Welsh Government

M4 Corridor around Newport

Local Model Validation Report

9392

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Appendices

1 Introduction

1.1.1 The Welsh Government commissioned Arup in 2014 to update the transport model for the M4 Corridor around Newport (M4CaN) Scheme.

1.1.2 This transport model is used to understand current traffic conditions in the area, to provide evidence for the planning of changes to the transport network and to produce traffic forecasts that are used in the detailed economic, social and environment appraisal of proposed interventions in the transport system.

1.1.3 The data used in the update of the transport model, collected in spring and autumn 2014, was traffic counts, roadside interview data, public transport passenger surveys, bus and rail ticket data and anonymised location data from mobile phones. This data was used to build trip matrices, which show the origin and destination of highway and public transport trips in the area, for a typical weekday in May 2014. The description of the highway network was also updated to 2014 and the demand model re-calibrated to reflect the observed choices made in the area in 2014.

1.2 Report Structure

1.2.1 This report summarises the development of the May 2014 base year transport model and its subsequent validation, in accordance with the guidance set out in the Welsh Government's appraisal guidance WelTAG which in turn refers to modelling guidance provided by the Department for Transport's WebTAG.

1.2.2 Following this introduction, the report structure is as follows:

- Chapter 2 provides an overview of the study area and the modelling approach;
- Chapter 3 describes the data used in the model development;
- Chapter 4 provides an overview of the update of the highway network;
- Chapter 5 outlines the development of the highway trip matrices;
- Chapter 6 discusses the model's assignment methodology;
- Chapter 7 summarises the calibration of the updated model;
- Chapter 8 presents the results of the model validation process by comparing observed and modelled flows;
- Chapter 9 describes the public transport model;
- Chapter 10 outlines the realism testing required for variable demand modelling; and
- Chapter 11 contains concluding comments.

2 Model Overview

2.1 Model Requirements

2.1.1 The key requirement of the updated M4CaN Transport Model is that it represents accurately the base year traffic patterns on the road network and therefore forms a robust basis on which to forecast future year network conditions, both with and without changes to the transport network in the area. Given the major change in the network proposed by the construction of the new section of motorway south of Newport and the re-classification of the existing M4, the model forecasts captures a range of responses to these changes. This includes the re-routing of traffic, the switching of trips between highways and public transport and people making more or longer trips in response to lower congestion levels (induced traffic).

2.1.2 The transport model base and future year traffic flows and conditions play an important role in scheme assessment, environmental appraisal, highway and junction design and economic assessments.

2.2 Overall Model Structure

2.2.1 The main component of the updated M4CaN model is the highway model which provides a representation of the highway network within the study area, the traffic using it and the resulting traffic conditions.

2.2.2 A variable demand model (VDM) is also necessary for a scheme of the scale of the M4CaN. This is to ensure that changes in travel patterns in response to changes in travel costs that result from the scheme are taken into account in the scheme appraisal such as changes in travel mode used and/or a change in trip destination.

2.2.3 Given the emergence in recent years of the proposals for electrification of the rail mainline and the Metro in Cardiff, the update of the model's base year to 2014 provided the opportunity to add a public transport module. This would allow highway demand to respond to public transport changes, and is handled explicitly within the model. The separate public transport model which replicates bus and rail services that compete with the M4 and that interact with the highway model was built using 2014 data provided by the public transport operators and supplemented by survey data.

2.2.4 Travel costs from the highway and public transport models both feed into the VDM to enable changes in highway demand to be calculated. The changes in forecast demand produced by the VDM are then fed back into the highway model for a final assignment of the highway demand to the road network which produces the forecast of traffic flows on each link and conditions on the highway network.

2.2.5 The overall model structure is illustrated in Figure 2.1.

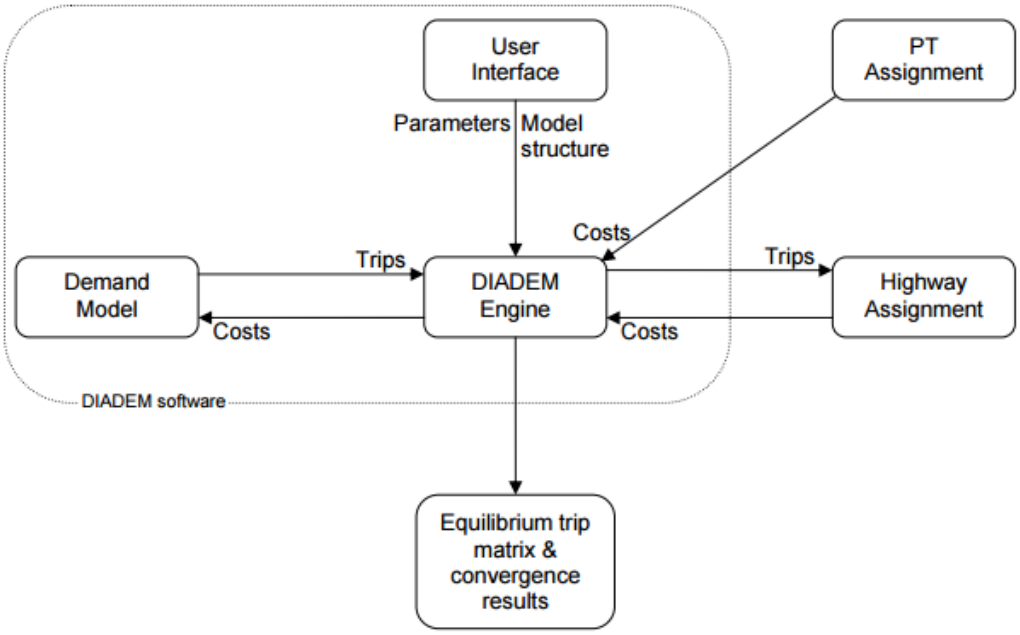

Figure 2.1 Overview of Transport Model Structure

2.3 Highway Model

2.3.1 The updated M4CaN model uses SATURN version 11.3.10 for the highway modelling of the M4CaN, which is a 'congested assignment' software suite that has been developed over a period of more than 30 years by the Institute for Transport Studies at the University of Leeds. It is widely used, both in this country and overseas, for the evaluation of all kinds of highway systems and proposals, and is recognised as an "industry standard" traffic assignment model that satisfies the requirements for modelling highway networks as set out in WelTAG/WebTAG[1].

2.3.2 The suite provides a combined traffic simulation and assignment model for the analysis of road proposals ranging from traffic management schemes over relatively localised networks to major infrastructure improvements. One of the key features of SATURN is its ability to simulate the operation of junctions in some detail, including the prediction of queues and delays, the effect of queues blocking back on adjacent junctions, and the influence of congestion at specific points in the network on route choice.

2.3.3 The basic inputs to the SATURN model are the transport demands, in the form of a matrix of trip movements between zones, and the 'supply' in the form of a detailed description of the road network. The highway modelling process is illustrated in Figure 2.2. Following the network building procedure, the trip matrix is assigned to the network

[1] Transport Analysis Guidance Unit M3.1, Highway Assignment Modelling, Department for Transport, January 2014

using an iterative series of loops between ‘assignment’ and ‘simulation’ until the model has converged.

2.3.4 The ‘assignment’ process calculates the minimum cost routes for trips in terms of a weighted combination of time and distance. The ‘simulation’ stage then simulates the operation of each junction in the network. It should be noted that as route costs can depend upon the routes taken by other vehicles, the junction simulations can lead to a different set of minimum cost routes. Thus, the process is repeated, until successive assignment-simulation loops produce an acceptably low level of change in vehicle flows, when the model is deemed to have achieved convergence.

2.3.5 Following the convergence of the model, the model is calibrated. The modelled number of vehicles on the network are compared with the observed counts. The description of the road network (supply) is checked carefully and a matrix estimation procedure is used to adjust the trip patterns in the trip matrices (demand) if required.

2.3.6 The final stage is to validate the model, in which comparisons are made between modelled flows and a separate and independent set of traffic count data that was not used in the calibration process. Modelled journey times are also compared with observed times.

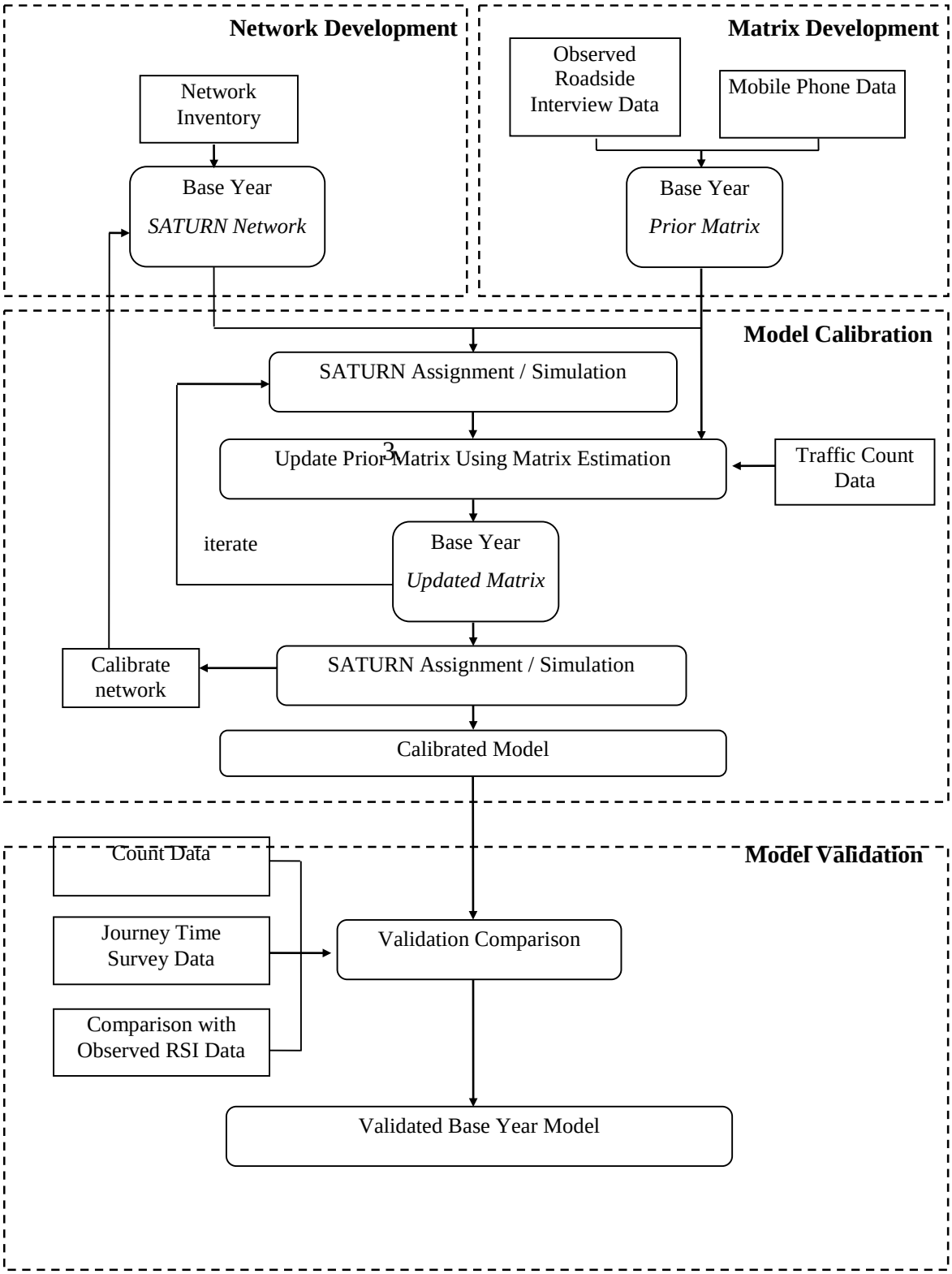

Figure 2.2 SATURN Highway Modelling Process

2.4 Public Transport Model

2.4.1 A base year public transport model was developed that provides information on bus and rail passenger trips, times and fares. A set of base year matrices was developed based on 2014 bus and rail passenger counts and surveys in the M4 corridor.

2.4.2 This data feeds into the VDM to enable mode choice modelling for movements where mode switch could have a material impact on highway flows and/or the transport benefits of the proposed new section of motorway south of Newport. Therefore the public transport model comprises passengers who are able to switch to car and who would travel in the M4 corridor if they switched. As such the public transport model covers:

- All rail journeys in the corridor Cardiff – Newport – Chepstow / Severn Tunnel
- All bus journeys between Newport and Cardiff.

2.4.3 The public transport network and assignment model was developed using version 4.1.4 of the specialist transport modelling software EMME.

2.4.4 EMME is a multi-modal travel demand forecasting software tool, produced by INRO, which can be used to assess traffic and public transport network performance. It has been used to model bus and rail trips for east-west movements that are in competition with the M4CaN. The basic inputs were matrices representing demand on these public transport services and a representation of the public transport network, including routes, locations of stops/stations, service frequency, journey time and fares.

2.4.5 The structure of the public transport model is shown in Figure 2.3.

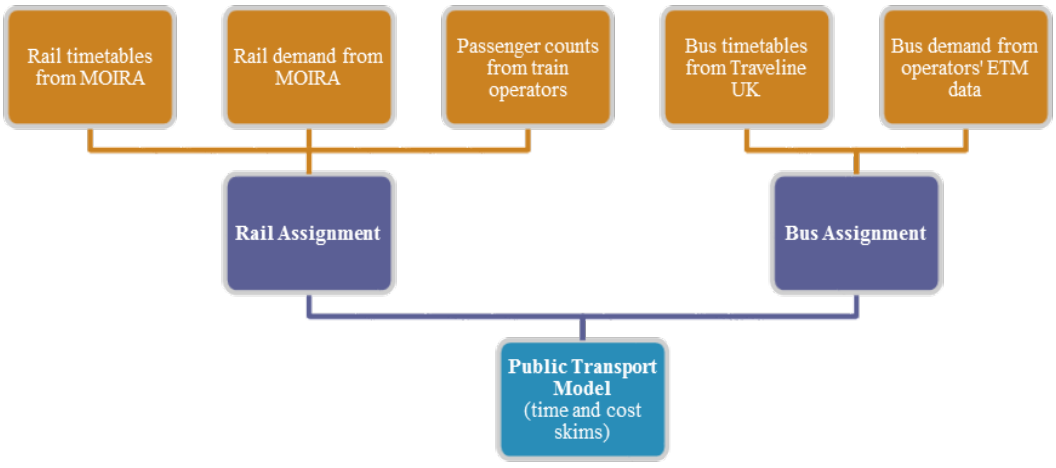

Figure 2.3 Structure of the Public Transport Model

2.5 Variable Demand Modelling

2.5.1 Transport schemes that have a significant impact on journey times and costs would, in principle, influence the level of demand for travel. The opening of a new scheme can elicit a number of responses by travellers including trip reassignment, re-timing, re-distribution and modal shift. These responses can result in additional trips and additional vehicle kilometreage on the road network, which collectively can be referred to as "induced traffic".

2.5.2 Conversely, in a 'Do-Minimum' scenario in which there is likely to be limited investment in new sections of highway capacity, the effects of forecast traffic growth and the subsequent increase in traffic congestion can lead to "trip suppression" which could manifest itself as peak spreading, modal switching to public transport, and/or a reduction in the number, length or frequency of journeys. These responses, as well as re-distribution, can lead to reduced vehicle kilometreage on the road network.

2.5.3 WebTAG[2] states that "the purpose of variable demand modelling is to predict and quantify these changes", and goes on to say that "there should be a presumption that the effects of variable demand on scheme benefits will be estimated quantitatively unless there is a compelling reason for not doing so".

2.5.4 WebTAG defines the following criteria required to justify not using variable demand modelling:

- *The scheme is quite modest either spatially or financially and is also quite modest in terms of its effect on travel costs. Schemes with a capital cost of less than £5 million can generally be considered as modest;*
- *There is no congestion or crowding on the network in the forecast year (10 to 15 years after opening), in the absence of the scheme;*
- *The scheme will have no appreciable effect on travel choices (e.g. mode choice or distribution) in the corridor(s) containing the scheme.*

2.5.5 The scale of the M4CaN Scheme is such that it is extremely likely current travel choices would change on the opening of the proposal which are likely to affect trip distribution and could impact on mode choice within the corridor. The Scheme is therefore considered to meet none of the criteria identified and therefore variable demand modelling has been incorporated in the model to allow for the proper assessment of the Scheme benefits.

2.5.6 The variable demand modelling was undertaken using the DIADEM software (version 5.0.9, 64-bit).

[2] Transport Analysis Guidance Unit M2, Variable Demand Modelling, Department for Transport, January 2014

2.6 Study Area

2.6.1 Four geographic areas have been defined for model zoning and network coverage comprising:

1. Area of Detailed Modelling
2. Rest of Fully Modelled Area
3. Wider Area of Influence
4. External Area

2.6.2 Figure 2.4 shows the first three modelled areas on a map base. The External Area comprises the rest of the UK outside these areas.

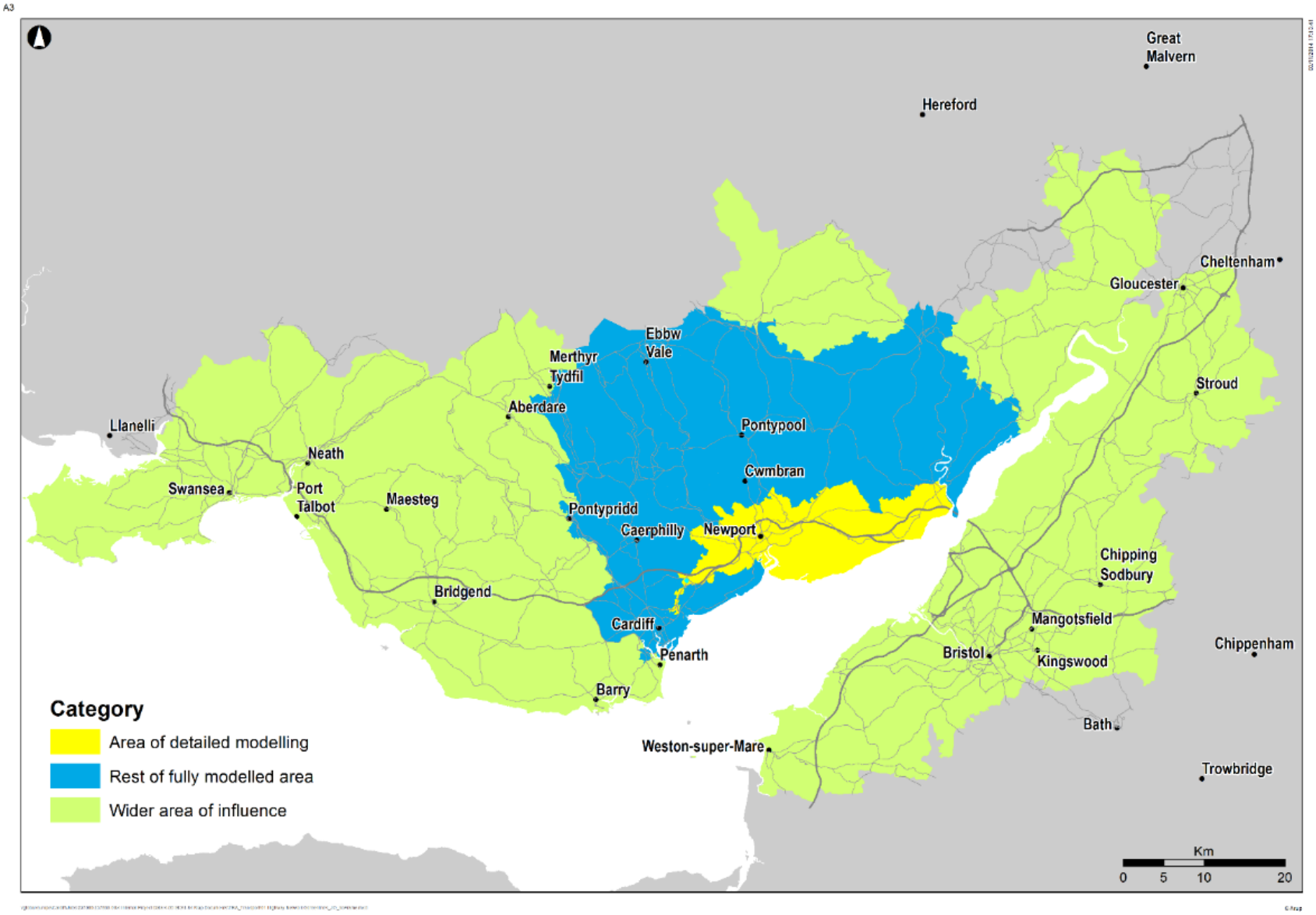

Figure 2.4 Model Coverage and Study Area

2.7 Model Time Periods

2.7.1 The variable demand model works on the basis of 24 hour trip productions and attractions, while the highway assignment model uses hourly trip origins and destinations covering the AM and PM peak hours and an average inter-peak hour, which is the standard recommended approach in WebTAG.

2.7.2 Based on the analysis of the traffic flow data the assignment model time periods are representative of the following:

- AM peak hour – 08:00 to 09:00;
- Inter-peak hour – Average hour between 10:00 and 16:00; and
- PM peak hour – 17:00 to 18:00.

2.7.3 For the peak period models, a pre-peak assignment was introduced, via the PASSQ function available within the SATURN software, as part of the calibration process. This enables any resultant queuing that may exist at the end of the pre-peak period to be passed through into the peak hour assignment. This helps to improve the route choice present within the assignment and the representation of journey times.

2.8 Demand Segmentation

Demand Segments for VDM

2.8.1 Different types of journeys are likely to display different characteristics in terms of trip distribution, mode sensitivity, travel time sensitivity and growth patterns. For this reason, car demand was split into the following three trip purposes:

- Employer's business;
- Commuting;
- Other purposes (including leisure, shopping and personal business trips).

2.8.2 Goods vehicles were separated into light goods vehicles (LGV) and heavy goods vehicles (HGV).

2.8.3 For the purposes of the VDM, 'home-based' trips (trips starting or ending at home) were modelled in a 24 hour production/attraction (P/A) format, as recommended by WebTAG. This was necessary in order to retain the link between outbound and return legs when calculating the resulting demand response of a return trip starting and ending at home. There was therefore a requirement to develop separate demand segments within each trip purpose, depending on whether the trips were 'home-based' (for trips starting or ending at home) or 'non-home-based' i.e. neither end of the trip being at home.

2.8.4 Long distance trips without at least one trip end located in the 'Area of Detailed Modelling' or Rest of Fully Modelled Area were also separated out in the demand model, as changes in travel costs are not fully modelled for these movements and they should therefore be treated as fixed within the VDM process.

2.8.5 The public transport demand was further split into 'car available' and 'no car available' to separate those trips that have the opportunity to switch to private car from those that do not have that opportunity. In this respect, 'No car available' trips are assumed to be captive to public transport. They are only included in the demand model to ensure that they are considered in the competition for trip ends in the doubly-constrained distribution model, which forms part of the variable demand model process.

2.8.6 The demand segments used in the variable demand model are specified in Table 2.1.

Table 2.1: Demand Segments in the Variable Demand Model

Demand Segment			Vehicle Type / Purpose
Highway	Public Transport		
	Car avail.	No car avail.	
1	1	11	Cars – Home-Based Employers' Business
2	2	12	Cars – Home-Based Others
3	3	13	Cars – Home-Based Work
4	N/A	N/A	Light Goods Vehicles (LGVs)
5	N/A	N/A	Heavy Goods Vehicles (HGVs)
6	6	14	Cars – Non-Home-Based Employers' Business,
7	7	15	Cars – Non-Home-Based Other
8	N/A	N/A	Cars – Employers' Business, Fixed
9	N/A	N/A	Cars – Other Purposes, Fixed
10	N/A	N/A	Cars – Commuting, Fixed

User Classes for Traffic Assignment

2.8.7 All demand matrices for the traffic assignment are required to be in origin-destination (O-D) format rather than the production/attraction (P/A) format used in the VDM. An O-D matrix stores trips according to the actual origin and destination zone of a trip. This information is needed so that the trips can be assigned onto the road network.

2.8.8 In the traffic assignments it is not necessary to retain the level of demand segmentation used in the VDM process. Instead, trip matrices for the traffic assignment are split into five different 'user classes'.

2.8.9 Table 2. lists the trip purposes and vehicle types that are used in the traffic assignment. Demand in the SATURN traffic assignment is expressed in terms of Passenger Car Units (PCU). The factors used to convert from vehicles to PCUs are also listed in the table below.

Table 2.2 Modelled User Classes in the Traffic Assignment

User Class	Vehicle Type / Purpose	PCU Factor
1	Cars – Employers' Business	1.0
2	Cars – Other Purposes	1.0
3	Cars – Work	1.0
4	Light Goods Vehicles (LGVs)	1.0
5	Heavy Goods Vehicles (HGVs)	2.5

3 Summary of Data Collection

3.1 Overview

3.1.1 The main source of data on trips made in the study area (demand) is that derived from mobile phone data that was collected across the Area of Detailed Modelling as shown earlier in Figure 2.4 in September 2014. This source of data was further supplemented by traffic and public transport data collected during spring and autumn 2014 respectively. Further details of the data collection exercise are given in the "Transport Surveys Report"[3].

3.1.2 This Chapter provides a summary of the data collection and a description of the existing sources of data that were used to develop the transport model for the M4CaN.

3.2 Existing Data Sources

Welsh Government Data

3.2.1 The Welsh Government continually monitors traffic flows across the trunk road network using a series of permanent Automatic Traffic Count (ATC) detectors. The ATC sites are located on all sections of the M4 and M48 and at frequent intervals on other trunk roads. ATC vehicle flows are presented by hour, by day, by month and in terms of Annual Average Daily Traffic (AADT) or Annual Average Weekday Traffic (AAWT) in each direction. This enables the profiles of traffic patterns to be analysed both over short and long term periods. Such information provides the data to factor traffic flows from one time period to another.

3.2.2 Traffic volume data was provided by the Welsh Government for all trunk roads (except the M4 motorway) within the area of detailed modelling, rest of the fully modelled area and the wider area of influence for that part within Wales. The ATC sites on the M4 motorway were largely destroyed during the major roadworks undertaken on the M4 within the study area during the period 2008-2011. Many of these sites remain out of commission or report limited data.

3.2.3 However, Traffic Wales operates the MIDAS (Motorway Incident Detection Automatic Signalling) system on behalf of the Welsh Government, which also monitors traffic volumes on each section of the M4. Comprehensive traffic volume and speed data for the M4 motorway in the study area were obtained from MIDAS.

[3] Transport Surveys Report, Arup, June 2015

3.2.4 As the ATC / MIDAS data provides the most reliable source of data for the average weekday, this information was used for validating the model on the different sections of the M4

Data from Local Authorities

3.2.5 Local authorities were contacted to obtain existing traffic count data for roads within their responsibility within the Rest of Fully Modelled Area, which was required for high-level calibration of the traffic volumes in this area. The format of the data varied in terms of period covered, duration, link or junction counts and whether they were classified or unclassified counts. Further details of how this data was used in the model development are given in Section 5.6 of this report.

Department for Transport Count Data

3.2.6 The 'street-level traffic data' which is available from the Department for Transport (DfT) website[4] has also been used to provide counts within the Rest of Fully Modelled Area. The DfT conducts one-day 12-hour counts each year at approximately 8,000 locations across the UK and then uses this as the basis for calculating AADT flows. This data was used in the creation of a synthetic demand matrix for the Rest of Fully Modelled Area.

TrafficMaster Data

3.2.7 TrafficMaster data was made available for the purposes of the model calibration / validation. TrafficMaster data consists of continuous GPS based data that is captured for a fleet of vehicles across the United Kingdom, indicating route and average speeds by waypoint. The data is provided in a processed state and linked to the Ordnance Survey's Integrated Transport Network (ITN).

3.2.8 In order to derive appropriate journey time data, the TrafficMaster dataset was interrogated to provide journey times along key routes within the Area of Detailed Modelling. Journey times along the strategic highway network within the Rest of Fully Modelled Area and the Wider Area of Influence were also checked.

3.2.9 The TrafficMaster journey time data was provided by ITN link for everyday between May and August 2014. The journey time analysis used the following data:

- link start time;
- journey time; and
- vehicle class.

[4] http://www.dft.gov.uk/traffic-counts/about.php

3.2.10 To facilitate the journey time validation, the data was processed into a SQL database which summarised information from all valid records into average speeds per link according to modelled time period. This enabled the cumulative journey time along the selected routes to be calculated.

3.2.11 The routes used to validate journey times through the highway model network are described in Section 8.4 of this report.

Base Year Freight Matrices

3.2.12 Base Year Freight Matrices (BYFM) are available from the DfT website[5]. The BYFM provide modelled road freight vehicle movements for a base year of 2006, produced by the BYFM study. The data consists of the number of vehicles per average day between each set of origin-destination zone pairs. Vehicles are split into three categories – articulated heavy vehicles, rigid heavy vehicles and vans.

3.2.13 A zone plan for the BYFM was obtained from the DfT and converted to the zoning system for the M4CaN transport model. Trips that are external to the study area were removed and factors from the DfT's National Transport Model (2006 to 2014) were applied to derive 2014 heavy goods vehicle volumes on the highway network around Newport.

Census Journey to Work Data

3.2.14 2011 Census journey to work statistics are available from the Office for National Statistics (ONS) website. The statistics represent the main mode used for journey to work (commute) movements for a typical day during the Census period. Data is given on the number of commuters between a set of origin-destination zone pairs and their mode of transport, namely private car (driver/passenger), bus, rail, walking or cycling.

3.2.15 The statistics were provided in Census Lower Super Output Area geographical definition. Population and employment data were used to disaggregate the data to the model zone areas.

Population Data

3.2.16 2011 Census usual resident population statistics are available from the ONS website. The statistics provide the number of people who permanently reside in each Census area. The statistics are available in Output Area geographical definition. Geographical coverage was used to disaggregate the data to the model zone areas.

[5] http://data.gov.uk/dataset/base-year-freight-matrices

Employment Data

3.2.17 Statistics from the 2013 Business Register and Employment Survey are available directly from ONS by a special licensing agreement. The statistics provide an estimate of employee and employment numbers in each Postcode area. The statistics have been processed in GIS to allocate employee and employment numbers within each of the model zones.

Bus Operator Ticket Data

3.2.18 Electronic Ticket Machine (ETM) data for the following bus routes were provided by Newport Bus and Cardiff Bus companies:

- Newport Bus Routes X30 and 30; and
- Cardiff Bus Route 30

3.2.19 The data provided information on the number of boarding passengers at each stage for each service, with some limited information on likely alighting zones for the cash fare journeys.

3.2.20 The boarding information for the reverse direction was used to distribute passengers alighting where:

- for the AM peak, the reverse PM peak was used;
- for the PM peak, the reverse of the AM peak was used; and
- for the inter-peak, the reverse of the inter-peak was used.

3.2.21 The resulting information was converted into a stop to stop matrix for use in the public transport model.

MOIRA Data

3.2.22 An 'All Wales' spring 2014 MOIRA[6] model was obtained from the Welsh Government/Association of Train Operating Companies (ATOC). MOIRA provides a database of annual journeys between train stations on the network. This data was used as the basis for the creation of a demand matrix for rail trips in the public transport model.

Rail Passenger Counts

3.2.23 Train passenger counts were provided by First Great Western, Arriva Trains Wales and Cross Country Trains. This data was used to split annual demand into demand by time period for the public transport model and to verify the modelled passenger volumes.

[6] MOIRA is the latest in a long line of demand models that were originally developed by the former British Rail Operational Research Division.

3.3 Data Collection

Mobile Phone Data

3.3.1 Mobile phone data was collected between 15 and 26 September 2014 to provide detailed information on movements within and through the Newport area during a typical weekday of a neutral month. The data collection was conducted by one of the Mobile Network Operators (MNO).

3.3.2 Figure 3.1 shows the area over which the mobile phone data was collected.

3.3.3 The data is derived through monitoring technical messages existing within the 2G, 3G and 4G networks, where the mobile phones are continuously connected to the network in order to provide service. From this it is possible to accurately locate each mobile device in space and time.

3.3.4 Each mobile device has a unique identifier which enabled the device to be tracked in terms of location, movement and speed. Each anonymised mobile device identifier was consistent throughout the two-week survey period to enable consistent tracking throughout the survey period.

Figure 3.1 Coverage of Mobile Phone Data Collection

3.3.5 The mobile device data was categorised into two forms:

- On-call (active) records, which are obtained from active connections to the network, due to activity on the mobile device such as phone calls, text messaging and internet activity. The location and time records generated by activity on the mobile are more spatially detailed.

- Off-call (passive) records, which are generated by passive connections into the network, when the mobile phone is inactive. The location and time records are generated at periodic intervals, or as the mobile moves from one group of cell towers to another. These records are less spatially detailed.

3.3.6 Each of the anonymous identifiers was tracked to give a sequence of events in space and time. This enables events such as 'movement' and 'stopped' to be identified, where 'stopped' consisted of at least 30 minutes in the same location. The data was also cleaned to remove duplicate events, where two mobiles travel in parallel for the entirety of their journey. It was assumed that only one person's trip was being traced and also that multiple people travelling in the same car would count as only one vehicular movement in any trip matrix. The events were examined to determine whether they were 'movement behaviour' or 'network flickering' between cells to achieve best signal strength.

3.3.7 From this, trip patterns were built up for each of the anonymous identifiers with start and end points and times identified. Trip matrices were then created by allocating model zones to the start and end points and time period.

3.3.8 The advantage of using mobile data to determine travel patterns within the study area is that, unlike Roadside Interview Surveys (RSIs), the data is unbiased in nature and has a large sample size. However, in order to generate events within the cellular network, a mobile must travel a minimum distance in order to trigger passive events or generate active events independently. Very short trips are therefore difficult to identify from mobile data and so all intra-zonal trips were removed from the matrices.

3.3.9 Demand matrices to represent travel within the study area from the mobile data were developed using algorithms that were created to determine mode of travel, vehicle type and journey purpose. The RSI, traffic count and land use data were used as supplements to the mobile phone data in order to determine these particular characteristics. The RSI data was also used to provide information on the start / end points of trips that travelled into or out of the mobile phone cordon.

Traffic Surveys

Roadside Interview Surveys

3.3.10 Roadside Interview Surveys (RSIs) were carried out at 27 locations on the strategic and local highway network around Newport, with two additional postcard/postal surveys at the Severn River Crossings. Figure 3.2 shows the locations of the roadside interview survey sites, which are listed in Table 3.1. The surveys were undertaken throughout a 12 hour period from 07:00 to 19:00.

3.3.11 Where possible, RSIs were undertaken in preference to postcard surveys, since these surveys capture data immediately and are not reliant on members of the public returning a questionnaire, which reduces the sample rates. Postcard surveys were undertaken only where it was deemed unsafe or impractical to interview drivers or during periods where traffic congestion became a significant issue.

3.3.12 A copy of the RSI and postcard questionnaire is given in Appendix A.

3.3.13 For the two Severn River Crossings, the safest way of undertaking surveys was through postcard questionnaires handed out at the toll plazas. In order to ensure that TAG customers were also surveyed, a separate postal questionnaire was issued with their monthly TAG statements.

Table 3.1 Roadside Interview Survey Locations

Site Ref	Location	Direction	Survey Type	Grid Reference		Date of Survey
				Easting	Northing	
1	M48 Severn Bridge	West	Postcard	356940	189572	25/06/2014
2	M4 Second Severn Crossing	West	Postcard	345699	187189	25/06/2014
3	M48 Jct 2, w/b on-slip	West	Interview	353342	191516	17/06/2014
4	M4 Jct 23A,e/b on-slip	East	Interview	342110	187891	17/06/2014
5	M4 Jct 23Aw/b on-slip	West	Interview	341797	187960	18/06/2014
6	A449 North of J24	South	Interview	337093	191105	19/06/2014, 25/06/2014[#]
7	A48 East of J24	West	Postcard	336684	189791	12/06/2014
8	A48 Newport SDR South of J24	North	Interview	335997	188931	11/06/2014
9	B4237 Chepstow Road West of J24	East	Interview	335417	189326	11/06/2014
10	M4 Jct 25, e/b on-slip	East	Interview	332407	189709	18/06/2014
11	A4042 Malpas Relief Road, North of M4	South	Interview	331248	191102	23/06/2014
12	A4042 Malpas Relief Road, South of M4	North	Interview	331235	189951	09/06/2014
13	A4051 Malpas Road, North of J26	South	Postcard	330335	189836	23/06/2014
14	A4051 Malpas Road, South of J26	North	Interview	330605	189522	09/06/2014
15	B4591 Glasllwch Crescent, NW of J27	South	Postcard	328319	187935	10/06/2014
16	B4591 Glasllwch Crescent, SE of J27	North	Postcard	328616	187730	24/06/2014
17	A467 Forge Road, North of J28	South	Postcard	328223	186029	10/06/2014, 26/06/2014[#]
18	A48 Cleppa Park, West of J28	North	Interview	328319	185423	02/06/2014
19	A48 Newport SDR, Maesglas	East	Interview	329951	185644	04/06/2014
20	B4237 Cardiff Rd, Maesglas	East	Interview	329738	186160	04/06/2014
21	M4 Junction 30 e/bon-slip	East	Interview	321952	183160	16/06/2014
22	A48/A4232 Pentwyn Link Road e/b on-slip	East	Interview	321784	181776	16/06/2014
23	B4245, Crick	North	Interview	350035	189960	12/06/2014
24	B4596 Newport Bridge* a) Chepstow Road b) Corporation Road c) Church Road	 West North West	Postcard	 331839 331690 331698	 188438 188264 188590	05/06/2014
25	B4237 George St Bridge	West	Postcard	331772	187616	03/06/2014
26	A48 Newport SDR Bridge	West	Postcard	332427	186882	03/06/2014
27	Bassaleg Road, East of M4	East	Interview	328990	187202	24/06/2014
28	A48 Berry Hill Farm, Castleton	West	Interview	326708	184242	02/06/2014
29	A40 West of Raglan	West	Interview	340915	207861	19/06/2014

***Undertaken as three separate postcard survey sites.**
[#]Repeat survey required.

A3

Figure 3.2 Roadside Interview Survey Locations

Classified Link Counts

3.3.14 Manual classified link counts at the locations of the RSI sites shown in Table 3.1 were undertaken on both the day of the origin-destination survey and a neutral day. This was done in order to provide a factor to adjust the origin-destination surveys to represent the flow for each vehicle class on a neutral day. These counts were undertaken for both the interview and non-interview direction.

3.3.15 The surveys covered a 12 hour period (07:00 – 19:00) with the vehicles classified as follows:

- Motorcycles;
- Cars;
- LGVs;
- OGV1;
- OGV2; and
- Buses & Coaches.

3.3.16 In addition, manual classified link counts were undertaken on the motorway links in the region. These were undertaken on a neutral day in May when RSI surveys were not occurring anywhere on the road network so as to not affect the neutrality of the counts. The locations of these additional counts are shown in Figure 3.3 and listed in Table 3.2.

Table 3.2 Manual Classified Link Counts

Ref	Location	Grid Reference		Date of Survey
		Easting	Northing	
L1	M48, between Junction 2 and M4 Junction 23	347810	189400	15/05/2014
L2	M4, between Junction 23a and Junction 24	339080	189240	15/05/2014
L3	M4, between Junction 24 and Junction 25	332680	189590	15/05/2014
L4	M4, between Junction 25a and Junction 26	330830	189820	15/05/2014
L5	M4, between Junction 26 and Junction 27	328600	188280	15/05/2014
L6	M4, between Junction 27 and Junction 28	328380	187350	15/05/2014
L7	M4, between Junction 28 and Junction 29	327140	184560	15/05/2014
L8	M4, between Junction 29 and Junction 30	324340	183930	15/05/2014
L9	A48(M), between M4 Jct 29 and Jct 29A (A48)	324880	183530	15/05/2014

Figure 3.3 Manual Classified Link Count Locations

Classified Junction Turning Counts

3.3.17 Manual classified junction turning counts were undertaken on a neutral day in May when origin-destination surveys were not occurring anywhere on the road network, so as not to affect the neutrality of the count. These surveys covered a 12 hour period (07:00 – 19:00) and were classified as detailed in Section 3.3.2.2. Figure 3.4 and Figure 3.5 show the locations of the manual classified junction turning counts, which are listed in Table 3.3.

Table 3.3 Manual Classified Junction Turning Counts

Site No.	Location	Grid Reference		Date of Survey
		Easting	Northing	
J1	Junction 28 roundabout, Tredegar Park	328379	185778	13/05/2014
J2	A48 / B4237 roundabout, Pont Ebbw	329316	185926	13/05/2014
J3	Junction 26 roundabout, Malpas	330498	189607	13/05/2014
J4	Junction 24 roundabout, Coldra	336023	189634	13/05/2014
J5	A467/A468 roundabout, Bassaleg	327827	186827	13/05/2014
J6	A48 Southern Distributor Road / Nash Road	333976	186706	13/05/2014
J7	A48 Southern Distributor Road / Queensway Meadows	334262	186835	13/05/2014
J8	Junction 23A roundabout, Magor	341961	187910	13/05/2014
J9	B4245 eastern junction with A4810 slips (roundabout)	341941	187603	13/05/2014
J10	B4245 western junction with A4810 slips	341758	187752	13/05/2014
J11	A4042 / A4051 roundabout, south of Cwmbran	330151	191915	13/05/2014
J12	A48 / Southern Way, Cardiff	320567	179329	13/05/2014
J13	A48 / Pentwyn, Cardiff	321041	180937	13/05/2014
J14	A48 / A4232 Pentwyn Link Rd, Cardiff	321699	181687	13/05/2014
J15	Junction 30 roundabout, Cardiff Gate	321826	183125	13/05/2014
J16	A48 / Cypress Drive, St Mellons	323841	181980	13/05/2014
J17	A48 / Marshfield Rd, Castleton	325227	183426	13/05/2014
J18	A48 / Blacksmiths Way, Cleppa Park	327603	184494	13/05/2014
J19	A48 / Pencarn Way, Cleppa Park	328347	185209	13/05/2014
J20	A467/B4591 Rogerstone (dumbbell roundabouts)	327128	187925	15/05/2014
J21	B4591 Chartist Dr / Cefn Rd, Rogerstone	327238	188608	14/05/2014
J22	Bassaleg Rd / Park View, Rogerstone	328195	187188	14/05/2014
J23	Junction 27 roundabout, High Cross	328387	187833	14/05/2014
J24	B4591 / Fields Park Rd	329525	187841	14/05/2014
J25	B4591 / Bassaleg Rd	330122	187635	14/05/2014
J26	B4591 Stow Hill / Caerau Rd	330356	187574	14/05/2014
J27	Stow Hill / Friars Rd	330762	187563	14/05/2014
J28	B4237 Cardiff Rd / Gaer Rd / Retail Park	330049	186574	14/05/2014
J29	B4239 / Duffryn Drive	329462	185682	14/05/2014

Site No.	Location	Grid Reference		Date of Survey
		Easting	Northing	
J30	A48 Southern Distributor Road / Docks Way, Maesglas	330520	185892	14/05/2014
J31	A48 Southern Distributor Road / Alexandra Rd	331556	186204	14/05/2014
J32	A48 Southern Distributor Road / A4042 Usk Way	332209	186800	14/05/2014
J33	A4042 Usk Way / Lower Dock St	331839	187370	14/05/2014
J34	B4237 George St / Lower Dock St	331567	187562	14/05/2014
J35	B4237 George St / Commercial Rd	331363	187471	14/05/2014
J36	B4237 Cardiff Rd / Mendalgief Rd	330910	187081	14/05/2014
J37	A4042 Usk Way / Emlyn St	331493	187867	14/05/2014
J38	A4042 / B4591 Old Green roundabout	331140	188384	14/05/2014
J39	B4591 Queensway / Bridge St	330770	188115	14/05/2014
J40	B4591 Clytha Park Rd / Caerau Rd	330570	188060	14/05/2014
J41	A4042 Malpas Bypass / Llantarnam Bypass roundabout	330575	191997	13/05/2014
J42	Queens Hill / Barrack Hill	330894	188893	14/05/2014
J43	A4042 / Sainsbury's, Crindau	331130	189717	15/05/2014
J44	A4042 Malpas Bypass / Brynglas Tunnel Relief Rd	331254	190004	13/05/2014
J45	A4051 Malpas Road / Bettws Lane	330238	190108	15/05/2014
J46	Junction 25 roundabout, B4596	332249	189785	13/05/2014
J47	B4596 / Duckpool Rd	332013	188993	15/05/2014
J48	B4237 Chepstow Rd / Wharf Rd	332381	188320	15/05/2014
J49	B4237 George St / Corporation Rd	332097	187942	15/05/2014
J50	B4237 Chepstow Rd / Somerton Rd	333385	188140	15/05/2014
J51	B4237 Chepstow Rd / Aberthaw Rd	333728	188220	15/05/2014
J52	A48 Southern Distributor Road / Balfe Rd	334664	187645	15/05/2014
J53	A48 Southern Distributor Road / Ringland Crescent	335091	187902	15/05/2014
J54	B4237 / Royal Oak Hill / Llanwern Rd	335219	189124	15/05/2014
J55	A48 Southern Distributor Road / Beatty Rd	335941	189150	15/05/2014
J56	A48 / Hilton rbt, Langstone	336378	189816	15/05/2014
J57	A48 / B4245, Langstone	338184	190338	15/05/2014
J58	B4245 / Station Rd, Rogiet	345704	187971	15/05/2014
J59	B4245 / Newport Rd, Caldicot	347560	187875	15/05/2014
J60	A48 / B4245 Parkwall roundabout	350473	190520	15/05/2014
J61	A48 / A466 roundabout, Chepstow	352626	193102	13/05/2014
J62	M48 Junction 2 roundabout, Newhouse	353511	191541	13/05/2014
J63	A4042 / A4051 Harlequin roundabout	331009	188916	15/05/2014

3.3.18 In some cases, the RSI/postcard survey site could not be set up in the ideal location to capture all of the required traffic movements for safety reasons. In these instances, supplementary classified turning counts were undertaken at

adjacent junctions to provide data on the number of vehicles accessing the road system from developments that would be missed by the RSI/postcard survey. Table 3.4 shows the location and dates of these supplementary counts, which are also shown on Figure 3.4.

Table 3.4 Supplementary Manual Classified Junction Turning Counts

Ref,	Location	Grid Reference		Date of Survey
		Easting	Easting	
RJ16	B4591 Glasllwch Crescent / Western Avenue	328469	187760	15/05/2014
RJ20				
a	B4237 Cardiff Road / Park Drive (western)	329545	186033	15/05/2014
b	B4237 Cardiff Road / Park Drive (eastern)	329779	186202	15/05/2014

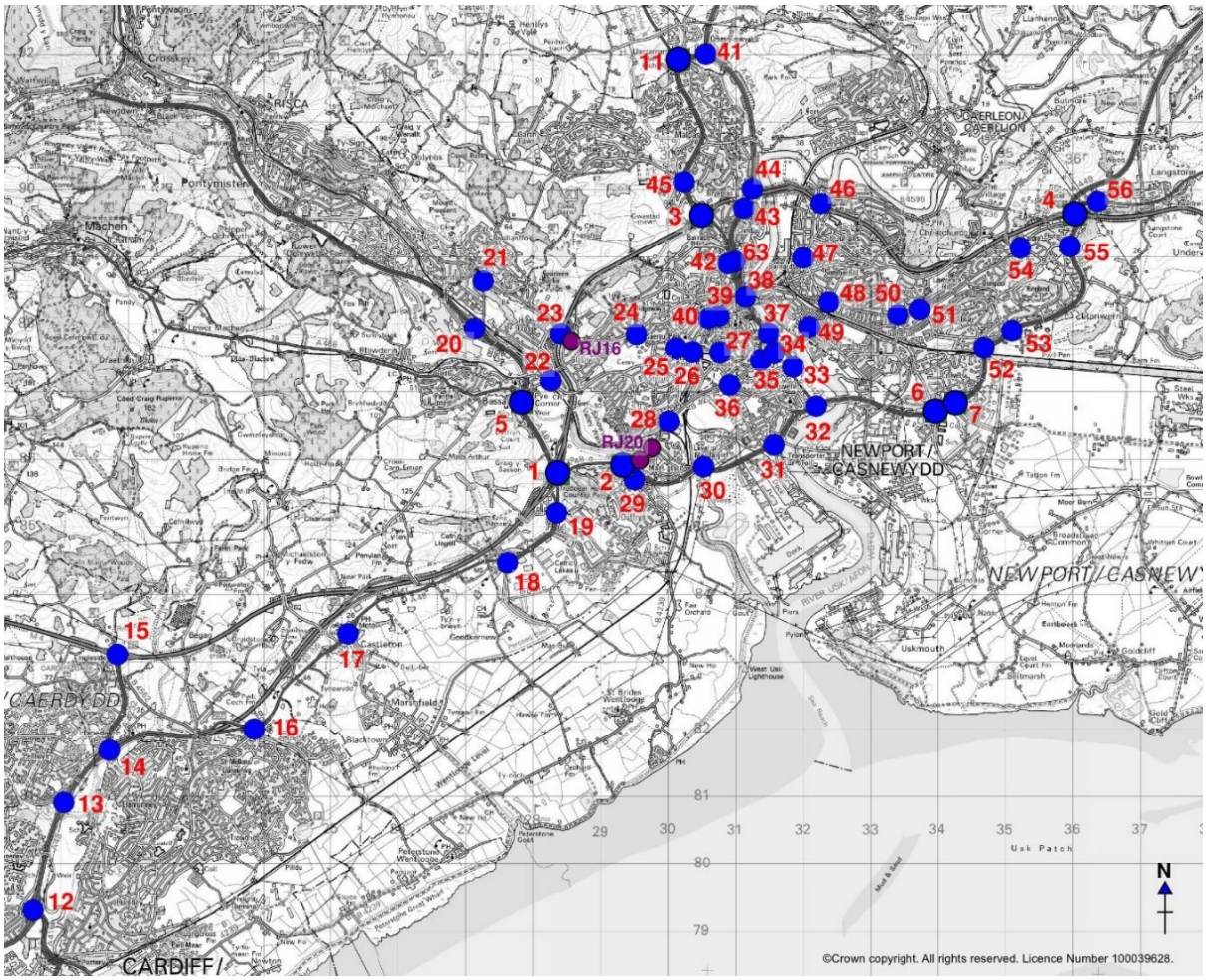

Figure 3.4 Manual Classified Junction Turning Counts – West Area

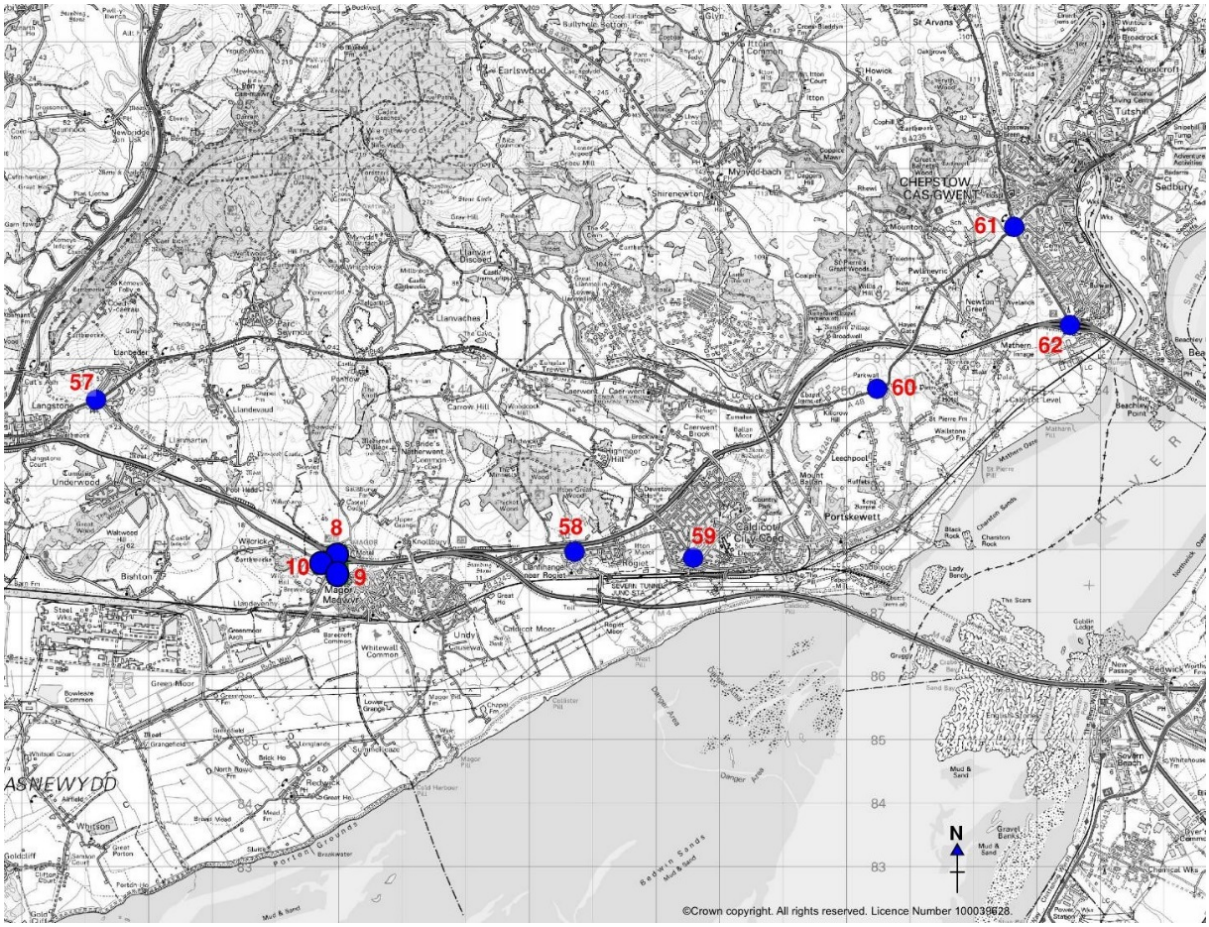

Figure 3.5 Manual Classified Junction Turning Counts – East Area

Automatic Traffic Counts

3.3.19 Automatic traffic counts (ATCs) were undertaken at the locations of the RSI sites shown in Table 3.1 in both the interview and non-interview direction. The exception to this was at the two Severn River Crossings and other, fast, dual carriageways where it was deemed unsafe to install the equipment. In these instances, data collected from nearby Welsh Government ATC sites was used instead.

