Welsh Government

# M4 Corridor around Newport - Motorway to the South of Newport

## Local Model Validation Report

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# 1 Introduction

## 1.1 Scheme Background

The M4 in South Wales forms part of the Trans-European Transport Network (TEN-T), which provides connections throughout Europe by road, rail, sea and air. The M4 plays a key strategic role in connecting South Wales with the rest of Europe, providing links to Ireland via the ports in South West Wales and to England and mainland Europe to the east. It is a key east-west route being the main gateway into South Wales and also one of the most heavily used roads in Wales.

In March 1989, the Secretary of State for Wales commissioned the South Wales Area Traffic Study (SWATS) to review traffic patterns over part of the trunk road network in South Wales in order to identify problem areas and propose possible solutions. The SWATS Report (1990) identified the need for substantial improvement to the M4 to address a growing capacity issue on the motorway, in particular the section between Magor and Castleton. As a consequence, a proposal for a new section of dual 3-lane motorway (to be known as the M4 Relief Road) was included in the Welsh Trunk Road Forward Programme in 1991.

This proposal was the subject of public consultation during 1993 and 1994, following which the Preferred Route for the M4 Relief Road was announced in 1995, and subsequently modified in 1997 to allow for development of the LG site at Duffryn.

In December 2004, the Minister for Economic Development and Transport reported on the outcome of his review of transport programmes. One of the conclusions was that additional capacity was required on the M4 motorway in South East Wales, in order to reduce congestion, improve resilience and remove an obstacle to greater prosperity along the whole corridor through to Swansea and West Wales.

In addition to widening the motorway north of Cardiff, the Minister announced proposals to develop a New M4 south of Newport between Magor and Castleton. At the same time, it was announced that the existing route could include priority measures for public transport and multiple occupancy vehicles. This meant that the M4 Relief Road scheme was re-named as the New M4 Project and advanced from the ‘On Hold’ category into Phase 2 of the Trunk Road Forward Programme, ie schemes that could start on site by 2010, subject to the satisfactory completion of statutory procedures and availability of finance.

Following a review of the Preferred Route and the Junction Strategy, the proposed scheme was amended to take account of the deletion of the Duffryn Link from the Newport Unitary Development Plan and the cessation of steelmaking activities at the Corus site at Llanwern.

However, a written statement in July 2009 by the then Deputy First Minister Ieuan Wyn Jones announced that the New M4 was not affordable, while accepting that there was a *“need to urgently address safety and capacity issues on the existing route”* through the introduction of *“a range of measures”*. The M4 Corridor

Enhancement Measures (CEM) Programme was thus initiated to create a package of measures addressing resilience, safety and reliability issues within the M4 corridor between Magor and Castleton.

Under the M4 CEM Programme, a long list of possible solutions was explored. No single solution was seen to deliver all the objectives set for transport provision along the M4 Corridor. However, packages that combined public transport, highway and other travel solutions were identified for appraisal. These included on line widening of the M4 between Junctions 24 and 29 as well as improvement to the existing road network to the south of the city centre and a new dual carriageway all-purpose road to the south of Newport.

As part of the M4 CEM Programme, a comprehensive engagement process was launched in September 2010 culminating in a Consultation held between March and July 2012. This has resulted in public support for the provision of an additional high quality road to the south of Newport.

An M4 CEM WelTAG[1] Stage 1 Appraisal concluded that the following measures are worthy of further consideration:

- a new dual carriageway route to the south of Newport;
- public transport enhancement; and
- common measures.

Recent initiatives including discussions between Welsh Government and HM Treasury/Department for Transport, have created potential funding opportunities for Welsh Government infrastructure projects. As a consequence, the decision was taken to further reconsider solutions to resolve capacity issues on the M4.

In order to inform the strategy for the M4 Corridor around Newport, a further WelTAG Stage 1 Appraisal[2] was undertaken in 2013 of options that included the M4 CEM short-listed measures, the provision of new motorway capacity routed to the south of Newport, public transport and complementary measures.

## 1.2 Base Year Traffic Assignment Model

A traffic model of the area is needed to enable traffic flow forecasts to be developed, which can be used to support the planning process for the M4 corridor proposals. Before traffic forecasts can be developed, a base year traffic model is required that accurately reflects traffic flows and conditions on the existing highway network. This will then provide a sound basis for any future scenario testing.

A base year traffic model for the M4 study area was developed and validated for a 2005 base year, and the validation of this model was the subject of a Local Model

[1] Welsh Transport Planning and Appraisal Guidance, available at http://wales.gov.uk/topics/transport/publications/weltag/?lang=en
[2] Welsh Government, M4 Corridor around Newport, WelTAG Appraisal Report Stage 1 (Strategy Level), Arup, June 2013, available at www.m4newport.com

Validation Report[3]. This model has formed the basis for all subsequent traffic forecasts and analyses produced for the project to date.

The Design Manual for Roads and Bridges[4] states that in assessing the validity of a traffic model and the adequacy of its output as an intended base for forecasting, where the trip information relies largely upon observations made more than about 6 years ago it will be necessary to ensure that this information is still valid by undertaking a 'present year validation'. In order to meet this requirement and ensure that the traffic model would continue to provide a valid source of traffic forecasts to support the development of proposals for the M4 corridor around Newport, the base year traffic model has been updated and revalidated to 2012 traffic count information.

## 1.3 Report Structure

This report summarises the development of the updated base year traffic model and its subsequent validation.

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 development of the model network;
- Chapter 5 outlines the development of the model demand matrices;
- Chapter 6 discusses the model 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 outlines the realism testing required for variable demand modelling; and
- Chapter 10 contains concluding comments.

[3] New M4 Project Magor to Castleton – Local Model Validation Report, Ove Arup and Partners, May 2008
[4] Design Manual for Roads and Bridges, Volume 12, Section 1, Part 1, Traffic Appraisal Manual, Department for Transport, November 1997

# 2 Overview of Traffic Model

## 2.1 Traffic Model Requirements

The key requirement of the M4 Corridor Traffic Model is that it should be capable of representing the existing traffic patterns on the strategic road network within the study area. This would then provide a sound basis for future year forecasts which need to be sensitive to route choice between any new routes tested, the existing M4 and other roads on the surrounding road network.

The traffic model will play an important role in scheme assessment by providing forecasts of traffic flows and conditions for environmental appraisal, highway and junction design and economic assessments.

## 2.2 Model Software

The M4 Corridor Traffic Model uses the SATURN software (Simulation and Assignment of Traffic to Urban Road Networks), 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 Volume 12 of the Design Manual for Roads and Bridges (DMRB)[5], and in WebTAG unit M3.1[6].

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.

The basic inputs to the SATURN model are the 'demand', in the form of the matrix of trip movements between zones, and the 'supply' in the form of the data file representing the road network. The basic modelling process is illustrated in Figure 2.1. Following the network building procedure, the trip matrix is assigned to the network using an iterative series of loops between 'assignment' and 'simulation' until the model has converged.

[5] Design Manual for Roads and Bridges, Volume 12 Section 2 Part 1, Traffic Appraisal in Urban Areas, Department for Transport, May 1996
[6] Transport Analysis Guidance Unit M3.1, Highway Assignment Modelling, Department for Transport, January 2014

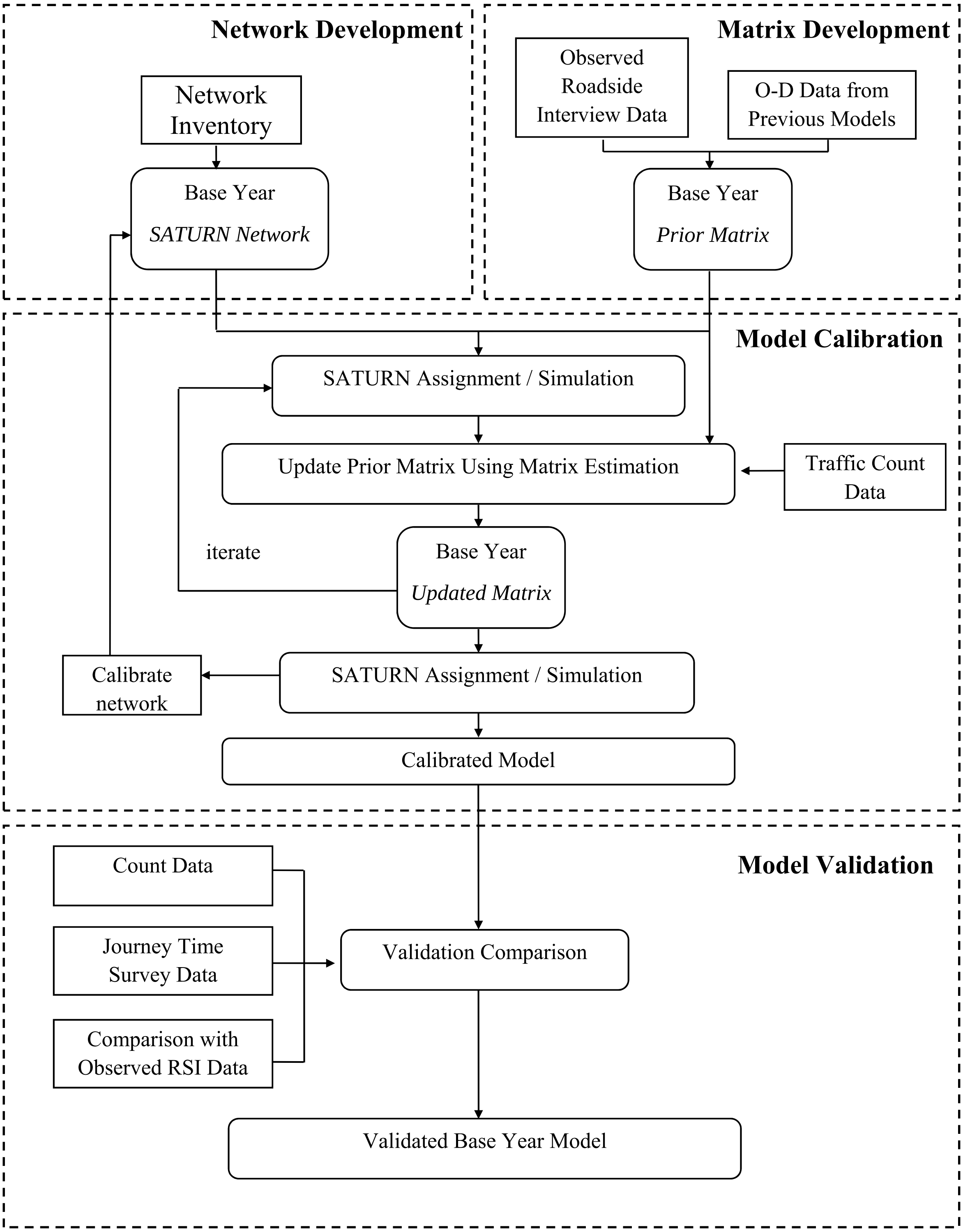


**Figure 2.1 The SATURN Modelling Process**

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.

Following the convergence of the model, a matrix estimation procedure is entered, in which those parts of the 'prior' trip matrix that are not directly observed at roadside interview surveys are adjusted in order to provide the best fit assignment to a set of traffic count data. Calibration checks are then carried out, both on the assignment results and the network description, to ensure that the model is performing correctly.

The final stage is to validate the model, in which comparisons are made between assigned flows and a separate set of traffic count data, and modelled journey times are compared with observed times. Normally, the calibration and validation processes need to be run through several loops before satisfactory validation can be achieved.

## 2.3 Study Area

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 periphery ensuring that traffic from more remote areas enters the simulation part of the network at the correct locations.

For the purposes of preparing traffic forecasts for the M4 Corridor model, a core simulation area covers the M4 between J30 in the west and J21 in the east, including junctions 29 and 23a that 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 River Usk that could connect Central Newport to the New M4 via intermediate junctions; and
- east / west routes through Newport via Newport Bridge, George Street Bridge and the Southern Distributor Road (SDR).

Within this core area, all significant junctions were fully simulated, while links were coded 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.

Outside the core area is a large area-of-influence where changes in traffic flow may be experienced following opening of a new scheme. 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 18a in the east. Major roads within this area-of-influence are modelled as a 'buffer' network with a lower level of detail.

The traffic model includes all trips that travel within the core (simulation) area, perhaps with the exception of very short trips within areas such as Newport, Magor and Chepstow. The area of influence (buffer network) only includes trips that would travel through the core area or trips that would potentially divert to travel through the study area.

Figure 2.2 shows the study area, comprising both the core area and the larger area of influence for the M4 Corridor.

## 2.4 Requirement for Variable Demand Modelling

Transport schemes that have an impact on journey times and cost will, 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, known as "induced traffic".

Conversely, in a 'Do-Minimum' scenario where 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 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.

WebTAG[7] 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".

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.*

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

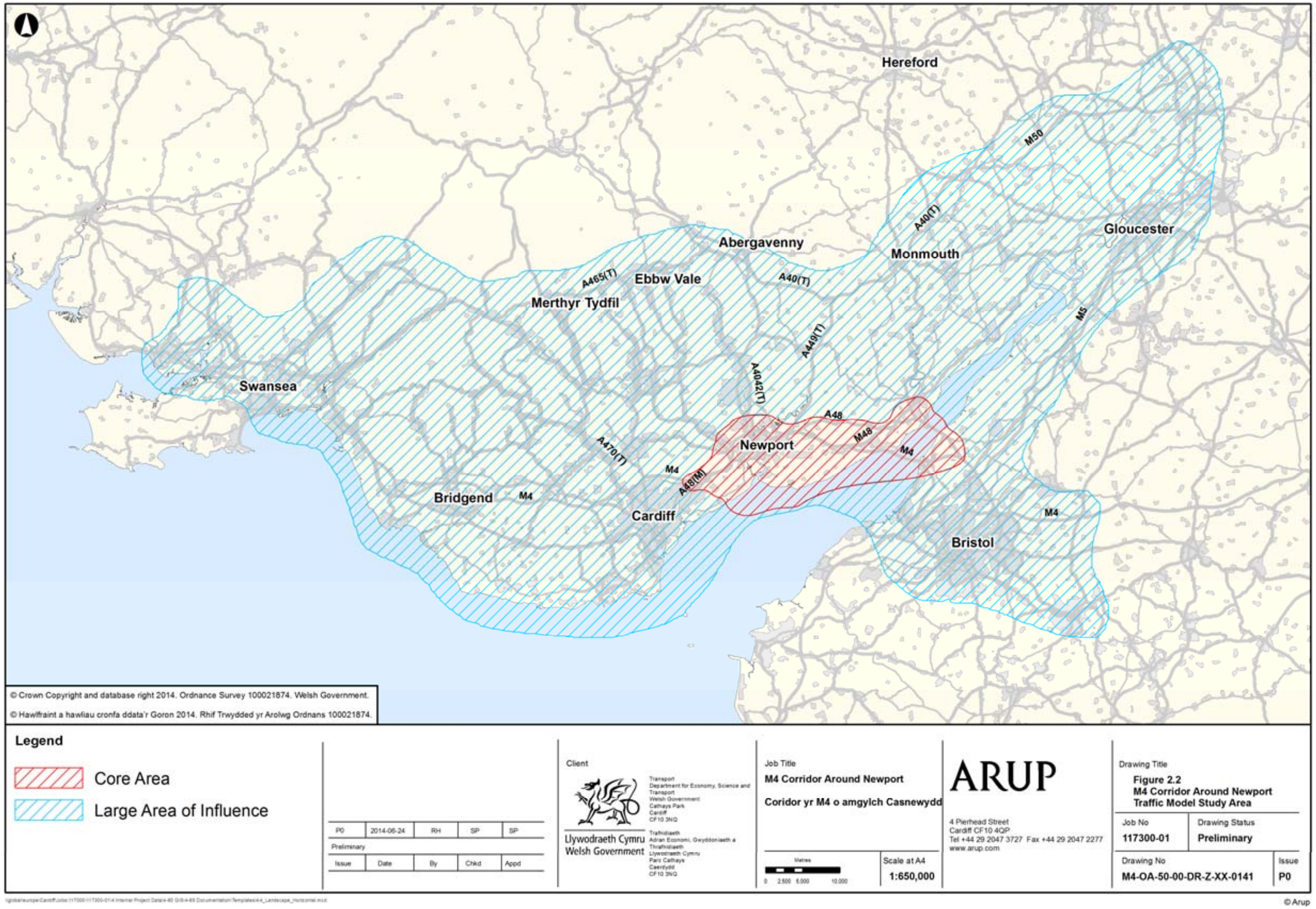


**Figure 2.2 M4 Traffic Model Study Area**

While the M4 scheme may be considered to have limited impact on mode choice in the corridor, it is likely to affect trip distribution. The scheme is therefore considered to meet none of the criteria identified, so that variable demand modelling is required for the proper assessment of the scheme benefits.

## 2.5 Land Use Modelling, Public Transport and Slow Modes

In order to incorporate a mode choice response, it would be necessary to develop either a multi-modal model or a separate public transport model with a mode choice function that can interact with the SATURN highway model.

As the demand for public transport movements on the M4 corridor is likely to be very limited whether or not the proposed scheme is implemented, it was considered that the modal transfer response will not be important, and that the development of a multi-modal model or a separate public transport model would therefore be disproportionate to the scheme being appraised.

## 2.6 Model Time Periods

For the M4 traffic model, three time periods are modelled covering the AM and PM peaks and the Interpeak period. Figure 2.3 shows an analysis of traffic volumes on the Malpas Straight (Junction 26 to Junction 27) for the average weekday in May 2012, which indicates clearly defined peak hours in the morning and evening.

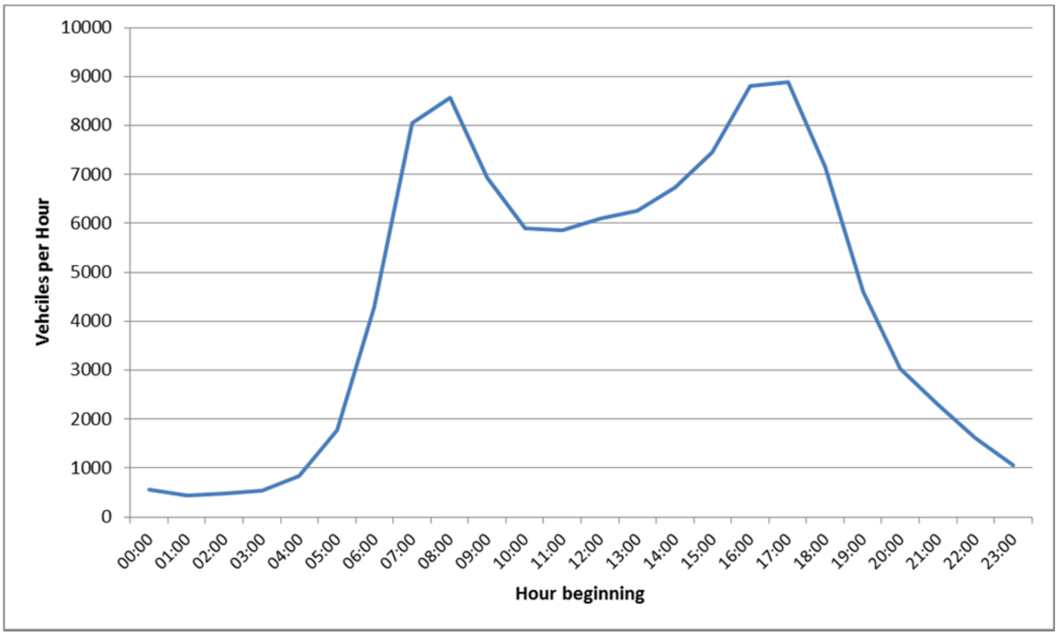


**Figure 2.3 Average Hourly Weekday Traffic Volumes, Junction 26-27, May 2012**

Based on these flow characteristics, the M4 model incorporates three separate time periods:

- AM Peak (08:00 to 09:00);
- Interpeak (13:00 to 14:00); and
- PM Peak (17:00 to 18:00).

## 2.7 Model User Classes

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, as with the 2005 model, the base year model trip matrices were split into five different 'user classes', and built in terms of Passenger Car Units (PCUs). Table 2.1 lists the modelled user classes and their associated PCU factor.

**Table 2.1: Modelled User Classes**

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

# 3 Data Sources

## 3.1 Overview

A key component in the data sources underlying the 2005 base model was a comprehensive set of 30 roadside interview surveys on all major approaches to the M4 motorway across the core model area, which were used to develop the base year trip matrices. These surveys are described in the previous Local Model Validation Report[8].

For the purpose of the model update, the re-basing and re-calibration of the model required the projection of the 2005 base matrices to the current year, with the model outputs compared with current traffic count data. Consequently, a programme of new traffic surveys was undertaken to provide the data for this comparison, as outlined in the following sections.

## 3.2 Welsh Government Data

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 or 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 is also useful to factor traffic flows from one time period to another.

Traffic volume data has been provided by the Welsh Government for all trunk roads within the core study area apart from the M4 motorway itself. 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.

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 has therefore been obtained from MIDAS.

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

## 3.3 Classified Junction Turning Counts

Manual Classified Counts (MCCs) were undertaken over a 12-hour period (07:00-19:00), broken down into 15-minute intervals, at key junctions in the core study area. The junction locations are shown in Figures 3.1 and 3.2, and are listed in Table 3.1.

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[8] New M4 Project Magor to Castleton – Local Model Validation Report, Ove Arup and Partners, May 2008

**Table 3.1: Classified Turning Counts, 2012**

| Ref | Location | Date |
|---|---|---|
| 1 | A48 Eastern Avenue / A4232 Southern Way, Cardiff | Tuesday 1 May |
| 2 | A48 Eastern Avenue / Pentwyn Road, Cardiff | Tuesday 1 May |
| 3 | A48 Eastern Avenue / A4232 Pentwyn Link Rd, Cardiff | Tuesday 1 May |
| 4 | M4 Junction 30 / A4232 roundabout, Cardiff Gate | Wednesday 2 May |
| 5 | A48 / Cypress Drive, St Mellons | Wednesday 2 May |
| 6 | A48 / Marshfield Rd, Castleton | Wednesday 28 March |
| 7 | A48 / Blacksmiths Way, Cleppa Park | Wednesday 28 March |
| 8 | A48 / Pencarn Way, Cleppa Park | Wednesday 28 March |
| 9 | A467 / B4591 Chartist Drive, Rogerstone | Wednesday 28 March |
| 10 | B4591 Chartist Dr / Cefn Rd, Rogerstone | Thursday 29 March |
| 11 | Bassaleg Rd / Park View, Rogerstone | Thursday 29 March |
| 12 | M4 Junction 27 / B4591 roundabout, High Cross | Tuesday 24 April |
| 13 | B4591 Risca Rd / Fields Park Rd, Newport | Thursday 29 March |
| 14 | B4591 Risca Rd / Bassaleg Rd, Newport | Thursday 29 March |
| 15 | B4591 Stow Hill / Caerau Rd, Newport | Thursday 29 March |
| 16 | Stow Hill / Friars Rd, Newport | Wednesday 16 May |
| 17 | B4237 Cardiff Rd / Gaer Rd, Newport | Wednesday 16 May |
| 18 | B4239 Lighthouse Rd / Duffryn Drive, Newport | Thursday 29 March |
| 19 | A48 Southern Distributor Road / Docks Way, Newport | Tuesday 24 April |
| 20 | A48 Southern Distributor Road / Alexandra Rd, Newport | Thursday 29 March |
| 21 | A48 Southern Distributor Road / A4042 Usk Way, Newport | Thursday 29 March |
| 22 | A4042 Usk Way / Lower Dock St, Newport | Thursday 29 March |
| 23 | B4237 George St / Lower Dock St, Newport | Wednesday 13 June |
| 24 | B4237 George St / Commercial Rd, Newport | Tuesday 3 April |
| 25 | B4237 Cardiff Rd / Mendalgief Rd, Newport | Tuesday 3 April |
| 26 | A4042 Usk Way / Emlyn St, Newport | Tuesday 3 April |
| 27 | A4042 Kingsway / B4591 Queensway, Newport | Tuesday 24 April |
| 28 | B4591 Queensway / Bridge St, Newport | Tuesday 3 April |
| 29 | B4591 Clytha Park Rd / Caerau Rd, Newport | Tuesday 3 April |
| 30 | A4042 Malpas Relief Rd / Llantarnam Bypass / A4051 | Tuesday 3 April |
| 31 | Queens Hill / Barrack Hill, Newport | Tuesday 3 April |
| 32 | A4042 Heidenheim Drive / Sainsbury's, Newport | Wednesday 2 May |
| 33 | A4042 / Brynglas Tunnel Relief Rd | Tuesday 3 April |
| 34 | A4051 / Bettws Lane, Malpas | Tuesday 3 April |
| 35 | M4 Junction 25 / B4596 Caerleon Rd roundabout, Newport | Monday 23 April |
| 36 | B4596 Caerleon Rd / Duckpool Rd, Newport | Tuesday 3 April |
| 37 | B4237 Chepstow Rd / Wharf Rd, Newport | Tuesday 3 April |
| 38 | B4237 George St / Corporation Rd, Newport | Tuesday 3 April |
| 39 | B4237 Chepstow Rd / Somerton Rd, Newport | Wednesday 4 April |
| 40 | B4237 Chepstow Rd / Aberthaw Rd, Newport | Wednesday 4 April |
| 41 | A48 Southern Distributor Road / Balfe Rd, Newport | Wednesday 4 April |
| 42 | A48 Southern Distributor Road / Ringland Crescent, Newport | Wednesday 4 April |
| 43 | B4237 Chepstow Rd / Royal Oak Hill / Llanwern Rd, Newport | Wednesday 4 April |
| 44 | A48 Southern Distributor Road / Beatty Rd, Newport | Wednesday 4 April |
| 45 | A48 Chepstow Rd / Hilton Hotel roundabout, Langstone | Wednesday 4 April |
| 46 | A48 Chepstow Rd / B4245 Magor Rd, Langstone | Wednesday 4 April |
| 47 | B4245 Caldicot Rd / Station Rd, Rogiet | Wednesday 4 April |
| 48 | B4245 / Newport Rd, Caldicot | Wednesday 4 April |
| 49 | A48 / B4245 Parkwall roundabout | Wednesday 4 April |
| 50 | A48 Newport Rd / A466 Wye Valley Link Rd, Chepstow | Monday 23 April |
| 51 | M48 Junction 2 / A466 roundabout, Newhouse | Monday 23 April |
| 52 | A4042 / A4051 Harlequin roundabout, Newport | Wednesday 13 June |

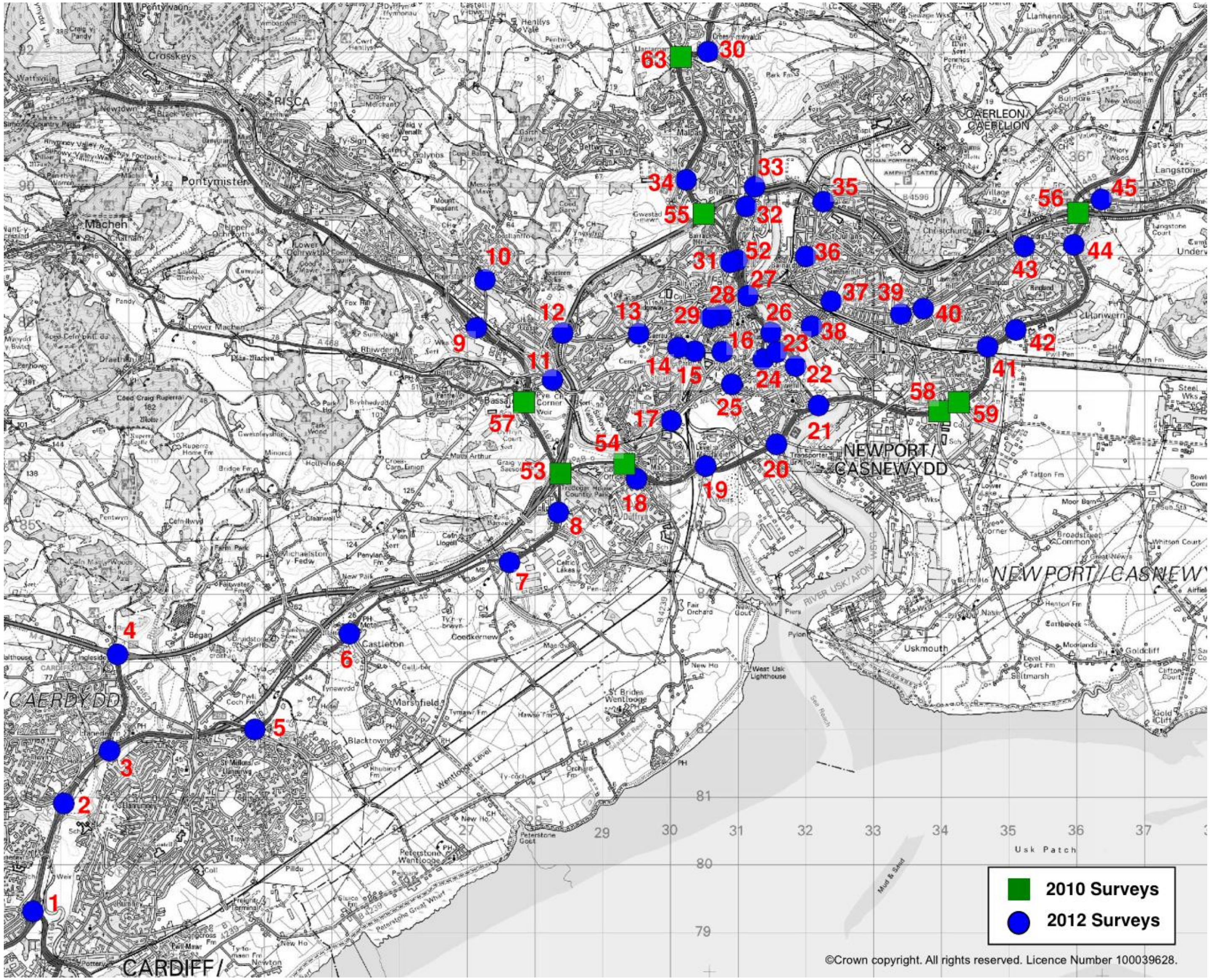



**Figure 3.1 Classified Turning Counts - West Area**

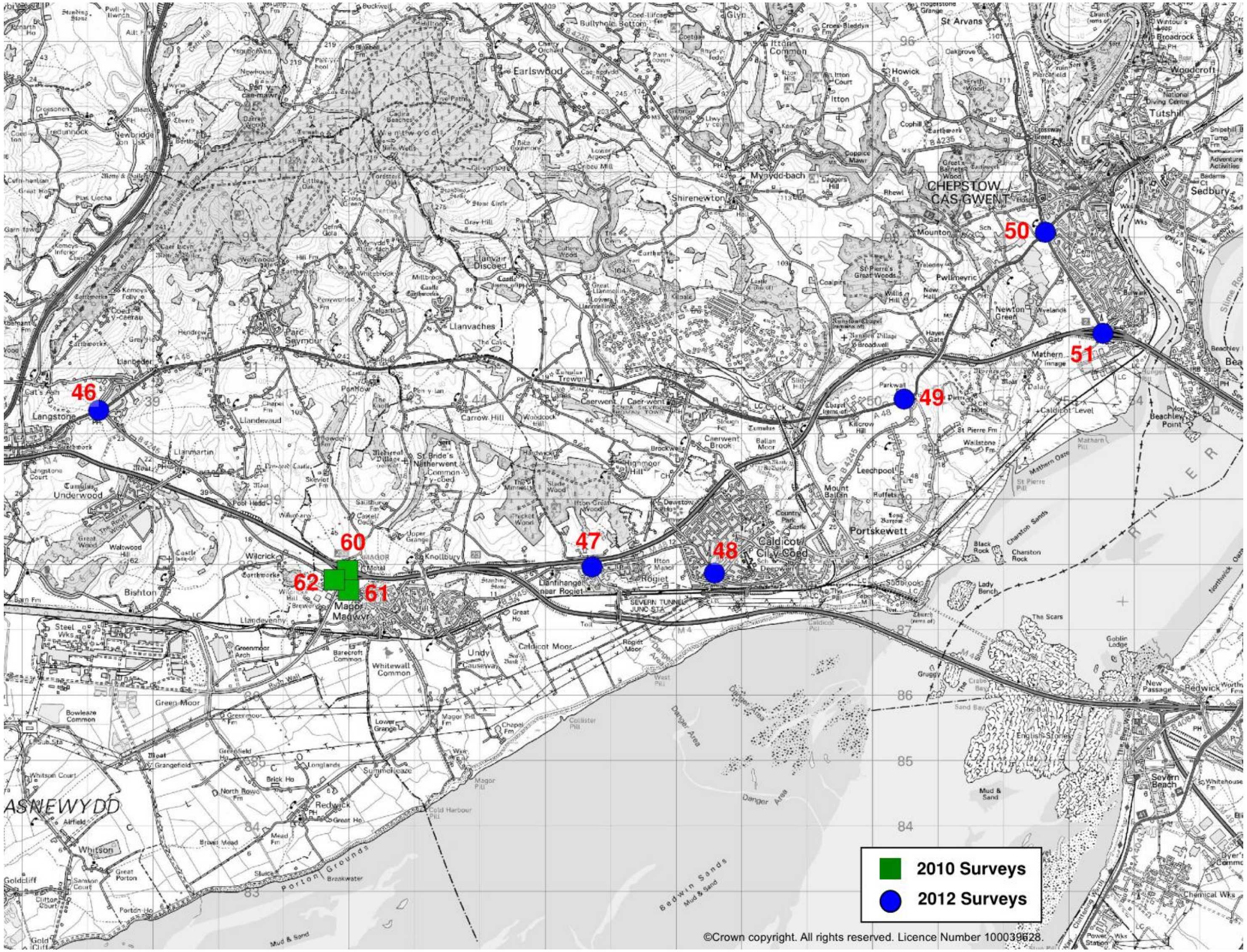



**Figure 3.2 Classified Turning Counts - East Area**

In addition to these junction counts, use was made of some existing junction turning count data, collected in 2010 as part of the analysis of the M4 Corridor Enhancement Measures. These sites are also shown in Figures 3.1 and 3.2, and are listed in Table 3.2.

**Table 3.2: M4 CEM Classified Turning Counts, 2010**

| Ref | Location | Date |
|---|---|---|
| 53 | M4 Junction 28 / A48 / A467 roundabout, Tredegar Park | Thursday 8 July 2010 |
| 54 | A48 Southern Distributor Rd / B4237 Pont Ebbw rbt | Wednesday 20 October 2010 |
| 55 | M4 Junction 26 / A4051 Malpas Rd roundabout, Malpas | Thursday 8 July 2010 |
| 56 | M4 Junction 24 / A449 / A48 roundabout, Coldra | Wednesday 7 July 2010 |
| 57 | A467 Forge Rd / A468 Bassaleg roundabout | Thursday 8 July 2010 |
| 58 | A48 Southern Distributor Rd / Nash Rd, Newport | Thursday 8 July 2010 |
| 59 | A48 Southern Distributor Rd / Queensway Meadows | Tuesday 29 June 2010 |
| 60 | M4 Junction 23a / B4245 roundabout, Magor | Tuesday 6 July 2010 |
| 61 | B4245 / Steelworks Access Rd link roundabout, Magor | Tuesday 29 June 2010 |
| 62 | B4245 / Steelworks Access Rd link (west junction), Magor | Tuesday 29 June 2010 |
| 63 | A4051 Malpas Rd / Cwmbran Drive roundabout | Tuesday 13 July 2010 |

Data from the junction turning counts listed in Tables 3.1 and 3.2 formed inputs to the matrix estimation process used for calibrating the M4 traffic model.

## 3.4 Classified Link Counts

In order to supplement the data obtained from MIDAS, twelve hour MCCs were undertaken on each of the motorway links in the study area, in each direction. The count locations are shown in Figure 3.3 and listed in Table 3.3. This information was used to validate the proportion of heavy vehicles on the motorway links, as this information is not available from ATC / MIDAS data.

**Table 3.3: Classified Link Counts, 2012**

| Ref | Location | Date |
|---|---|---|
| L1 | M48 Severn Bridge toll booths | Thursday 3 May |
| L2 | M48, between Junction 2 and M4 Junction 23 | Tuesday 15 May |
| L3 | M4 Second Severn Crossing toll booths | Tuesday 15 May |
| L4 | M4, between Junction 23a and Junction 24 | Tuesday 15 May |
| L5 | M4, between Junction 24 and Junction 25 | Tuesday 15 May |
| L6 | M4, between Junction 25a and Junction 26 | Tuesday 15 May |
| L7 | M4, between Junction 26 and Junction 27 | Tuesday 15 May |
| L8 | M4, between Junction 27 and Junction 28 | Tuesday 15 May |
| L9 | M4, between Junction 28 and Junction 29 | Wednesday 16 May |
| L10 | M4, between Junction 29 and Junction 30 | Wednesday 16 May |
| L11 | A48(M), between M4 Junction 29 and Junction 29a (A48) | Wednesday 16 May |


**Figure 3.3 Classified Link Counts**

## 3.5 Automatic Traffic Counts

In addition to the ATC and MIDAS data supplied by the Welsh Government, a number of ATC sites were installed on strategic links within the study area, providing classified count data in each direction. The ATC sites are shown in Figure 3.4 and are listed in Table 3.4. This information was used for model validation purposes on the River Usk screenline.

**Table 3.4: Automatic Traffic Counts, 2012**

| Ref | Location | Dates |
|---|---|---|
| A | A48 Southern Distributor Rd, Usk Bridge | 28 March – 19 June |
| B | B4237 George Street Bridge | 27 March – 18 June |
| C | B4591 Clarence Place Bridge | 24 March – 20 May |
| D | A48 east of Tredegar Park | 24 March – 27 April<br>5 May – 15 June |
| E | A467 north of Pye Corner | 24 March – 15 June |
| F | A48 Southern Distributor Road, south of Beatty Rd | 24 March – 15 June |
| G | Brynglas Tunnel Relief Rd (M4 J25a – A4042) | 18 April – 19 June |
| H | A4042 Usk Way, south of Harlequin Roundabout | 24 March – 15 June |

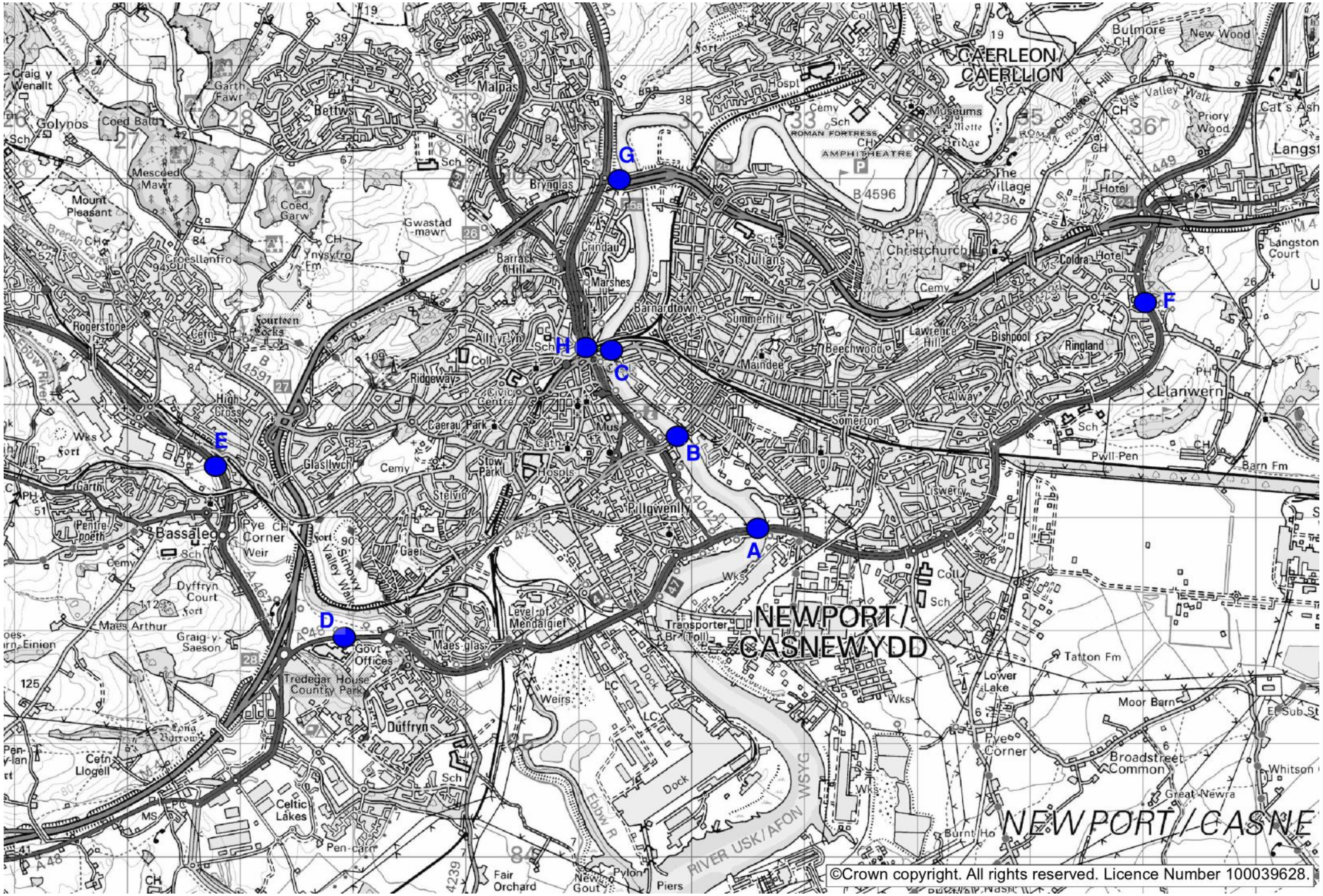



**Figure 3.4 Automatic Traffic Counts**

## 3.6 Journey Time Surveys

Journey time surveys were commissioned on 11 routes within the model simulation area. Each route was travelled a minimum of six times during the morning peak, inter peak and evening peak time periods on a selection of representative days. The average journey times were calculated for use in the model validation process in order to verify that the model is capable of correctly replicating travel times and speeds. Figure 3.5 illustrates the routes of the journey time surveys.

The journey time survey data was used to validate the model network through a comparison the modelled journey times over the same routes.

## 3.7 Data Processing

To ensure the development of a robust traffic model, it is important that all survey data is carefully reviewed and checked for consistency or any potential errors. This includes a review of the raw data to identify any entries which were inconsistent with ‘neighbouring’ survey data. Such inconsistencies are likely to reflect errors in the data recording process or unusual traffic patterns. All of the traffic count data collected was subject to range and logic checks to identify any problems or omissions and, where possible, to rectify them.

Consideration was given to the derivation of a suitable factor to convert the 2010 manual counts listed in Table 3.2 to 2012 levels. Automatic count data on the M4 was not considered suitable for this purpose because of the different characteristics of this road to those covered by the count sites. In addition, the M4 was subject to major roadworks throughout 2010, making any count data here potentially unreliable.

A comparison was made of ATC data on the A4042 Malpas Relief Road between June 2010 and June 2012, which showed that the average weekday traffic volume in 2012 was 0.6% lower than that in 2010. In addition, the Department for Transport’s (DfT’s) National Trip End Model (TEMPRO) predicts a marginal increase in car trips in the Newport area on an average weekday of 0.9% between 2010 and 2012. Taking both of these factors into account, it was considered appropriate not to apply any adjustment factor to the 2010 counts to bring them to 2012 levels.

