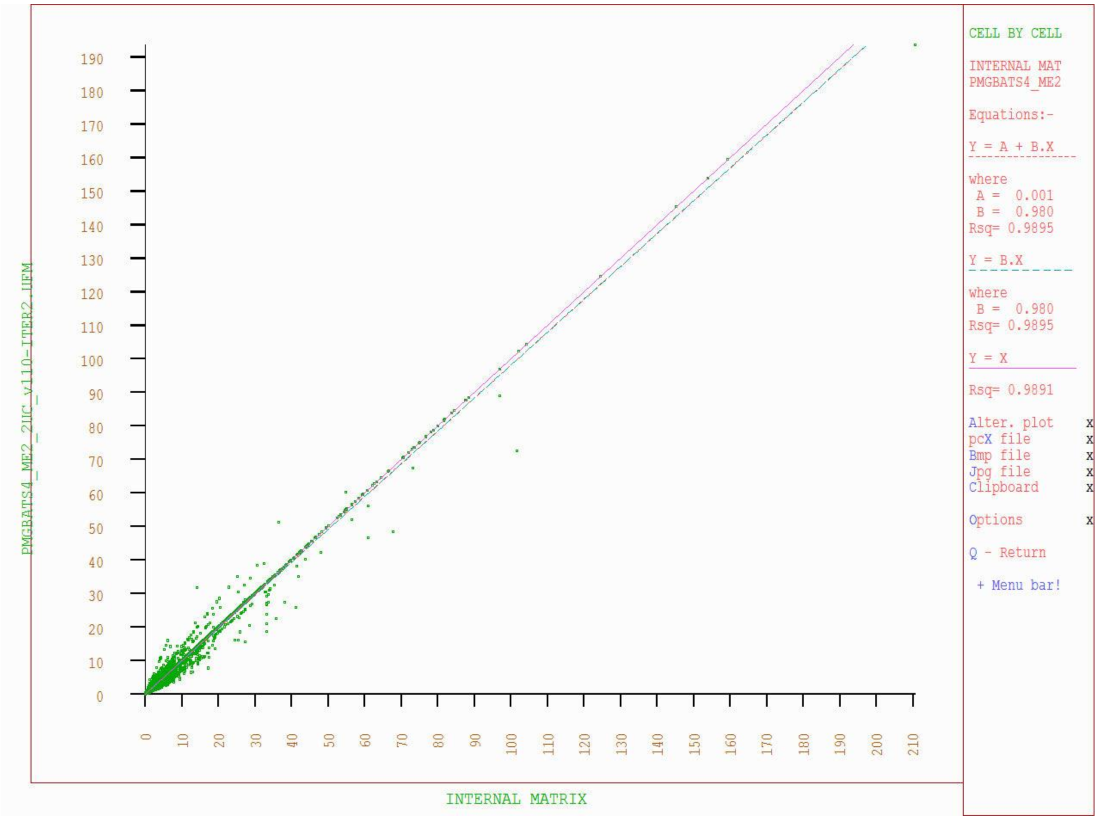


FIGURE C6

PM Matrix Zonal Trip Ends Scatterplot