3.3.20 The ATC survey programme ran continuously over a six-week period, from approximately 12 May to approximately 22 June 2014. The purpose of this was to capture traffic patterns before the RSI surveys commenced and during the RSI surveys. Data was not always collected continuously over this period at all sites due to some issues with the survey equipment, but this did not adversely affect the expansion of the RSI data to observed volumes.

3.3.21 The ATCs were split into 15 minute intervals and were classified so as to be compatible with the manual classified count vehicle categories, detailed in Section 3.3.2.2.

Public Transport Surveys

Bus Passenger Surveys

3.3.22 A survey of bus passengers was carried out on 7, 8 and 9 October 2014, between 11:00 and 19:00 on the following services:

- Cardiff Bus service 30; and
- Newport Bus services 30 and X30.

3.3.23 The survey was conducted through face-to-face interviews on buses with interviewers asking questions and entering passengers' responses into a mobile tablet. The survey collected 409 valid responses in total. Surveys were undertaken in the inter-peak and PM peak periods, but passengers were also asked about their outward journey earlier in the day to provide information on travel time and journey purpose patterns during the AM peak period.

Rail Passenger Surveys

3.3.24 The rail passenger survey was undertaken on 13, 14, 15 and 16 October 2014, between 06:30 and 19:30. The survey was conducted on train services provided by the following operators into and out of Cardiff Central and Newport stations:

- Arriva Train Wales;
- Great Western; and
- Cross Country.

3.3.25 The survey was conducted through face-to-face interviews on station platforms and on train, with interviewers asking questions and entering passengers' responses into a mobile tablet. The survey collected 761 valid responses in total.

3.4 Data Cleaning, Processing and Expansion

Traffic Counts

3.4.1 The traffic counts from the different data sources were combined into a single traffic count database. The following checks were undertaken on the manual and ATC data to ensure that:

- there were no periods with zero flows, or disproportionately high or low flows;
- the heaviest flows occur during the AM and PM peak periods;
- tidality of traffic flows was appropriate for that site; and
- the split between vehicle types was sensible, with cars being the highest, followed by LGV, OGV1 and OGV2.

Roadside Interview Data

3.4.2 Since RSI data only gives a sample of the traffic movements passing each surveyed location it was necessary to expand the survey records to reflect the full volume of traffic at each site. Traffic counts at the location of the RSI site as well as the raw RSI survey responses were used for this activity. A spreadsheet template was set up to ensure that the approach used in cleaning, processing and expanding the data from each site was consistent.

3.4.3 In the first instance it was necessary to undertake a rigorous checking and cleaning exercise of the RSI data in order to ensure that any illogical responses or erroneously recorded data were corrected or filtered out before any data expansion was undertaken. All processing of RSI data was logged and records that were manually edited were highlighted in the processing template for each site to ensure a full audit trail.

3.4.4 Further processing of RSI site records included the following steps:

- Look-up of coordinates based on origin and destination postcodes using Ordnance Survey's Code-Point data;
- Appending of zone labels to the origin and destination of each record using GIS;
- Categorisation of records by vehicle type and trip purpose in preparation for data expansion;
- Conversion of demand from vehicles to PCUs;
- Calculation and checking of expansion factors.

3.4.5 Manual classified counts (MCCs) collected on a neutral day were used to inform the split of vehicle types in data expansion. Automatic traffic counts (ATCs) collected in conjunction with each RSI site over a minimum two weeks were used to control the overall expansion of traffic volumes across the combined vehicle types.

3.4.6 Thorough checks were also undertaken on the count data to ensure that erroneous ATC or MCC data was filtered out before data expansion was undertaken.

3.4.7 This check was conducted by graphically comparing count data at each site between 07:00 and 19:00 from:

- The average ATC over the full data collection period (two to four weeks);
- The ATC of the day of the RSI;
- The MCC of the day of the RSI; and
- A MCC collected before the RSI data collection.

3.4.8 Separate graphical checks were undertaken to compare the individual weeks of data from the ATC to the overall average. This helped identify days that potentially contained incorrect data.

3.4.9 The types of inaccuracies encountered in some counts were:

- Data could on occasion be affected by excessive queuing across the ATC counter caused by the stopping of traffic as part of the RSI or other traffic incidents in the area, which resulted in count data being lower than on a typical day;
- Days with partially incomplete data due to damaged equipment or storage capacity being reached, which leads to hours or days containing no data at all;
- Swapped directional labels, which could be identified by a check of tidality of flows.

3.4.10 Hours in which there was erroneous or partial count data were always excluded from the analysis in order to avoid skewing the average count data used for expansion. In the interest of achieving the highest possible sample of trips and hence the lowest possible expansion rates for the RSI records, an attempt was always made to salvage records instead of discarding them in the first instance. For example, on RSI records where it was evident that origin and destination had been swapped, these were reversed and the records included in the subsequent processing.

3.4.11 The output from the RSI processing was a set of peak period matrices covering the AM, inter-peak and PM peaks and split by demand segments for each RSI site. Interview and non-interview direction matrices were created separately. The time of travel for non-interview direction trips was informed by the respondent's specified return time. Where a return time was not specified AM outbound trips were assumed to return in the PM peak, inter-peak were assumed to return in the inter-peak and PM peak trips were assumed to return in the AM peak.

3.4.12 The demand segmentation for the RSI site matrices was set up in such a way that the matrices could be converted into the formats required for 24 hour P/A modelling as well as O-D peak hour assignments at a later stage. This demand segmentation was consistent throughout the base year prior matrix development and is referred to in more detail in Section 5.3 of this report.

Mobile Phone Data

3.4.13 Since mobile phone data only gives a sample of traffic movements within a defined cordon it was necessary to expand the records to represent the full volume of traffic within the area.

3.4.14 In the first instance, an expansion factor was applied to account for the mobile phone operator's market share. As this is an 'all Wales' market share, rather than a market share specific to the study area, further expansion factors were applied. These were determined by undertaking a sector-based analysis on the mobile phone data, using the sector system shown in Figure 3.6, and comparing the totals against observed traffic count data at screenlines defined by the sector boundaries.

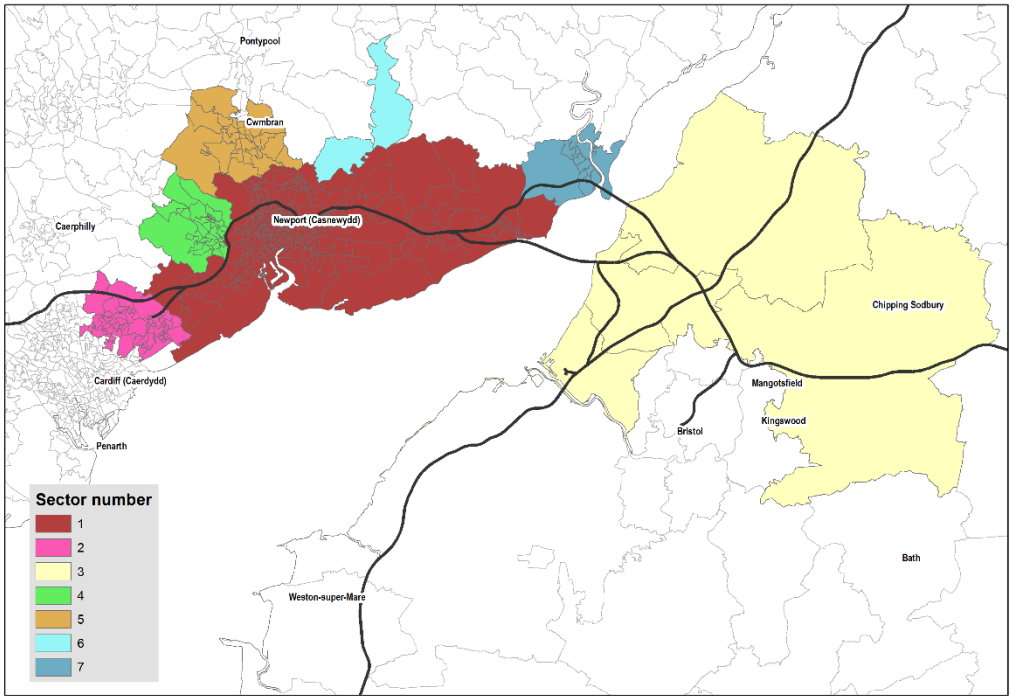

Figure 3.6 Sector System used for Mobile Phone Data Processing

3.4.15 The latter expansion of data was based on the average uplift required across all screenlines. These screenlines capture all external traffic entering and exiting the core mobile phone data collection area, shown as sector 1 in Figure 3.6. The resulting expansion factors are shown in Table 3.5. No expansion factor was applied to HGV trips as these were not derived from mobile phone data.

Table 3.5 Expansion Factors applied to Mobile Phone Data

Vehicle Class	Expansion Factor for Mobile Phone Data
Cars	1.46
Light Goods Vehicles	1.81

3.4.16 In addition to the application of the above expansion factors, traffic volumes were also rebalanced by controlling them to observed traffic volumes into and out of the core mobile phone area from the various external sectors at 24 hour level.

4 Highway Network Development

4.1 Modelled Areas

4.1.1 SATURN networks can comprise either a 'simulation' network, in which the operation of junctions is simulated, or a less detailed 'buffer' network, which essentially functions as a more conventional link-based model. Frequently, SATURN networks are set up as a combination of the two, with the less-detailed 'buffer' area on the model periphery ensuring that traffic from more remote areas enters the simulation part of the network at the correct locations.

4.1.2 For the purposes of preparing traffic forecasts for the updated M4CaN model, the Area of Detailed Modelling comprises a Core Simulation Area that covers the M4 between J30 in the west and J21 in the east, as shown in Figure 2.4. This area includes junctions 29 and 23a, which form the western and eastern ends respectively of the proposed new section of motorway. Within this core area are key roads and corridors of interest including:

- the existing M4 and proposed alternative routes;
- the M48 motorway;
- access routes to the existing M4 and M48 motorways from Cardiff, Newport, Chepstow and the hinterland north of Newport;
- the corridors on the east and west banks of the Usk River that could connect Central Newport to the new section of motorway via intermediate junctions; and
- east-west routes through Newport via Newport Bridge, George Street Bridge and the Southern Distributor Road (SDR).

4.1.3 Within this core area, all significant junctions are fully simulated, and links are coded where appropriate to give a representation of their speed and capacity. This level of detail reflects the significance of the key links and junctions in route choice decisions through the study network.

4.1.4 The Core Simulation Area extends along key radial routes outside the Area of Detailed Modelling to ensure that route choice for traffic entering this area is accurately represented.

4.1.5 Outside the Core Simulation Area is the Rest of Fully Modelled Area, which includes Cardiff and is bounded north of Cardiff by the A470 to the west, the A465/A40 to the north, and the A466 to the east. While trips are fully represented, this area is modelled in less detail as buffer network only, with no simulation of junctions. All links in this area are allocated speed-flow curves.

4.1.6 Outside the Rest of Fully Modelled Area is a large wider area of influence where changes in traffic flow may be experienced following the opening of the M4 South of Newport. This extends to Skewen (M4 J43) in the west, the A465 Heads of the Valleys Road and M50 in the north, and the M5 J8 to J18a in the east. Major roads within this wider area of influence are also modelled as a 'buffer' network with a lower level of detail, using fixed speeds.

4.1.7 The traffic model includes all trips that travel within the Core Simulation Area and the Rest of Fully Modelled Area. The area of influence only includes trips that would travel through the first two areas or trips that would potentially divert to travel through these areas.

4.1.8 The full extent of the model network is shown in Figure 4.1, while the more detailed Core Simulation Area is shown in Figure 4.2

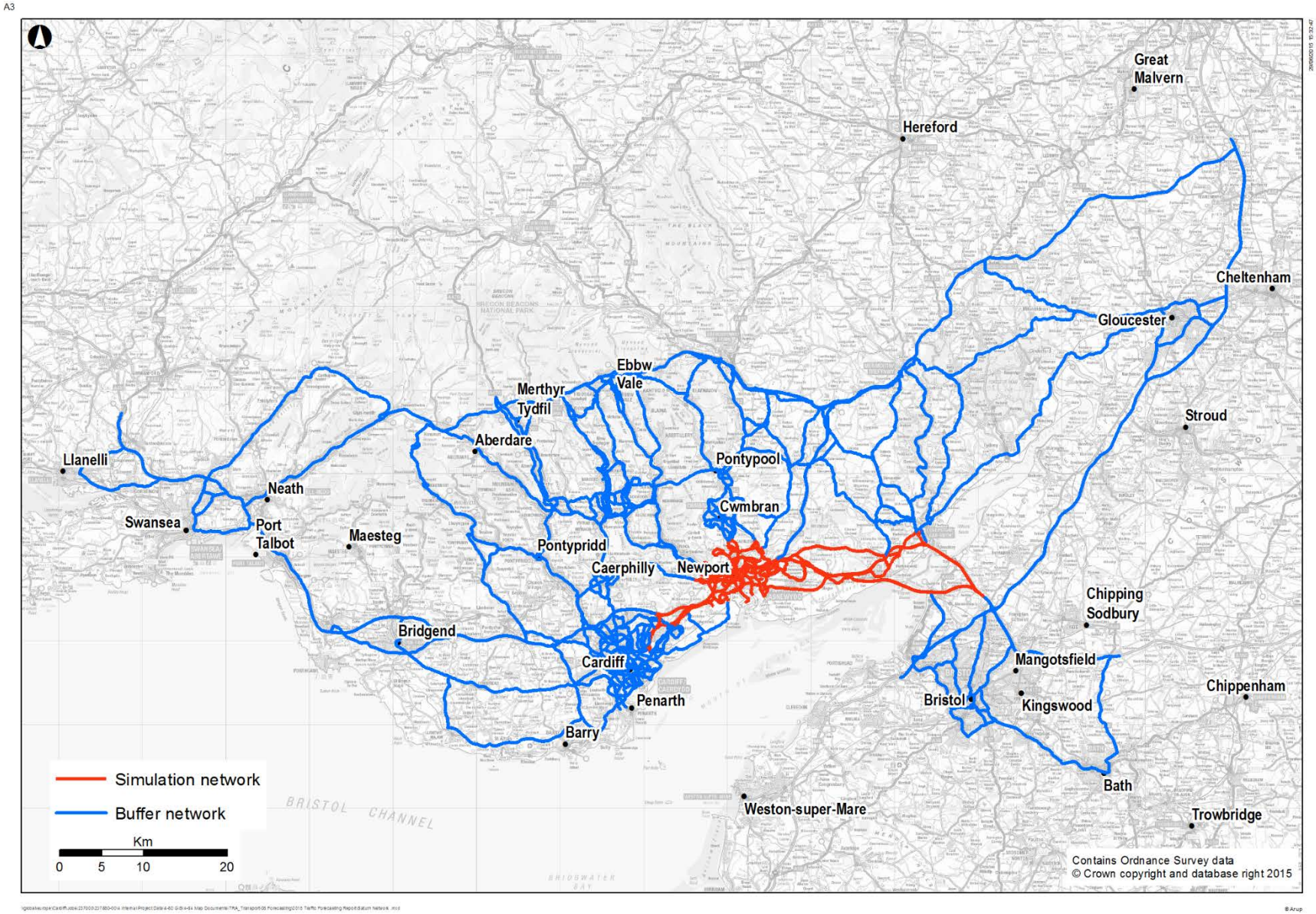

Figure 4.1 Full Model Network

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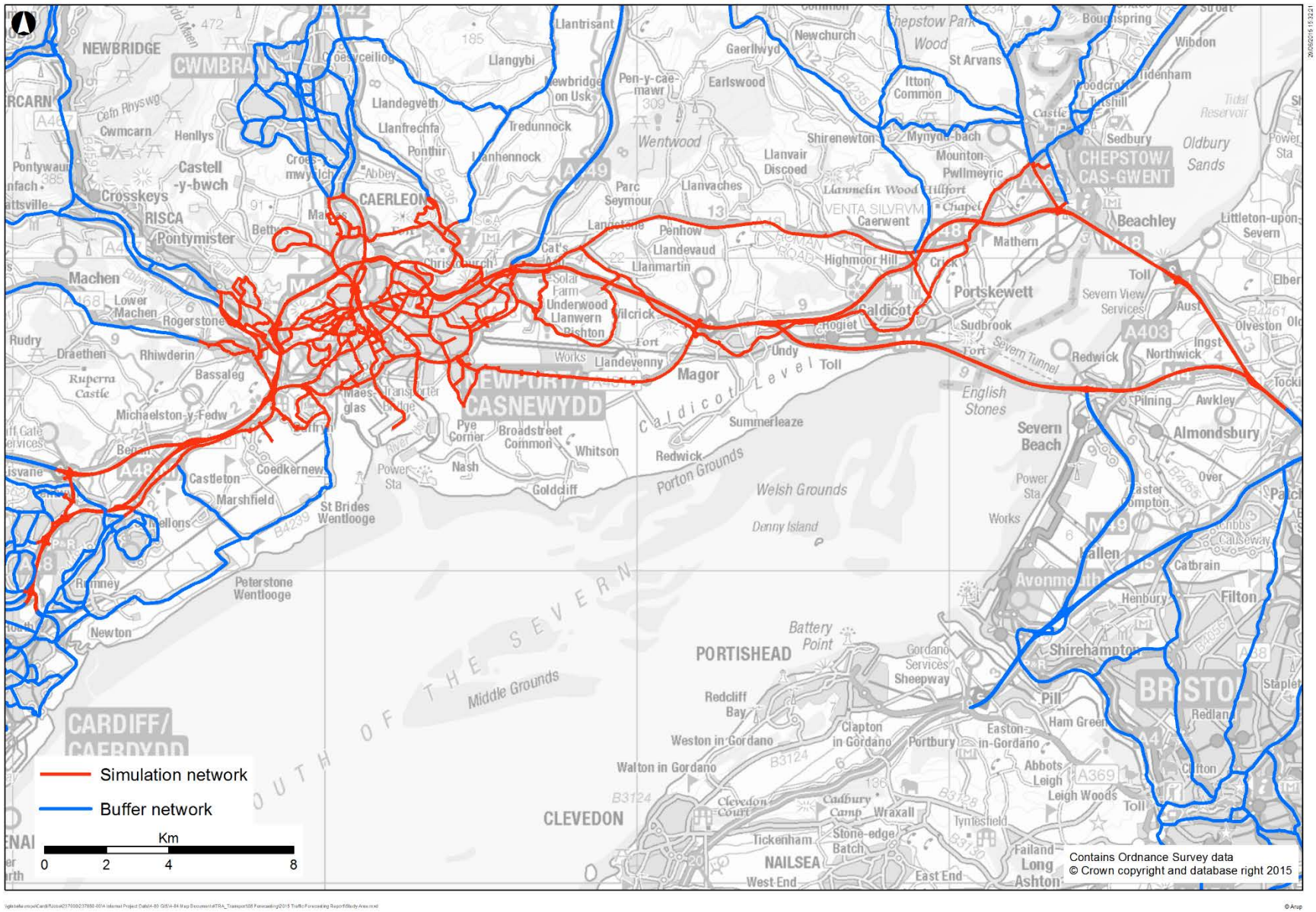


Figure 4.2 Core Simulation Network

4.2 Network Coding

4.2.1 The coding of the base network in the Core Simulation Area was undertaken in detail to ensure its suitability for representing the existing situation. This included the following:

- Links were plotted in a computer-based GIS to enable an accurate measurement to be obtained for all link lengths in the model network;
- Junction types and layouts were cross-checked against imaging from 'Google Streetview', in combination with local knowledge and on-site observations;
- Saturation flows for all signalised and roundabout junctions were estimated from geometric measurements;
- Timings at all signal controlled junctions were derived from observations undertaken in 2012, enabling the calculation of average green and inter-green times for each approach to these junctions. Many junctions were found to have demand-responsive signal controls, producing stages of variable duration or, in some cases, 'on-demand' only. In such cases, an average cycle was coded by double cycling or factoring as appropriate to ensure that the turning capacities modelled represented the real situation.
- The locations of current speed limits were reviewed, with adjustments made to the link speeds and speed-flow curves where necessary.

4.3 Link Speeds

4.3.1 A variable speed limit control system on the M4 between Junction 24 and Junction 28 was implemented in July 2011, which has a significant impact on traffic speeds particularly during periods of high flows. Consequently, new speed-flow curves were calibrated for each motorway section between Junction 23 and Junction 29, using traffic counts and monitored speed data from MIDAS collected during March, April and May 2014. The speed-flow curves from the MIDAS data are illustrated in Appendix B, and listed in Table 4.1.

Table 4.1 M4 Calibrated Speed-Flow Curves

Section	Free flow Speed	Speed at Capacity	Flow at Capacity (PCUs/hr)	Power
Westbound				
J23a to J24	114	84	6990	2.606
J24 to J25	104	80	6990	2.373
J25 to J26	94	70	4200	2.687
J26 to J27	105	82	6990	2.687
J27 to J28	107	86	6990	2.259
J28 to J29	107	94	6990	2.738
Eastbound				
J29 to J28	115	100	6990	3.225
J28 to J27	105	69	6990	3.203
J27 to J26	111	72	6990	3.580
J26 to J25	102	82	4200	1.816
J25 to J24	102	76	6990	2.150
J24 to J23a	115	84	6990	3.328

4.3.2 The calibration of the speed-flow curves is essentially based on speeds observed below capacity, and uses the relationships given in the SATURN manual to describe the standard 'COBA-10' speed-flow curves developed by the Department for Transport and described in the Design Manual for Roads and Bridges.[7] Each curve has three relationships:

- Between zero vehicle flow and the flow at break-point speed:

$$S(V) = S_0 + (S_1 - S_0) * (V / F) \quad (10)$$

- Between the flow at break-point speed and the flow at capacity:

$$S(V) = S_1 + (S_2 - S_1)(V – F) / (C – F) \quad (11)$$

- Vehicle flows above capacity:

$$S(V) = S_2 / (1 + S_2 (V – C) / 8dC) \quad (12)$$

where:

V is the vehicle flow

F is the maximum flow at which free-flow conditions hold

C is the flow at capacity

S0 is the free flow speed

[7] Design Manual for Roads and Bridges, Volume 13 Economic Assessment of Roads Schemes, Section 1, Part 5, Speeds on Links, Department for Transport, May 2002

S1 is the intermediate break-point speed

S2 is the speed at capacity

4.3.3 The SATURN manual then states that the "best-fit" value of the power 'n' may be determined by the equation:

13. $n = (R_1 * R_2 - 1) / (B_1 + B_2 - 1) - 1$

where:

$B_1 = ((F / C) R_1 \log R_1) / (R_1 - 1)$

$B_2 = ((1 - F / C) R_1 * R_2 \log R_2) / (R_2 - 1)$

$R_1 = S_0 / S_1$

$R_2 = S_1 / S_2$

4.3.4 For other links in the Core Simulation area, in general the presumption is that speeds and delays in the urban area are mainly determined by the simulation of junctions and not by link speed flow effects. However, in rural areas and on the motorway links speeds and delays are modelled through link speed flow effects. For these links, and for all the links in the Rest of Fully Modelled Area, speed flow relationships have been estimated in accordance with the methodology set out in WebTAG[8].

4.3.5 Roads in the less-detailed buffer network outside the Rest of Fully Modelled Area are not fully modelled, as traffic that would not pass through the Rest of Modelled Area or Area of Detailed Modelling are not included in the matrices. This means that speed flow relationships cannot be used to ascertain the speeds on these links. Fixed buffer link speeds were therefore estimated based on recorded speed data or by applying the default speed-flow relationships to existing traffic count data. The buffer network was coded with these fixed speeds to give representative journey times for trips into/out of the study area.

[8] Transport Analysis Guidance Unit M3.1, Highway Assignment Modelling, Appendix D: Speed/Flow Relationships, Department for Transport, January 2014

5 Trip Matrix Development

5.1 Zone System

5.1.1 The M4CaN transport model zone system covers the whole of Great Britain, with zone sizes within the Area of Detailed Modelling at a highly disaggregate level of detail. The zone sizes increase with distance away from the Area of Detailed Modelling to give a progressively more aggregate zone structure in the Rest of Fully Modelled Area, the Wider Area of Influence and the External Area respectively

Core Simulation Area

5.1.2 The Area of Detailed Modelling is centred around Newport, extending from the Severn River Crossings to the eastern edge of Cardiff. The zone system used in this area is shown in Figure 5.1. The zone boundaries have been drawn to ensure that they are consistent with both the DfT's National Trip End Model zones and the Census Output Areas.

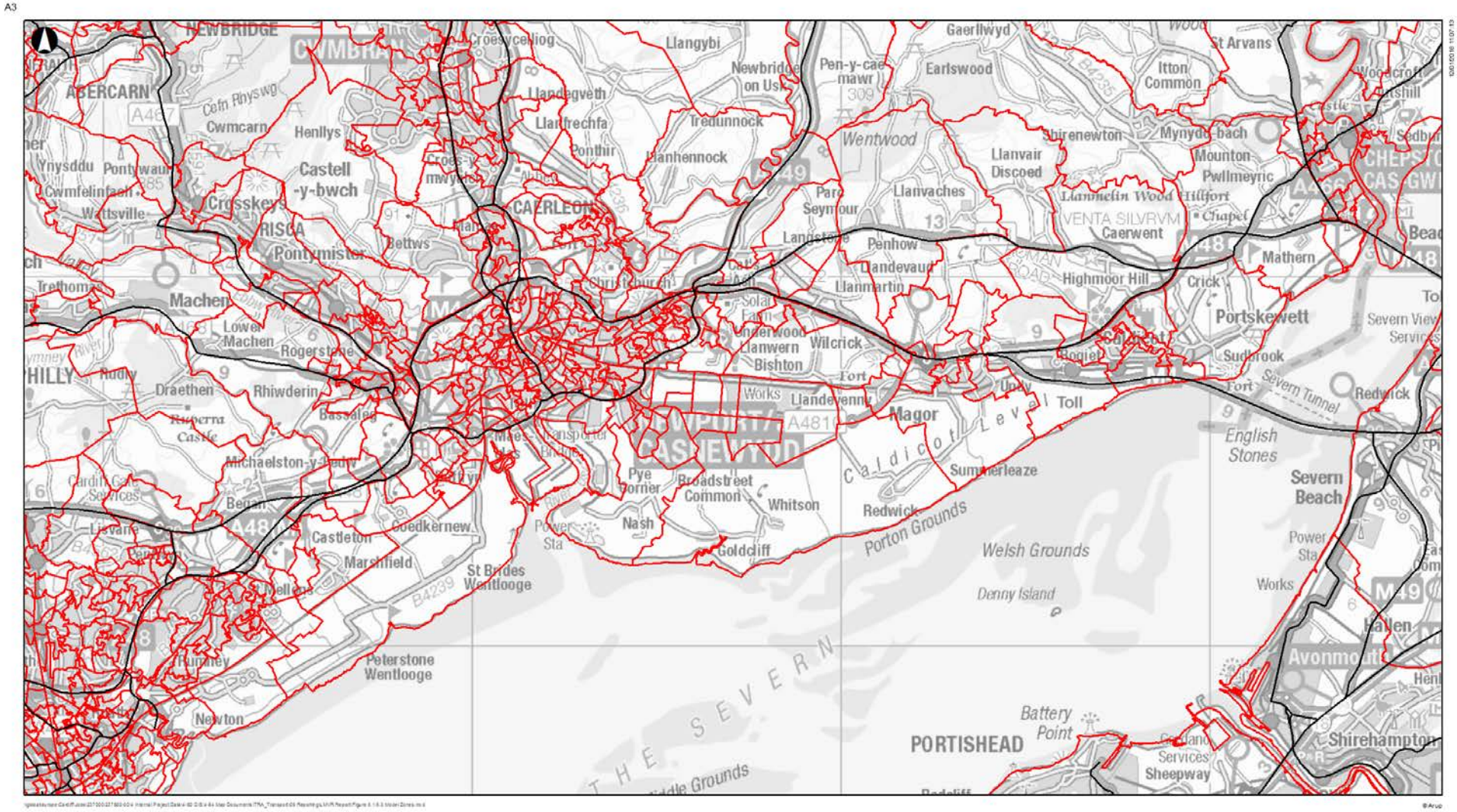


Figure 5.1 Model Zones, Core Simulation Area

Rest of Fully Modelled Area

5.1.3 The Rest of Fully Modelled Area is bounded to the west by the A470 and the western edge of Cardiff, by the A465 and the A40 to the north, and by the River Wye to the east.

5.1.4 In order to represent all trips in this area, it is necessary that a sufficiently detailed network is coded that provides sufficient available route choice alternatives. Therefore, the zone system in this area is designed so that the zones represent the represent the most likely loading points for these trips.

5.1.5 As with the Area of Detailed Modelling, zone boundaries have been drawn to coincide with the boundaries used in the DfT's National Trip End Model and the Census Output Areas. The zone system in this area is shown in Figure 5.2.

A3

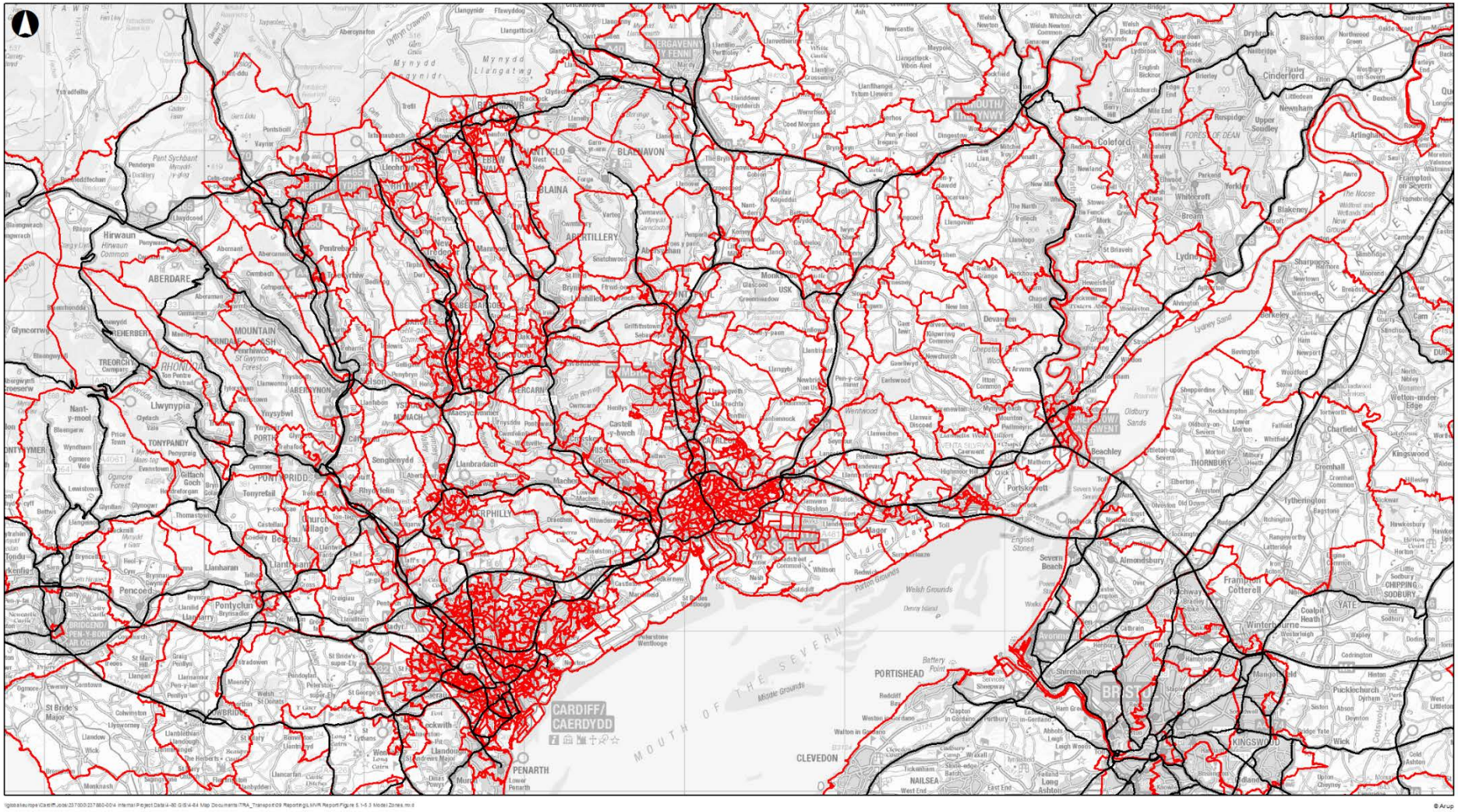


Figure 5.2 Model Zones, Rest of Fully Modelled Area

Wider Area of Influence

5.1.6 The 'Wider Area of Influence' is coded as a buffer network outside the Rest of Fully Modelled Area. It includes long-distance movements which could be influenced by the proposed new section of motorway south of Newport. Fixed speeds are used on the links in this part of the network.

5.1.7 The zone system in the 'Wider Area of Influence' is shown in Figure 5.3. It is not as fine as those in the Core Simulation and 'Rest of Fully Modelled Area', but the zones have been drawn to ensure consistency with the DfT's National Trip End Model and Census Output Areas.

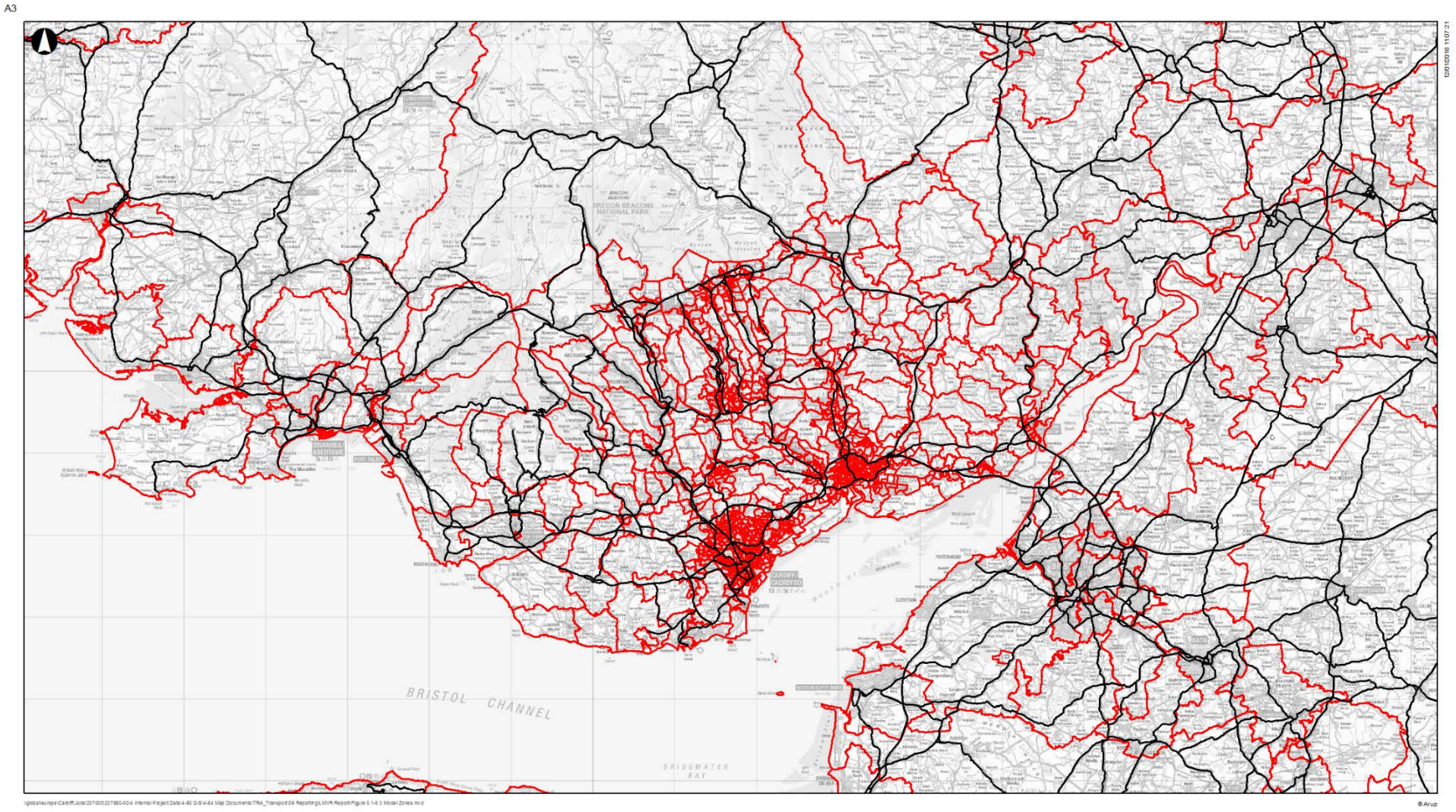


Figure 5.3 Model Zones, Wider Area of Influence

External Area

5.1.8 The External Area comprises the rest of the UK outside of the Wider Area of Influence, and does not have an explicit network representation. The external zones are connected to the network at the edge of the Wider Area of Influence by means of long distance centroid connectors, again using fixed speeds.

5.1.9 Because of the limited number of long distance routes available for this traffic to enter the main modelled areas, the zones in these areas are considerably larger. The External Area zone system is consistent with DfT's National Trip End Model zones and Census Output Areas, and is shown in. Figure 5.4

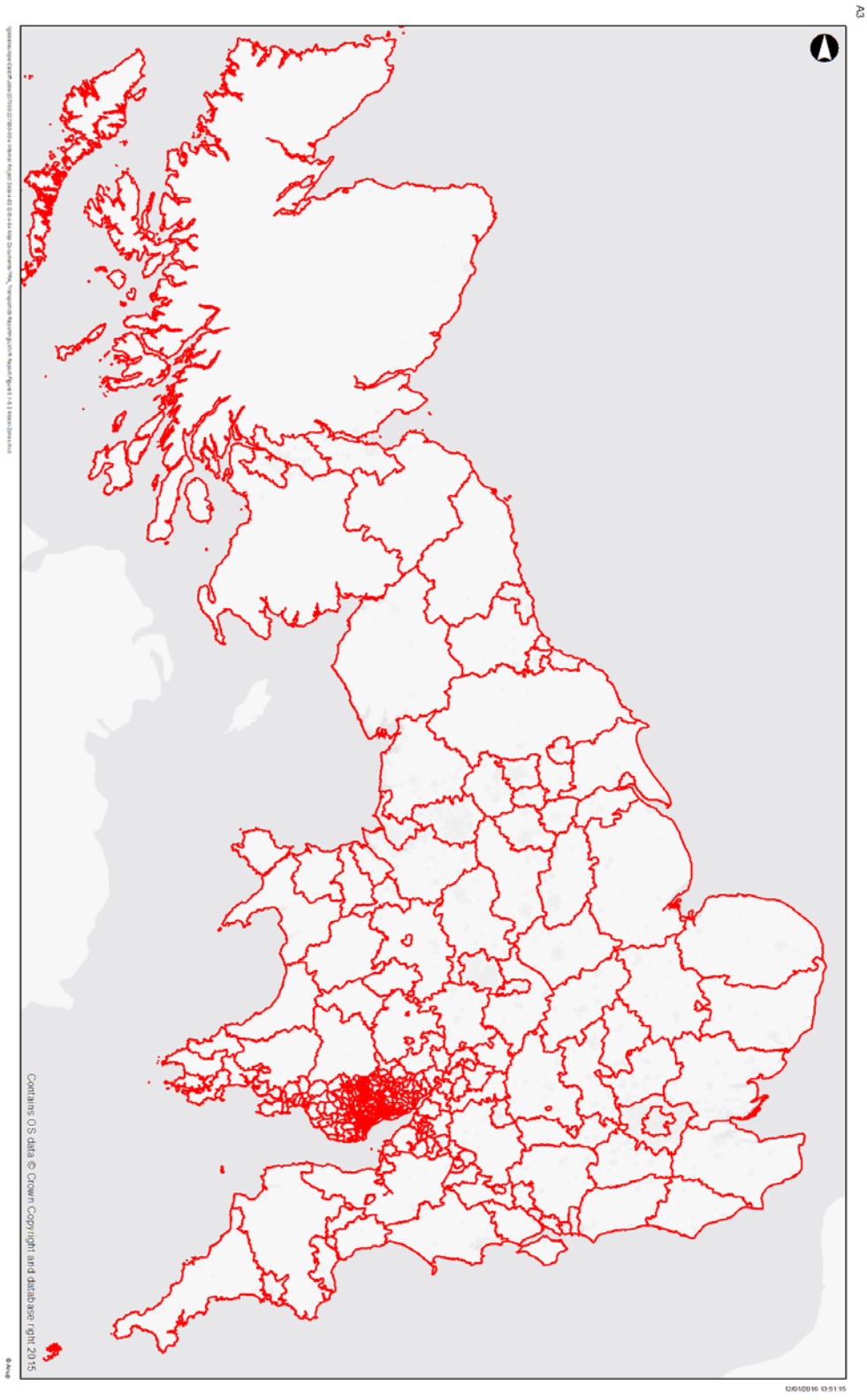


Figure 5.4 Model Zones, External Area

5.2 Approach to Matrix Development

5.2.1 In developing the 'prior' trip matrices for assignment and input to the model calibration and validation process, the approach was for all movements in the Area of Detailed Modelling to be derived from fully observed data, with movements outside this area being based on synthesised demand.

5.2.2 WebTAG[9] guidance notes that variable demand models ideally require base year matrices to be developed in production/attraction (P/A) form. In most cases these are expected to be available at an all-day level, on the basis that both outbound and return trips are undertaken in the same day. Accordingly, information on whether the home-end of a home-based trip was at the origin or destination of a trip was retained throughout the matrix development process, so that the demand matrices could be converted into P/A format representing a 24-hour weekday period for variable demand modelling.

5.2.3 As it is only the VDM that requires matrices to be in P/A format, the prior trip matrices were developed in O-D format for each peak period and from there converted to the peak hour for the updated M4CaN traffic assignment model.

5.2.4 The basis of the fully observed trip data in the Area of Detailed Modelling is the mobile phone data described in Section 3.3.1 and the base year freight matrices described in Section 3.2.5. Data from the merged RSI surveys described in Section 3.4.2 was then used to append trip end information to mobile phone records, since VDM requires full journey trip information from true origin to destination.

5.3 Demand Segmentation for Matrix Development

5.3.1 As a result of the requirement for a 24 hour P/A matrix within the VDM and a peak hour O-D demand matrix for traffic assignment, separate demand segments needed to be set up for the matrix development stage. These provide a way of retaining information on whether the home end of a home-based trip was at the trip origin or destination. This information is need for the conversion of demand from O-D to P/A format for variable demand modelling.

5.3.2 Table 5.1 shows the demand segmentation used during matrix development through to the completion of the base year prior matrix. All matrices derived from mobile phone data, RSI data or from the synthesised demand, described in Section 5.6, follow this convention.

[9] Transport Analysis Guidance Unit M2, Variable Demand Modelling, Department for Transport, January 2014

Table 5.1 Demand Segments during Prior Trip Matrix Development

Demand Segment	Vehicle Type / Purpose
1	Cars – Commuting, from home
2	Cars – Commuting, to home
3	Cars – Other Purposes, from home
4	Cars – Other Purposes, to home
5	Cars – Other Purposes, non-home-based
6	Cars – Employers' Business, from home
7	Cars – Employers' Business, to home
8	Cars – Employers' Business, non-home-based
9	Light Goods Vehicles (LGVs)
10	Heavy Goods Vehicles (HGVs)

5.4 Time Periods for Matrix Development

5.4.1 During matrix development the time periods represented within the matrices refer to the full demand within each peak period, as follows:

- AM peak period – 07:00 to 10:00;
- Inter-peak period –10:00 to 16:00;
- PM peak period – 16:00 to 19:00; and
- Off-peak period – 19:00 to 07:00.

5.4.2 This configuration was selected as the most flexible with a view to creating both a 24 hour P/A VDM model and peak hour traffic assignments. A factor is applied to convert from 'average hour within peak period' to 'peak hour' in order to run the final highway assignments

5.5 Mobile Phone Trip Matrices

5.5.1 All mobile phone events recorded were mapped to an aggregation of the model zone system, based on the location of the mobile cell base station being used. The data was processed to identify trip ends, mode, time of day, home location and repeat patterns using a set of defined algorithms. The main algorithms used in this process are given in Table 5.2.

5.5.2 Checks were made on the data through a comparison of trip ends with the DfT's National Trip End Model (NTEM), and a comparison of the distribution of trips (trip lengths) with TrafficMaster data.

5.5.3 The proportion of home locations identified from the mobile phone data in the various NTEM zones was compared with the zonal population proportions. Only two of the NTEM zones showed a significant variation between the two datasets, both of them on the periphery of the modelled area, in South Gloucestershire and Avonmouth. For the purpose of modelling traffic flows in Wales, the

comparison was considered to be a robust verification of the proportion of home locations.

Table 5.2 Mobile Data Processing Parameters

Parameter	Algorithm	Criteria	Range
Trip Separation	Mobiles stationary for a certain time constitute a break between trips	30 mins	30-60 mins
	Mobiles that are switched off and reappear in the same place have been stationary in the meantime.		
Mode Split	Rail trips follow definable routes along the rail network		
	Motorised trips have an average speed above: and/or a peak speed above:	8 kph 15 kph	6-8 kph 15-25 kph
	Slow trips are those that are not Rail or Motorised		
Home Identification	Mobiles that are stationary for a minimum duration during the night (22:00-06:00) are taken to have spent the night in that location	4 hrs	4-5 hrs
	Home is located by: • a mobile spending the night at a location for a minimum number of times during the week, or • a minimum time during the weekends on at least 3 weekend days	4 nights 8 hrs	2-5 nights 4-10 hrs
Trip Repeats	A trip being repeated on more than one day must be between the same two points, and by the same mode, with the second trip starting in the same time period as the first.		
Purpose	Repeating trips with one end identified as home are Home-Based, all others are Non-Home-Based.		
	Home-Based trips with an external other end are classed as Home-Based Work (HBW). Those with an internal other end are classed based on the majority land use of the cell zone.		
	Cells that are mainly industrial or office imply HBW trips. Those that are mainly educational establishments imply Home-Based Education trips. All other cells imply that the trip is for Other purposes.		
Day	Only trips falling on Monday – Thursday (excluding bank holidays) are included.		
	A day runs from 07:00 to 07:00 to avoid splitting the off-peak period across two days.		
Time of Day	AM peak period is 07:00-10:00 Inter-peak period is 10:00-16:00 PM peak period is 16:00-19:00 All other times are off-peak		
	Trips are assigned to one of the four periods based on the time the trip starts.		

5.5.4 The comparison with the distribution of trips in the TrafficMaster data was made at a sector-sector level, which showed a very good match between the origin-destination patterns in the two datasets. The largest variation occurred in the central Newport sector, where zones are small and the trips often short, and therefore difficult for the mobile phone dataset to identify all short distance movements. The shortage of around 700 trips over a 24 hour weekday in this sector was therefore considered reasonable, while variations between other sector-sector movements were of a lower order of magnitude.

5.5.5 The observed mobile phone movements were converted into travel demand matrices by expanding the data as described in Section 3.4.3.

5.5.6 Data from the RSI surveys was used to split motorised trips between From-Home, To-Home and Non-home-based, and also between Work, Other and Employers' Business trips. For home-based rail trips, data from the NTEM was used to estimate this split.

5.5.7 The number of trips contained in the final base year mobile phone matrices for each vehicle type are shown in Table 5.2.

Table 5.2: Mobile Phone Travel Demand Matrices (Average 24 Hour Weekday)

Purpose	Direction	AM peak	Inter Peak	PM peak	Off Peak
Home-based Work (vehs/hr)	From home	9,921	1,156	2,426	929
	To home	1,659	2,311	9,050	1,160
Home-based Other (vehs/hr)	From home	10,234	8,677	5,233	2,192
	To home	4,526	8,846	10,124	3,250
Non Home-based Other (vehs/hr)	Non home-based	5,079	4,480	4,304	776
Home-based Employers' Business (vehs/hr)	From home	2,057	1,850	1,049	360
	To home	604	1,949	2,496	627
Non Home-based Employers' Business (vehs/hr)	Non home-based	470	804	740	126
Light Goods Vehicles (vehs/hr)		5,930	4,296	5,205	1,220
Heavy Goods Vehicles (vehs/hr)		1,109	1,798	1,877	528
Rail (person trips)		233	140	163	22

5.6 Synthesised Trip Matrices

Overview

5.6.1 While the mobile phone trip matrices provide full coverage of trips taking place in the Area of Detailed Modelling, this is not the case in other areas of the model. In the 'Rest of Fully Modelled Area', the mobile phone matrices only provide partial coverage of trip making. However, as this area incorporates speed-flow relationships on all of

the modelled links, it is necessary that the trip matrices in this area represent the full level of demand for travel on these links to ensure the level of required accuracy in the modelling of vehicle speeds and the consequent choice of routes through the area.

5.6.2 The infilling of trips within the 'Rest of Fully Modelled Area' was achieved through synthesising the travel demand

5.6.3 The key steps in developing the synthetic matrices were:

1. Derivation of zonal trip productions / attractions by trip purpose.
2. Development of the trip distribution based on a conventional gravity model approach.
3. Creation of a simple network model based on the Ordnance Survey MasterMap Integrated Transport Network (ITN) layer and using speed data extracted from TrafficMaster.
4. Skim of trip costs from the above used to inform the travel impedance in the calculation of friction factors.
5. Model calibration using observed data.

5.6.4 The synthetic output matrices were then merged with the mobile phone matrices produced for the Area of Detailed Modelling in order to produce the overall demand matrix. In this merging process, the mobile phone data took precedence over the synthesised data, so that trips in the synthesised demand matrices that were common to those derived from mobile phone were screened out. Thus the synthesised demand matrices only represented fully unobserved movements in the final matrices.

Zonal Trip Production/Attraction

5.6.5 Trip production and attraction totals for private vehicle trips were extracted from NTEM. This data was output as productions and attractions for the following:

- Year 2014;
- Average weekday;
- Total trip ends;
- Car drivers only;
- By trip purpose.

5.6.6 It was necessary to disaggregate the data extracted from NTEM to the SATURN network model zone system. This was done using population data available from the 2011 Census and employment data extracted from the Business Register and Employment Survey (BRES). The data sources used for disaggregating the NTEM data for each trip purpose are shown in Appendix C.

5.6.7 The trip generation and distribution for goods vehicles were extracted from the DfT's Base Year Freight Matrices, in the following format:

- 2006 base year data.
- Total vehicles per day, split by mode (road / rail) and by vehicle type (articulated HGV/rigid HGV/van).
- Zone system based on local authority district and unitary authority boundaries.

5.6.8 These matrices were uplifted to 2014 (based on the DfT's National Road Traffic Forecasts), factored to the modelled time periods using local count data, and then disaggregated to the model zone system based on available TrafficMaster data described in Section 3.2.4.