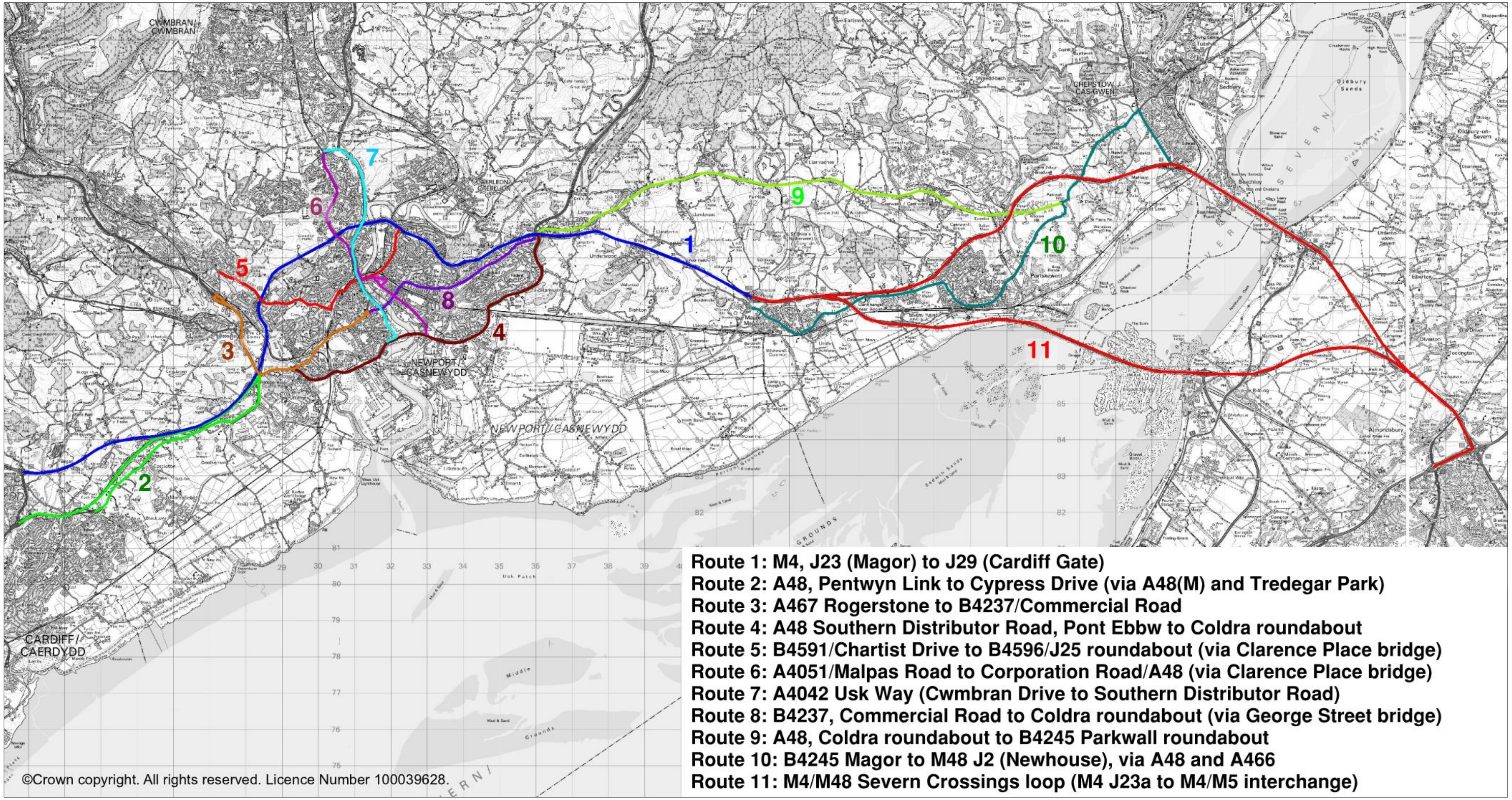



**Figure 3.5 Journey Time Survey Routes**

# 4 Model Network Development

## 4.1 Overview

The SATURN model network comprises a detailed ‘simulation’ area that covers the core area and a less detailed ‘buffer’ network that covers the wider area of influence, both as defined in Section 2.3 of this report. The areas covered by the two types of network data were the same as those used for the validated 2005 base model, which formed the starting point for the 2012 update. The full extent of the model network is shown in Figure 4.1, while the more detailed simulation area is shown in Figure 4.2.

## 4.2 Network Changes

The 2005 base model was made available to inform the separate development of an updated Newport traffic model as part of the Newport Citywide Transport Strategy, produced by Capita Symonds on behalf of Newport City Council. Following the completion of this work, a copy of the updated Newport model was made available by Capita Symonds to inform the update of the M4 model.

The updated 2010 Newport model introduced a number of changes to the model network to reflect improvements that had been introduced on the ground since 2005. These changes include:

- Improvements at the Coldra roundabout (M4 Junction 24), including the ‘hamburger’ layout and the signal control system;
- Relocation of Kingsway Car Park and revised bus station layout;
- Improvements to Queensway and railway station car park;
- Introduction of traffic signals at the Harlequin roundabout;
- Addition of bus route information and the modelling of bus lanes on Malpas Road, Cardiff Road, Queensway, Clarence Bridge, together with the revised bus station access / egress arrangements;
- Relocation of Sainsbury’s foodstore to Crindau, accessed from a new signal-controlled junction on the A4042 Heidenheim Drive; and
- New Asda foodstore, accessed from a new signal-controlled junction on Lower Dock Street.

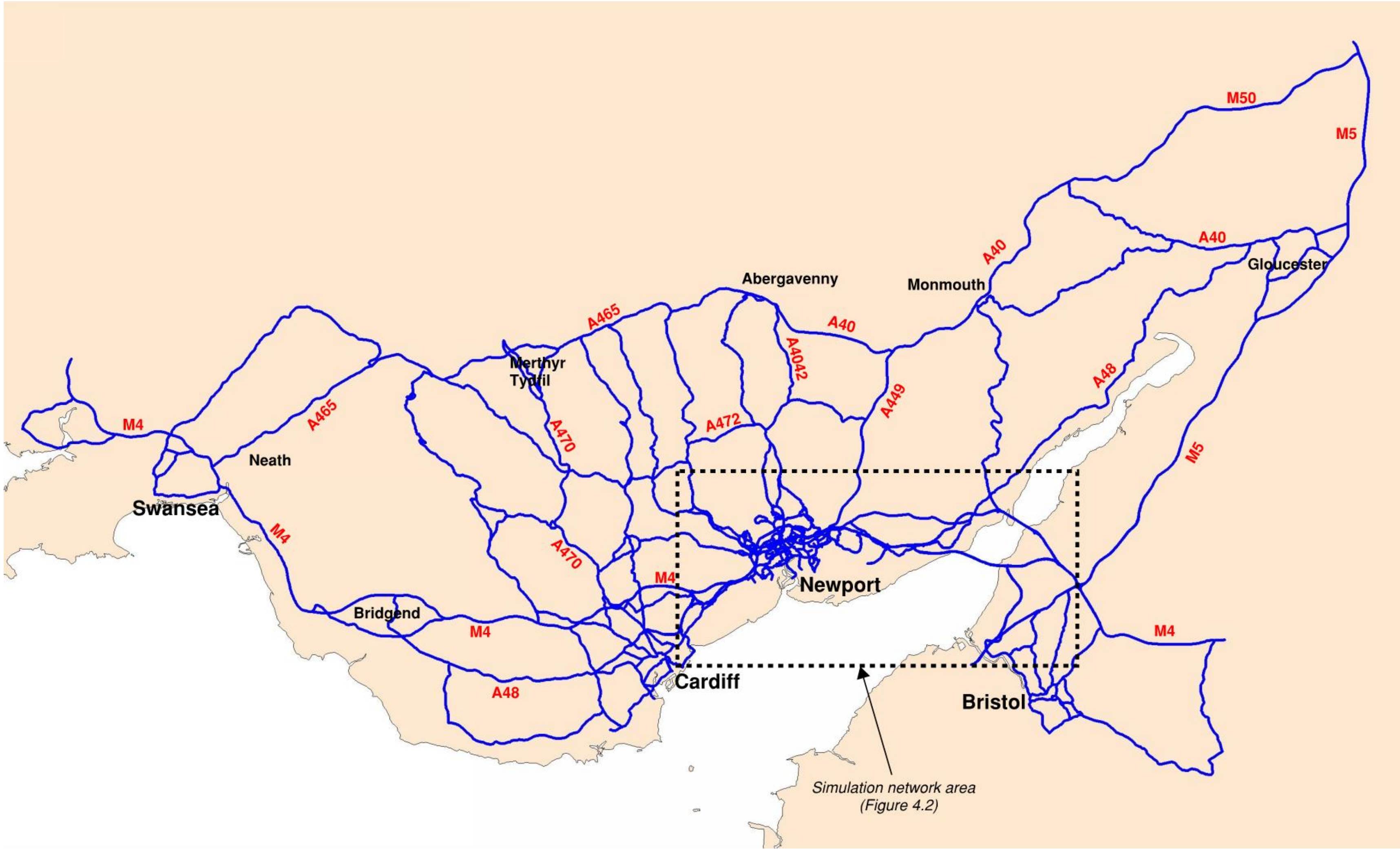



**Figure 4.1 Model Network**

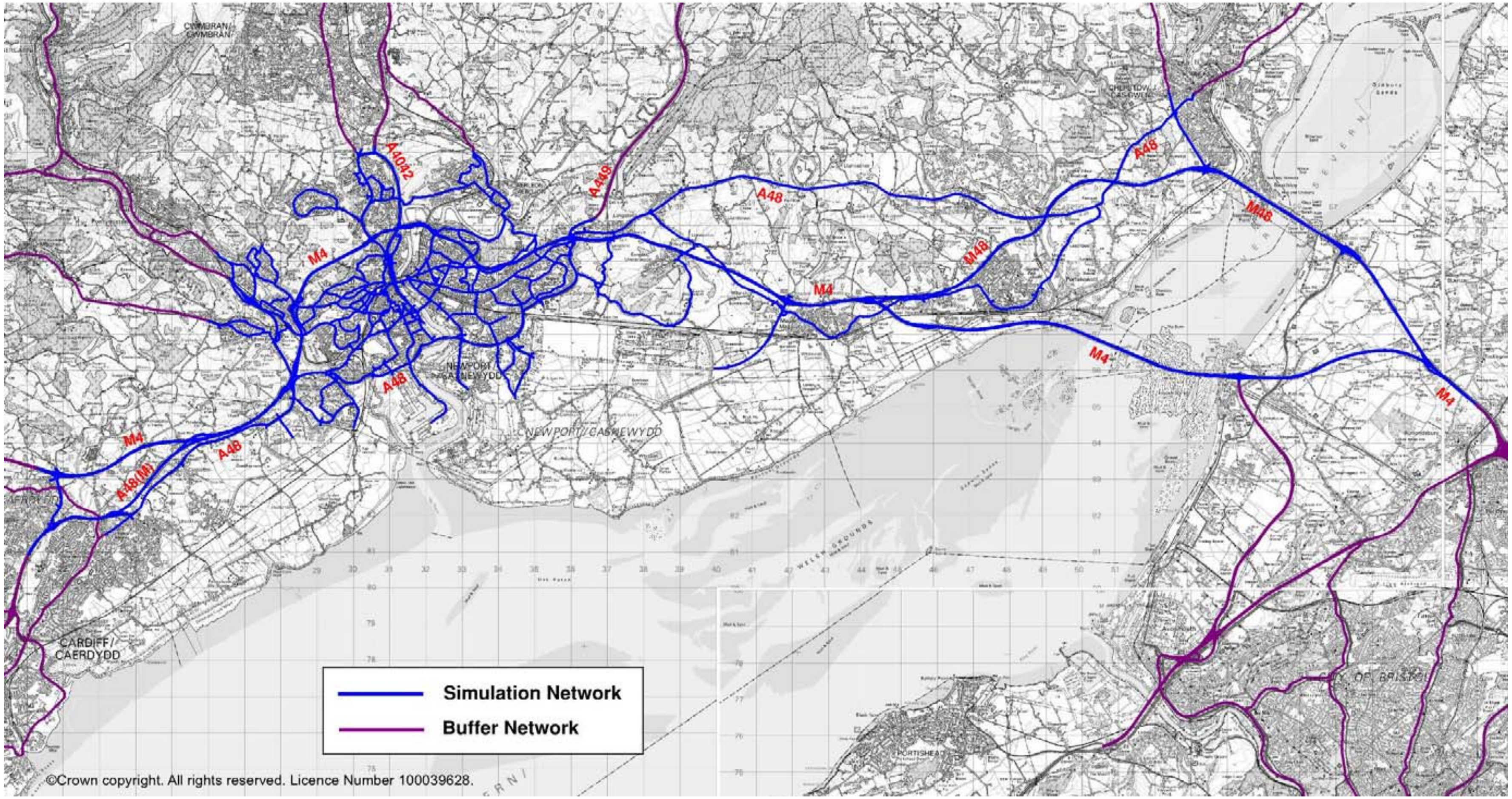



**Figure 4.2 Model Simulation Network**

## 4.3 Network Review

The coding of the base network, as updated from the 2010 Newport model, was comprehensively reviewed to ensure its suitability for representing the current situation. This review covered 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 was cross-checked against imaging from ‘Google Streetview’, in combination with local knowledge and on-site observations, and amended as necessary to take account of any changes since 2010. These included:
  - Revised access arrangements and bus priority measures at the Kingsway Car Park entrance from Emlyn Street; and
  - Revised junction arrangement at Cardiff Road / Commercial Street.
- Saturation flows for all signalised and roundabout junctions were re-estimated from updated geometric measurements;
- Observations were carried out of the current timings at all signal controlled junctions. This enabled the average green and inter-green times for each approach to these junctions to be calculated. 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.

## 4.4 Link Speeds

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 2012. The speed-flow curves from MIDAS data are illustrated in Appendix A, 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 | 112 | 84 | 6990 | 2.897 |
| J24 to J25 | 100 | 75 | 6990 | 2.423 |
| J25 to J26 | 90 | 72 | 4200 | 2.750 |
| J26 to J27 | 105 | 80 | 6990 | 2.750 |
| J27 to J28 | 106 | 84 | 6990 | 2.298 |
| J28 to J29 | 109 | 92 | 6990 | 1.746 |
| **Eastbound** | | | | |
| J29 to J28 | 115 | 100 | 6990 | 2.737 |
| J28 to J27 | 104 | 72 | 6990 | 2.710 |
| J27 to J26 | 108 | 75 | 6990 | 3.585 |
| J26 to J25 | 98 | 80 | 4200 | 2.721 |
| J25 to J24 | 100 | 75 | 6990 | 2.957 |
| J24 to J23a | 115 | 84 | 6990 | 2.170 |

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.[9]. Each curve has three relationships:

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

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

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

$$S(V) = S_1 + (S_2 - S_1)(V - F) / (C - F)$$

3. Vehicle flows above capacity:

$$S(V) = S_2 / (1 + S_2 (V - C) / 8dC)$$

where:

V is the vehicle flow

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

C is the flow at capacity

$S_0$ is the free flow speed

$S_1$ is the intermediate break-point speed

$S_2$ is the speed at capacity

[9] 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

The SATURN manual then states that the “best-fit” value of the power ‘n’ may be determined by the equation:

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

where:

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

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

$R_1 = S_0 / S_1$

$R_2 = S_1 / S_2$

For other links, in general the presumption is that speeds and delays in the urban area are mainly determined by the simulation of junctions. However, there are some links where this does not apply, particularly in the rural areas and on the motorway sections east of Junction 23a and west of Junction 29. For these links, a set of default relationships derived from the COBA10 speed-flow curves is used based on road types. The default speed-flow curves used are listed in Table 4.2.

**Table 4.2: Default Speed-Flow Curves**

| Road Type | Free flow Speed | Speed at Capacity | Flow at Capacity (PCUs/hr) | Power |
|---|---|---|---|---|
| D3 Motorway | 109 | 84 | 6990 | 2.944 |
| D2 Motorway | 104 | 78 | 4660 | 3.187 |
| D2 All-Purpose (grade separated) | 104 | 78 | 4400 | 2.949 |
| D2 All-Purpose | 99 | 77 | 4400 | 2.433 |
| D2 All-Purpose (50mph limit) | 85 | 66 | 4400 | 3.391 |
| S2 Principal | 88 | 62 | 1410 | 1.728 |
| S2 Other | 88 | 45 | 1410 | 3.850 |

Roads in the less-detailed buffer network outside the main simulation network are not fully modelled, in that traffic that would not pass through the study area is excluded. As the links in the buffer network do not include the full traffic flows, speed-flow relationships could not be used directly to ascertain the speed 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 then coded with these fixed speeds to give representative journey times for trips into/out of the study area.

# 5 Trip Matrix Development

## 5.1 Zone System

The zone system was based on the 2005 model, with adjustments in the Newport area to reflect the more detailed changes made for the 2010 Newport traffic model. Further minor modifications and refinements were made to introduce new zones where development has occurred or is proposed, and to disaggregate existing zones to better represent land use or to provide a greater level of detail within the extended simulation network.

Figures 5.1 to 5.3 illustrate the M4 Corridor traffic model zones.

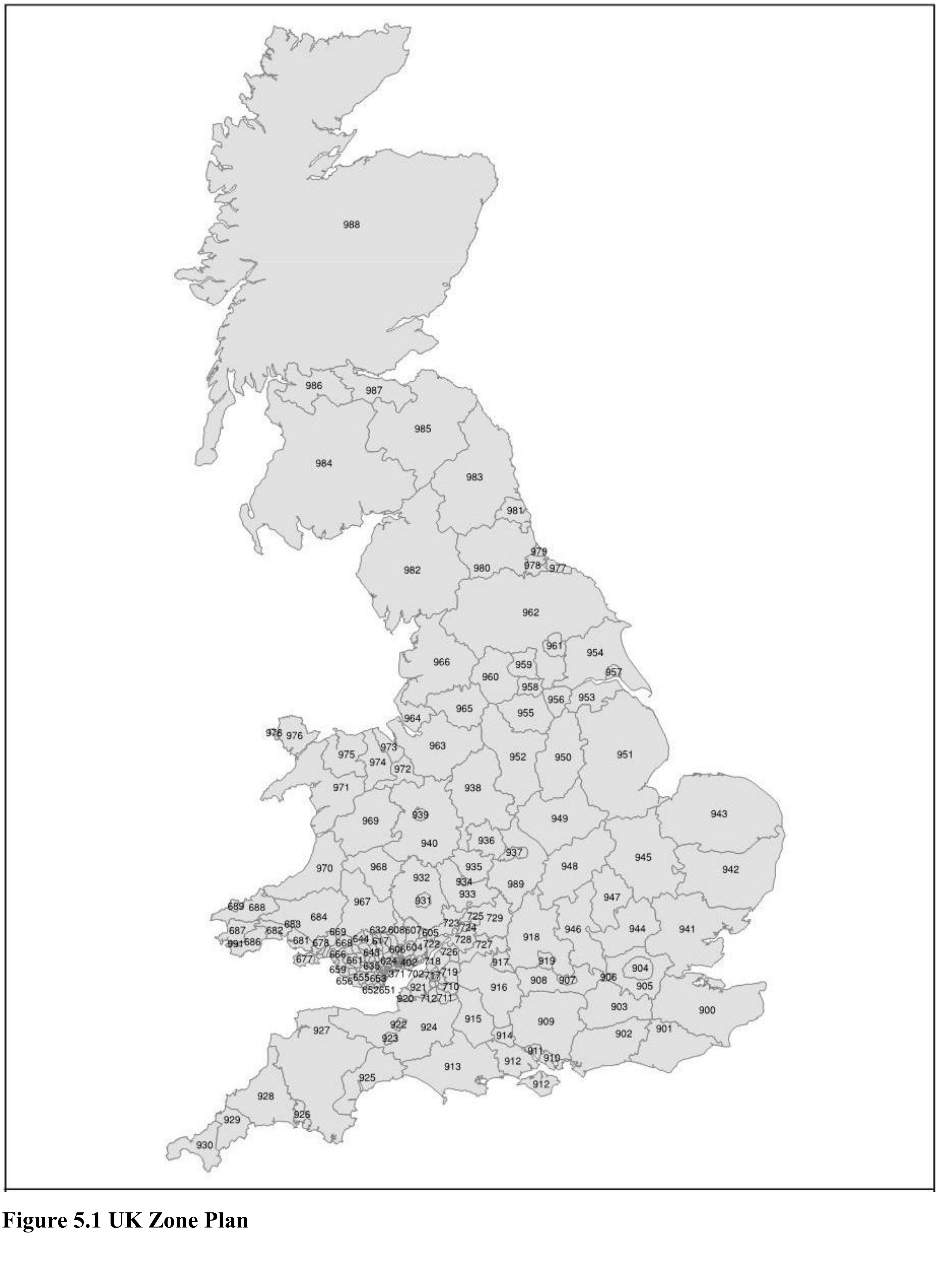



Figure 5.1 UK Zone Plan

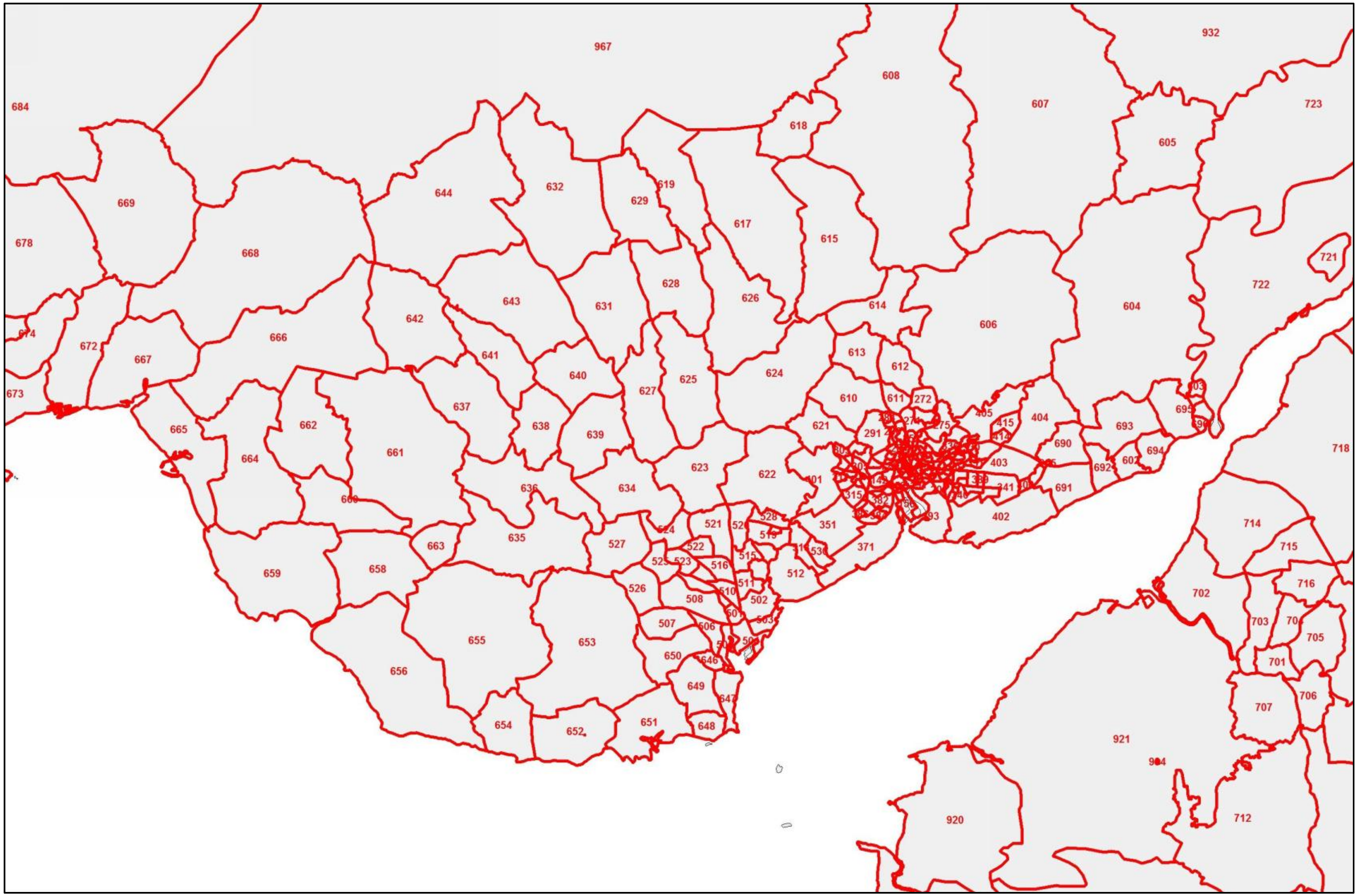



**Figure 5.2 South East Wales Zone Plan**

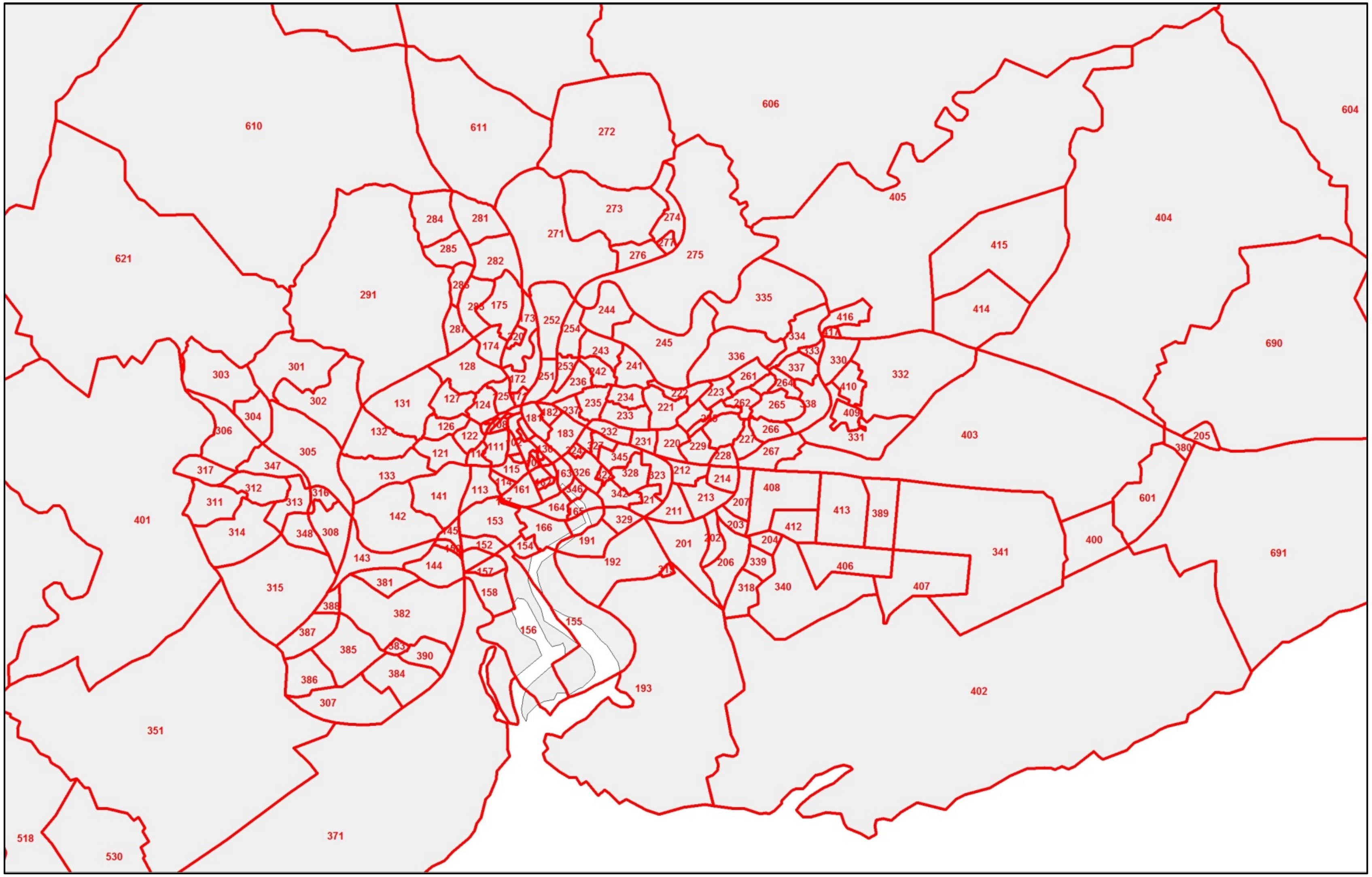


**Figure 5.3 Newport Area Zone Plan**

## 5.2 Matrix Development

As noted in Section 4.2, the Newport traffic model was developed for a 2010 base year from the information contained in the M4 2005 model. As such, the Newport model was considered to provide the best source of trip data for internal movements within the Newport area. As the Newport model was developed for the AM and PM peak hours only, trip information for the interpeak model was based entirely on the M4 2005 model.

For the purpose of merging the validated AM and PM peak trip matrices from the Newport traffic model with those from the 2005 M4 model, they were first factored to 2012 levels, using growth factors for the local areas that were derived from the Department for Transport's National Trip End Model[10].

Once the zone systems had been refined to a common base, the internal movements within the Newport area were extracted from the Newport model, and used to replace the equivalent trip data in the AM and PM peak M4 model matrices. This ensured that the trip information for movements using the M4 motorway, which was based on the 2005 roadside interview survey programme, was retained.

While the Newport model included a representation of some developments that were implemented between 2005 and 2010, it was necessary to take account of those developments put in place since 2010, together with those introduced since 2005 outside the main Newport area. Trip information for these developments was taken from forecasts, using appropriate factors to take account of the ongoing nature of some of these developments. These developments are listed in Table 5.1.

**Table 5.1: Developments Implemented since 2005**

| Ref | Development | Location | Trip Data Source |
|---|---|---|---|
| 1 | Langstone Business Park | Priory Drive, Langstone | Newport model |
| 2 | B&Q store | Corporation Road | Newport model |
| 3 | George Street offices (partial) | Lower Dock Street | Newport model |
| 4 | Lidl foodstore | Granville Road | Forecast |
| 5 | Residential development | Morgan Way, Duffryn | Forecast |
| 6 | Phoenix Business Park | Former Pirelli site, Telford St | Newport model |
| 7 | Residential development | St Joseph's School, Duffryn | Newport model |
| 8 | Asda foodstore | Lower Dock Street | Newport model |
| 9 | Wales 1 Business Park (partial) | M4 Junction 23a, Magor | Forecast |
| 10 | Sainsbury's foodstore | Crindau | Forecast |
| 11 | Celtic Springs Business Park (partial) | Cleppa Park | Forecast |
| 12 | Residential development | Spytty Pill / Corporation Rd | Newport model |
| 13 | Residential development | Old Town Dock, Usk Way | Newport model |
| 14 | Parc Lysaght: residential (partial) and Morrisons foodstore | Corporation Rd | Forecast |
| 15 | University Campus | City Centre riverfront | Forecast |
| 16 | Lysaght village (former Orb works - partial) | Corporation Rd | Forecast |

[10] National Trip End Model, TEMPRO version 6.2, Department for Transport, July 2011

# 6 Assignment Methodology

## 6.1 Assignment Algorithm

The assignment process is an important element as it predicts the routes that drivers will choose taking into account the level of traffic demand and the available road capacity. The assignment technique used for the M4 model was 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

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 will be those which minimise distance, conversely if PPM is high low cost routes will be those that minimise the travel time.

WebTAG Unit 3.5.6[11] Tables 1 and 2 provide monetary values of time, which can be used to derive values of time in an assignment model in terms of pence per minute (PPM). Similarly Tables 10 to 12 provide parameters to calculate fuel costs and Table 15 provides parameters to calculate 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 3.5.6 states that, in non-work time it is assumed that travellers do not perceive non-fuel vehicle operating costs, and so these have been omitted from the overall calculation of generalised costs for commuting and other trips. The PPM and PPK parameters then give the overall generalised cost for each of the different user classes.

For the purpose of the 2012 model update, the generalised costs derived from the most recent version of WebTAG 3.5.6 have been calculated in 2010 prices. These have been converted to 2012 prices using national statistics on the change in average earnings and the GDP. The generalised cost parameters in 2012 prices used in the updated base model are shown in Table 6.1.

[11] Transport Analysis Guidance Unit 3.5.6, Values of Time and Operating Costs, Department for Transport, October 2012

**Table 6.1: Generalised Cost Parameter Values, 2012 Prices**

| | AM Peak | | Inter Peak | | PM Peak | |
|---|---|---|---|---|---|---|
| | PPM | PPK | PPM | PPK | PPM | PPK |
| Car, Employer's Business | 56.05 | 13.56 | 55.37 | 13.48 | 58.41 | 13.58 |
| Car, Other | 14.75 | 7.82 | 15.18 | 7.68 | 15.62 | 7.74 |
| Car, Commuting | 12.56 | 7.70 | 12.77 | 7.68 | 12.80 | 7.67 |
| Light Goods Vehicle | 24.34 | 17.68 | 23.84 | 17.89 | 24.71 | 17.72 |
| Heavy Goods Vehicle | 20.99 | 44.79 | 20.71 | 45.17 | 20.72 | 47.38 |

## 6.3 Assignment Convergence

Convergence of the model is important in providing 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 real, rather than relating to differing degrees of model convergence.

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.

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.

Table 6.2 shows the level of convergence achieved by the updated M4 Corridor 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 | 55 | 10 | 14 |
| 'Delta' Function (%GAP) | 0.0020% | 0.00001% | 0.00028% |
| Percentage of link with flow change of less than 1% (final four iterations) | 98.88%<br>98.08%<br>99.40%<br>99.16% | 99.67%<br>99.82%<br>99.33%<br>98.68% | 98.91%<br>98.70%<br>98.46%<br>98.41% |

[12] Transport Analysis Guidance, Highway Assignment Modelling, Unit 3.19, Department for Transport, August 2012

# 7 Model Calibration

## 7.1 Network Checks

Following the initial assignments, a matrix estimation procedure was required to calibrate the updated M4 Corridor model. 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 were made before matrix estimation was started.

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.

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

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.

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 trip matrix. Within the SATURN suite, this process is run through the SATME2 program.

In order to properly validate the traffic model, it is important that the traffic counts used for validation are not also used in the process of developing 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.

Successive applications of matrix estimation always 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.

WebTAG[13] suggests a set of benchmark criteria 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<br>Intercept near zero<br>$R^2$ in excess of 0.95 |
| Matrix zonal trip ends | Slope within 0.99 and 1.01<br>Intercept near zero<br>$R^2$ in excess of 0.98 |
| Trip length distributions | Means within 5%<br>Standard deviations within 5% |
| Sector to sector level matrices | Differences within 5% |

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 M4 model, this was considered to cover the full M4 corridor covered in simulation within the model. The analysis excluded all intrazonal movements from the matrices (which were not affected through matrix estimation).

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. In general terms this indicates that some exceedances occur for each time period.

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

| | AM Peak | | | Interpeak | | | PM Peak | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cell Values | Rows | Cols | Cell Values | Rows | Cols | Cell Values | Rows | Cols |
| **Slope** | 0.80 | 0.84 | 0.87 | 0.76 | 0.82 | 0.83 | 0.84 | 0.92 | 0.86 |
| **Intercept** | 0.01 | 1.86 | 5.31 | 0.01 | 1.74 | 13.40 | 0.01 | -0.18 | 7.39 |
| **$R^2$** | 0.65 | 0.84 | 0.92 | 0.61 | 0.83 | 0.86 | 0.65 | 0.88 | 0.90 |

[13] Transport Analysis Guidance Unit 3.19, Highway Assignment Modelling, Department for Transport, August 2012

Checks were therefore undertaken to ensure that the ME2 process had not distorted the trip matrix unrealistically. Table 7.3 shows that most cells within the matrices did not change at all, while the number of matrix cells changing by fewer than three trips was less than 0.03% of the total number of cells. The GEH error statistic, which is described in more detail in Section 7.3, compares both absolute and relative values, and this indicated that the great majority of cells achieved a value of less than 2.0.

**Table 7.3: Matrix Estimation – Changes to Cell Values**

| | Change in Matrix Cell Value | | GEH Error Statistic | |
|---|---|---|---|---|
| | **No Change** | **Fewer than 3 trips** | **Zero** | **Less than 2.0** |
| AM Peak | 83.65% | 99.78% | 83.45% | 99.85% |
| Inter Peak | 91.70% | 99.84% | 91.64% | 99.86% |
| PM Peak | 83.59% | 99.77% | 83.35% | 99.84% |

The changes in trip length distribution that result from matrix estimation are shown in Table 7.4. In most cases, the results show that the changes in trip lengths fall within the benchmarks suggested by WebTAG, with only the average trip length in the interpeak being slightly greater.

**Table 7.4: Changes in Trip Length (km) due to Matrix Estimation**

| | Mean | | | Standard Deviation | | |
|---|---|---|---|---|---|---|
| | **Pre-ME2** | **Post-ME2** | **% Diff** | **Pre-ME2** | **Post-ME2** | **% Diff** |
| AM Peak | 43.32 | 43.63 | 0.72% | 70.40 | 72.41 | 2.86% |
| Inter Peak | 48.95 | 45.90 | -6.24% | 79.40 | 78.70 | -0.89% |
| PM Peak | 39.28 | 38.34 | -2.39% | 68.89 | 68.68 | -0.30% |

A check was made on the average length of trips using the M4, and the results are shown in Table 7.5. While the size of the changes varied by section, they were all less than the suggested benchmark of 5%, including those in the interpeak period. It was therefore concluded that the changes brought about by the matrix estimation process did not impact significantly on the area of the model of greatest interest, that of the M4 motorway.

**Table 7.5: Changes in Trip Length on the M4 Motorway**

| Location | AM | | | IP | | | PM | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Avge Trip Length (km)** | | **% change** | **Avge Trip Length (km)** | | **% change** | **Avge Trip Length (km)** | | **% change** |
| | **Pre-ME2** | **Post ME2** | | **Pre-ME2** | **Post ME2** | | **Pre-ME2** | **Post ME2** | |
| M4, J28–J29 | 88.19 | 86.44 | -2.0% | 106.23 | 110.53 | +4.0% | 89.00 | 88.77 | -0.3% |
| M4, Brynglas Tunnels | 123.86 | 119.72 | -3.3% | 144.42 | 145.72 | +0.9% | 123.19 | 126.54 | +2.7% |
| M4, J23a–J24 | 103.21 | 104.04 | +0.8% | 119.02 | 120.16 | +1.0% | 110.38 | 109.41 | -0.9% |

## 7.3 Traffic Flow Calibration

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. GEH is a form of 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.

Advice on acceptable criteria for traffic model calibration and validation is given in WebTAG[14]. The criteria for link flows are based on relative and absolute differences and the GEH statistic, and are summarised in Table 7.6.

**Table 7.6: 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 |

The screenlines used for model calibration are shown in Figure 7.1, and Tables 7.7 to 7.9 show a comparison of the observed traffic flows with the modelled flows following matrix estimation for the morning peak, interpeak and evening peak hours respectively.

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 traffic flows on the model network.

[14] Transport Analysis Guidance, Highway Assignment Modelling, Unit 3.19, Department for Transport, August 2012

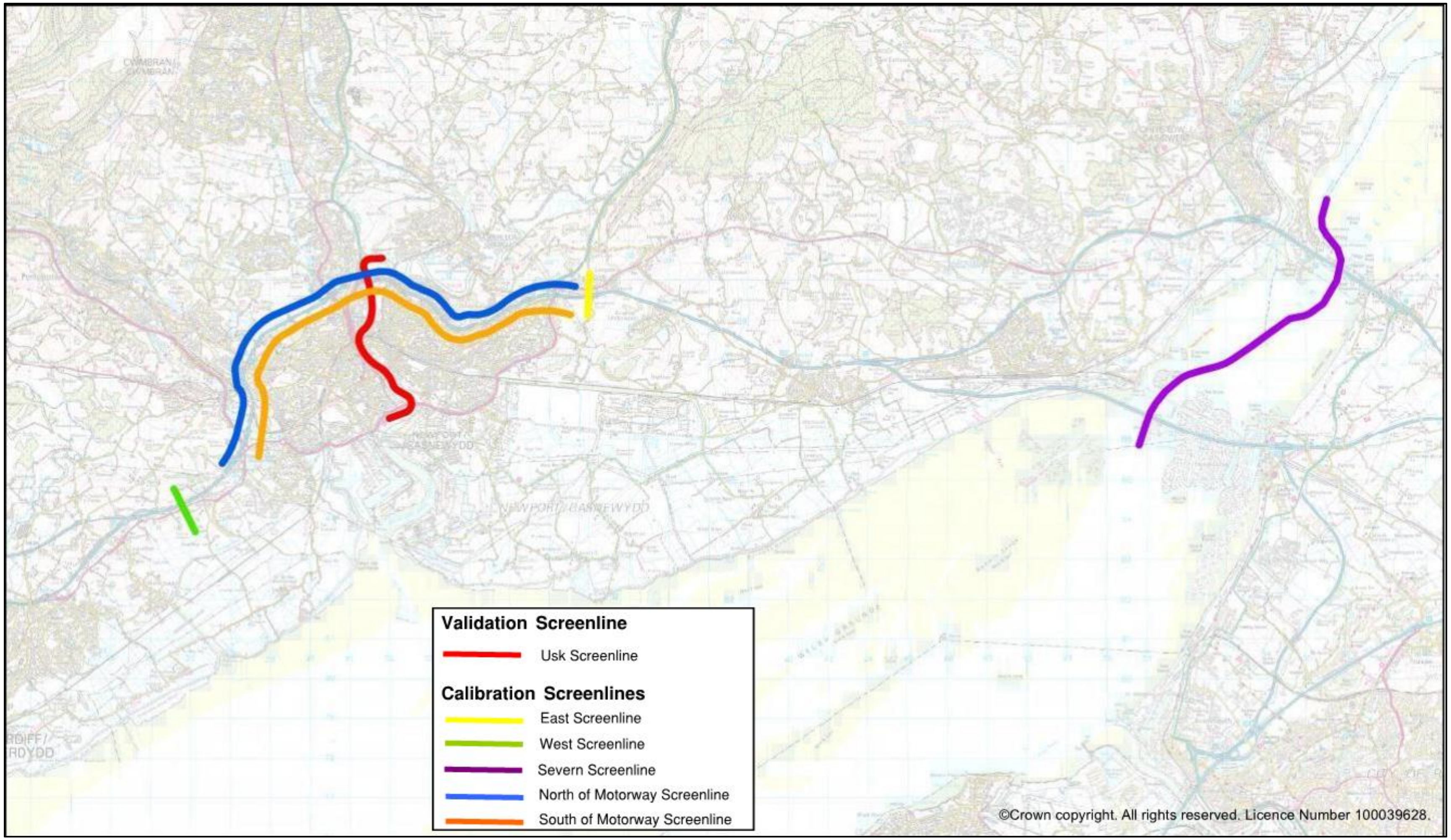



**Figure 7.1 Calibration / Validation Screenlines**

## Table 7.7a: 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 | 4010 | 3894 | 1.85 | PASS | PASS |
| A48 east of J24, eastbound | 685 | 740 | 2.06 | PASS | PASS |
| ***East Screenline Total*** | **4695** | **4634** | **0.90** | **PASS** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, eastbound | 5604 | 5741 | 1.83 | PASS | PASS |
| A48 Castleton, eastbound | 1141 | 1289 | 4.23 | PASS | PASS |
| ***West Screenline Total*** | **6745** | **7030** | **3.43** | **PASS** | **PASS** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, eastbound | 1236 | 1292 | 1.59 | PASS | PASS |
| M4 Second Severn Crossing, eastbound | 3286 | 3411 | 2.15 | PASS | PASS |
| ***Severn Screenline Total*** | **4522** | **4703** | **2.66** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, southbound | 1325 | 1245 | 2.22 | PASS | PASS |
| B4591 north of J27, southbound | 1135 | 1159 | 0.71 | PASS | PASS |
| A4051 north of J26, southbound | 2228 | 2084 | 3.10 | PASS | PASS |
| A4042 Malpas Relief Road, southbound | 2337 | 2329 | 0.16 | PASS | PASS |
| B4596 north of J25, southbound | 685 | 768 | 3.11 | PASS | PASS |
| A449 north of J24, southbound | 1702 | 1714 | 0.29 | PASS | PASS |
| A48 east of J24, westbound | 1016 | 1033 | 0.54 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **10428** | **10332** | **0.92** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, eastbound | 1727 | 1665 | 1.50 | PASS | PASS |
| B4591 Risca Rd, eastbound | 736 | 883 | 5.16 | FAIL | FAIL |
| A4051 south of J26, southbound | 934 | 918 | 0.53 | PASS | PASS |
| A4042 south of J25a, southbound | 2440 | 2492 | 1.05 | PASS | PASS |
| B4596 south of J25, southbound | 555 | 577 | 0.94 | PASS | PASS |
| B4237 west of J24, westbound | 739 | 791 | 1.89 | PASS | PASS |
| A48 SDR south of J24, southbound | 1160 | 1144 | 0.47 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **8291** | **8470** | **0.33** | **PASS** | **PASS** |
| **Motorway Links** | | | | | |
| M4, J32-J30, eastbound | 4476 | 4657 | 2.68 | PASS | PASS |
| M4, J30-J29, eastbound | 3315 | 3443 | 2.20 | PASS | PASS |
| A48(M), J29a–J29, eastbound | 2289 | 2232 | 1.20 | PASS | PASS |
| M4, J23a-J23, eastbound | 3938 | 3606 | 5.40 | PASS | FAIL |
| M48, east of M4, eastbound | 652 | 596 | 2.24 | PASS | PASS |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **<u>Motorway Sliproads</u>** | | | | | |
| M4 J30 eastbound offslip | 1439 | 1532 | 2.41 | PASS | PASS |
| M4 J30 eastbound onslip | 277 | 317 | 2.31 | PASS | PASS |
| M4 J28 eastbound offslip | 1364 | 1411 | 1.28 | PASS | PASS |
| M4 J28 eastbound onslip | 803 | 791 | 0.41 | PASS | PASS |
| M4 J27 eastbound offslip | 553 | 580 | 1.17 | PASS | PASS |
| M4 J27 eastbound onslip | 673 | 645 | 1.09 | PASS | PASS |
| M4 J26 eastbound offslip | 1752 | 1653 | 2.41 | PASS | PASS |
| M4 J26 eastbound onslip | 224 | 161 | 4.51 | PASS | PASS |
| M4 J25a eastbound onslip | 981 | 1044 | 1.98 | PASS | PASS |
| M4 J25 eastbound onslip | 178 | 172 | 0.44 | PASS | PASS |
| M4 J24 eastbound offslip | 1509 | 1559 | 1.31 | PASS | PASS |
| M4 J24 eastbound onslip | 726 | 804 | 2.84 | PASS | PASS |
| M4 J23a eastbound offslip | 652 | 716 | 2.45 | PASS | PASS |
| M4 J23a eastbound onslip | 580 | 571 | 0.38 | PASS | PASS |
| **<u>Miscellaneous Sites</u>** | | | | | |
| A4232 south of J30, southbound | 1528 | 1562 | 0.85 | PASS | PASS |
| A48 west of A4232, eastbound | 3896 | 3660 | 3.83 | PASS | PASS |
| A48, A4232 to A48(M) J29a, eastbound | 4061 | 3964 | 1.53 | PASS | PASS |
| B4245 east of Magor rbt, eastbound | 438 | 459 | 0.96 | PASS | PASS |
| A48 west of Parkwall rbt, eastbound | 183 | 207 | 1.72 | PASS | PASS |
| A48 east of Parkwall rbt, eastbound | 603 | 602 | 0.05 | PASS | PASS |
| B4245 south of Parkwall rbt, southbound | 487 | 431 | 2.61 | PASS | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **98%** | **86%** |