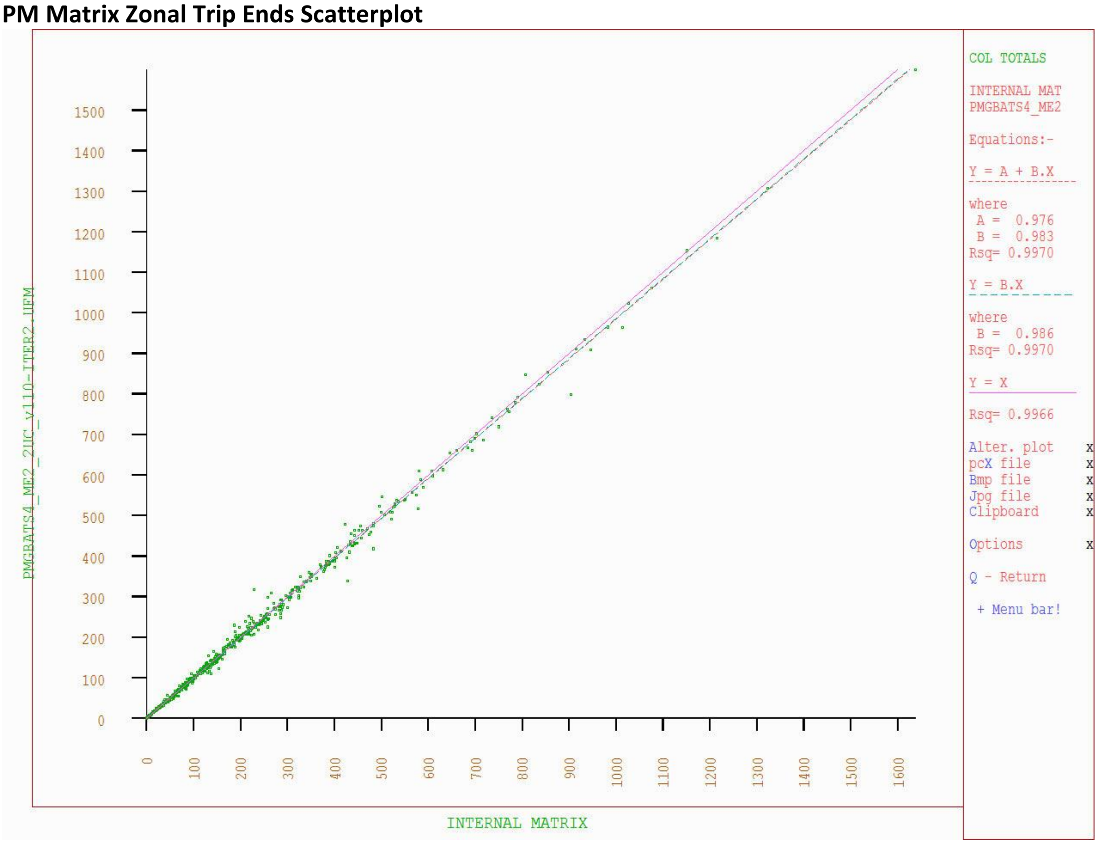


FIGURE C7
AM Trip Length Distribution

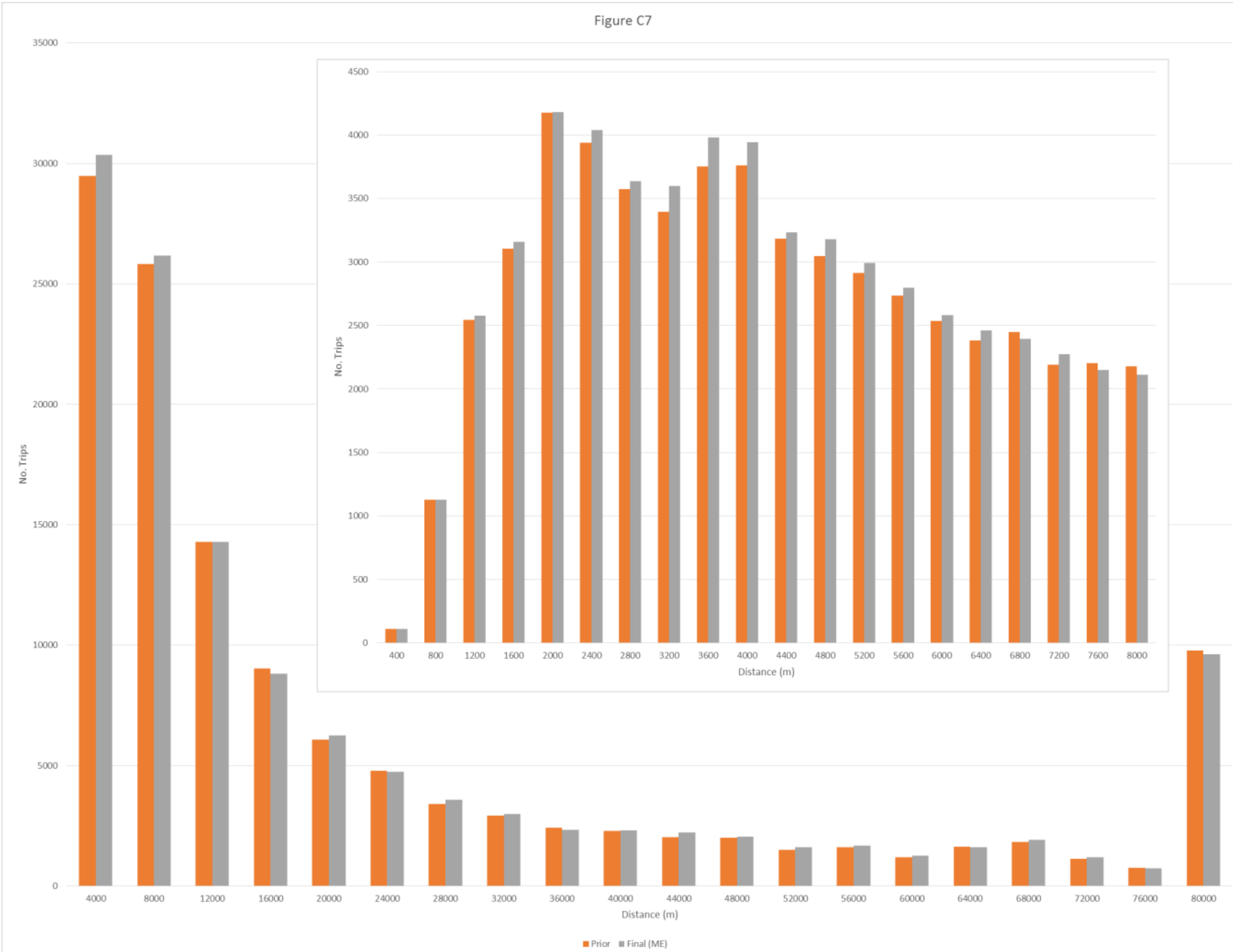


FIGURE C8