Travel Impedance

5.6.9 A simplified traffic model was set up within SATURN (buffer network only) in order to derive generalised costs for use in the calculation of the values for the deterrence function within the gravity model. The buffer network used for this purpose was based on the Ordnance Survey ITN network layer for the Rest of Fully Modelled Area together with observed speeds appended to the network from TrafficMaster data. The full SATURN traffic model zone system was included within this simplified traffic model, and this enabled zone to zone generalised costs to be produced and input to the gravity model in order to calculate the required friction factors for each origin-destination movement.

Gravity Model Development

5.6.10 The gravity model was scripted using the SATURN MX matrix manipulation module. It follows general advice for the creation of doubly-constrained trip distribution models:

$$T_{ij} = P_i * \frac{A_j * f(t_{ij}) * K_{ij}}{\sum A_{j'} * f(t_{ij'}) * K_{ij'}}$$

Where:

T_{ij} = number of trips that are produced in zone i and attracted to zone j;
P_i = total number of trips produced in zone i;
A_j = number of trips attracted to zone j;
$f(t_{ij})$ = friction factor based on travel impedance; and
K_{ij} = socio-economic adjustment factor for calibration of attractiveness.

5.6.11 Friction factors for each movement were calculated using a deterrence function in the form of a 'gamma function':

$$f(t_{ij}) = \alpha * t_{ij}^{\beta} * e^{(\gamma * t_{ij})}$$

Where:

$\alpha, \beta$and $\gamma$are gamma function scaling factors, which are used to calibrate the gravity model in order to replicate an observed trip length distribution.

Gravity Model Calibration

5.6.12 The socio-economic adjustment (K) factors are important in the calibration of the gravity model trip distribution. They are used to control the relative attractiveness of movements between different sectors. In order to verify the realism of the calculated trip distribution, the trip length distribution and average trip length for each trip purpose was compared with observed data.

5.6.13 Three sources of data were used for this:

- Local RSI data extracted from appropriate processed roadside interview sites throughout the study area.
- Journey-to-work (JTW) data from the Census 2011, which was used to calibrate commuter trips generated by the gravity model.
- National Travel Survey Data from 2013 which shows average car driver trip lengths by trip purpose.

5.6.14 The first step in calibrating the gravity model was to determine 'gamma function' parameters which would return sensible trip length distributions from the gravity model. The α parameter was set to 1 for all trip purposes as it has no direct impact on the gravity model results. It is used purely as a scaling parameter in cases when 'gamma functions' for different user classes are to be displayed on the same graph. The settings for the other 'gamma function' parameters are shown in Table 5.3.

Table 5.3 Gravity Model 'Gamma Function' Calibration Parameters

Trip Purpose	'Gamma Function' Parameters	
	β	γ
Cars - Employers' Business, Home-based (HBEB)	-0.85	-0.0008
Cars - Employers' Business, Non-home-based (NHBEB)		
Cars - Other, Home-Based (HBO)	-0.7	-0.0019
Cars - Other, Non-Home-Based (NHBO)		
Cars - Commuting (HBW)	-0.4	-0.0012

5.6.15 In order to check the trip length distribution of commuter trips, the gravity model output was compared against Census JTW data. For Employers' Business and Other trips there is no comparable data source equivalent to the Census JTW data and therefore the gravity model output was compared against RSI data instead.

5.6.16 Figures 5.5 to 5.9 illustrate that a good match in trip length distribution with observed data was achieved for each user class. Additionally, the JTW data compared to RSI data in Figure 5.9 suggests that the RSI data is generally lacking some short trips, which is to be expected when considering the mostly strategic nature of roads on which vehicles were generally intercepted in the surveys. The trip length distribution from the RSI data was therefore only used indicatively to ensure that the gravity models broadly reflect the correct trip length distribution in the first instance. Further calibration checks were then undertaken to ensure the robustness of the outputs as outlined below.

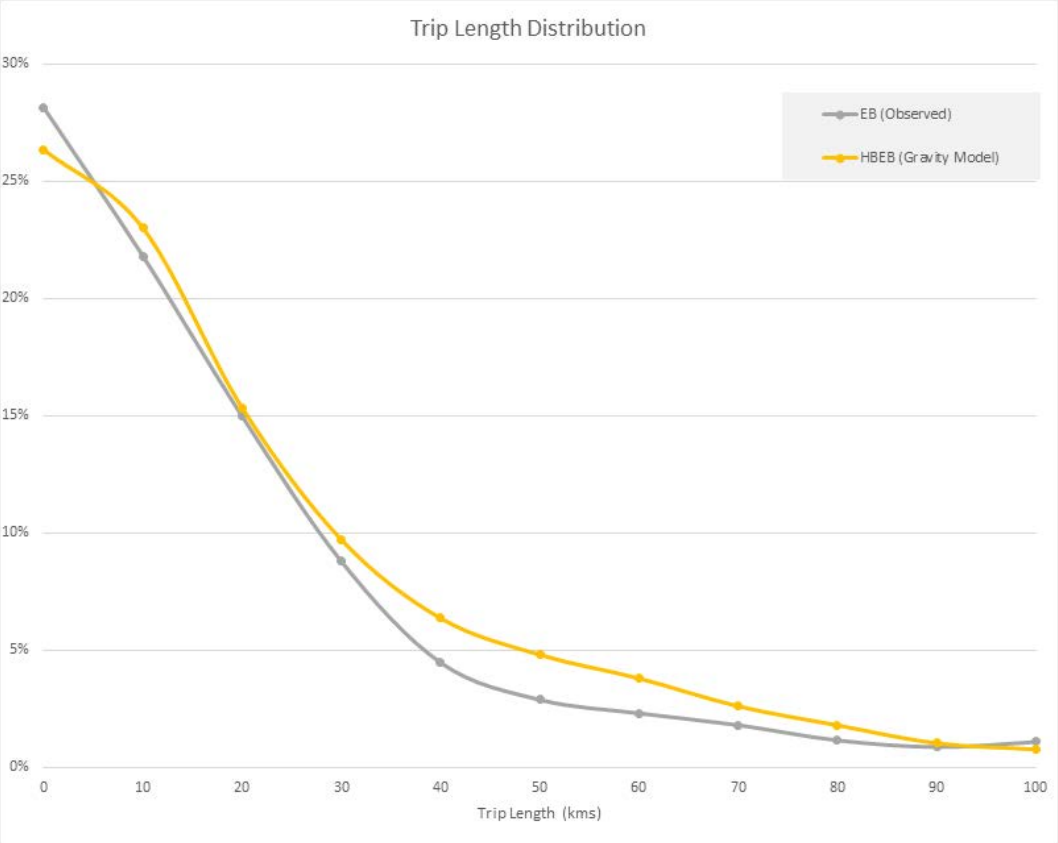


Figure 5.5 Gravity Model versus RSI Trip Length Distribution, HBEB

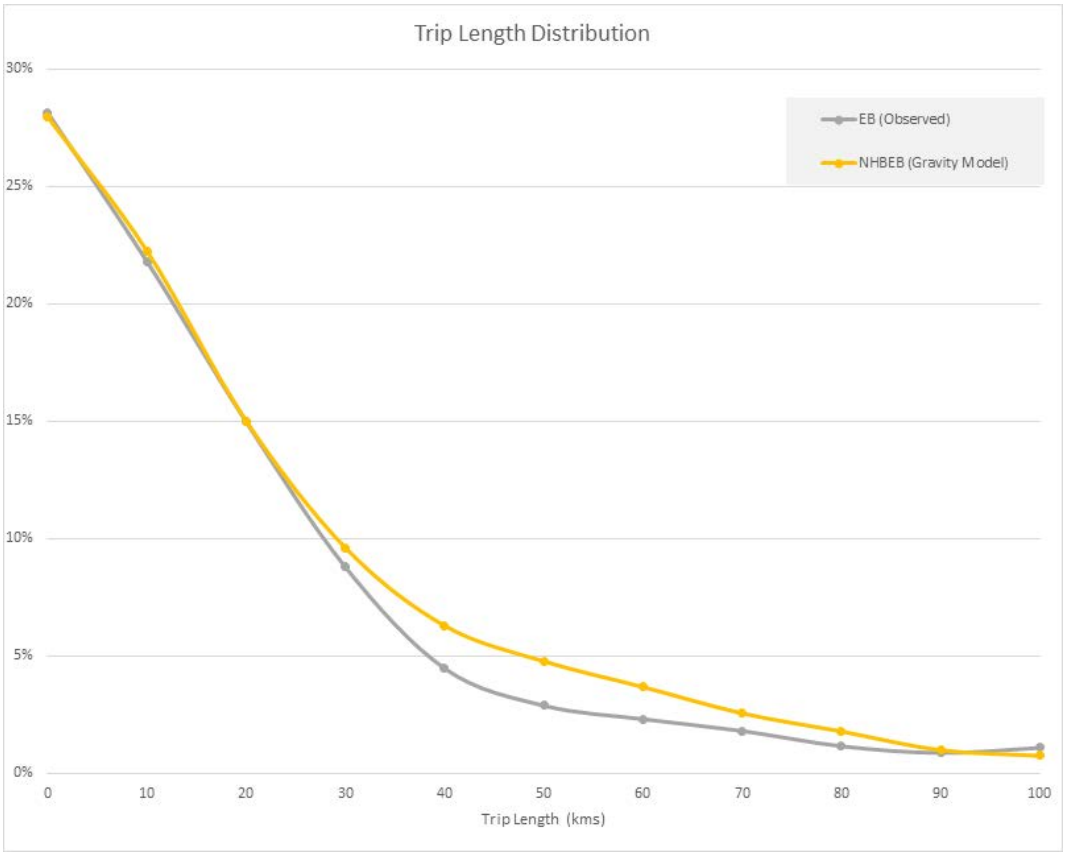


Figure 5.6 Gravity Model versus RSI Trip Length Distribution, NHBEB

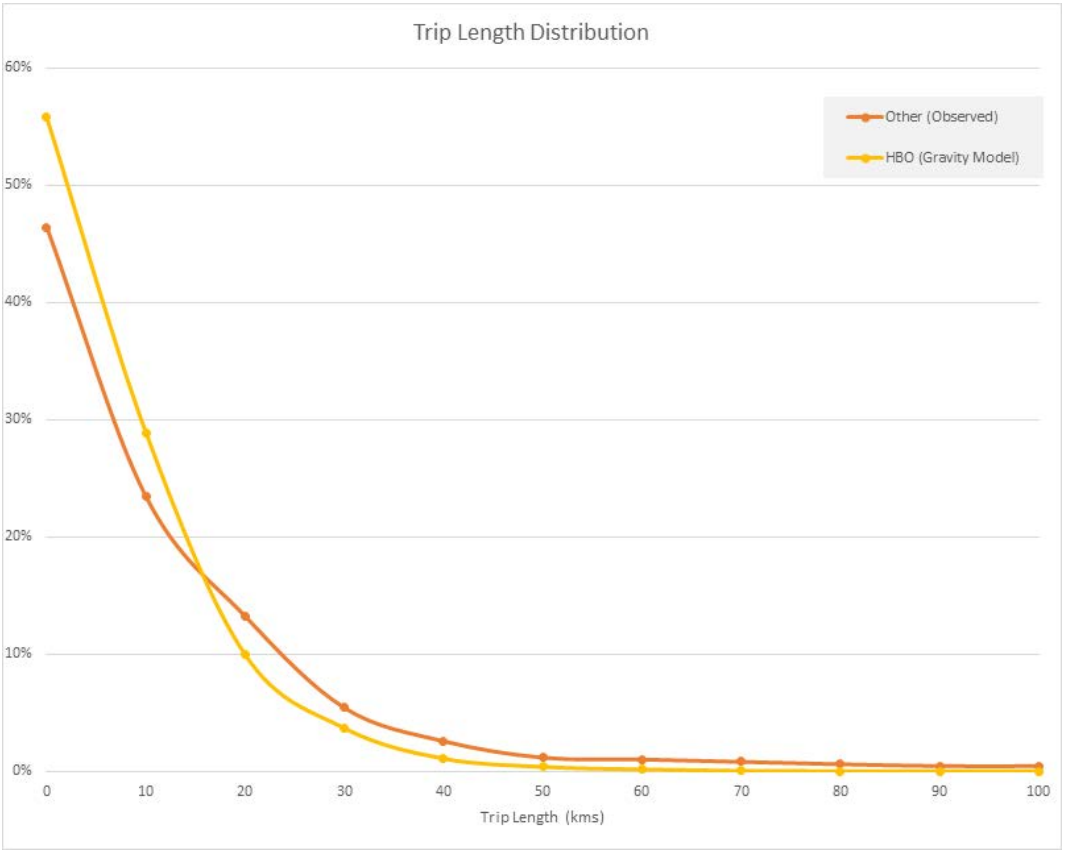


Figure 5.7 Gravity Model versus RSI Trip Length Distribution, HBO

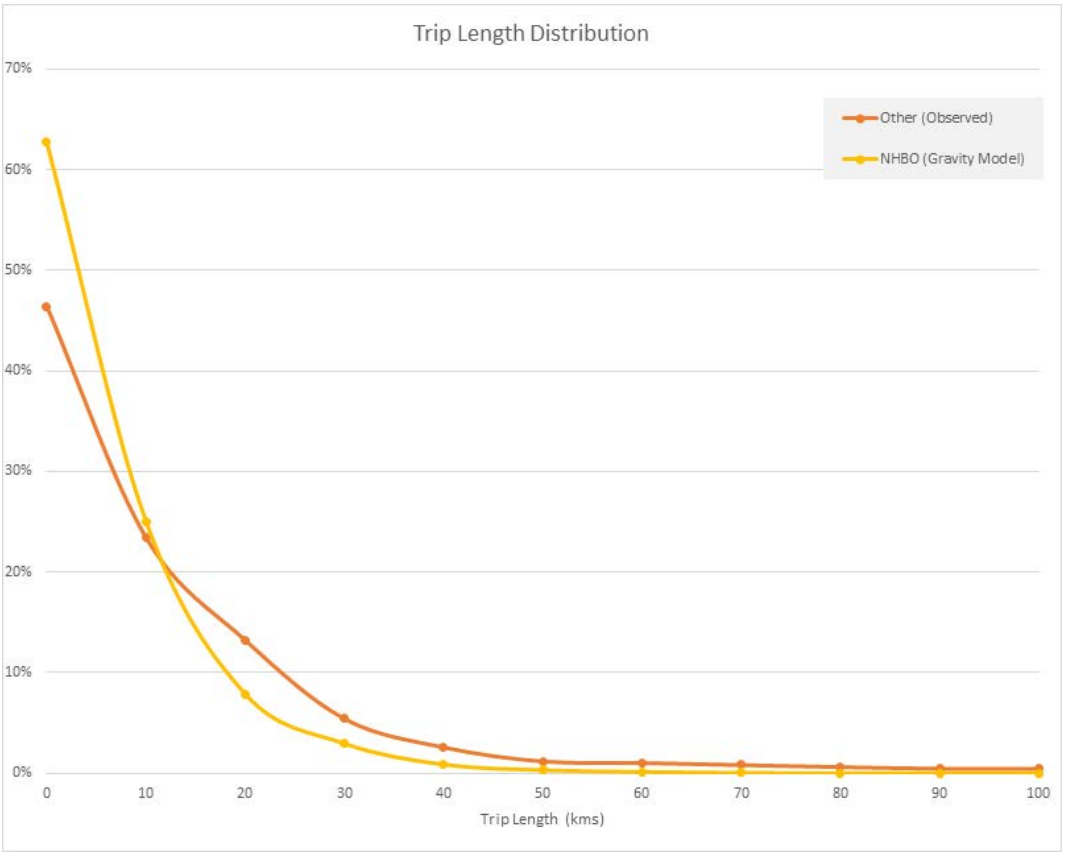


Figure 5.8 Gravity Model versus RSI Trip Length Distribution, NHBO

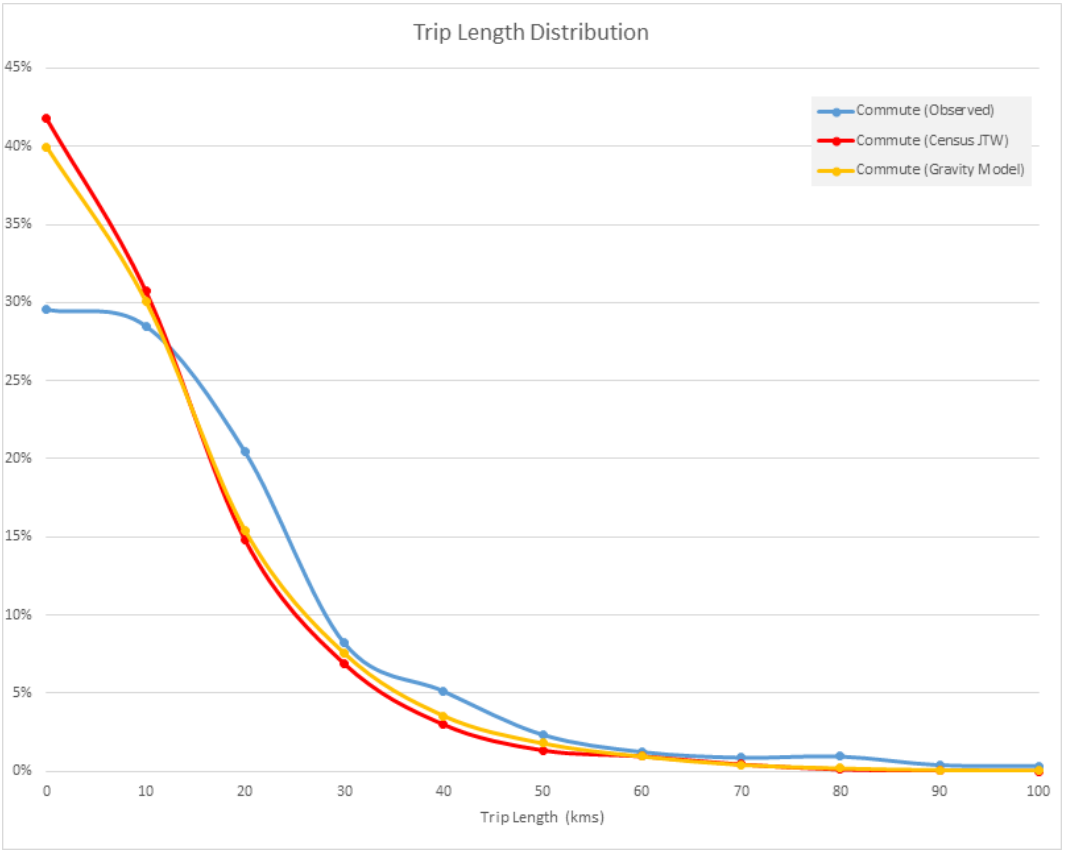


Figure 5.9 Gravity Model versus RSI Trip Length Distribution, HBW

5.6.17 A sector system was defined to assist in calibrating the synthetic demand matrix against traffic count data. Trip totals across screenlines, illustrated in Figure 5.10 were compared with classified traffic counts by time period to ensure that the overall scale of trips between sectors was realistic. Classified traffic counts were derived from data collected and published by the DfT and Traffic Wales.

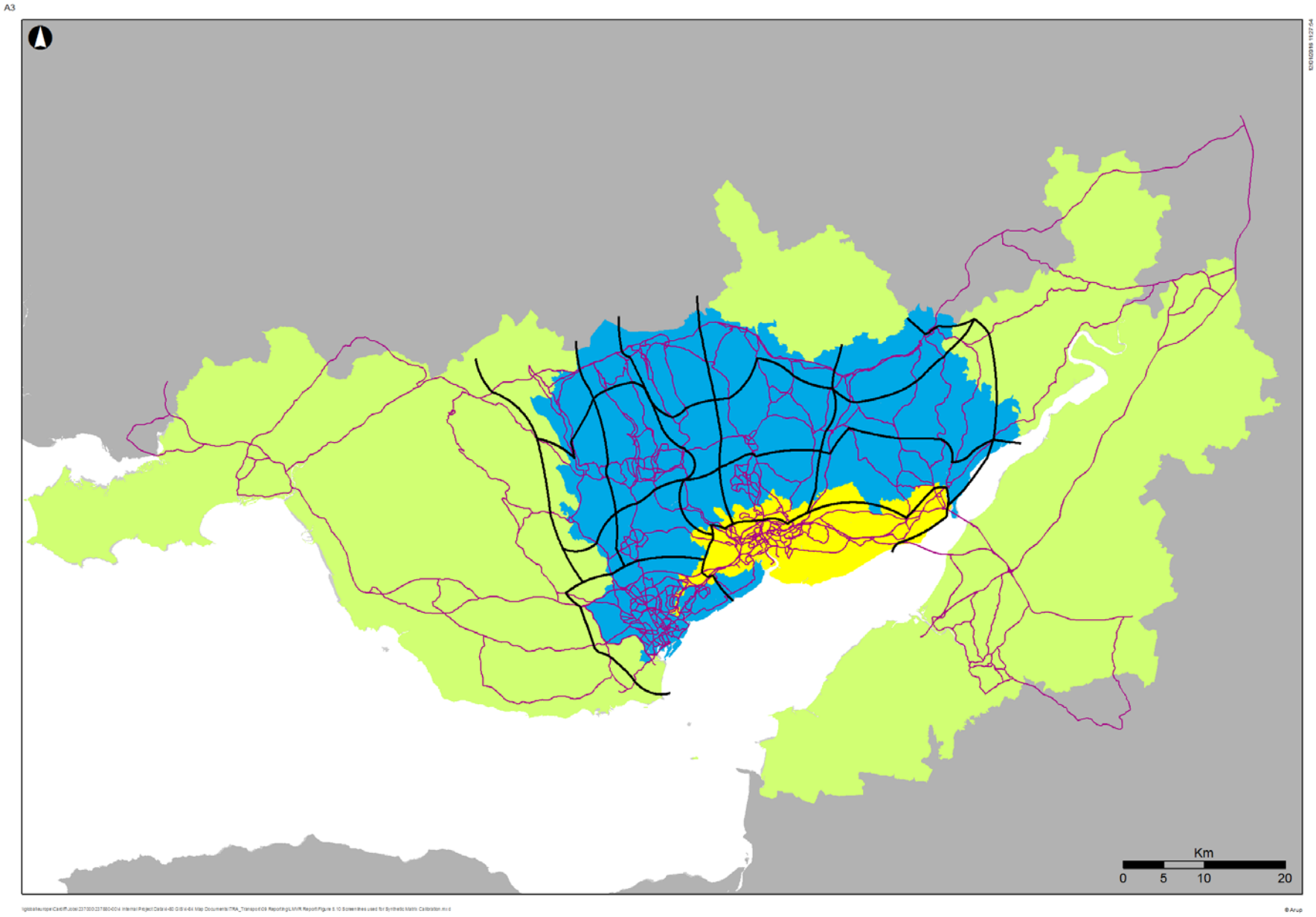


Figure 5.10 Screenlines used for Synthetic Matrix Calibration

5.6.18 Overall, the gravity model produced a good match against observed data across the screenlines shown. On average, the gravity model is 6% higher than the observed data over a full average weekday 24 hour period. The western and eastern boundaries of the gravity model area and cordons around Cardiff and Newport also show a good match against observed data as shown in Table 5.4.

Table 5.4 Gravity Model comparison with Count Data

Boundary / Cordon / Screenline	2-way AAWT, Cars		Difference	%Difference
	Observed	Modelled		
Western Edge	190,793	191,642	848	0%
Eastern Edge	69,146	66,369	-2,776	-4%
Cardiff	339,310	363,652	24,342	7%
Newport	327,163	330,082	2,919	1%
Total across all Screenlines	1,140,668	1,208,055	67,387	6%

5.6.19 Analysis of the 2011 Census journey-to-work (JTW) data indicates that, when disaggregated to the SATURN model zone system, 9.4% of trips would be intra-zonal. The gravity model output for commuter journeys produced a distribution which gave 10% of intra-zonals and therefore showed a good match.

5.6.20 The average trip length of commuter journeys from the gravity model was also compared against data from the JTW dataset for the study area. The JTW data for the South Wales region showed that the average car driver trip length in the area was 16 km. The gravity model produced commuter trips with an average length of 16.8 km and therefore showed a very good correlation with this data.

5.6.21 Data showing average car driver trip lengths by trip purpose was also extracted from the National Travel Survey (NTS) from 2013[10]. This confirmed that the average car driver on a journey to or from work would be expected to travel a length of 16 km – thereby confirming the value from the JTW data for South Wales. It also gave average trip lengths for car drivers on Employers' Business and Other trip purposes, which were used as benchmarks to calibrate the gravity model as shown in Table 5.5.

Table 5.5 Gravity Model comparison versus NTS Data from 2013

Trip Purpose	Average Trip Length (km), Car Driver	
	NTS	Gravity Model
Cars - Employers' Business, Home-based	32.7	33.0
Cars - Employers' Business, Non-home-based		32.5
Cars - Other, Home-Based	11.5	11.6

[10] Analysis of National Travel Survey (2013) tables NTS0409 and NTS0410.

Trip Purpose	Average Trip Length (km), Car Driver	
	NTS	Gravity Model
Cars - Other, Non-Home-Based		10.3
Cars - Commuting	16.0	16.8

5.6.22 Together the calibration checks demonstrate that various aspects of the gravity model outputs replicate observed data well and that it is therefore sufficiently robust to be used as infill within the highway model prior trip matrices for movements that were not observed by mobile phone or RSI data.

5.7 Roadside Interview Matrices

Combining RSI Site Matrices

5.7.1 The ERICA software was used to combine expanded trip records at individual RSI sites into a single demand matrix. Within the process any double counting of trips between RSI sites is eliminated without the need to run traffic assignments.

5.7.2 The ERICA process relies on user defined watertight screenlines, which are drawn up in such a way that any trips crossing the screenlines would be captured by one of the RSIs. For example, the Usk River forms a natural barrier for trips between East and West Newport and all vehicular movements across the Usk bridges were intercepted by RSIs. The river was therefore used as one of the screenlines in the ERICA process.

5.7.3 Following these principles, the study area was split into six sectors with screenlines forming the boundaries between them. Where screenlines intercepted each other they were split into separate screenline segments.

5.7.4 Based on the above, the full set of ERICA inputs included the following files:

- SATURN zone to ERICA sector correspondence list;
- RSI site to screenline segment correspondence list; and
- Definition of which screenline segments must be crossed for each sector-to-sector movement.

Check of Output

5.7.5 Trip purpose splits of the private vehicle demand matrices produced in ERICA were checked against the 2012 version of the model in which the demand matrices were produced by an alternative methodology. The two sets of matrices showed a good correlation as shown in Table 5.6 below.

Table 5.6 Purpose Split of Private Vehicle Trips

2014 ERICA output			
	AM	IP	PM
Work	49%	18%	45%
Other	32%	64%	41%
Business	19%	18%	15%
2012 Validated Base Matrix			
	AM	IP	PM
Work	51%	19%	39%
Other	31%	63%	43%
Business	18%	18%	18%

5.7.6 The matrices produced in ERICA were converted to peak hour matrices by applying a global time period factor to each peak period matrix. These were assigned, and volumes at RSI site locations and on the M4 motorway around Newport were compared with count data. This check generally showed a good match between travel demand in the assignment and the corresponding observed count.

5.8 Highway Prior Trip Matrices

Overview of Data Combining Methodology

5.8.1 Following the creation of the individual mobile phone, RSI, synthetic and BYFM matrices, they were combined to form prior matrices, for the purpose of base model calibration and the variable demand model realism testing. The method of combining the data aimed to utilise data in order of hierarchy of data quality and robustness.

5.8.2 For car and light goods vehicle trips this was as follows:

- Mobile phone data;
- Roadside interview data;
- Synthetic data.

5.8.3 For heavy goods vehicles data was taken directly from BYFM in all areas. This was because none of the above data sources were able to provide information about goods vehicle movements with sufficient detail or accuracy. Whilst RSI data would have been able to provide some information about goods vehicles, the distribution obtained from RSIs is invariably ‘lumpy’ due to the low sample rates for HGVs at many sites and further data would have also been required to ensure that the full demand across the South East Wales region was correctly captured.

Appending RSI data to Mobile Phone Records

5.8.4 The mobile phone demand was sectored according to the sector system shown in Section 3.4.3. For convenience, Figure 3.7 is replicated below as Figure 5.11.

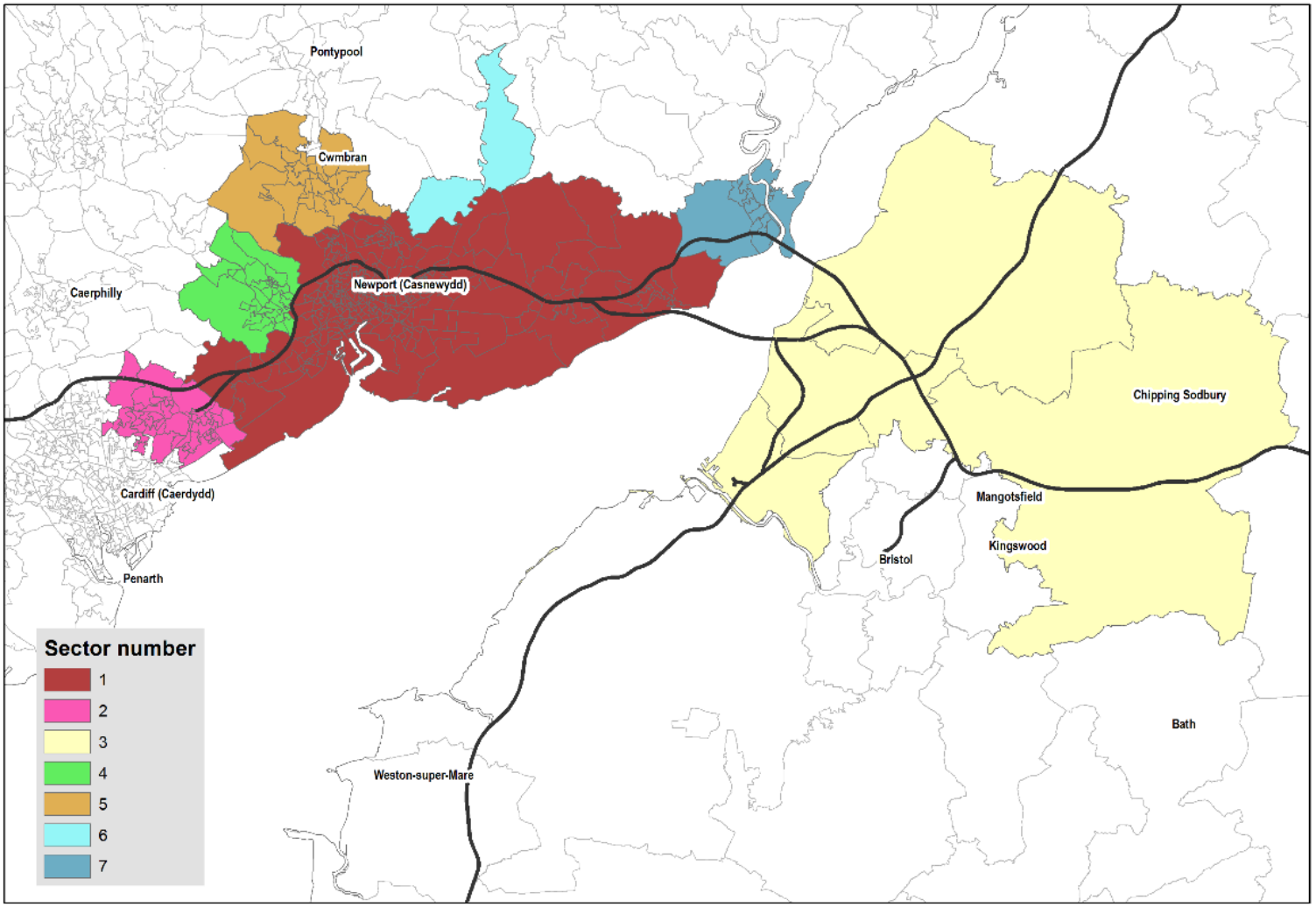


Figure 5.11 Sector System used for Mobile Phone Data Processing

5.8.5 Outside of the highlighted sectors no mobile phone data was collected. Trips within Sector 1, representing the wider Newport area were adopted directly from the mobile phone data. For trips with one or both trip ends within one of the other sectors RSI data was used to append trip end data. The distribution of the true origin/destination of these journeys was determined from the RSI observations. This was undertaken because it is a requirement for variable demand modelling for the demand matrix to represent the full journey between the true origin and destination, even when these lie outside of the Area of Detailed Modelling.

5.8.6 The appending of RSI data to mobile phone demand was based on the following methodology:

- A unit matrix was assigned onto the SATURN ITN network (using TrafficMaster speeds) that had already been developed at the synthetic matrix creation stage;
- Select link analyses were undertaken at cordon boundaries between Sector 1 and each of the other sectors by direction;
- Select link analyses were processed to create flag matrices that defined catchment areas of trip ends for each cordon entry or exit point;
- Separate catchment flag matrices were created for all possible combinations of entries and exits from the mobile phone cordon;
- These catchment flag matrices were each applied to the merged RSI data in turn;
- The above matrices were then factored to match travel demand totals observed in the mobile phone data for each sector-to-sector movement;
- The resulting output was combined and added to the processed mobile phone data containing trips internal to sector 1 only.

5.8.7 The above method ensured that outside of the core mobile phone data collection area (Sector 1 representing the wider area around Newport), the trip distribution was adopted directly from merged RSI data and that demand totals for each sector-to-sector movement travelling through the mobile phone cordon still matched the observations from the mobile phone dataset.

Freight demand

5.8.8 Freight demand was taken from BYFM, due to the lumpiness of data contained in both the TrafficMaster and RSI O-D data.

Synthetic Demand

5.8.9 The synthetic demand matrices derived using the gravity models were split from 24 hour AAWT matrices into separate peak period matrices

using time period factors derived from the combined roadside interview and mobile phone matrix that were described in Section 5.8.2. These factors are shown in Table 5.7.

Table 5.7 Time Period Factors applied to Synthetic Demand

Demand Segment	AM Period	IP Period	PM Period	OP Period
1 Cars – Commuting, from home	0.585	0.110	0.107	0.198
2 Cars – Commuting, to home	0.085	0.207	0.495	0.213
3 Cars – Other Purposes, from home	0.237	0.423	0.132	0.208
4 Cars – Other Purposes, to home	0.104	0.396	0.229	0.272
5 Cars – Other Purposes, non-home-based	0.247	0.410	0.220	0.123
6 Cars – Employers' Business, from home	0.303	0.387	0.135	0.175
7 Cars – Employers' Business, to home	0.053	0.396	0.290	0.261
8 Cars – Employers' Business, non-home-based	0.152	0.485	0.263	0.100
9 Light Goods Vehicles (LGVs)	0.245	0.361	0.189	0.205

5.8.10 The catchment flags for each sector-to-sector movement created to append the RSI data to mobile phone data were all combined into a single mask matrix, which was used to identify the O-D pairs that were fully observed by mobile phone / RSI data. Using this, a mask matrix was created to identify movements that had not already been captured by the combined mobile phone and RSI data. This was applied to the synthetic demand and the resulting matrix was added to the combined mobile phone and RSI matrix.

Incorporating RSI Demand on A40

5.8.11 The last step in the creation of the base year prior matrix was to replace synthetic demand where a higher quality data source was available.

5.8.12 As the only RSI site that was not within or near the mobile phone data collection area, Site 29 on theA40 at Raglan was incorporated into the

demand matrix separately. This was achieved by creating an assignment using the matrix that had been developed up to this point.

5.8.13 Using this assignment, a select link analysis was undertaken on the A40 at Raglan and the resulting output subtracted from the full trip matrix. To replace this, the expanded RSI matrices from site 29 were added in instead. This completed the prior matrix development.

6 Assignment Methodology

6.1 Assignment Algorithm

6.1.1 The assignment process predicts the routes that drivers would choose taking into account the level of traffic demand and the available road capacity. The assignment technique used in the updated M4CaN model is the Wardrop equilibrium assignment for multiple user classes. The principle of this assignment is that traffic arranges itself on the network such that the cost of travel on all routes used between each origin and destination is equal to the minimum cost of travel and all unused routes have equal or greater cost.

6.2 Generalised Costs

6.2.1 The generalised cost of travel is based on a combination of factors that drivers take into account when choosing routes, mainly time and distance. Generalised cost parameters are used in a SATURN model to represent travellers' value of time by pence per minute (PPM) and distance by pence per kilometre (PPK). Values of PPK and PPM can be set universally for the entire model or individually by user class. Where a choice of route exists (as in nearly all cases) these values are used to determine which available route has a lower 'cost' to the traveller. Thus if PPK value is high, low cost routes would be those which minimise distance, conversely if PPM is high low cost routes would be those that minimise the travel time.

The SATURN assignment procedure uses the following generalised time formulation:

*Generalised Time = Time + (PPK/PPM) * Distance + Toll / PPM.*

Where: PPM = pence per minute, and

PPK = pence per kilometre.

6.2.2 TAG Unit A1.3[11] provides monetary values of time, which can be used to derive values of time in an assignment model in terms of pence per minute (PPM). It also provides parameters to calculate fuel costs and non-fuel vehicle operating costs. When added together, the fuel and non-fuel elements give the total vehicle operating costs in terms of pence per kilometre (PPK) for different transport users. Unit A1.3 states that non-fuel vehicle operating costs are only perceived during work time, and so these have been omitted from the overall calculation of generalised costs for commuting and other trips. The

[11] Transport Analysis Guidance Unit A1.3, User and Provider Impacts, Department for Transport, November 2014

PPM and PPK parameters then give the overall generalised cost for each of the different user classes.

6.2.3 The generalised costs derived from TAG Unit A1.3 are calculated in 2010 prices. These have been converted to 2014 prices using national statistics on the change in average earnings and the GDP. The generalised cost parameters in 2014 prices used in the updated base model are shown in Table 6.1.

Table 6.1 Generalised Cost Parameter Values, 2014 Prices

	AM peak		Inter Peak		PM peak	
	PPM	**PPK**	**PPM**	**PPK**	**PPM**	**PPK**
Cars – Employers' Business	47.99	13.62	47.54	13.52	48.27	13.70
Cars – Other	15.59	7.52	17.12	7.45	17.07	7.54
Cars – Commuting	14.27	7.42	15.08	7.44	14.74	7.44
Light Goods Vehicle	25.92	16.29	23.95	16.45	24.71	16.29
Heavy Goods Vehicle	23.57	46.17	25.44	47.20	25.43	49.75

6.3 Assignment Convergence

6.3.1 Convergence of all transport models is required in order to ensure consistent and robust model results. In particular, there needs to be confidence that any differences reported by the model between a 'Do-Minimum' and a 'Do-Something' scenario are realistic and the direct result of the proposal, rather than relating to differing degrees of model convergence.

6.3.2 Guidance on the degree of model convergence is given in WebTAG[12]. The main measure of the convergence of a traffic assignment is the Delta statistic, or %GAP. This is the difference between the costs along the chosen routes and those along the minimum cost routes, expressed as a percentage of the minimum costs. WebTAG recommends a guideline target for the %GAP value of 0.1% or less.

6.3.3 In addition, WebTAG recommends that the proportion of links in which the changes in traffic volumes is less than 1% should be at least 98% for four consecutive iterations.

[12] Transport Analysis Guidance, Highway Assignment Modelling, Unit M3.1, Department for Transport, January 2014

6.3.4 Table 6.2 shows the level of convergence achieved by the updated M4CaN model for each time period. The results indicate that the model achieves a good level of convergence that complies with the criteria set out in WebTAG.

Table 6.2 M4 Model Convergence Statistics

	AM peak	Inter Peak	PM peak
Number of Iterations	14	16	15
'Delta' Function (%GAP)	0.045	0.0026	0.022
Percentage of link with flow change of less than 1% (final four iterations)	98.0 98.4 99.0 99.0	98.4 98.5 98.8 99.1	98.3 98.3 98.7 98.9

7 Model Calibration

7.1 Network Checks

7.1.1 Following the initial assignment of the 'prior' matrix, a matrix estimation procedure was undertaken to be consistent with the principles contained in WebTAG. Before commencing matrix estimation, it was important to ensure that the network was assigning trips in a realistic way to avoid matrix distortion due to network errors. For this reason, detailed checks were undertaken and corrections made before matrix estimation was started.

7.1.2 The network building print files produced by SATURN contain a great deal of information to facilitate the identification of errors in the network coding, and these were reviewed as part of the checking process. In addition to this, other checks were carried out, including:

- a review of link lengths, speeds and connectivity;
- a review of junction coding, including junction types, capacities and lane allocations;
- the checking of the minimum-cost routes through the network for selected traffic movements;
- select link analyses of the origin-destination pattern of trips using key links, including the Usk river crossings, and motorway links and slip roads, to identify any implausible movements; and
- a review of network attributes to identify locations of poor convergence, long delays and high volume/capacity ratios.

7.1.3 Following this process, the final base year SATURN networks were considered to accurately represent the physical layouts and operation of the highway network in the study area.

7.2 Matrix Estimation

7.2.1 Matrix estimation is a modelling technique that has become a standard feature in many traffic models. Essentially, its purpose is to produce a 'most likely' trip matrix that fits with available traffic count data. It is based on the theoretical procedure properly entitled 'Matrix Estimation from Maximum Entropy', and is generally referred to as ME2.

7.2.2 Essentially, the process uses an iterative procedure to find a set of balancing factors for the origin-destination movements on each counted link to ensure that the assigned flows match the counts within certain user-defined limits. ME2 can be used to create a new trip matrix from scratch, but the best results are obtained when it is used to update an existing or 'prior' trip matrix. Within the SATURN suite, this process is run through the SATME2 program.

7.2.3 In order to properly validate the traffic model, it is important that the traffic counts to be used for validation are not also used in the process of developing and calibrating the trip matrices. Validation needs to be completed against independent count data, which therefore cannot be used for matrix estimation purposes. The count data selected for matrix estimation, therefore, have not been used for the validation of the traffic model. Taking this into account, the count sites selected for the matrix estimation process were distributed across the network based on the need to update the 'prior' trip matrix in particular locations.

7.2.4 Successive applications of matrix estimation utilised the same defined 'prior' trip matrix as an input, to prevent the process magnifying specific matrix changes on successive runs. For each modelled time period, matrix estimation was applied separately to the different vehicle classes. This was essential for the purposes of the multi-user class assignment being used in the SATURN model, and required separate counts of cars, light goods and heavy vehicles to be used for the matrix estimation process.

7.2.5 WebTAG[13] suggests a set of benchmark criteria to be used to review the extent of changes due to matrix estimation. These criteria are outlined in Table 7.1 shown below.

Table 7.1 Significance of Matrix Estimation Changes

Measure	Benchmark Criteria
Matrix zonal cell values	Slope within 0.98 and 1.02 Intercept near zero R^2 in excess of 0.95
Matrix zonal trip ends	Slope within 0.99 and 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%

7.2.6 The guidance identifies that any exceedances do not mean that the model is unsuitable for the intended uses. The performance of the model should be reviewed against these criteria and exceedances should be examined and assessed for their importance particularly in relation to the area of influence of the scheme to be assessed. In relation to the M4CaN model, this was considered to cover the M4 corridor contained within the core simulation area of the model. The analysis excluded all intra-zonal movements from the matrices (which were not affected through matrix estimation).

[13] Transport Analysis Guidance, Highway Assignment Modelling, Unit M3.1, Department for Transport, January 2014

7.2.7 Table 7.2 provides a summary of the cell and trip end changes due to matrix estimation in line with the benchmarks provided within WebTAG. It can be seen that the changes made during the matrix estimation process are within the benchmark values provided in WebTAG in almost all cases. The only exceedances of the WebTAG benchmarks occur in the inter-peak model, with row totals showing a slope of 0.98 and an R^2 of 0.95. Although these are outside the benchmark values in WebTAG, the values are not considered to be unreasonably high given that the time period affected is the inter-peak.

Table 7.2 Matrix Estimation Changes to Zonal Cell Values and Trip Ends

	AM Peak			Inter-peak			PM Peak		
	Cell Values	Rows	Cols	Cell Values	Rows	Cols	Cell Values	Rows	Cols
Slope	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.99	0.99
Intercept	0	0	0	0	0	0	0	0	0
R^2	0.99	0.98	0.98	0.99	0.95	0.97	0.99	0.98	0.99

7.2.8 The changes in trip length distribution that result from matrix estimation are shown in Table 7.3. The results show that the changes in trip lengths fall within the benchmarks suggested by WebTAG.

Table 7.3 Changes in Trip Length (km) due to Matrix Estimation

	Mean			Standard Deviation		
	Pre-ME2	Post-ME2	% Diff	Pre-ME2	Post-ME2	% Diff
AM Peak	19.2	19.2	0%	40.0	41.0	2%
Inter Peak	22.3	22.0	-1%	51.6	51.6	0%
PM Peak	19.7	19.9	1%	43.0	45.3	5%

7.3 Traffic Flow Calibration

7.3.1 A standard method for checking model calibration and validation is to compare observed values against modelled. Acceptability guidelines on "goodness of fit" are given in WebTAG. These are presented in terms of percentage or absolute difference in modelled flows and GEH. The GEH statistic is a form of the chi square test that incorporates both relative and absolute errors. The GEH formula is outlined below:

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

where: GEH is the GEH statistic

M is the modelled flow; and

C is the observed flow.

7.3.2 Advice on acceptable criteria for traffic model calibration and validation is given in TAG Unit M3.1. The criteria for link flows are based on relative and absolute differences and the GEH statistic. These are summarised in Table 7.4.

Table 7.4 Flow Comparison Guidelines

Criteria and Measures	Acceptability Guideline
Assigned Hourly Flows Compared with Observed Flows	
Individual flows within 15% for flows 700 – 2700 vph	> 85% of cases
Individual flows within 100 vph for flows <700 vph	> 85% of cases
Individual flows within 400 vph for flows >2700 vph	> 85% of cases
Total screenline/cordon flows (>5 links) to be within 5%	All (or nearly all) screenlines
GEH Statistic	
Individual flows: GEH < 5.0	> 85% of cases

7.3.3 The screenlines used for model calibration are shown in Table 7.2. Tables 7.5 to 7.7 show a comparison of the observed traffic flows with the modelled flows following matrix estimation for the morning peak, inter-peak and evening peak hours respectively.

7.3.4 The latest guidance in TAG Unit M3.1 provides validation criteria only for screenlines with more than five links. This criteria is that, for all or nearly all of these screenlines, the sum of the observed and modelled flows should be within plus or minus 5% of each other. Previous WebTAG guidance also provided a GEH based criteria for screenlines of any length. This criteria was that all or nearly all screenlines should have a GEH of less than 4. Using either of these measures the model meets the validation criteria in each time period.

7.3.5 The results show that in most cases, the link flows and screenline totals meet the WebTAG criteria. This indicates that the model provides an accurate representation of base year traffic flows on the model network.