**Table 7.7b: Link Calibration Results (PCUs), AM Peak Westbound / Northbound / Out from Newport**

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **East Screenline** | | | | | |
| M4, J24-J23a, westbound | 3634 | 3594 | 0.65 | PASS | PASS |
| A48 east of J24, westbound | 1016 | 1033 | 0.54 | PASS | PASS |
| ***East Screenline Total*** | **4650** | **4627** | **0.32** | **PASS** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, westbound | 5264 | 5233 | 0.43 | PASS | PASS |
| A48 Castleton, westbound | 738 | 720 | 0.69 | PASS | PASS |
| ***West Screenline Total*** | **6002** | **5953** | **0.64** | **PASS** | **PASS** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, westbound | 655 | 564 | 3.70 | PASS | PASS |
| M4 Second Severn Crossing, westbound | 2201 | 2211 | 0.21 | PASS | PASS |
| ***Severn Screenline Total*** | **2856** | **2775** | **1.53** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, northbound | 1092 | 1202 | 3.24 | PASS | PASS |
| B4591 north of J27, northbound | 684 | 714 | 1.14 | PASS | PASS |
| A4051 north of J26, northbound | 1961 | 1897 | 1.45 | PASS | PASS |
| A4042 Malpas Relief Road, northbound | 1617 | 1655 | 0.93 | PASS | PASS |
| B4596 north of J25, northbound | 379 | 498 | 5.86 | FAIL | FAIL |
| A449 north of J24, northbound | 1049 | 1075 | 0.79 | PASS | PASS |
| A48 east of J24, eastbound | 685 | 740 | 2.06 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **7467** | **7781** | **3.58** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, westbound | 1099 | 994 | 3.23 | PASS | PASS |
| B4591 Risca Rd, westbound | 866 | 1238 | 11.47 | FAIL | FAIL |
| A4051 south of J26, northbound | 1156 | 989 | 5.12 | FAIL | FAIL |
| A4042 south of J25a, northbound | 1276 | 1285 | 0.24 | PASS | PASS |
| B4596 south of J25, northbound | 773 | 749 | 0.86 | PASS | PASS |
| B4237 west of J24, eastbound | 445 | 482 | 1.75 | PASS | PASS |
| A48 SDR south of J24, northbound | 627 | 681 | 2.12 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **6242** | **6418** | **2.22** | **PASS** | **PASS** |
| **Motorway Links** | | | | | |
| M4, J32-J30, westbound | 3544 | 3316 | 3.88 | PASS | PASS |
| M4, J30-J29, westbound | 3205 | 3134 | 1.26 | PASS | PASS |
| A48(M), J29a – J29, westbound | 2059 | 2103 | 0.97 | PASS | PASS |
| M4, J23a-J23, westbound | 2945 | 2915 | 0.56 | PASS | PASS |
| M48, east of M4, westbound | 745 | 728 | 0.62 | PASS | PASS |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Sliproads** | | | | | |
| M4 J30 westbound offslip | 317 | 318 | 0.02 | PASS | PASS |
| M4 J30 westbound onslip | 1006 | 1008 | 0.07 | PASS | PASS |
| M4 J28 westbound offslip | 791 | 789 | 0.06 | PASS | PASS |
| M4 J28 westbound onslip | 1781 | 1770 | 0.28 | PASS | PASS |
| M4 J27 westbound offslip | 126 | 145 | 1.65 | PASS | PASS |
| M4 J27 westbound onslip | 954 | 1018 | 2.02 | PASS | PASS |
| M4 J26 westbound offslip | 102 | 112 | 0.96 | PASS | PASS |
| M4 J26 westbound onslip | 2120 | 2048 | 1.59 | PASS | PASS |
| M4 J25a westbound onslip | 414 | 409 | 0.26 | PASS | PASS |
| M4 J25 westbound onslip | 875 | 999 | 4.05 | PASS | PASS |
| M4 J24 westbound offslip | 1750 | 1847 | 2.29 | PASS | PASS |
| M4 J24 westbound onslip | 991 | 878 | 3.70 | PASS | PASS |
| M4 J23a westbound offslip | 691 | 662 | 1.12 | PASS | PASS |
| M4 J23a westbound onslip | 1030 | 847 | 5.98 | FAIL | FAIL |
| **Miscellaneous Sites** | | | | | |
| A4232 south of J30, northbound | 1691 | 1470 | 5.54 | PASS | FAIL |
| A48 west of A4232, westbound | 3676 | 3721 | 0.74 | PASS | PASS |
| A48, A4232 to A48(M) J29a, westbound | 3316 | 3154 | 2.84 | PASS | PASS |
| B4245 east of Magor rbt, westbound | 1042 | 1153 | 3.35 | PASS | PASS |
| A48 west of Parkwall rbt, westbound | 256 | 218 | 2.51 | PASS | PASS |
| A48 east of Parkwall rbt, westbound | 723 | 479 | 9.96 | FAIL | FAIL |
| B4245 south of Parkwall rbt, northbound | 532 | 301 | 11.32 | FAIL | FAIL |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **87%** | **85%** |

## Table 7.8a: Link Calibration Results (PCUs), Interpeak Eastbound / Southbound / In to Newport

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **East Screenline** | | | | | |
| M4, J24-J23a, eastbound | 3105 | 2940 | 2.99 | PASS | PASS |
| A48 east of J24, eastbound | 593 | 665 | 2.89 | PASS | PASS |
| ***East Screenline Total*** | **3698** | **3605** | **1.52** | **PASS** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, eastbound | 3713 | 4003 | 4.68 | PASS | PASS |
| A48 Castleton, eastbound | 381 | 431 | 2.47 | PASS | PASS |
| ***West Screenline Total*** | **4094** | **4434** | **5.21** | **FAIL** | **FAIL** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, eastbound | 583 | 601 | 0.75 | PASS | PASS |
| M4 Second Severn Crossing, eastbound | 2574 | 2527 | 0.93 | PASS | PASS |
| ***Severn Screenline Total*** | **3157** | **3128** | **0.51** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, southbound | 1212 | 1239 | 0.77 | PASS | PASS |
| B4591 north of J27, southbound | 528 | 550 | 0.94 | PASS | PASS |
| A4051 north of J26, southbound | 1338 | 1374 | 0.98 | PASS | PASS |
| A4042 Malpas Relief Road, southbound | 1219 | 1217 | 0.05 | PASS | PASS |
| B4596 north of J25, southbound | 447 | 489 | 1.96 | PASS | PASS |
| A449 north of J24, southbound | 1043 | 1129 | 2.63 | PASS | PASS |
| A48 east of J24, westbound | 621 | 683 | 2.44 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **6408** | **6682** | **3.39** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, eastbound | 1267 | 1201 | 1.87 | PASS | PASS |
| B4591 Risca Rd, eastbound | 472 | 531 | 2.61 | PASS | PASS |
| A4051 south of J26, southbound | 775 | 764 | 0.38 | PASS | PASS |
| A4042 south of J25a, southbound | 1206 | 1244 | 1.08 | PASS | PASS |
| B4596 south of J25, southbound | 453 | 426 | 1.28 | PASS | PASS |
| B4237 west of J24, westbound | 535 | 516 | 0.85 | PASS | PASS |
| A48 SDR south of J24, southbound | 880 | 820 | 2.03 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **5588** | **5502** | **1.15** | **PASS** | **PASS** |
| **Motorway Links** | | | | | |
| M4, J32-J30, eastbound | 2597 | 2472 | 2.48 | PASS | PASS |
| M4, J30-J29, eastbound | 2252 | 2227 | 0.53 | PASS | PASS |
| A48(M), J29a – J29, eastbound | 1461 | 1477 | 0.42 | PASS | PASS |
| M4, J23a-J23, eastbound | 2993 | 2895 | 1.81 | PASS | PASS |
| M48, east of M4, eastbound | 420 | 371 | 2.46 | PASS | PASS |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Sliproads** | | | | | |
| M4 J30 eastbound offslip | 549 | 451 | 4.38 | PASS | PASS |
| M4 J30 eastbound onslip | 204 | 201 | 0.22 | PASS | PASS |
| M4 J28 eastbound offslip | 768 | 853 | 2.99 | PASS | PASS |
| M4 J28 eastbound onslip | 638 | 796 | 5.92 | FAIL | FAIL |
| M4 J27 eastbound offslip | 248 | 262 | 0.87 | PASS | PASS |
| M4 J27 eastbound onslip | 291 | 315 | 1.39 | PASS | PASS |
| M4 J26 eastbound offslip | 1026 | 1085 | 1.83 | PASS | PASS |
| M4 J26 eastbound onslip | 91 | 101 | 1.01 | PASS | PASS |
| M4 J25a eastbound onslip | 713 | 635 | 2.99 | PASS | PASS |
| M4 J25 eastbound onslip | 57 | 84 | 3.20 | PASS | PASS |
| M4 J24 eastbound offslip | 1050 | 1078 | 0.85 | PASS | PASS |
| M4 J24 eastbound onslip | 695 | 701 | 0.22 | PASS | PASS |
| M4 J23a eastbound offslip | 611 | 623 | 0.50 | PASS | PASS |
| M4 J23a eastbound onslip | 500 | 474 | 1.15 | PASS | PASS |
| **Miscellaneous Sites** | | | | | |
| A4232 south of J30, southbound | 892 | 742 | 5.24 | FAIL | FAIL |
| A48 west of A4232, eastbound | 2357 | 2341 | 0.33 | PASS | PASS |
| A48, A4232 to A48(M) J29a, eastbound | 2272 | 2267 | 0.09 | PASS | PASS |
| B4245 east of Magor rbt, eastbound | 432 | 436 | 0.23 | PASS | PASS |
| A48 west of Parkwall rbt, eastbound | 201 | 227 | 1.82 | PASS | PASS |
| A48 east of Parkwall rbt, eastbound | 462 | 492 | 1.36 | PASS | PASS |
| B4245 south of Parkwall rbt, southbound | 289 | 357 | 0.45 | PASS | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **96%** | **96%** |

## Table 7.8b: Link Calibration Results (PCUs), Interpeak Westbound / Northbound / Out from Newport

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **East Screenline** | | | | | |
| M4, J24-J23a, westbound | 3102 | 2850 | 4.62 | PASS | PASS |
| A48 east of J24, westbound | 621 | 683 | 2.44 | PASS | PASS |
| ***East Screenline Total*** | **3723** | **3533** | **3.15** | **FAIL** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, westbound | 3713 | 3778 | 1.07 | PASS | PASS |
| A48 Castleton, westbound | 387 | 448 | 2.98 | PASS | PASS |
| ***West Screenline Total*** | **4100** | **4226** | **1.95** | **PASS** | **PASS** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, westbound | 517 | 558 | 1.76 | PASS | PASS |
| M4 Second Severn Crossing, westbound | 2181 | 2098 | 1.79 | PASS | PASS |
| ***Severn Screenline Total*** | **2698** | **2656** | **0.81** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, northbound | 1093 | 1181 | 2.61 | PASS | PASS |
| B4591 north of J27, northbound | 768 | 707 | 2.28 | PASS | PASS |
| A4051 north of J26, northbound | 1341 | 1364 | 0.62 | PASS | PASS |
| A4042 Malpas Relief Road, northbound | 1263 | 1237 | 0.73 | PASS | PASS |
| B4596 north of J25, northbound | 482 | 463 | 0.87 | PASS | PASS |
| A449 north of J24, northbound | 957 | 969 | 0.39 | PASS | PASS |
| A48 east of J24, eastbound | 593 | 665 | 2.89 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **6497** | **6586** | **1.10** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, westbound | 1248 | 1224 | 0.68 | PASS | PASS |
| B4591 Risca Rd, westbound | 518 | 575 | 2.43 | PASS | PASS |
| A4051 south of J26, northbound | 900 | 851 | 1.69 | PASS | PASS |
| A4042 south of J25a, northbound | 1228 | 1120 | 3.13 | PASS | PASS |
| B4596 south of J25, northbound | 495 | 449 | 2.09 | PASS | PASS |
| B4237 west of J24, eastbound | 452 | 460 | 0.39 | PASS | PASS |
| A48 SDR south of J24, northbound | 748 | 805 | 2.04 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **5589** | **5484** | **1.40** | **PASS** | **PASS** |
| **Motorway Links** | | | | | |
| M4, J32-J30, westbound | 2339 | 2286 | 1.11 | PASS | PASS |
| M4, J30-J29, westbound | 2046 | 1987 | 1.31 | PASS | PASS |
| A48(M), J29a – J29, westbound | 1446 | 1433 | 0.34 | PASS | PASS |
| M4, J23a-J23, westbound | 2663 | 2578 | 1.67 | PASS | PASS |
| M48, east of M4, westbound | 482 | 477 | 0.23 | PASS | PASS |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Sliproads** | | | | | |
| M4 J30 westbound offslip | 298 | 290 | 0.48 | PASS | PASS |
| M4 J30 westbound onslip | 738 | 757 | 0.71 | PASS | PASS |
| M4 J28 westbound offslip | 709 | 615 | 3.65 | FAIL | PASS |
| M4 J28 westbound onslip | 1055 | 1110 | 1.68 | PASS | PASS |
| M4 J27 westbound offslip | 123 | 108 | 1.44 | PASS | PASS |
| M4 J27 westbound onslip | 663 | 641 | 0.87 | PASS | PASS |
| M4 J26 westbound offslip | 95 | 90 | 0.56 | PASS | PASS |
| M4 J26 westbound onslip | 1149 | 1170 | 0.61 | PASS | PASS |
| M4 J25a westbound onslip | 421 | 452 | 1.49 | PASS | PASS |
| M4 J25 westbound onslip | 137 | 254 | 8.31 | FAIL | FAIL |
| M4 J24 westbound offslip | 801 | 761 | 1.42 | PASS | PASS |
| M4 J24 westbound onslip | 859 | 822 | 1.30 | PASS | PASS |
| M4 J23a westbound offslip | 264 | 211 | 3.41 | PASS | PASS |
| M4 J23a westbound onslip | 557 | 500 | 2.49 | PASS | PASS |
| **Miscellaneous Sites** | | | | | |
| A4232 south of J30, northbound | 820 | 772 | 1.71 | PASS | PASS |
| A48 west of A4232, westbound | 2338 | 2293 | 0.94 | PASS | PASS |
| A48, A4232 to A48(M) J29a, westbound | 2240 | 2187 | 1.13 | PASS | PASS |
| B4245 east of Magor rbt, westbound | 554 | 600 | 1.93 | PASS | PASS |
| A48 west of Parkwall rbt, westbound | 238 | 232 | 0.41 | PASS | PASS |
| A48 east of Parkwall rbt, westbound | 556 | 552 | 0.17 | PASS | PASS |
| B4245 south of Parkwall rbt, northbound | 348 | 357 | 0.50 | PASS | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **96%** | **98%** |

## Table 7.9a: 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 | 3533 | 3459 | 1.24 | PASS | PASS |
| A48 east of J24, eastbound | 1029 | 1064 | 1.08 | PASS | PASS |
| ***East Screenline Total*** | **4562** | **4523** | **0.57** | **PASS** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, eastbound | 5088 | 5041 | 0.66 | PASS | PASS |
| A48 Castleton, eastbound | 599 | 667 | 2.69 | PASS | PASS |
| ***West Screenline Total*** | **5687** | **5708** | **0.28** | **PASS** | **PASS** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, eastbound | 588 | 650 | 2.48 | PASS | PASS |
| M4 Second Severn Crossing, eastbound | 2511 | 2532 | 0.41 | PASS | PASS |
| ***Severn Screenline Total*** | **3099** | **3182** | **1.47** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, southbound | 1126 | 1241 | 3.32 | PASS | PASS |
| B4591 north of J27, southbound | 653 | 615 | 1.50 | PASS | PASS |
| A4051 north of J26, southbound | 1907 | 1811 | 2.23 | PASS | PASS |
| A4042 Malpas Relief Road, southbound | 1484 | 1485 | 0.04 | PASS | PASS |
| B4596 north of J25, southbound | 391 | 456 | 3.14 | PASS | PASS |
| A449 north of J24, southbound | 1101 | 1149 | 1.41 | PASS | PASS |
| A48 east of J24, westbound | 876 | 975 | 3.27 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **7538** | **7732** | **2.21** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, eastbound | 1025 | 1065 | 1.24 | PASS | PASS |
| B4591 Risca Rd, eastbound | 640 | 833 | 7.13 | FAIL | FAIL |
| A4051 south of J26, southbound | 855 | 866 | 0.39 | PASS | PASS |
| A4042 south of J25a, southbound | 1369 | 1464 | 2.52 | PASS | PASS |
| B4596 south of J25, southbound | 739 | 633 | 4.06 | FAIL | PASS |
| B4237 west of J24, westbound | 568 | 697 | 5.13 | FAIL | FAIL |
| A48 SDR south of J24, southbound | 731 | 788 | 2.08 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **5927** | **6346** | **5.36** | **FAIL** | **FAIL** |
| **Motorway Links** | | | | | |
| M4, J32-J30, eastbound | 3051 | 3109 | 1.04 | PASS | PASS |
| M4, J30-J29, eastbound | 2703 | 2726 | 0.43 | PASS | PASS |
| A48(M), J29a – J29, eastbound | 2385 | 2213 | 3.58 | PASS | PASS |
| M4, J23a-J23, eastbound | 3093 | 3022 | 1.29 | PASS | PASS |
| M48, east of M4, eastbound | 582 | 493 | 3.82 | PASS | PASS |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Sliproads** | | | | | |
| M4 J30 eastbound offslip | 753 | 760 | 0.26 | PASS | PASS |
| M4 J30 eastbound onslip | 405 | 400 | 0.26 | PASS | PASS |
| M4 J28 eastbound offslip | 1285 | 981 | 9.03 | FAIL | FAIL |
| M4 J28 eastbound onslip | 970 | 1140 | 5.23 | PASS | FAIL |
| M4 J27 eastbound offslip | 409 | 633 | 9.81 | FAIL | FAIL |
| M4 J27 eastbound onslip | 381 | 359 | 1.12 | PASS | PASS |
| M4 J26 eastbound offslip | 1336 | 1712 | 1.83 | PASS | PASS |
| M4 J26 eastbound onslip | 90 | 117 | 2.74 | PASS | PASS |
| M4 J25a eastbound onslip | 923 | 915 | 0.27 | PASS | PASS |
| M4 J25 eastbound onslip | 142 | 127 | 1.23 | PASS | PASS |
| M4 J24 eastbound offslip | 1480 | 1484 | 0.11 | PASS | PASS |
| M4 J24 eastbound onslip | 748 | 752 | 0.14 | PASS | PASS |
| M4 J23a eastbound offslip | 805 | 806 | 0.06 | PASS | PASS |
| M4 J23a eastbound onslip | 368 | 366 | 0.10 | PASS | PASS |
| **Miscellaneous Sites** | | | | | |
| A4232 south of J30, southbound | 1368 | 1405 | 1.00 | PASS | PASS |
| A48 west of A4232, eastbound | 3582 | 3497 | 1.42 | PASS | PASS |
| A48, A4232 to A48(M) J29a, eastbound | 3475 | 3449 | 0.43 | PASS | PASS |
| B4245 east of Magor rbt, eastbound | 930 | 943 | 0.41 | PASS | PASS |
| A48 west of Parkwall rbt, eastbound | 155 | 186 | 2.36 | PASS | PASS |
| A48 east of Parkwall rbt, eastbound | 465 | 489 | 1.12 | PASS | PASS |
| B4245 south of Parkwall rbt, southbound | 328 | 453 | 0.02 | PASS | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **89%** | **89%** |

## Table 7.9b: Link Calibration Results (PCUs), PM Peak Westbound / Northbound / Out from Newport

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **East Screenline** | | | | | |
| M4, J24-J23a, westbound | 3760 | 3824 | 1.04 | PASS | PASS |
| A48 east of J24, westbound | 876 | 975 | 3.27 | PASS | PASS |
| ***East Screenline Total*** | **4636** | **4799** | **2.38** | **PASS** | **PASS** |
| **West Screenline** | | | | | |
| M4. J29-J28, westbound | 5088 | 5300 | 2.95 | PASS | PASS |
| A48 Castleton, westbound | 904 | 981 | 2.52 | PASS | PASS |
| ***West Screenline Total*** | **5992** | **6281** | **3.70** | **PASS** | **PASS** |
| **Severn Screenline** | | | | | |
| M48 Severn Bridge, westbound | 1397 | 1362 | 0.94 | PASS | PASS |
| M4 Second Severn Crossing, westbound | 2849 | 2849 | 0.00 | PASS | PASS |
| ***Severn Screenline Total*** | **4246** | **4211** | **0.53** | **PASS** | **PASS** |
| **North of Motorway Screenline** | | | | | |
| A467 north of J28, northbound | 1904 | 1826 | 1.80 | PASS | PASS |
| B4591 north of J27, northbound | 1092 | 1208 | 3.41 | PASS | PASS |
| A4051 north of J26, northbound | 1927 | 2019 | 2.07 | PASS | PASS |
| A4042 Malpas Relief Road, northbound | 1973 | 1998 | 0.55 | PASS | PASS |
| B4596 north of J25, northbound | 758 | 778 | 0.73 | PASS | PASS |
| A449 north of J24, northbound | 1207 | 1257 | 1.42 | PASS | PASS |
| A48 east of J24, eastbound | 1029 | 1064 | 1.08 | PASS | PASS |
| ***North of Motorway Screenline Total*** | **9890** | **10150** | **2.59** | **PASS** | **PASS** |
| **South of Motorway Screenline** | | | | | |
| A48 SDR east of J28, westbound | 1119 | 1098 | 0.66 | PASS | PASS |
| B4591 Risca Rd, westbound | 677 | 837 | 5.81 | FAIL | FAIL |
| A4051 south of J26, northbound | 1344 | 1314 | 0.83 | PASS | PASS |
| A4042 south of J25a, northbound | 2073 | 1789 | 6.45 | FAIL | FAIL |
| B4596 south of J25, northbound | 824 | 783 | 1.46 | PASS | PASS |
| B4237 west of J24, eastbound | 497 | 491 | 0.26 | PASS | PASS |
| A48 SDR south of J24, northbound | 974 | 1042 | 2.15 | PASS | PASS |
| ***South of Motorway Screenline Total*** | **7508** | **7354** | **1.79** | **PASS** | **PASS** |
| **Motorway Links** | | | | | |
| M4, J32-J30, westbound | 3720 | 3859 | 2.26 | PASS | PASS |
| M4, J30-J29, westbound | 2916 | 3055 | 2.55 | PASS | PASS |
| A48(M), J29a – J29, westbound | 2280 | 2198 | 1.75 | PASS | PASS |
| M4, J23a-J23, westbound | 3441 | 3624 | 3.07 | PASS | PASS |
| M48, east of M4, westbound | 592 | 768 | 6.74 | FAIL | FAIL |

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Sliproads** | | | | | |
| M4 J30 westbound offslip | 389 | 478 | 4.30 | PASS | PASS |
| M4 J30 westbound onslip | 708 | 719 | 0.41 | PASS | PASS |
| M4 J28 westbound offslip | 782 | 858 | 2.64 | PASS | PASS |
| M4 J28 westbound onslip | 1461 | 1462 | 0.04 | PASS | PASS |
| M4 J27 westbound offslip | 156 | 169 | 0.99 | PASS | PASS |
| M4 J27 westbound onslip | 977 | 853 | 4.09 | PASS | PASS |
| M4 J26 westbound offslip | 123 | 132 | 0.84 | PASS | PASS |
| M4 J26 westbound onslip | 2103 | 1966 | 3.05 | PASS | PASS |
| M4 J25a westbound onslip | 819 | 746 | 2.63 | PASS | PASS |
| M4 J25 westbound onslip | 432 | 376 | 2.79 | PASS | PASS |
| M4 J24 westbound offslip | 860 | 904 | 1.47 | PASS | PASS |
| M4 J24 westbound onslip | 1158 | 1152 | 0.16 | PASS | PASS |
| M4 J23a westbound offslip | 318 | 345 | 1.50 | PASS | PASS |
| M4 J23a westbound onslip | 1122 | 1116 | 0.20 | PASS | PASS |
| **Miscellaneous Sites** | | | | | |
| A4232 south of J30, northbound | 1092 | 1103 | 0.34 | PASS | PASS |
| A48 west of A4232, westbound | 3661 | 3784 | 2.01 | PASS | PASS |
| A48, A4232 to A48(M) J29a, westbound | 3690 | 3762 | 1.18 | PASS | PASS |
| B4245 east of Magor rbt, westbound | 548 | 596 | 2.01 | PASS | PASS |
| A48 west of Parkwall rbt, westbound | 237 | 234 | 0.22 | PASS | PASS |
| A48 east of Parkwall rbt, westbound | 671 | 658 | 0.50 | PASS | PASS |
| B4245 south of Parkwall rbt, northbound | 452 | 328 | 0.05 | PASS | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **93%** | **93%** |

# 8 Model Validation

## 8.1 Introduction

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 development. This section outlines the outcomes from the M4 model validation process.

## 8.2 Flow Validation

The WebTAG requirements for flow validation are shown in Table 7.3. For the M4 model, validation was carried out on the mainline motorway links between Junction 23a and 29, together with a screenline of links crossing the River Usk in the Newport area, as shown in Figure 7.1. Tables 8.1 to 8.3 provide a comparison between modelled and observed flows on the validation links.

The results show that, in all time periods, the validation of flows on the motorway links between Junction 23a and Junction 29 passed both the flow and GEH criteria in all cases. This was also the case for the links crossing the River Usk, together with the total screenline flow.

Overall, the total percentage of validation links satisfying both criteria was well above the required 85% recommended in WebTAG in all time periods. The results therefore indicate that the validation of traffic flows is very good.

## Table 8.1: AM Peak Flow Validation (PCUs)

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Eastbound Flows** | | | | | |
| M4, J29-J28, eastbound | 5604 | 5741 | 1.83 | PASS | PASS |
| M4, J28-J27, eastbound | 5043 | 5165 | 1.70 | PASS | PASS |
| M4, J27-J26, eastbound | 5164 | 5308 | 1.99 | PASS | PASS |
| M4, J26-J25a, eastbound | 3636 | 3617 | 0.31 | PASS | PASS |
| M4, J25a-J25, eastbound | 4617 | 4548 | 1.02 | PASS | PASS |
| M4, J25-J24, eastbound | 4795 | 4738 | 0.83 | PASS | PASS |
| M4, J24-J23a, eastbound | 4010 | 3894 | 1.85 | PASS | PASS |
| **Motorway Westbound Flows** | | | | | |
| M4, J28-J29, westbound | 5264 | 5233 | 0.43 | PASS | PASS |
| M4, J27-J28, westbound | 6023 | 6032 | 0.12 | PASS | PASS |
| M4, J26-J27, westbound | 5562 | 5357 | 2.78 | PASS | PASS |
| M4, J25a-J26, westbound | 3544 | 3435 | 1.85 | PASS | PASS |
| M4, J25-J25a, westbound | 4498 | 4452 | 0.69 | PASS | PASS |
| M4, J24-J25, westbound | 4624 | 4607 | 0.24 | PASS | PASS |
| M4, J23a-J24, westbound | 3634 | 3594 | 0.65 | PASS | PASS |
| **Usk Screenline, Eastbound Flows** | | | | | |
| M4, J26-J25a, eastbound | 3636 | 3617 | 0.31 | PASS | PASS |
| Brynglas Relief Rd, eastbound to J25a | 1515 | 1530 | 0.39 | PASS | PASS |
| B4591 Newport Bridge, eastbound | 1071 | 1053 | 0.54 | PASS | PASS |
| B4237 George Street Bridge, eastbound | 488 | 458 | 1.40 | PASS | PASS |
| A48 SDR Bridge, eastbound | 1438 | 1471 | 0.86 | PASS | PASS |
| ***Usk Screenline, Eastbound Total*** | **8148** | **8129** | **0.21** | **PASS** | **PASS** |
| **Usk Screenline, Westbound Flows** | | | | | |
| M4, J25a-J26, westbound | 3544 | 3435 | 1.85 | PASS | PASS |
| Brynglas Relief Rd, westbound from J25a | 1959 | 2023 | 1.45 | PASS | PASS |
| B4591 Newport Bridge, westbound | 924 | 863 | 2.04 | PASS | PASS |
| B4237 George Street Bridge, westbound | 802 | 854 | 1.82 | PASS | PASS |
| A48 SDR Bridge, westbound | 1335 | 1326 | 0.23 | PASS | PASS |
| ***Usk Screenline, Westbound Total*** | **8563** | **8502** | **0.67** | **PASS** | **PASS** |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **100%** | **100%** |

## Table 8.2: Interpeak Flow Validation (PCUs)

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Eastbound Flows** | | | | | |
| M4, J29-J28, eastbound | 3713 | 4003 | 4.68 | PASS | PASS |
| M4, J28-J27, eastbound | 3582 | 3803 | 3.64 | PASS | PASS |
| M4, J27-J26, eastbound | 3624 | 3838 | 3.49 | PASS | PASS |
| M4, J26-J25a, eastbound | 2690 | 2737 | 0.90 | PASS | PASS |
| M4, J25a-J25, eastbound | 3403 | 3495 | 1.56 | PASS | PASS |
| M4, J25-J24, eastbound | 3460 | 3588 | 2.16 | PASS | PASS |
| M4, J24-J23a, eastbound | 3105 | 2940 | 2.99 | PASS | PASS |
| **Motorway Westbound Flows** | | | | | |
| M4, J28-J29, westbound | 3492 | 3778 | 4.75 | PASS | FAIL |
| M4, J27-J28, westbound | 3433 | 3558 | 2.12 | PASS | PASS |
| M4, J26-J27, westbound | 3716 | 3788 | 1.17 | PASS | PASS |
| M4, J25a-J26, westbound | 2662 | 2688 | 0.49 | PASS | PASS |
| M4, J25-J25a, westbound | 3325 | 3329 | 0.06 | PASS | PASS |
| M4, J24-J25, westbound | 3449 | 3457 | 0.14 | PASS | PASS |
| M4, J23a-J24, westbound | 3102 | 2850 | 4.62 | PASS | PASS |
| **Usk Screenline, Eastbound Flows** | | | | | |
| M4, J26-J25a, eastbound | 2690 | 2737 | 0.90 | PASS | PASS |
| Brynglas Relief Rd, eastbound to J25a | 1156 | 1156 | 0.00 | PASS | PASS |
| B4591 Newport Bridge, eastbound | 837 | 963 | 4.19 | PASS | PASS |
| B4237 George Street Bridge, eastbound | 637 | 627 | 0.39 | PASS | PASS |
| A48 SDR Bridge, eastbound | 1423 | 1382 | 1.09 | PASS | PASS |
| ***Usk Screenline, Eastbound Total*** | **6743** | **6865** | **1.48** | **PASS** | **PASS** |
| **Usk Screenline, Westbound Flows** | | | | | |
| M4, J25a-J26, westbound | 2662 | 2688 | 0.49 | PASS | PASS |
| Brynglas Relief Rd, westbound from J25a | 1179 | 1156 | 0.68 | PASS | PASS |
| B4591 Newport Bridge, westbound | 911 | 885 | 0.85 | PASS | PASS |
| B4237 George Street Bridge, westbound | 649 | 624 | 0.99 | PASS | PASS |
| A48 SDR Bridge, westbound | 1292 | 1304 | 0.34 | PASS | PASS |
| ***Usk Screenline, Westbound Total*** | **6693** | **6657** | **0.44** | **PASS** | **PASS** |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **100%** | **96%** |

## Table 8.3: PM Peak Flow Validation (PCUs)

| | Modelled Flow | Observed Flow | GEH | Flow Criteria | GEH Criteria |
|---|---|---|---|---|---|
| **Motorway Eastbound Flows** | | | | | |
| M4, J29-J28, eastbound | 5088 | 5041 | 0.66 | PASS | PASS |
| M4, J28-J27, eastbound | 4773 | 5049 | 3.94 | PASS | PASS |
| M4, J27-J26, eastbound | 4745 | 4810 | 0.94 | PASS | PASS |
| M4, J26-J25a, eastbound | 3199 | 3140 | 1.04 | PASS | PASS |
| M4, J25a-J25, eastbound | 4123 | 4027 | 1.50 | PASS | PASS |
| M4, J25-J24, eastbound | 4264 | 4181 | 1.28 | PASS | PASS |
| M4, J24-J23a, eastbound | 3533 | 3459 | 1.24 | PASS | PASS |
| **Motorway Westbound Flows** | | | | | |
| M4, J28-J29, westbound | 5196 | 5300 | 1.44 | PASS | PASS |
| M4, J27-J28, westbound | 4898 | 4875 | 0.33 | PASS | PASS |
| M4, J26-J27, westbound | 5286 | 5145 | 1.95 | PASS | PASS |
| M4, J25a-J26, westbound | 3305 | 3513 | 3.56 | PASS | PASS |
| M4, J25-J25a, westbound | 4283 | 4367 | 1.28 | PASS | PASS |
| M4, J24-J25, westbound | 4439 | 4539 | 1.51 | PASS | PASS |
| M4, J23a-J24, westbound | 3760 | 3824 | 1.04 | PASS | PASS |
| **Usk Screenline, Eastbound Flows** | | | | | |
| M4, J26-J25a, eastbound | 3199 | 3140 | 1.04 | PASS | PASS |
| Brynglas Relief Rd, eastbound to J25a | 1852 | 1710 | 3.36 | PASS | PASS |
| B4591 Newport Bridge, eastbound | 1097 | 1175 | 2.31 | PASS | PASS |
| B4237 George Street Bridge, eastbound | 745 | 778 | 1.20 | PASS | PASS |
| A48 SDR Bridge, eastbound | 1316 | 1416 | 2.70 | PASS | PASS |
| ***Usk Screenline, Eastbound Total*** | **8209** | **8219** | **0.12** | **PASS** | **PASS** |
| **Usk Screenline, Westbound Flows** | | | | | |
| M4, J25a-J26, westbound | 3305 | 3513 | 3.56 | PASS | PASS |
| Brynglas Relief Rd, westbound from J25a | 1636 | 1782 | 3.52 | PASS | PASS |
| B4591 Newport Bridge, westbound | 930 | 894 | 1.19 | PASS | PASS |
| B4237 George Street Bridge, westbound | 629 | 592 | 1.48 | PASS | PASS |
| A48 SDR Bridge, westbound | 1386 | 1355 | 0.84 | PASS | PASS |
| ***Usk Screenline, Westbound Total*** | **7886** | **8136** | **2.79** | **PASS** | **PASS** |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | **100%** | **100%** |

## 8.3 Proportion of Heavy Goods Vehicles

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.

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.

**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 | 4060 | 4056 | 300 | 280 | 7.4% | 6.9% |
| M4 J30-J29, e/b | 2876 | 2928 | 265 | 258 | 9.2% | 8.8% |
| A48(M) J29a-J29, e/b | 2043 | 2095 | 120 | 124 | 5.9% | 5.9% |
| M4 J29-J28, e/b | 5083 | 5023 | 436 | 382 | 8.6% | 7.6% |
| M4 J28-J27, e/b | 4568 | 4549 | 408 | 324 | 8.9% | 7.1% |
| M4 J27-J26, e/b | 4671 | 4661 | 422 | 331 | 9.0% | 7.1% |
| M4 J26-J25a, e/b | 3103 | 3216 | 337 | 280 | 10.9% | 8.7% |
| M4 J25-J24, e/b | 4156 | 4307 | 377 | 323 | 9.1% | 7.5% |
| M4 J24-J23a, e/b | 3324 | 3470 | 382 | 359 | 11.5% | 10.3% |
| M4 J23a-J23, e/b | 3127 | 3399 | 322 | 358 | 10.3% | 10.5% |
| M48 J23 (M4)-J2, e/b | 520 | 571 | 50 | 53 | 9.5% | 9.3% |
| M4 J23-J22, e/b | 2975 | 2828 | 311 | 306 | 10.5% | 10.8% |
| | | | | ***Average Percentage HGVs*** | **9.8%** | **8.4%** |
| M4 J30-J32, w/b | 2858 | 3050 | 366 | 329 | 12.8% | 10.8% |
| M4 J29-J30, w/b | 2704 | 2722 | 345 | 322 | 12.7% | 11.8% |
| A48(M) J29-J29a, w/b | 1922 | 1919 | 127 | 91 | 6.6% | 4.7% |
| M4 J28-J29, w/b | 4630 | 4640 | 427 | 413 | 9.2% | 8.9% |
| M4 J27-J28, w/b | 5394 | 5482 | 417 | 357 | 7.7% | 6.5% |
| M4 J26-J27, w/b | 4692 | 5011 | 443 | 365 | 9.4% | 7.3% |
| M4 J25a-J26, w/b | 2885 | 3068 | 366 | 317 | 12.7% | 10.3% |
| M4 J24-J25, w/b | 3958 | 4085 | 432 | 358 | 10.9% | 8.8% |
| M4 J23a-J24, w/b | 3074 | 3193 | 351 | 292 | 11.4% | 9.2% |
| M4 J23-J23a, w/b | 2465 | 2499 | 296 | 298 | 12.0% | 11.9% |
| M48 J2-J23 (M4), w/b | 634 | 646 | 62 | 66 | 9.7% | 10.2% |
| M4 J22-J23, w/b | 1858 | 1853 | 235 | 232 | 12.6% | 12.5% |
| | | | | ***Average Percentage HGVs*** | **10.5%** | **9.0%** |

## Table 8.5: HGV Flow Validation, Interpeak

| Link | Total Vehicles | | HGVs | | Percentage HGVs | |
|---|---|---|---|---|---|---|
| | Observed | Modelled | Observed | Modelled | Observed | Modelled |
| M4 J32-J30, e/b | 2012 | 2135 | 299 | 307 | 14.9% | 14.4% |
| M4 J30-J29, e/b | 1797 | 1825 | 276 | 283 | 15.4% | 15.5% |
| A48(M) J29a-J29, e/b | 1264 | 1248 | 135 | 138 | 10.7% | 11.0% |
| M4 J29-J28, e/b | 3270 | 3073 | 506 | 421 | 15.5% | 13.7% |
| M4 J28-J27, e/b | 3180 | 3057 | 447 | 345 | 14.1% | 11.3% |
| M4 J27-J26, e/b | 3234 | 3099 | 431 | 345 | 13.3% | 11.1% |
| M4 J26-J25a, e/b | 2268 | 2239 | 317 | 299 | 14.0% | 13.3% |
| M4 J25-J24, e/b | 2969 | 2914 | 430 | 360 | 14.5% | 12.4% |
| M4 J24-J23a, e/b | 2365 | 2503 | 388 | 397 | 16.4% | 15.9% |
| M4 J23a-J23, e/b | 2241 | 2325 | 436 | 442 | 19.5% | 19.0% |
| M48 J23 (M4)-J2, e/b | 294 | 332 | 61 | 57 | 19.2% | 17.2% |
| M4 J23-J22, e/b | 2018 | 1993 | 394 | 385 | 19.5% | 19.3% |
| | | | | ***Average Percentage HGVs*** | **15.3%** | **13.8%** |
| M4 J30-J32, w/b | 1875 | 1946 | 278 | 261 | 14.8% | 13.4% |
| M4 J29-J30, w/b | 1602 | 1654 | 265 | 260 | 16.5% | 15.7% |
| A48(M) J29-J29a, w/b | 1208 | 1222 | 147 | 144 | 12.2% | 11.8% |
| M4 J28-J29, w/b | 3088 | 2876 | 468 | 404 | 15.1% | 14.1% |
| M4 J27-J28, w/b | 2981 | 2853 | 393 | 380 | 13.2% | 13.3% |
| M4 J26-J27, w/b | 3126 | 3124 | 458 | 389 | 14.7% | 12.4% |
| M4 J25a-J26, w/b | 2152 | 2130 | 358 | 353 | 16.6% | 16.6% |
| M4 J24-J25, w/b | 2843 | 2850 | 422 | 395 | 14.8% | 13.9% |
| M4 J23a-J24, w/b | 2319 | 2497 | 354 | 400 | 15.3% | 16.0% |
| M4 J23-J23a, w/b | 2025 | 2084 | 350 | 383 | 17.3% | 18.4% |
| M48 J2-J23 (M4), w/b | 384 | 381 | 65 | 65 | 17.1% | 17.1% |
| M4 J22-J23, w/b | 1786 | 1703 | 309 | 318 | 17.3% | 18.7% |
| | | | | ***Average Percentage HGVs*** | **15.2%** | **14.9%** |

**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 | 2745 | 2704 | 228 | 227 | 8.3% | 8.4% |
| M4 J30-J29, e/b | 2399 | 2380 | 213 | 216 | 8.9% | 9.1% |
| A48(M) J29a-J29, e/b | 2094 | 2262 | 77 | 77 | 3.7% | 3.4% |
| M4 J29-J28, e/b | 4572 | 4642 | 312 | 293 | 6.8% | 6.3% |
| M4 J28-J27, e/b | 4668 | 4349 | 254 | 278 | 5.4% | 6.4% |
| M4 J27-J26, e/b | 4414 | 4330 | 266 | 272 | 6.0% | 6.3% |
| M4 J26-J25a, e/b | 2779 | 2809 | 233 | 259 | 8.4% | 9.2% |
| M4 J25-J24, e/b | 3774 | 3842 | 275 | 279 | 7.3% | 7.3% |
| M4 J24-J23a, e/b | 3033 | 3135 | 277 | 263 | 9.1% | 8.4% |
| M4 J23a-J23, e/b | 2612 | 2677 | 254 | 277 | 9.7% | 10.3% |
| M48 J23 (M4)-J2, e/b | 448 | 529 | 30 | 35 | 6.7% | 6.6% |
| M4 J23-J22, e/b | 2501 | 2147 | 260 | 242 | 10.4% | 11.3% |
| | | | | ***Average Percentage HGVs*** | **7.6%** | **7.7%** |
| M4 J30-J32, w/b | 3533 | 3440 | 182 | 187 | 5.2% | 5.4% |
| M4 J29-J30, w/b | 2772 | 2639 | 175 | 185 | 6.3% | 7.0% |
| A48(M) J29-J29a, w/b | 2080 | 2173 | 69 | 68 | 3.3% | 3.1% |
| M4 J28-J29, w/b | 4936 | 4812 | 244 | 253 | 4.9% | 5.2% |
| M4 J27-J28, w/b | 4552 | 4529 | 222 | 242 | 4.9% | 5.4% |
| M4 J26-J27, w/b | 4806 | 4909 | 237 | 247 | 4.9% | 5.0% |
| M4 J25a-J26, w/b | 3202 | 2959 | 233 | 230 | 7.3% | 7.8% |
| M4 J24-J25, w/b | 4189 | 4055 | 238 | 254 | 5.7% | 6.3% |
| M4 J23a-J24, w/b | 3486 | 3415 | 227 | 229 | 6.5% | 6.7% |
| M4 J23-J23a, w/b | 3274 | 3115 | 205 | 216 | 6.3% | 6.9% |
| M48 J2-J23 (M4), w/b | 725 | 548 | 27 | 29 | 3.7% | 5.4% |
| M4 J22-J23, w/b | 3180 | 2567 | 218 | 187 | 6.9% | 7.3% |
| | | | | ***Average Percentage HGVs*** | **5.5%** | **6.0%** |

## 8.4 Journey Time Validation

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 1 minute if higher) on at least 85% of routes surveyed.