IP Trip Length Distribution

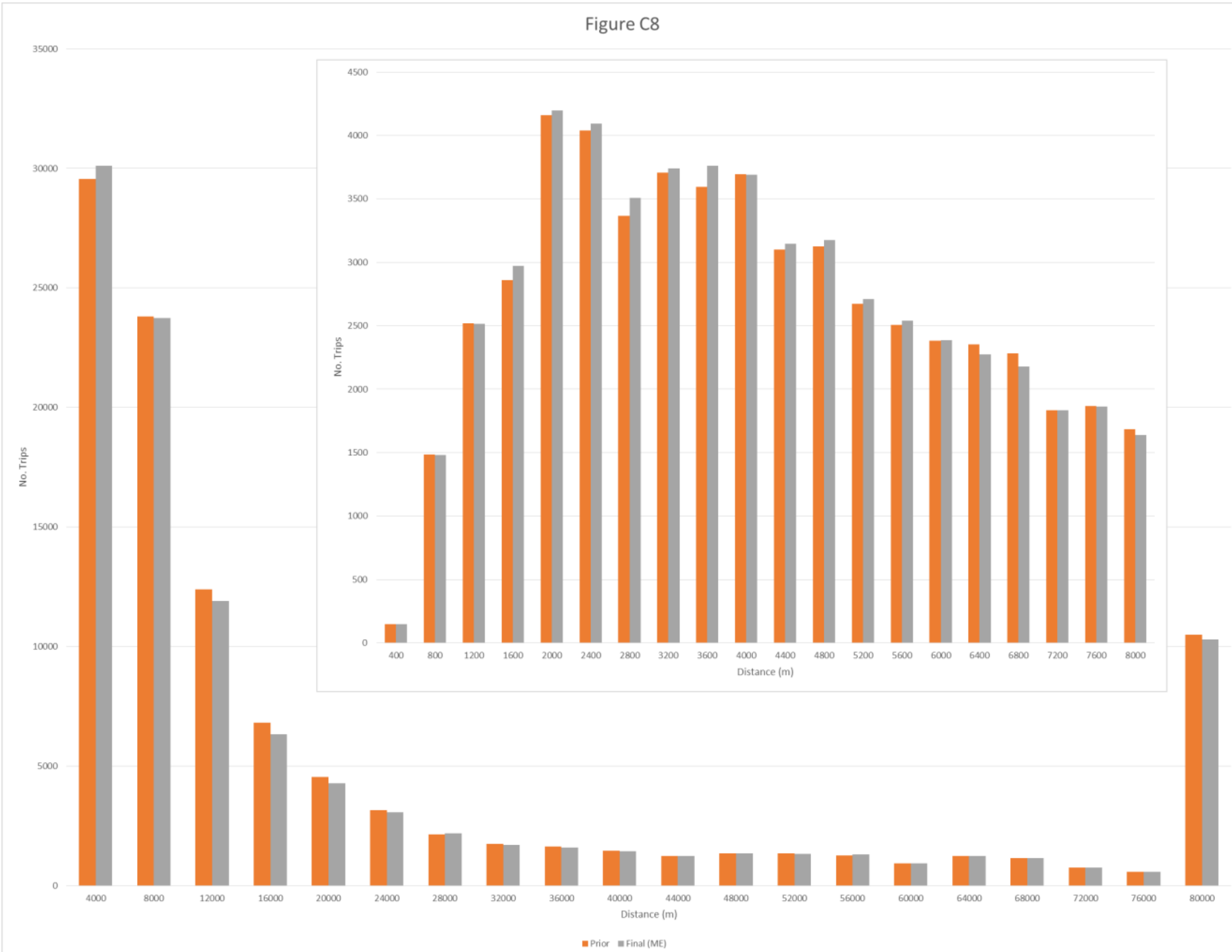


FIGURE C9

PM Trip Length Distribution