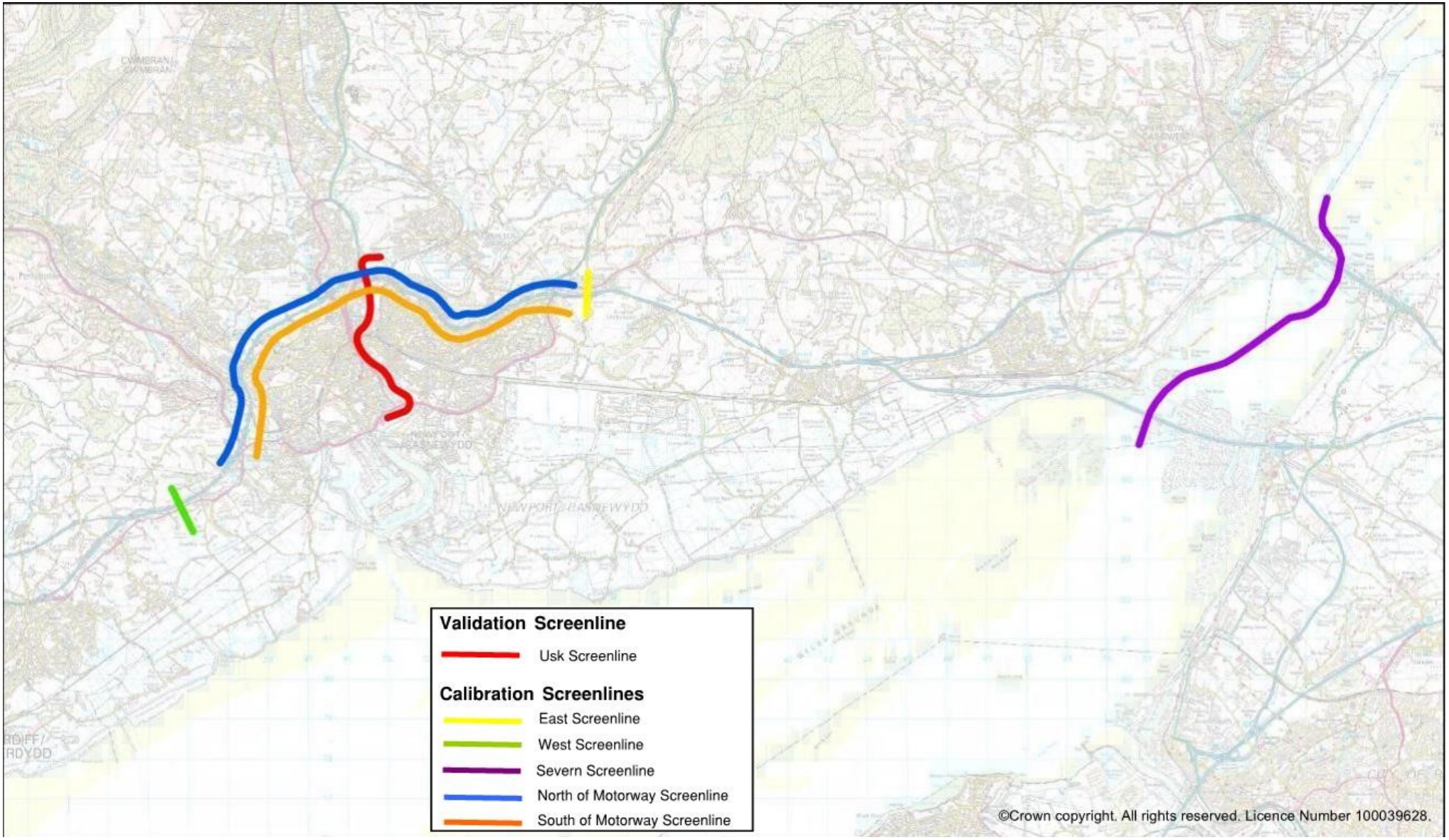


Figure 7.12 Calibration/Validation Screenlines

Table 7.5a Link Calibration Results (PCUs), AM peak Eastbound / Southbound / In to Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J24-J23a, eastbound	3,886	3,989	1.64	PASS	PASS
A48 east of J24, eastbound	881	857	0.81	PASS	PASS
East Screenline Total	**4,767**	**4,846**	**1.14**	**PASS**	**PASS**
West Screenline					
M4 J29-J28, eastbound	5,464	5,774	4.14	PASS	PASS
A48 Castleton, eastbound	1,287	1,262	0.70	PASS	PASS
West Screenline Total	**6,751**	**7,036**	**3.44**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, eastbound	1,230	1,247	0.48	PASS	PASS
M4 Second Severn Crossing, eastbound	3,077	3,060	0.31	PASS	PASS
Severn Screenline Total	**4,307**	**4,307**	**0.00**	**PASS**	**PASS**
North of Motorway Screenline					
A467 north of J28, southbound	1,351	1,109	6.92	FAIL	FAIL
B4591 north of J27, southbound	1,020	1,103	2.54	PASS	PASS
A4051 north of J26, southbound	2,168	2,175	0.15	PASS	PASS
A4042 Malpas Relief Road, southbound	2,418	2,449	0.63	PASS	PASS
B4596 north of J25, southbound	742	758	0.57	PASS	PASS
A449 north of J24, southbound	1,741	1,685	1.33	PASS	PASS
A48 east of J24, westbound	1,061	1,052	0.27	PASS	PASS
North of Motorway Screenline Total	**10,501**	**10,331**	**1.67**	**PASS**	**PASS**
South of Motorway Screenline					
A48 SDR east of J28, eastbound	1,827	1,727	2.38	PASS	PASS
B4591 Risca Rd, eastbound	991	940	1.64	PASS	PASS
A4051 south of J26, southbound	967	999	1.04	PASS	PASS
A4042 south of J25a, southbound	2,158	2,310	3.23	PASS	PASS
B4596 south of J25, southbound	590	597	0.27	PASS	PASS
B4237 west of J24, westbound	600	610	0.39	PASS	PASS
A48 SDR south of J24, southbound	1,084	1,047	1.13	PASS	PASS
South of Motorway Screenline Total	**8,217**	**8,230**	**0.15**	**PASS**	**PASS**
Motorway Links					
M4 J32-J30, eastbound	4,527	4,488	0.59	PASS	PASS
M4 J30-J29, eastbound	3,337	3,330	0.12	PASS	PASS
A48(M) J29a-J29, eastbound	2,127	2,088	0.85	PASS	PASS
M4 J23a-J23, eastbound	3,765	3,840	1.22	PASS	PASS
M48, east of M4, eastbound	688	780	3.42	PASS	PASS
Motorway Sliproads					
M4 J30 eastbound offslip	1,539	1,578	1.00	PASS	PASS
M4 J30 eastbound onslip	348	421	3.69	PASS	PASS
M4 J28 eastbound offslip	1,491	1,431	1.58	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 eastbound onslip	832	810	0.78	PASS	PASS
M4 J27 eastbound offslip	617	577	1.66	PASS	PASS
M4 J27 eastbound onslip	678	544	5.42	FAIL	FAIL
M4 J26 eastbound offslip	1,668	1,704	0.88	PASS	PASS
M4 J26 eastbound onslip	128	135	0.54	PASS	PASS
M4 J25a eastbound onslip	1,110	1,095	0.46	PASS	PASS
M4 J25 eastbound onslip	327	165	10.37	FAIL	FAIL
M4 J24 eastbound offslip	1,646	1,658	0.31	PASS	PASS
M4 J24 eastbound onslip	769	759	0.35	PASS	PASS
M4 J23a eastbound offslip	698	733	1.30	PASS	PASS
M4 J23a eastbound onslip	576	585	0.35	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, southbound	1,709	1,753	1.06	PASS	PASS
A48 west of A4232, eastbound	3,322	3,791	7.87	FAIL	FAIL
A48, A4232 to A48(M) J29a, eastbound	3,868	3,901	0.54	PASS	PASS
B4245 east of Magor rbt, eastbound	443	444	0.04	PASS	PASS
A48 west of Parkwall rbt, eastbound	215	225	0.71	PASS	PASS
A48 east of Parkwall rbt, eastbound	714	736	0.84	PASS	PASS
B4245 south of Parkwall rbt, southbound	497	563	2.90	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 7.5b Link Calibration Results (PCUs), AM peak Westbound / Northbound / Out from Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J23a-J24, westbound	3,641	3,438	3.40	PASS	PASS
A48 east of J24, westbound	1,061	1,025	1.12	PASS	PASS
East Screenline Total	**4,702**	**4,464**	**3.52**	**FAIL**	**PASS**
West Screenline					
M4 J28-J29, westbound	5,274	5,622	4.71	PASS	PASS
A48 Castleton, westbound	819	705	4.13	FAIL	PASS
West Screenline Total	**6,093**	**6,327**	**2.96**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, westbound	521	507	0.58	PASS	PASS
M4 Second Severn Crossing, westbound	2,526	2,344	3.69	PASS	PASS
Severn Screenline Total	**3,046**	**2,851**	**3.60**	**FAIL**	**PASS**
North of Motorway Screenline					
A467 north of J28, northbound	1,247	1,273	0.73	PASS	PASS
B4591 north of J27, northbound	543	510	1.42	PASS	PASS
A4051 north of J26, northbound	1,683	1,727	1.07	PASS	PASS
A4042 Malpas Relief Road, northbound	1,667	1,619	1.17	PASS	PASS
B4596 north of J25, northbound	533	536	0.14	PASS	PASS
A449 north of J24, northbound	1,123	1,184	1.79	PASS	PASS
A48 east of J24, eastbound	881	874	0.23	PASS	PASS
North of Motorway Screenline Total	**7,676**	**7,723**	**0.54**	**PASS**	**PASS**
South of Motorway Screenline					
A48 SDR east of J28, westbound	922	853	2.33	PASS	PASS
B4591 Risca Rd, westbound	1,141	1,206	1.91	PASS	PASS
A4051 south of J26, northbound	967	921	1.48	PASS	PASS
A4042 south of J25a, northbound	1,132	1,277	4.17	PASS	PASS
B4596 south of J25, northbound	804	782	0.80	PASS	PASS
B4237 west of J24, eastbound	547	549	0.06	PASS	PASS
A48 SDR south of J24, northbound	613	593	0.81	PASS	PASS
South of Motorway Screenline Total	**6,126**	**6,180**	**0.69**	**PASS**	**PASS**
Motorway Links					
M4 J30-J32, westbound	3,452	3,402	0.85	PASS	PASS
M4 J29-J30, westbound	3,443	3,428	0.26	PASS	PASS
A48(M) J29-J29a, westbound	1,832	2,017	4.21	PASS	PASS
M4 J23-J23a, westbound	3,211	3,061	2.68	PASS	PASS
M48, east of M4, westbound	685	717	1.20	PASS	PASS
Motorway Sliproads					
M4 J30 westbound offslip	672	827	5.64	FAIL	FAIL
M4 J30 westbound onslip	681	801	4.39	FAIL	PASS
M4 J28 westbound offslip	1,725	1,808	1.96	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 westbound onslip	1,063	1,175	3.35	PASS	PASS
M4 J27 westbound offslip	362	371	0.49	PASS	PASS
M4 J27 westbound onslip	929	1,050	3.87	PASS	PASS
M4 J26 westbound offslip	94	96	0.19	PASS	PASS
M4 J26 westbound onslip	1,968	1,966	0.06	PASS	PASS
M4 J25a westbound offslip	1,115	1,179	1.91	PASS	PASS
M4 J25 westbound offslip	173	164	0.75	PASS	PASS
M4 J24 westbound offslip	611	629	0.70	PASS	PASS
M4 J24 westbound onslip	1,755	1,772	0.42	PASS	PASS
M4 J23a westbound offslip	349	437	4.44	PASS	PASS
M4 J23a westbound onslip	779	708	2.58	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, northbound	1,442	1,462	0.51	PASS	PASS
A48 west of A4232, westbound	3,294	3,588	5.02	PASS	FAIL
A48, A4232 to A48(M) J29a, westbound	2,680	2,884	3.87	PASS	PASS
B4245 east of Magor rbt, westbound	971	989	0.55	PASS	PASS
A48 west of Parkwall rbt, westbound	168	173	0.33	PASS	PASS
A48 east of Parkwall rbt, westbound	490	496	0.27	PASS	PASS
B4245 south of Parkwall rbt, northbound	319	376	3.02	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 7.6a Link Calibration Results (PCUs), Inter-peak Eastbound / Southbound / In to Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J24-J23a, eastbound	3,034	3,027	0.13	PASS	PASS
A48 east of J24, eastbound	589	613	0.98	PASS	PASS
East Screenline Total	**3,623**	**3,640**	**0.29**	**PASS**	**PASS**
West Screenline					
M4 J29-J28, eastbound	3,936	4,052	1.84	PASS	PASS
A48 Castleton, eastbound	399	399	0.01	PASS	PASS
West Screenline Total	**4,334**	**4,451**	**1.76**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, eastbound	673	602	2.82	PASS	PASS
M4 Second Severn Crossing, eastbound	2,492	2,507	0.29	PASS	PASS
Severn Screenline Total	**3,165**	**3,109**	**1.01**	**PASS**	**PASS**
North of Motorway Screenline					
A467 north of J28, southbound	1,154	1,160	0.17	PASS	PASS
B4591 north of J27, southbound	575	547	1.17	PASS	PASS
A4051 north of J26, southbound	1,401	1,404	0.10	PASS	PASS
A4042 Malpas Relief Road, southbound	1,115	1,103	0.35	PASS	PASS
B4596 north of J25, southbound	497	489	0.36	PASS	PASS
A449 north of J24, southbound	1,091	1,035	1.73	PASS	PASS
A48 east of J24, westbound	629	625	0.16	PASS	PASS
North of Motorway Screenline Total	**6,461**	**6,363**	**1.23**	**PASS**	**PASS**
South of Motorway Screenline					
A48 SDR east of J28, eastbound	1,150	1,137	0.36	PASS	PASS
B4591 Risca Rd, eastbound	592	585	0.27	PASS	PASS
A4051 south of J26, southbound	888	844	1.50	PASS	PASS
A4042 south of J25a, southbound	1,086	1,119	1.00	PASS	PASS
B4596 south of J25, southbound	452	454	0.12	PASS	PASS
B4237 west of J24, westbound	400	401	0.03	PASS	PASS
A48 SDR south of J24, southbound	713	718	0.21	PASS	PASS
South of Motorway Screenline Total	**5,280**	**5,259**	**0.29**	**PASS**	**PASS**
Motorway Links					
M4 J32-J30, eastbound	2,649	2,735	1.65	PASS	PASS
M4 J30-J29, eastbound	2,426	2,449	0.47	PASS	PASS
A48(M) J29a-J29, eastbound	1,510	1,425	2.21	PASS	PASS
M4 J23a-J23, eastbound	2,978	2,929	0.90	PASS	PASS
M48, east of M4, eastbound	486	422	2.98	PASS	PASS
Motorway Sliproads					
M4 J30 eastbound offslip	450	510	2.75	PASS	PASS
M4 J30 eastbound onslip	227	225	0.12	PASS	PASS
M4 J28 eastbound offslip	764	912	5.10	FAIL	FAIL

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 eastbound onslip	678	763	3.15	PASS	PASS
M4 J27 eastbound offslip	231	242	0.69	PASS	PASS
M4 J27 eastbound onslip	271	267	0.20	PASS	PASS
M4 J26 eastbound offslip	1,040	1,069	0.87	PASS	PASS
M4 J26 eastbound onslip	81	81	0.01	PASS	PASS
M4 J25a eastbound onslip	600	677	3.05	PASS	PASS
M4 J25 eastbound onslip	208	92	9.51	FAIL	FAIL
M4 J24 eastbound offslip	1,168	1,188	0.58	PASS	PASS
M4 J24 eastbound onslip	464	538	3.28	PASS	PASS
M4 J23a eastbound offslip	462	494	1.49	PASS	PASS
M4 J23a eastbound onslip	406	417	0.56	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, southbound	635	636	0.04	PASS	PASS
A48 west of A4232, eastbound	2,321	2,297	0.49	PASS	PASS
A48, A4232 to A48(M) J29a, eastbound	2,253	2,170	1.76	PASS	PASS
B4245 east of Magor rbt, eastbound	475	481	0.28	PASS	PASS
A48 west of Parkwall rbt, eastbound	183	188	0.37	PASS	PASS
A48 east of Parkwall rbt, eastbound	504	511	0.31	PASS	PASS
B4245 south of Parkwall rbt, southbound	319	362	2.36	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 7.6b Link Calibration Results (PCUs), Inter-peak Westbound / Northbound / Out from Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J23a-J24, westbound	2,644	2,786	2.73	PASS	PASS
A48 east of J24, westbound	629	639	0.37	PASS	PASS
East Screenline Total	**3,273**	**3,424**	**2.62**	**PASS**	**PASS**
West Screenline					
M4 J28-J29, westbound	3,764	3,854	1.46	PASS	PASS
A48 Castleton, westbound	411	412	0.05	PASS	PASS
West Screenline Total	**4,175**	**4,266**	**1.40**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, westbound	580	554	1.08	PASS	PASS
M4 Second Severn Crossing, westbound	2,067	2,160	2.03	PASS	PASS
Severn Screenline Total	**2,647**	**2,715**	**1.31**	**PASS**	**PASS**
North of Motorway Screenline					
A467 north of J28, northbound	1,172	1,184	0.35	PASS	PASS
B4591 north of J27, northbound	690	672	0.66	PASS	PASS
A4051 north of J26, northbound	1,276	1,263	0.38	PASS	PASS
A4042 Malpas Relief Road, northbound	1,227	1,204	0.67	PASS	PASS
B4596 north of J25, northbound	518	522	0.14	PASS	PASS
A449 north of J24, northbound	1,053	967	2.71	PASS	PASS
A48 east of J24, eastbound	589	605	0.68	PASS	PASS
North of Motorway Screenline Total	**6,525**	**6,417**	**1.35**	**PASS**	**PASS**
South of Motorway Screenline					
A48 SDR east of J28, westbound	1,275	1,152	3.54	PASS	PASS
B4591 Risca Rd, westbound	589	592	0.11	PASS	PASS
A4051 south of J26, northbound	880	878	0.06	PASS	PASS
A4042 south of J25a, northbound	1,100	1,171	2.10	PASS	PASS
B4596 south of J25, northbound	574	558	0.70	PASS	PASS
B4237 west of J24, eastbound	384	386	0.10	PASS	PASS
A48 SDR south of J24, northbound	709	697	0.45	PASS	PASS
South of Motorway Screenline Total	**5,512**	**5,433**	**1.06**	**PASS**	**PASS**
Motorway Links					
M4 J30-J32, westbound	2,626	2,685	1.15	PASS	PASS
M4 J29-J30, westbound	2,348	2,352	0.08	PASS	PASS
A48(M) J29-J29a, westbound	1,416	1,353	1.69	PASS	PASS
M4 J23-J23a, westbound	2,560	2,649	1.74	PASS	PASS
M48, east of M4, westbound	493	489	0.21	PASS	PASS
Motorway Sliproads					
M4 J30 westbound offslip	240	232	0.56	PASS	PASS
M4 J30 westbound onslip	518	565	2.01	PASS	PASS
M4 J28 westbound offslip	577	679	4.04	FAIL	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 westbound onslip	852	874	0.73	PASS	PASS
M4 J27 westbound offslip	397	399	0.13	PASS	PASS
M4 J27 westbound onslip	240	228	0.80	PASS	PASS
M4 J26 westbound offslip	82	84	0.22	PASS	PASS
M4 J26 westbound onslip	1,127	1,132	0.17	PASS	PASS
M4 J25a westbound offslip	605	729	4.80	FAIL	PASS
M4 J25 westbound offslip	201	106	7.66	PASS	FAIL
M4 J24 westbound offslip	432	510	3.62	PASS	PASS
M4 J24 westbound onslip	1,195	1,224	0.83	PASS	PASS
M4 J23a westbound offslip	360	372	0.60	PASS	PASS
M4 J23a westbound onslip	443	477	1.58	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, northbound	669	679	0.38	PASS	PASS
A48 west of A4232, westbound	2,249	2,227	0.46	PASS	PASS
A48, A4232 to A48(M) J29a, westbound	2,193	2,129	1.39	PASS	PASS
B4245 east of Magor rbt, westbound	433	440	0.35	PASS	PASS
A48 west of Parkwall rbt, westbound	195	206	0.77	PASS	PASS
A48 east of Parkwall rbt, westbound	495	508	0.58	PASS	PASS
B4245 south of Parkwall rbt, northbound	298	342	2.44	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 7.7a Link Calibration Results (PCUs), PM peak Eastbound / Southbound / In to Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J24-J23a, eastbound	3,202	3,218	0.28	PASS	PASS
A48 east of J24, eastbound	935	986	1.63	PASS	PASS
East Screenline Total	**4,137**	**4,204**	**1.03**	**PASS**	**PASS**
West Screenline					
M4 J29-J28, eastbound	5,034	5,342	4.28	PASS	PASS
A48 Castleton, eastbound	891	662	8.20	FAIL	FAIL
West Screenline Total	**5,925**	**6,211**	**3.67**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, eastbound	627	668	1.62	PASS	PASS
M4 Second Severn Crossing, eastbound	2,273	2,427	3.18	PASS	PASS
Severn Screenline Total	**2,899**	**3,094**	**3.56**	**FAIL**	**PASS**
North of Motorway Screenline					
A467 north of J28, southbound	1,336	1,319	0.48	PASS	PASS
B4591 north of J27, southbound	535	532	0.11	PASS	PASS
A4051 north of J26, southbound	1,939	1,914	0.56	PASS	PASS
A4042 Malpas Relief Road, southbound	1,563	1,570	0.16	PASS	PASS
B4596 north of J25, southbound	527	518	0.39	PASS	PASS
A449 north of J24, southbound	1,301	1,191	3.13	PASS	PASS
A48 east of J24, westbound	957	939	0.59	PASS	PASS
North of Motorway Screenline Total	**8,159**	**7,983**	**1.96**	**PASS**	**PASS**
South of Motorway Screenline					
A48 SDR east of J28, eastbound	1,092	1,140	1.43	PASS	PASS
B4591 Risca Rd, eastbound	835	761	2.61	PASS	PASS
A4051 south of J26, southbound	1,124	1,030	2.86	PASS	PASS
A4042 south of J25a, southbound	1,336	1,438	2.73	PASS	PASS
B4596 south of J25, southbound	624	639	0.60	PASS	PASS
B4237 west of J24, westbound	758	702	2.05	PASS	PASS
A48 SDR south of J24, southbound	871	949	2.59	PASS	PASS
South of Motorway Screenline Total	**6,640**	**6,660**	**0.24**	**PASS**	**PASS**
Motorway Links					
M4 J32-J30, eastbound	3,178	3,257	1.38	PASS	PASS
M4 J30-J29, eastbound	2,910	2,911	0.02	PASS	PASS
A48(M) J29a-J29, eastbound	2,125	2,322	4.19	PASS	PASS
M4 J23a-J23, eastbound	2,953	3,066	2.06	PASS	PASS
M48, east of M4, eastbound	681	640	1.59	PASS	PASS
Motorway Sliproads					
M4 J30 eastbound offslip	745	747	0.08	PASS	PASS
M4 J30 eastbound onslip	477	401	3.59	PASS	PASS
M4 J28 eastbound offslip	1,386	1,310	2.07	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 eastbound onslip	1,334	1,127	5.91	FAIL	FAIL
M4 J27 eastbound offslip	616	572	1.79	PASS	PASS
M4 J27 eastbound onslip	333	296	2.08	PASS	PASS
M4 J26 eastbound offslip	1,861	1,932	1.63	PASS	PASS
M4 J26 eastbound onslip	104	100	0.43	PASS	PASS
M4 J25a eastbound onslip	964	944	0.66	PASS	PASS
M4 J25 eastbound onslip	308	126	12.33	FAIL	FAIL
M4 J24 eastbound offslip	1,611	1,604	0.17	PASS	PASS
M4 J24 eastbound onslip	599	604	0.20	PASS	PASS
M4 J23a eastbound offslip	670	648	0.85	PASS	PASS
M4 J23a eastbound onslip	421	439	0.86	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, southbound	1,405	1,437	0.85	PASS	PASS
A48 west of A4232, eastbound	3,260	3,569	5.29	PASS	FAIL
A48, A4232 to A48(M) J29a, eastbound	3,307	3,507	3.42	PASS	PASS
B4245 east of Magor rbt, eastbound	966	980	0.45	PASS	PASS
A48 west of Parkwall rbt, eastbound	194	194	0.00	PASS	PASS
A48 east of Parkwall rbt, eastbound	561	564	0.13	PASS	PASS
B4245 south of Parkwall rbt, southbound	365	414	2.47	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 7.7b Link Calibration Results (PCUs), PM peak Westbound / Northbound / Out from Newport

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
East Screenline					
M4 J23a-J24, westbound	3,988	3,917	1.14	PASS	PASS
A48 east of J24, westbound	957	955	0.07	PASS	PASS
East Screenline Total	**4,945**	**4,872**	**1.05**	**PASS**	**PASS**
West Screenline					
M4 J28-J29, westbound	5,162	5,440	3.81	PASS	PASS
A48 Castleton, westbound	1,097	1,005	2.84	PASS	PASS
West Screenline Total	**6,259**	**6,445**	**2.33**	**PASS**	**PASS**
Severn Screenline					
M48 Severn Bridge, westbound	1,471	1,276	5.26	FAIL	FAIL
M4 Second Severn Crossing, westbound	3,108	3,055	0.95	PASS	PASS
Severn Screenline Total	**4,579**	**4,332**	**3.71**	**FAIL**	**PASS**
North of Motorway Screenline					
A467 north of J28, northbound	1,897	1,896	0.04	PASS	PASS
B4591 north of J27, northbound	1,159	1,245	2.50	PASS	PASS
A4051 north of J26, northbound	2,027	2,077	1.10	PASS	PASS
A4042 Malpas Relief Road, northbound	1,926	2,118	4.28	PASS	PASS
B4596 north of J25, northbound	788	844	1.94	PASS	PASS
A449 north of J24, northbound	1,364	1,354	0.26	PASS	PASS
A48 east of J24, eastbound	935	992	1.82	PASS	PASS
North of Motorway Screenline Total	**10,097**	**10,526**	**4.23**	**PASS**	**FAIL**
South of Motorway Screenline					
A48 SDR east of J28, westbound	1,122	1,042	2.43	PASS	PASS
B4591 Risca Rd, westbound	895	897	0.07	PASS	PASS
A4051 south of J26, northbound	1,362	1,167	5.49	FAIL	FAIL
A4042 south of J25a, northbound	1,905	1,854	1.16	PASS	PASS
B4596 south of J25, northbound	802	778	0.86	PASS	PASS
B4237 west of J24, eastbound	491	522	1.37	PASS	PASS
A48 SDR south of J24, northbound	957	944	0.41	PASS	PASS
South of Motorway Screenline Total	**7,534**	**7,205**	**3.84**	**PASS**	**PASS**
Motorway Links					
M4 J30-J32, westbound	3,854	3,872	0.29	PASS	PASS
M4 J29-J30, westbound	3,029	3,032	0.06	PASS	PASS
A48(M) J29-J29a, westbound	2,133	2,151	0.40	PASS	PASS
M4 J23-J23a, westbound	4,003	4,024	0.33	PASS	PASS
M48, east of M4, westbound	895	968	2.41	PASS	PASS
Motorway Sliproads					
M4 J30 westbound offslip	398	380	0.92	PASS	PASS
M4 J30 westbound onslip	1,223	1,219	0.11	PASS	PASS
M4 J28 westbound offslip	943	937	0.19	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
M4 J28 westbound onslip	1,063	1,344	8.10	FAIL	FAIL
M4 J27 westbound offslip	704	700	0.16	PASS	PASS
M4 J27 westbound onslip	423	427	0.19	PASS	PASS
M4 J26 westbound offslip	152	153	0.06	PASS	PASS
M4 J26 westbound onslip	1,846	1,854	0.18	PASS	PASS
M4 J25a westbound offslip	824	829	0.20	PASS	PASS
M4 J25 westbound offslip	324	162	10.44	FAIL	FAIL
M4 J24 westbound offslip	893	909	0.55	PASS	PASS
M4 J24 westbound onslip	1,681	1,683	0.04	PASS	PASS
M4 J23a westbound offslip	551	543	0.33	PASS	PASS
M4 J23a westbound onslip	536	510	1.12	PASS	PASS
Miscellaneous Sites					
A4232 south of J30, northbound	1,183	1,162	0.60	PASS	PASS
A48 west of A4232, westbound	3,409	3,715	5.12	PASS	FAIL
A48, A4232 to A48(M) J29a, westbound	3,683	3,683	0.00	PASS	PASS
B4245 east of Magor rbt, westbound	451	455	0.18	PASS	PASS
A48 west of Parkwall rbt, westbound	269	273	0.26	PASS	PASS
A48 east of Parkwall rbt, westbound	725	742	0.64	PASS	PASS
B4245 south of Parkwall rbt, northbound	454	513	2.68	PASS	PASS
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

8 Model Validation

8.1 Introduction

8.1.1 Validation is the process of demonstrating the quality of the model by comparing the model output with observed data, which should be independent of data used for model calibration. This section outlines the outcomes from the M4 model validation process.

8.2 Flow Validation

8.2.1 The WebTAG requirements for flow validation are shown in Table 7.4. For the M4CaN model, validation was carried out on the mainline motorway links between Junction 23a and 29, together with a screenline of links crossing the Usk River in the Newport area, as shown in Figure 7.12. Tables 8.1 to 8.3 provide a comparison between modelled and observed flows on the validation links.

8.2.2 The results show that, in the PM peak and inter-peak hours, the validation of flows on the motorway links between Junction 23a and Junction 29 passed both the flow and GEH criteria in all cases. The AM peak hour has only one link that fails the GEH criteria, but this passes the flow criteria. This shows that the model provides an accurate representation of existing traffic volumes on the M4 around Newport.

8.2.3 The flows crossing the Usk River screenline pass the validation criteria, with only some individual counts failing the criteria during certain time periods.

8.2.4 Overall, the validation of the traffic flows on the mainline motorway and the Usk River screenline exceeded the WebTAG requirements, with over 85% of the modelled flows passing the flow/GEH criteria in all three time periods.

8.2.5 As well as checking the mainline motorway flows and the flows crossing the Usk River screenline as part of the validation process, a number of miscellaneous sites within Newport, which are on less critical links, were also checked. When these links were included in the model validation statistics, the AM and PM peak hour models still met the WebTAG GEH requirement and the inter-peak model reached 83%. This shows that the matrix validates well against independent counts.

Table 8.1 AM peak Flow Validation (PCUs)

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
Motorway Eastbound Flows					
M4, J29-J28, eastbound	5,464	5,774	4.14	PASS	PASS
M4, J28-J27, eastbound	4,805	5,153	4.94	PASS	PASS
M4, J27-J26, eastbound	4,866	5,207	4.81	PASS	PASS
M4, J26-J25a, eastbound	3,326	3,626	5.09	PASS	FAIL
M4, J25a-J25, eastbound	4,436	4,691	3.78	PASS	PASS
M4, J25-J24, eastbound	4,763	4,856	1.34	PASS	PASS
M4, J24-J23a, eastbound	3,886	3,989	1.64	PASS	PASS
Motorway Westbound Flows					
M4, J28-J29, westbound	5,274	5,622	4.71	PASS	PASS
M4, J27-J28, westbound	5,937	6,255	4.07	PASS	PASS
M4, J26-J27, westbound	5,370	5,505	1.82	PASS	PASS
M4, J25a-J26, westbound	3,496	3,600	1.74	PASS	PASS
M4, J25-J25a, westbound	4,610	4,544	0.99	PASS	PASS
M4, J24-J25, westbound	4,784	4,707	1.11	PASS	PASS
M4, J23a-J24, westbound	3,641	3,438	3.40	PASS	PASS
Usk Screenline, Eastbound Flows					
M4, J26-J25a, eastbound	3,326	3,626	5.09	PASS	FAIL
Brynglas Relief Rd, eastbound to J25a	1,727	1,621	2.58	PASS	PASS
B4591 Newport Bridge, eastbound	1,061	1,034	0.83	PASS	PASS
B4237 George Street Bridge, eastbound	689	444	10.29	FAIL	FAIL
A48 SDR Bridge, eastbound	1,501	1,523	0.56	PASS	PASS
Usk Screenline, Eastbound Total	**8,304**	**8,249**	**0.61**	**PASS**	**PASS**
Usk Screenline, Westbound Flows					
M4, J25a-J26, westbound	3,496	3,600	1.74	PASS	PASS
Brynglas Relief Rd, westbound from J25a	2,001	1,987	0.32	PASS	PASS
B4591 Newport Bridge, westbound	897	793	3.60	PASS	PASS
B4237 George Street Bridge, westbound	1,030	849	5.93	FAIL	FAIL
A48 SDR Bridge, westbound	1,526	1,583	1.43	PASS	PASS
Usk Screenline, Westbound Total	**8,951**	**8,811**	**1.49**	**PASS**	**PASS**
Newport Miscellaneous Sites					
B4591 Risca Rd e of Fields Park Rd, e/b	556	508	2.10	PASS	PASS
B4591 Risca Rd e of Fields Park Rd, w/b	343	333	0.51	PASS	PASS
B4591 Queensway e of Bridge St, e/b	948	947	0.03	PASS	PASS
B4591 Queensway e of Bridge St, w/b	966	1085	3.71	PASS	PASS
A4042 slips s of Harlequin rbt, n/b	242	219	1.57	PASS	PASS
A4042 slips s of Harlequin rbt, s/b	495	333	7.96	FAIL	FAIL
B4591 slips s of Harlequin rbt, n/b	585	644	2.37	PASS	PASS
B4591 slips s of Harlequin rbt, s/b	1,013	1,041	0.87	PASS	PASS
B4237 Cardiff Rd, e of Mendalgief Rd, e/b	616	688	2.79	PASS	PASS
B4237 Cardiff Rd, e of Mendalgief Rd, w/b	749	603	5.64	FAIL	FAIL
A48 SDR, w of Alexandra Rd, e/b	1,093	1,070	0.71	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
A48 SDR, w of Alexandra Rd, w/b	1,259	1,187	2.08	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, n/b	253	273	1.22	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, s/b	219	259	2.54	PASS	PASS
B4591 Chepstow Rd, w of Wharf Rd, e/b	546	601	2.33	PASS	PASS
B4591 Chepstow Rd, w of Wharf Rd, w/b	463	547	3.74	PASS	PASS
B4591 Chepstow Rd, e of Somerton Rd, e/b	627	643	0.63	PASS	PASS
B4591 Chepstow Rd, e of Somerton Rd, w/b	932	884	1.61	PASS	PASS
A48 SDR, e of Queensway Meadows, e/b	634	631	0.12	PASS	PASS
A48 SDR, e of Queensway Meadows, w/b	1,233	1,212	0.61	PASS	PASS
OVERALL PERCENTAGE MEETING CRITERIA				**90%**	**88%**
TOTAL ACCEPTABILITY CRITERIA				**PASS**	**PASS**

Table 8.2 Inter-peak Flow Validation (PCUs)

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
Motorway Eastbound Flows					
M4, J29-J28, eastbound	3,936	4,052	1.84	PASS	PASS
M4, J28-J27, eastbound	3,849	3,903	0.85	PASS	PASS
M4, J27-J26, eastbound	3,889	3,936	0.74	PASS	PASS
M4, J26-J25a, eastbound	2,930	2,935	0.09	PASS	PASS
M4, J25a-J25, eastbound	3,530	3,520	0.16	PASS	PASS
M4, J25-J24, eastbound	3,738	3,612	2.08	PASS	PASS
M4, J24-J23a, eastbound	3,034	3,027	0.13	PASS	PASS
Motorway Westbound Flows					
M4, J28-J29, westbound	3,764	3,854	1.46	PASS	PASS
M4, J27-J28, westbound	3,489	3,659	2.84	PASS	PASS
M4, J26-J27, westbound	3,646	3,817	2.79	PASS	PASS
M4, J25a-J26, westbound	2,602	2,738	2.65	PASS	PASS
M4, J25-J25a, westbound	3,206	3,356	2.61	PASS	PASS
M4, J24-J25, westbound	3,407	3,462	0.93	PASS	PASS
M4, J23a-J24, westbound	2,644	2,786	2.73	PASS	PASS
Usk Screenline, Eastbound Flows					
M4, J26-J25a, eastbound	2930	2,935	0.09	PASS	PASS
Brynglas Relief Rd, eastbound to J25a	1106	1,124	0.55	PASS	PASS
B4591 Newport Bridge, eastbound	942	897	1.47	PASS	PASS
B4237 George Street Bridge, eastbound	541	678	5.54	FAIL	FAIL
A48 SDR Bridge, eastbound	1322	1,330	0.20	PASS	PASS
Usk Screenline, Eastbound Total	**6,841**	**6,964**	**1.48**	**PASS**	**PASS**
Usk Screenline, Westbound Flows					
M4, J25a-J26, westbound	2,602	2,738	2.65	PASS	PASS
Brynglas Relief Rd, westbound from J25a	1,205	1,173	0.93	PASS	PASS
B4591 Newport Bridge, westbound	924	820	3.50	PASS	PASS
B4237 George Street Bridge, westbound	527	627	4.15	PASS	PASS
A48 SDR Bridge, westbound	1,323	1,413	2.42	PASS	PASS
Usk Screenline, Westbound Total	**6,580**	**6,771**	**2.33**	**PASS**	**PASS**
Newport Miscellaneous Sites					
B4591 Risca Rd e of Fields Park Rd, e/b	330	295	1.98	PASS	PASS
B4591 Risca Rd e of Fields Park Rd, w/b	325	283	2.36	PASS	PASS
B4591 Queensway e of Bridge St, e/b	733	750	0.60	PASS	PASS
B4591 Queensway e of Bridge St, w/b	734	860	4.45	PASS	PASS
A4042 slips s of Harlequin rbt, n/b	227	337	6.54	FAIL	FAIL
A4042 slips s of Harlequin rbt, s/b	341	277	3.64	PASS	PASS
B4591 slips s of Harlequin rbt, n/b	590	704	4.47	FAIL	PASS
B4591 slips s of Harlequin rbt, s/b	692	704	0.44	PASS	PASS
B4237 Cardiff Rd, e of Mendalgief Rd, e/b	486	610	5.31	FAIL	FAIL
B4237 Cardiff Rd, e of Mendalgief Rd, w/b	731	596	5.25	FAIL	FAIL
A48 SDR, w of Alexandra Rd, e/b	1,107	1,053	1.64	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
A48 SDR, w of Alexandra Rd, w/b	1,086	1,024	1.91	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, n/b	202	277	4.82	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, s/b	137	217	5.96	PASS	FAIL
B4591 Chepstow Rd, w of Wharf Rd, e/b	322	622	13.84	FAIL	FAIL
B4591 Chepstow Rd, w of Wharf Rd, w/b	303	548	11.90	FAIL	FAIL
B4591 Chepstow Rd, e of Somerton Rd, e/b	630	698	2.64	PASS	PASS
B4591 Chepstow Rd, e of Somerton Rd, w/b	884	817	2.28	PASS	PASS
A48 SDR, e of Queensway Meadows, e/b	957	953	0.15	PASS	PASS
A48 SDR, e of Queensway Meadows, w/b	1,037	1,043	0.19	PASS	PASS
OVERALL PERCENTAGE MEETING CRITERIA				**83%**	**83%**
TOTAL ACCEPTABILITY CRITERIA				**FAIL**	**FAIL**

Table 8.3 PM peak Flow Validation (PCUs)

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
Motorway Eastbound Flows					
M4, J29-J28, eastbound	5,034	5,342	4.28	PASS	PASS
M4, J28-J27, eastbound	4,982	5,159	2.49	PASS	PASS
M4, J27-J26, eastbound	4,699	4,915	3.11	PASS	PASS
M4, J26-J25a, eastbound	2,942	3,126	3.34	PASS	PASS
M4, J25a-J25, eastbound	3,906	3,982	1.20	PASS	PASS
M4, J25-J24, eastbound	4,214	4,108	1.64	PASS	PASS
M4, J24-J23a, eastbound	3,202	3,218	0.28	PASS	PASS
Motorway Westbound Flows					
M4, J28-J29, westbound	5,162	5,440	3.81	PASS	PASS
M4, J27-J28, westbound	5,042	5,033	0.13	PASS	PASS
M4, J26-J27, westbound	5,323	5,268	0.75	PASS	PASS
M4, J25a-J26, westbound	3,629	3,589	0.67	PASS	PASS
M4, J25-J25a, westbound	4,452	4,572	1.79	PASS	PASS
M4, J24-J25, westbound	4,777	4,734	0.62	PASS	PASS
M4, J23a-J24, westbound	3,988	3,917	1.14	PASS	PASS
Usk Screenline, Eastbound Flows					
M4, J26-J25a, eastbound	2,942	3,126	3.34	PASS	PASS
Brynglas Relief Rd, eastbound to J25a	1,819	1,508	7.62	FAIL	FAIL
B4591 Newport Bridge, eastbound	1,134	1,202	1.98	PASS	PASS
B4237 George Street Bridge, eastbound	845	906	2.05	PASS	PASS
A48 SDR Bridge, eastbound	1,593	1,572	0.52	PASS	PASS
Usk Screenline, Eastbound Total	**8,333**	**8,314**	**0.21**	**PASS**	**PASS**
Usk Screenline, Westbound Flows					
M4, J25a-J26, westbound	3,629	3,589	0.67	PASS	PASS
Brynglas Relief Rd, westbound from J25a	1,613	1,722	2.65	PASS	PASS
B4591 Newport Bridge, westbound	928	977	1.58	PASS	PASS
B4237 George Street Bridge, westbound	722	652	2.70	PASS	PASS
A48 SDR Bridge, westbound	1,277	1,422	3.93	PASS	PASS
Usk Screenline, Westbound Total	**8,170**	**8,360**	**2.10**	**PASS**	**PASS**
Newport Miscellaneous Sites					
B4591 Risca Rd e of Fields Park Rd, e/b	415	366	2.47	PASS	PASS
B4591 Risca Rd e of Fields Park Rd, w/b	447	415	1.57	PASS	PASS
B4591 Queensway e of Bridge St, e/b	1,127	1,032	2.88	PASS	PASS
B4591 Queensway e of Bridge St, w/b	1,037	1,116	2.42	PASS	PASS
A4042 slips s of Harlequin rbt, n/b	508	306	9.98	FAIL	FAIL
A4042 slips s of Harlequin rbt, s/b	394	217	10.11	FAIL	FAIL
B4591 slips s of Harlequin rbt, n/b	888	1,101	6.75	FAIL	FAIL
B4591 slips s of Harlequin rbt, s/b	822	843	0.74	PASS	PASS
B4237 Cardiff Rd, e of Mendalgief Rd, e/b	695	710	0.56	PASS	PASS
B4237 Cardiff Rd, e of Mendalgief Rd, w/b	787	673	4.21	FAIL	PASS
A48 SDR, w of Alexandra Rd, e/b	1,129	1,074	1.67	PASS	PASS

	Modelled Flow	Observed Flow	GEH	Flow Criteria	GEH Criteria
A48 SDR, w of Alexandra Rd, w/b	1,042	983	1.86	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, n/b	350	430	4.04	PASS	PASS
B4596 Caerleon Rd, s of Duckpool Rd, s/b	125	257	9.59	FAIL	FAIL
B4591 Chepstow Rd, w of Wharf Rd, e/b	683	712	1.08	PASS	PASS
B4591 Chepstow Rd, w of Wharf Rd, w/b	597	642	1.84	PASS	PASS
B4591 Chepstow Rd, e of Somerton Rd, e/b	848	883	1.21	PASS	PASS
B4591 Chepstow Rd, e of Somerton Rd, w/b	1,160	980	5.50	FAIL	FAIL
A48 SDR, e of Queensway Meadows, e/b	1,270	1,226	1.23	PASS	PASS
A48 SDR, e of Queensway Meadows, w/b	1,023	1,044	0.65	PASS	PASS
OVERALL PERCENTAGE MEETING CRITERIA				**83%**	**86%**
TOTAL ACCEPTABILITY CRITERIA				**FAIL**	**PASS**

8.3 Proportion of Heavy Goods Vehicles

8.3.1 In addition to the traffic flow validation, additional checks were made on the percentage of Heavy Goods Vehicles (HGVs) modelled on the motorway. The proportion of HGVs is important for use in the environmental assessment of air quality and noise.

8.3.2 Tables 8.4 to 8.6 show the modelled and observed volumes of HGVs on the motorway links around Newport. The results show that the HGV volumes and their percentage of total flow on the motorway links in the model closely represent the observed situation.

8.3.3 Note that the flows in Tables 8.4 to 8.6 are in terms of vehicles, whereas all other flows in this report are quoted in terms of PCUs.

Table 8.4 HGV Flow Validation, AM peak

Link	Total Vehicles		HGVs		Percentage HGVs	
	Observed	Modelled	Observed	Modelled	Observed	Modelled
M4 J32-J30, e/b	3,958	3,981	353	364	8.9%	9.1%
M4 J30-J29, e/b	2,855	2,864	316	315	11.1%	11.0%
A48(M) J29a-J29, e/b	1,925	1,993	109	90	5.6%	4.5%
M4 J29-J28, e/b	5,099	4,857	450	405	8.8%	8.3%
M4 J28-J27, e/b	4,583	4,303	380	335	8.3%	7.8%
M4 J27-J26, e/b	4,630	4,355	384	340	8.3%	7.8%
M4 J26-J25a, e/b	3,170	2,887	304	293	9.6%	10.1%
M4 J25-J24, e/b	4,302	4,180	370	388	8.6%	9.3%
M4 J24-J23a, e/b	3,436	3,317	369	379	10.7%	11.4%
M4 J23a-J23, e/b	3,284	3,180	371	390	11.3%	12.3%
M48 J23 (M4)-J2, e/b	696	605	56	55	8.0%	9.1%
M4 J23-J22, e/b	2,587	2,575	315	335	12.2%	13.0%
Average Percentage HGVs					**9.3%**	**9.5%**
M4 J30-J32, w/b	2,798	2,845	402	405	14.4%	14.2%
M4 J29-J30, w/b	2,846	2,862	388	387	13.6%	13.5%
A48(M) J29-J29a, w/b	1,851	1,649	111	122	6.0%	7.4%
M4 J28-J29, w/b	4,843	4,511	519	509	10.7%	11.3%
M4 J27-J28, w/b	5,500	5,278	504	439	9.2%	8.3%
M4 J26-J27, w/b	4,749	4,721	504	433	10.6%	9.2%
M4 J25a-J26, w/b	2,959	2,935	427	374	14.4%	12.7%
M4 J24-J25, w/b	3,992	4,007	477	518	11.9%	12.9%
M4 J23a-J24, w/b	2,903	3,000	357	427	12.3%	14.2%
M4 J23-J23a, w/b	2,512	2,576	366	424	14.6%	16.4%
M48 J2-J23 (M4), w/b	608	591	73	63	12.0%	10.6%
M4 J22-J23, w/b	1,904	1,985	293	361	15.4%	18.2%
Average Percentage HGVs					**12.1%**	**12.4%**

Table 8.5 HGV Flow Validation, Inter-peak

Link	Total Vehicles		HGVs		Percentage HGVs	
	Observed	Modelled	Observed	Modelled	Observed	Modelled
M4 J32-J30, e/b	2,169	2,116	377	355	17.4%	16.8%
M4 J30-J29, e/b	1,932	1,909	345	344	17.9%	18.0%
A48(M) J29a-J29, e/b	1,306	1,312	79	131	6.0%	10.0%
M4 J29-J28, e/b	3,323	3,222	486	476	14.6%	14.8%
M4 J28-J27, e/b	3,221	3,171	454	452	14.1%	14.3%
M4 J27-J26, e/b	3,260	3,210	450	453	13.8%	14.1%
M4 J26-J25a, e/b	2,334	2,326	401	403	17.2%	17.3%
M4 J25-J24, e/b	2,949	3,038	442	467	15.0%	15.4%
M4 J24-J23a, e/b	2,401	2,434	417	400	17.4%	16.4%
M4 J23a-J23, e/b	2,308	2,338	414	427	18.0%	18.3%
M48 J23 (M4)-J2, e/b	360	396	42	60	11.6%	15.0%
M4 J23-J22, e/b	1,948	1,941	373	367	19.1%	18.9%
Average Percentage HGVs					**15.2%**	**15.8%**
M4 J30-J32, w/b	2,206	2,171	319	303	14.5%	14.0%
M4 J29-J30, w/b	1,909	1,906	295	295	15.4%	15.5%
A48(M) J29-J29a, w/b	1,238	1,235	77	121	6.2%	9.8%
M4 J28-J29, w/b	3,231	3,140	415	416	12.8%	13.2%
M4 J27-J28, w/b	3,066	2,908	396	388	12.9%	13.3%
M4 J26-J27, w/b	3,218	3,052	399	396	12.4%	13.0%
M4 J25a-J26, w/b	2,229	2,084	340	345	15.2%	16.6%
M4 J24-J25, w/b	2,885	2,821	384	391	13.3%	13.9%
M4 J23a-J24, w/b	2,295	2,190	327	302	14.2%	13.8%
M4 J23-J23a, w/b	2,127	2,060	348	333	16.4%	16.2%
M48 J2-J23 (M4), w/b	417	410	48	56	17.5%	13.6%
M4 J22-J23, w/b	1,711	1,651	300	278	25.9%	16.8%
Average Percentage HGVs					**13.5%**	**14.1%**

Table 8.6 HGV Flow Validation, PM peak

Link	Total Vehicles		HGVs		Percentage HGVs	
	Observed	Modelled	Observed	Modelled	Observed	Modelled
M4 J32-J30, e/b	2,912	2,877	230	200	7.9%	7.0%
M4 J30-J29, e/b	2,581	2,581	220	219	8.5%	8.5%
A48(M) J29a-J29, e/b	2,241	2,009	54	77	2.4%	3.8%
M4 J29-J28, e/b	4,906	4,591	291	295	5.9%	6.4%
M4 J28-J27, e/b	4,742	4,573	278	272	5.9%	6.0%
M4 J27-J26, e/b	4,465	4,294	299	270	6.7%	6.3%
M4 J26-J25a, e/b	2,751	2,562	250	253	9.1%	9.9%
M4 J25-J24, e/b	3,721	3,718	258	330	6.9%	8.9%
M4 J24-J23a, e/b	2,828	2,779	260	282	9.2%	10.2%
M4 J23a-J23, e/b	2,575	2,497	328	304	12.7%	12.2%
M48 J23 (M4)-J2, e/b	591	593	33	58	5.6%	9.8%
M4 J23-J22, e/b	1,984	1,904	295	246	14.9%	12.9%
Average Percentage HGVs					**8.0%**	**8.5%**
M4 J30-J32, w/b	3,614	3,625	172	153	4.8%	4.2%
M4 J29-J30, w/b	2,774	2,776	172	169	6.2%	6.1%
A48(M) J29-J29a, w/b	2,074	2,062	51	47	2.5%	2.3%
M4 J28-J29, w/b	5,094	4,839	230	216	4.5%	4.5%
M4 J27-J28, w/b	4,700	4,673	222	246	4.7%	5.3%
M4 J26-J27, w/b	4,932	4,943	224	254	4.5%	5.1%
M4 J25a-J26, w/b	3,291	3,275	198	236	6.0%	7.2%
M4 J24-J25, w/b	4,382	4,353	234	283	5.3%	6.5%
M4 J23a-J24, w/b	3,623	3,596	196	262	5.4%	7.3%
M4 J23-J23a, w/b	3,603	3,568	280	290	7.8%	8.1%
M48 J2-J23 (M4), w/b	881	834	58	41	6.6%	4.9%
M4 J22-J23, w/b	2,722	2,735	222	249	8.2%	9.1%
Average Percentage HGVs					**5.5%**	**5.9%**

8.4 Journey Time Validation

8.4.1 The purpose of journey time validation is to show that the model is correctly replicating journey times on critical routes. The WebTAG criterion for journey time comparisons is that the modelled journey times should be within 15% of the observed time (or one minute if higher) on at least 85% of routes surveyed.

8.4.2 Journey time surveys were carried out on 12 key routes through the Area of Detailed Modelling, as shown in Figure 8.1, together with a further eight strategic routes in the Rest of Modelled Areas, shown in Figure 8.2.

8.4.3 The journey time comparisons for the Area of Detailed Modelling routes in the morning and evening peak periods are shown in Tables 8.7 to 8.9, while those for the strategic routes are given in Tables 8.10

to 8.12. Graphs illustrating the cumulative modelled and observed journey times for the surveyed routes are given in Appendix D.

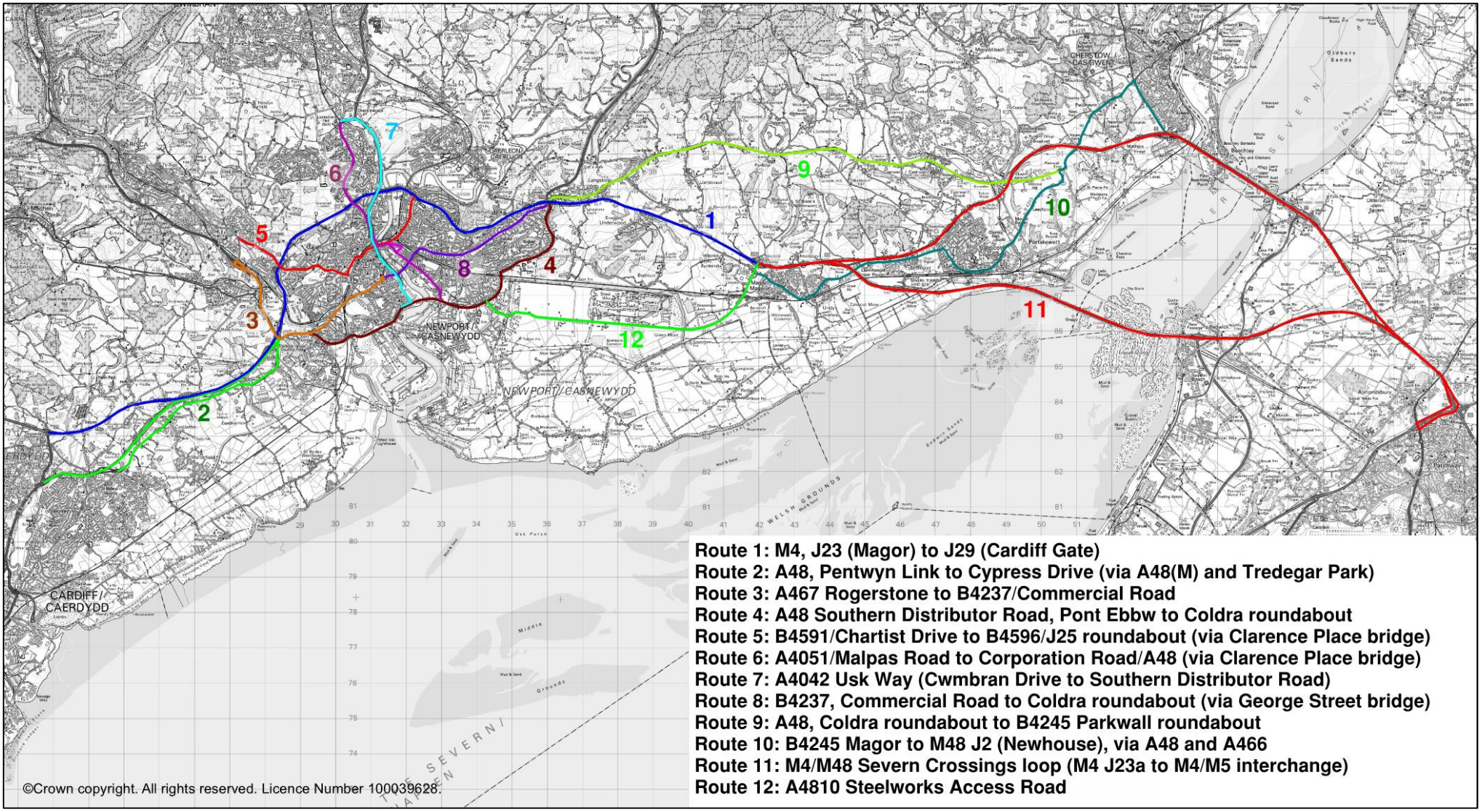


Figure 8.1 Journey Time Routes in the Core Simulation Area

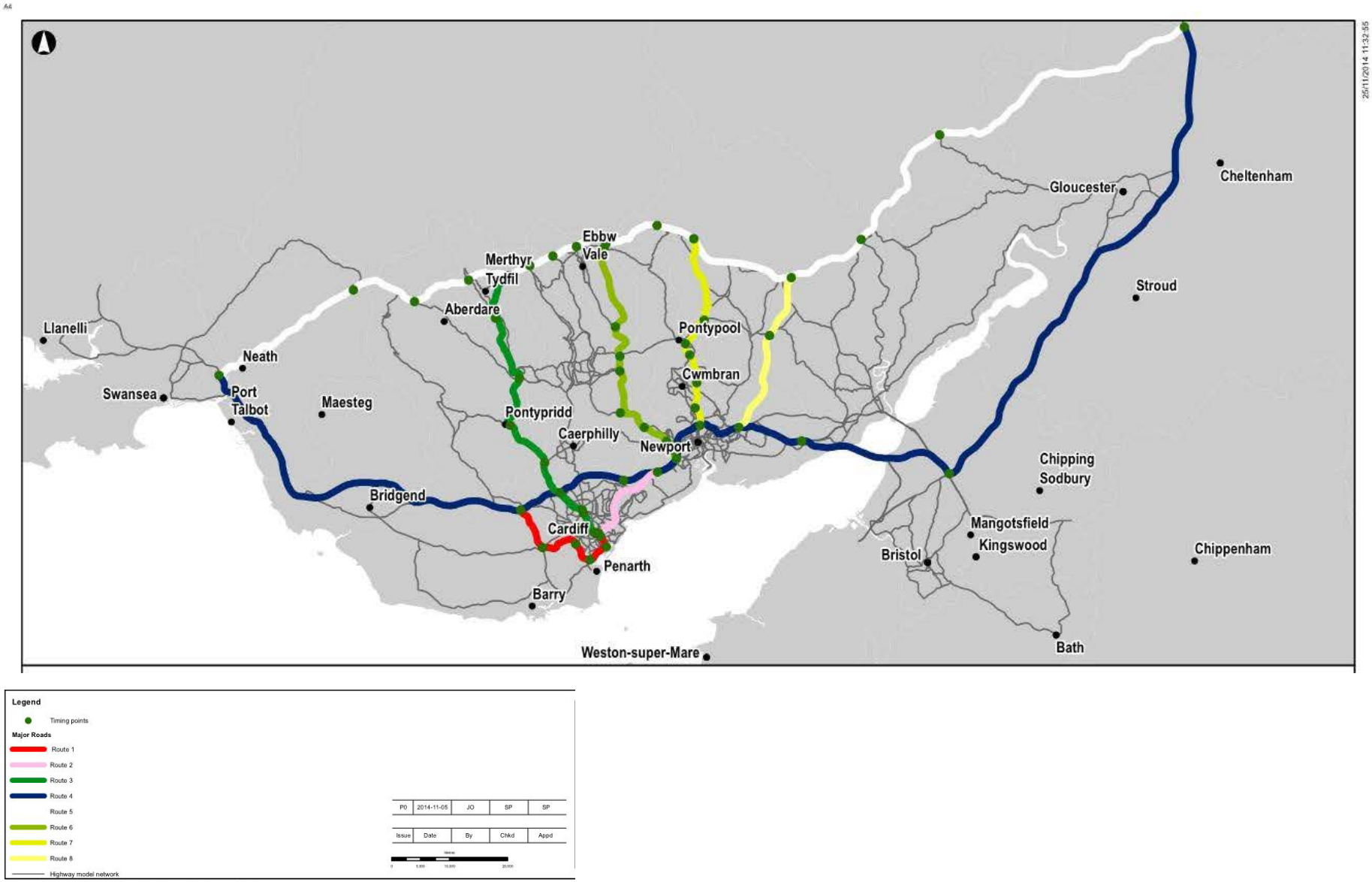


Figure 8.2 Strategic Journey Time Routes

8.4.5 The results show that the validation of journey times in each of the modelled time periods meets the WebTAG requirements on all of the surveyed routes, indicating a robust representation of the network operation in the Area of Detailed Modelling.