Journey time surveys were carried out on 11 key routes through the study area, as shown in Figure 3.4. The journey time comparisons for each of the surveyed routes in the morning and evening peak periods are shown in Tables 8.7 to 8.9. Graphs illustrating the cumulative modelled and observed journey times for the surveyed routes are given in Appendix B.

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 satisfactory representation of the network operation in the study area.

## Table 8.7: AM Peak Journey Time Validation

| No | Route Description | | Observed Time (mins:secs) Min | Avge | Max | Modelled Time (mins:secs) | % diff from avge | DMRB Criteria |
|---|---|---|---|---|---|---|---|---|
| 1 | M4, J23a to J30 | east | 14:55 | 15:33 | 16:36 | 15:56 | +2.5% | PASS |
| | | west | 14:46 | 15:32 | 16:38 | 16:33 | +6.5% | PASS |
| 2 | A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28) | anti c/wise | 12:06 | 13:24 | 14:25 | 13:28 | +0.5% | PASS |
| | | c/wise | 12:12 | 13:45 | 16:02 | 13:55 | +1.2% | PASS |
| 3 | A467/B4591 Rogerstone to B4237/Kingsway | east | 09:17 | 12:38 | 18:56 | 13:36 | +7.6% | PASS |
| | | west | 08:16 | 10:18 | 14:45 | 11:00 | +6.8% | PASS |
| 4 | A48 SDR, Pont Ebbw rbt to M4 J24 | east | 10:03 | 10:47 | 12:04 | 10:58 | +1.7% | PASS |
| | | west | 10:31 | 12:25 | 13:17 | 11:47 | -5.1% | PASS |
| 5 | B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge) | east | 11:30 | 13:32 | 16:08 | 13:55 | +2.8% | PASS |
| | | west | 11:11 | 13:24 | 16:21 | 13:47 | +2.9% | PASS |
| 6 | A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd | south | 12:34 | 14:49 | 17:36 | 15:24 | +3.9% | PASS |
| | | north | 14:34 | 16:09 | 19:41 | 16:22 | +1.3% | PASS |
| 7 | A4042 Usk Way, Cwmbran Drive to A48 SDR | south | 07:02 | 08:06 | 09:10 | 08:41 | +7.2% | PASS |
| | | north | 06:41 | 07:29 | 08:19 | 08:01 | +7.1% | PASS |
| 8 | B4237, M4 J24 to Kingsway | east | 07:57 | 09:00 | 10:58 | 9:07 | +1.3% | PASS |
| | | west | 10:06 | 13:26 | 22:51 | 12:53 | -4.1% | PASS |
| 9 | A48, M4 J24 to B4245 Parkwall rbt | east | 12:37 | 13:04 | 13:29 | 12:25 | -5.0% | PASS |
| | | west | 12:54 | 13:41 | 15:14 | 12:23 | -9.5% | PASS |
| 10 | B4245 Magor rbt to M48 J2 | east | 17:22 | 18:19 | 19:55 | 18:37 | +1.6% | PASS |
| | | west | 17:07 | 18:53 | 22:19 | 18:51 | -0.2% | PASS |
| 11 | M4 / M48 Severn crossings loop, between J23a and M5 interchange | anti c/wise | 30:43 | 33:36 | 38:34 | 31.45 | -5.5% | PASS |
| | | c/wise | 29:17 | 31:51 | 36:54 | 31:44 | -0.4% | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | | | | | **100%** |

## Table 8.8: Interpeak Journey Time Validation

| No | Route Description | | Observed Time (mins:secs) Min | Observed Time (mins:secs) Avge | Observed Time (mins:secs) Max | Modelled Time (mins:secs) | % diff from avge | DMRB Criteria |
|---|---|---|---|---|---|---|---|---|
| 1 | M4, J23a to J30 | east | 14:15 | 14:48 | 16:12 | 15:02 | +1.6% | PASS |
| | | west | 14:35 | 14:52 | 15:13 | 15:19 | +3.0% | PASS |
| 2 | A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28) | anti c/wise | 11:26 | 11:58 | 12:31 | 12:23 | +3.5% | PASS |
| | | c/wise | 12:26 | 12:37 | 13:02 | 12:59 | +2.9% | PASS |
| 3 | A467/B4591 Rogerstone to B4237/Kingsway | east | 10:41 | 12:19 | 15:10 | 11:21 | -7.8% | PASS |
| | | west | 08:29 | 09:17 | 10:27 | 09:08 | -1.6% | PASS |
| 4 | A48 SDR, Pont Ebbw rbt to M4 J24 | east | 10:32 | 11:15 | 12:15 | 11:08 | -1.0% | PASS |
| | | west | 09:27 | 11:07 | 12:41 | 10:53 | -2.1% | PASS |
| 5 | B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge) | east | 11:28 | 12:28 | 13:07 | 12:19 | -1.2% | PASS |
| | | west | 11:55 | 12:56 | 13:30 | 14:14 | +10.0% | PASS |
| 6 | A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd | south | 13:15 | 14:51 | 17:25 | 13:47 | -7.2% | PASS |
| | | north | 13:48 | 15:17 | 16:14 | 14:33 | -4.8% | PASS |
| 7 | A4042 Usk Way, Cwmbran Drive to A48 SDR | south | 08:09 | 08:58 | 10:00 | 08:36 | -4.1% | PASS |
| | | north | 07:16 | 08:10 | 09:10 | 07:48 | -4.5% | PASS |
| 8 | B4237, M4 J24 to Kingsway | east | 09:11 | 11:04 | 13:41 | 10:13 | -7.7% | PASS |
| | | west | 11:56 | 13:11 | 15:04 | 12:41 | -3.8% | PASS |
| 9 | A48, M4 J24 to B4245 Parkwall rbt | east | 12:51 | 13:12 | 13:42 | 12:25 | -5.9% | PASS |
| | | west | 13:03 | 13:16 | 14:00 | 12:13 | -7.9% | PASS |
| 10 | B4245 Magor rbt to M48 J2 | east | 17:38 | 18:07 | 19:24 | 18:25 | +1.7% | PASS |
| | | west | 17:05 | 17:38 | 18:14 | 18:38 | +5.7% | PASS |
| 11 | M4 / M48 Severn crossings loop, between J23a and M5 interchange | anti c/wise | 26:14 | 30:50 | 34:15 | 30:50 | 0.0% | PASS |
| | | c/wise | 29:02 | 30:03 | 33:10 | 31:20 | +4.3% | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | | | | | **100%** |

## Table 8.9: PM Peak Journey Time Validation

| No | Route Description | | Observed Time (mins:secs) Min | Avge | Max | Modelled Time (mins:secs) | % diff from avge | DMRB Criteria |
|---|---|---|---|---|---|---|---|---|
| 1 | M4, J23a to J30 | east | 14:09 | 14:36 | 15:03 | 15:31 | +6.3% | PASS |
| | | west | 14:59 | 16:03 | 17:14 | 16:09 | +0.6% | PASS |
| 2 | A48/A4232 to A48 Cypress Drive rbt (via A48(M) and M4 J28) | anti c/wise | 13:01 | 14:14 | 15:58 | 14:22 | +0.9% | PASS |
| | | c/wise | 12:38 | 14:54 | 16:45 | 14:29 | -2.8% | PASS |
| 3 | A467/B4591 Rogerstone to B4237/Kingsway | east | 09:49 | 11:31 | 12:03 | 11:17 | -2.0% | PASS |
| | | west | 08:39 | 13:30 | 17:33 | 13:44 | +1.7% | PASS |
| 4 | A48 SDR, Pont Ebbw rbt to M4 J24 | east | 11:18 | 13:18 | 18:24 | 12:03 | -9.4% | PASS |
| | | west | 10:37 | 11:22 | 12:03 | 11:32 | +1.5% | PASS |
| 5 | B4591 Chartist Drive, Rogerstone to M4 J25 (via Newport Bridge) | east | 10:59 | 13:24 | 17:16 | 12:41 | -5.3% | PASS |
| | | west | 11:45 | 13:54 | 19:13 | 14:20 | +3.1% | PASS |
| 6 | A4051 Malpas Rd/Cwmbran Drive to A48 SDR / Corporation Rd | south | 13:24 | 15:12 | 17:29 | 15:36 | +2.6% | PASS |
| | | north | 13:48 | 17:31 | 20:35 | 17:07 | -2.3% | PASS |
| 7 | A4042 Usk Way, Cwmbran Drive to A48 SDR | south | 08:17 | 09:36 | 11:41 | 08:48 | -8.3% | PASS |
| | | north | 09:11 | 10:41 | 14:39 | 10:08 | -5.1% | PASS |
| 8 | B4237, M4 J24 to Kingsway | east | 09:39 | 12:20 | 17:42 | 11:55 | +3.9% | PASS |
| | | west | 11:08 | 14:28 | 16:42 | 13:53 | -4.0% | PASS |
| 9 | A48, M4 J24 to B4245 Parkwall rbt | east | 12:00 | 12:41 | 13:25 | 12:24 | -2.2% | PASS |
| | | west | 12:06 | 13:00 | 13:36 | 12:12 | -6.1% | PASS |
| 10 | B4245 Magor rbt to M48 J2 | east | 16:42 | 19:24 | 21:42 | 18:31 | -4.5% | PASS |
| | | west | 16:07 | 18:19 | 20:31 | 19:01 | +3.8% | PASS |
| 11 | M4 / M48 Severn crossings loop, between J23a and M5 interchange | anti c/wise | 28:31 | 30:04 | 33:16 | 31:24 | +4.4% | PASS |
| | | c/wise | 29:06 | 30:08 | 32:21 | 31:25 | +4.3% | PASS |
| **TOTAL ACCEPTABILITY CRITERIA** | | | | | | | | **100%** |

# 9 Variable Demand Model Calibration

## 9.1 Introduction

Current Transport Analysis Guidance indicates that traffic forecasts should be produced using variable demand modelling as reported in section 9.2 below. 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. WebTAG Unit M2[15] states that checks should be carried out for each user class and for each time period with respect to changes in car fuel cost and car journey time.

The variable demand modelling is undertaken using 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.

## 9.2 The Need for Variable Demand Modelling

WebTAG 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.

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.

Assessing these criteria in the context of the M4 corridor around Newport 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.

## 9.3 Form of the Demand Model and Matrices

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

The variable demand model for the M4 traffic model uses trip demand matrices in Origin-Destination (O-D) format rather than Production-Attraction (P-A) format. This is because at the time that the base matrices were originally developed from

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

the 2005 roadside interview surveys, the DIADEM software was only able to process matrices in O-D format.

## 9.4 Responses in Variable Demand Modelling

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.

In the case of the M4 model, the trip generation / frequency and redistribution responses have been included. In the absence of a mode choice model, the frequency response has also been used as a proxy for mode transfer.

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.

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.

In the case of the M4 study, it is unlikely that future year scenarios will introduce a differential in travel cost at different times of day which would be strong enough to lead to a significant shift in trips from peak to interpeak. Whilst congestion levels within the peak are forecast to increase 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.

In DIADEM, each demand response is controlled by the spread parameter $\lambda$ and, where there is more than one response, the scaling parameter $\theta$. 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:

- Commuter trips are doubly constrained in all time periods;
- Employer's Business and Other trip purposes are origin-constrained in the AM peak and Interpeak, and destination-constrained in the PM peak.

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 9.6 of this report.

## 9.5 Convergence

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.

The objective of this process is to achieve well converged models with realistic demand responses, thereby improving the accuracy of the scheme benefit calculations. WebTAG 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.

Table 9.1 shows the gap convergence measure achieved by the M4 base year model. The results indicate that the demand/supply gap for all the time periods is around 0.1% or less and that an acceptable level of convergence has therefore been achieved.

**Table 9.1: Realism Test Model Convergence**

| Time Period | Gap Convergence |
|---|---|
| AM Peak | 0.11% |
| Interpeak | 0.06% |
| PM Peak | 0.08% |

## 9.6 Realism Testing

### 9.6.1 Fuel Cost Elasticity

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.

For the M4 base year model the elasticity of vehicle kilometres with respect to fuel cost was calculated for all three modelled time periods, based on a 10% increase in fuel price as recommended in WebTAG Unit M2.

The formulation used to calculate the fuel cost elasticity is:

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

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**.

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 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. Long distance journeys which both start and end a long distance away from the M4 corridor around Newport were treated as fixed demand.

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 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 C.

Cost damping parameters are defined such that trips which are longer than 30km start to experience some form of reduction to their generalised costs which leads to a weakened demand response. The effect of cost damping increases with increasing trip length, so that long trips become less responsive to changes in travel costs resulting from the M4 scheme around Newport compared to short trips.

The results of the fuel cost realism tests are summarised in Table 9.2, along with the final calibrated spread parameters λ and the scaling parameters θ. These parameters will be carried forward to the variable demand forecast models.

**Table 9.2: Realism Test Results – Fuel Cost Elasticity**

| Time Period | User Class | Control Parameters | | Network-based Elasticity | | | Matrix-based Elasticity | | |
|---|---|---|---|---|---|---|---|---|---|
| | | λ | θ | User Class | Time Period | Annual Average | User Class | Time Period | Annual Average |
| AM Peak | Business | -0.074 | 0.05 | -0.09 | -0.24 | -0.27 | -0.12 | -0.28 | -0.39 |
| | Other | -0.083 | 0.05 | -0.47 | | | -0.70 | | |
| | Commute | -0.065 | 0.05 | -0.22 | | | -0.20 | | |
| Interpeak | Business | -0.074 | 0.05 | -0.11 | -0.28 | | -0.17 | -0.44 | |
| | Other | -0.083 | 0.05 | -0.41 | | | -0.69 | | |
| | Commute | -0.065 | 0.05 | -0.19 | | | -0.17 | | |
| PM Peak | Business | -0.074 | 0.05 | -0.10 | -0.23 | | -0.15 | -0.31 | |
| | Other | -0.083 | 0.05 | -0.37 | | | -0.59 | | |
| | Commute | -0.065 | 0.05 | -0.19 | | | -0.18 | | |

The arc elasticities calculated are based on the vehicle kilometres from the SATURN simulation and buffer networks, excluding 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 from peak periods to daily flows, derived from automatic count data.

As the frequency response is known to be relatively small in relation to the distribution response, θ was given a low value for each user class. 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 frequency response is still lowest for employer's business trips and highest for 'other' trips due to the relative magnitude of the λ parameters for each trip purpose.

With the parameters selected, the reduction in trips for a 10% increase in fuel costs was less than 0.7% in all cases. This is small in comparison to the reduction in vehicle kilometres resulting from the redistribution of trips. The very low reduction in trips is considered realistic in terms of the expected level of trip suppression and also the limited potential for transfer to public transport to impact on highway demand in the study area.

The results show an overall annual fuel cost elasticity of -0.27 for the network-based analysis, and that the employer's 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 WebTAG 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 employer's 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.

The overall annual fuel cost elasticity of -0.39 from the matrix-based analysis shows a scale of response slightly outside the target range suggested in WebTAG. Justification for this can be found in the coarseness of external zones and the high level at which highway links are represented in those areas.

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 will result in appropriate demand responses to changes in travel costs in the forecast traffic model runs.

### 9.6.2 Journey Time Elasticity

WebTAG lists a requirement for 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.

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.

Rather than being based on the change in vehicle kilometres the journey time elasticity is defined as a change in 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**.

Table 9.3 shows the journey time elasticity, as calculated using the above methodology. The results indicate that the calculated average annual journey time elasticity is -0.1 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 -0.1 is so large that the more detailed method would be very unlikely to result in a different conclusion.

**Table 9.3: Realism Test Results – Journey Time Elasticity**

| Time Period | User Class | User Class Arc Elasticity | Time Period Arc Elasticity | Daily Arc Elasticity |
|---|---|---|---|---|
| AM Peak | Employer's Business<br>Other<br>Commuter | -0.11<br>-0.06<br>-0.10 | -0.09 | -0.10 |
| Interpeak | Employer's Business<br>Other<br>Commuter | -0.11<br>-0.09<br>-0.10 | -0.10 | |
| PM Peak | Employer's Business<br>Other<br>Commuter | -0.09<br>-0.14<br>-0.12 | -0.12 | |

## 9.7 Summary

Realism tests have been carried out on the base model to ensure that the 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 WebTAG guidance and will therefore provide a robust basis for variable demand modelling in future year scenarios.

# 10 Conclusions

This report describes the present year validation of the base year traffic model for the M4 Corridor, which has been revised to a base year of 2012. The following time periods have been modelled:

- AM peak hour – 08:00 to 09:00;
- Interpeak hour – 13:00 to 14:00; and
- PM peak hour – 17:00 to 18:00.

An extensive data collection exercise was undertaken to inform the model update. The main basis of the trip matrices remains the Roadside Interview survey data that was collected during Autumn 2005, but these have been augmented by a significant volume of new traffic count data in the study area to allow the trip matrices to be updated to a 2012 base.

The demand has been split into five user classes, which are compatible with the trip purpose/vehicle type groups in the Department for Transport's National Trip End Model, for use in traffic forecasting.

The 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.

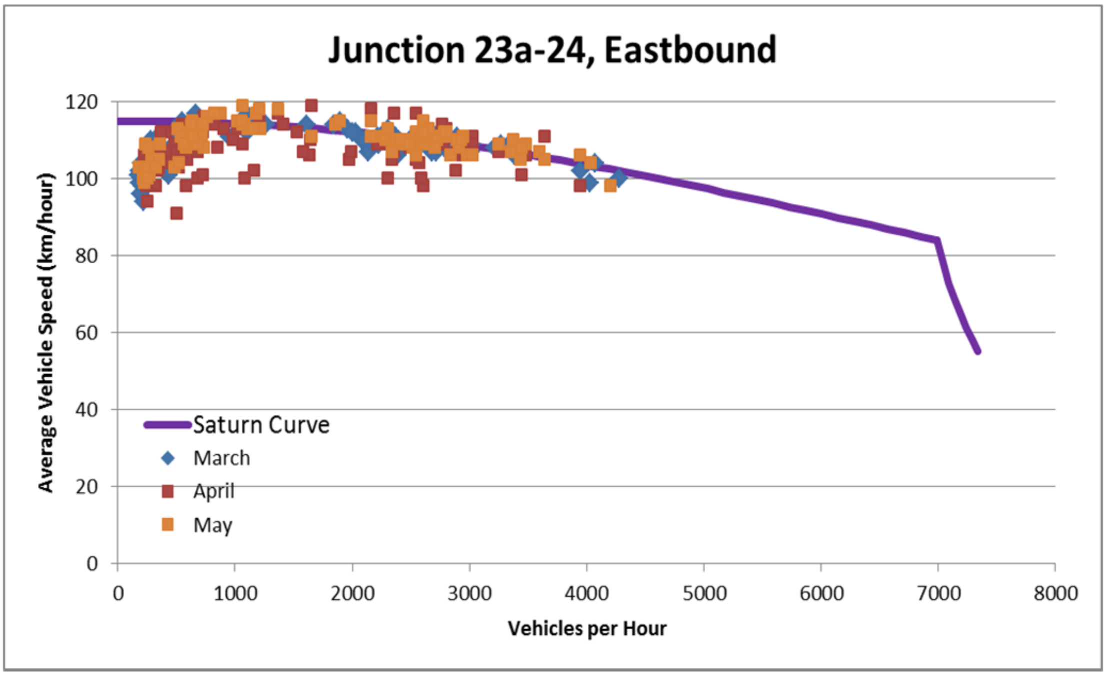
Variable demand modelling will be required in preparing the M4 model traffic forecasts. The base model therefore needed to be tested in order to ensure that it responds realistically to given changes in travel costs. This realism testing has proved satisfactory in respect of changes in fuel costs and journey times in accordance with WebTAG guidance.

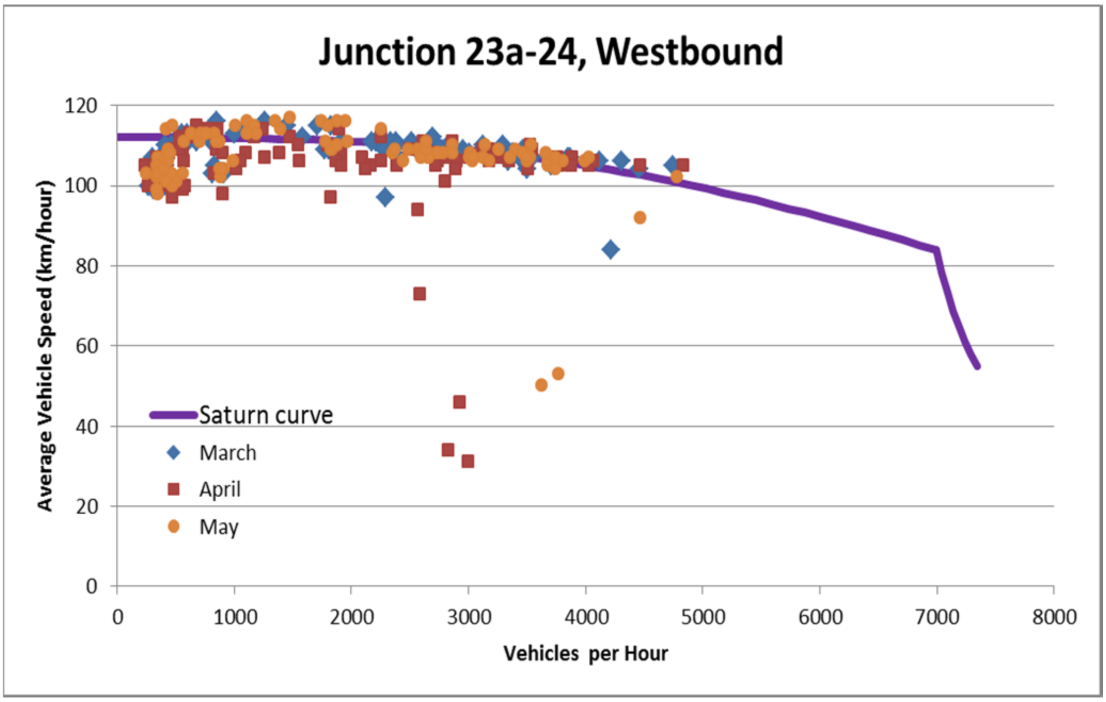
The updated M4 traffic model is thus deemed to be suitable to prepare future year traffic forecasts the M4 study area.