Table 8.7 AM peak Journey Time Validation, Area of Detailed Modelling Routes

No	Route Description		Average Observed Time (mins:secs)	Modelled Time (mins:secs)	% diff from avge	WebTAG Criteria
1	M4, J23a to J30	east west	17:08 16:52	15:52 16:57	-7% 1%	PASS PASS
2	A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28)	anti c/wise c/wise	17:55 17:34	17:37 15:59	-2% -9%	PASS PASS
3	A467/B4591 Rogerstone to B4237/Kingsway	east west	15:37 11:28	13:14 11:37	-15% 1%	PASS PASS
4	A48 SDR, Pont Ebbw rbt to M4 J24	east west	11:06 11:11	11:50 12:55	7% 16%	PASS FAIL
5	B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge)	east west	14:57 14:38	12:23 13:33	-17% -7%	FAIL PASS
6	A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd	south north	16:02 15:58	14:45 15:39	-8% -2%	PASS PASS
7	A4042 Usk Way, Cwmbran Drive to A48 SDR	south north	08:55 08:06	08:45 08:32	-2% 5%	PASS PASS
8	B4237, M4 J24 to Kingsway	east west	09:34 11:17	09:25 12:42	-2% 13%	PASS PASS
9	A48, M4 J24 to B4245 Parkwall rbt	east west	12:57 13:06	13:02 13:07	1% 0%	PASS PASS
10	B4245 Magor rbt to M48 J2	east west	19:13 18:14	20:27 18:43	6% 3%	PASS PASS
11	M4 / M48 Severn crossings loop, between J23a and M5 interchange	anti c/wise c/wise	29:59 30:16	29:01 29:03	-3% -4%	PASS PASS
12	A4810	east west	11:24 10:28	11:03 10:46	-3% 3%	PASS PASS
TOTAL ACCEPTABILITY CRITERIA						**92%**

Table 8.8 Inter-peak Journey Time Validation, Area of Detailed Modelling Routes

No	Route Description		Average Observed Time (mins:secs)	Modelled Time (mins:secs)	% diff from avge	WebTAG Criteria
1	M4, J23a to J30	east	14:57	14:52	0%	PASS
		west	15:38	15:01	-4%	PASS
2	A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28)	anti c/wise	14:21	14:08	-1%	PASS
		c/wise	14:35	13:59	-4%	PASS
3	A467/B4591 Rogerstone to B4237/Kingsway	east	10:44	12:57	21%	FAIL
		west	10:33	10:05	-4%	PASS
4	A48 SDR, Pont Ebbw rbt to M4 J24	east	11:45	12:01	2%	PASS
		west	11:41	11:30	-2%	PASS
5	B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge)	east	13:22	11:45	-12%	PASS
		west	14:26	14:51	3%	PASS
6	A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd	south	15:14	15:49	4%	PASS
		north	14:37	14:42	1%	PASS
7	A4042 Usk Way, Cwmbran Drive to A48 SDR	south	09:09	08:51	-3%	PASS
		north	08:41	08:06	-7%	PASS
8	B4237, M4 J24 to Kingsway	east	10:30	10:15	-2%	PASS
		west	13:20	13:23	0%	PASS
9	A48, M4 J24 to B4245 Parkwall rbt	east	13:16	12:57	-2%	PASS
		west	14:03	12:42	-10%	PASS
10	B4245 Magor rbt to M48 J2	east	18:59	19:24	2%	PASS
		west	18:42	17:47	-5%	PASS
11	M4 / M48 Severn crossings loop, between J23a and M5 interchange	anti c/wise	30:07	28:28	-5%	PASS
		c/wise	31:41	28:35	-10%	PASS
12	A4810	east	10:46	10:52	1%	PASS
		west	10:57	10:34	-4%	PASS
TOTAL ACCEPTABILITY CRITERIA						**96%**

Table 8.9 PM peak Journey Time Validation, Area of Detailed Modelling Routes

No	Route Description		Average Observed Time (mins:secs)	Modelled Time (mins:secs)	% diff from avge	WebTAG Criteria
1	M4, J23a to J30	east	15:38	15:14	-3%	PASS
		west	20:02	17:13	-14%	PASS
2	A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28)	anti c/wise	16:48	16:36	-1%	PASS
		c/wise	15:18	15:39	2%	PASS
3	A467/B4591 Rogerstone to B4237/Kingsway	east	11:11	11:29	3%	PASS
		west	15:35	18:20	18%	FAIL
4	A48 SDR, Pont Ebbw rbt to M4 J24	east	11:41	12:22	6%	PASS
		west	12:31	11:26	-9%	PASS
5	B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge)	east	13:26	12:54	-4%	PASS
		west	16:16	14:50	-9%	PASS
6	A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd	south	16:27	15:54	-3%	PASS
		north	16:21	16:37	2%	PASS
7	A4042 Usk Way, Cwmbran Drive to A48 SDR	south	09:27	08:45	-7%	PASS
		north	10:46	09:07	-15%	PASS
8	B4237, M4 J24 to Kingsway	east	11:06	11:01	-1%	PASS
		west	13:01	13:45	6%	PASS
9	A48, M4 J24 to B4245 Parkwall rbt	east	12:57	13:15	2%	PASS
		west	13:21	12:54	-3%	PASS
10	B4245 Magor rbt to M48 J2	east	19:53	20:33	3%	PASS
		west	19:29	18:37	-4%	PASS
11	M4 / M48 Severn crossings loop, between J23a and M5 interchange	anti c/wise	31:08	28:59	-7%	PASS
		c/wise	33:03	29:29	-11%	PASS
12	A4810	east	10:24	11:06	7%	PASS
		west	11:07	10:44	-3%	PASS
TOTAL ACCEPTABILITY CRITERIA						**96%**

Table 8.10 AM peak Journey Time Validation, Strategic Routes

No	Route Description		Average Observed Time (h:mins:secs)	Modelled Time (h:mins:secs)	Percentage Difference
1	A4232, Junction 33 to Cardiff Bay	south north	0:13:57 0:13:34	0:15:12 0:12:43	9% -6%
2	A48(M) Junction 29 to Cardiff City Centre via A4161 Newport Rd	east west	0:16:38 0:19:13	0:17:24 0:25:44	5% 34%
3	A470 Cardiff City Centre to A465/A4060 Dowlais Top	south north	0:44:03 0:36:44	0:39:52 0:37:50	-10% 3%
4	M4 Junction 43 to M5 Junction 8 via M4 Second Severn Crossing	east west	1:43:17 1:43:36	1:46:42 1:46:28	3% 3%
5	M4 Junction 43 to M5 Junction 8 via A465/A40/M50	east west	1:38:55 1:43:05	1:33:18 1:36:53	-6% -6%
6	A467 from Junction 28, Newport to A465 Brynmawr	south north	0:35:30 0:32:05	0:31:25 0:26:44	-12% -17%
7	A4042 from Junction 25A, Newport to A40/A465, Abergavenny	south north	0:22:01 0:22:10	0:26:12 0:19:50	19% -11%
8	A449 from Junction 24, Newport to A40 Raglan	south north	0:12:27 0:11:49	0:14:20 0:12:28	15% 5%

Table 8.11 Inter-peak Journey Time Validation, Strategic Routes

No	Route Description		Average Observed Time (h:mins:secs)	Modelled Time (h:mins:secs)	Percentage Difference
1	A4232, Junction 33 to Cardiff Bay	south north	0:12:57 0:13:29	0:11:35 0:11:47	-11% -13%
2	A48(M) Junction 29 to Cardiff City Centre via A4161 Newport Rd	east west	0:15:44 0:14:54	0:13:03 0:12:29	-17% -16%
3	A470 Cardiff City Centre to A465/A4060 Dowlais Top	south north	0:38:00 0:37:32	0:27:38 0:32:03	-27% -15%
4	M4 Junction 43 to M5 Junction 8 via M4 Second Severn Crossing	east west	1:40:05 1:44:38	1:42:52 1:43:39	3% -1%
5	M4 Junction 43 to M5 Junction 8 via A465/A40/M50	east west	1:39:02 1:40:43	1:32:30 1:34:12	-7% -6%
6	A467 from Junction 28, Newport to A465 Brynmawr	south north	0:31:27 0:31:57	0:25:54 0:25:27	-18% -20%
7	A4042 from Junction 25A, Newport to A40/A465, Abergavenny	south north	0:21:56 0:22:25	0:18:36 0:19:01	-15% -15%
8	A449 from Junction 24, Newport to A40 Raglan	South north	0:12:21 0:11:48	0:13:13 0:12:24	7% 5%

Table 8.12 PM peak Journey Time Validation, Strategic Routes

No	Route Description		Average Observed Time (h:mins:secs)	Modelled Time (h:mins:secs)	Percentage Difference
1	A4232, Junction 33 to Cardiff Bay	south north	0:14:09 0:18:17	0:12:17 0:14:53	-13% -19%
2	A48(M) Junction 29 to Cardiff City Centre via A4161 Newport Rd	east west	0:20:48 0:16:24	0:26:54 0:19:08	29% 17%
3	A470 Cardiff City Centre to A465/A4060 Dowlais Top	south north	0:41:00 0:44:11	0:29:54 0:54:14	-27% 23%
4	M4 Junction 43 to M5 Junction 8 via M4 Second Severn Crossing	east west	1:40:31 1:57:21	1:44:13 1:50:40	4% -6%
5	M4 Junction 43 to M5 Junction 8 via A465/A40/M50	east west	1:36:30 1:43:50	1:39:40 1:48:32	3% 5%
6	A467 from Junction 28, Newport to A465 Brynmawr	south north	0:30:44 0:32:27	0:27:42 0:29:15	-10% -10%
7	A4042 from Junction 25A, Newport to A40/A465, Abergavenny	south north	0:21:31 0:24:38	0:20:17 0:19:40	-6% -20%
8	A449 from Junction 24, Newport to A40 Raglan	south north	0:12:00 0:11:16	0:13:24 0:12:35	12% 12%

8.5 Summary of Model Validation

8.5.1 This chapter has described the highway models' representation of baseline traffic conditions in 2014. Traffic flows at key locations on the highway network, the percentage HGVs on motorway links and journey times along important corridors have all been checked against observed data. The overall match falls well within the bounds of WebTAG requirements and as such the model is considered to provide a good representation of existing conditions on the highway network in South East Wales in 2014.

9 Public Transport Model

9.1 Overview

9.1.1 The public transport model supplies the VDM with zone-to-zone bus and rail passenger trips, times and costs. The trips come from a set of base matrices developed specifically for the M4CaN using bus and rail passenger counts and surveys. The times and costs come from an EMME public transport assignment model, which allows the trips to be loaded onto the networks and enables skimming of zone-to-zone public transport times and costs.

9.1.2 The public transport model has been designed specifically to provide public transport inputs to the M4CaN VDM. It is not designed to forecast public transport impacts, passenger volumes or benefits of other highway or public transport projects. The model provides the public transport demands and times/costs required to enable mode choice modelling within the VDM forecasting for the Scheme.

Model Coverage

9.1.3 Public transport demand was considered to be in-scope in the context of the M4CaN where:

- the passengers are able to switch to car; and
- the passengers would travel in the M4 corridor if they switched.

9.1.4 The first criterion restricts demand to 'car available' (CA) trips. Individuals with no car available are effectively captive to PT and cannot switch to car.

9.1.5 The second criterion requires that the route taken (in an equivalent trip by car) would be in the corridor of the Scheme and could potentially affect flows on the M4 and competing/feeding roads.

9.1.6 Rail services tend to have a high proportion of 'car available' travellers and consequently a high level of competition with car. At the other end of the spectrum are coach services and low frequency local buses, particularly those operating outside the main cities where the market is dominated by concessionary pass users, with low levels of car availability.

9.1.7 The filtering process resulted in the following inclusions:

- All rail journeys in the corridor Cardiff – Newport – Chepstow / Severn Tunnel including all through trips such as London to Swansea.
- All bus journeys between Newport and Cardiff.

9.1.8 The included services are summarised in Table 9.1.

Table 9.1 Included Services

Mode	Service	Operator
Rail	Carmarthen, Swansea and Cardiff – London Paddington	First Great Western
Rail	West Wales, Swansea and Cardiff – Manchester, Chester, North Wales	Arriva Trains Wales
Rail	Cardiff – Taunton	First Great Western
Rail	Cardiff – Portsmouth Harbour	First Great Western
Rail	Cardiff – Birmingham, Nottingham	Cross Country
Rail	Maesteg – Cardiff – Cheltenham	Arriva Trains Wales
Rail	Cardiff – Ebbw Vale	Arriva Trains Wales
Bus	X30 Newport – Cardiff Express	Newport Bus
Bus	30 Newport – Cardiff	Newport Bus & Cardiff Bus

9.1.9 The following low frequency bus and coach services operating in corridor east of Newport area, or passing around Newport, were excluded:

- Megabus (M7) and National Express (201/202, 509) coach services
- X3 Cardiff - Pontypool
- 62 Newport – Caldicot
- X74/73/74 Newport – Chepstow
- X7 Newport – Bristol
- 100 Swansea – Bristol Airport

9.1.10 These services were excluded on the basis of their limited ability to impact on highway flows due to low frequency, low capacity, low car availability, low level of competition with cars, or because they do not serve the relevant corridor.

9.1.11 All trip movements (O-D pairs) served by the 30 and X30 buses were considered to be in-scope.

9.1.12 All rail O-D pairs via the Cardiff-Newport, Newport-Chepstow and Newport-Severn Tunnel arcs were considered to be in-scope. However, when interchanging is accounted for, there are a large number of O-D combinations. In this instance, demand was aggregated to sectors or groups of stations in outer areas. These groups were used for long distance trips to/from External Areas where accurate access/egress times were not necessary (access costs make up only a very small proportion of total generalised cost on long distance flows; furthermore, long distance generalised costs are damped in the VDM, making any accuracy in this regard rather spurious).

Time Periods

9.1.13 The VDM developed for the M4CaN transport model operates on a production/attraction (P/A) matrix at the daily (24 hour weekday) level. The public transport demand input to the VDM has been developed for each of four time periods in P/A format for the VDM and in O-D format for assignment.

9.1.14 The public transport assignment model, which provides the public transport times and costs, has been prepared for an average hour within the AM peak, PM peak and inter-peak periods, to be consistent with the highway modelled periods within the VDM:

- Weekday AM peak: average hour 07:00-10:00
- Weekday inter-peak: average hour 10:00-16:00
- Weekday PM peak: average hour 16:00-19:00

9.1.15 A set of time period factors has been prepared to convert between daily trips and trips in each assignment time period. In calculating these factors, it has been assumed that a trip is included in the time slice if it passes midway between Cardiff and Newport inside the time slice in question.

9.1.16 The public transport base model has been developed to simulate current demand and network conditions for May 2014, to be consistent with the highway assignment model.

Zones

9.1.17 The M4 public transport model zone plan is the same as that adopted for the highway assignment model to ensure a consistent approach in the VDM.

9.2 Public Transport Networks

9.2.1 Table 9.2 summarises the data used to create service timetables for the public transport model.

Table 9.2 Data Sources for Public Transport Network

Item	Source
'All Wales' MOIRA model	ATOC/Welsh Government
Traveline bus timetables for Cardiff and Newport	Traveline National Data Set

Rail network

9.2.2 Base year rail service timetables were created from the 'May 2014 All Wales' MOIRA model provided by the Welsh Government. To encompass all services that pass through the study area, this included

all services to, from or through South and Mid Wales, plus all services via Swindon and Great Malvern.

9.2.3 Figure 9.1 shows the existing rail network in the South Wales area, although the modelled rail network extends much further than this.

Figure 9.1 Existing Rail Network in the South Wales Area

9.2.4 Time periods were assigned to services based on departure time at the listed stations. For example, all services that depart Cardiff Central between 7:00am and 9:59am were assigned to the AM peak. Time catchments for other stations were offset from Cardiff Central.

9.2.5 The model zones are connected to the rail stations through centroid connectors. Centroid connector times were calculated based on multi-modal travel times, and the proportion of car and non-car users in relation to access/egress distances to/from the rail stations.

Bus Network

9.2.6 The bus service network was created from Traveline National Data Set service timetables and National Public Transport Access Nodes database service stop locations. The 30 and X30 service routes and stops in the study area were coded from this data. Model zones are connected to service stops through centroid connectors and centroid connector distances were prepared to represent average walk times.

9.3 Public Transport Demand

9.3.1 Table 9.3 summarises the data used to create the public transport demand matrices.

Table 9.3 Data Sources for Public Transport Demand

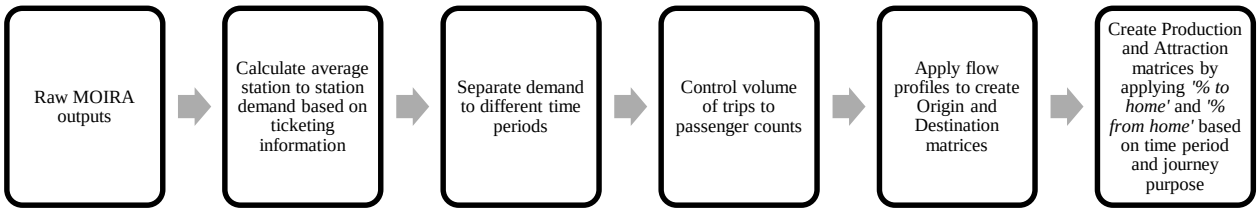
Item	Provider
ETM data for Routes X30 and 30	Newport Bus
ETM data for Route 30	Cardiff Bus
MOIRA model – annual journeys between stations	Welsh Government
Passenger counts	First Great Western, Arriva Trains Wales and Cross Country Trains
Rail station footfall	ORR
TEMPro growth factors	DfT

9.3.2 Data gathered from the Public Transport Surveys were used to separate the bus and rail demand matrices into the required user classes. This information included car availability, journey purpose splits and mode of travel for access/egress to and from the public transport services.

Rail Demand

9.3.3 Annual station to station matrices were extracted from MOIRA. This rail demand was allocated to the different time periods according to the train's time at Castleton (between Newport and Cardiff Central stations). The passenger counts were used to control the volume of trips on each train service. Figure 9.2 summarises the rail demand matrix creation process.

Figure 9.2 Rail Matrix Building



9.3.4 A gravity model was prepared to distribute the rail trips from the railway station to the ultimate origin/destination model zones. The gravity model distributed the rail trips to the model zones according to journey purpose and direction of travel. For example, for the home-based work outward leg, the total number of jobs per zone was used to distribute the 'Station to Zone' end and the total population per zone was used to distribute the 'Zone to Station' end.

9.3.5 As an independent check, the modelled number of passengers using Newport station was compared against the official estimated Newport station usage, published by the Office of Rail Regulation. As can be

seen from Table 9.4, the modelled numbers closely match the official estimation, with the difference being less than 1%.

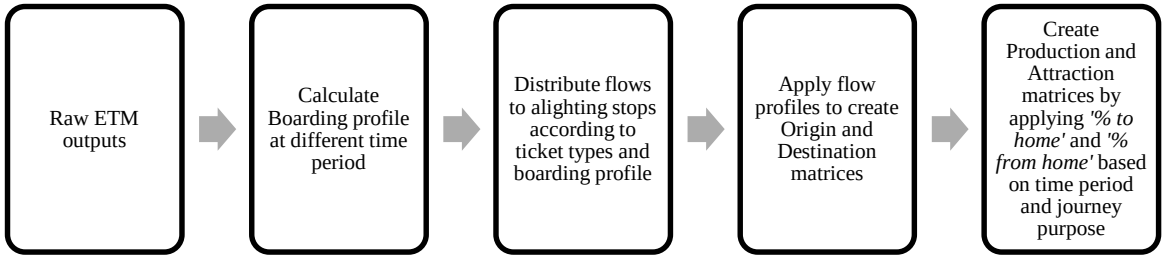
Table 9.4 Newport Station Usage

	Estimated station usage 2013/14 (Office of Rail and Road)	Modelled station usage (approximated)
Number of people using Newport station per year	1,145,522	1,151,100 (3,837 daily trips * 52 weeks / year * 6 days / week)

Bus Demand

9.3.6 Electronic ticket machine (ETM) data from Cardiff Bus and Newport Bus was used to create bus demand matrices for the 30 and X30 services. The data represents journeys on these services connecting Cardiff and Newport.

Figure 9.3 Bus Matrix Building



9.3.7 A gravity model was prepared to distribute bus matrices from trip ends (service stops) to model zones. The gravity model distributed the trips to zones according to journey purpose and direction of travel. For example, the total number of jobs per zone was used to distribute the 'bus stop to Zone' end of the Home-based Work outward leg matrices and the total population per zone was used to distribute the 'Zone to bus stop' end of the same matrices.

9.4 Public Transport Assignment and Validation

Rail Assignment

9.4.1 The rail demand was assigned onto the network and validation was undertaken by comparing the modelled passenger flows against passenger count data. The Castleton section of the railway, between Newport, Rogerstone and Cardiff Central Station was taken as the reference point for validation purposes.

9.4.2 The average hourly passenger volumes were compared for each service passing through Castleton. These were aggregated to calculate the volumes passing through key stations on the network as well, namely Bristol Temple Meads, Bristol Parkway, Chepstow, Cwmbran

and Ebbw Vale stations. This was done for each of the modelled time periods.

9.4.3 The rail passenger volumes have not been published in this report due to the commercial sensitivity of the data. The validation results show that the total modelled flows closely match the passenger volume count data in all time periods and in both directions. The percentage difference between the modelled and observed flows is shown in Table 9.5. Where the percentage difference is large, the difference in absolute numbers is low.

Table 9.5 Comparison of Modelled and Observed Rail Passenger Volumes

Time Period	Service Group	Percentage Difference Between Modelled and Observed Number of Rail Passengers	
		Eastbound	Westbound
AM peak hour	Portsmouth Harbour	-29%	-1%
	Ebbw Vale	21%	3%
	London Paddington	19%	15%
	Nottingham	-16%	6%
	Taunton	-21%	22%
	Cheltenham	119%	-1%
	Manchester	-1%	-33%
	North Wales	18%	1%
	Total	**0%**	**0%**
Inter-peak hour	Portsmouth Harbour	-10%	8%
	Ebbw Vale	6%	5%
	London Paddington	12%	15%
	Nottingham	-35%	-25%
	Taunton	-2%	-1%
	Cheltenham	11%	-39%
	Manchester	-1%	-16%
	North Wales	-20%	-3%
	Total	**0%**	**0%**
PM peak hour	Portsmouth Harbour	-4%	-27%
	Ebbw Vale	2%	12%
	London Paddington	10%	13%
	Nottingham	-31%	-18%
	Taunton	19%	71%
	Cheltenham	-17%	75%
	Manchester	22%	-34%
	North Wales	-43%	45%
	Total	**0%**	**0%**

Bus Assignment

9.4.4 The bus demand was assigned onto the network and validation was undertaken by comparing the modelled passenger flows against bus passenger counts. The reference point for validation of the bus assignment was also taken as Castleton, near the local authority boundary between Newport and Cardiff. The passenger counts were derived by calculating the cumulative bus occupancy at Castleton from the ETM data

9.4.5 The bus passenger volumes have not been published in this report due to commercial sensitivity of the data. The validation results show that the total modelled flows closely match the observed data in all time periods and both directions. The percentage difference between the modelled and observed flows is shown in Table 9.5.

Table 9.5: Comparison of Modelled and Observed Bus Passenger Volumes

Time Period	Percentage Difference Between Modelled and Observed Bus Volumes	
	Eastbound	Westbound
AM peak hour	19%	-4%
Inter-peak hour	5%	-13%
PM peak hour	2%	-19%

9.5 Public Transport Inputs for the VDM

9.5.1 The output from the public transport model was used as input to the VDM, to enable the future mode transfer of trips between car and public transport as a result of the M4CaN to be calculated.

9.5.2 The following outputs were required by the VDM:

- Passenger demand matrices in P/A format, broken down by trip purpose, car availability and time period;
- Fare matrices, with concessionary fares taken into account; and
- Time skim matrices for base and electrified scenarios.

9.5.3 The above matrices were extracted for bus and rail as a combined public transport mode. In most cases, the origin-destination zone pairs in the matrices were exclusive to either bus or rail. However, there were some origin-destination pairs which were common to both bus and rail, such as Cardiff to Newport movements, in which case a weighted value was given.

9.5.4 The VDM used the above matrices to predict the switch of trips between the car matrix and the public transport (car available) matrix

as the relative costs between the different modes change in future year scenarios.

10 Variable Demand Model Calibration

10.1 Introduction

10.1.1 WebTAG indicates that for the M4 corridor, traffic forecasts should be produced using variable demand modelling. Before the variable demand traffic forecasts are prepared, realism testing on the base year model is required to demonstrate that the M4 traffic model responds to changes in cost and time in a realistic way. TAG Unit M2[14] states that checks should be carried out for each user class and for each time period with respect to changes in car fuel cost, car journey time and public transport fares.

10.1.2 The variable demand modelling is undertaken using the DfT's DIADEM software, which has been developed to provide a consistent tool by which current WebTAG advice on variable demand modelling can be applied. This chapter describes the realism tests undertaken on the M4 validated base year traffic model.

10.2 The Need for Variable Demand Modelling

10.2.1 TAG Unit M2 states that under certain circumstances it is acceptable to base the assessment of a scheme on a fixed demand traffic model. This is the case when the scheme is quite modest either spatially or financially and also in terms of its effect on travel costs. However, scheme costs for options considered for the M4 corridor around Newport are significantly in excess of the £5 million limit defined within WebTAG.

10.2.2 A fixed demand traffic model would therefore only be deemed sufficient to assess the M4 corridor around Newport if the following criteria are met:

- No congestion on the network in the forecast years in the absence of the scheme; and
- No appreciable effect on travel choices such as mode of travel or the distribution of travel patterns in the corridor containing the scheme.

10.2.3 Assessing these criteria in the context of the M4CaN indicates the need for variable demand modelling because even under existing conditions traffic congestion is regularly observed and is forecast to worsen as a result of underlying growth in travel demand. The Scheme is also expected to have a slight effect on distribution of travel patterns and competition between private travel modes and public transport in the study area.

[14] Transport Analysis Guidance Unit M2, Variable Demand Modelling, Department for Transport, January 2014

10.3 Form of the Demand Model and Matrices

10.3.1 The variable demand model for the updated M4CaN model uses trip demand matrices in production/attraction (P/A) format rather than origin-destination (O-D) format. For home-based trips this means that the demand responses in the variable demand model take into account changes in travel costs of both outbound and return legs of a journey rather than treating them as entirely separate entities.

10.3.2 The use of P/A matrices also has implications on the form of the demand model as outlined below. During the assignment model calibration the base year O-D matrix was adjusted at peak hour level using matrix estimation in order to improve the level of validation of the assignment. There is no direct way in which these adjustments can be conveyed to the P/A-based demand model. The result is a discrepancy between the demand model and the assignment model.

10.3.3 The DfT's recommendation in WebTAG has therefore been followed in setting up an incremental rather than an absolute model. Incremental models predict *changes* in demand when fed by *changes* in costs.

10.3.4 Essentially, after converting the output of the demand model from P/A to O-D, the resulting matrix is not directly assigned, but is compared with a base case, and the implied changes are used to adjust an independently validated "assignment matrix".

10.4 Responses in Variable Demand Modelling

10.4.1 Variable demand modelling can include a number of different responses to changes in travel costs. One of these is changing route, which is controlled by the M4 SATURN model as part of the model assignment process. Four additional potential model responses are available in DIADEM:

- trip generation / frequency;
- mode choice;
- trip distribution; and
- time of day choice.

10.4.2 In the case of the M4 model, the mode choice and redistribution responses have been included.

10.4.3 According to WebTAG a trip frequency response may be thought of as, mainly, the transfer between active modes (walk/cycle) and mechanised modes and, as such, it is considered reasonable to omit this response in this model. A trip frequency response was therefore not included in the demand model.

10.4.4 Another possible response is the re-timing of trips, which can be split into two distinct elements:

- macro time period choice, where travellers alter the timing of their activities and hence the time of day in which they travel; and
- micro time period choice, representing much smaller adjustments to departure times resulting in peak spreading.

10.4.5 Macro time period choice is typically only required where time period specific toll charges are introduced on highway schemes. If forecast models predict unrealistically severe congestion within peak hours then micro time period choice modelling can be introduced to reallocate trips between the peak hour and the shoulders of the peak to achieve a more realistic estimate.

10.4.6 In the case of the M4CaN, it is unlikely that future year scenarios would introduce a differential in travel cost at different times of day which would be substantial enough to lead to a significant shift in trips from the peaks to inter-peak or off-peak. Whilst congestion levels within the peaks are forecast to increase if there are no increases in highway capacity the majority of peak spreading would occur within the peak hours represented in the M4 SATURN model and would therefore not lead to a notable change in the demand within the peak hour. For these reasons, the re-timing of trips has not been included as a response in the M4 variable demand modelling.

10.4.7 In DIADEM, each demand response is controlled by the spread parameter λ and, where there is more than one response, a scaling parameter θ. In order to quantify the scale of redistribution of trips, appropriate spread parameter values were required for each of the modelled trip purposes. In the case of the M4 base year model it was assumed that:

- Home-based work trips are doubly constrained in all time periods;
- Employers' Business and Other trip purposes are origin-constrained in the AM peak and inter-peak, and destination-constrained in the PM peak.

10.4.8 In developing the variable demand model parameters to be used in forecasting, the initial values were based on median illustrative values of λ by journey purpose quoted in WebTAG. A systematic approach was then followed to calibrate the parameters as described in Section 10.6 of this report.

10.5 Convergence

10.5.1 DIADEM software undertakes the variable demand modelling process in response to changing travel times or costs. The process is iterative and modifies the model demand matrices between SATURN assignments until a balance is achieved between the traffic assignment and the demand model. How well this balance or equilibrium has been achieved is defined using convergence criteria such as the demand/supply gap.

10.5.2 The objective of this process is to achieve well converged models with realistic demand responses, thereby improving the accuracy of the scheme benefit calculations. TAG Unit M2 recommends, where possible, to achieve a demand/supply gap of less than 0.1%. If that cannot be reached then a convergence level of at least 0.2% is recommended.

10.5.3 Table 10.1 shows the gap convergence measure achieved by the updated M4CaN base year model. The results indicate that the demand/supply gap for the fuel cost and public transport fare realism test is around 0.1% or less and that an acceptable level of convergence has therefore been achieved.

Table 10.1 Realism Test Demand Model Convergence

Realism Test	Gap Convergence
Fuel Cost Elasticity	0.09%
Fare Elasticity	0.10%

10.6 Realism Testing

Fuel Cost Elasticity

10.6.1 Once a variable demand model has been constructed, it is essential to ensure that it behaves "realistically", by changing the various components of travel costs and checking that the overall response of demand accords with empirical data.

10.6.2 For the updated M4CaN base year model the elasticity of vehicle kilometres with respect to fuel cost was calculated for all four modelled time periods, based on a 10% increase in fuel price as recommended in TAG Unit M2.

The formulation used to calculate the fuel cost elasticity is:

$$\mathbf{e}_{fuel} = \frac{\left(\mathbf{log}(\boldsymbol{T}^{\mathbf{1}}) - \mathbf{log}(\boldsymbol{T}^{\mathbf{0}})\right)}{\left(\mathbf{log}(\boldsymbol{C}^{\mathbf{1}}) - \mathbf{log}(\boldsymbol{C}^{\mathbf{0}})\right)}$$

where the superscripts 0 and 1 indicate values of the demand, T, and cost, C, before and after the fuel cost change respectively.

The outturn elasticity of car kilometres with respect to fuel cost should lie between -0.25 and -0.35.

10.6.3 Two separate tests are required to establish the response of trips to changes in fuel cost. One is based on an analysis of the network and the other is based on an analysis of the matrix. The matrix-based analysis includes long distance journeys travelling between the study

area and destinations spread throughout the rest of the UK, whereas the network-based test helps to isolate the effect of variable demand responses within the area of the model that has been represented in the highest level of detail without being skewed by the effect of long distance travel to destinations throughout the UK. Strategic trips which both start and end a long distance away from the M4 corridor around Newport were treated as fixed demand and are therefore not included in the calculation of a matrix-based fuel cost elasticity. However, the network-based calculation includes a proportion of fixed long distance external-to-external, and therefore the expectation is that the network-based elasticity would be marginally weaker than the matrix-based elasticity.

10.6.4 A systematic calibration process was followed in order to establish a set of parameters that would return the required outturn fuel cost elasticity. Initial calibration runs were based on illustrative parameter values from WebTAG and excluded cost damping. However, WebTAG states that there is some evidence that the sensitivity of demand responses to changes in travel cost reduces with increasing trip length and that this variation may need to be represented in the demand model. Consequently cost damping was introduced into the M4 variable demand model as part of the calibration process after initial runs without cost damping had shown to be too responsive to changes in travel costs, in particular for longer distance trips. Details of the calibration of variable demand parameters including those used for cost damping are included in Appendix E.

10.6.5 The results of the fuel cost realism tests are summarised in Table 10.2, along with the final calibrated spread parameters λ and the scaling parameters θ. These parameters would be carried forward to the variable demand forecast models.

Table 10.2 Realism Test Results – Fuel Cost Elasticity

<table>
<tr><th rowspan="2">Time Period</th><th rowspan="2">User Class</th><th colspan="3">Control Parameters</th><th colspan="3">Network-based Elasticity</th><th colspan="3">Matrix-based Elasticity</th></tr>
<tr><th>λ (Hwy)</th><th>λ (PT)</th><th>θ</th><th>User Class</th><th>Time Period</th><th>Annual Average</th><th>User Class</th><th>Time Period</th><th>Annual Average</th></tr>
<tr><td rowspan="9">AM peak</td><td>HBEB</td><td>-0.067</td><td>-</td><td>0.45</td><td rowspan="2">-0.05</td><td rowspan="5">-0.25</td><td rowspan="14">-0.26</td><td>-0.10</td><td rowspan="5">-0.27</td><td rowspan="14">-0.31</td></tr>
<tr><td>NHBEB</td><td>-0.081</td><td>-</td><td>0.73</td></tr>
<tr><td>HBO</td><td>-0.090</td><td>-</td><td>0.53</td><td rowspan="2">-0.30</td><td rowspan="2">-0.42</td></tr>
<tr><td>NHBO</td><td>-0.077</td><td>-</td><td>0.81</td></tr>
<tr><td>HBW</td><td>-0.065</td><td>-</td><td>0.68</td><td>-0.23</td><td>-0.17</td></tr>
<tr><td rowspan="9">Inter-peak</td><td>HBEB</td><td>-0.067</td><td>-</td><td>0.45</td><td rowspan="2">-0.09</td><td rowspan="5">-0.31</td><td>-0.09</td><td rowspan="5">-0.35</td></tr>
<tr><td>NHBEB</td><td>-0.081</td><td>-</td><td>0.73</td></tr>
<tr><td>HBO</td><td>-0.090</td><td>-</td><td>0.53</td><td rowspan="2">-0.38</td><td rowspan="2">-0.49</td></tr>
<tr><td>NHBO</td><td>-0.077</td><td>-</td><td>0.81</td></tr>
<tr><td>HBW</td><td>-0.065</td><td>-</td><td>0.68</td><td>-0.27</td><td>-0.17</td></tr>
</table>

Time Period	User Class	Control Parameters			Network-based Elasticity			Matrix-based Elasticity		
		λ (Hwy)	λ (PT)	θ	User Class	Time Period	Annual Average	User Class	Time Period	Annual Average
PM peak	HBEB	-0.067	-	0.45	-0.07	-0.23		-0.09	-0.29	
	NHBEB	-0.081	-	0.73						
	HBO	-0.090	-	0.53	-0.28			-0.46		
	NHBO	-0.077	-	0.81						
	HBW	-0.065	-	0.68	-0.22			-0.17		
Off-peak	HBEB	-0.067	-	0.45	-0.07	-0.25		-0.08	-0.33	
	NHBEB	-0.081	-	0.73						
	HBO	-0.090	-	0.53	-0.31			-0.47		
	NHBO	-0.077	-	0.81						
	HBW	-0.065	-	0.68	-0.20			-0.16		

10.6.6 The arc elasticities calculated are based on the vehicle kilometres from the SATURN simulation network and exclude any data from buffer links or zone connectors. Annual average fuel cost elasticities were calculated by taking the vehicle kilometres for each time period and factoring these up by applying expansion factors to convert from average hours within peak periods to daily.

10.6.7 The strength of modal shift in response to changes in highway or public transport travel costs is controlled by the θ parameter. The value of θ is a scaling parameter that is influenced by strength of the distribution response controlled by the λ parameter, so that the strength of the mode choice response is still lowest for Employers' Business trips and highest for 'Other' trips due to the relative magnitude of the λ parameters for each trip purpose.

10.6.8 The results show an overall annual fuel cost elasticity of -0.26 for the network-based analysis, and that the Employers' Business user class is the least responsive trip purpose and the more discretionary 'Other' category is the most responsive. This is in line with the advice in TAG Unit M2, which states that the average fuel cost elasticity should lie within the range -0.25 to -0.35. For individual purposes, it suggests that values for Employers' Business trips should be near to -0.1, discretionary trips near to -0.4, and commuting trips near to the average, although the guidance notes that there is little or no empirical evidence to support this variation.

10.6.9 The overall annual fuel cost elasticity of -0.31 from the matrix-based analysis shows a scale of response very close to the middle of the target range suggested in WebTAG.

10.6.10 The results of the fuel cost elasticity realism test are therefore considered to demonstrate that the demand model is robust, and that

the parameters selected would result in appropriate demand responses to changes in travel costs in the forecast traffic model runs.

Public Transport Fare Elasticity

10.6.11 It is also necessary to demonstrate that the demand model responds realistically to changes in the public transport fare. According to WebTAG elasticities of public transport trips with respect to public transport fares have been found to lie typically in the range -0.2 to -0.9 for changes over a period longer than a year (TAG Unit M2). Values close to -0.2 are unlikely for the whole public transport market unless this includes a high proportion of concessionary fare trips with a significant number made free of charge.

10.6.12 For the M4 base year model the elasticity of public transport trips with respect to fare changes was calculated for all four modelled time periods, based on a 10% increase in public transport fares as recommended in TAG Unit M2, and these elasticities are shown in Table 10.3.

10.6.13 The arc elasticities calculated are based on the total public transport trips contained within the demand matrices. Annual average fare elasticities were calculated by taking the public transport trips for each time period and factoring these up by applying expansion factors to convert from average hours within peak periods to daily.

10.6.14 The results show an overall annual public transport fare elasticity of -0.30, and that the Employers' business user class is the least responsive trip purpose and the more discretionary 'other' category is the most responsive. This is in line with the advice in TAG Unit M2. The Model outputs also meet the expectations from the guidance that peak period elasticities should be lower than inter-peak elasticities which should be lower than off-peak elasticities.

Table 10.3 Realism Test Results – Public Transport Fare Elasticity

Time Period	User Class	Control Parameters			Matrix-based Elasticity		
		λ (Hwy)	λ (PT)	θ	User Class	Time Period	Annual Average
AM peak	HBEB	-0.067	-0.036	0.45	-0.08	-0.27	-0.30
	NHBEB	-0.081	-0.042	0.73	-0.21		
	HBO	-0.090	-0.036	0.53	-0.47		
	NHBO	-0.077	-0.033	0.81	-0.48		
	HBW	-0.065	-0.033	0.68	-0.26		
Inter-peak	HBEB	-0.067	-0.036	0.45	-0.08	-0.32	
	NHBEB	-0.081	-0.042	0.73	-0.13		
	HBO	-0.090	-0.036	0.53	-0.44		
	NHBO	-0.077	-0.033	0.81	-0.58		
	HBW	-0.065	-0.033	0.68	-0.25		
PM peak	HBEB	-0.067	-0.036	0.45	-0.09	-0.27	
	NHBEB	-0.081	-0.042	0.73	-0.07		
	HBO	-0.090	-0.036	0.53	-0.47		
	NHBO	-0.077	-0.033	0.81	-0.42		
	HBW	-0.065	-0.033	0.68	-0.26		
Off-peak	HBEB	-0.067	-0.036	0.45	-0.08	-0.34	
	NHBEB	-0.081	-0.042	0.73	-0.13		
	HBO	-0.090	-0.036	0.53	-0.50		
	NHBO	-0.077	-0.033	0.81	-0.55		
	HBW	-0.065	-0.033	0.68	-0.28		

Journey Time Elasticity

10.6.15 WebTAG guidance lists a requirement to check the elasticity of car trips with respect to the change in journey time to be analysed to ensure that the model responds "realistically" to changes in traffic congestion or time savings, for example those resulting from the introduction of the scheme in future year models.

10.6.16 The recommended approach is for the journey time elasticities to be calculated using a single run of the demand model. However, this is not possible in DIADEM and therefore a 'crude method' is used which derives the journey time elasticity using the fuel cost elasticity and the relationship of time and distance related travel cost components in the overall generalised cost formulation. This method was in the past included in WebTAG and the DIADEM user manual and is therefore considered an acceptable alternative.

10.6.17 Rather than being based on the change in vehicle kilometres the journey time elasticity is defined as a change in number of vehicle

trips with respect to changes in journey time. The fuel cost elasticity was therefore recalculated on this basis, so that the journey time elasticity could be derived using the network-wide fuel and time costs for each movement in the model as shown in the formula below.

The formulation used to calculate the journey time elasticity is:

$$\mathbf{e}_{JT} = \mathbf{e}_{fuel} \times \frac{\left(\sum \boldsymbol{C}_{time\ i,j} \times \boldsymbol{T}_{i,j}\right)}{\left(\sum \boldsymbol{C}_{fuel\ i,j} \times \boldsymbol{T}_{i,j}\right)}$$

where C_{time} and C_{fuel} are the time and fuel element of the generalised travel costs and T is the demand.

The outturn elasticity of car trips with respect to journey time should lie below -2.0.

10.6.18 Table 10.4 shows the journey time elasticity, as calculated using the above methodology. The results indicate that the calculated average annual journey time elasticity is -0.003 and therefore the test has proved satisfactory. The scale of the result also indicates that the margin between the acceptable limit of -2.0 and the actual result of -0.003 is so large that the more detailed method would not result in a different conclusion.

Table 10.4 Realism Test Results – Journey Time Elasticity

Time Period	User Class	Control Parameters			Journey Time Elasticity		
		λ (Hwy)	λ (PT)	θ	User Class	Time Period	Annual Average
AM peak	HBEB	-0.067	-0.036	0.45	-0.010	-0.003	-0.003
	NHBEB	-0.081	-0.042	0.73			
	HBO	-0.090	-0.036	0.53	-0.002		
	NHBO	-0.077	-0.033	0.81			
	HBW	-0.065	-0.033	0.68	-0.004		
Inter-peak	HBEB	-0.067	-0.036	0.45	-0.011	-0.004	
	NHBEB	-0.081	-0.042	0.73			
	HBO	-0.090	-0.036	0.53	-0.003		
	NHBO	-0.077	-0.033	0.81			
	HBW	-0.065	-0.033	0.68	-0.003		
PM peak	HBEB	-0.067	-0.036	0.45	-0.013	-0.004	
	NHBEB	-0.081	-0.042	0.73			
	HBO	-0.090	-0.036	0.53	-0.003		
	NHBO	-0.077	-0.033	0.81			
	HBW	-0.065	-0.033	0.68	-0.004		
Off-peak	HBEB	-0.067	-0.036	0.45	-0.010	-0.002	
	NHBEB	-0.081	-0.042	0.73			
	HBO	-0.090	-0.036	0.53	-0.002		
	NHBO	-0.077	-0.033	0.81			
	HBW	-0.065	-0.033	0.68	-0.002		

10.7 Summary

10.7.1 Realism tests have been carried out on the base model to ensure that the variable demand model responds realistically to changes in journey costs. The results show that the model's response to changing costs satisfies the criteria set out in the current guidance and would therefore provide a robust basis for variable demand modelling for the future year scenarios.

11 Conclusions

11.1.1 This report describes the development and subsequent validation of the update of the M4CaN model. The transport model is made up of several components, including a highway assignment model, a public transport model and a variable demand model.

11.1.2 The VDM works on the basis of 24 hour productions and attractions whilst the public transport and highway assignment models operate on the basis of hourly origin-destination demand.

11.1.3 The following time periods have been modelled in the final validated base year highway assignments:

- AM peak hour – 08:00 to 09:00;
- Average inter-peak hour; and
- PM peak hour – 17:00 to 18:00.

11.1.4 An extensive data collection exercise was undertaken to inform the model update. The main basis of the trip matrices is mobile phone data, which was collected in and around Newport in autumn 2014. Roadside Interview Surveys and an extensive programme of traffic count surveys were also undertaken in spring 2014 to supplement the mobile data.

11.1.5 Passenger surveys were undertaken on bus and rail services within the Newport-Cardiff area to inform the development of the public transport module within the model.

11.1.6 The demand within the model has been split according to journey purpose/vehicle type to be compatible with WebTAG guidance on VDM and the Department for Transport's National Trip End Model, for use in traffic forecasting.

11.1.7 The highway assignment model validation process has been carried out in accordance with guidance in WebTAG. The documented outcomes demonstrate that the comparisons of modelled with observed values fall within acceptable ranges.

11.1.8 The variable demand response in the model were tested in order to ensure that the model responds realistically to given changes in travel costs. This realism testing has proved satisfactory in respect of changes in fuel costs, journey times and public transport fares in accordance with WebTAG guidance.

11.1.9 The updated M4 traffic model is thus deemed to be suitable to prepare future year traffic forecasts for the M4CaN.

Appendix A

Roadside Interview and Postcard Questionnaire

Please complete these questions about the journey you were making when you received this form, and the identical journey in the reverse direction (if you made one).

Q1. Time you received this postcard
(to the nearest half hour) (Please use the 24 hour clock)

☐☐ : ☐☐

Q2. Vehicle Type
(please select one only)

1. Car / taxi ☐
2. Light goods vehicle ☐
   2 axles, single tyres on rear axle
3. Heavy goods vehicle ☐
   2 axles with twin tyres, 3 axle rigid vehicle
4. Heavy goods vehicle ☐
   3 or 4 axle articulated, 5 or more axles rigid or articulated
5. Motor cycle ☐

Q3. No. of people in the vehicle at the time of survey
(incl. driver) ☐

Q4. Please provide the exact address of where you had just come from
(Your last stop please)

Organisation or house name .....
Number and street .....
Town .....
Postcode ☐☐☐☐☐☐☐☐

Q6. Did you or are you intending to travel on the M4 in Wales as part of your journey? Yes ☐ No ☐

Q7. If you have made / will make, a trip in the reverse direction today, please indicate when you were / will be in the area where you picked up this questionnaire? *(to the nearest half hour)*
(Please use the 24 hour clock)

☐☐ : ☐☐

Q8. Please provide the exact address of where you were going to
(Your next stop please)

Organisation or house name .....
Number and street .....
Town .....
Postcode ☐☐☐☐☐☐☐☐

Q5. Reason for being there?
(please select one only)

1. Home ☐
2. Tourism ☐
3. Usual place of work ☐
4. Employers business ☐
5. Education ☐
6. Shopping ☐
7. Personal business ☐
8. Visit friends ☐
9. Recreation / leisure ☐

Q9. Reason for being there?
(please select one only)

1. Home ☐
2. Tourism ☐
3. Usual place of work ☐
4. Employers business ☐
5. Education ☐
6. Shopping ☐
7. Personal business ☐
8. Visit friends ☐
9. Recreation / leisure ☐

Q10. Do you have to pay for car parking at the non-home end of this trip?
(please select one only)

No – private car park ☐
No – park on-street ☐
Yes ☐
Don't know ☐

Q11. Do you ever use public transport to make this journey?
(please select one only)

More than once a week ☐
Once a week ☐
2-3 times a month ☐
Once a month ☐
Rarely ☐
Never ☐

If you would be willing for us to contact you as part of a further study of travel habits in South Wales, please provide your contact details below. The details you provide will not be linked to the responses you have provided above.

Name .....
Address .....
Postcode ☐☐☐☐☐☐☐☐
Email .....
Phone .....

Freepost Plus RSJR-UHRK-
HRBJ
PO Box 445
Halifax
HX1 9GN

Z00001

Llywodraeth Cymru
Welsh Government

www.cymru.gov.uk

South-East Wales Travel Surveys

Welsh Government is carrying out surveys to assess travel patterns in South-East Wales. We are interested in details of individual journeys. Please complete the questionnaire in relation to the journey you were making when you received this form, and the identical journey in the reverse direction (if applicable).

Whilst individual address and trips made data will be used during the analysis, the final analysis will not contain any reference to individual addresses or trips. All data will be stored in compliance with the Data Protection Act 1998 and personal data will not be passed on to any third party not involved in this study.

To return this form please separate the half that you have completed (English or Welsh language) by tearing along the perforation and use the gummed edges to seal the postcard shut. No stamp is required, just place the postcard in your nearest post box by 4th July.

Alternatively, you can complete the questionnaire online until the 4th July by visiting: www.southwalestransportsurvey.co.uk

Or scan here to go to the online survey:

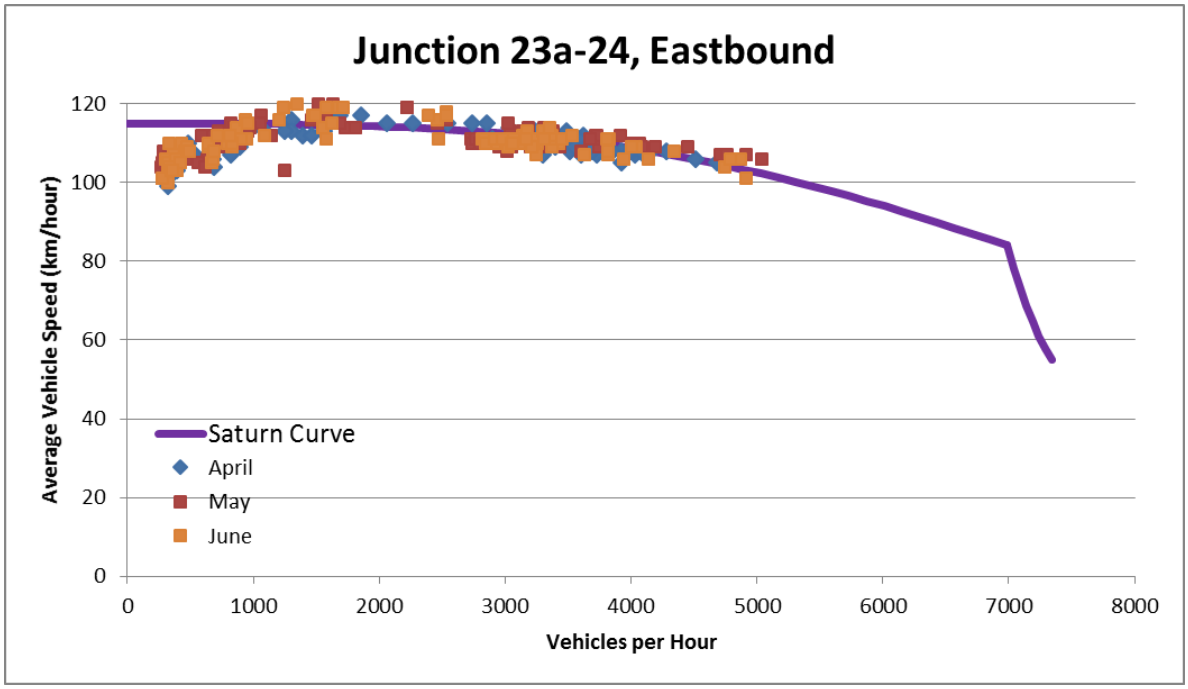
If you have any queries please contact us via **email** on southwalessurveys@arup.com or **phone** 02920 473727 quoting “South Wales Traffic Surveys”.

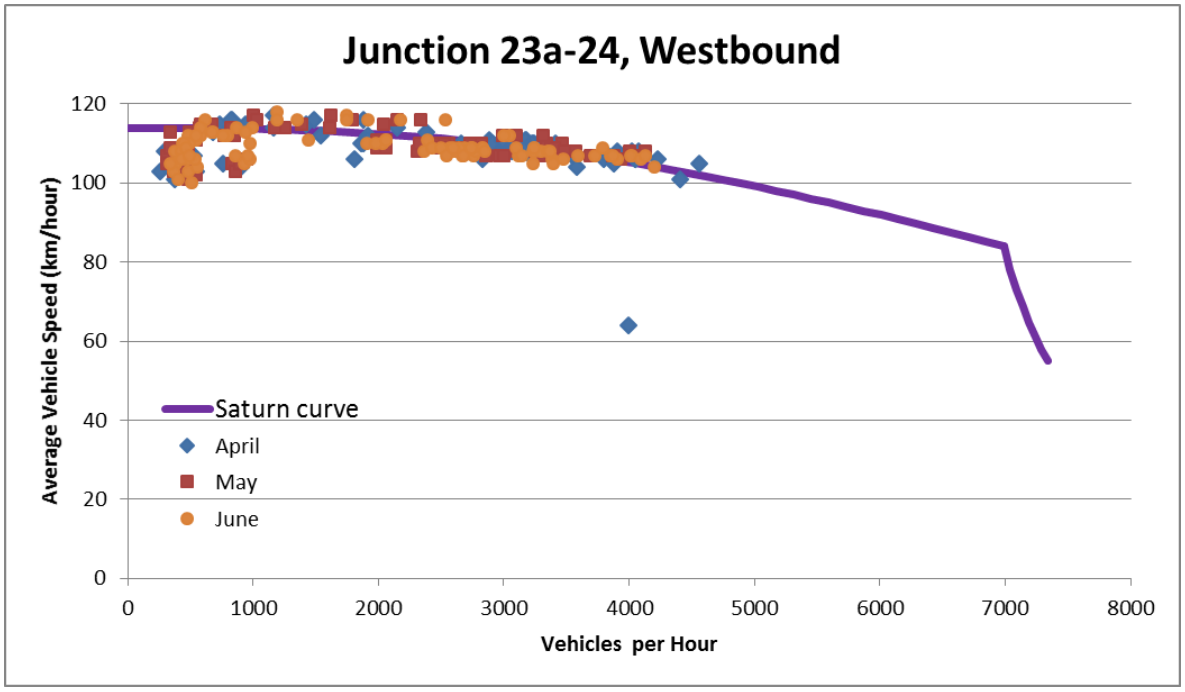
We thank you for your cooperation.

Appendix B

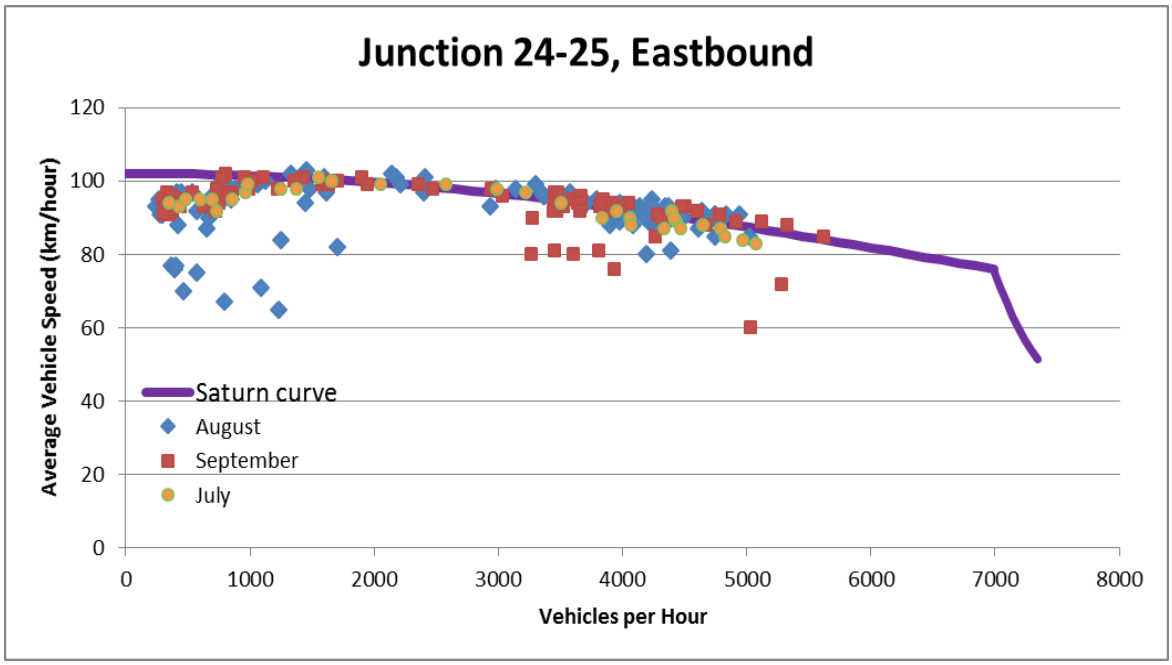
M4 Speed-Flow Curves from MIDAS Data

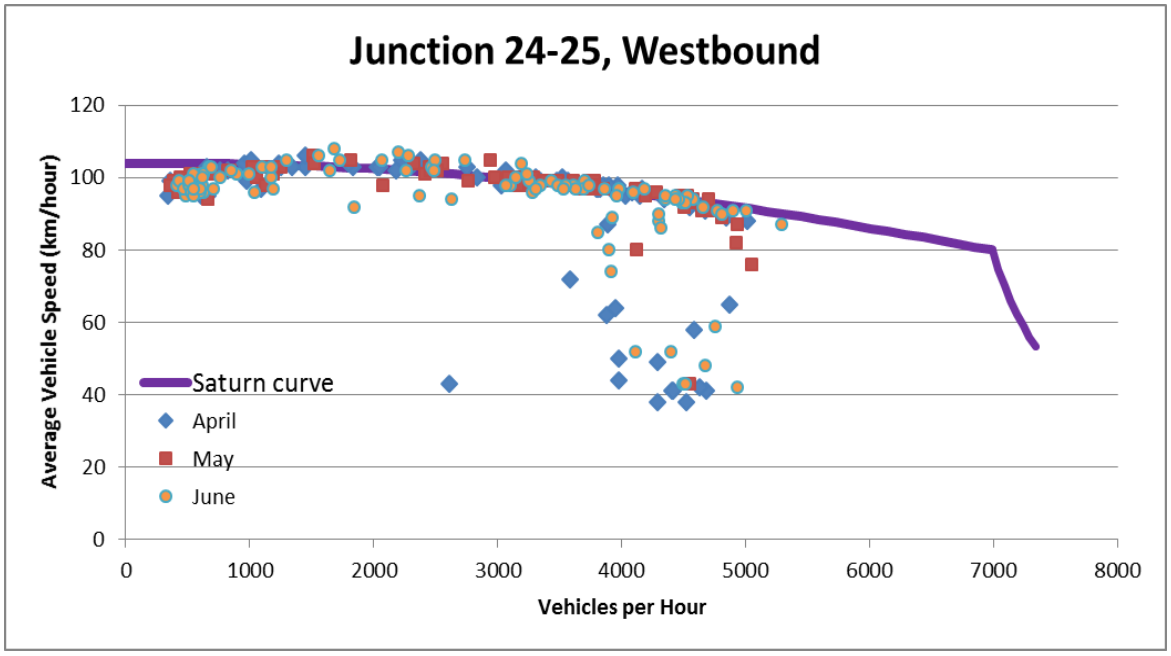
B1 Junction 23A to Junction 24



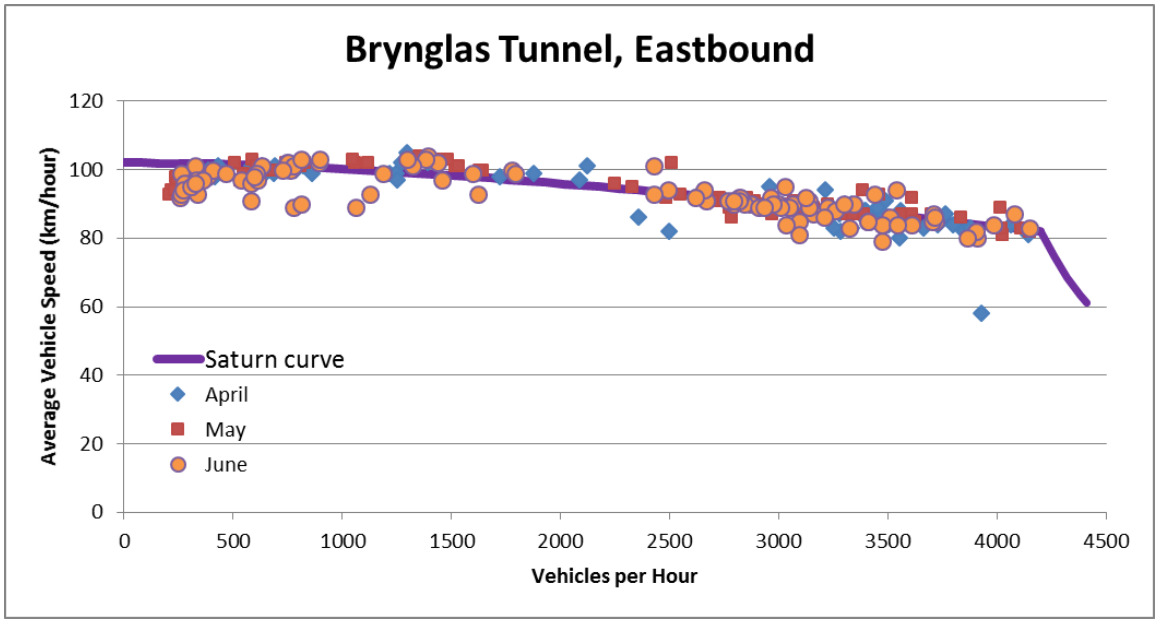


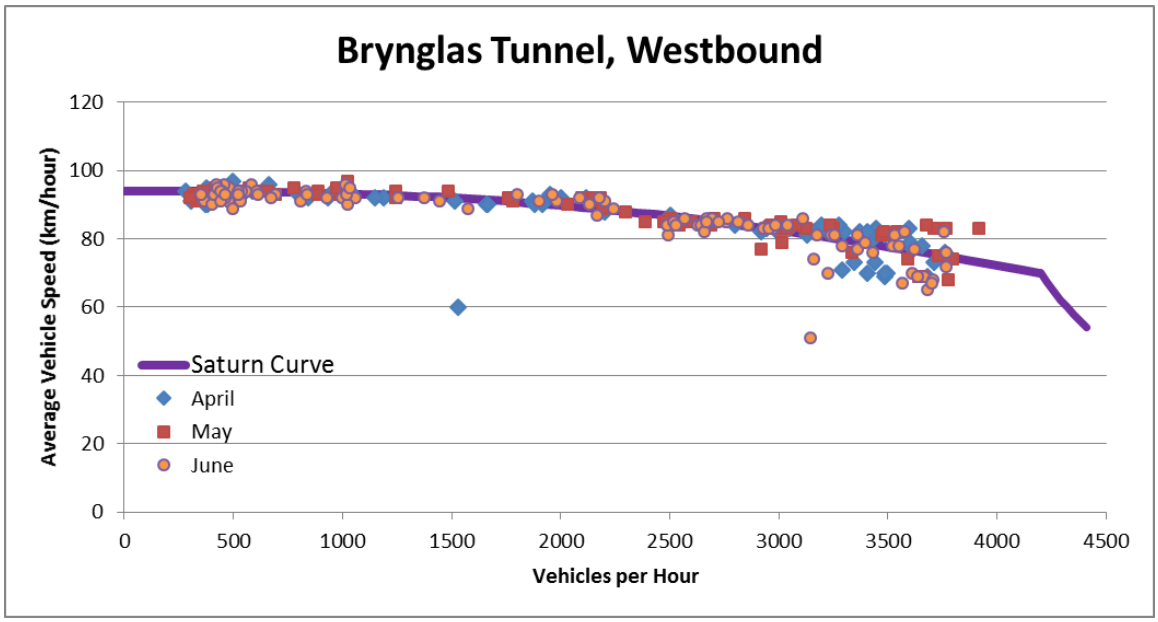
B2 Junction 24 to Junction 25



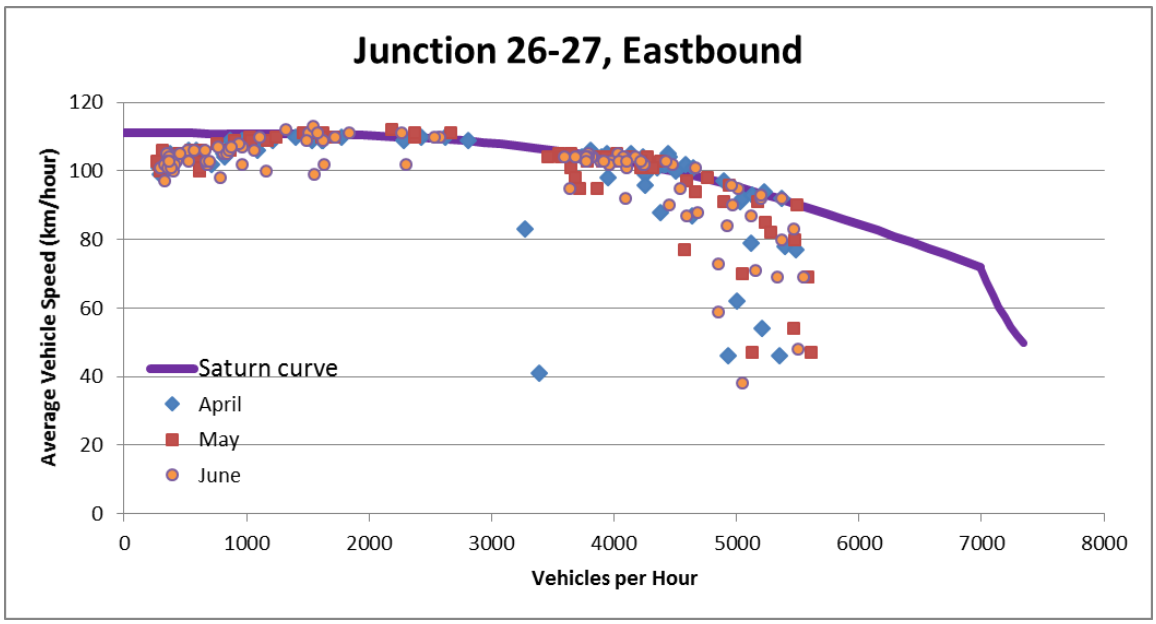


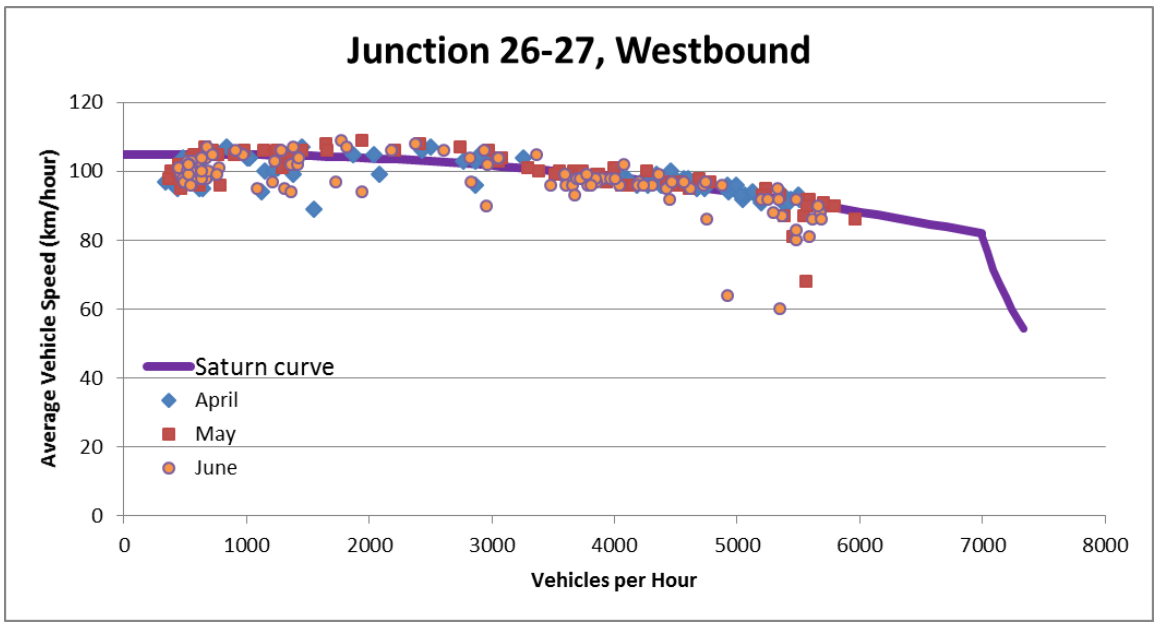
B3 Junction 25 to Junction 26



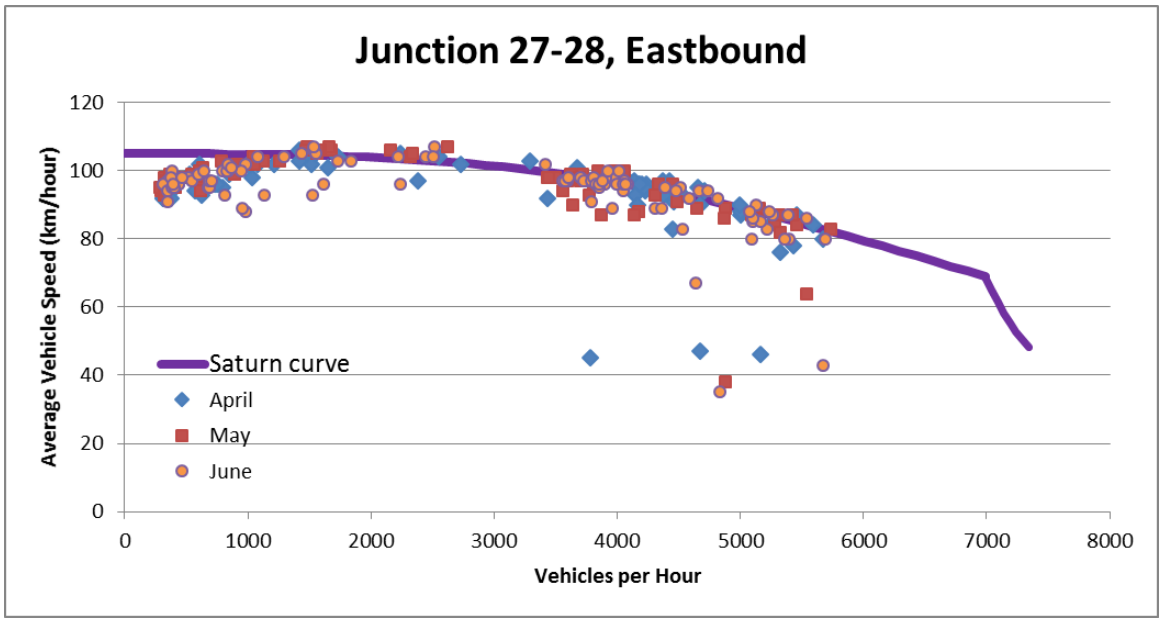


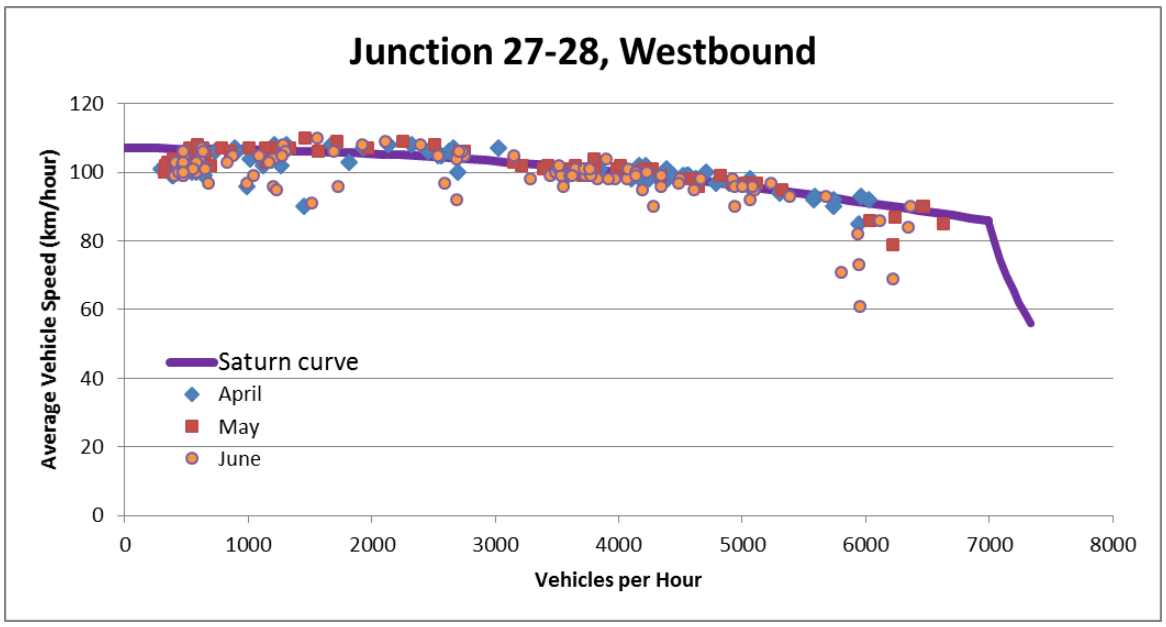
B4 Junction 26 to Junction 27



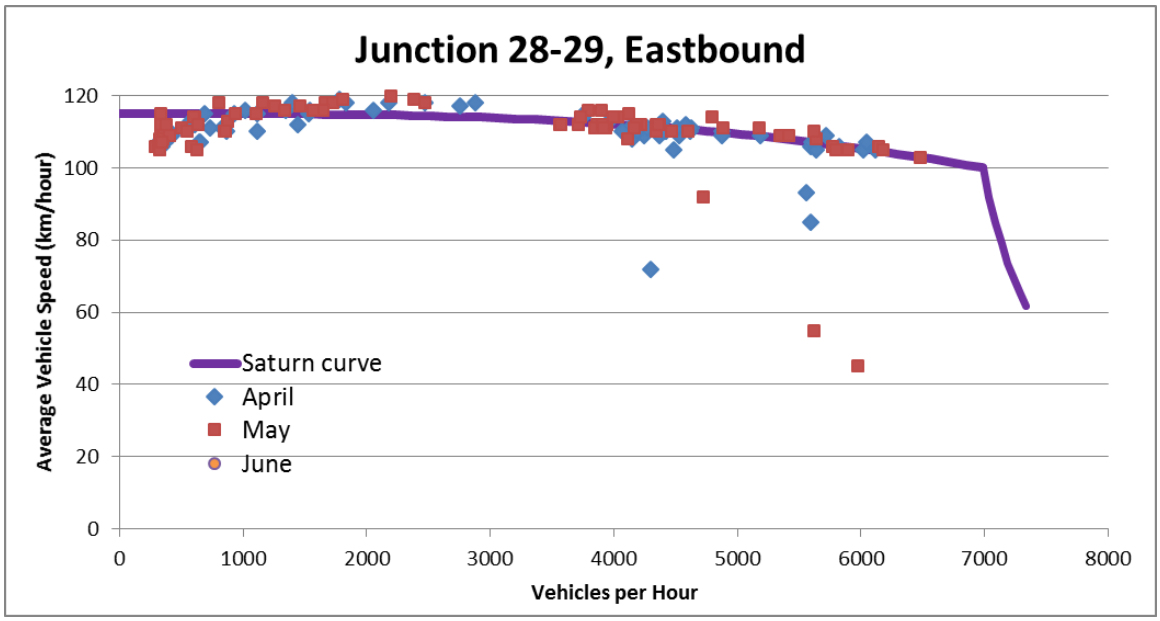


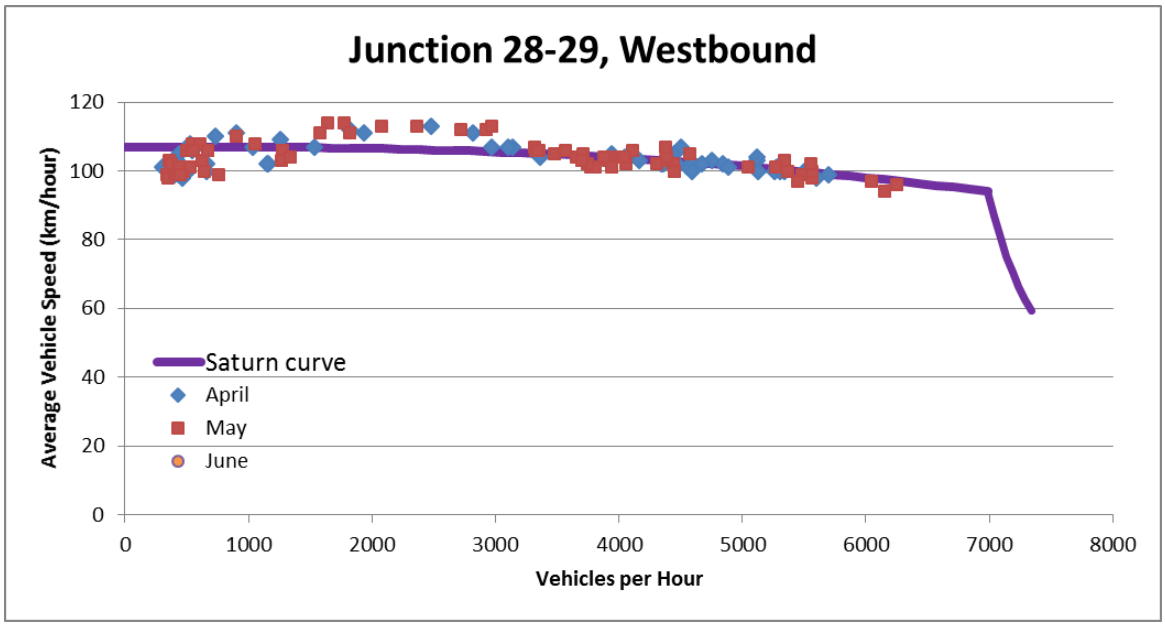
B5 Junction 27 to Junction 28





B6 Junction 28 to Junction 29





Appendix C

Synthesised Matrices - Sources of Trip Ends

C1 Sources of Trip Ends

UC	Assignment User Class	Demand Model UC	Synthetic Matrix User Class based on NTEM Trip Ends	Data for Disaggregation to SATURN Zones	
				Origin	Destination
1	Cars – Work	HB Work (P to A)	HB Work (P to A)	Population	Employment
		HB Work (A to P)	HB Work (A to P)	Employment	Population
2	Cars – Other	HB Other (P to A)	HB Education (P to A)	Population	Population
			HB Shopping (P to A)	Population	Employment in Retail
			HB Personal Business (P to A)	Population	Employment + Population
			HB Recreation / Social (P to A)	Population	Emp in BRES BIG18 +9*
			HB VF and Relatives (P to A)	Population	Population
			HB Holiday / Day Trip (P to A)	Population	Emp in BRES BIG18 +9*
		HB Other (A to P)	HB Education (A to P)	Education	Population
			HB Shopping (A to P)	Employment in Retail	Population
			HB Personal Business (A to P)	Employment + Population	Population
			HB Recreation / Social (A to P)	Emp in BRES BIG18 +9*	Population
			HB VF and Relatives (A to P)	Population	Population
			HB Holiday / Day Trip (A to P)	Emp in BRES BIG18 +9*	Population
		NHB Other	NHB Work	Employment + Population	Employment
			NHB Education	Employment + Population	Population
			NHB Shopping	Employment + Population	Employment in Retail
			NHB Personal Business	Employment + Population	Employment + Population
			NHB Recreation / Social	Employment + Population	Emp in BRES BIG18 +9*
			NHB VF and Relatives	Employment + Population	Population

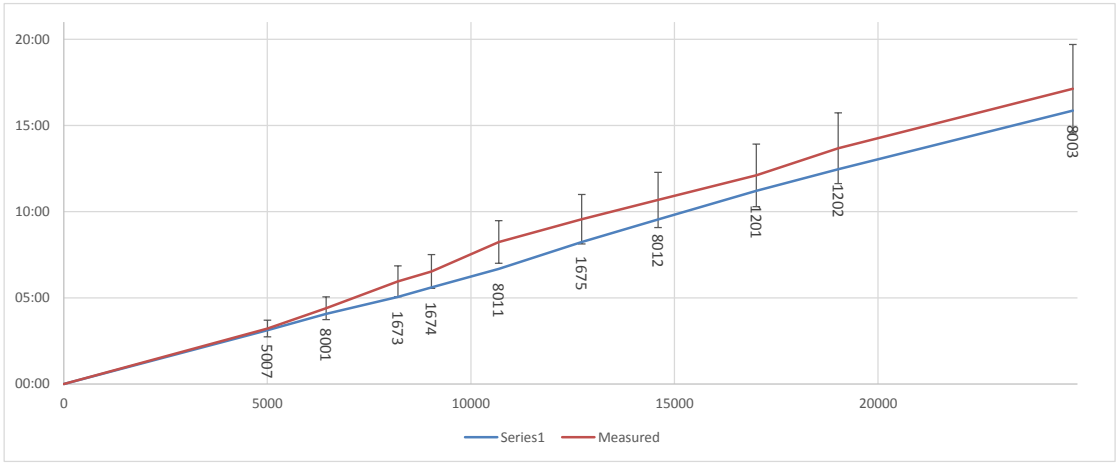
UC	Assignment User Class	Demand Model UC	Synthetic Matrix User Class based on NTEM Trip Ends	Data for Disaggregation to SATURN Zones	
				Origin	Destination
			NHB Holiday / Day Trip	Employment + Population	Emp in BRES BIG18 +9*
3	Cars – Employers Business	HB EB (P to A)	HB EB (P to A)	Population	Employment + Population
		HB EB (A to P)	HB EB (A to P)	Employment + Population	Population
		NHB EB	NHB EB	Employment + Population	Employment + Population
4	Light Goods Vehicles	LGV	Base Year Freight Matrices		
5	Heavy Goods Vehicles	HGV	Base Year Freight Matrices		

Appendix D

Journey Time Validation Graphs

Route1EB

AM



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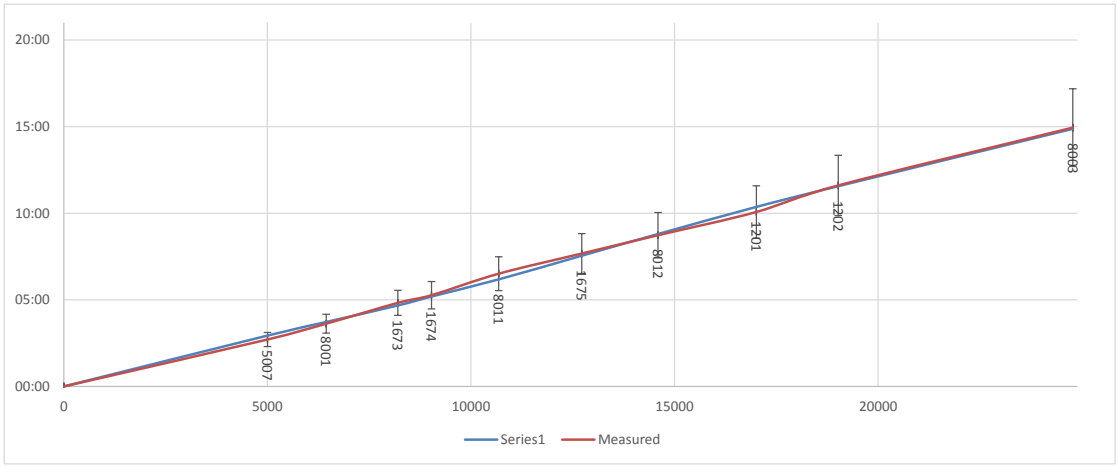
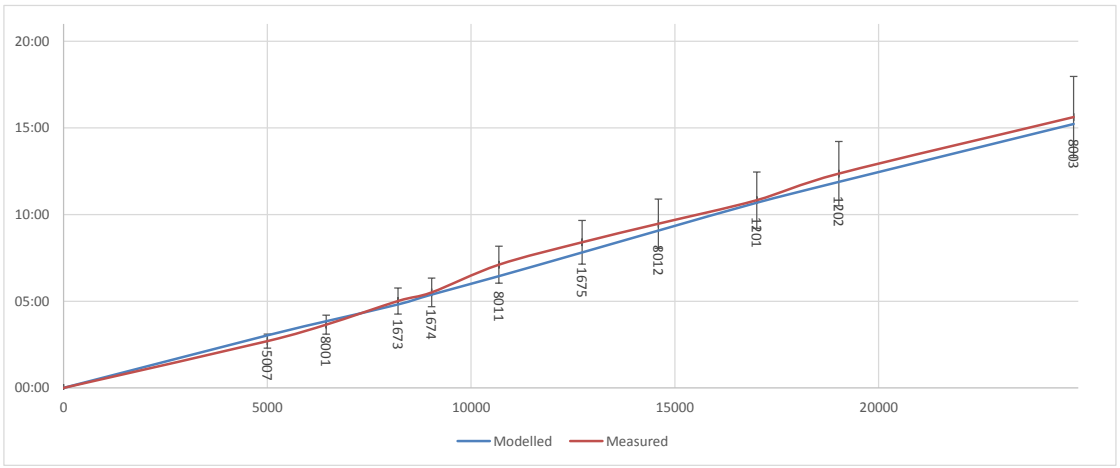
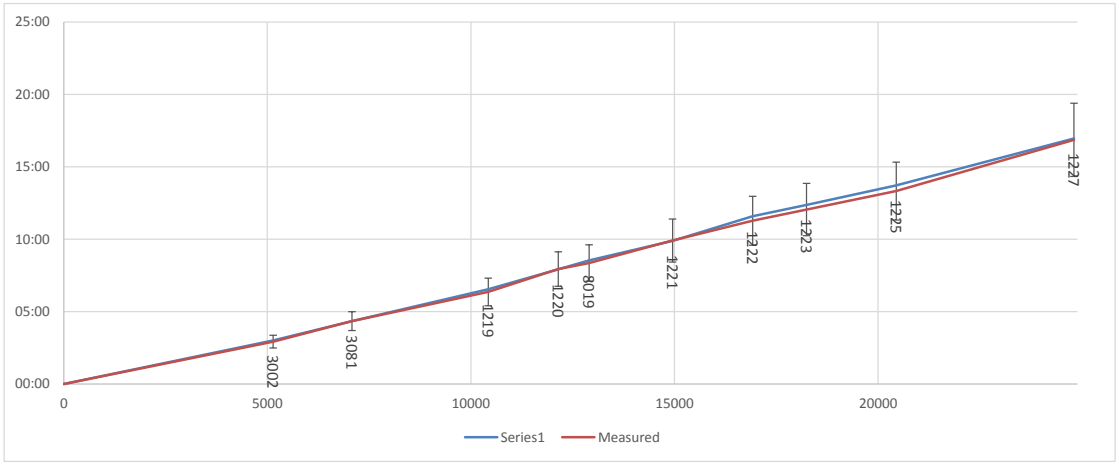


PM



Route1WB

AM



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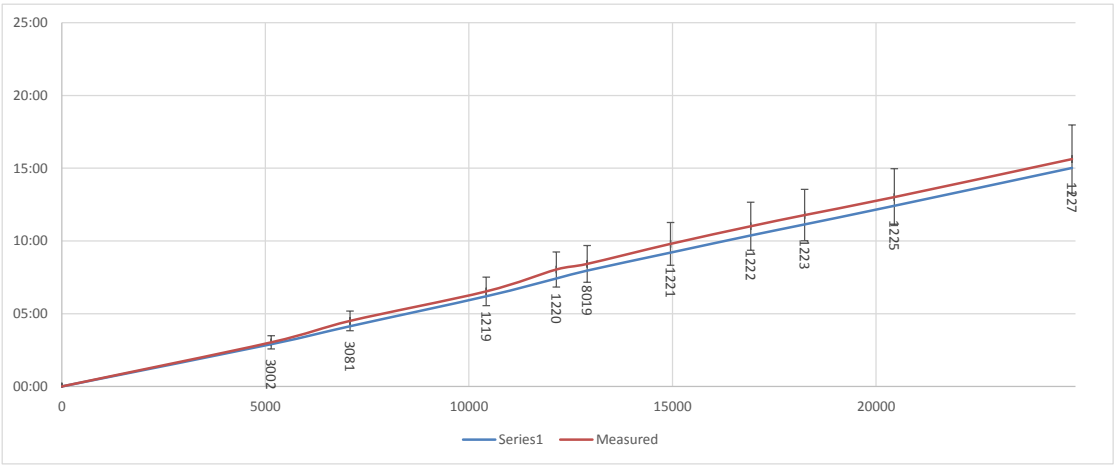
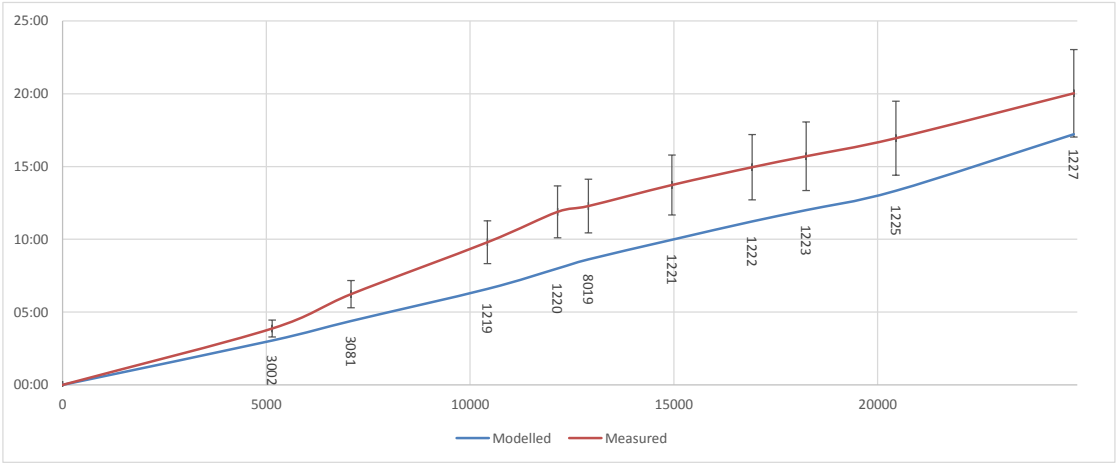
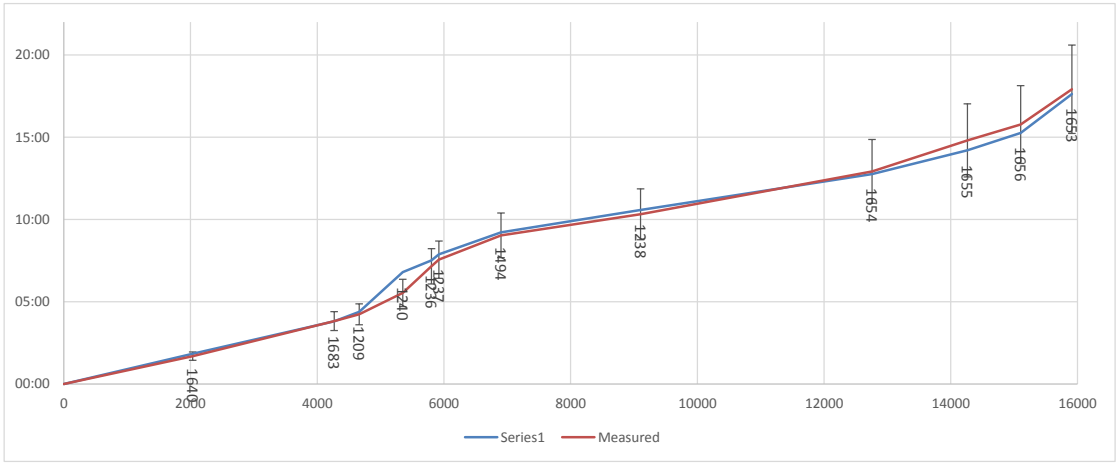


PM

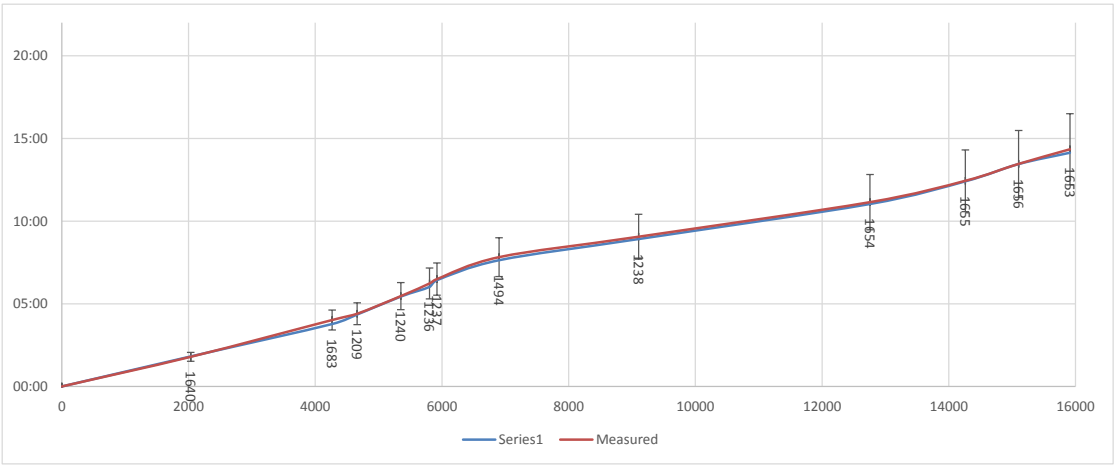


Route2ACW

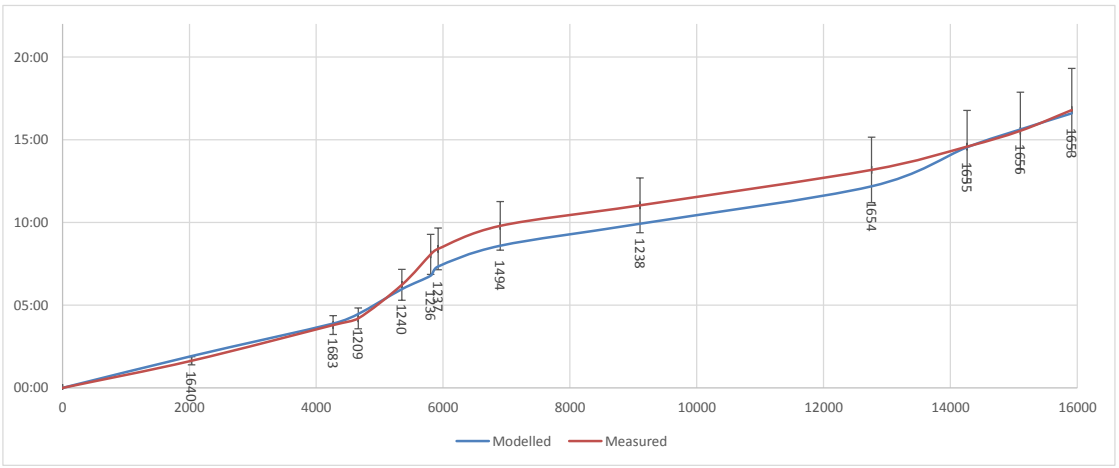
AM



IP

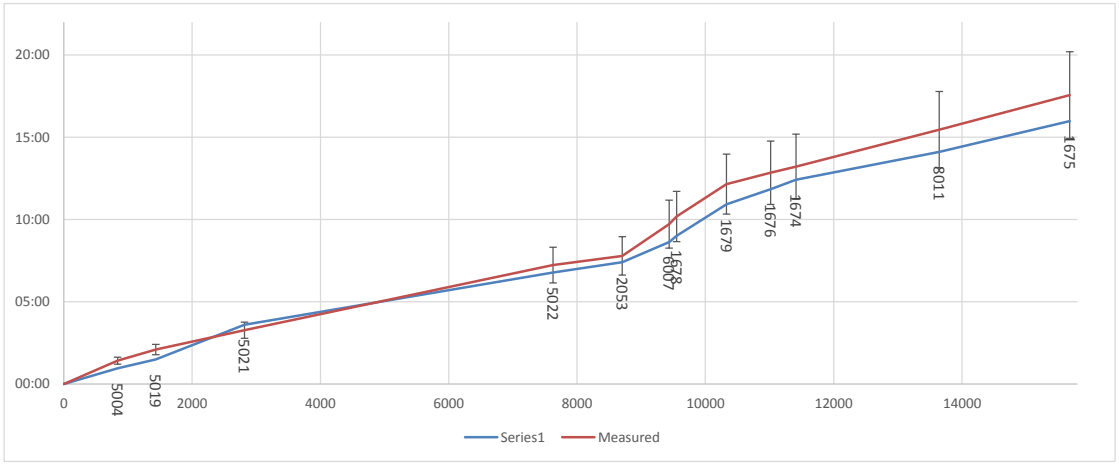


PM



Route2CW

AM



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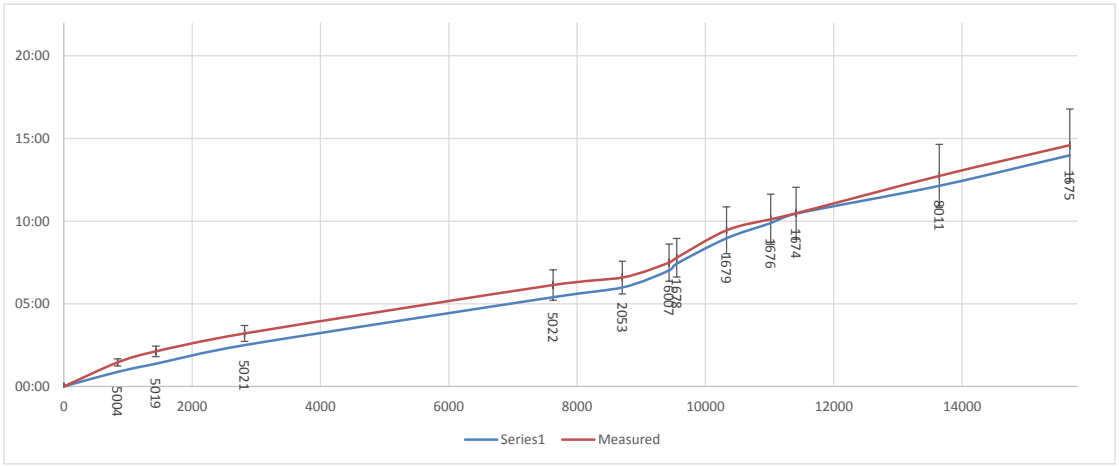

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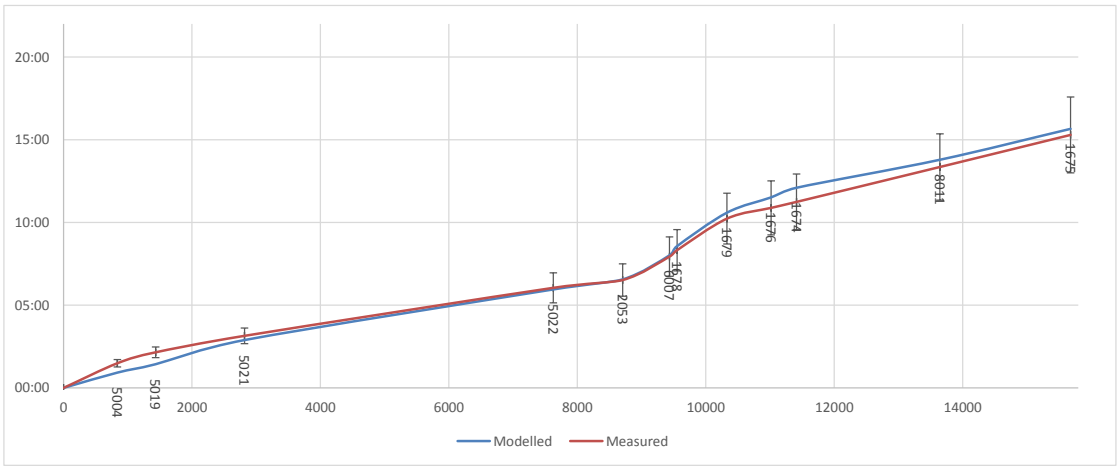
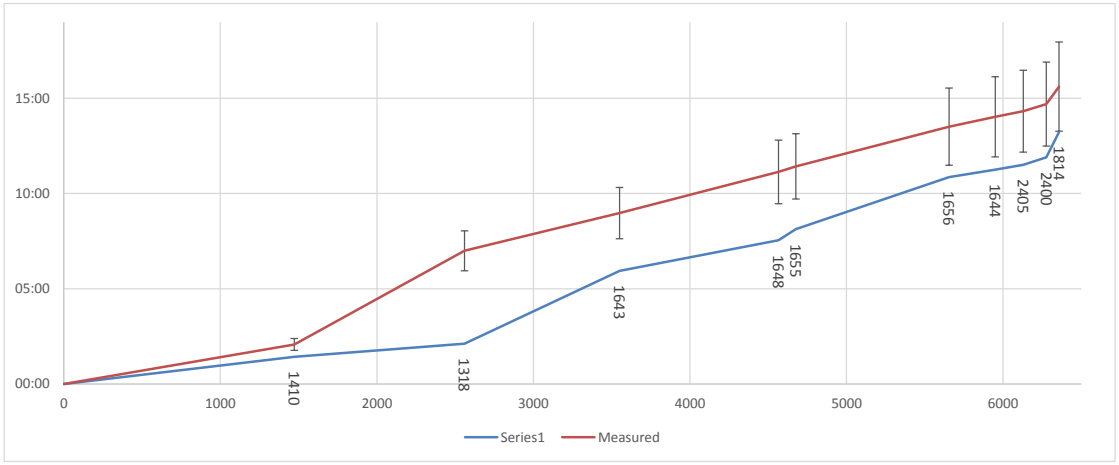


Route3EB

AM



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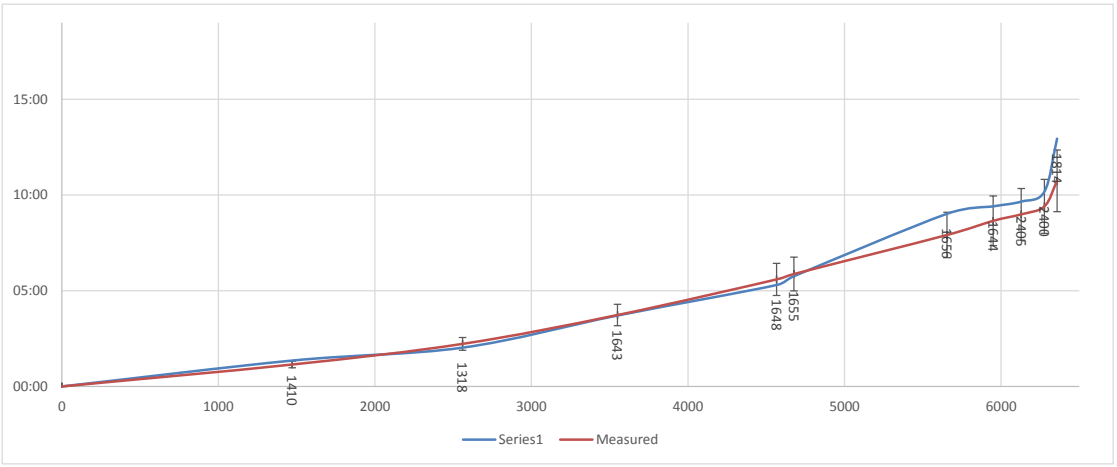