# Appendix A

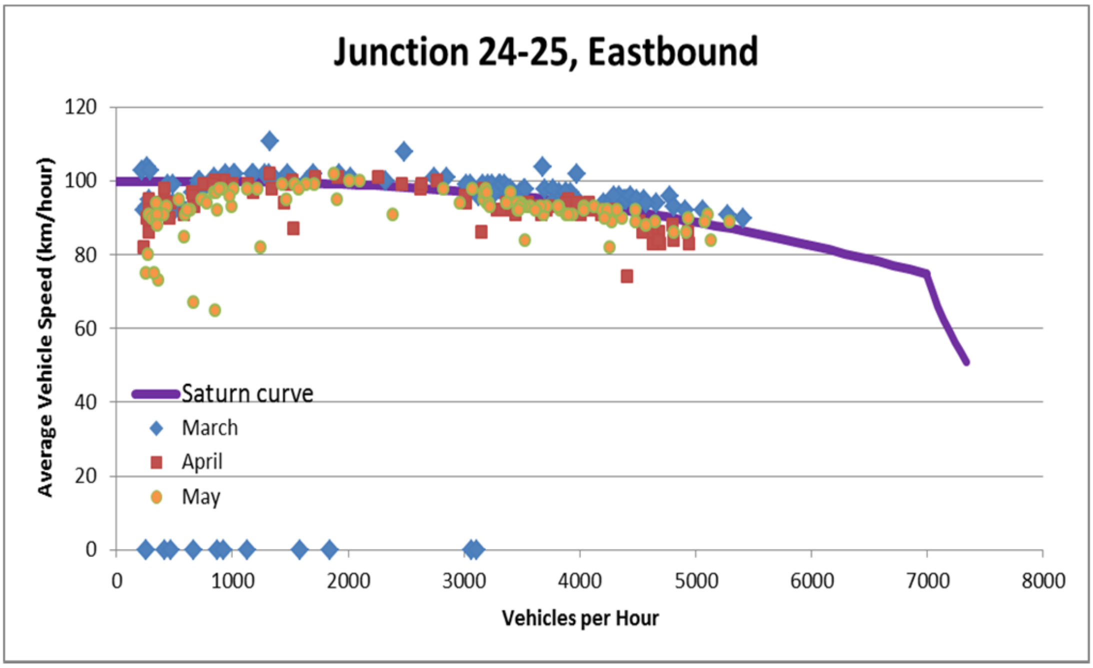
## M4 Speed-Flow Curves from MIDAS Data

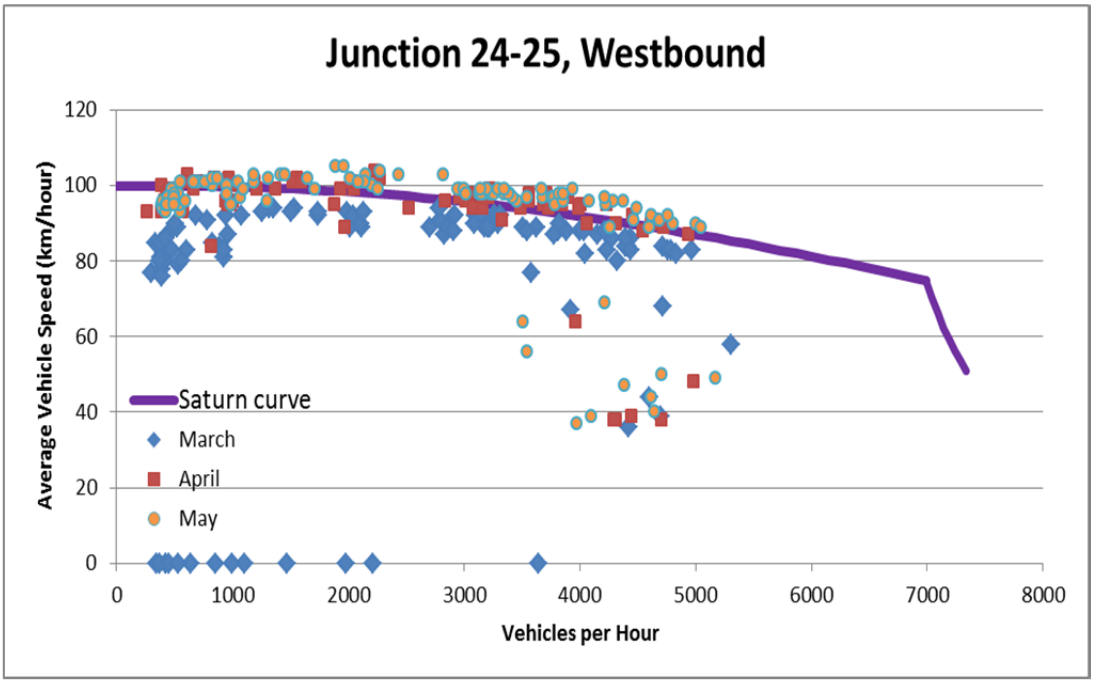
# A1 Junction 23a to Junction 24



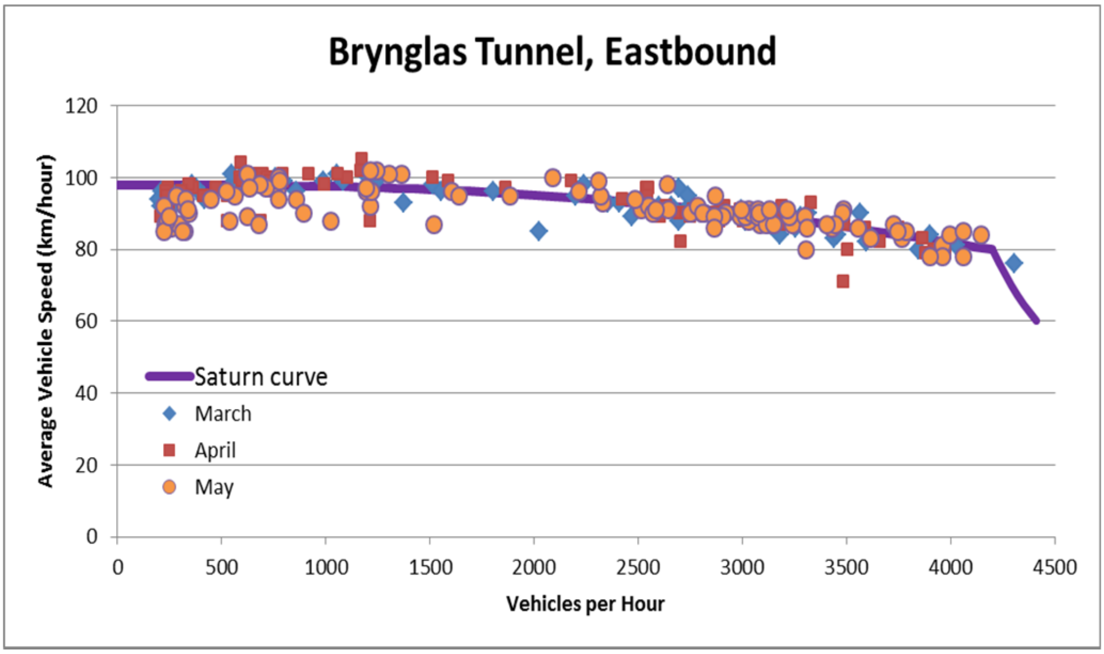



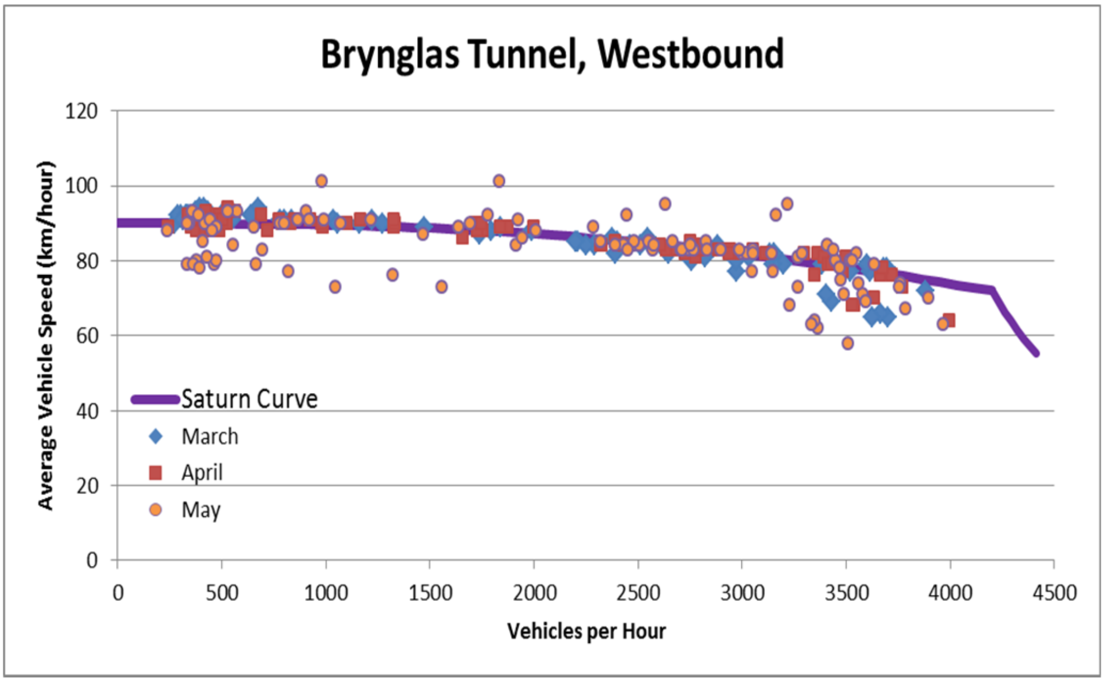
# A2 Junction 24 to Junction 25



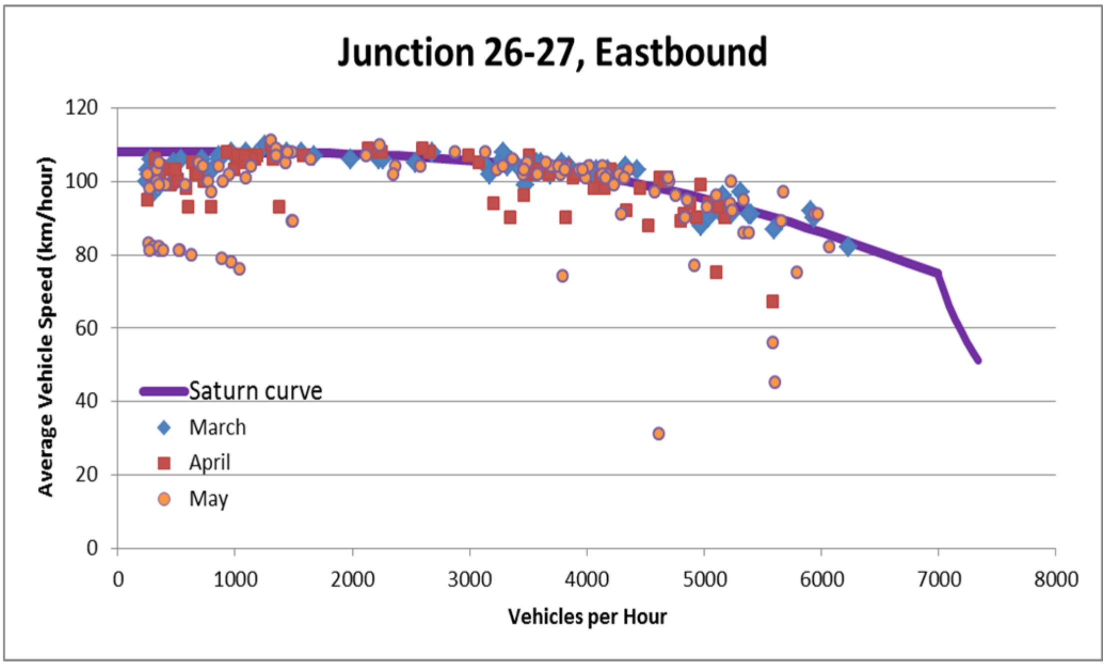



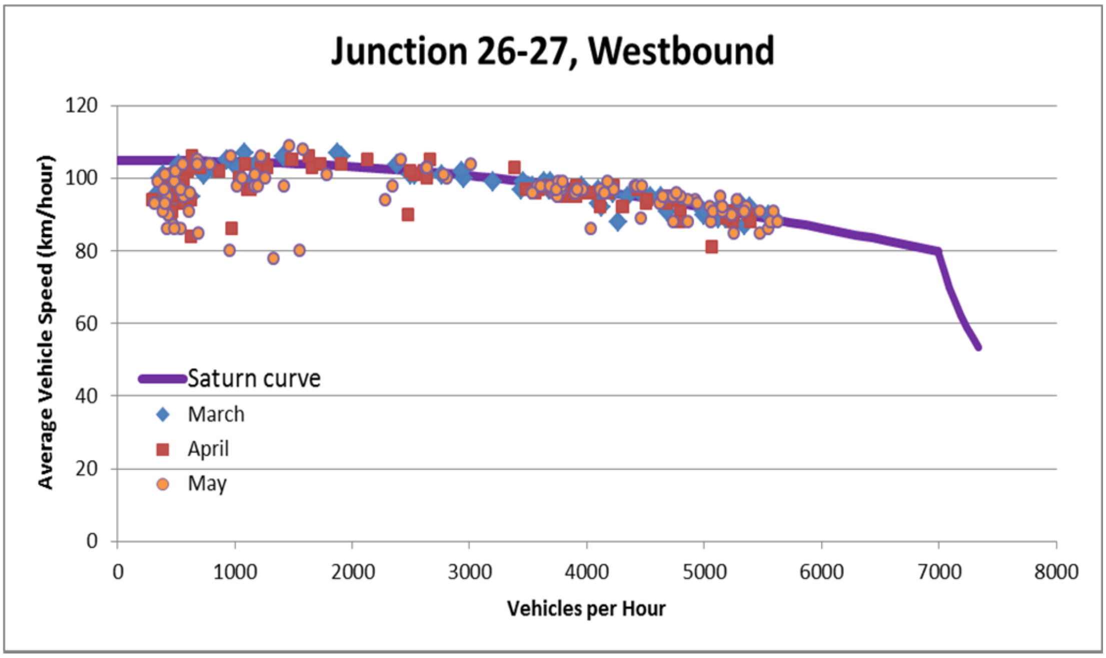
# A3 Junction 25 to Junction 26



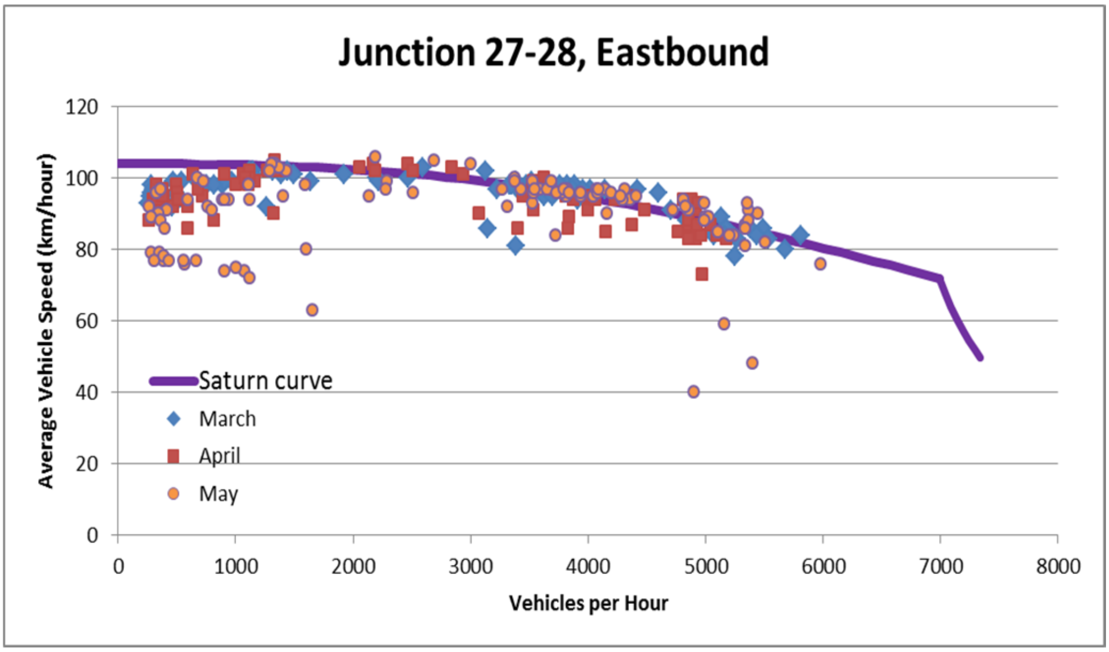



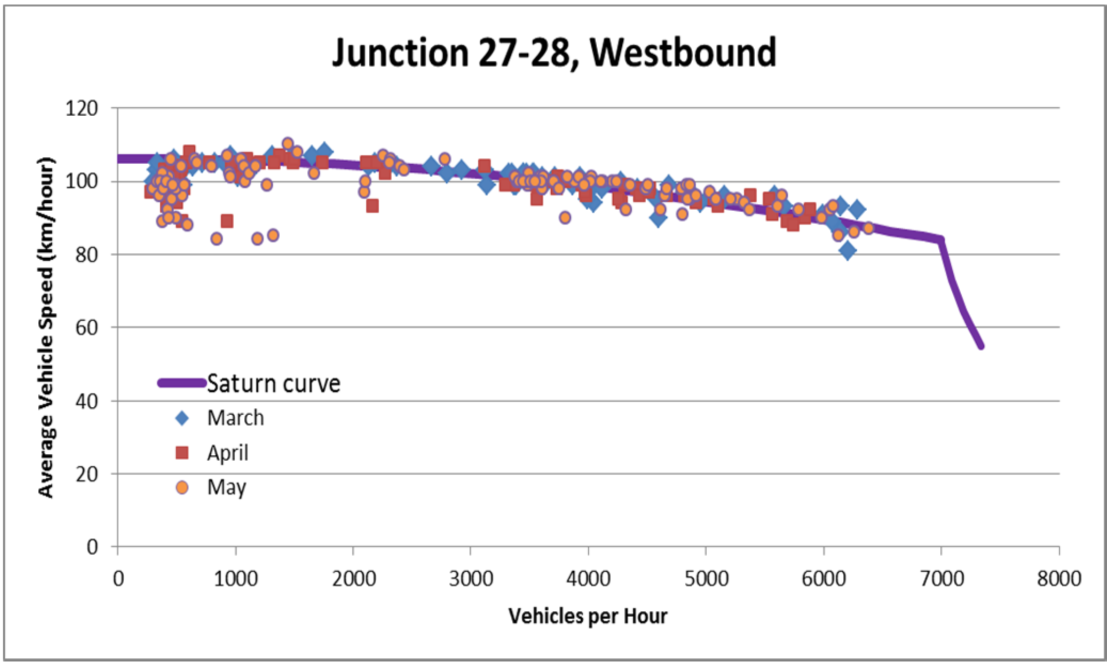
# A4 Junction 26 to Junction 27



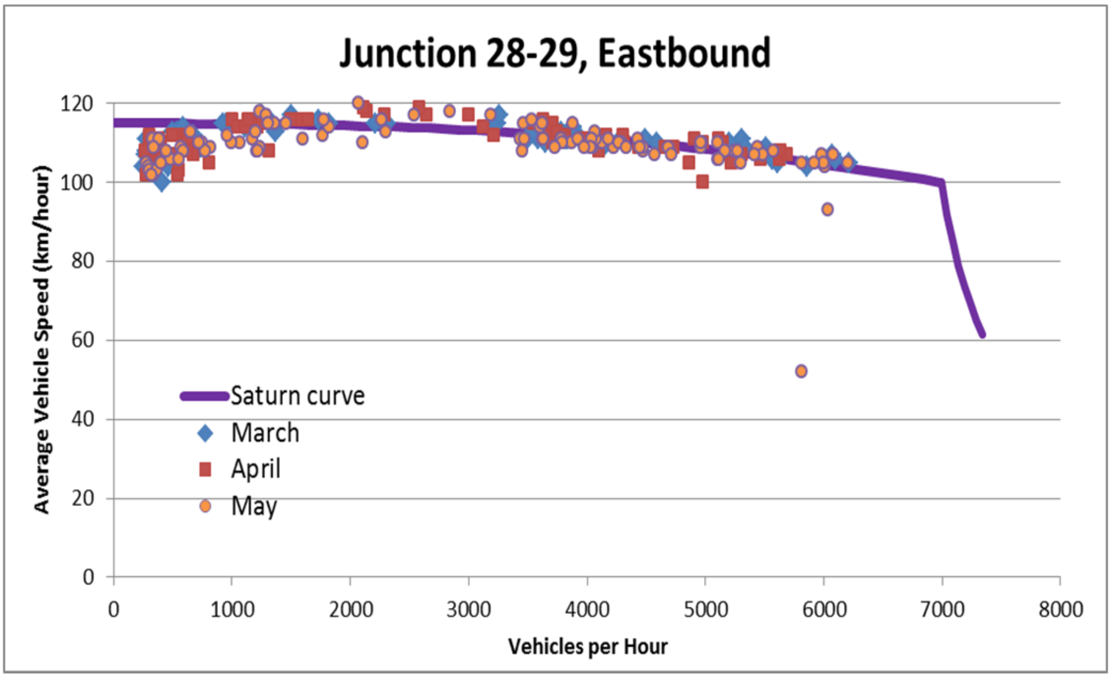



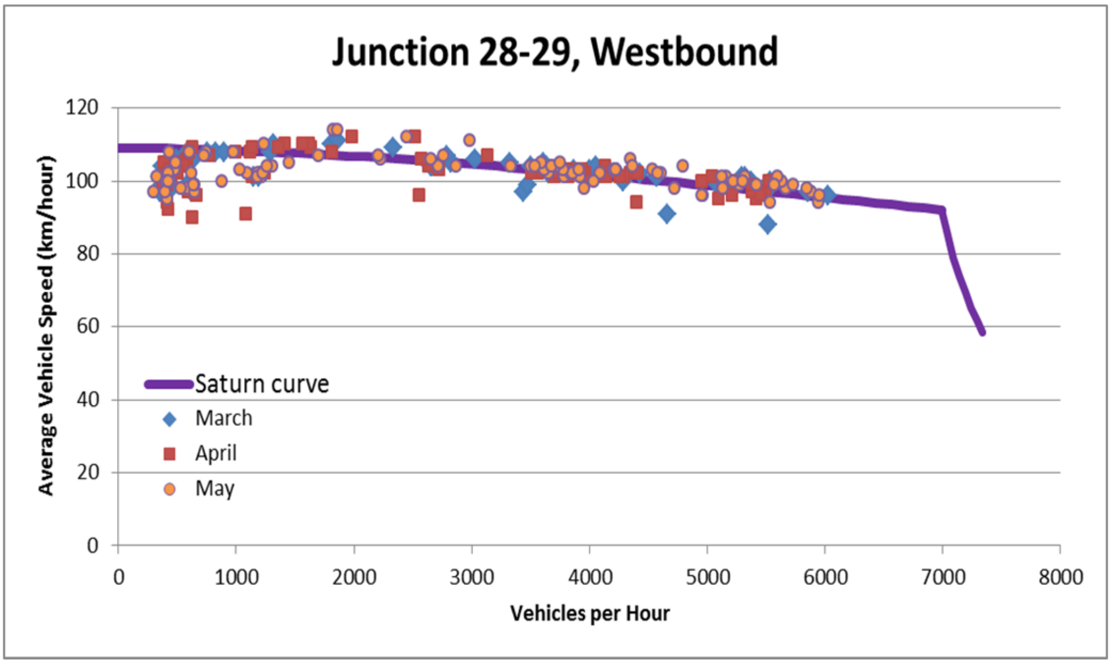
# A5 Junction 27 to Junction 28



# A6 Junction 28 to Junction 29



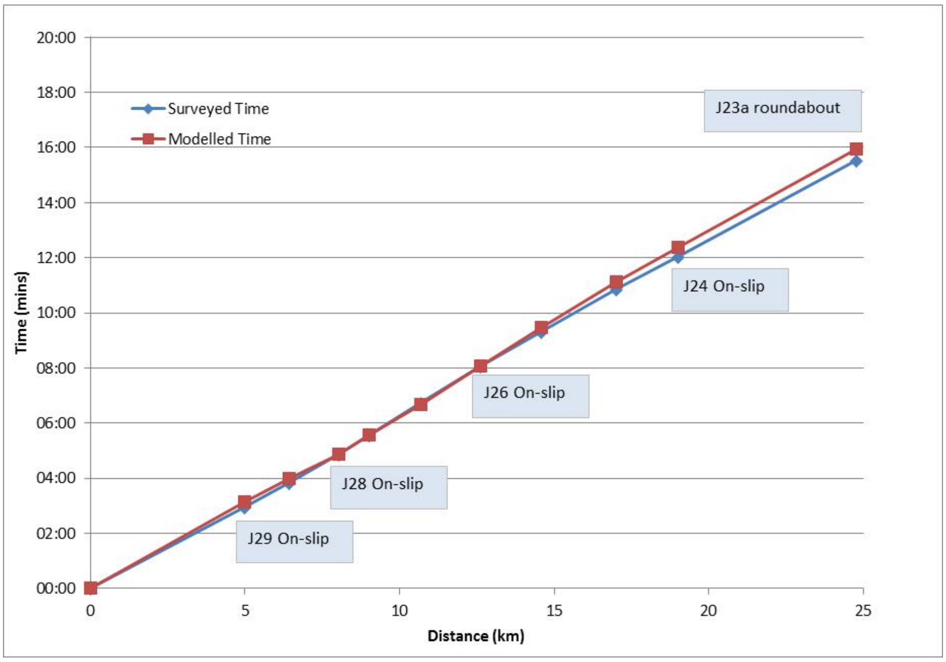



# Appendix B

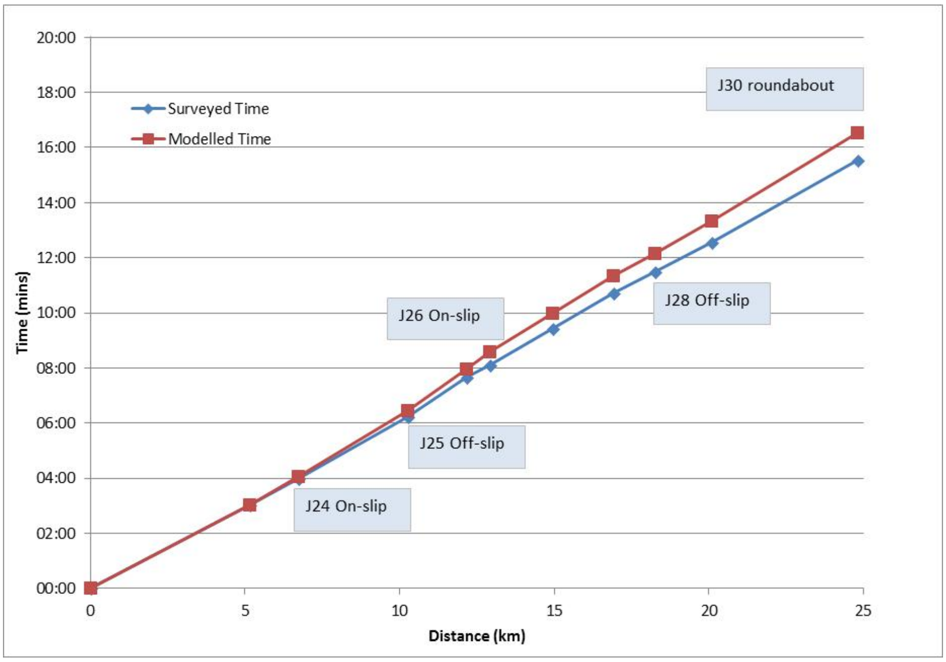
Journey Time Validation Graphs

# B1 Route 1: M4 J23 (Magor) to J30 (Cardiff Gate)

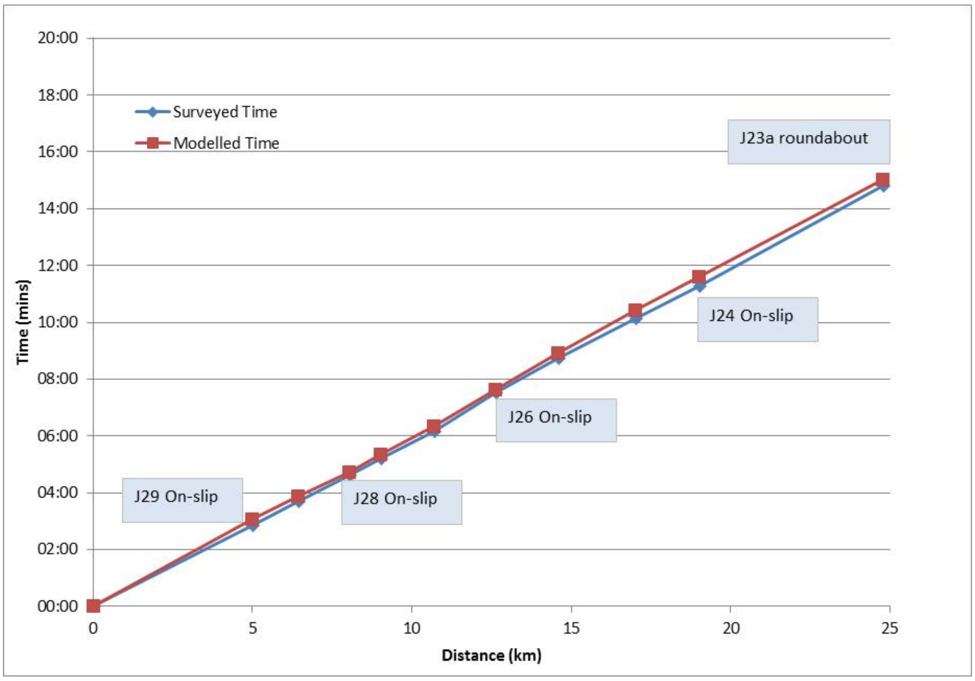
## B1.1 AM Peak – Eastbound



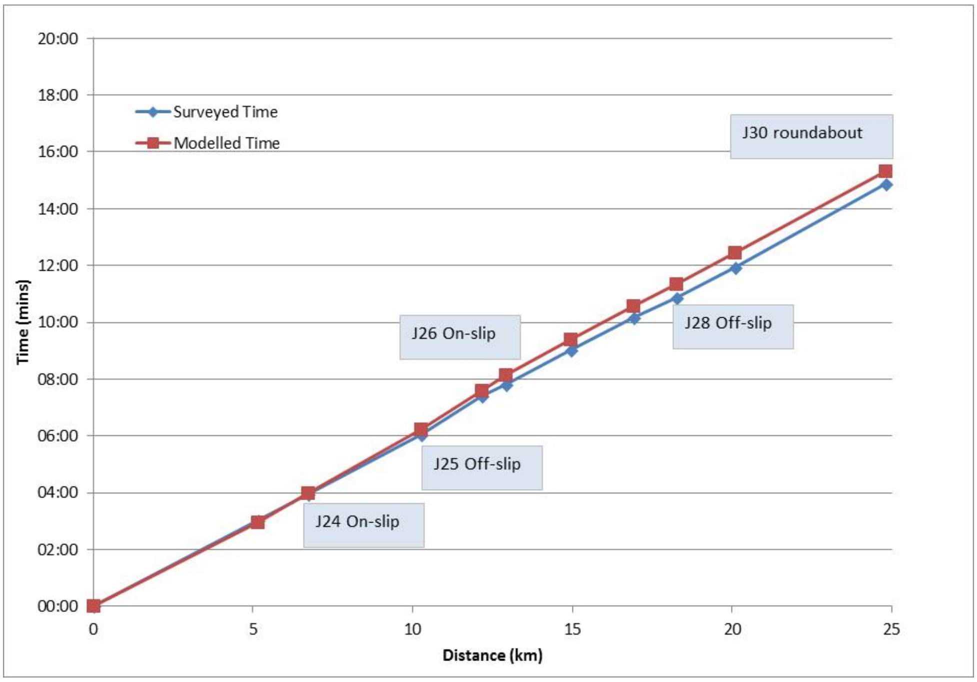

## B1.2 AM Peak – Westbound



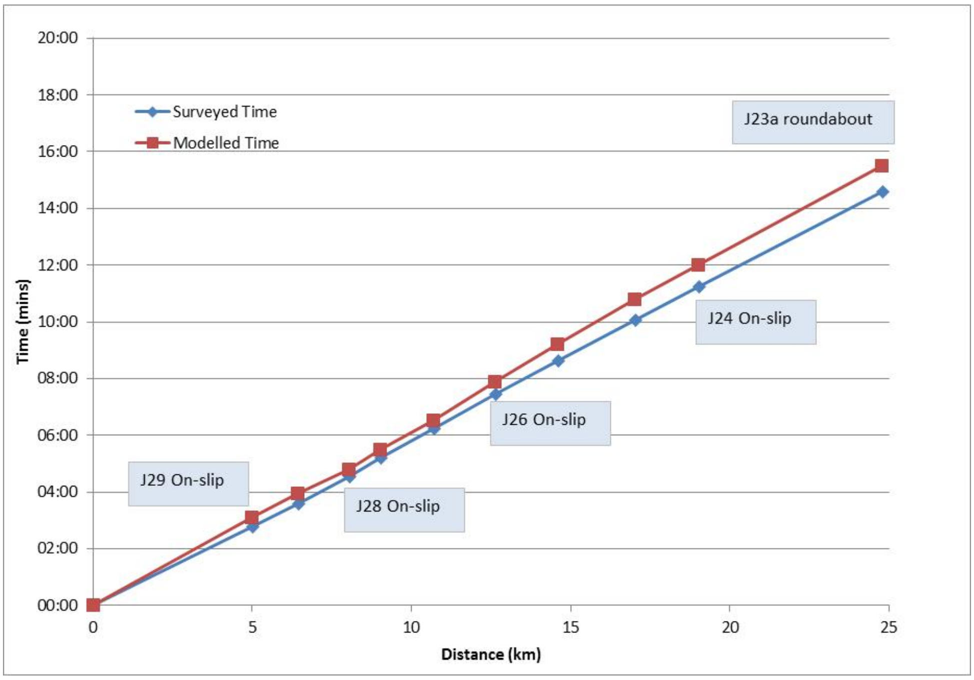
## B1.3 Inter Peak – Eastbound



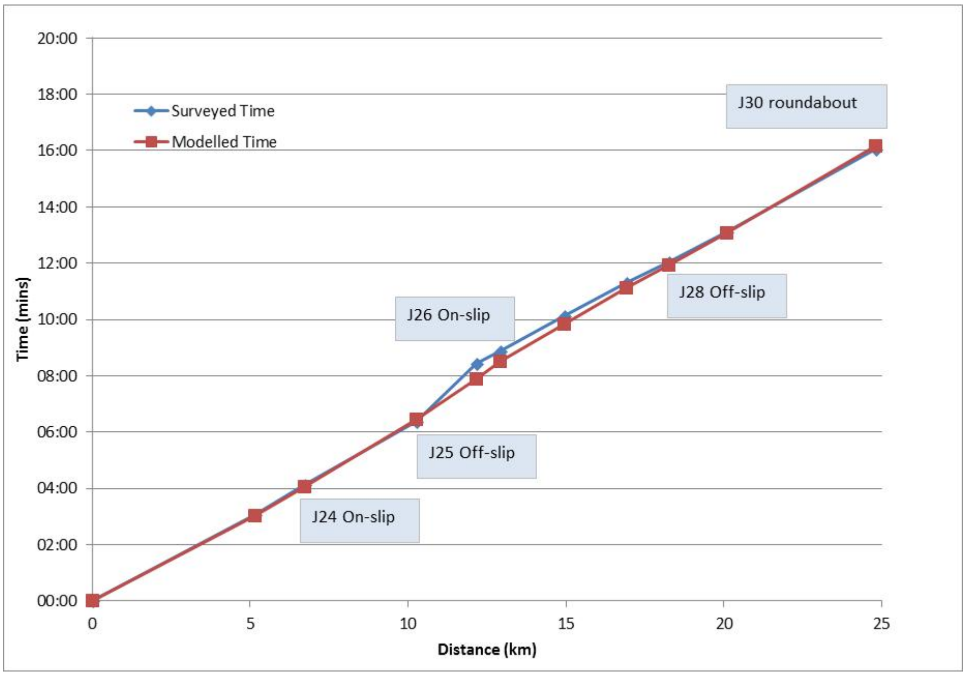

## B1.4 Inter Peak – Westbound



## B1.5 PM Peak – Eastbound

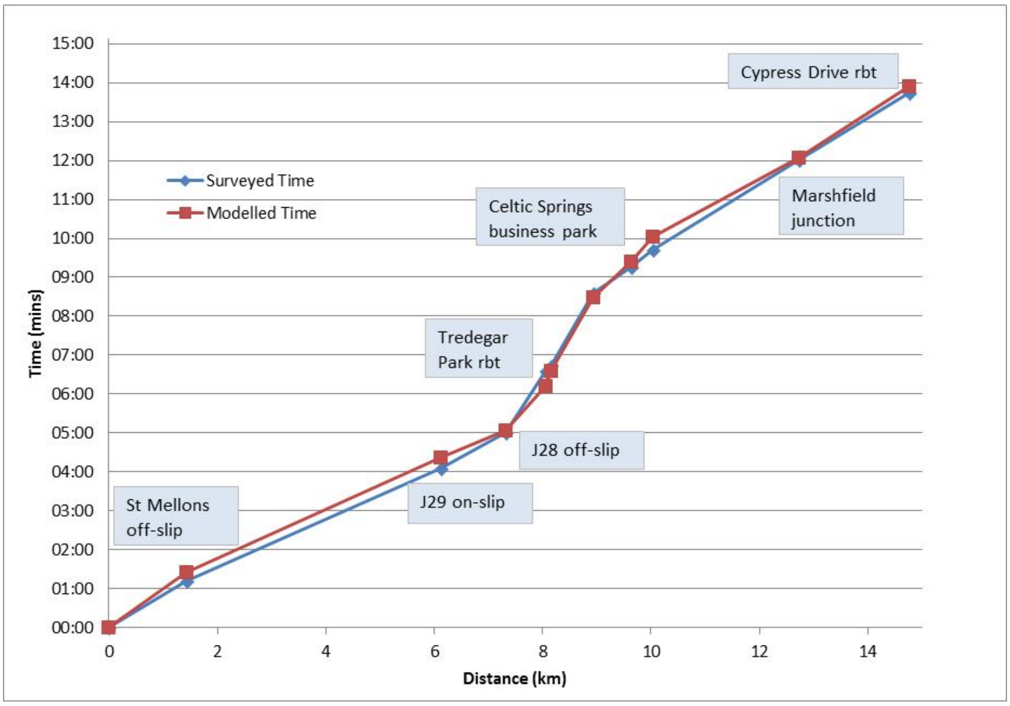



## B1.6 PM Peak – Westbound

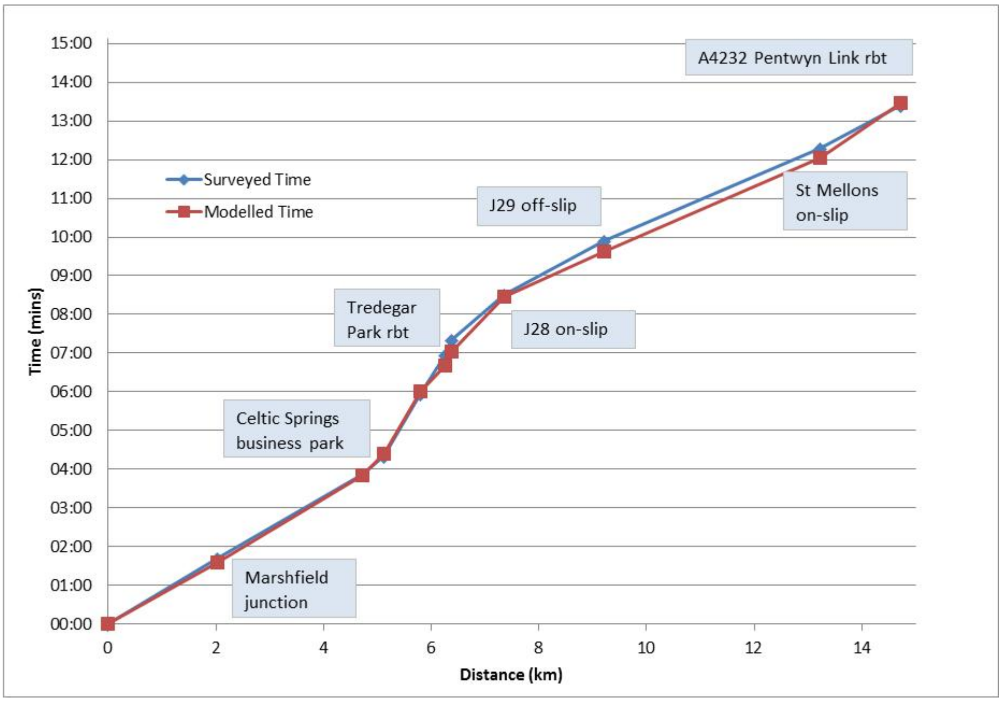


# B2 Route 2: A48 Pentwyn Link to Cypress Drive (via A48(M) and Tredegar Park

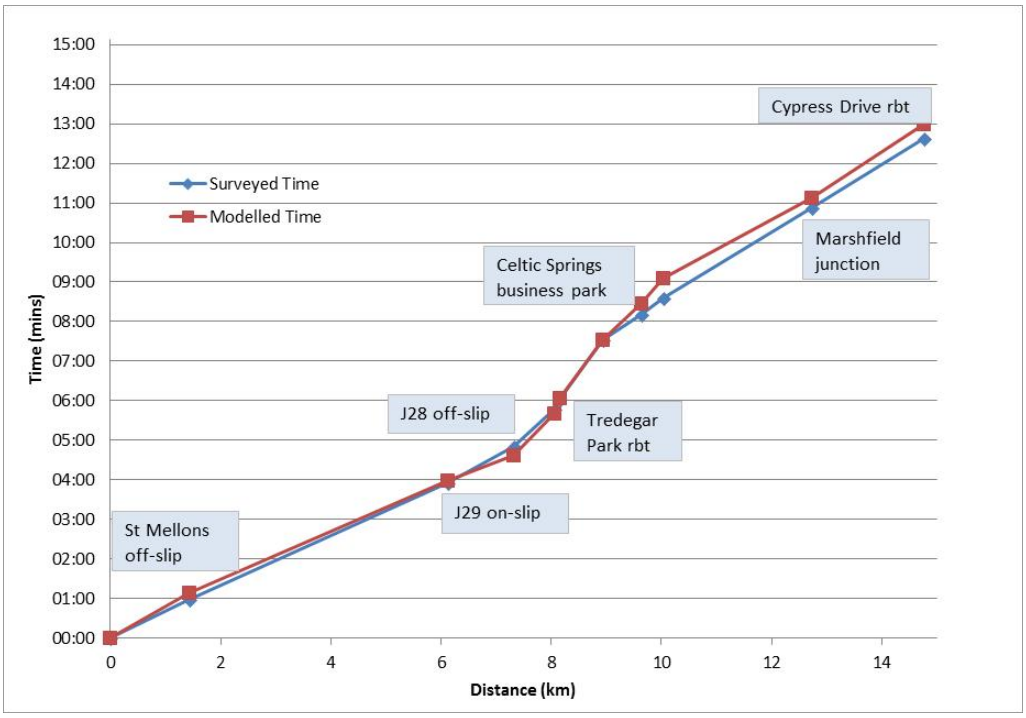
## B2.1 AM Peak – Clockwise



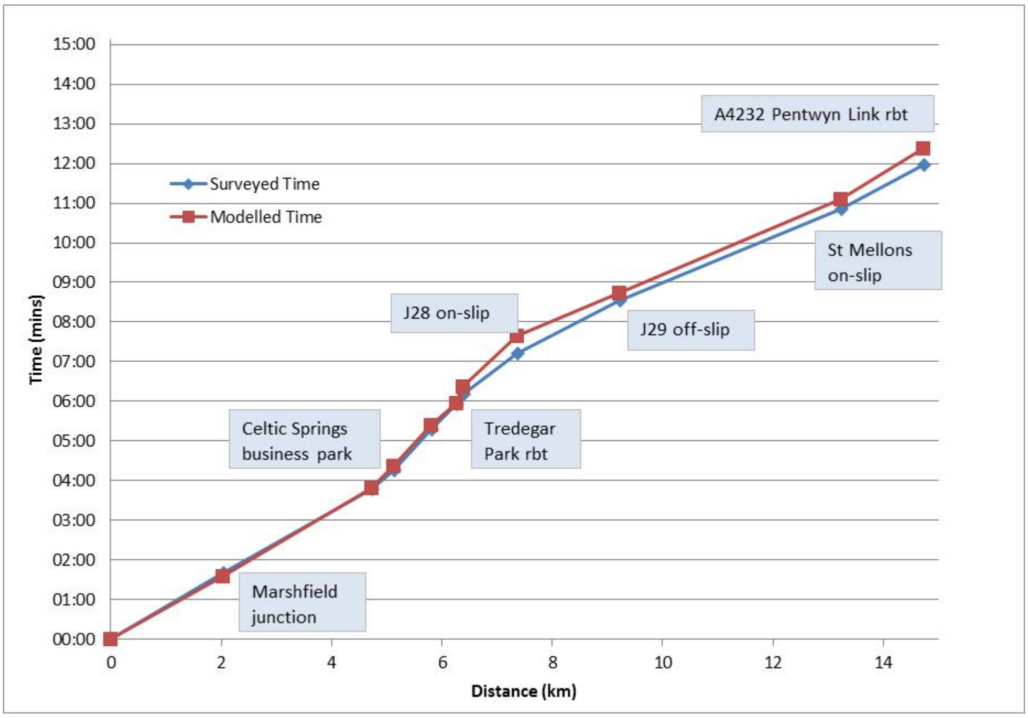

## B2.2 AM Peak – Anticlockwise



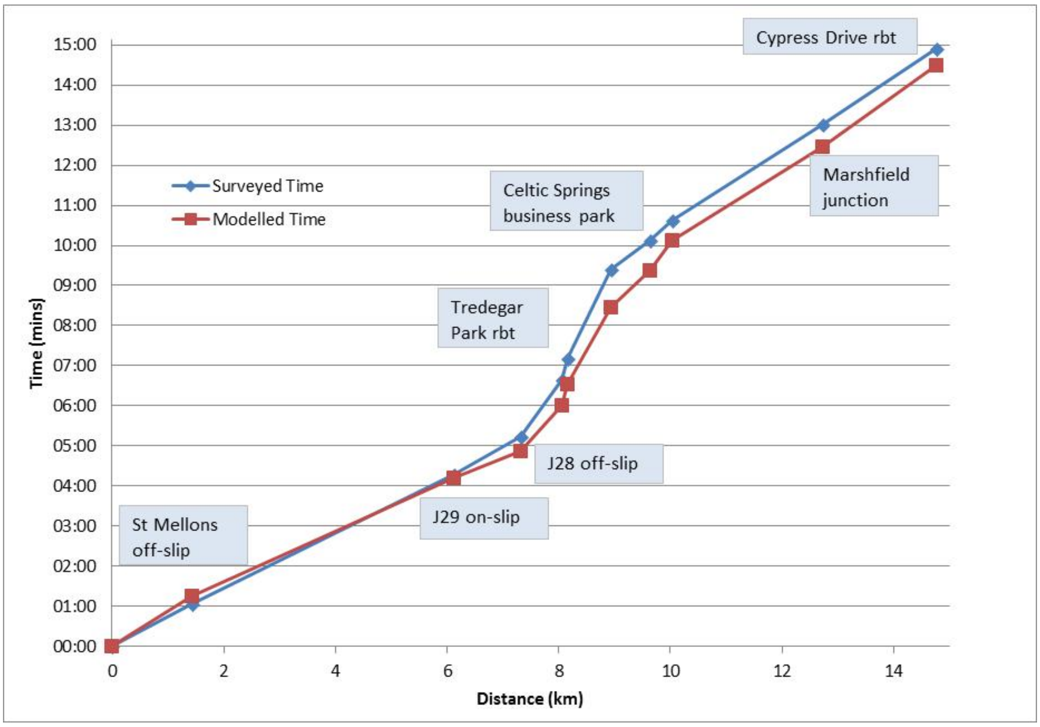
## B2.3 Inter Peak – Clockwise



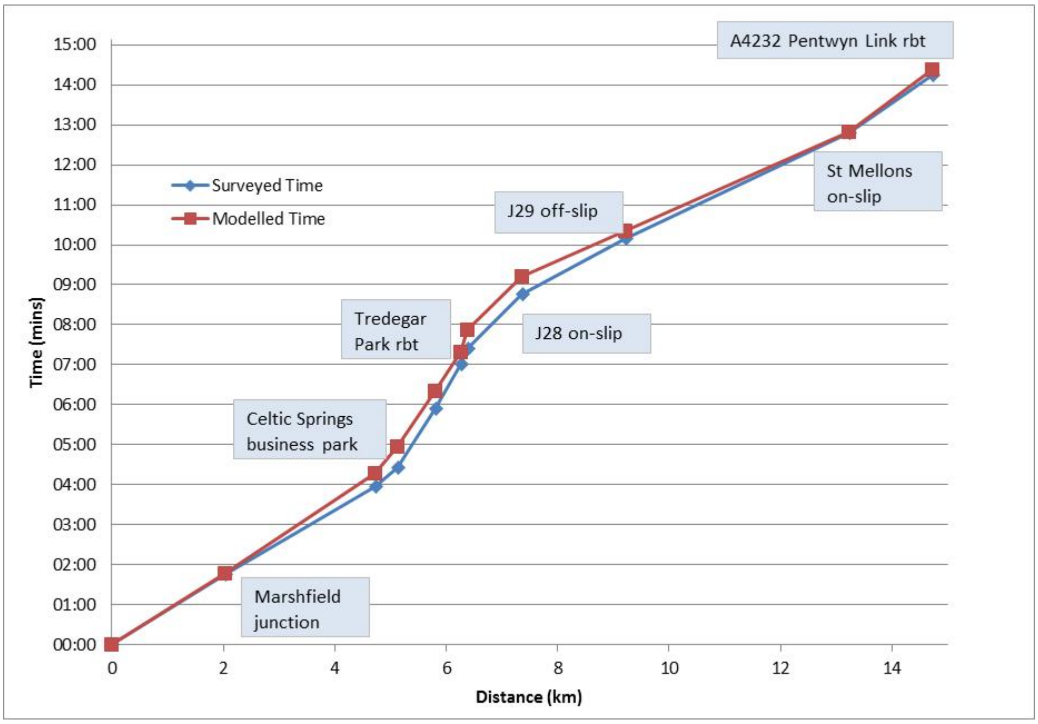

## B2.4 Inter Peak – Anticlockwise



## B2.5 PM Peak – Clockwise

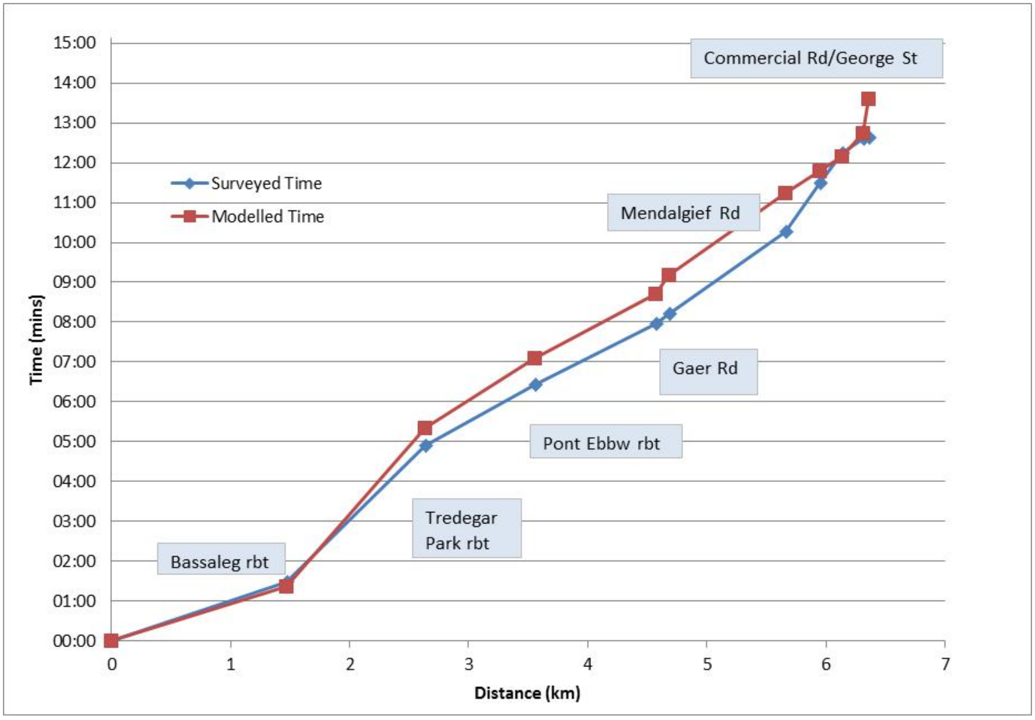



## B2.6 PM Peak – Anticlockwise

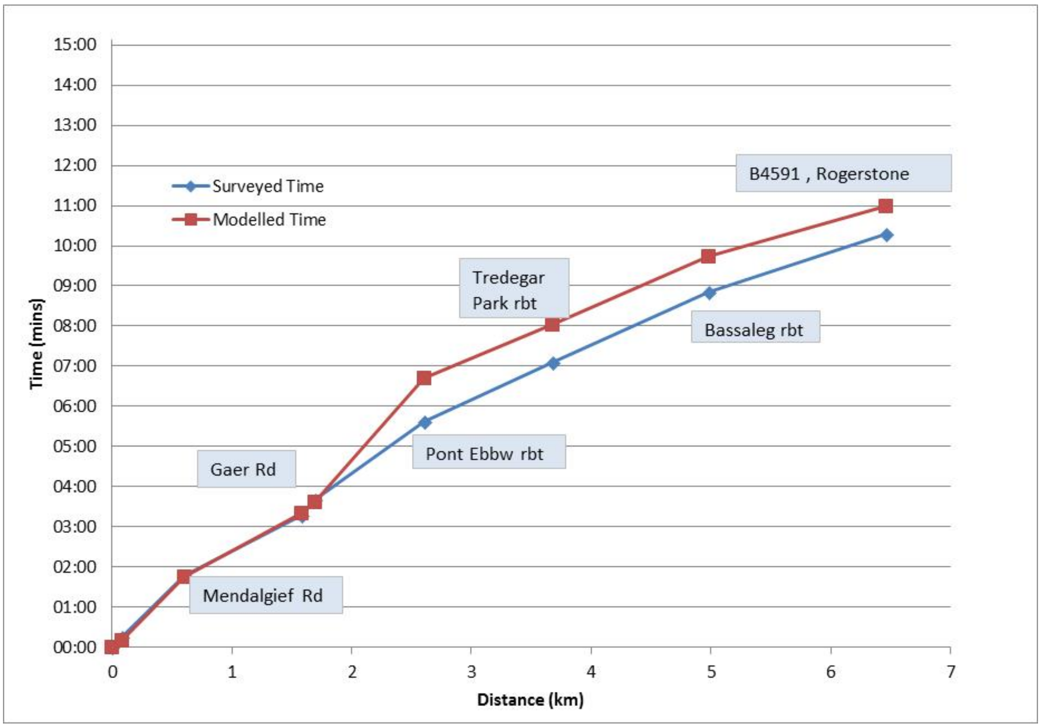


# B3 Route 3: A467 Rogerstone to B4237 / Commercial Road

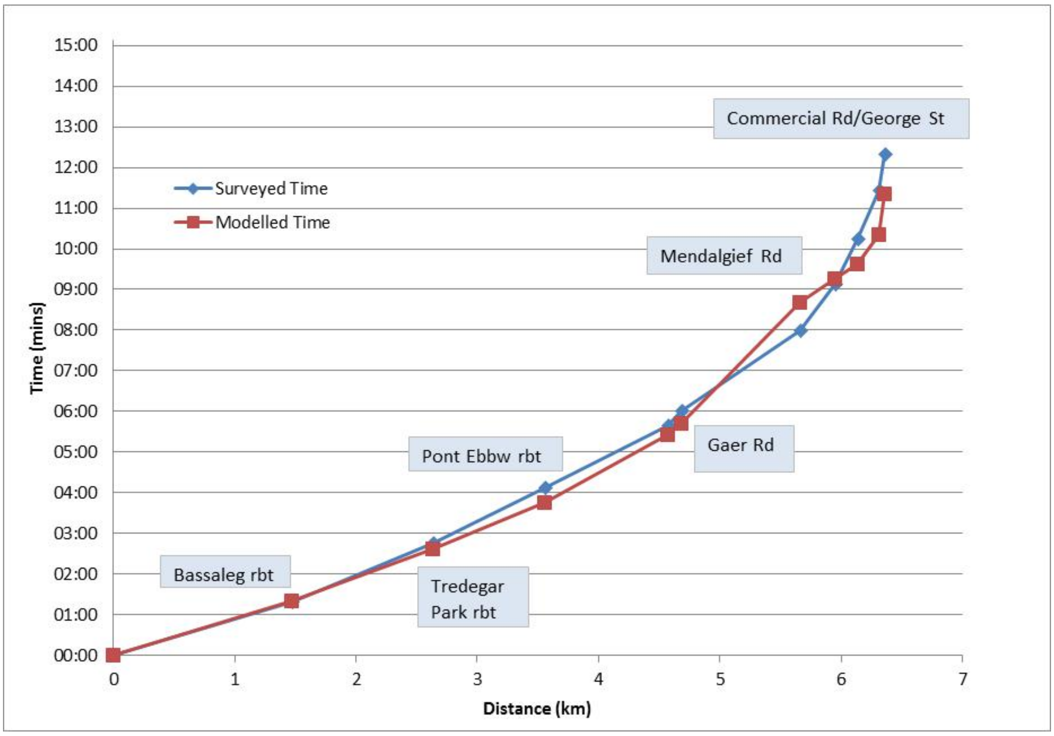
## B3.1 AM Peak – Eastbound



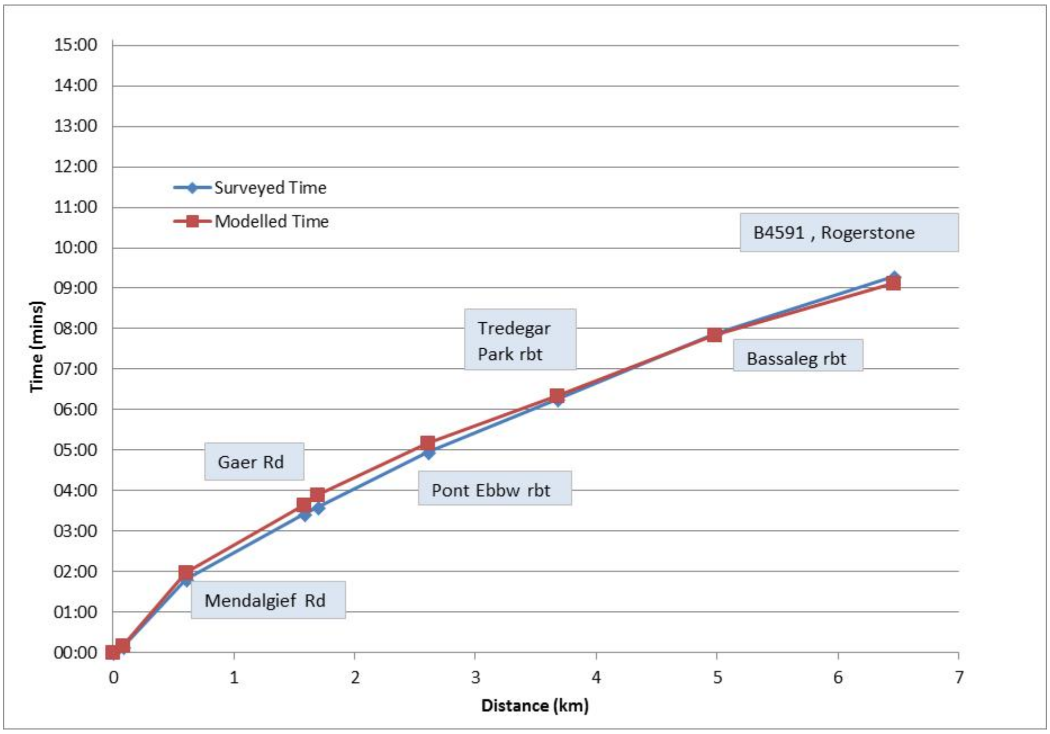

## B3.2 AM Peak – Westbound



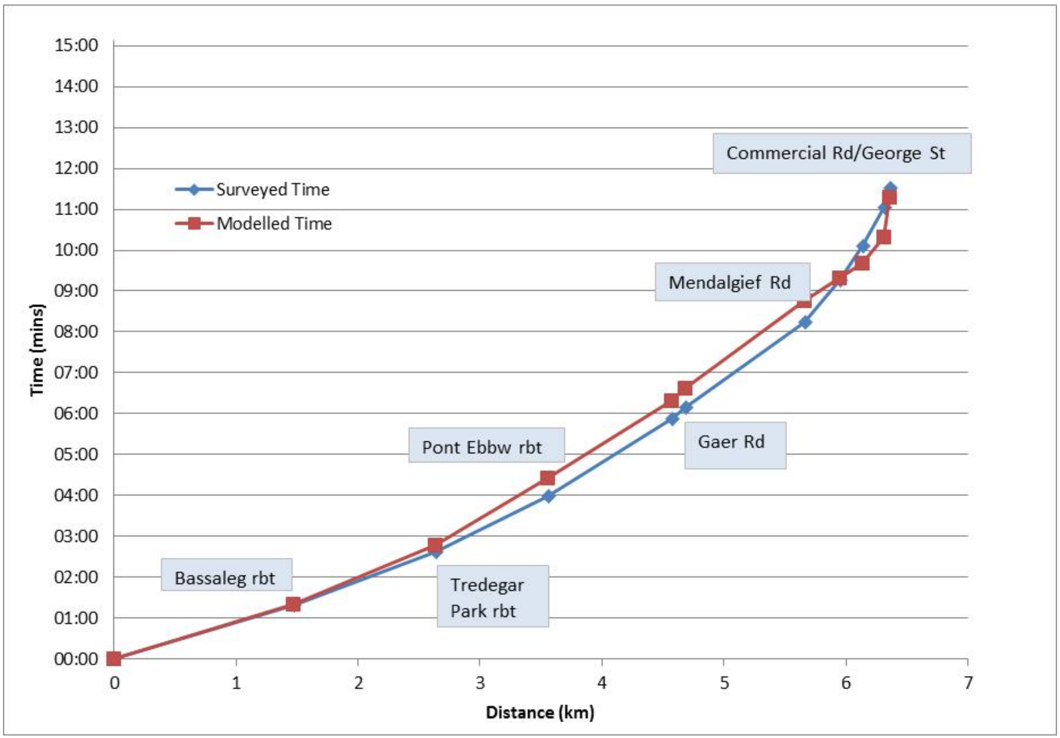
## B3.3 Inter Peak – Eastbound



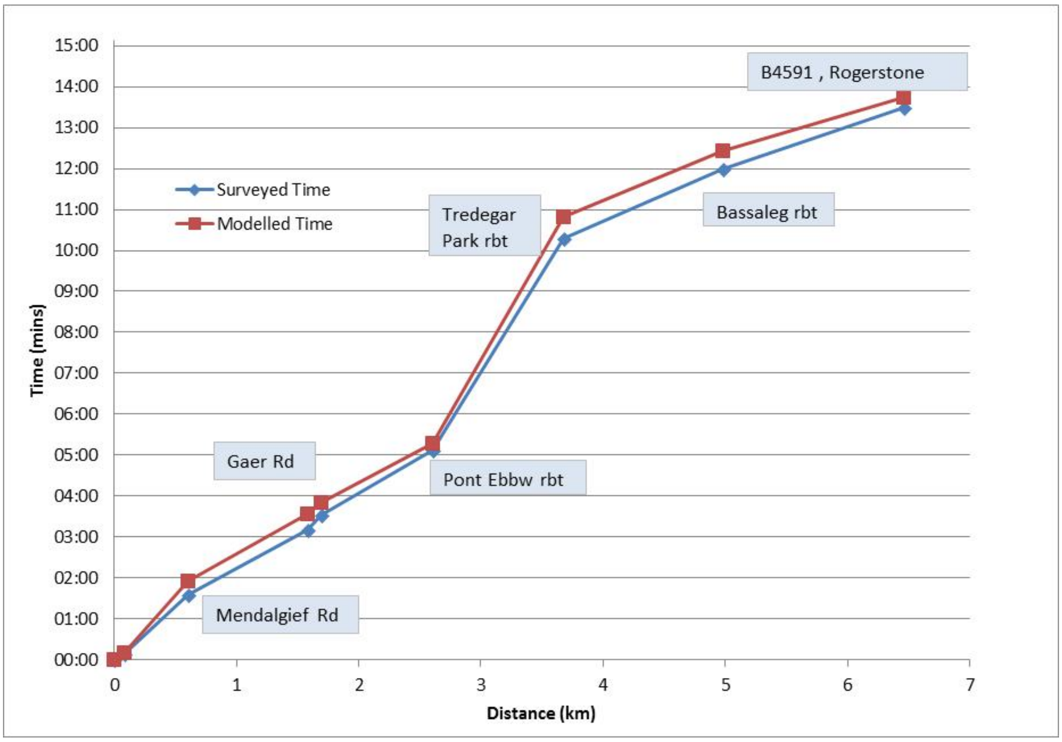

## B3.4 Inter Peak – Westbound



# B3.5 PM Peak – Eastbound

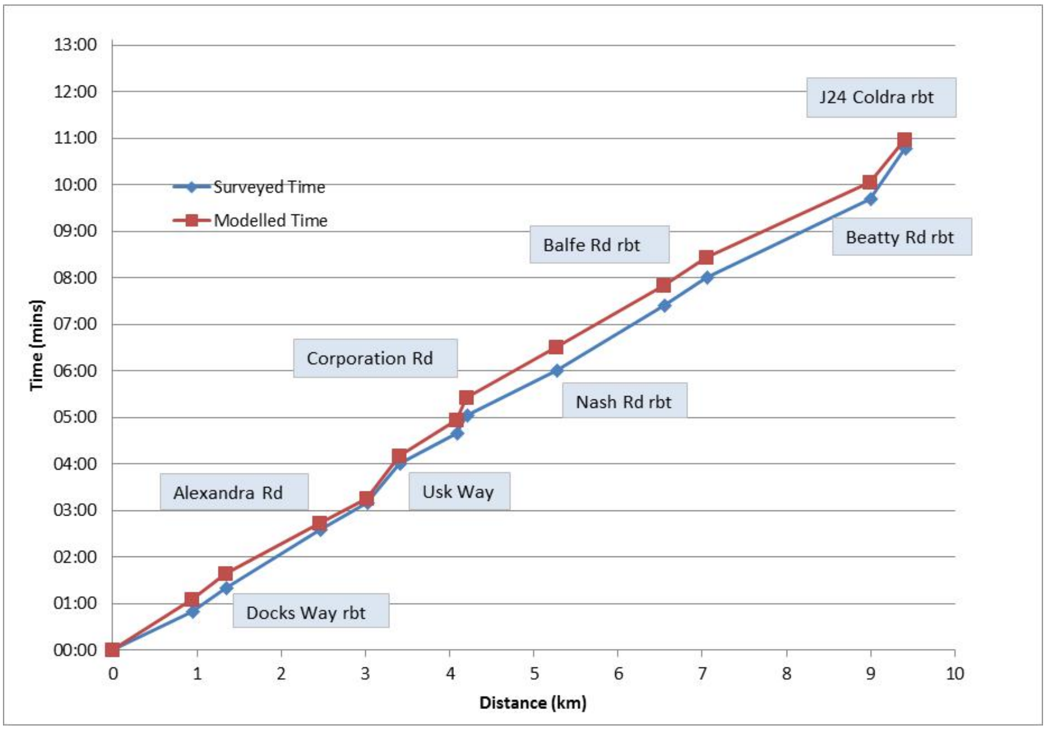



# B3.6 PM Peak – Westbound

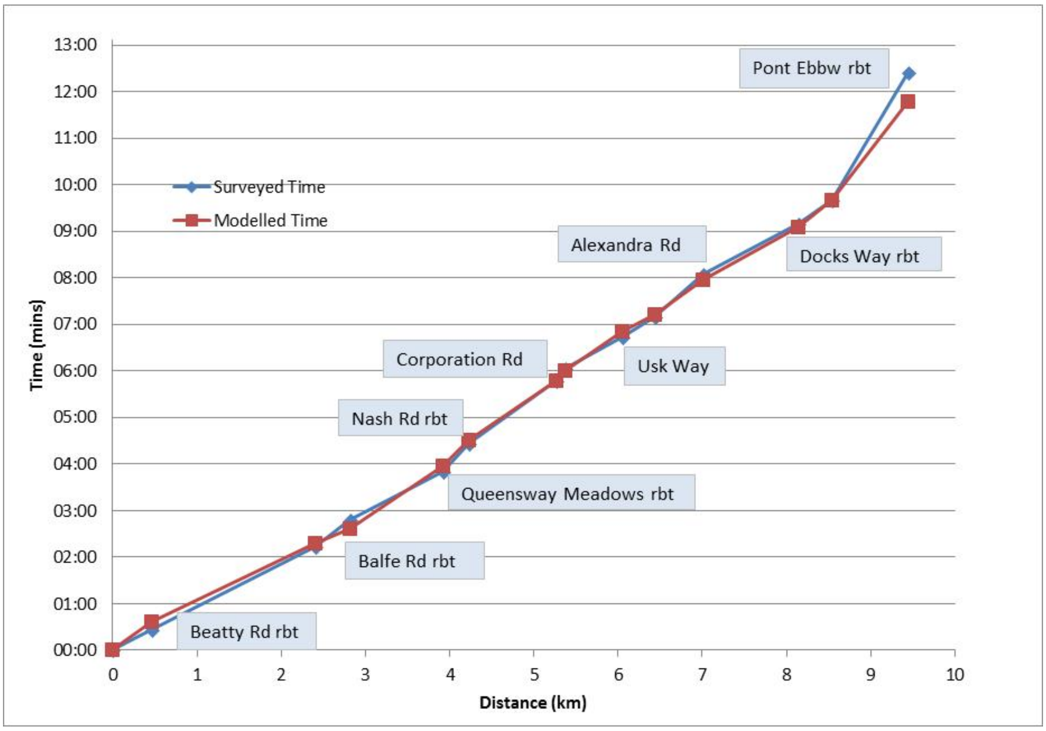


# B4 Route 4: A48 Southern Distributor Road, Pont Ebbw to Coldra roundabout

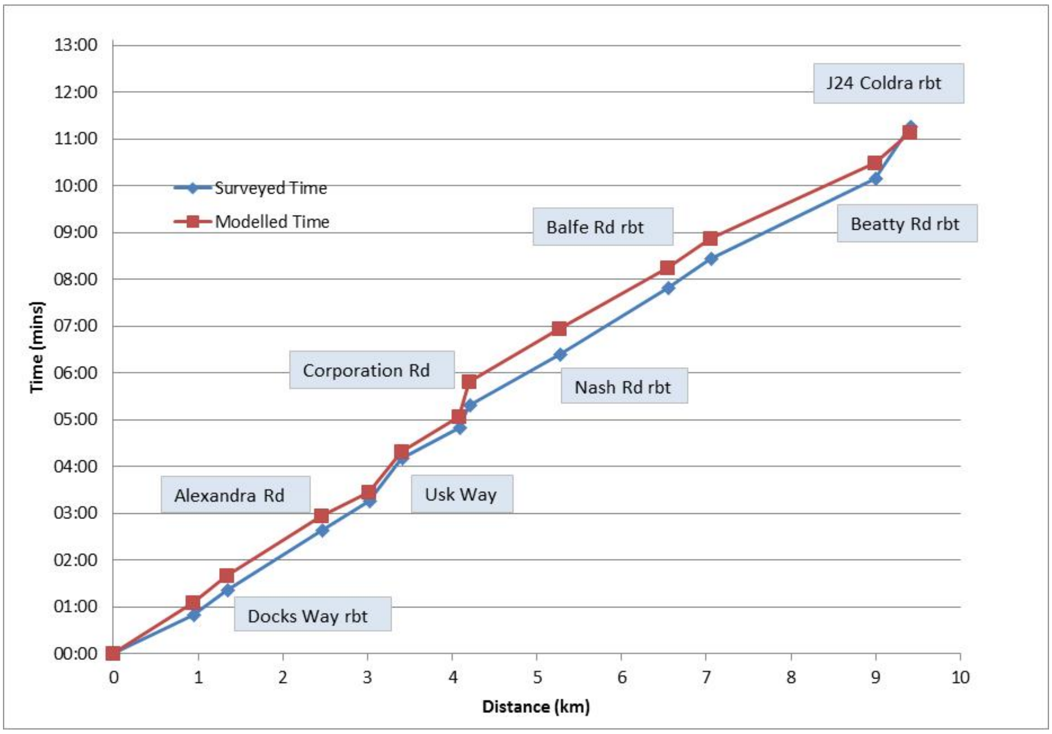
## B4.1 AM Peak – Eastbound



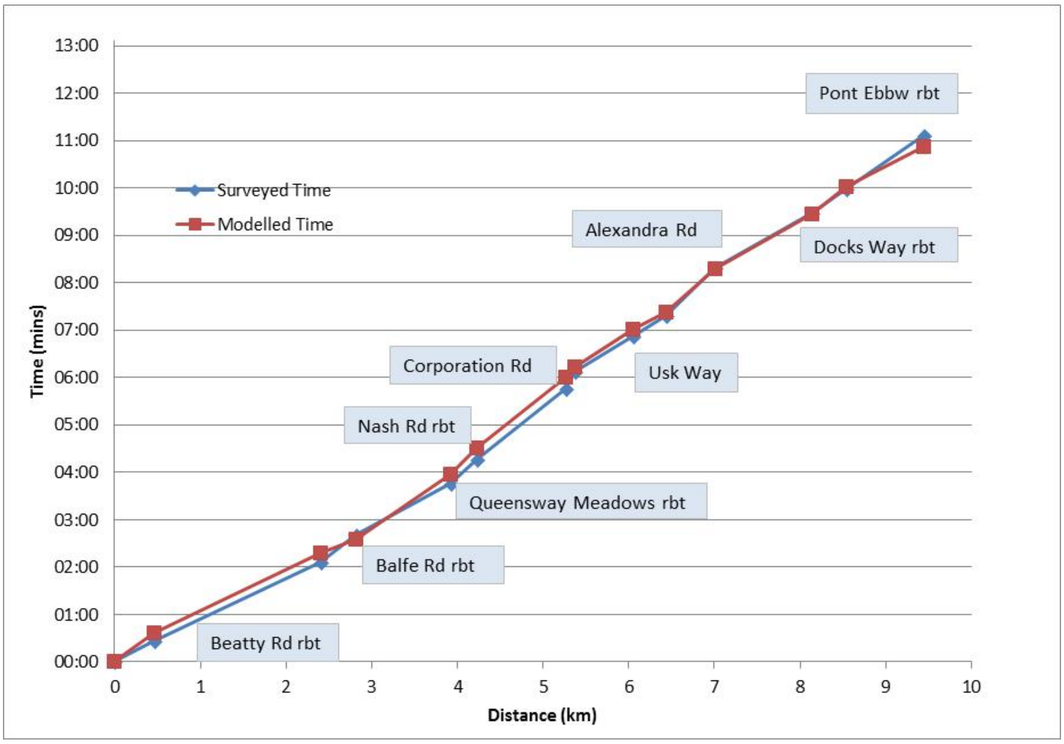

## B4.2 AM Peak – Westbound



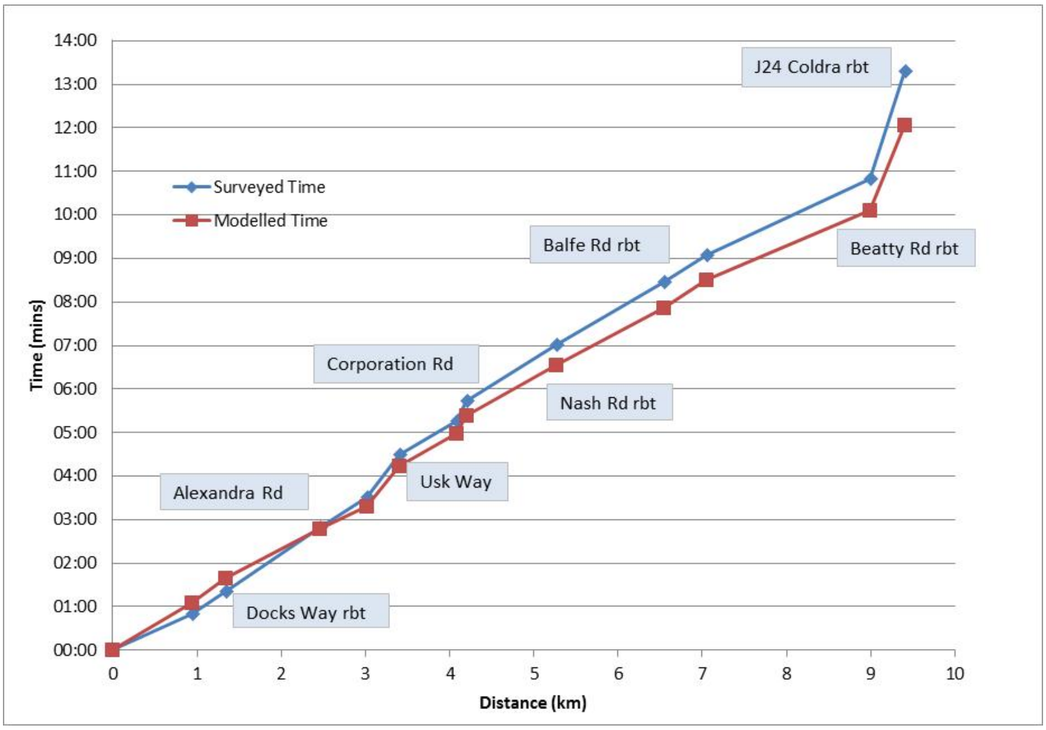
# B4.3 Inter Peak – Eastbound



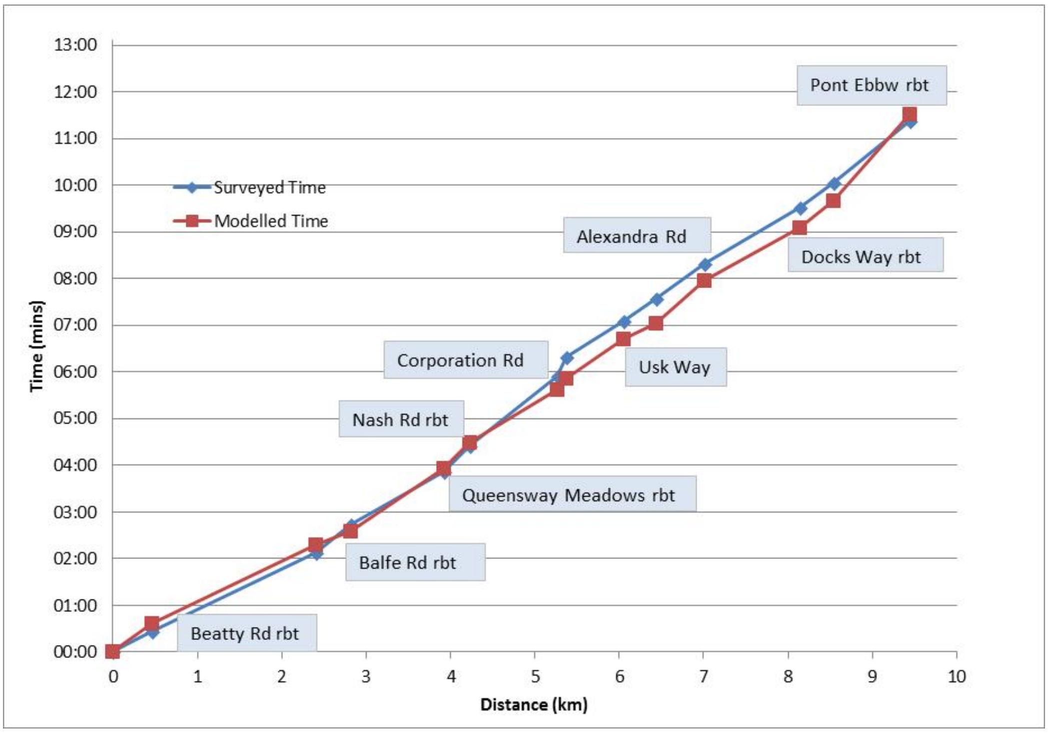

# B4.4 Inter Peak – Westbound



## B4.5 PM Peak – Eastbound

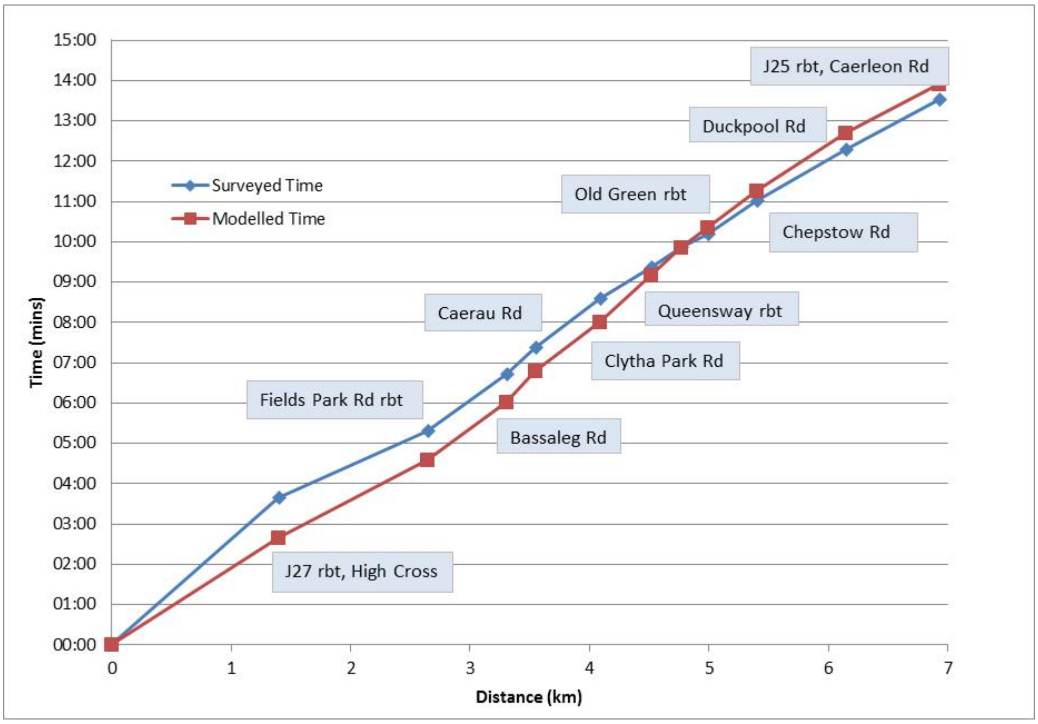



## B4.6 PM Peak – Westbound

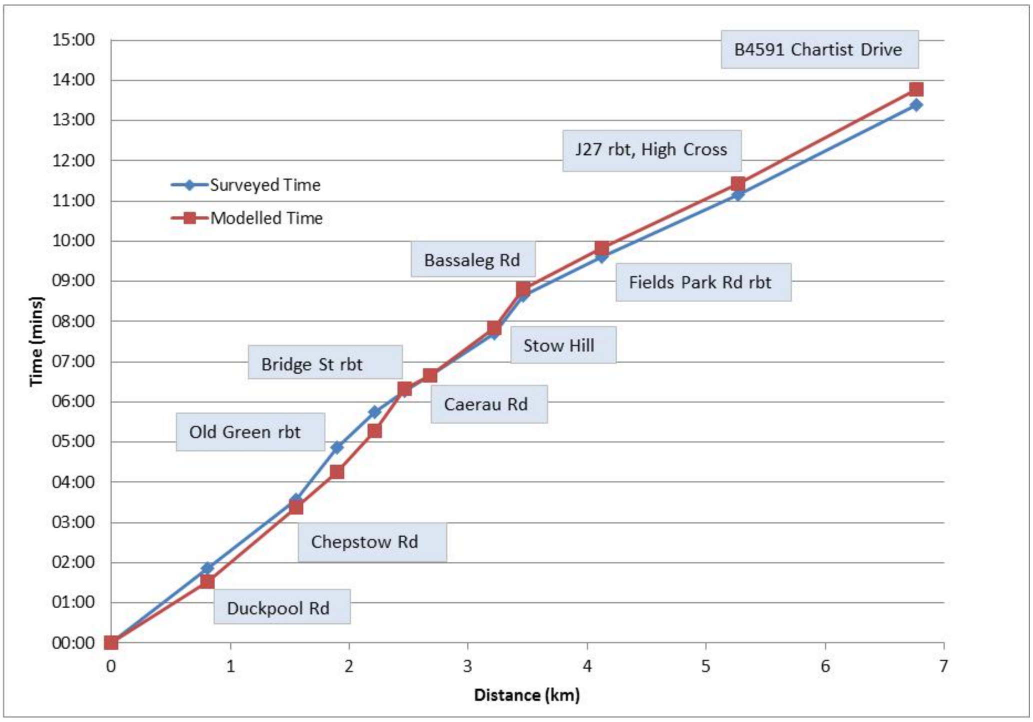


# B5 Route 5: B4591/Chartist Drive to B4596/J25 roundabout (via Clarence Place Bridge)

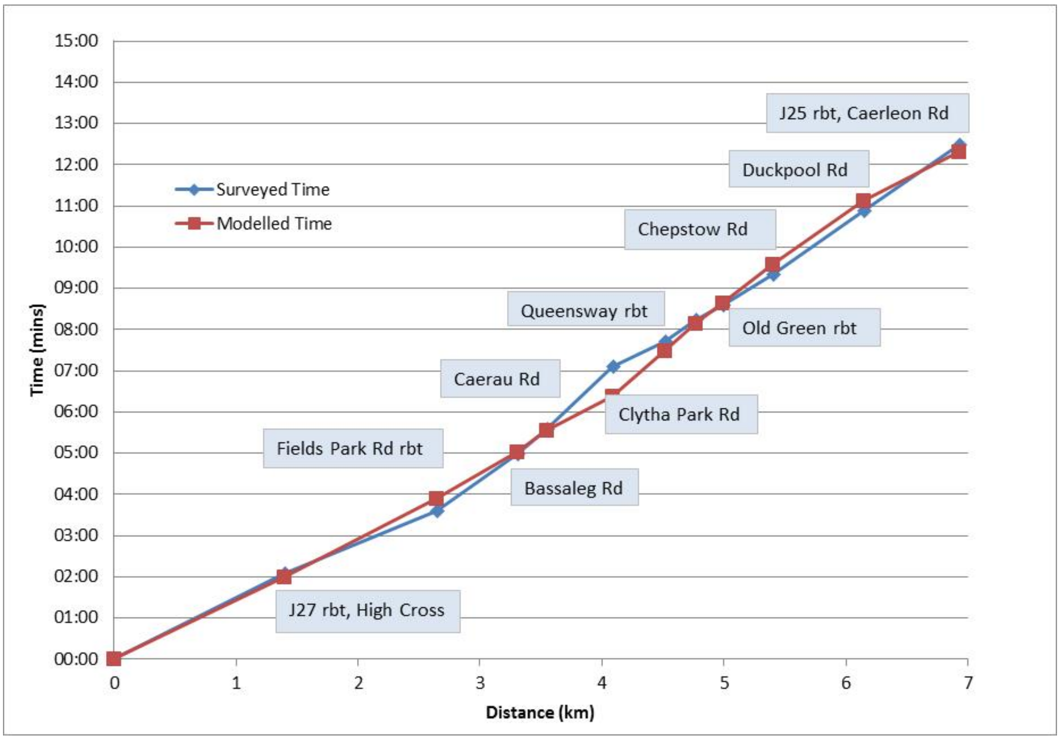
## B5.1 AM Peak – Eastbound



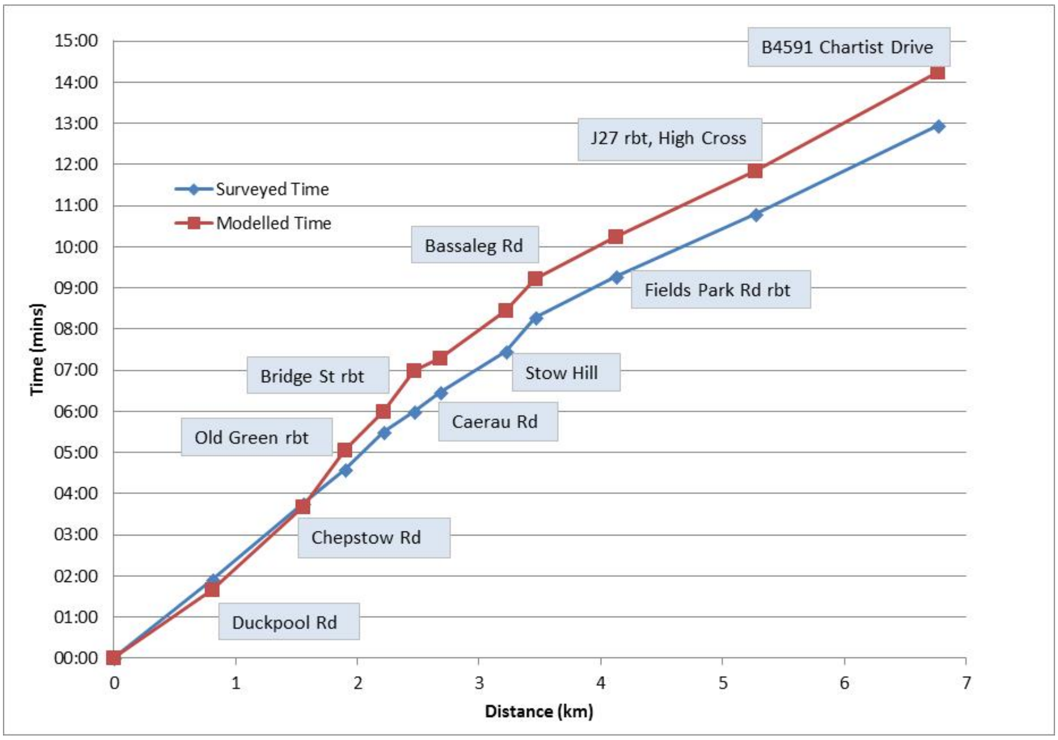

## B5.2 AM Peak – Westbound



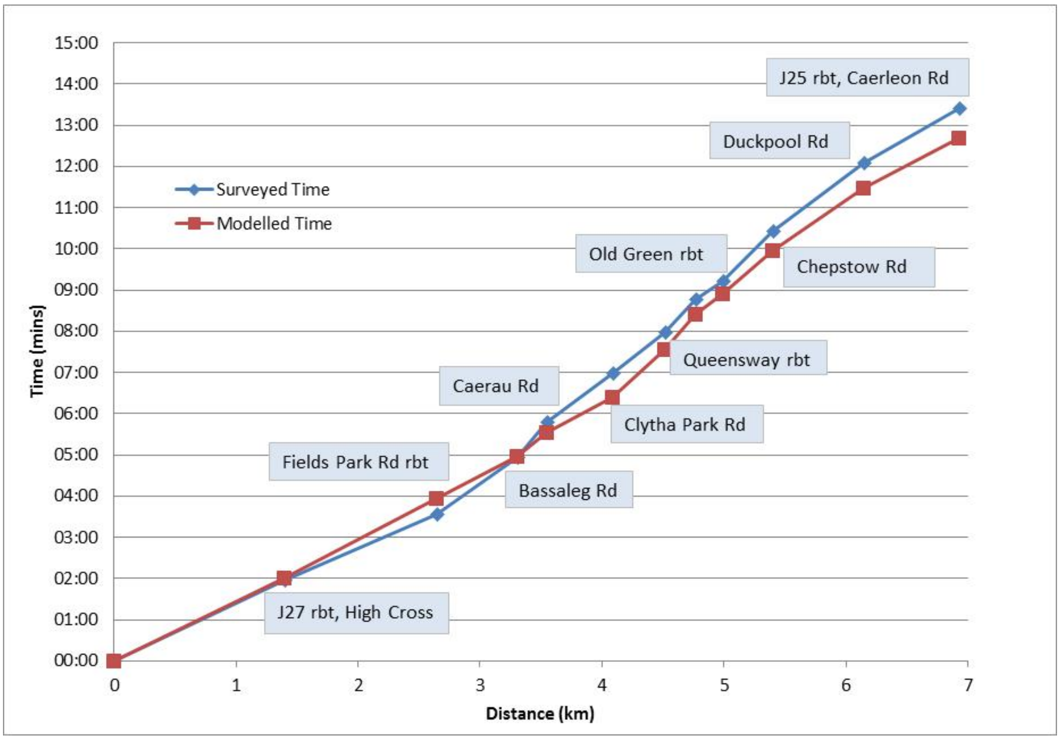
## B5.3 Inter Peak – Eastbound



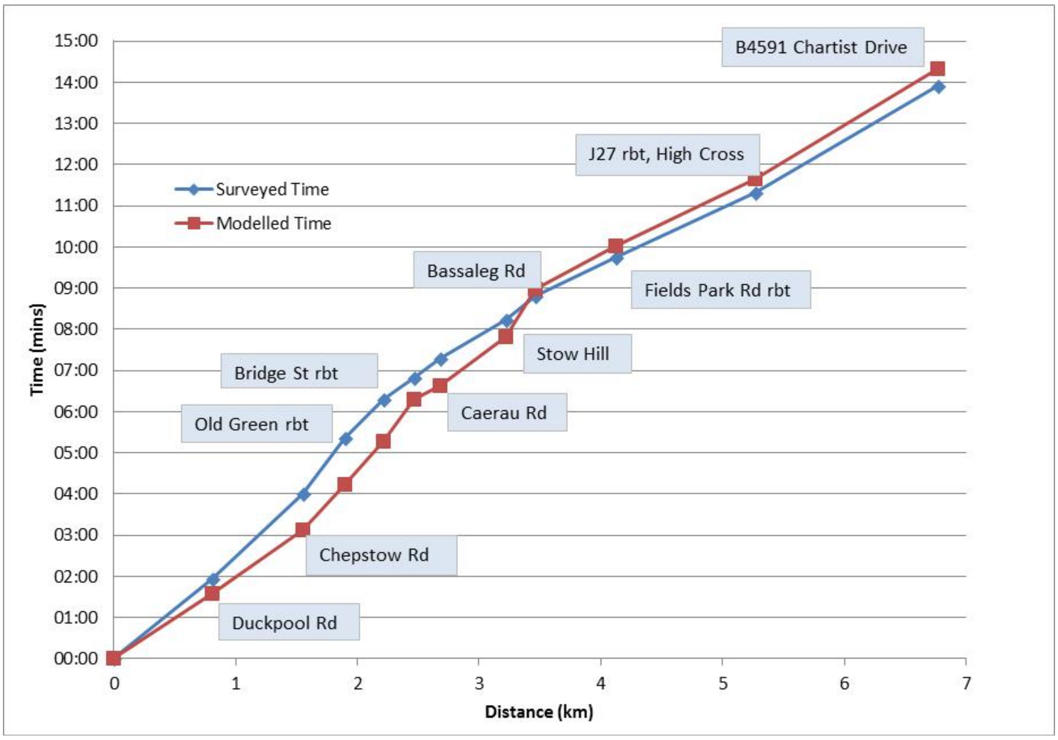

## B5.4 Inter Peak – Westbound



## B5.5 PM Peak – Eastbound

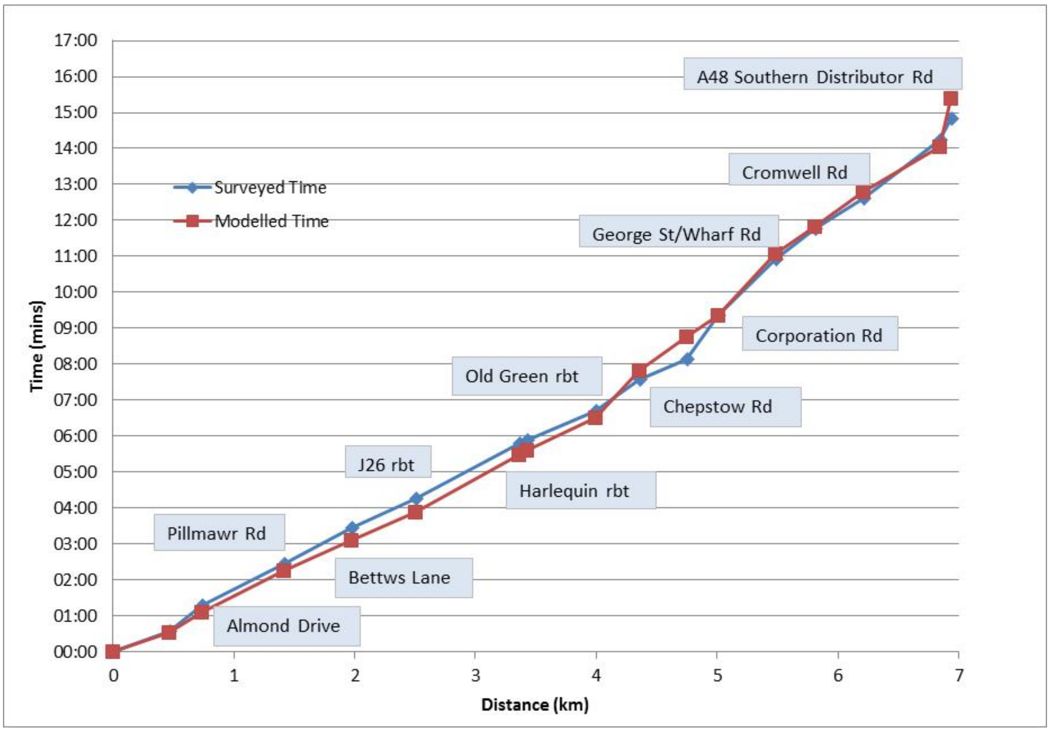



## B5.6 PM Peak – Westbound

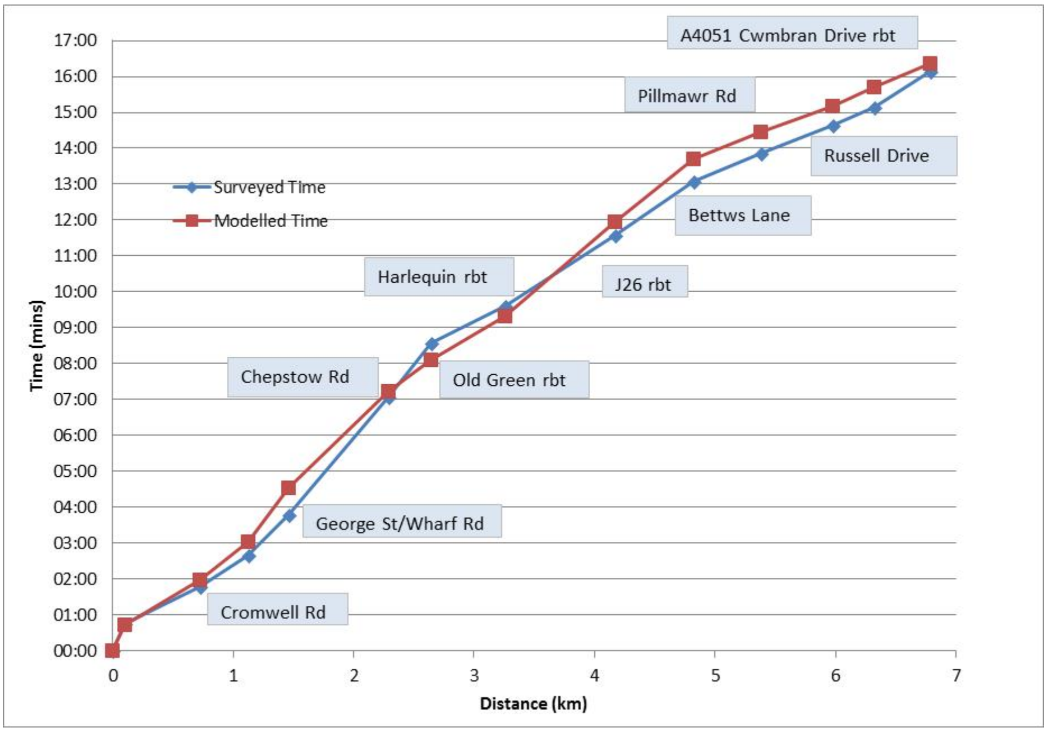


# B6 Route 6: A4051 Malpas Rd to Corporation Rd / A48 (via Clarence Place Bridge)

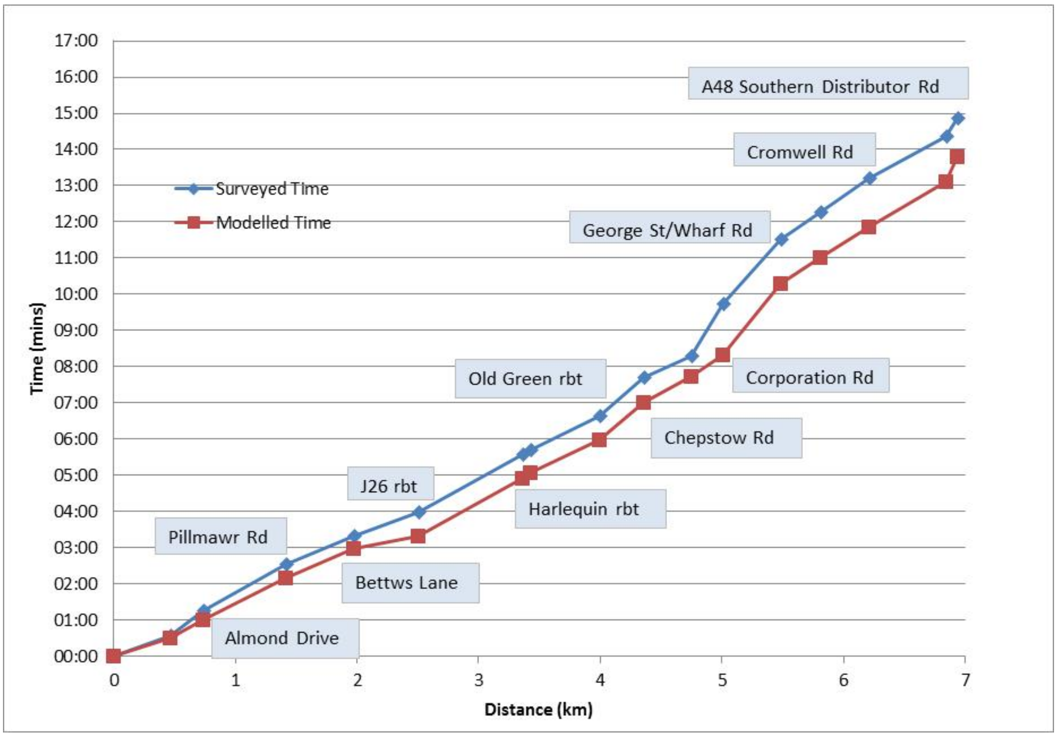
## B6.1 AM Peak – Southbound



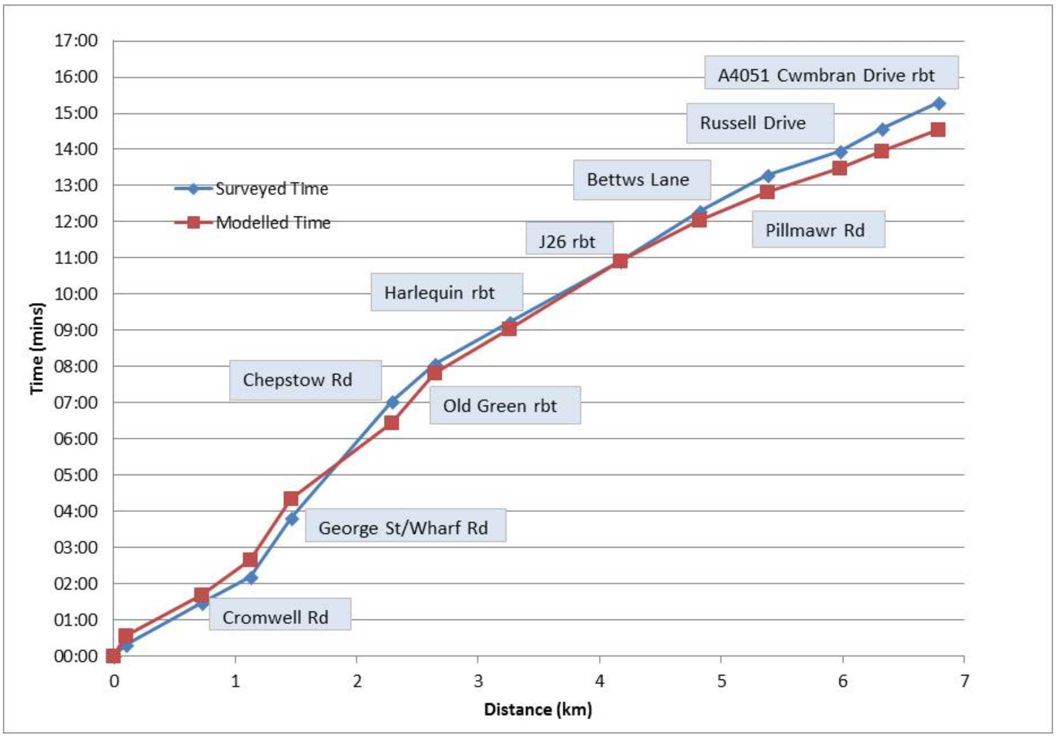

## B6.2 AM Peak – Northbound



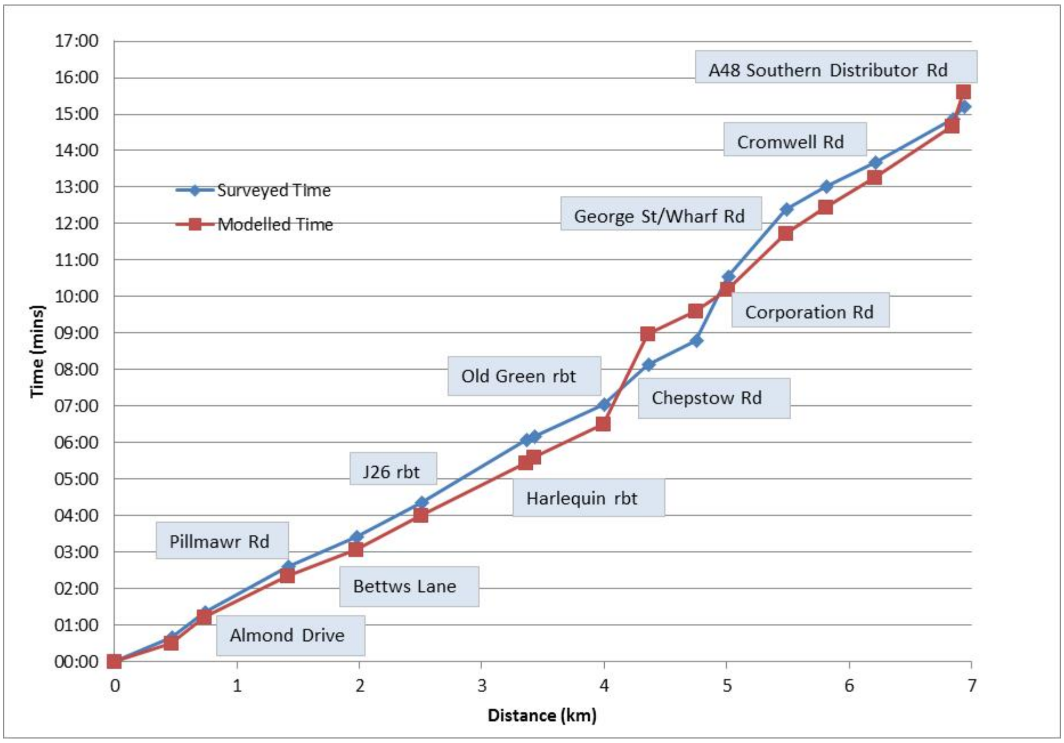
## B6.3 Inter Peak – Southbound



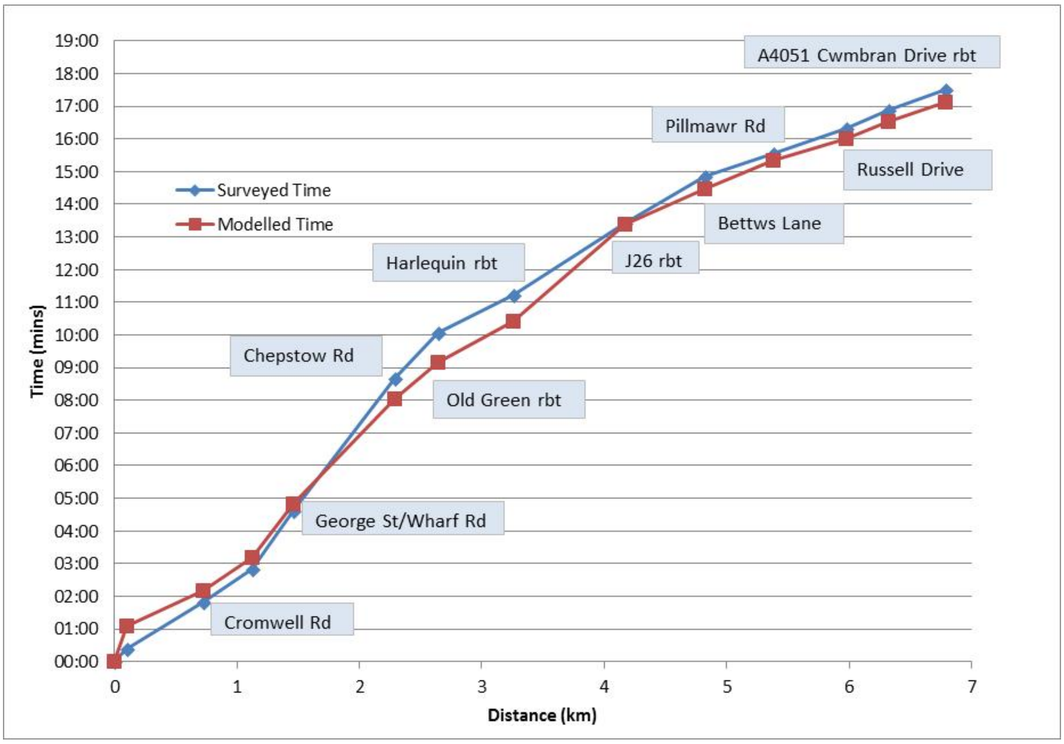

## B6.4 Inter Peak – Northbound



## B6.5 PM Peak – Southbound

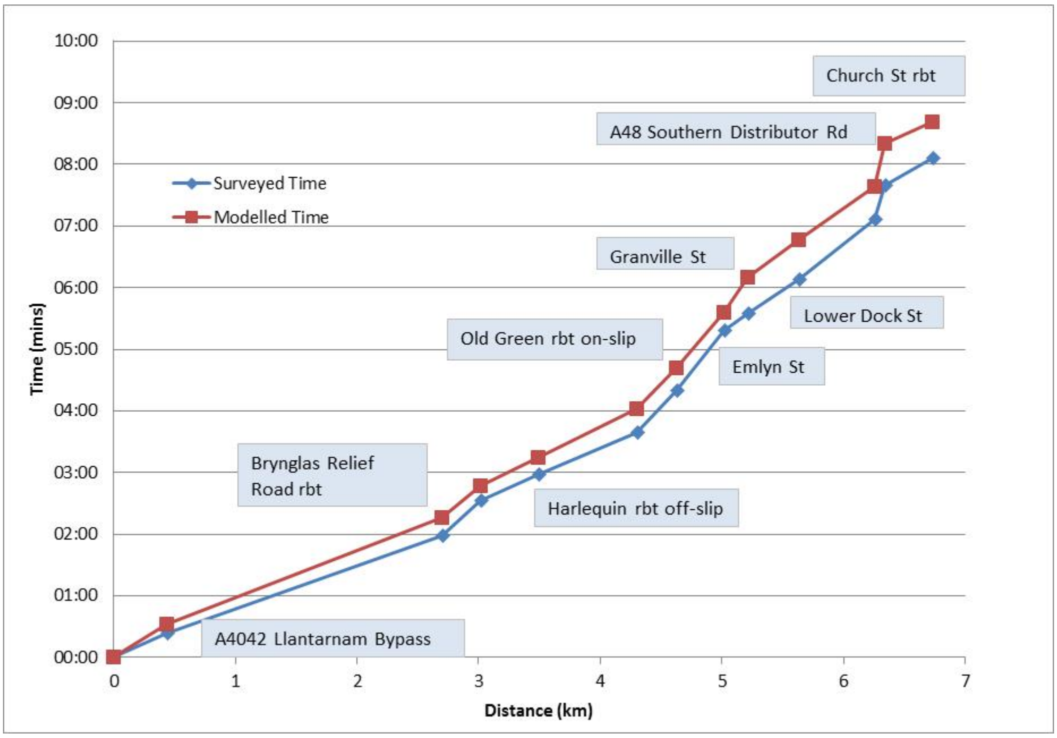



## B6.6 PM Peak – Northbound

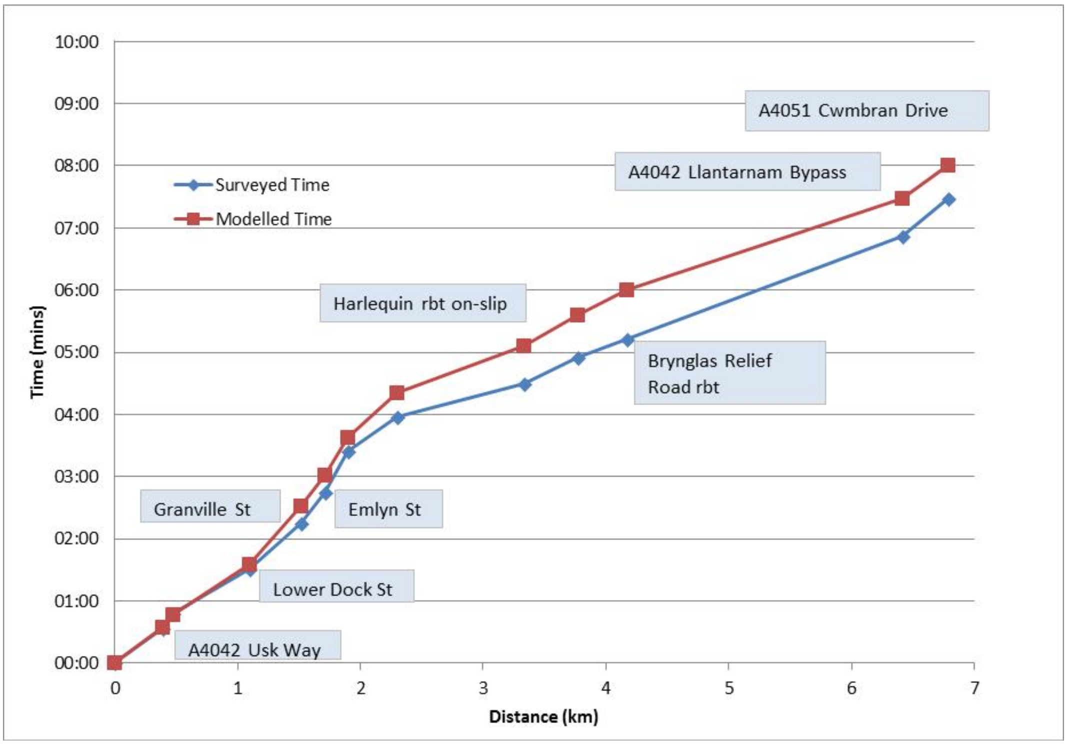


# B7 Route 7: A4042 Usk Way (Cwmbran Drive to Southern Distributor Road)

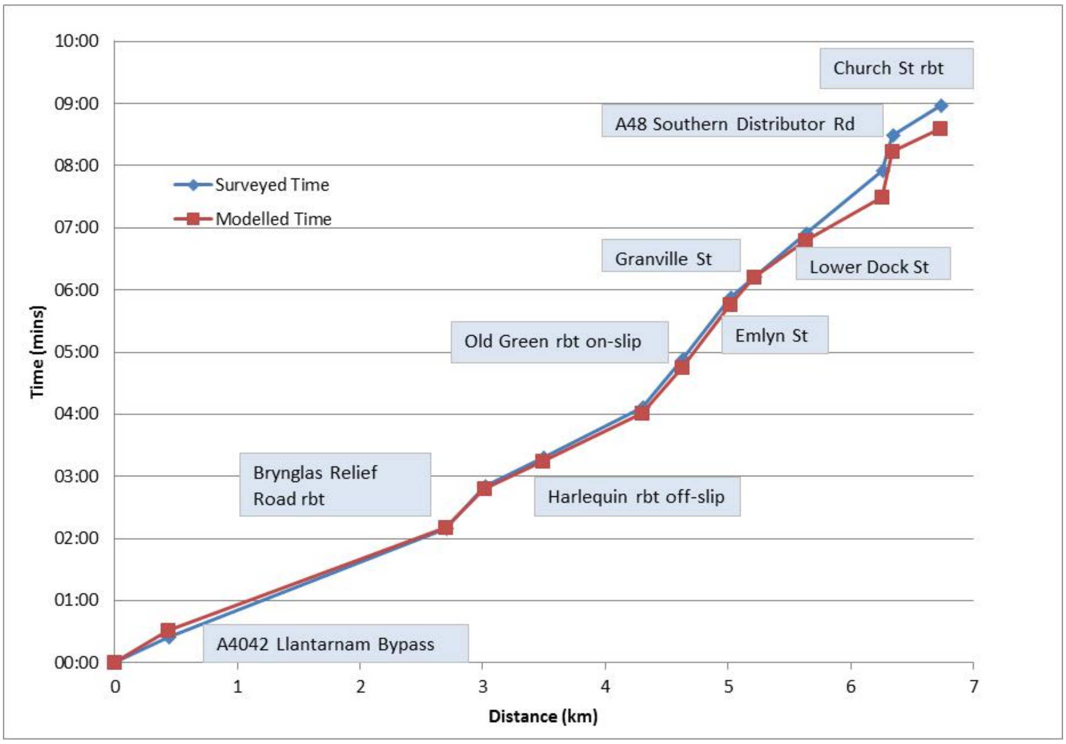
## B7.1 AM Peak – Southbound



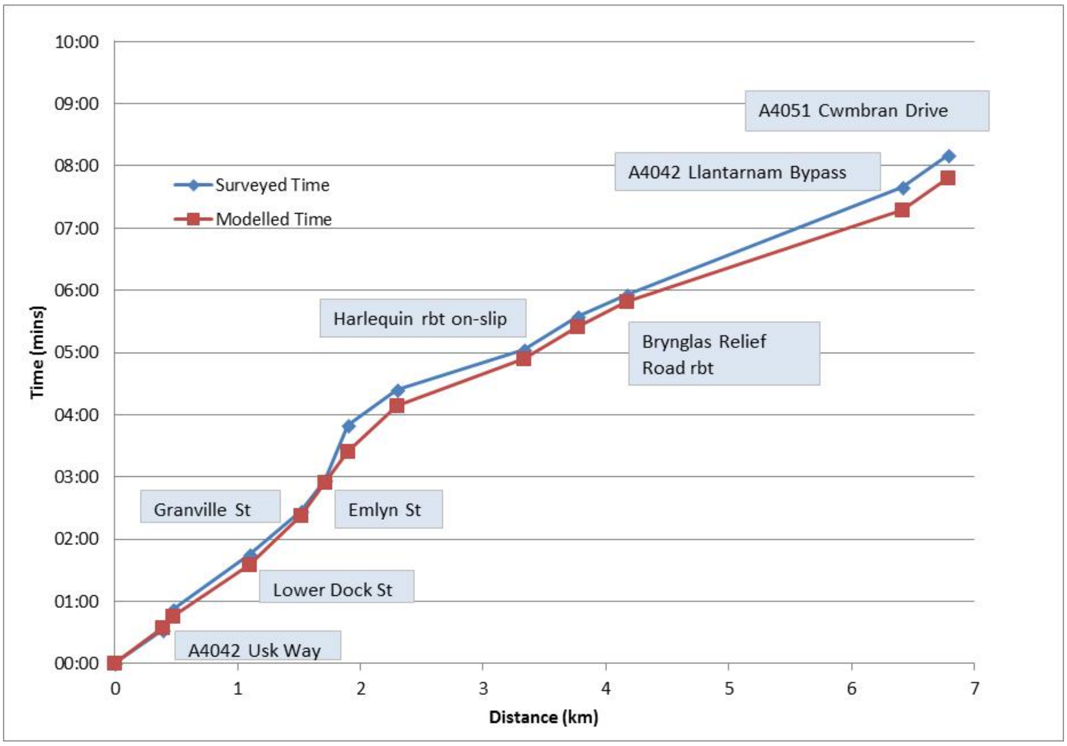

## B7.2 AM Peak – Northbound



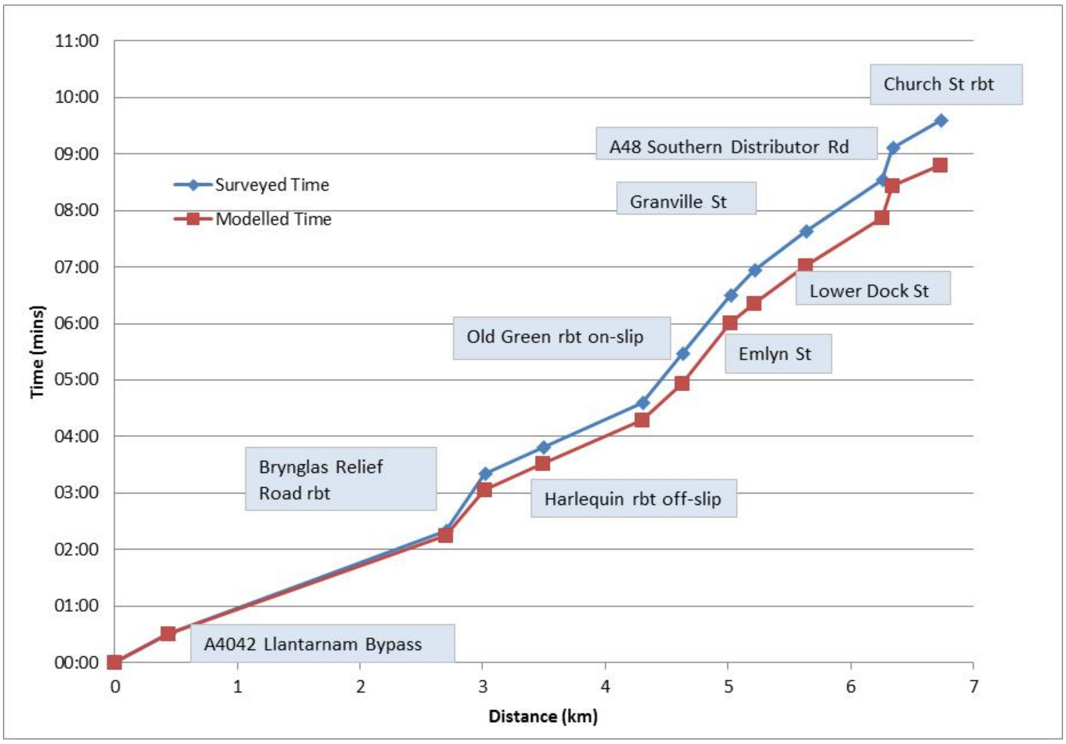
## B7.3 Inter Peak – Southbound



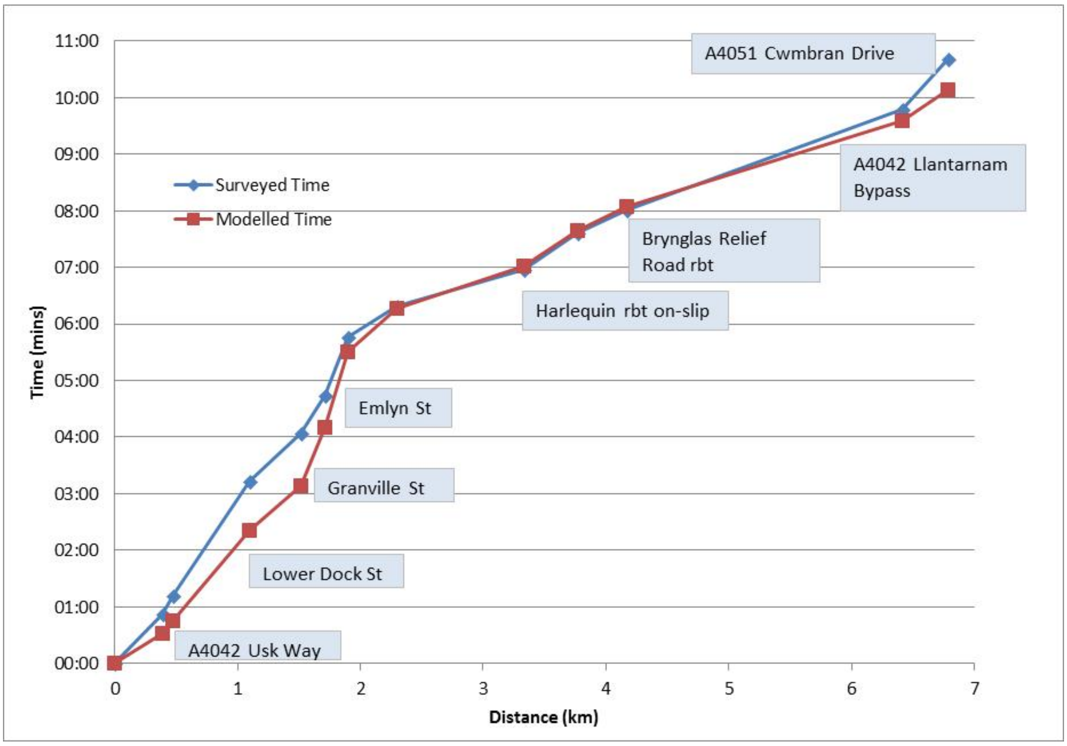

## B7.4 Inter Peak – Northbound



## B7.5 PM Peak – Southbound

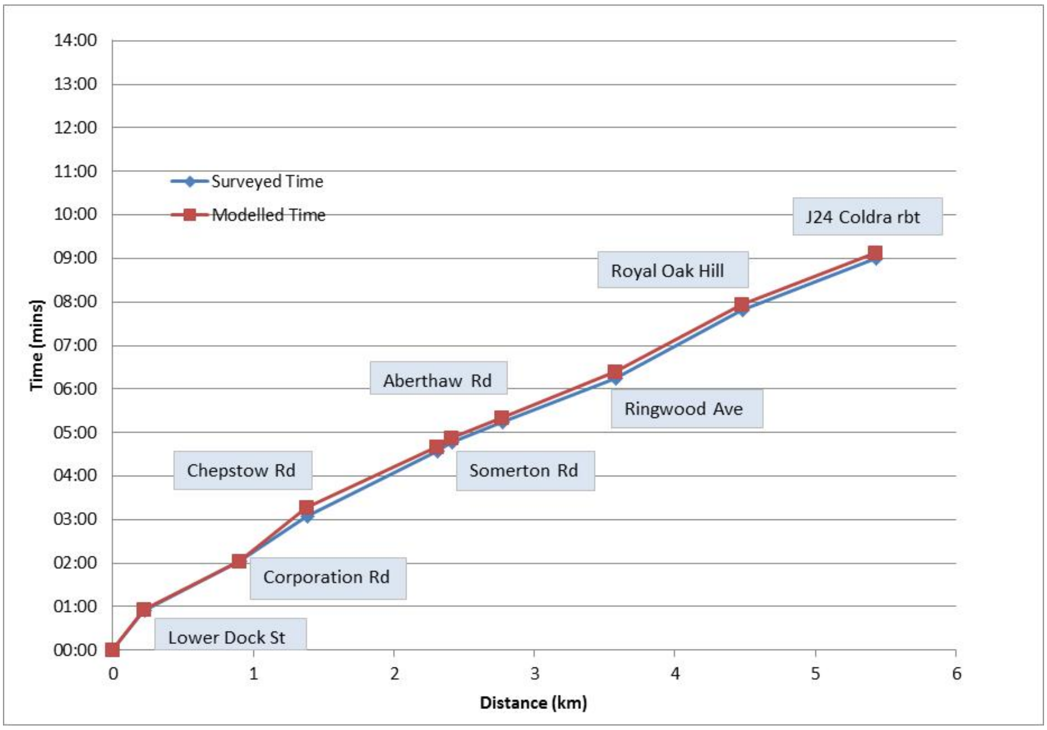



## B7.6 PM Peak – Northbound

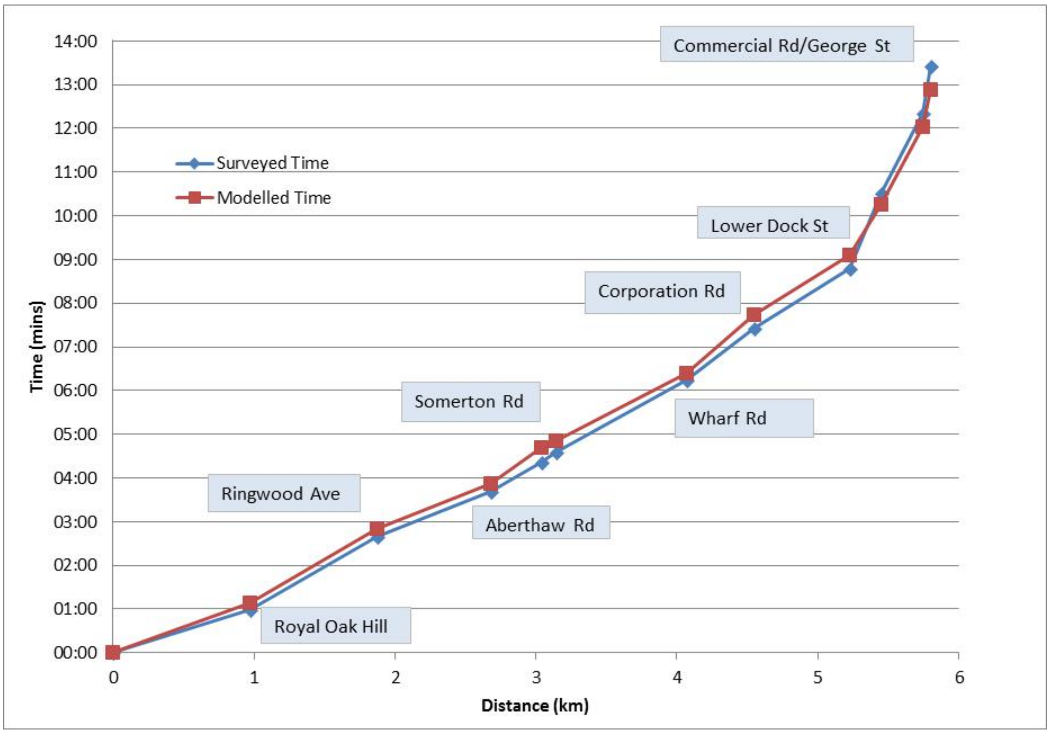


# B8 Route 8: B4237, Commercial Rd to Coldra roundabout (via George St Bridge)

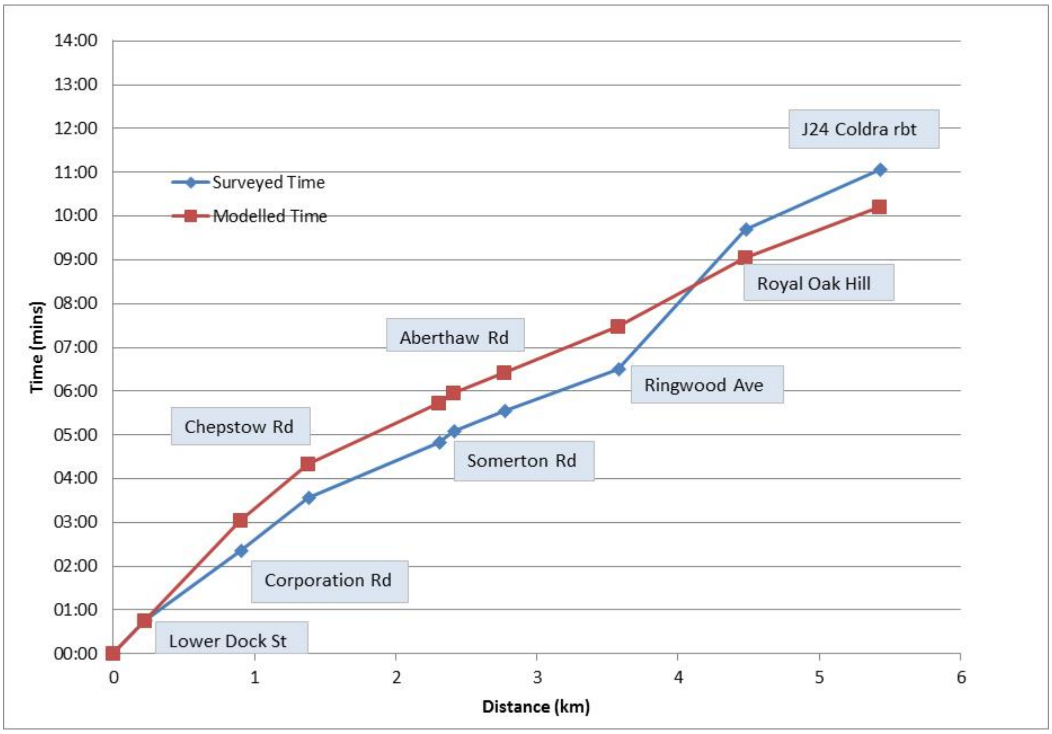
## B8.1 AM Peak – Eastbound



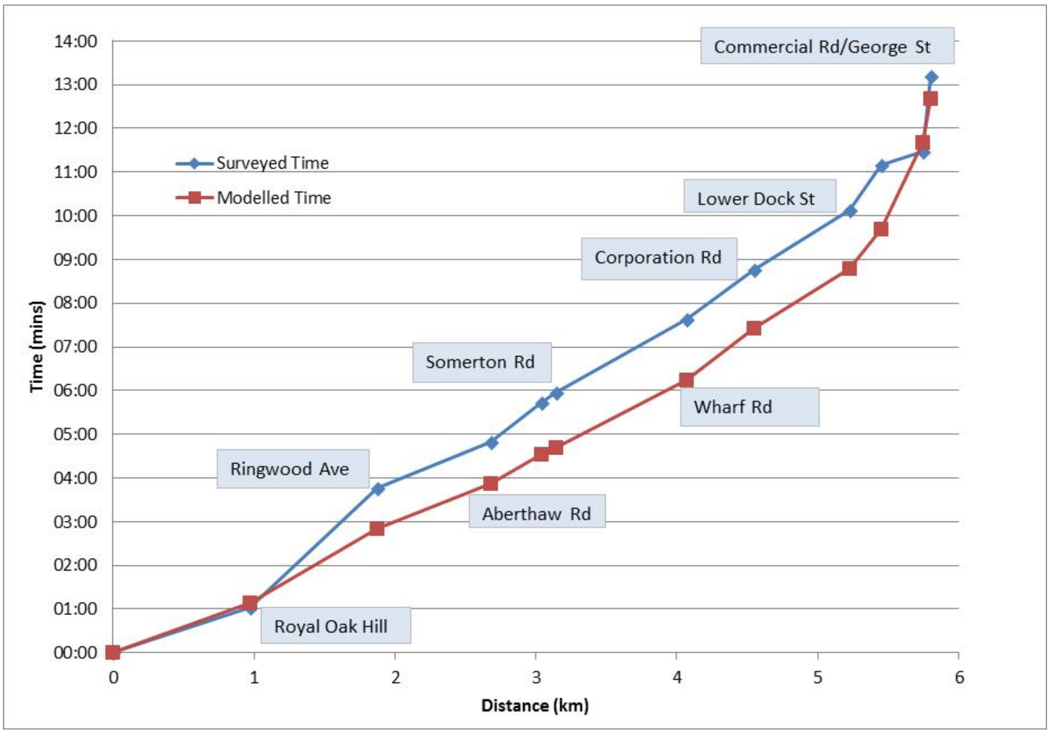

## B8.2 AM Peak – Westbound



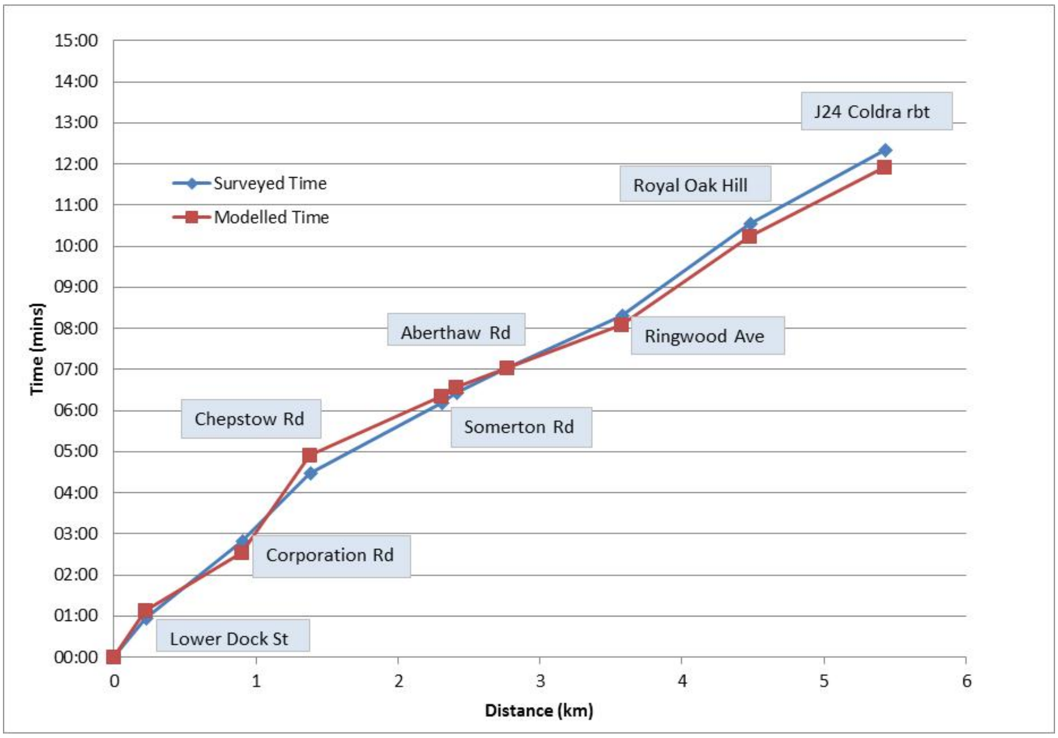
## B8.3 Inter Peak – Eastbound



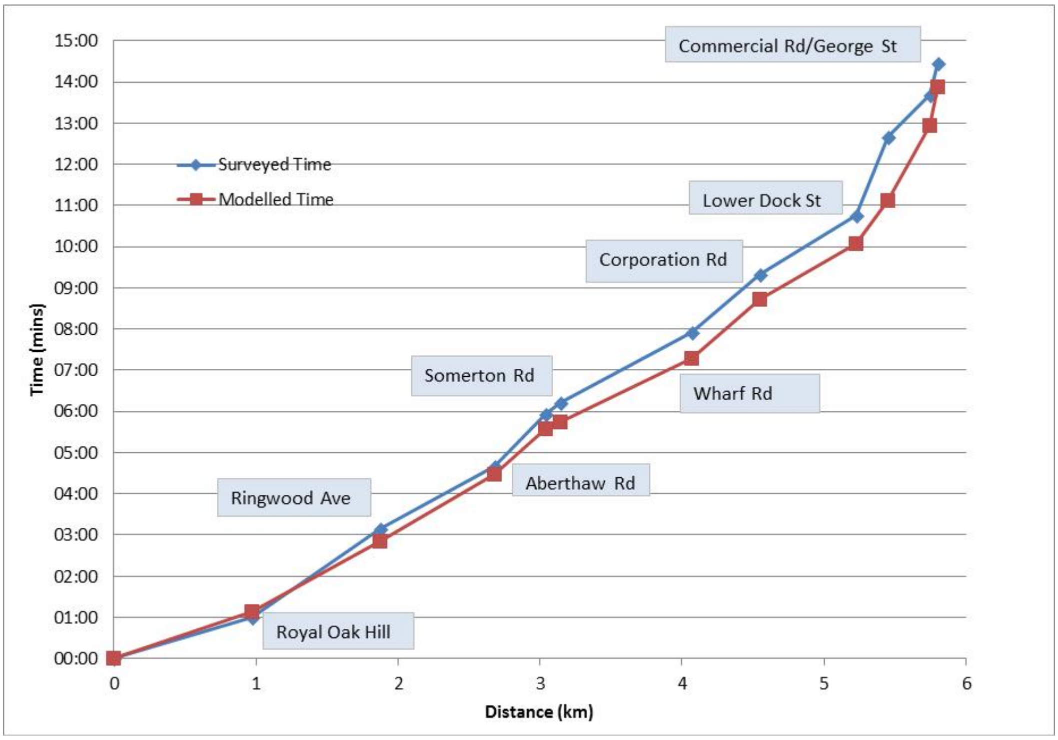

## B8.4 Inter Peak – Westbound



## B8.5 PM Peak – Eastbound

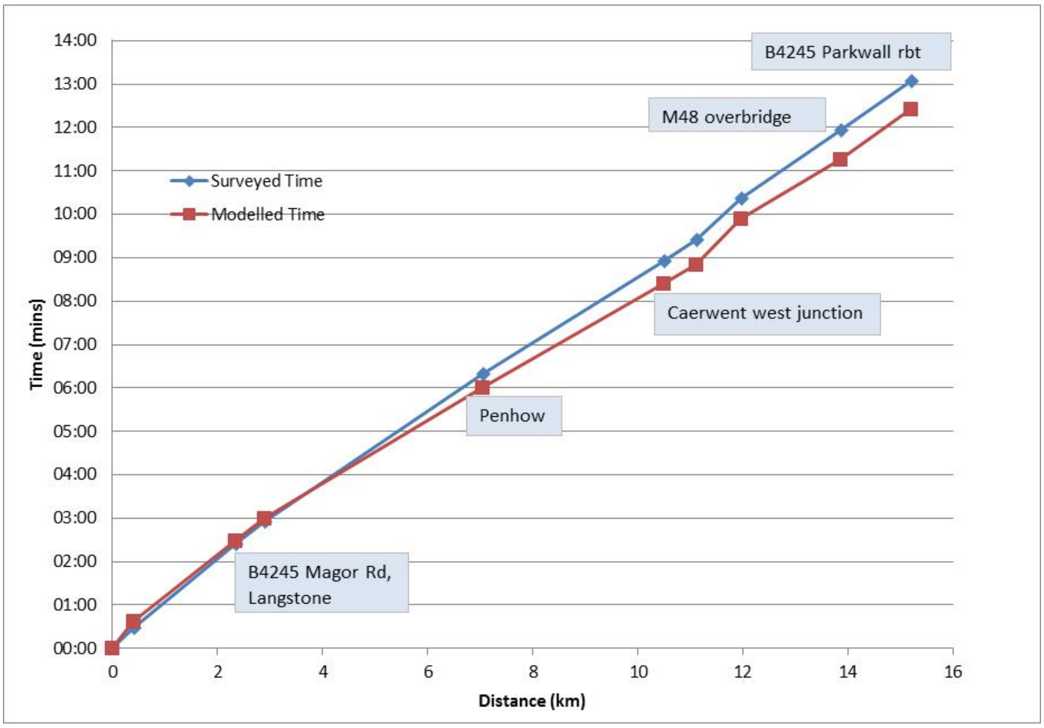