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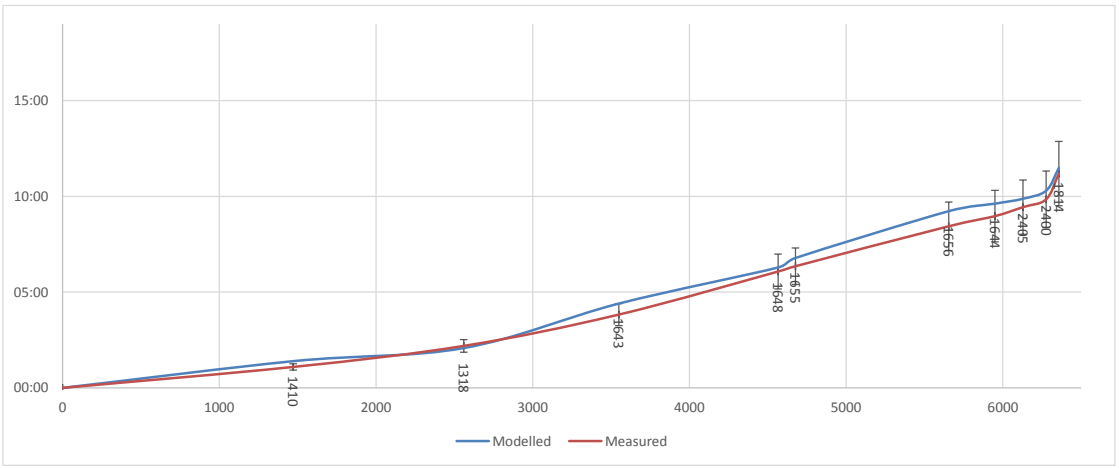
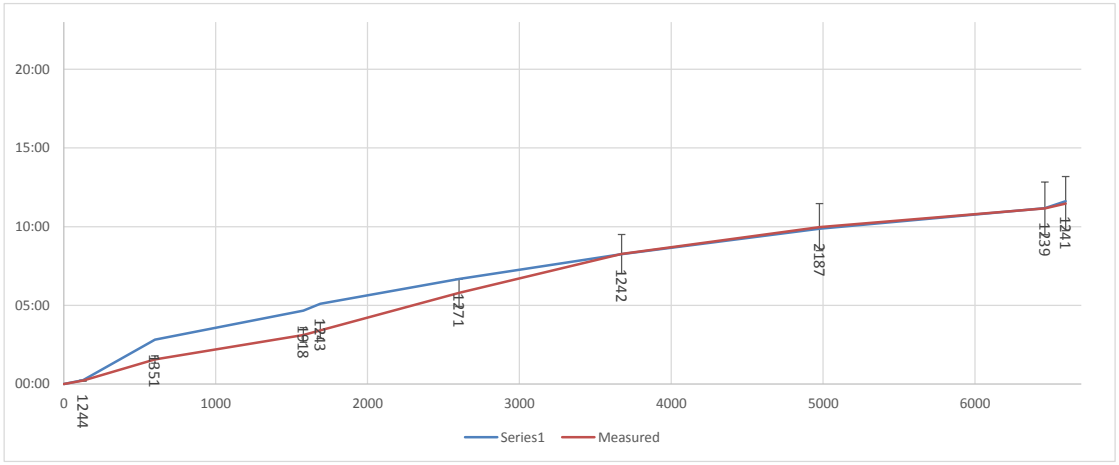


Route3WB

AM



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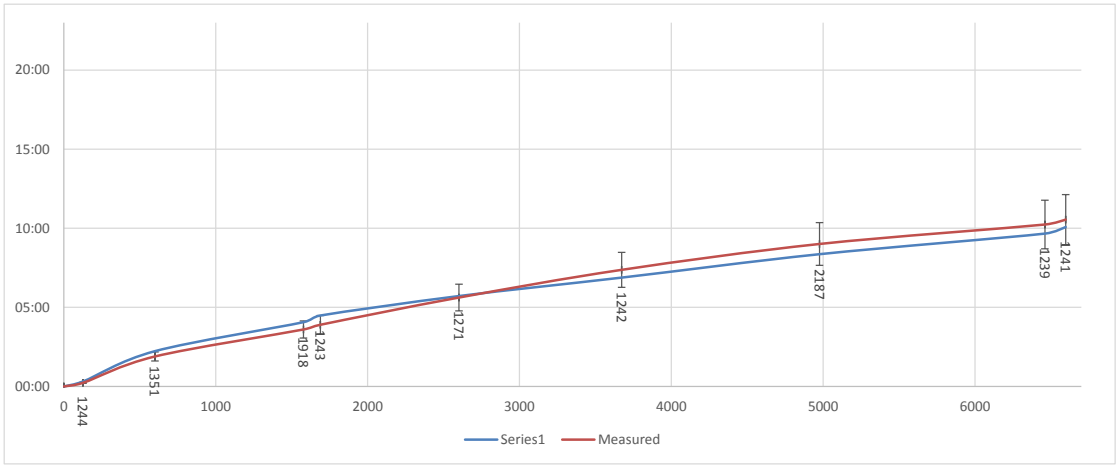

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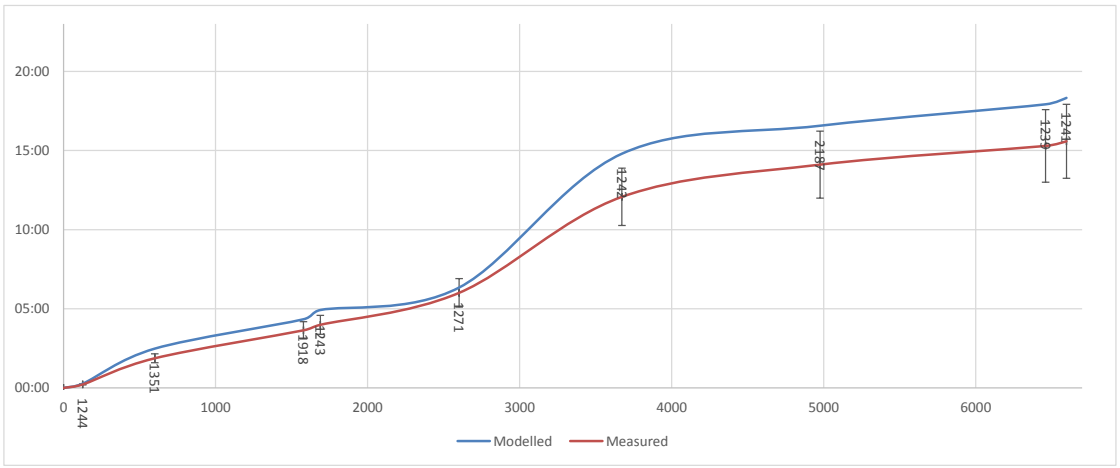

Route4EB

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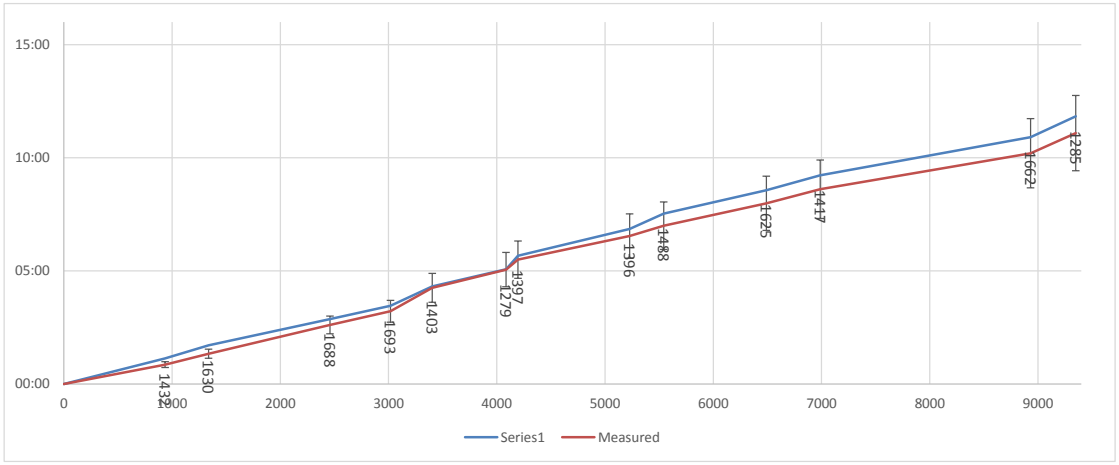

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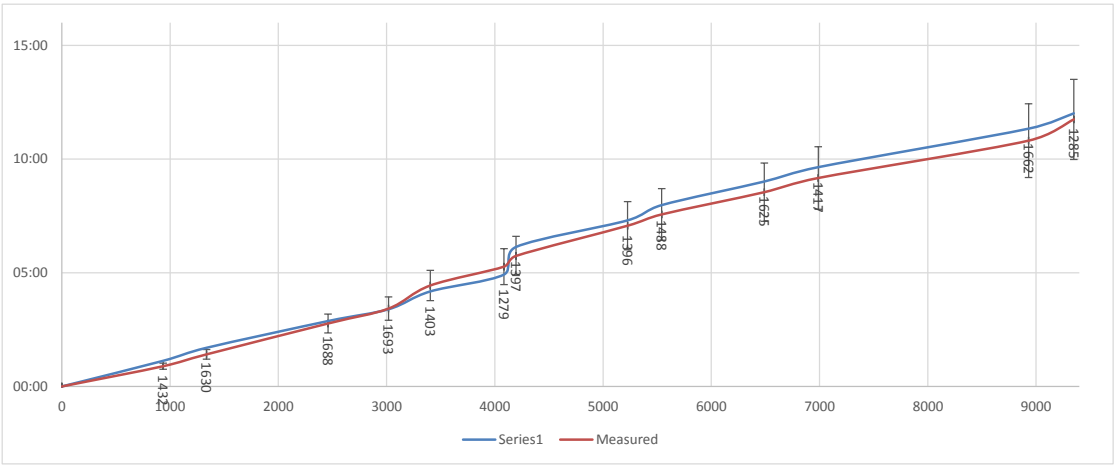

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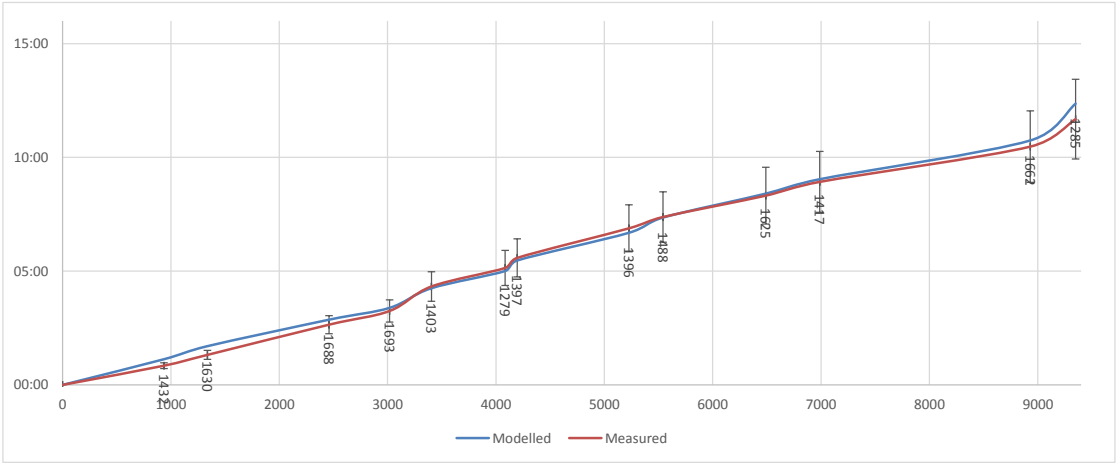
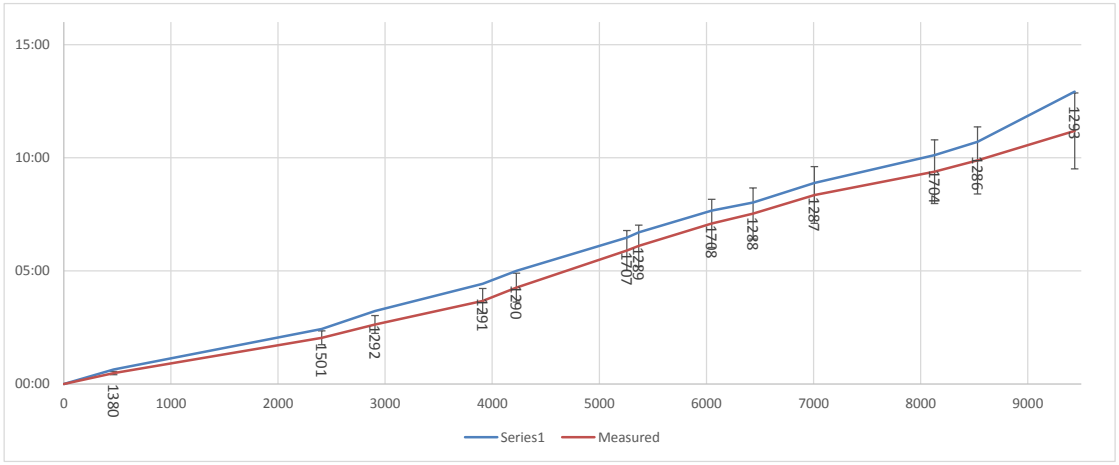


Route4WB

AM



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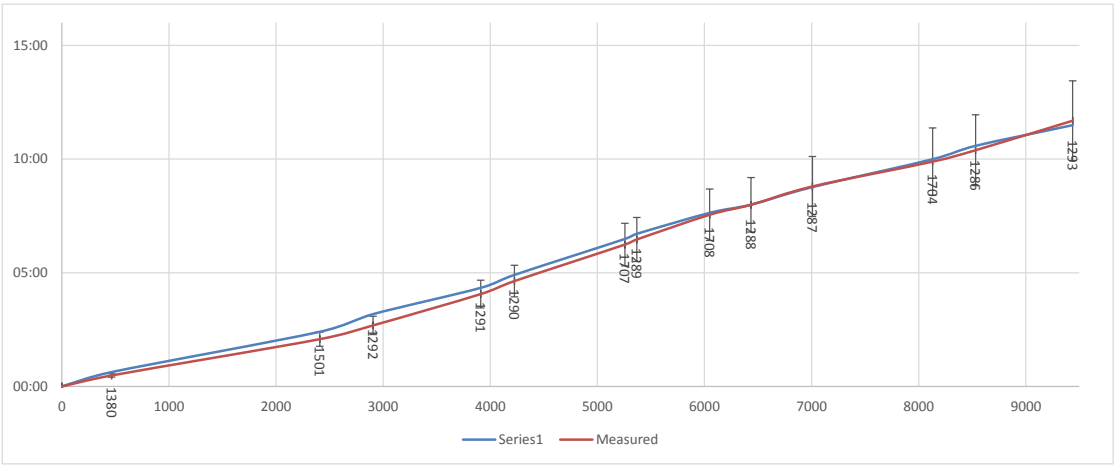

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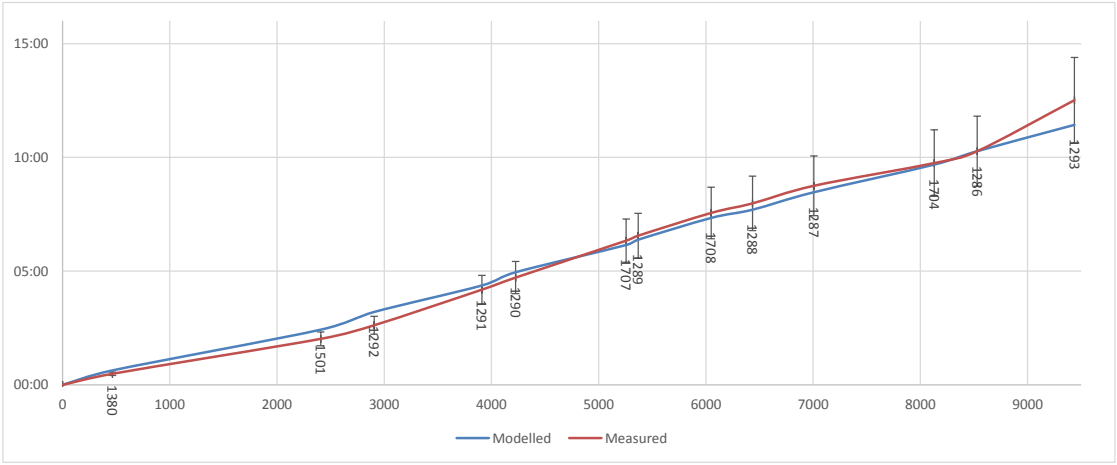
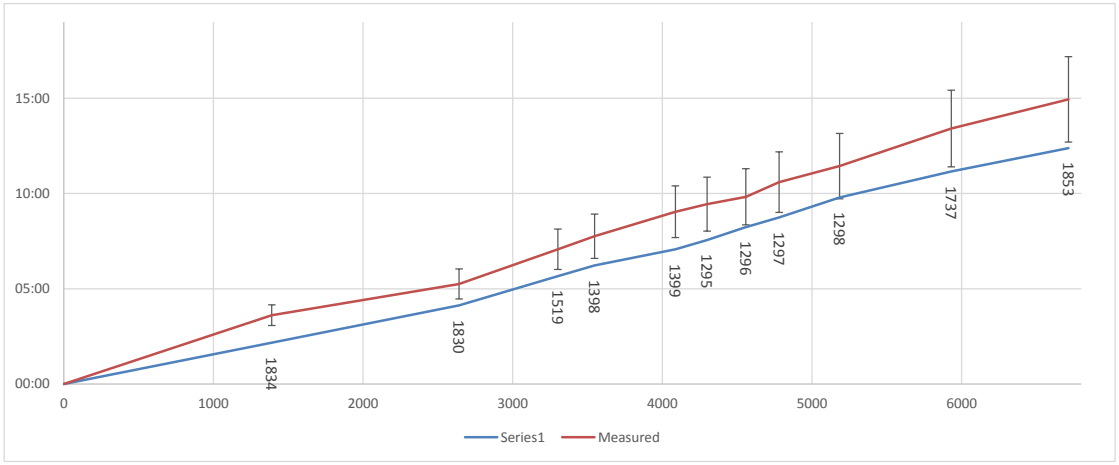


Route5EB

AM



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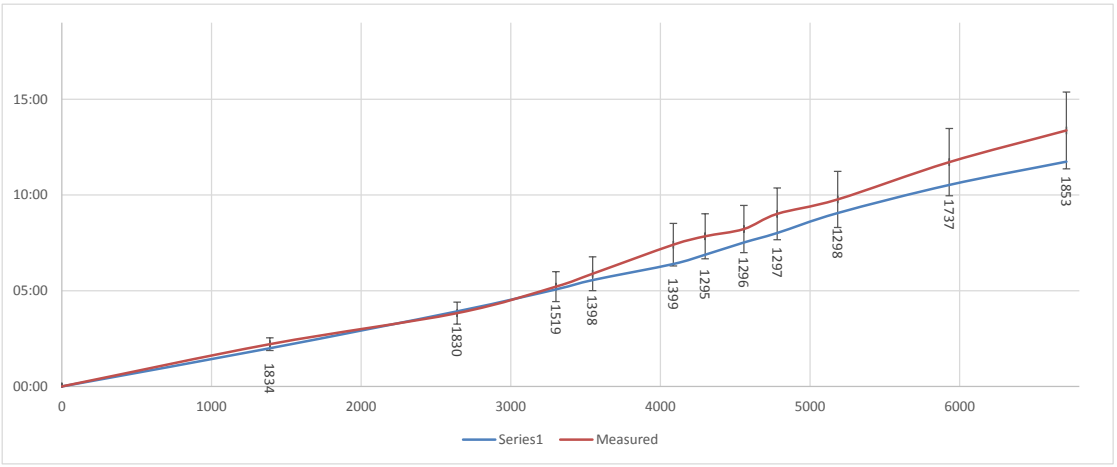

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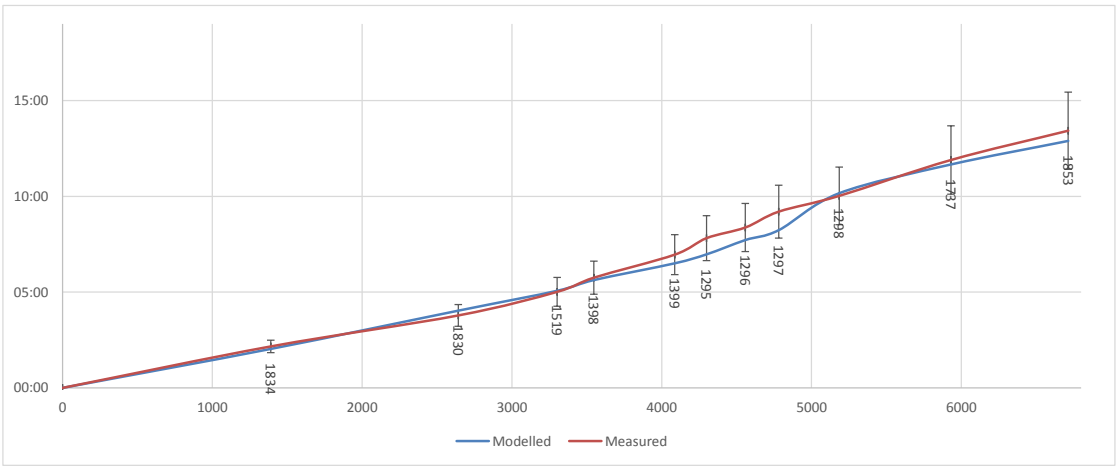
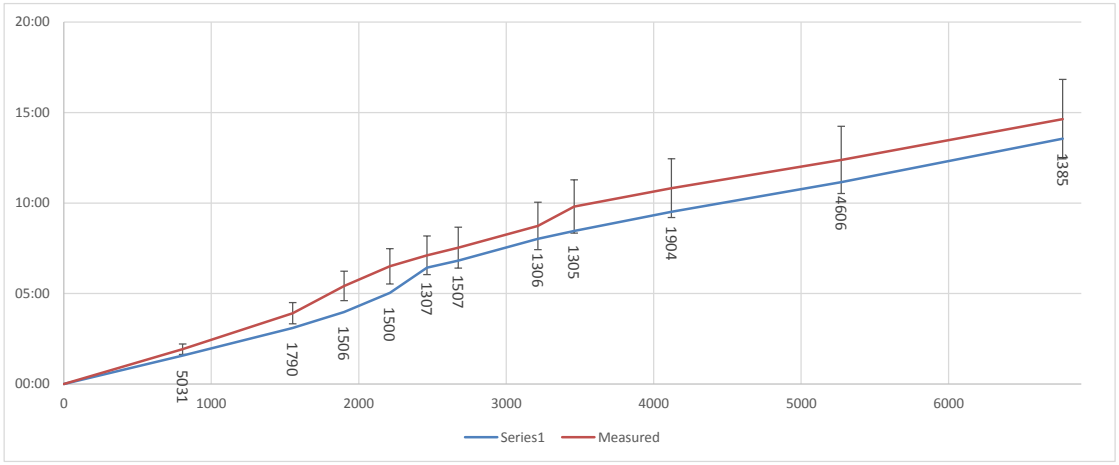


Route5WB

AM



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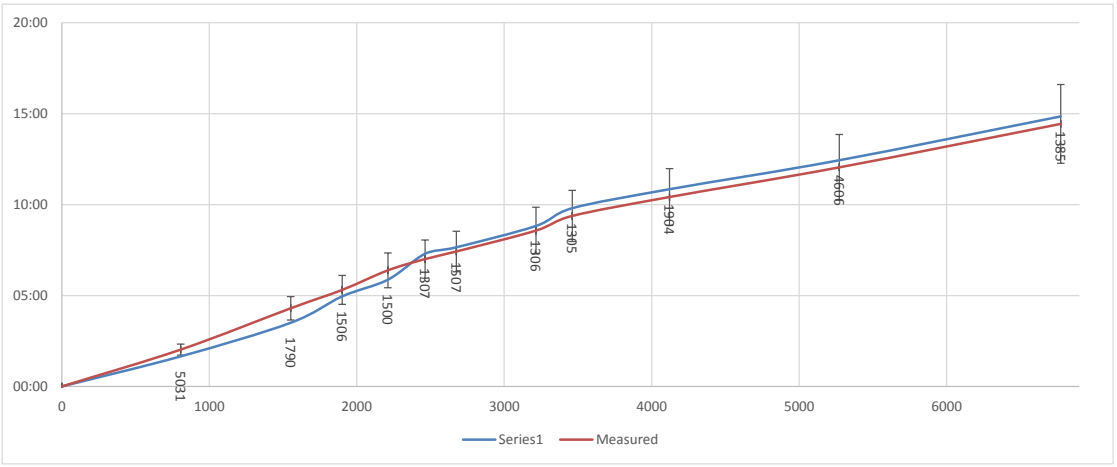

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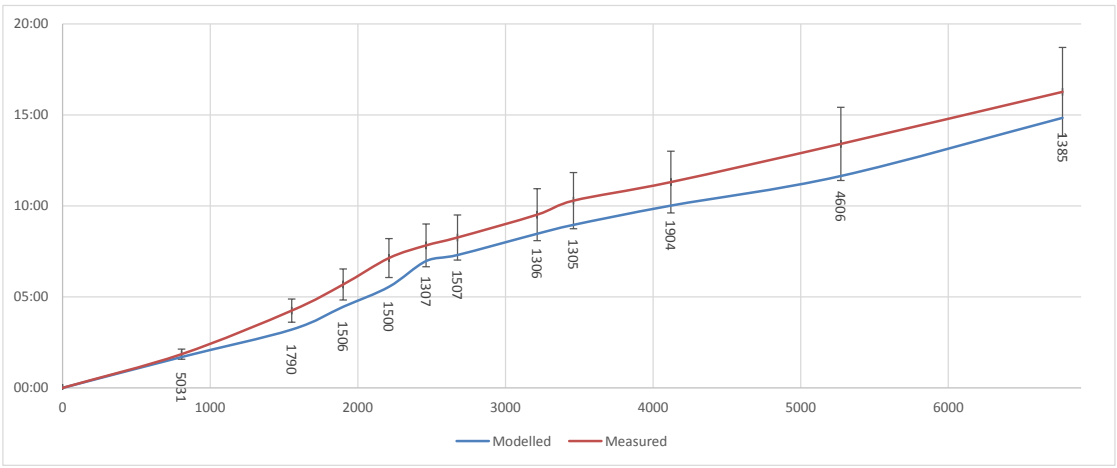
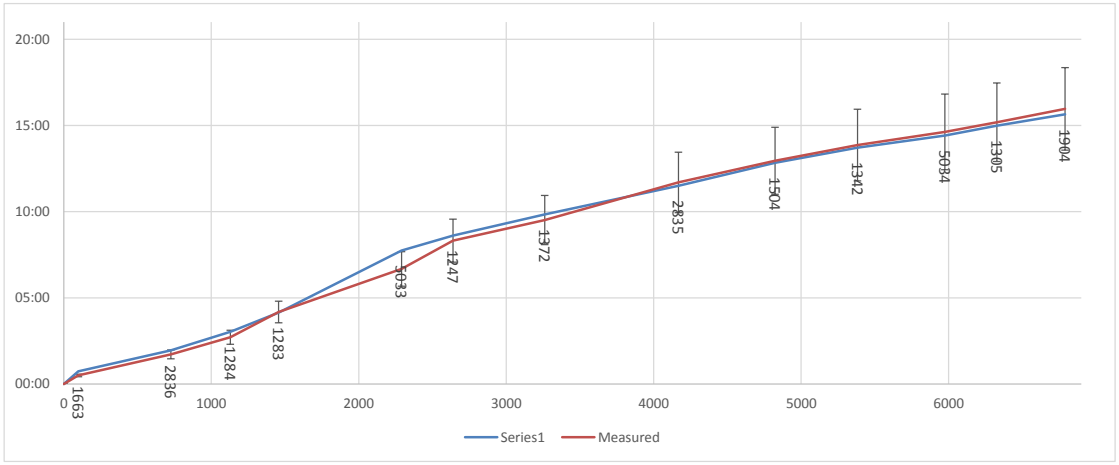


Route6NB

AM



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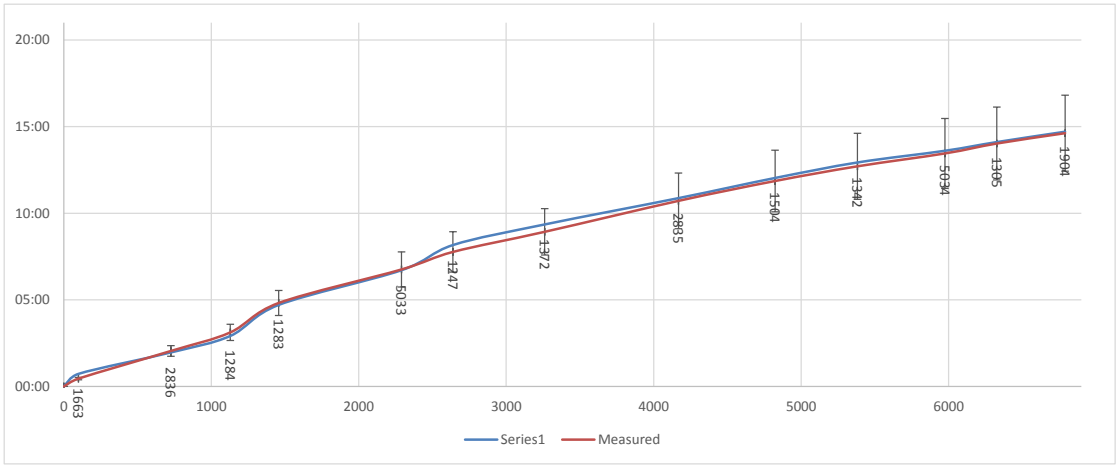

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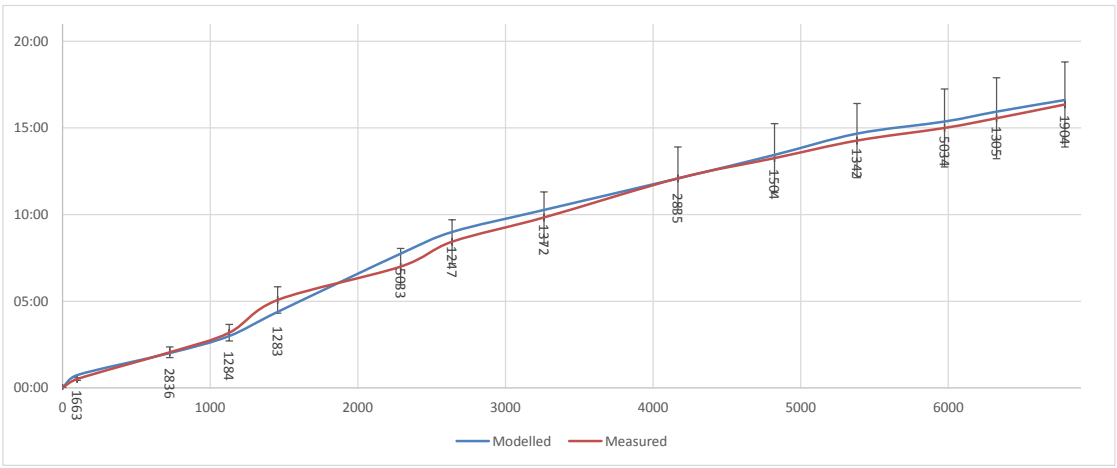
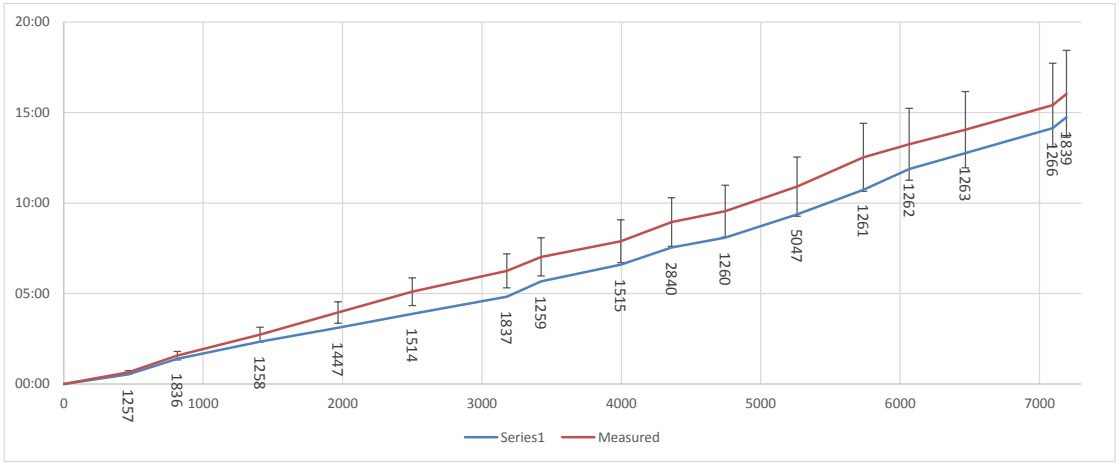


Route6SB

AM



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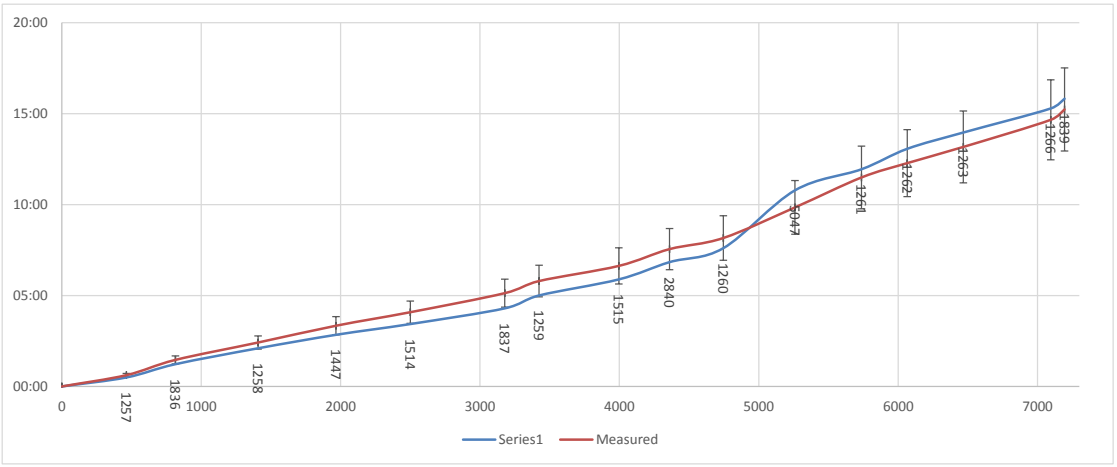

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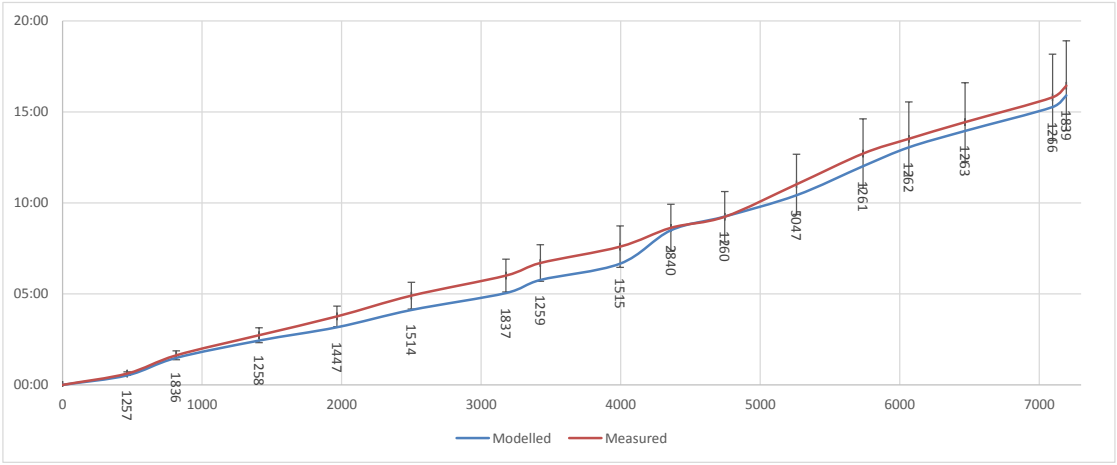
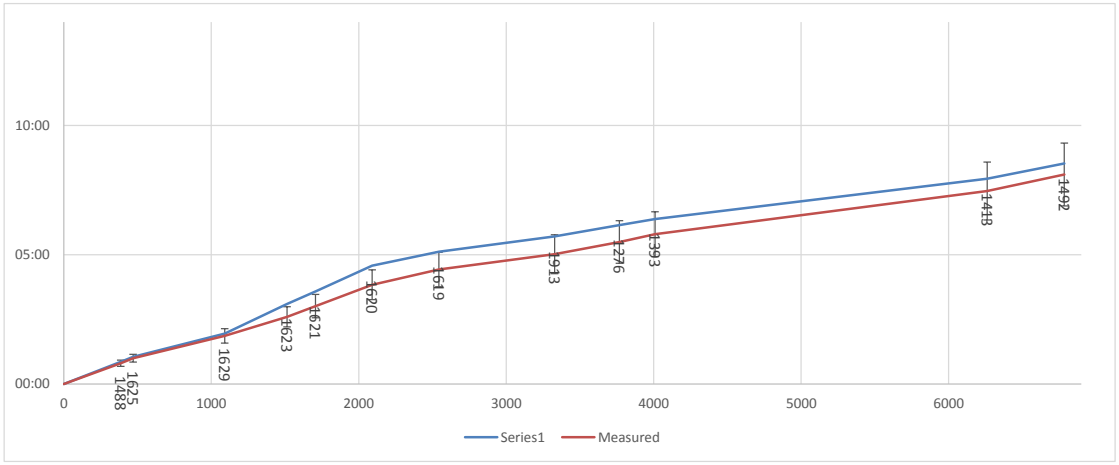


Route7NB

AM



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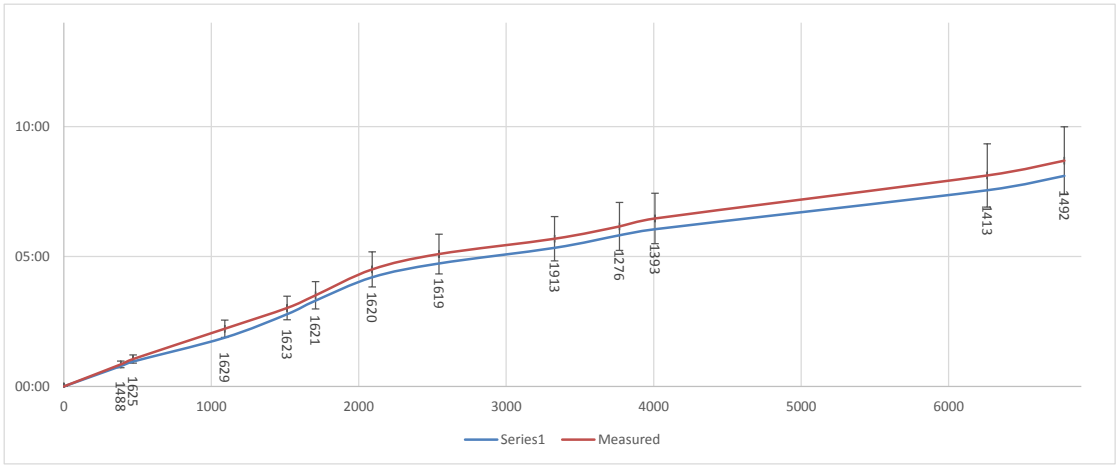

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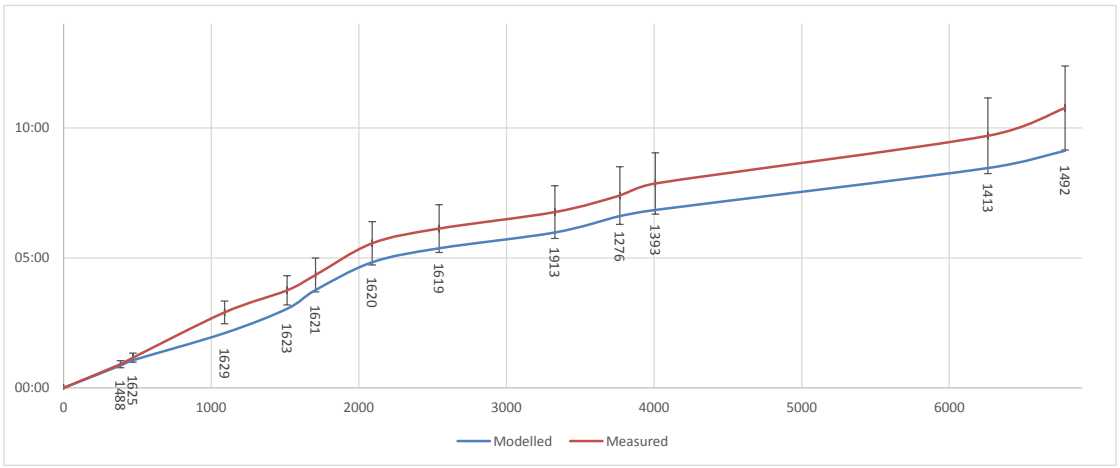
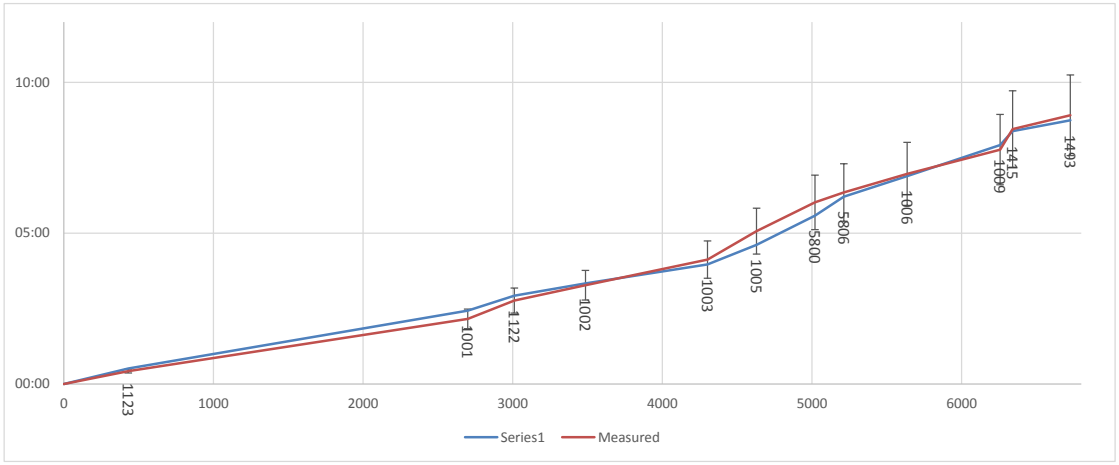


Route7SB

AM



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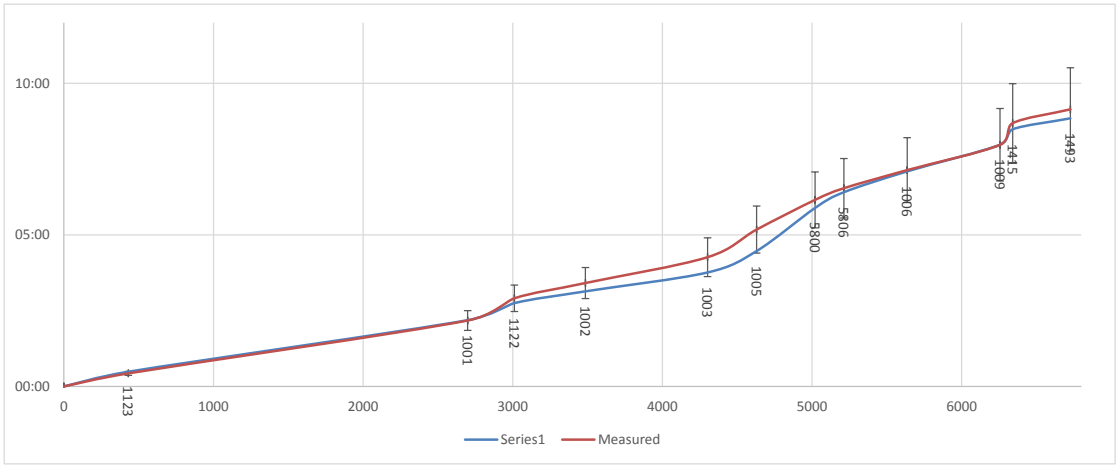

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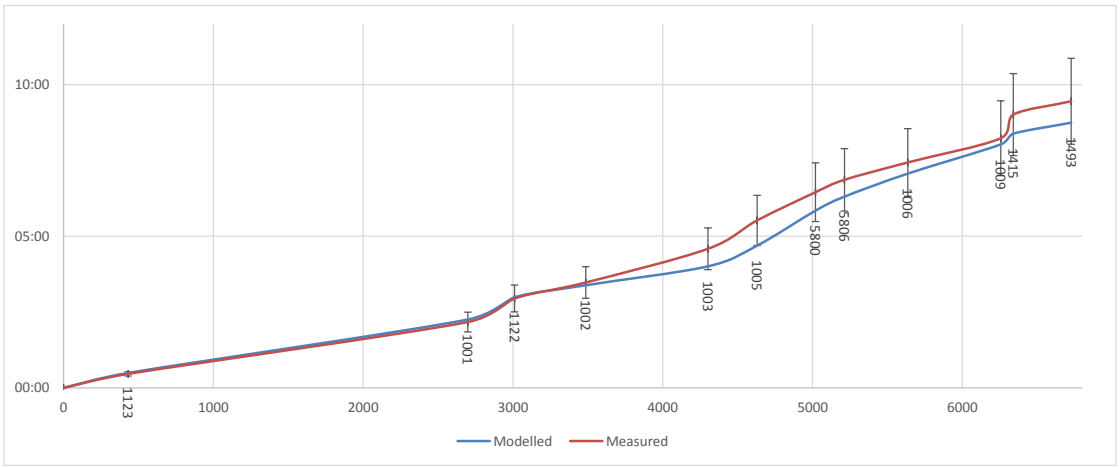
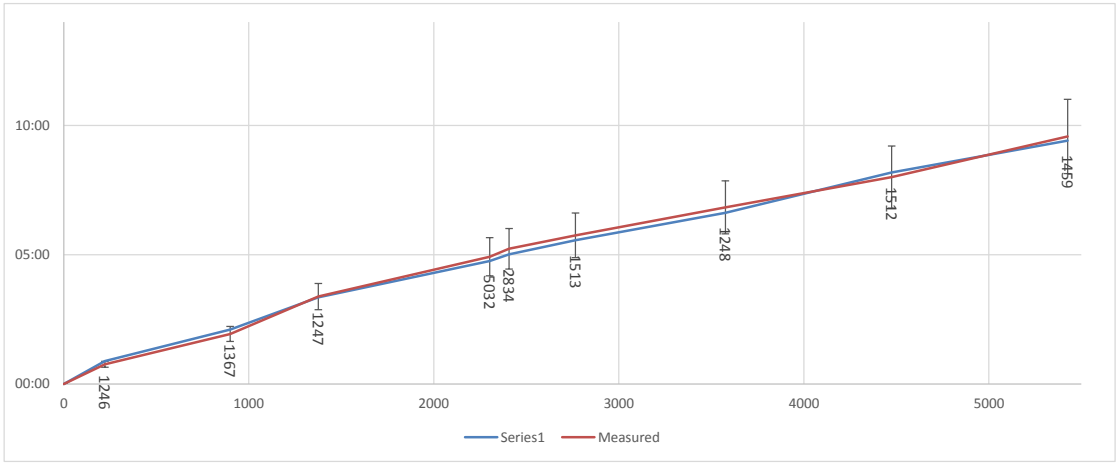


Route8EB

AM



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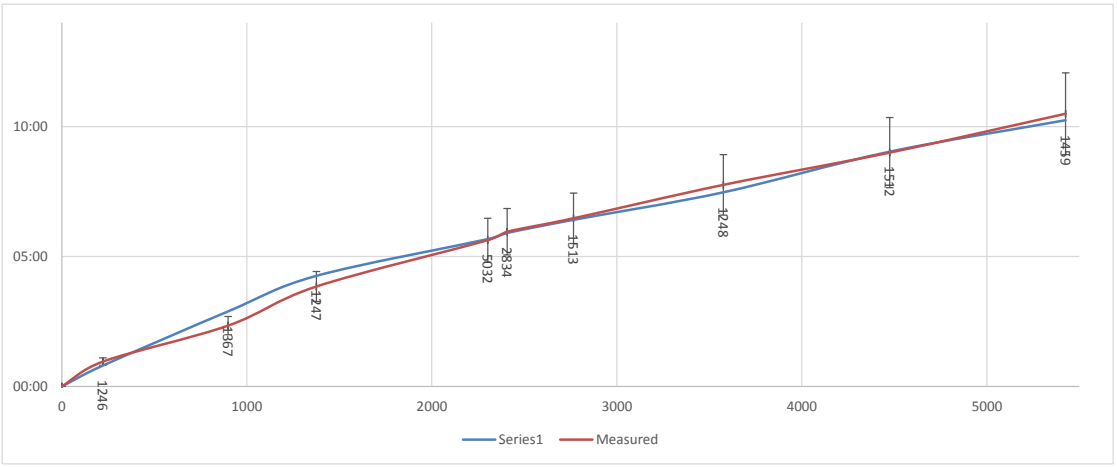

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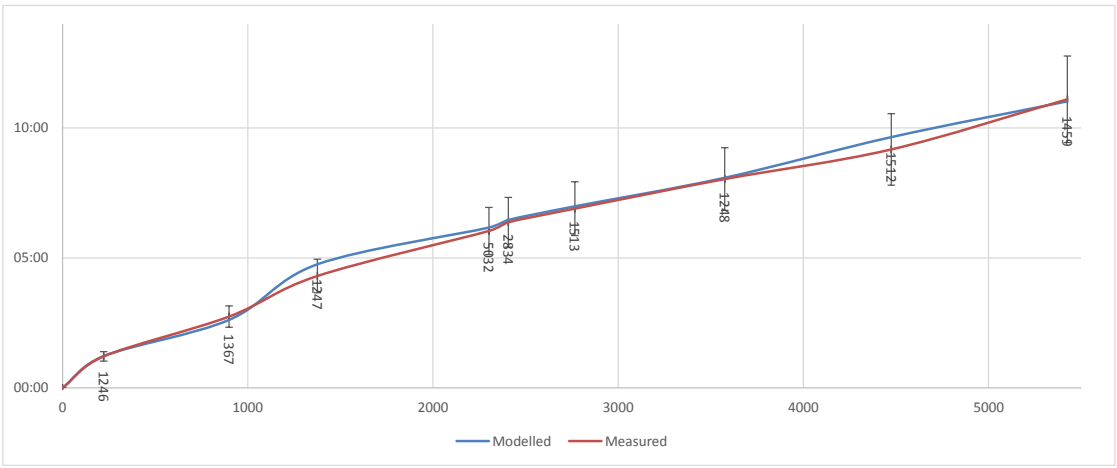
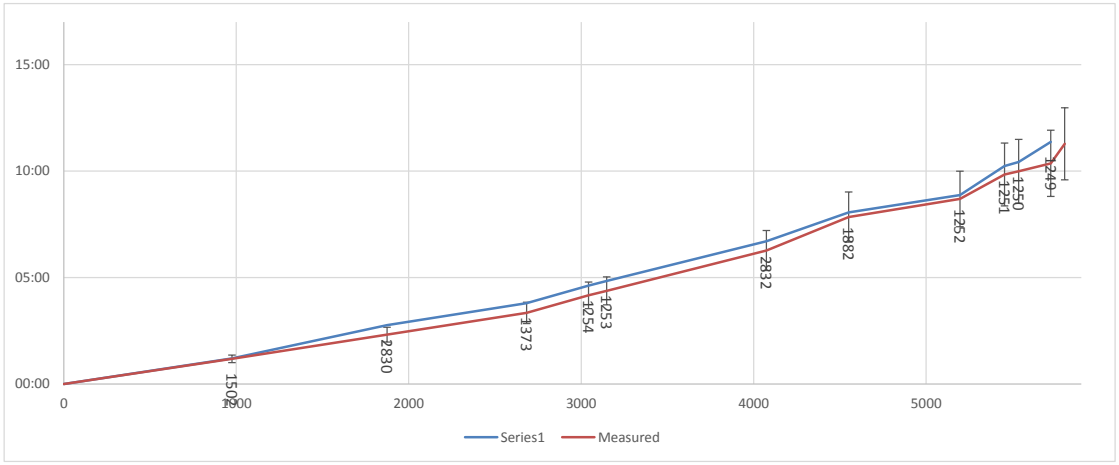