## B8.6 PM Peak – Westbound

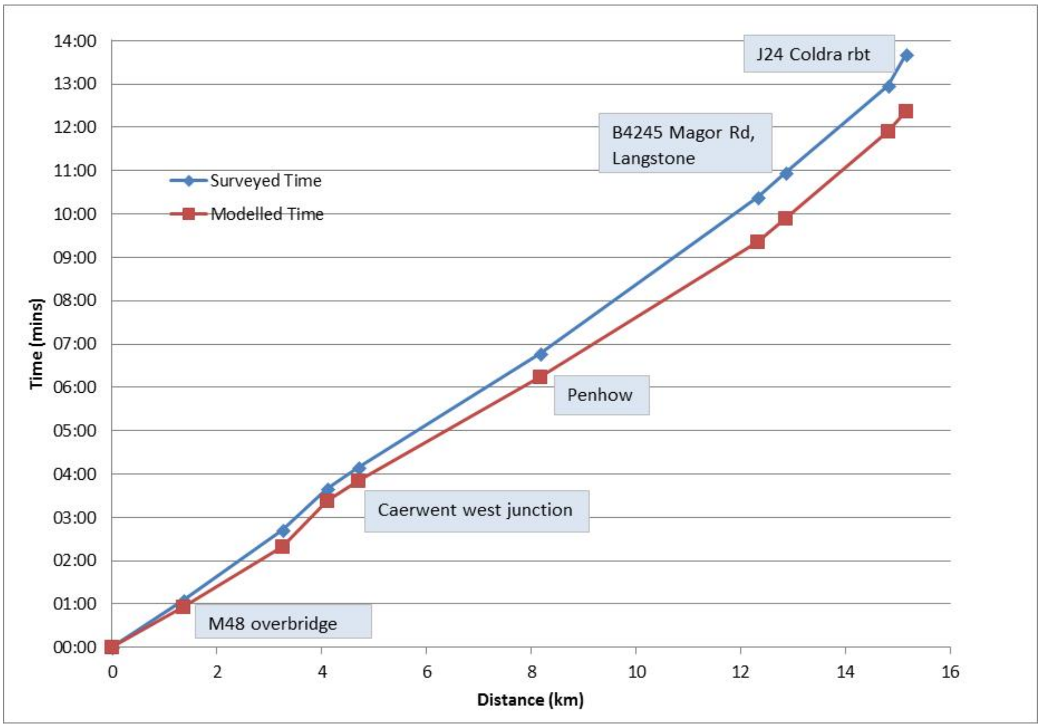


# B9 Route 9: A48, Coldra roundabout to B4245 Parkwall roundabout

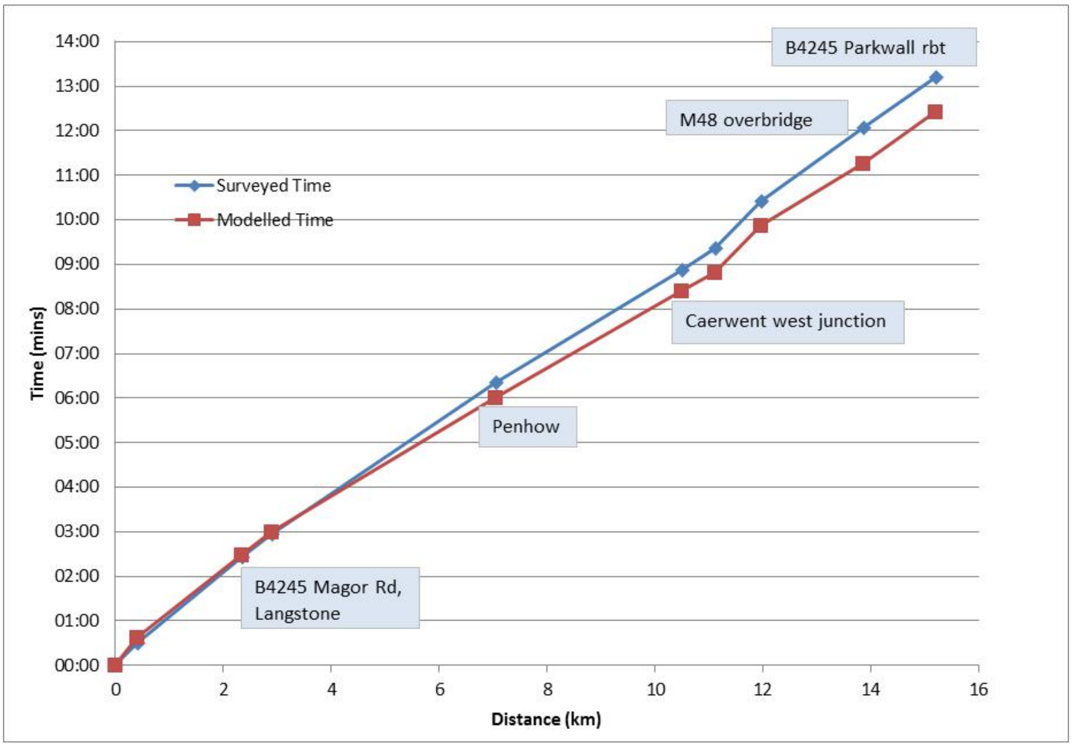
## B9.1 AM Peak – Eastbound



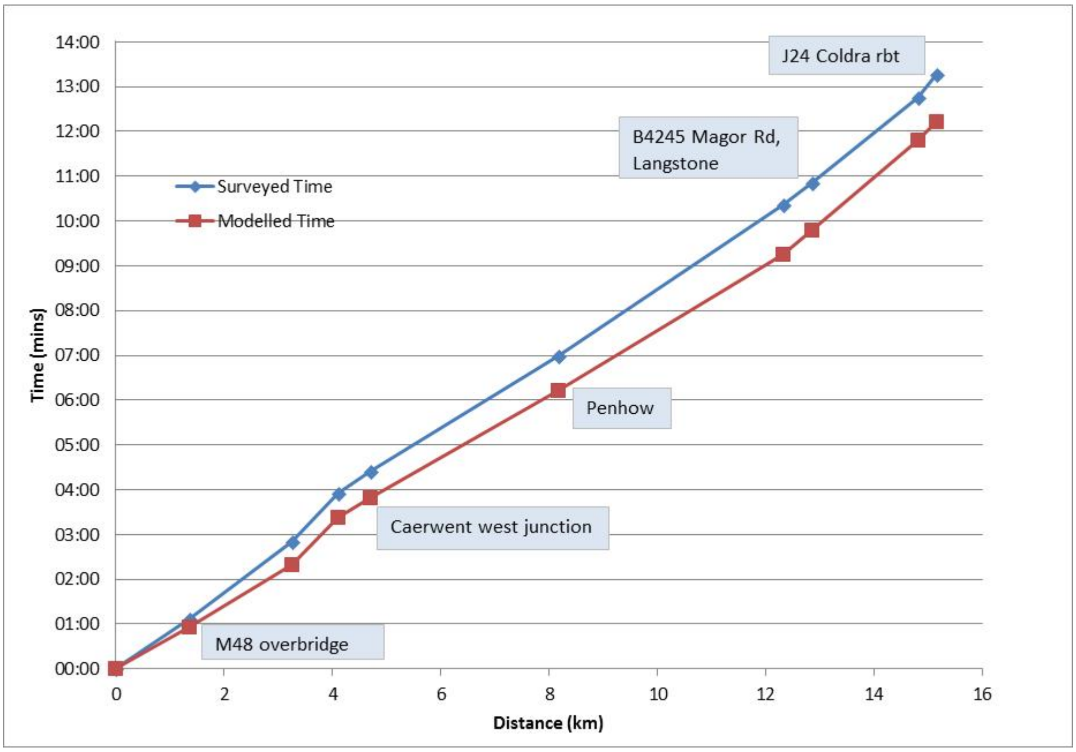

## B9.2 AM Peak – Westbound



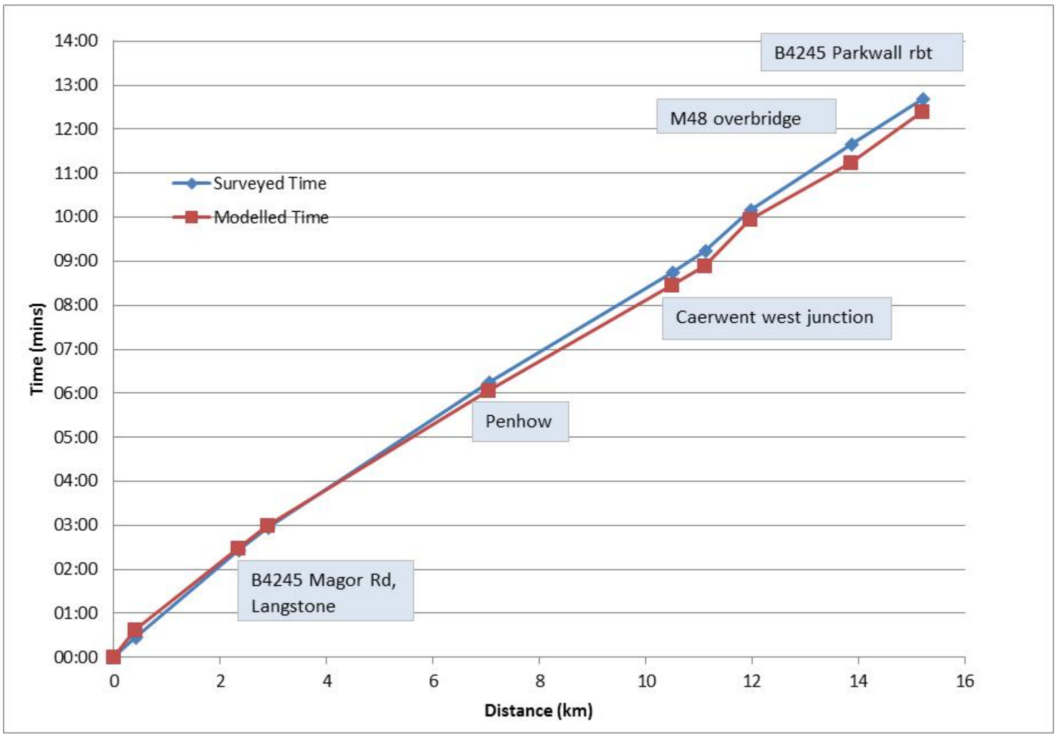
# B9.3 Inter Peak – Eastbound



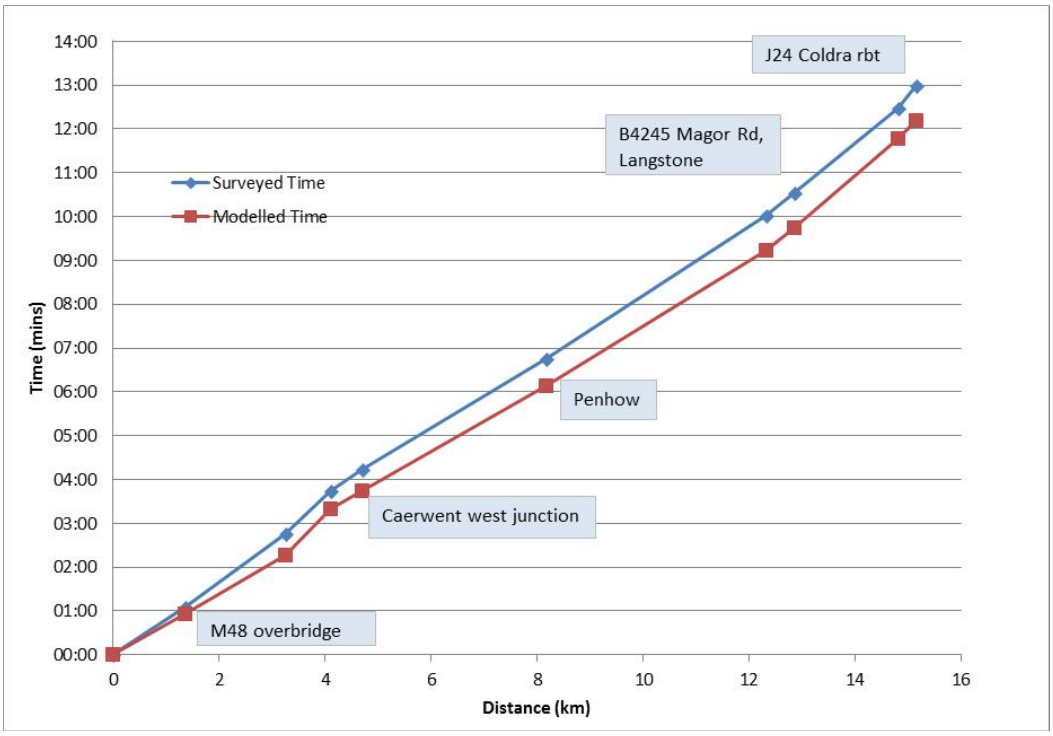

# B9.4 Inter Peak – Westbound



# B9.5 PM Peak – Eastbound

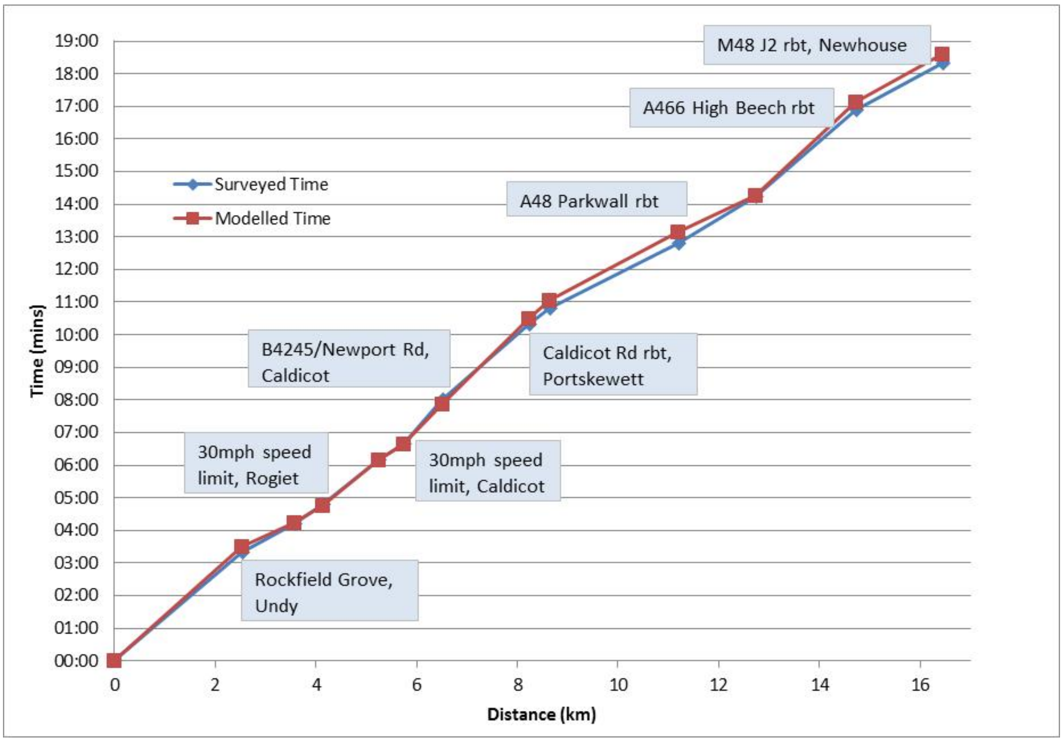



# B9.6 PM Peak – Westbound

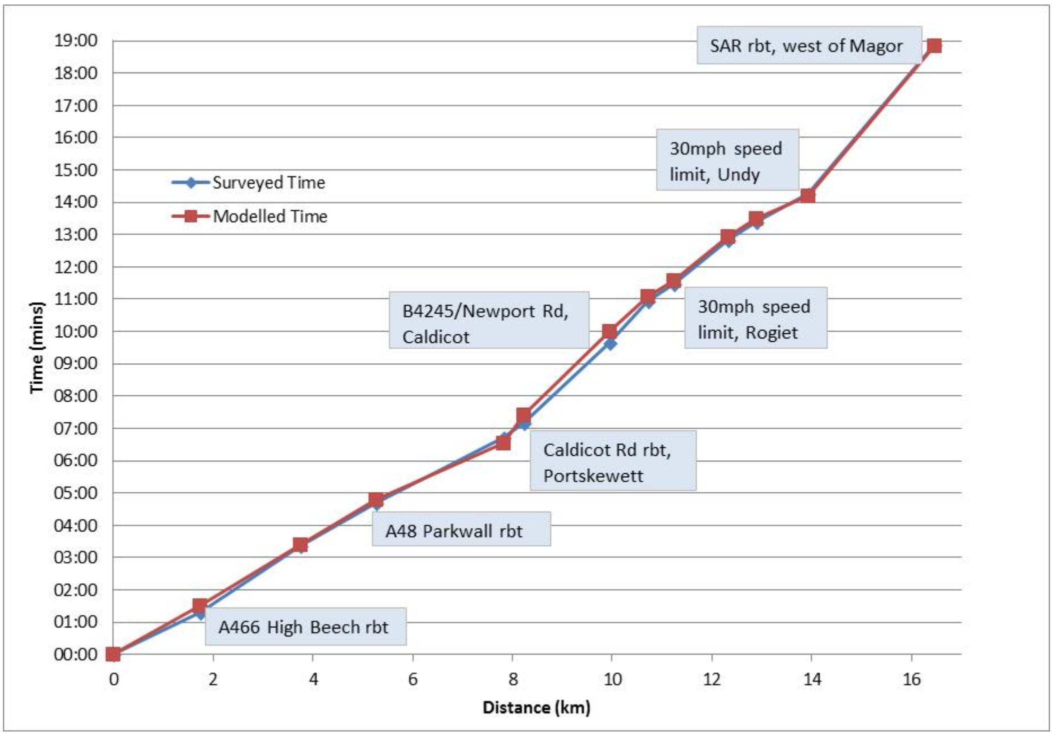


# B10 Route 10: B4245 Magor to M48 J2 (Newhouse), via A48 and A466

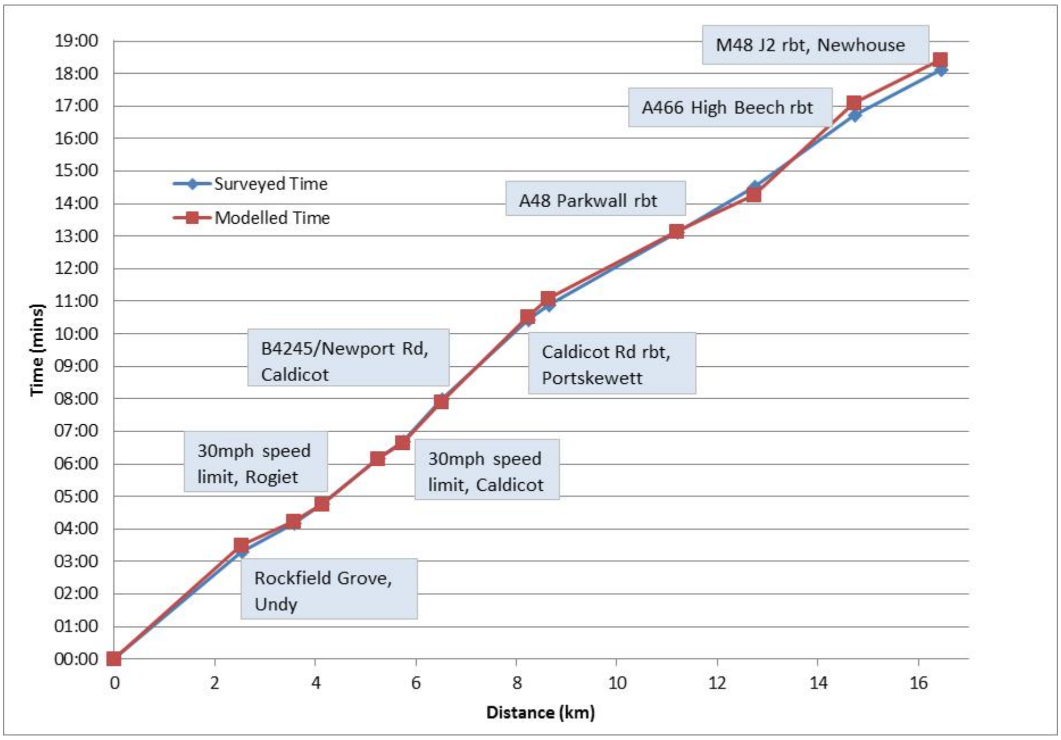
## B10.1 AM Peak – Eastbound



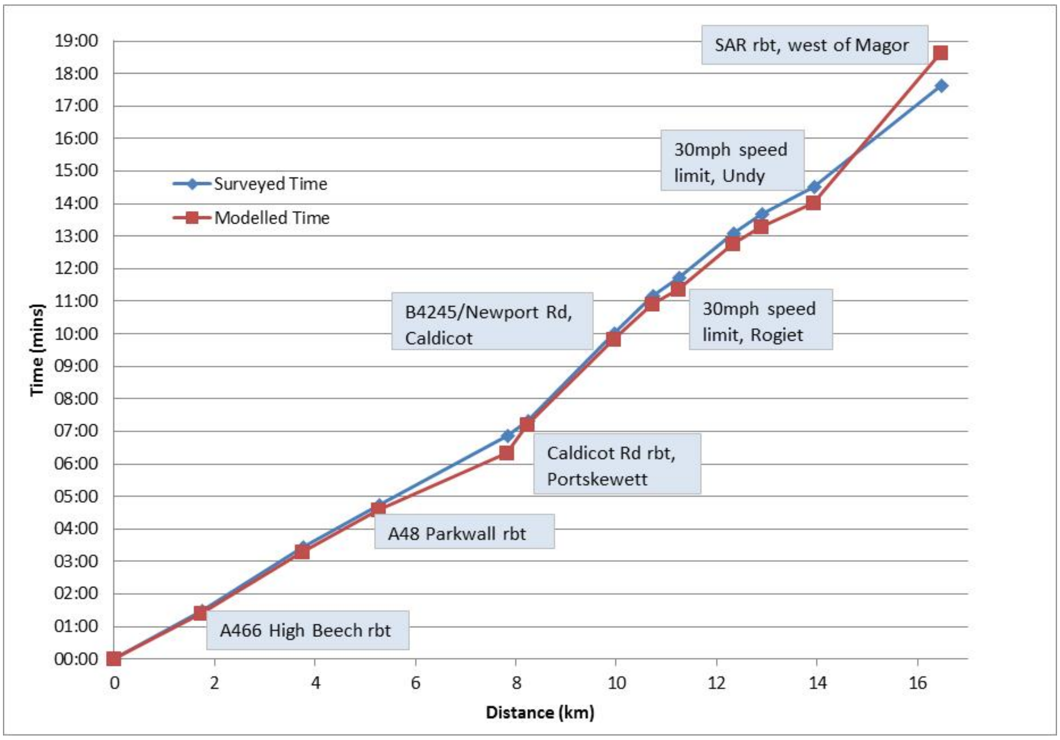

## B10.2 AM Peak – Westbound



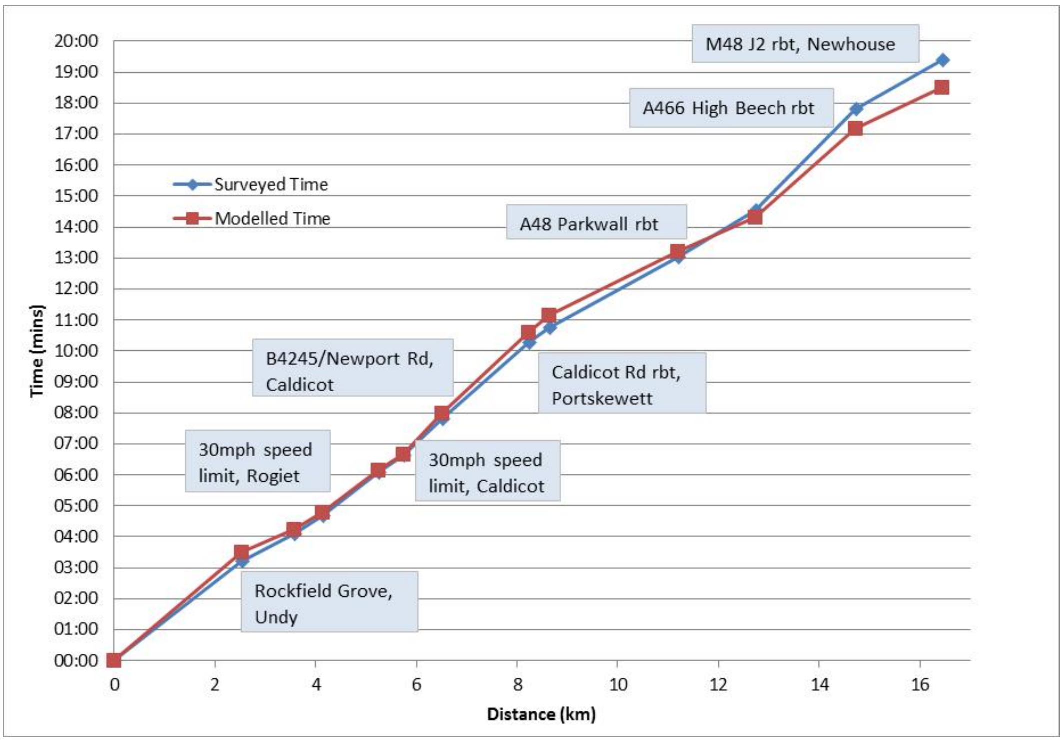
# B10.3 Inter Peak – Eastbound



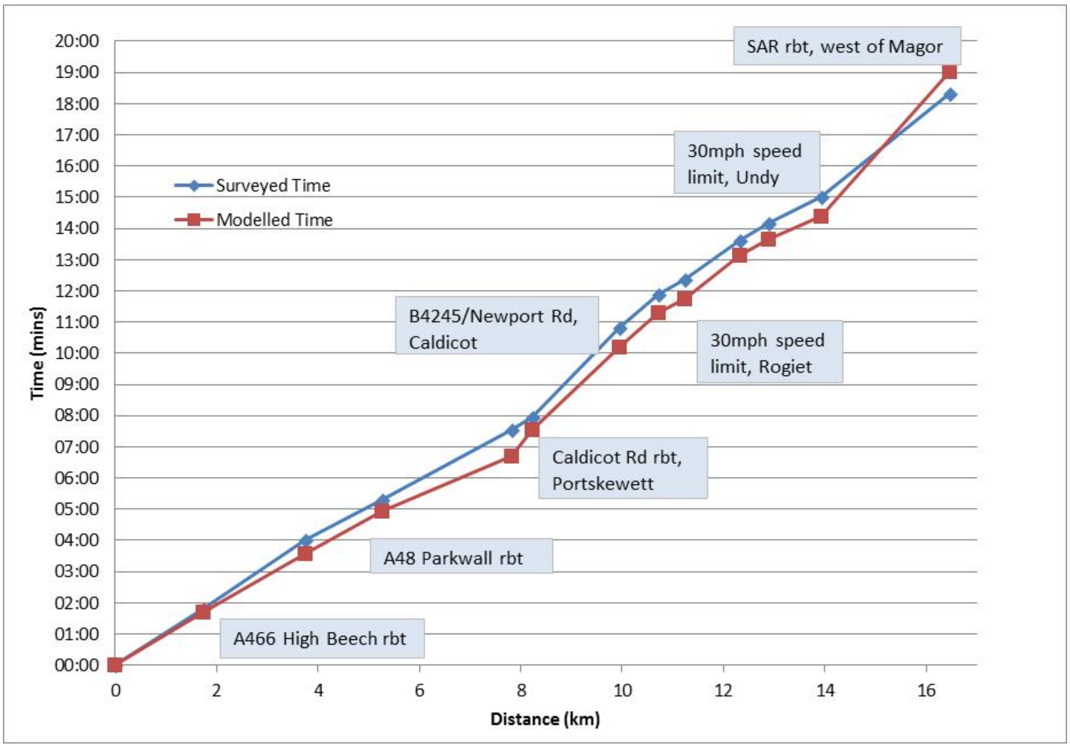

# B10.4 Inter Peak – Westbound



## B10.5 PM Peak – Eastbound

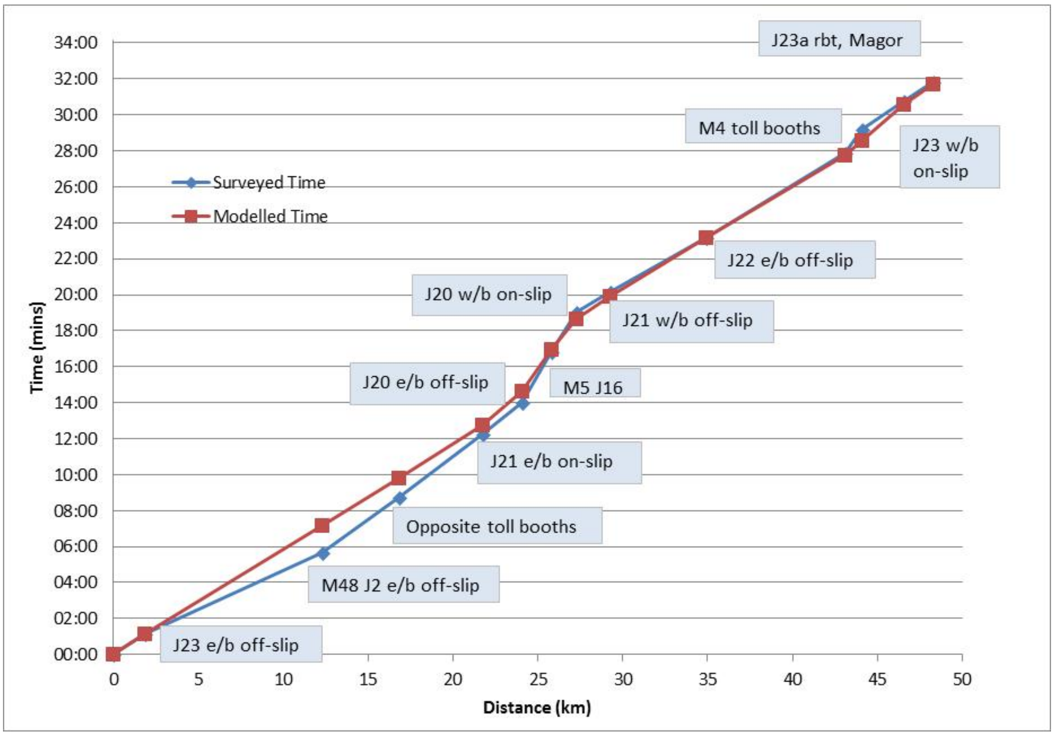



## B10.6 PM Peak – Westbound

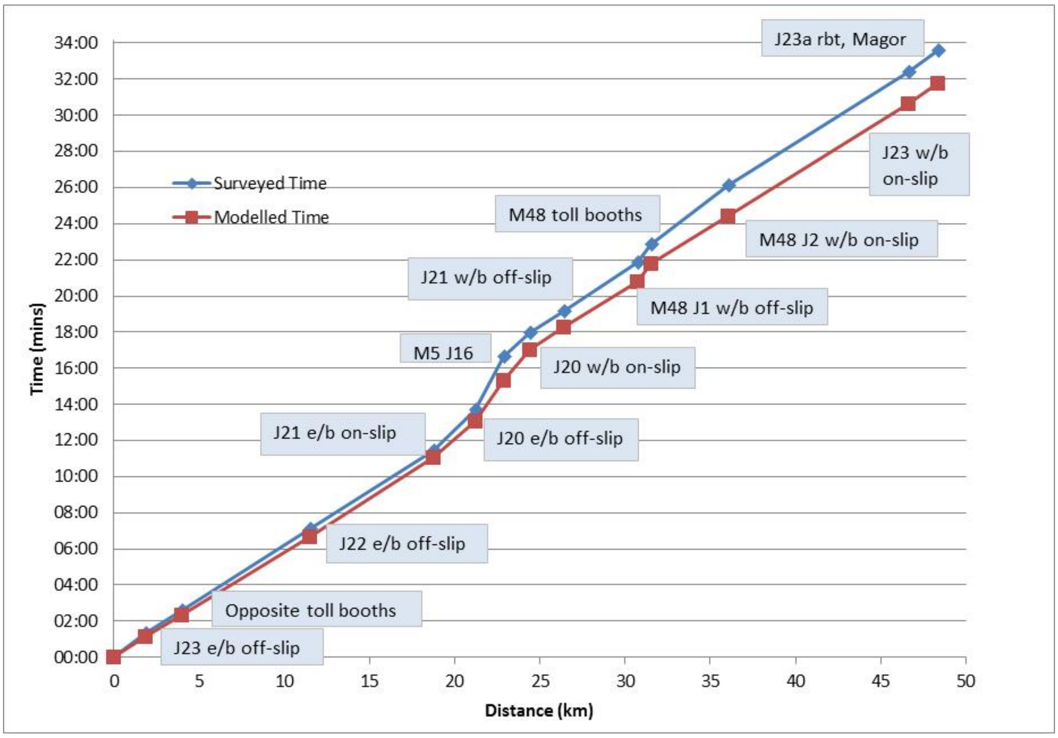


# B11 Route 11: M4/M48 Severn Crossings loop (M4 J23a to M4/M5 interchange)

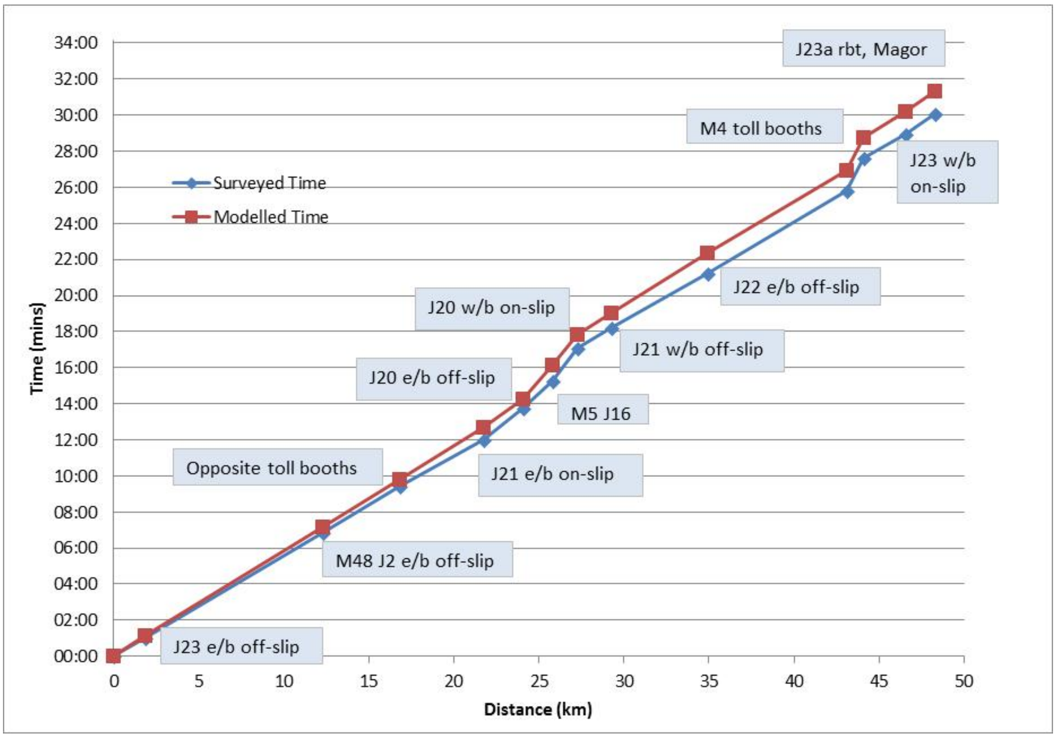
## B11.1 AM Peak – Clockwise



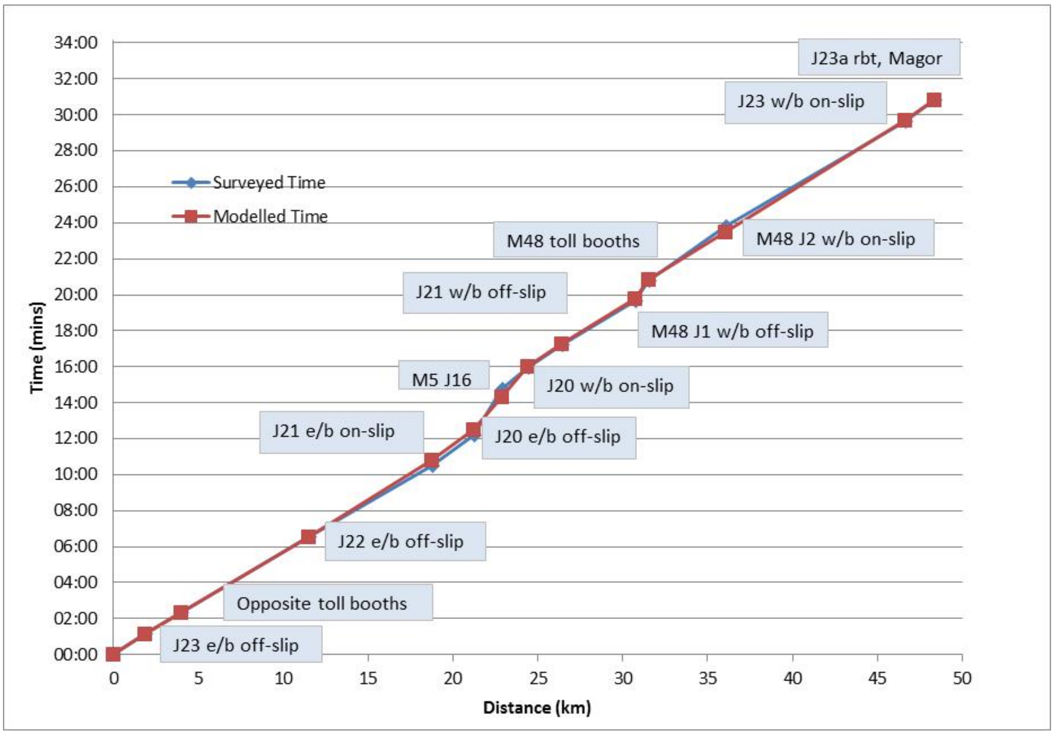

## B11.2 AM Peak – Anticlockwise



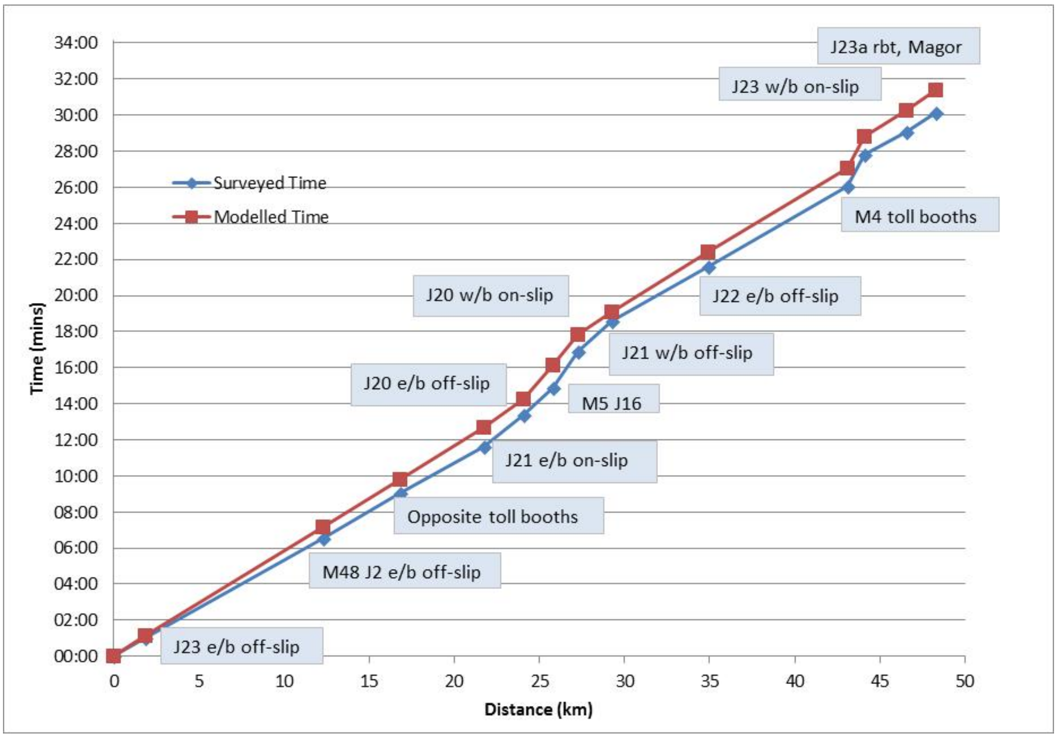
# B11.3 Inter Peak – Clockwise



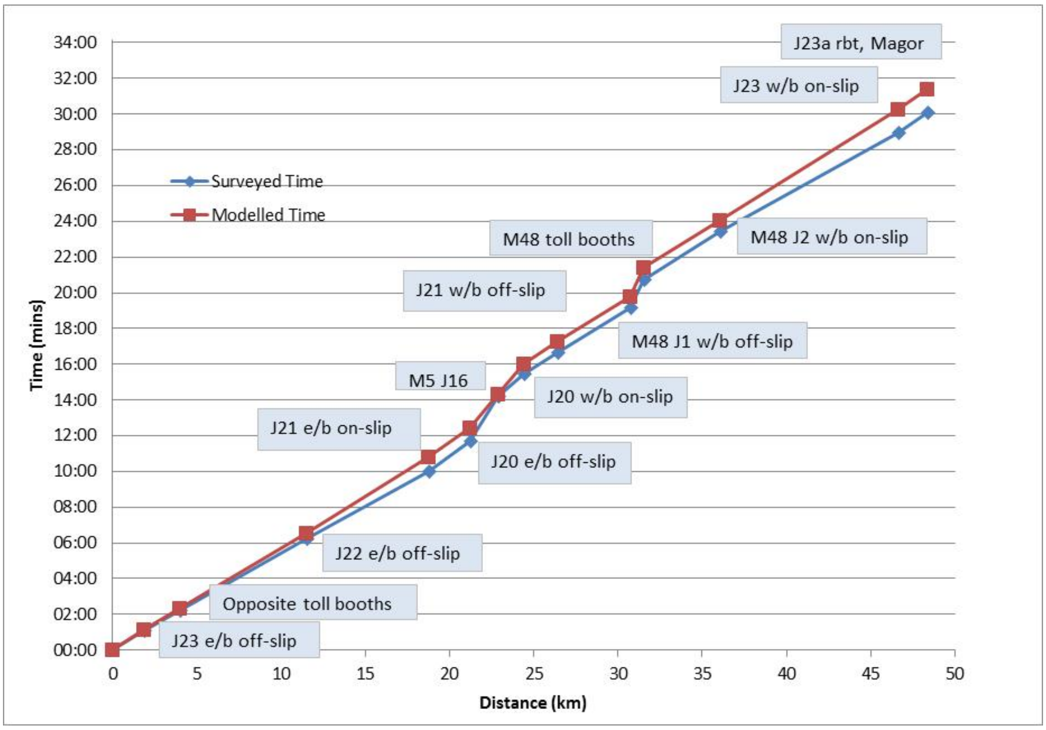

# B11.4 Inter Peak – Anticlockwise



## B11.5 PM Peak – Clockwise




## B11.6 PM Peak – Anticlockwise



# Appendix C

## Details of Variable Demand Model Calibration

# C1 Variable Demand Model Setup

## C1.1 Base Demand

The observed base demand in the M4 traffic model represents highway trips only. Because of the method in which mode choice was included in the demand model it was not necessary to derive a base demand for other modes. Instead, a change in trip frequency was used as a proxy for mode switch. Trips for individual movements were scaled up or down purely on the basis of a change in highway travel costs.

In modelling detailed demand responses, some segmentation by trip and traveller type is essential. At minimum there should be categorisation by trip purpose broken down into commuting, employer's business, and 'other' purposes. In this model private trip demand has been split into these three categories. As set out in WebTAG guidance, commuting trips are treated as doubly constrained, whilst employer's business and 'other' trips are treated as singly production end constrained. This means the origin end is contrained in the AM peak and the destination end in the PM peak. Education trips form part of the 'other' trip purpose.

## C1.2 Initial Control Parameters

Initial redistribution parameters for the M4 Variable Demand Model (VDM) were taken from the median illustrative values in WebTAG as shown in Table C1.1.

**Table C1.1: Destination Choice Parameters**

| Trip Purpose | WebTAG Illustrative Median Value | Adopted Value |
|---|---|---|
| Car, Home-based work | -0.065 | -0.065 |
| Car, Home-based business | -0.067 | -0.074 |
| Car, Non-home-based business | -0.081 | |
| Car, Home-based other | -0.090 | -0.083 |
| Car, Non-home-based other | -0.077 | |

Trip frequency parameters were calibrated during realism testing in order to achieve outturn fuel cost and journey time elasticities within the acceptable range specified within WebTAG guidance. The parameter was specified in the form of scaling parameter θ, which controls the trip frequency response relative to the destination choice response. The selected parameter value was used to represent the combined effect of actual trip frequency response (expected to be marginal) and modal switch in the absence of a detailed multi-modal model.

## C1.3 Long Distance External Movements

In many variable demand modelling applications it is desirable to freeze certain movements in the trip matrix so that they are not subject to the same variable demand response as other trips. This is most often done for external to external trips, on the basis that the costs are not usually fully modelled for such trips or they are only represented very coarsely.

Spatial segmentation is a feature in DIADEM whereby the distribution model parameter ($\lambda$ or $\theta$, depending on its position in the hierarchy) can vary according to the origin-destination movement.

For this demand model spatial segmentation has been applied to scale down the sensitivity parameter for external to external movements, thereby effectively lowering the response for these movements to the extent that they are essentially treated as fixed.

## C1.4 Cost Damping

WebTAG states that there is some evidence that the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length. In order to ensure that the M4 traffic model met the requirements of the variable demand modelling realism tests, it was necessary to include this variation.

The mechanisms by which this could be achieved are generally referred to as ‘cost damping’. The idea behind cost damping is to factor down the changes in travel costs for longer trips so that their sensitivity to individual cost components like fuel cost or travel time is reduced.

If cost damping is employed, it should apply to all trip purposes that are not treated as fixed. While the starting position should be that the same cost damping parameter values are used for both modes, it is sometimes necessary to vary the cost damping parameters between the modes or individual trip purposes in order to achieve satisfactory realism test results.

Cost damping parameters were shown to be necessary following initial realism tests. This conclusion was drawn from the fact that the matrix-based fuel cost elasticity test, which includes long-distance trips representing internal-to-external and external-to-internal movements, initially showed a significantly higher response than the network-based fuel cost elasticity test, which does not include such long-distance movements. Initial cost damping parameters were taken from WebTAG and were adjusted until both the network-based and matrix-based fuel cost elasticity tests gave elasticities within or close to the range specified by the guidance.

The form of the cost damping applied in the M4 model is a function of distance as shown below:

$$\boldsymbol{G'} = \left(\frac{\boldsymbol{d}}{\boldsymbol{k}}\right)^{-\boldsymbol{\alpha}} \cdot \left(\boldsymbol{t} + \frac{\boldsymbol{c}}{\boldsymbol{VOT}}\right)$$

where

| | |
|---|---|
| $t, c$ | are trip time and monetary cost respectively; |
| $VOT$ | is the value of time; |
| $\left(t + \frac{c}{VOT}\right)$ | is generalised cost; |
| $G'$ | is the damped generalised cost; |
| $d$ | is the trip length; |
| $\alpha$ and $k$ | are cost damping parameters that need to be calibrated. |

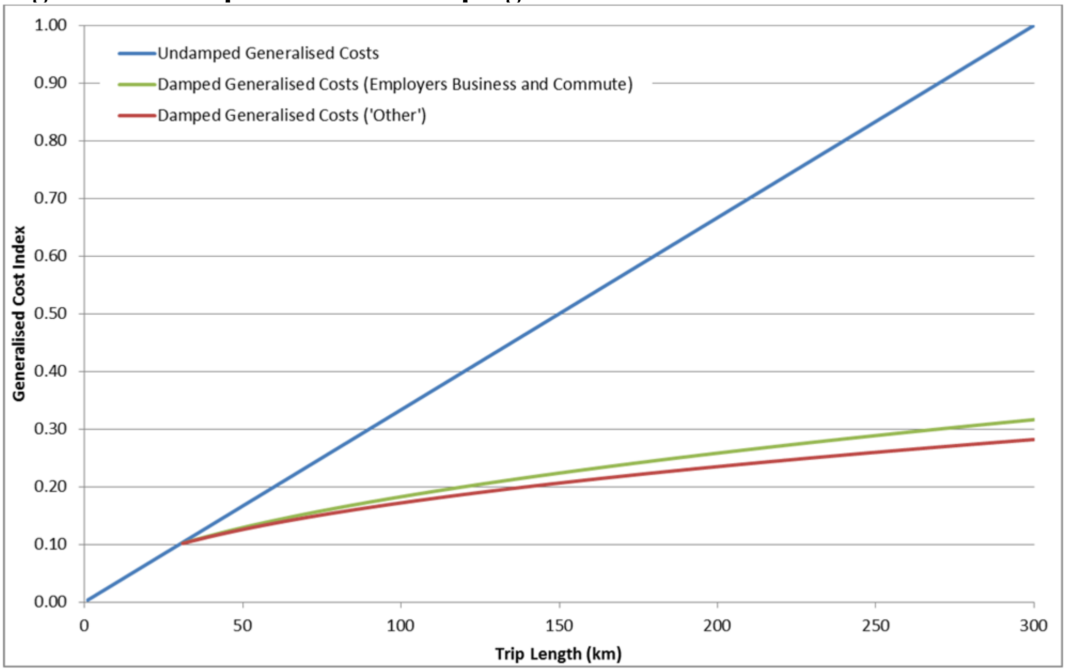
WebTAG guidance states that models that have used this form of cost damping have found it necessary to apply a minimum distance cut-off, below which the cost damping does not apply. The purpose of such a cut-off is to prevent short-distance trips, particularly intra-zonal trips, becoming unduly sensitive to cost changes. Where a cut-off is used it is necessary to specify the distance below which generalised costs would not be reduced, that is the distance, $d'$, up to which the full change in generalised cost would apply.

Commonly used parameter values are quoted as follows in WebTAG:
$\alpha$ = 0.5;
$k$ = 30km; and
$d'$ = 30km.

The parameters given in WebTAG have been adopted without change for the employer's business and commuter trips. However, a comparison of the results of the network-based and matrix-based fuel cost elasticity realism test by user class need demonstrated the need to scale up the $\alpha$ parameter for the 'other' user class. It was therefore adjusted to 0.55 for the car user class containing 'other' trips.

The effect of the selected cost damping parameters is illustrated in Figure C1.1 using the slight approximation that generalised cost varies linearly with distance for this example. For illustration purposes the graph includes only trips in the length range of 0 to 300km. The figure shows that no adjustment to generalised costs is applied for trips less than 30km in length, whereas a trip of 300km in length is scaled down to around 28-32% of the equivalent undamped generalised cost depending on its trip purpose. Cost damping starts to be applied for trips greater than 30km in length. The reduction in generalised cost demonstrates how much less responsive to cost changes trips over several hundred kilometres in length become in comparison to the same run without cost damping applied.

# Figure C1.1: Impact of Cost Damping on Generalised Costs



# C1.5 Summary of VDM Setup

A summary checklist of the variable demand model setup in the context of requirements specified in WebTAG is shown in Table C1.2.

**Table C1.2: Summary of Variable Demand Model Setup**

| Category | Item | Guidance Document | TAG Unit M2 Reference (Jan 2014 Release) | M4 Model | Comment |
|---|---|---|---|---|---|
| VDM Setup | Form of Model | DfT preference is to use an incremental rather than an absolute model | 2.5.6 | ✓ | Incremental model used |
| | Trip Frequency Response | For most purposes it is satisfactory to take the observed trip pattern and modify this pattern incrementally by making it respond to changes in travel times & costs | 2.6.7 | ✓ | Trip frequency response includes proxy for mode choice |
| | Mode Choice | Where there is limited scope for transfer between modes, the demand model may not require a mode choice element or representation of the costs of alternative modes | 2.3.6 | ! | Mode choice response is approximated by including it in the frequency response |