Route8WB

AM



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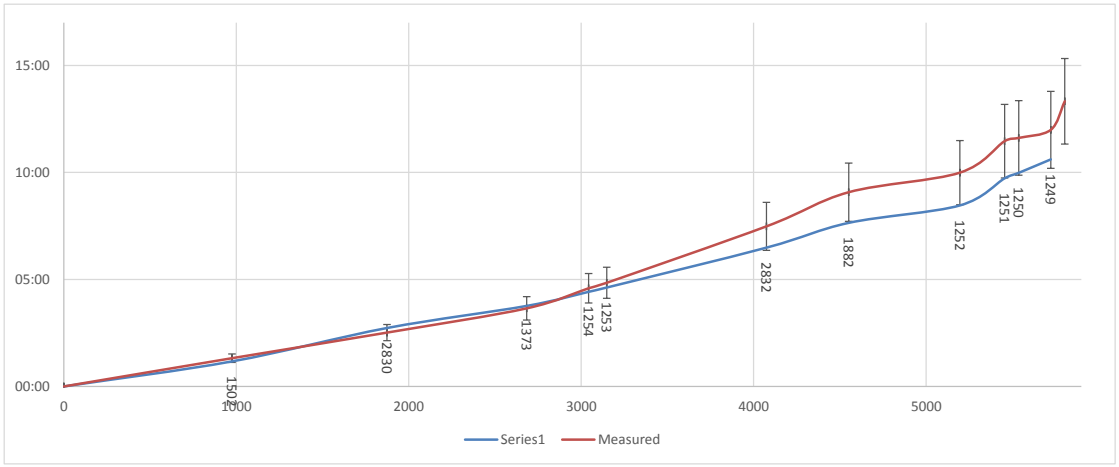

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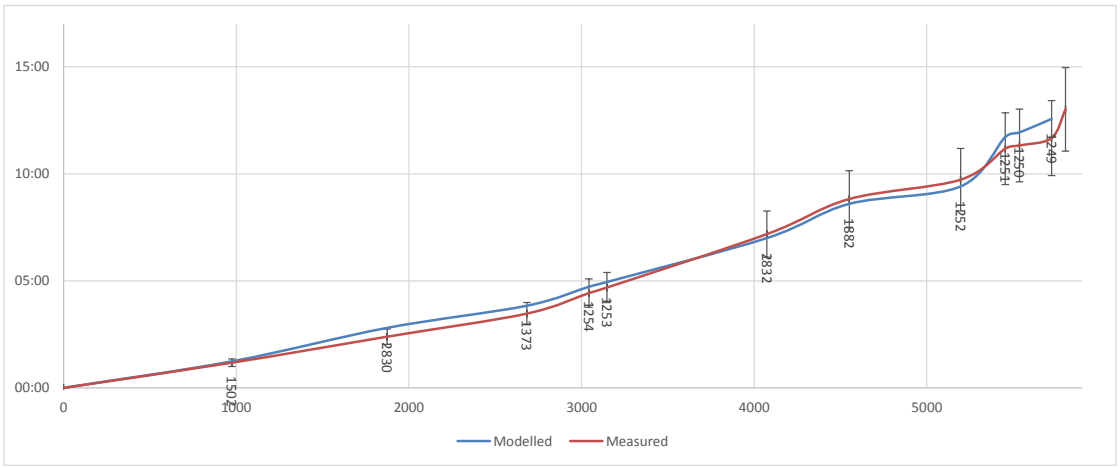
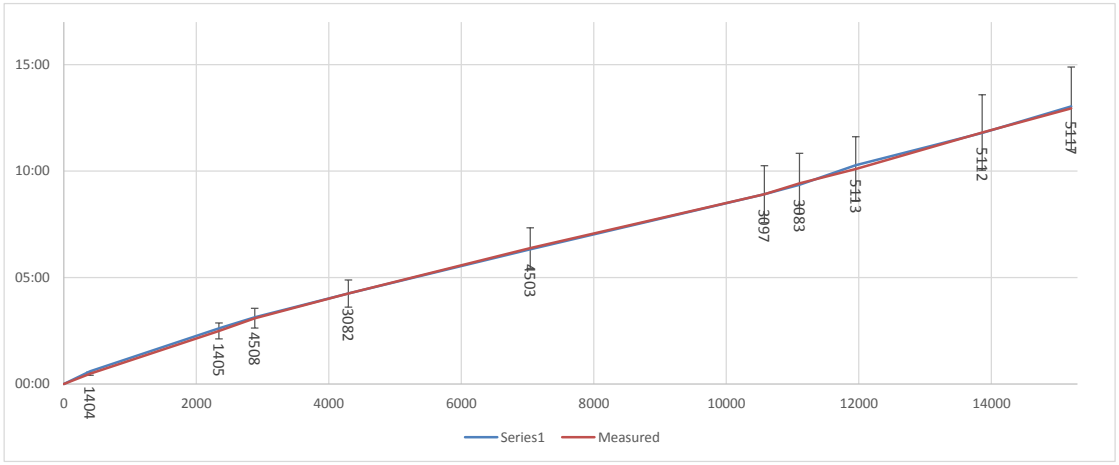


Route9EB

AM



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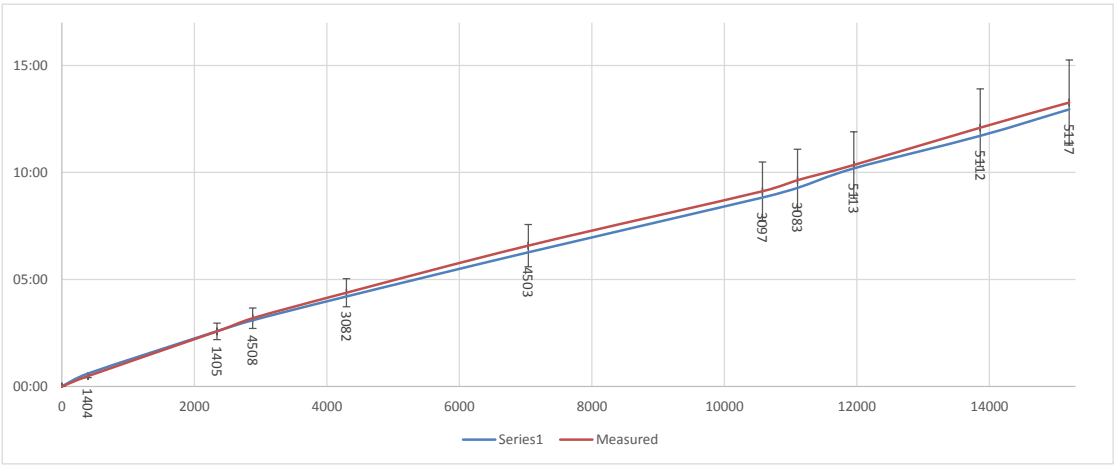

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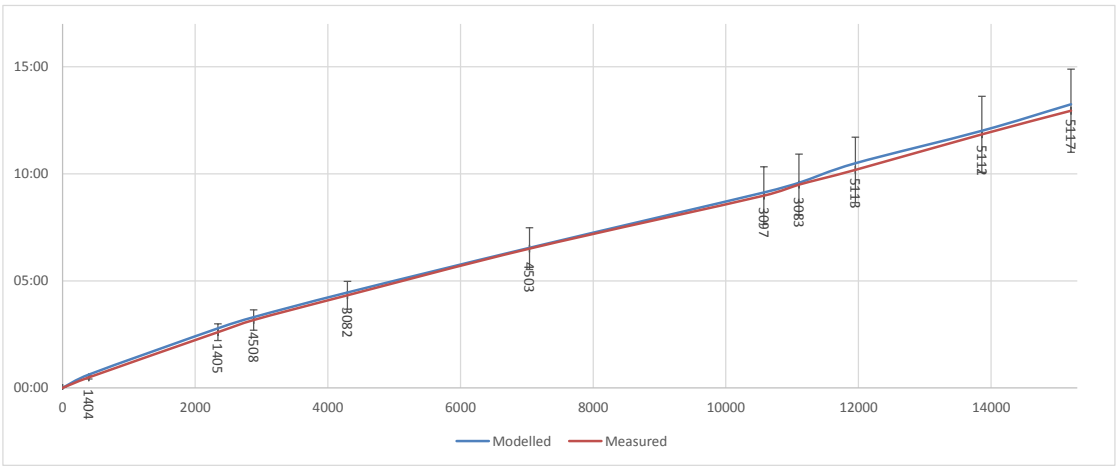
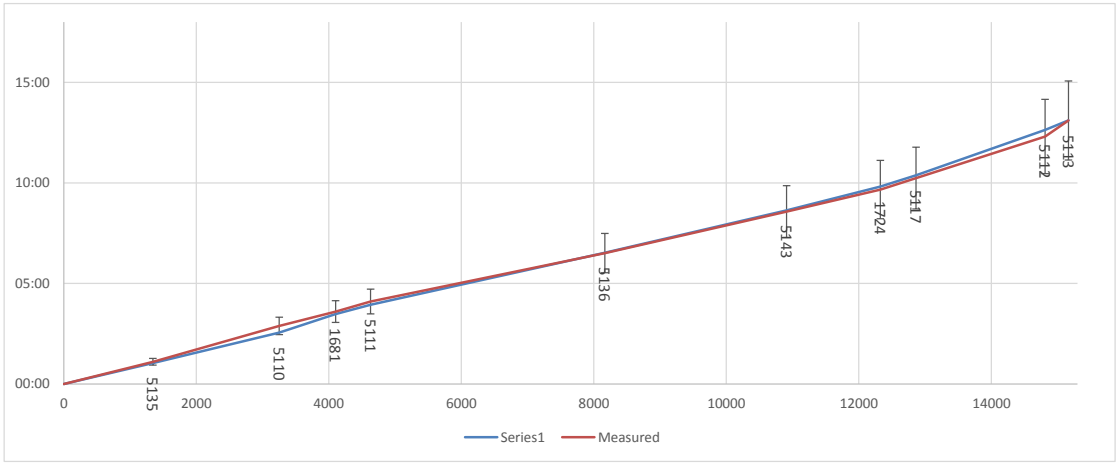


Route9WB

AM



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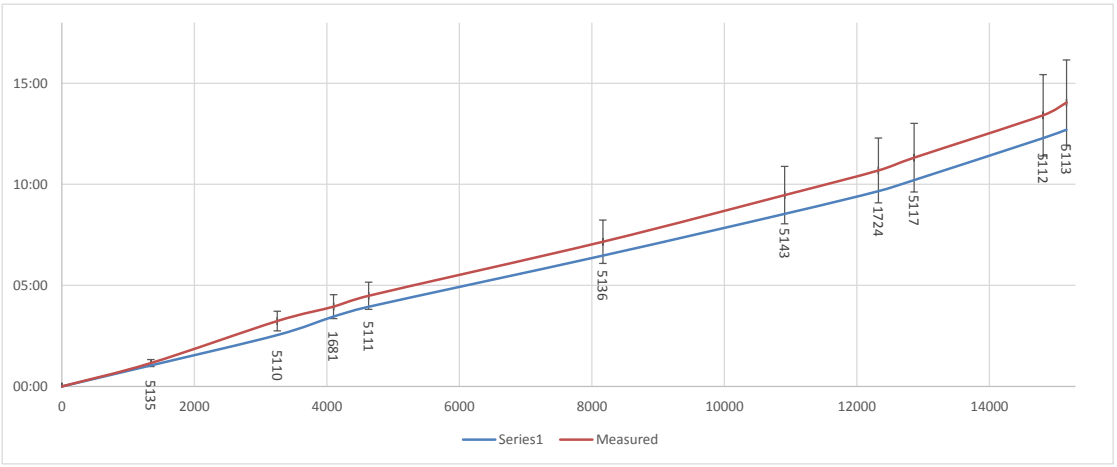

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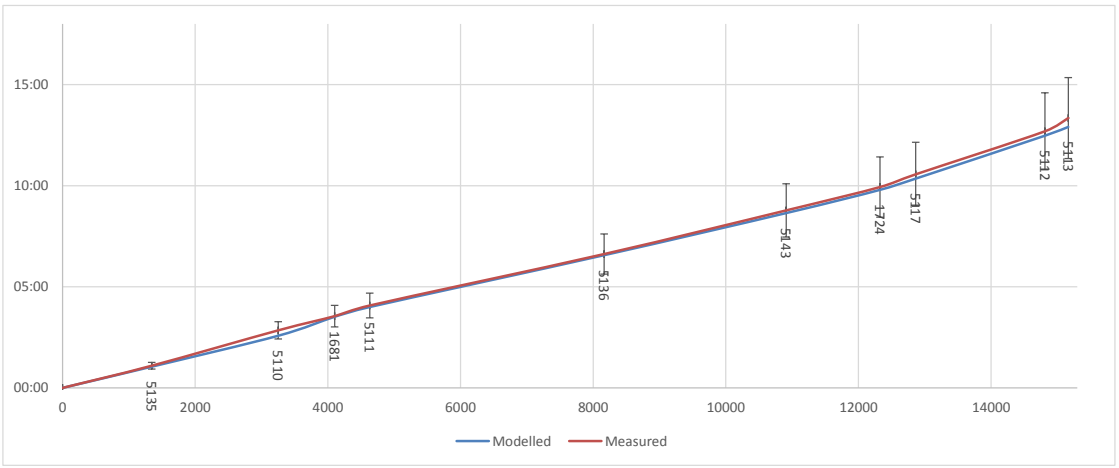
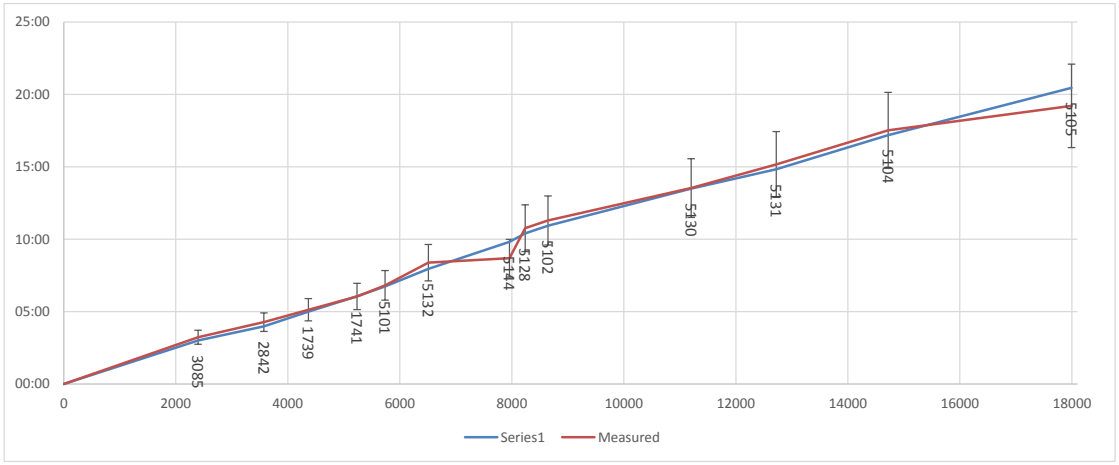


Route10EB

AM



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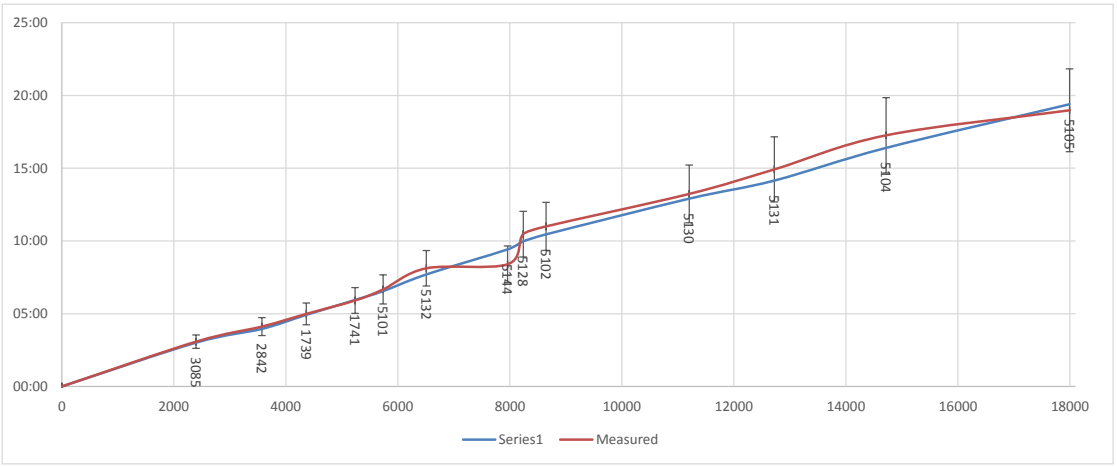

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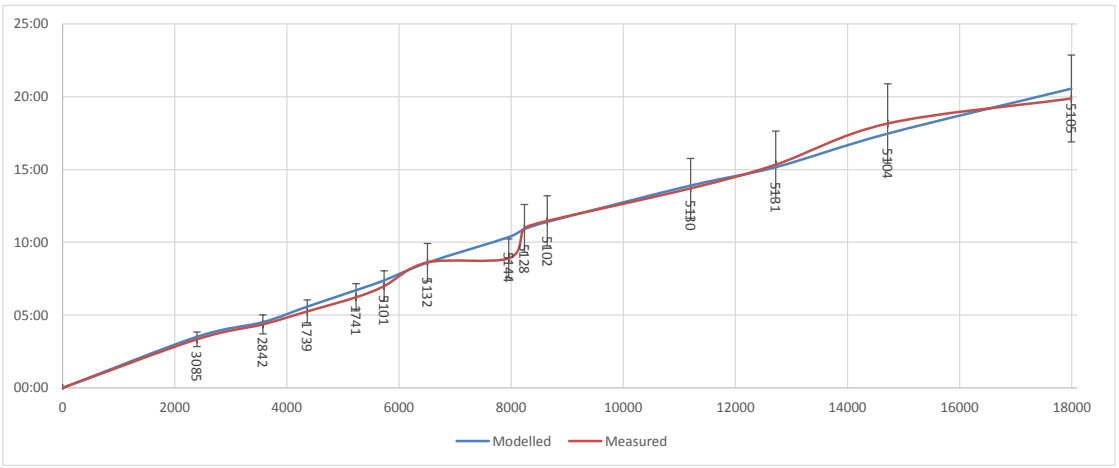
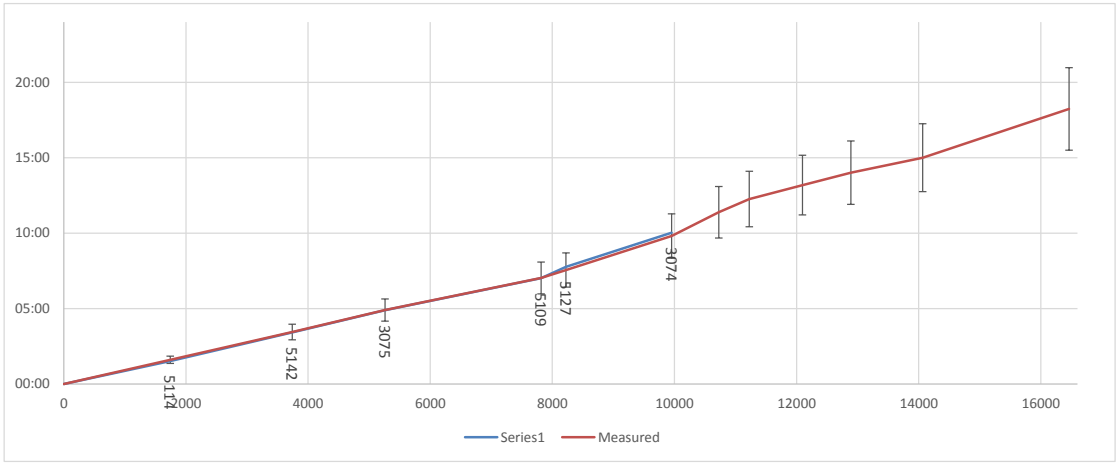


Route10WB

AM



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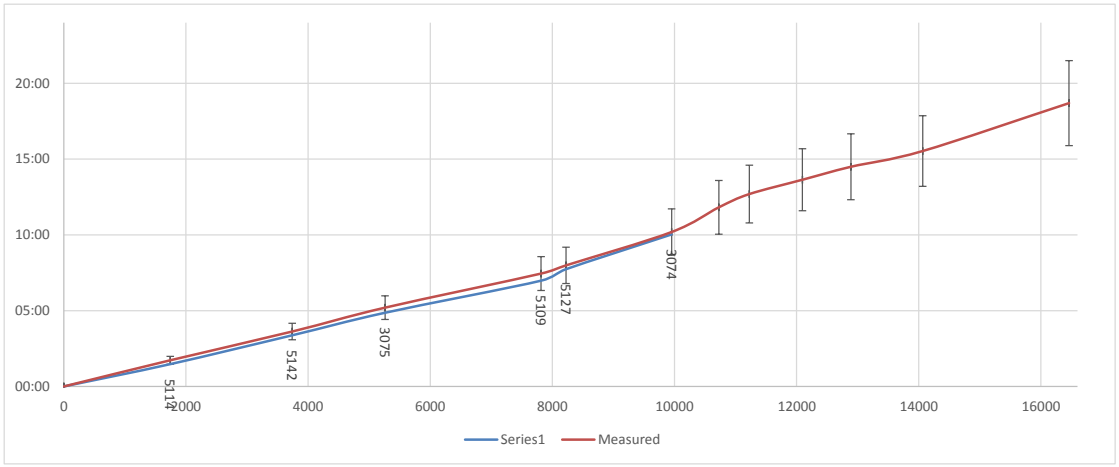

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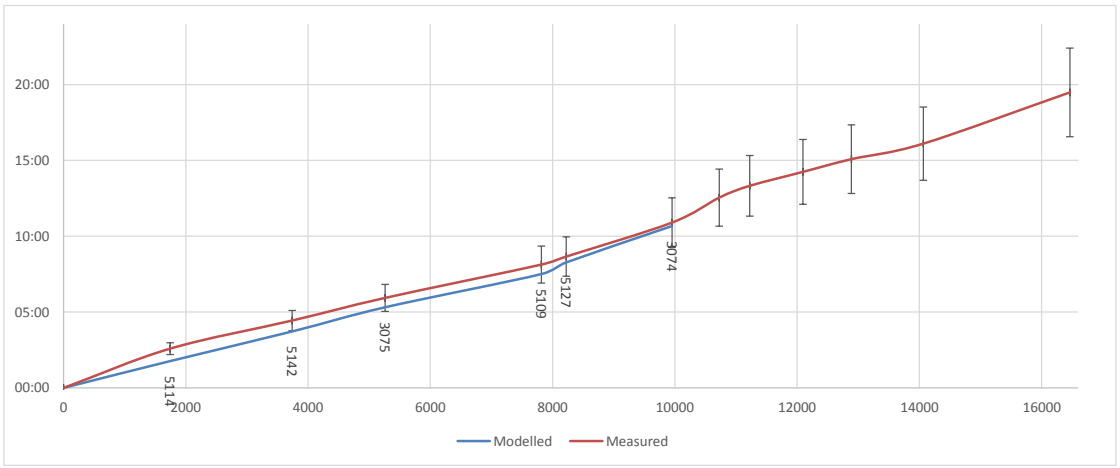
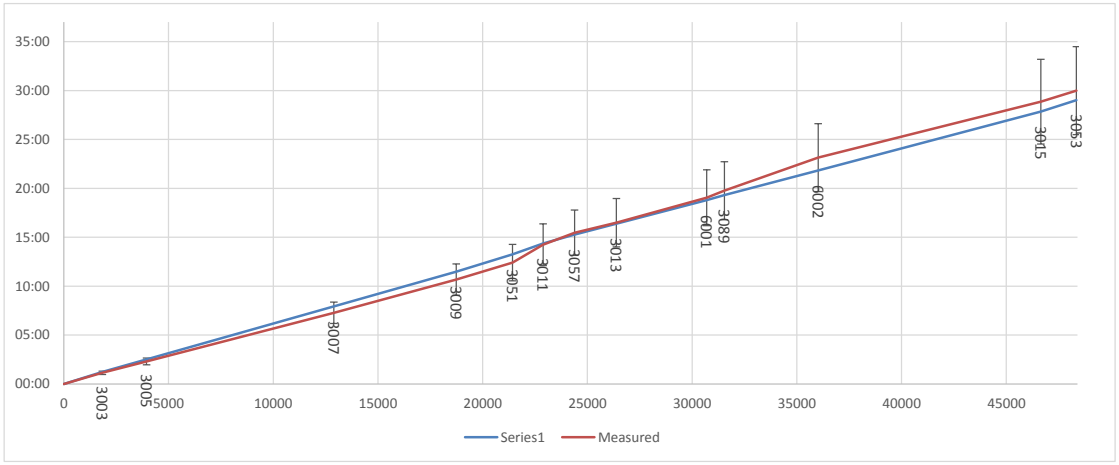


Route11ACW

AM



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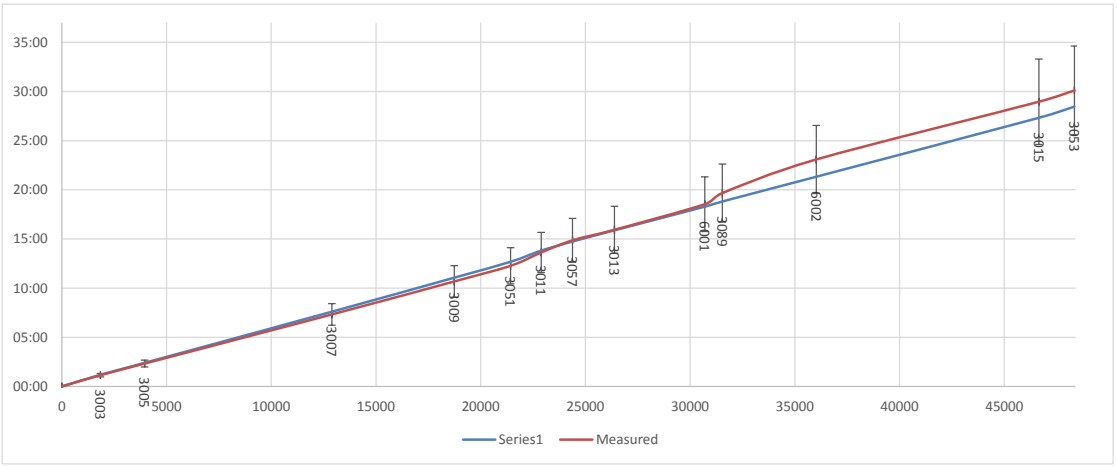

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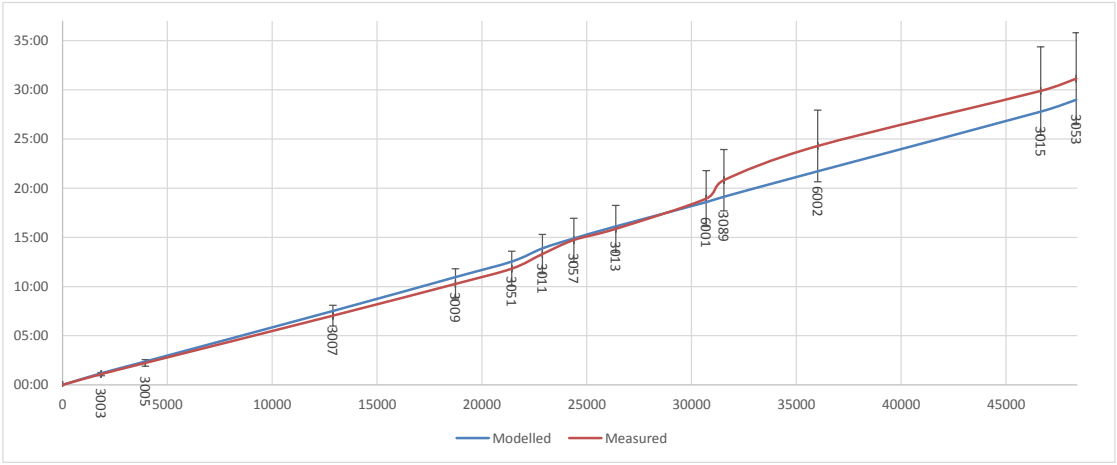
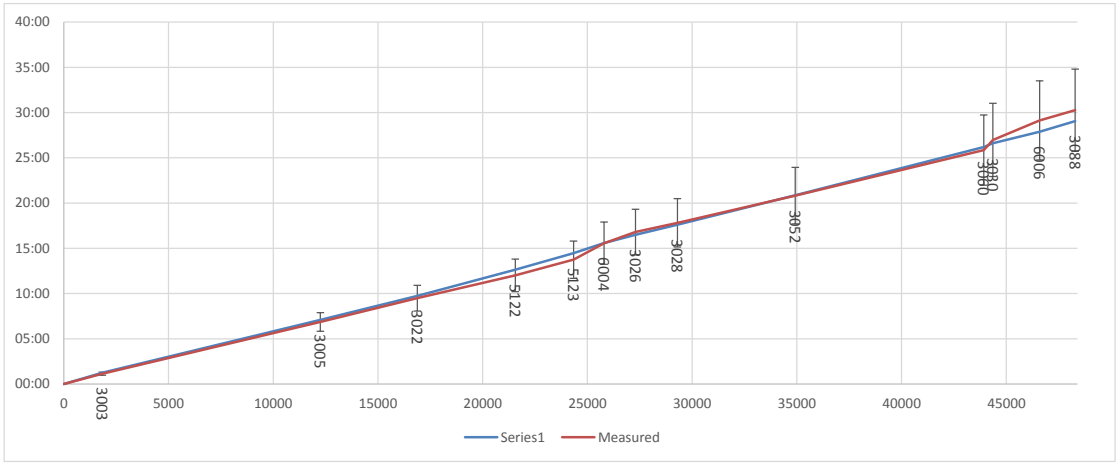


Route11CW

AM



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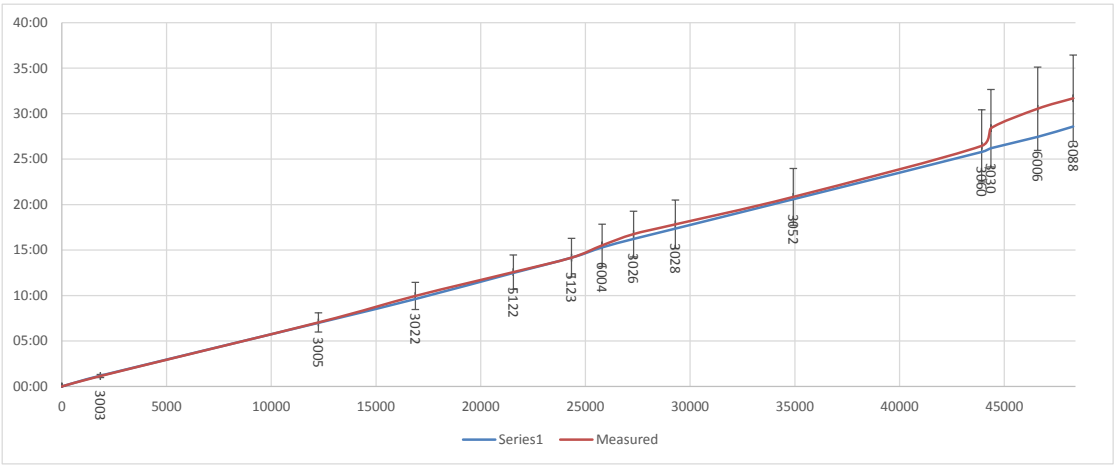

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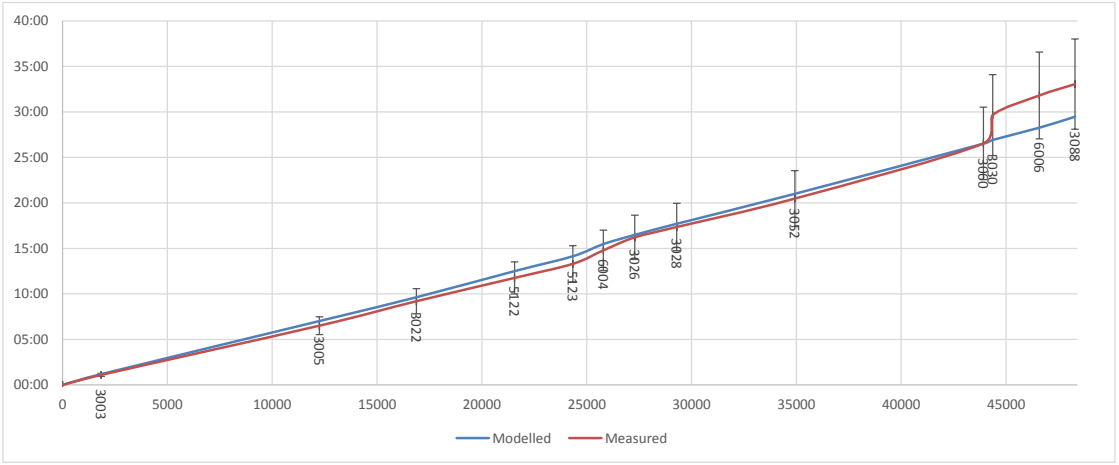
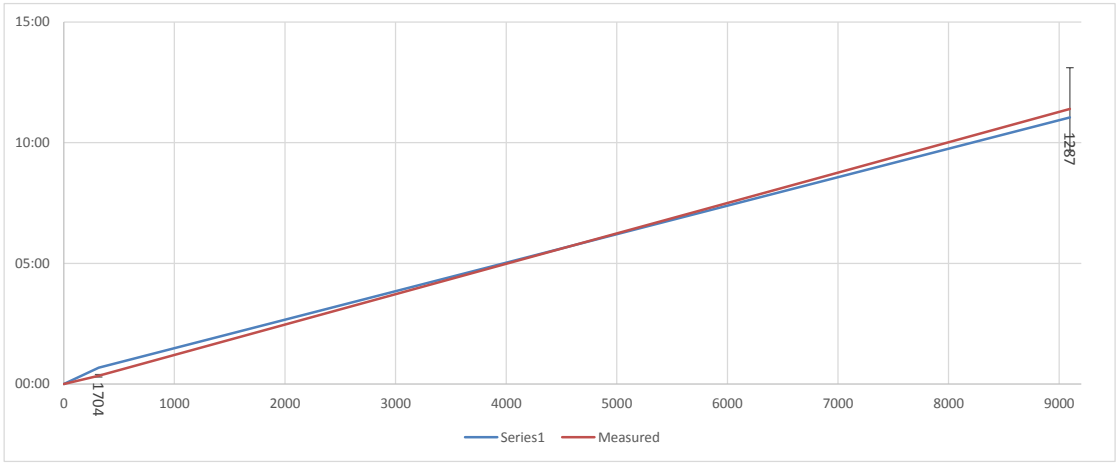


Route12EB

AM



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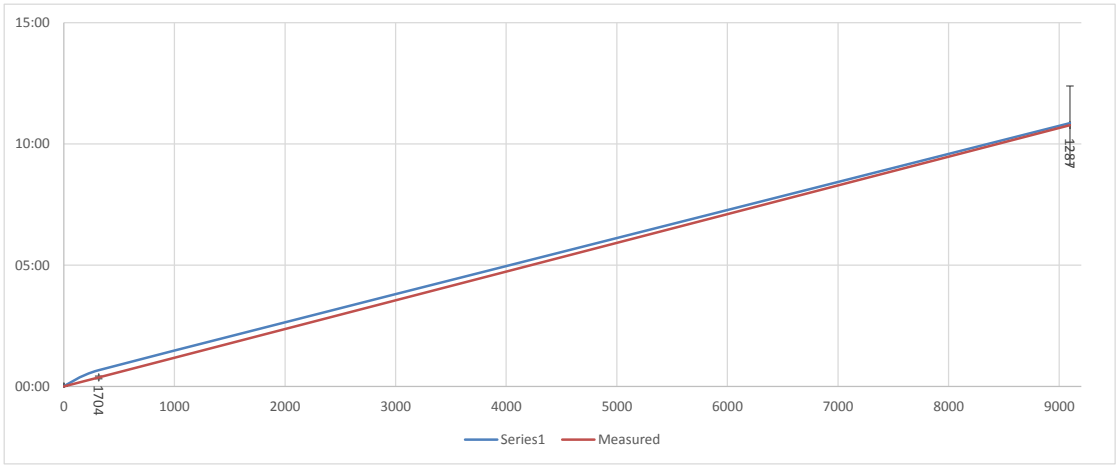

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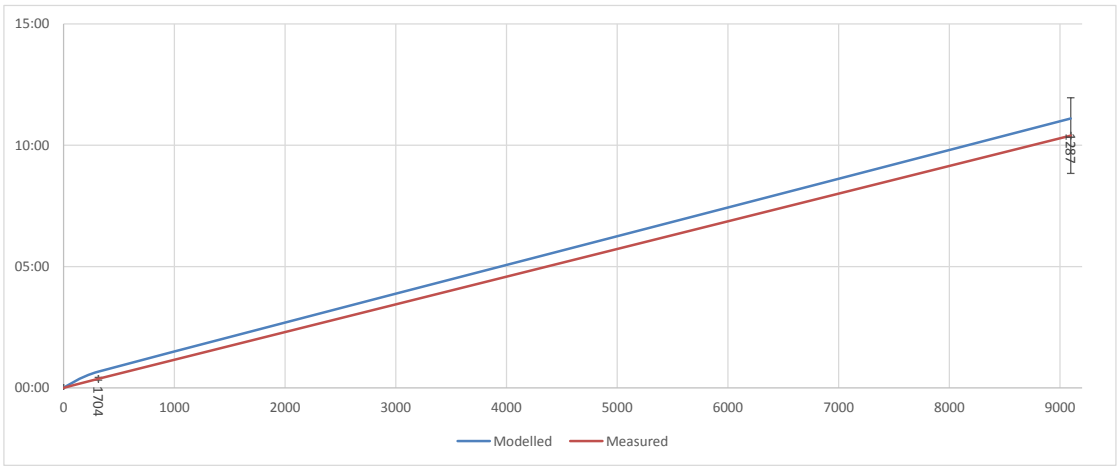
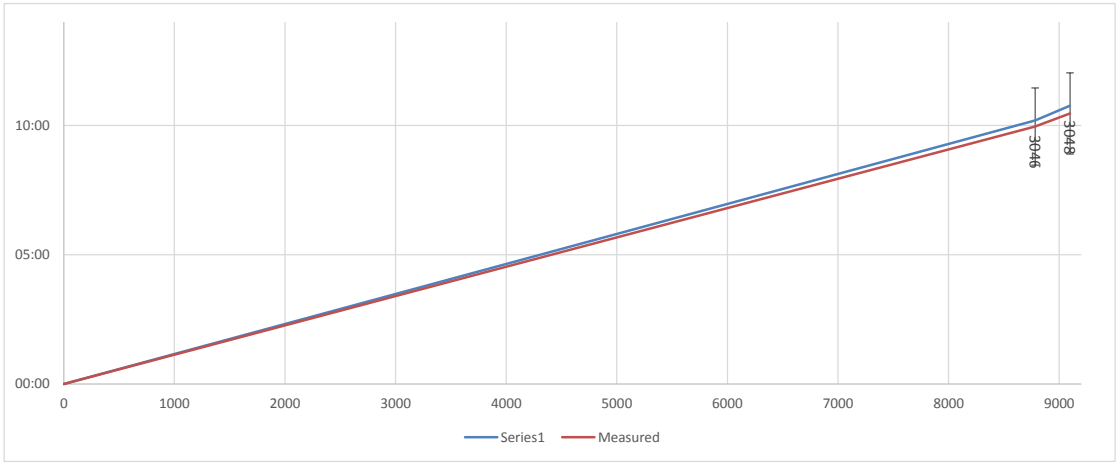
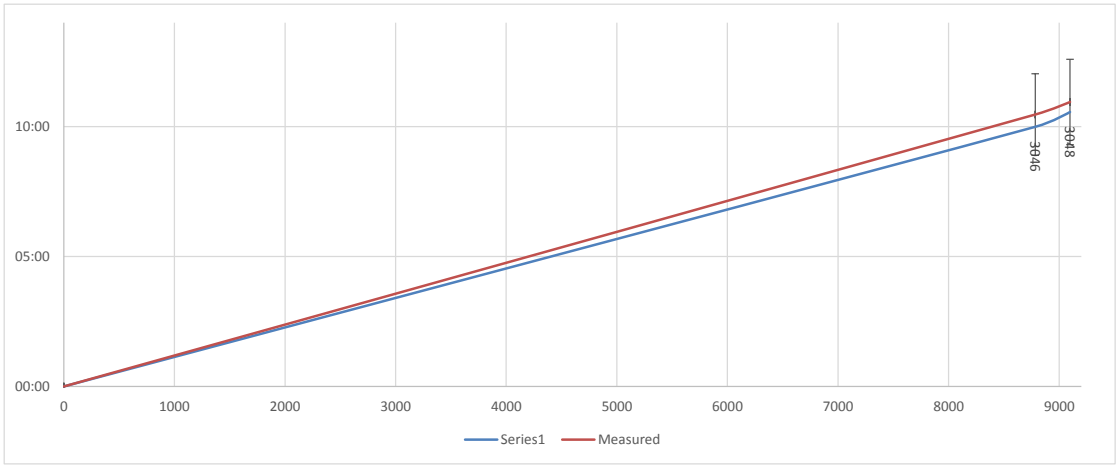


Route12WB

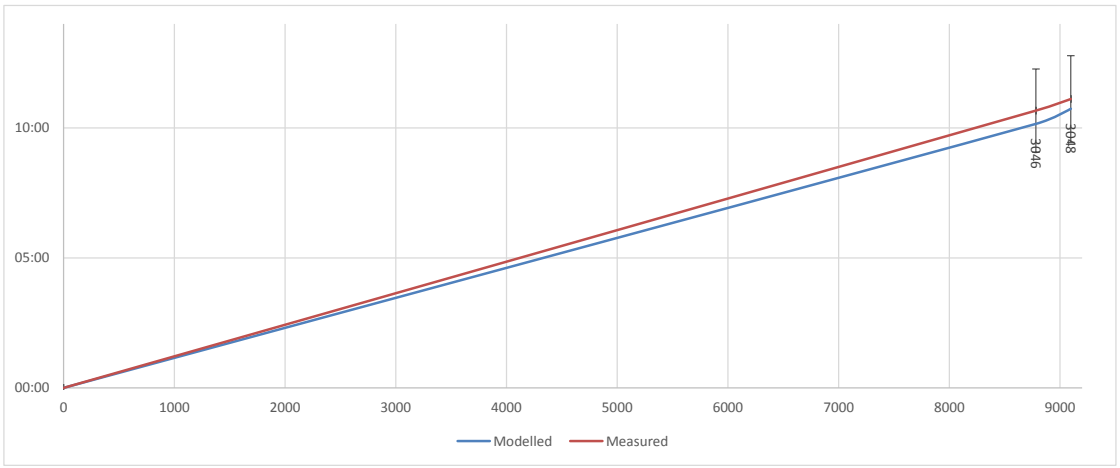
AM



IP



PM



Appendix E

Calibration of VDM Parameters

Calibration of VDM Parameters

RUN ID	ALGORITHM	TIME PERIOD	USER CLASS	%GAP	DISTRIBUTION RESPONSE	MODE CHOICE	PARAMETERS			COST DAMPING			EXT-EXT TRIPS FROZEN	NETWORK-BASED: SIMULATION LINKS ONLY					MATRIX-BASED: TOTAL EXCLUDING EXTERNAL-EXTERNAL MOVEMENTS				
							λ (HWY)	λ (PT)	θ	k	α	d'		PCU-KMS BASE	PCU-KMS TEST	UC ARC ELASTICITY	TP ARC ELASTICITY	ANNUAL ARC ELASTICITY	PCU-KMS BASE	PCU-KMS TEST	UC ARC ELASTICITY	TP ARC ELASTICITY	ANNUAL ARC ELASTICITY
R001	Algorithm 1	AM	HBEB	0.10%	Prod. Constrained	Yes	-0.067	-0.036	0.45	1	0.0	0	Yes	47,011	46,757	-0.06	-0.32	-0.37	249,930	243,731	-0.26	-0.63	-0.83
			NHBEB		Orig. Constrained		-0.081	-0.042	0.73	1	0.0	0											
			HBO		Prod. Constrained		-0.090	-0.036	0.53	1	0.0	0		244,731	235,839	-0.39			918,009	823,644	-1.14		
			NHBO		Orig. Constrained		-0.077	-0.033	0.81	1	0.0	0											
			HBW		Doubly Constrained		-0.065	-0.033	0.68	1	0.0	0		164,454	160,015	-0.29			886,772	867,909	-0.23		
		IP	HBEB		as above		as above			as above			as above	56,783	56,209	-0.11	-0.39		280,379	272,821	-0.29	-0.99	
			NHBEB																				
			HBO											208,624	199,378	-0.48			828,581	722,119	-1.44		
			NHBO																				
			HBW											38,693	37,537	-0.32			206,808	202,162	-0.24		
		PM	HBEB		as above		as above			as above			as above	67,635	66,744	-0.14	-0.34		315,167	307,702	-0.25	-0.73	
			NHBEB																				
			HBO											260,644	250,294	-0.43			1,048,225	928,192	-1.28		
			NHBO																				
			HBW											147,762	143,885	-0.28			791,905	775,010	-0.23		
		OP	HBEB		as above		as above			as above			as above	13,932	13,748	-0.14	-0.42		64,097	62,199	-0.32	-0.96	
			NHBEB																				
			HBO											70,923	67,515	-0.52			300,232	261,651	-1.44		
			NHBO																				
			HBW											25,085	24,355	-0.31			134,110	131,082	-0.24		
R002	Algorithm 1	AM	HBEB	0.12%	Prod. Constrained	Yes	-0.084	-0.045	0.45	1	0.0	0	Yes	47,011	46,732	-0.06	-0.36	-0.43	249,930	243,196	-0.29	-0.71	-0.95
			NHBEB		Orig. Constrained		-0.101	-0.053	0.73	1	0.0	0											
			HBO		Prod. Constrained		-0.113	-0.045	0.53	1	0.0	0		244,731	234,649	-0.44			918,009	812,405	-1.28		
			NHBO		Orig. Constrained		-0.096	-0.041	0.81	1	0.0	0											
			HBW		Doubly Constrained		-0.081	-0.041	0.68	1	0.0	0		164,454	159,307	-0.33			886,772	863,937	-0.27		
		IP	HBEB		as above		as above			as above			as above	56,783	56,217	-0.11	-0.44		280,379	273,119	-0.28	-1.13	
			NHBEB																				
			HBO											208,624	198,162	-0.54			828,581	707,722	-1.65		
			NHBO																				
			HBW											38,693	37,353	-0.37			206,808	201,091	-0.29		
		PM	HBEB		as above		as above			as above			as above	67,635	66,724	-0.14	-0.39		315,167	307,375	-0.26	-0.83	
			NHBEB																				
			HBO											260,644	248,535	-0.50			1,048,225	912,623	-1.45		
			NHBO																				
			HBW											147,762	143,234	-0.33			791,905	771,442	-0.27		
		OP	HBEB		as above		as above			as above			as above	13,932	13,736	-0.15	-0.51		64,097	62,023	-0.35	-1.10	
			NHBEB																				
			HBO											70,923	66,772	-0.63			300,232	256,349	-1.66		
			NHBO																				
			HBW											25,085	24,185	-0.38			134,110	130,329	-0.30		
R007	Algorithm 1	AM	HBEB	0.08%	Prod. Constrained	Yes	-0.067	-0.036	0.56	30,000	0.5	30,000	Yes	47,011	46,838	-0.04	-0.24	-0.26	249,930	247,202	-0.12	-0.33	-0.42
			NHBEB		Orig. Constrained		-0.081	-0.042	0.91	30,000	0.5	30,000											
			HBO		Prod. Constrained		-0.090	-0.036	0.66	30,000	0.5	30,000		244,731	238,200	-0.28			918,009	870,628	-0.56		
			NHBO		Orig. Constrained		-0.077	-0.033	1.00	30,000	0.5	30,000											
			HBW		Doubly Constrained		-0.065	-0.033	0.85	30,000	0.5	30,000		164,454	160,928	-0.23			886,772	872,784	-0.17		
		IP	HBEB		as above		as above			as above			as above	56,783	56,414	-0.07	-0.27		280,379	276,875	-0.13	-0.48	
			NHBEB																				
			HBO											208,624	202,049	-0.34			828,581	776,803	-0.68		
			NHBO																				
			HBW											38,693	37,776	-0.25			206,808	203,385	-0.18		
		PM	HBEB		as above		as above			as above			as above	67,635	67,055	-0.09	-0.24		315,167	311,658	-0.12	-0.38	
			NHBEB																				
			HBO											260,644	253,362	-0.30			1,048,225	988,219	-0.62		
			NHBO																				
			HBW											147,762	144,708	-0.22			791,905	779,340	-0.17		
		OP	HBEB		as above		as above			as above			as above	13,932	13,822	-0.08	-0.29		64,097	63,358	-0.12	-0.46	
			NHBEB																				
			HBO											70,923	68,536	-0.36			300,232	281,592	-0.67		
			NHBO																				
			HBW											25,085	24,536	-0.23			134,110	131,931	-0.17		
R008	Algorithm 1	AM	HBEB	0.06%	Prod. Constrained	Yes	-0.067	-0.036	0.45	30,000	0.6	30,000	Yes	47,011	46,828	-0.04	-0.22	-0.25	249,930	247,612	-0.10	-0.29	-0.36
			NHBEB		Orig. Constrained		-0.081	-0.042	0.73	30,000	0.6	30,000											
			HBO		Prod. Constrained		-0.090	-0.036	0.53	30,000	0.6	30,000		244,731	238,597	-0.27			918,009	877,818	-0.47		
			NHBO		Orig. Constrained		-0.077	-0.033	0.81	30,000	0.6	30,000											
			HBW		Doubly Constrained		-0.065	-0.033	0.68	30,000	0.6	30,000		164,454	161,118	-0.22			886,772	873,408	-0.16		
		IP	HBEB		as above		as above			as above			as above	56,783	56,446	-0.06	-0.26		280,379	277,338	-0.11	-0.41	
			NHBEB																				
			HBO											208,624	202,402	-0.32			828,581	784,454	-0.57		
			NHBO																				
			HBW											38,693	37,812	-0.24			206,808	203,521	-0.17		
		PM	HBEB		as above		as above			as above			as above	67,635	67,097	-0.08	-0.23		315,167	312,109	-0.10	-0.33	
			NHBEB																				
			HBO											260,644	253,785	-0.28			1,048,225	997,043	-0.53		
			NHBO																				
			HBW											147,762	144,805	-0.21			791,905	779,881	-0.16		
		OP	HBEB		as above		as above			as above			as above	13,932	13,832	-0.08	-0.28		64,097	63,491	-0.10	-0.39	
			NHBEB																				
			HBO											70,923	68,674	-0.34			300,232	284,521	-0.56		
			NHBO																				
			HBW											25,085	24,560	-0.22			134,110	132,026	-0.16		
R017	Algorithm 1	AM	HBEB	0.09%	Prod. Constrained	Yes	-0.067	-0.036	0.45	30,000	0.7	30,000	Yes	47,011	46,773	-0.05	-0.25	-0.26	249,930	247,646	-0.10	-0.27	-0.31
			NHBEB		Orig. Constrained		-0.081	-0.042	0.73	30,000	0.7	30,000											
			HBO		Prod. Constrained		-0.090	-0.036	0.53	30,000	0.7	30,000		244,731	237,886	-0.30			918,009	881,643	-0.42		
			NHBO		Orig. Constrained		-0.077	-0.033	0.81	30,000	0.7	30,000											
			HBW		Doubly Constrained		-0.065	-0.033	0.68	30,000	0.7	30,000		164,454	160,901	-0.23			886,772	872,842	-0.17		
		IP	HBEB		as above		as above			as above			as above	56,783	56,304	-0.09	-0.31		280,379	278,006	-0.09	-0.35	
			NHBEB																				
			HBO											208,624	201,113	-0.38			828,581	790,945	-0.49		
			NHBO																				
			HBW											38,693	37,710	-0.27			206,808	203,561	-0.17		
		PM	HBEB		as above		as above			as above			as above	67,635	67,206	-0.07	-0.23		315,167	312,595	-0.09	-0.29	
			NHBEB																				
			HBO											260,644	253,848	-0.28			1,048,225	1,003,626	-0.46		
			NHBO																				
			HBW											147,762	144,747	-0.22			791,905	779,454	-0.17		
		OP	HBEB		as above		as above			as above			as above	13,932	13,842	-0.07	-0.25		64,097	63,601	-0.08	-0.33	
			NHBEB																				
			HBO											70,923	68,861	-0.31			300,232	287,146	-0.47		
			NHBO																				
			HBW											25,085	24,614	-0.20			134,110	132,139	-0.16		