| | Time of Day Choice | It is recommended that large 'macro' adjustments only need to be modelled when considering differential pricing between time periods or access restrictions | 4.1.2 | ✓ | Time of day choice not required |
| | Peak Spreading | If congestion during the peak becomes particularly severe HADES can be used to include peak spreading in the VDM responses | 4.8.8 | ✓ | Peak spreading not required |
| | Destination Choice | It is expected that distribution models will be included in all variable demand models | 1.3.1 | ✓ | Redistribution response included |
| | Hierarchy of Responses | In the absence of strong evidence to the contrary, the model should adopt the default hierarchy of responses as recommended in Section 4.5 of TAG unit M2 | 4.5 | ✓ | Diadem default is compliant with WebTAG |
| | Origin or Destination Constraints | In general, doubly constrained models should be used for commuting and education with other purposes typically modelled as singly production-end constrained | 4.9.10 & 4.9.11 | ✓ | Education trips not modelled separately, but other user classes constrained as specified |
| | Cost Damping | There is some evidence that the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length | 3.3.1 | ✓ | Cost damping applied to trips > 30km |
| | External Movements | There is a suggestion that external to external movements may be treated as fixed | 6.4.13 | ✓ | External to external trips treated as fixed; zones with buffer centroid connectors > 50km treated as external |
| | VDM Control Parameters | Preference is to use local data to calibrate parameters, but where that is not possible illustrative parameters should be used | 5.6.3 | ✓ | Illustrative parameter values used |
| | Base Demand | It is usually necessary to have a base of trips that can transfer to and from car | Table 2.1 | ! | Base demand represents highway trips only - total demand required if mode choice is modelled in more detail |
| | Segmentation by Trip and Traveller Type | Categorisation by trip purpose broken down into commuting, employer's business, and 'other' purposes | Table 2.1 | ✓ | Specified categorisation of demand by trip purpose adopted |
| | Car Availability | Some form of distinction between travellers with and without a car available is very desirable and is expected where mode choice is to be considered | Table 2.1 | ! | Car availability not included - only required if mode choice is modelled in more detail |

# C2 Systematic Approach to VDM Calibration

The DfT recommends in WebTAG that a record of all changes made as part of the VDM calibration process should be kept in order to reduce the chances of peculiar combinations of parameter values being selected without a solid evidence base.

Where local data is not available for the calibration of demand response parameters the WebTAG median illustrative values should be adopted in the first instance. Cost damping should not initially be included until the need for it has been illustrated.

Details of all runs that were conducted to derive the adopted parameters for VDM are shown in the model run log included in Section C2.1 of this appendix. The demand model outputs were initially checked based on the network-based fuel cost elasticity realism test in order to gauge whether they were giving sensible outputs. For runs where acceptable outturn elasticities were achieved for the network-based test the matrix-based fuel cost elasticity analysis was then also carried out. The model run log therefore does not show results for the matrix-based fuel cost elasticity for every calibration run if it was not deemed necessary.

The principle of how parameters were derived was as follows:

- Undertake a demand model run with median distribution parameters from WebTAG with no cost damping;
- If necessary, run a second test with cost damping enabled;
- If necessary, run a third test with minimum or maximum distribution parameters and cost damping to assess how far the distribution parameters need to be stretched in order to reach acceptable fuel cost and journey time elasticity's.
- Then run further tests to calibrate the responses until all criteria specified in WebTAG are met.

The adopted values from run 'R007' are highlighted in grey in the model run log. These are the parameters that are proposed for use in traffic forecasting for the M4 model.

A summary of the realism testing process and results in the context of requirements specified in WebTAG is shown in Section C2.2.

# C2.1 Record of VDM Parameter Calibration Runs

| RUN ID | TIME PERIOD | USER CLASS | %GAP | DISTRIBUTION RESPONSE | SENSITIVITY λ | SENSITIVITY θ | COST DAMPING k | COST DAMPING α | COST DAMPING d' | EXT-EXT TRIPS FROZEN | FUEL COST BASE | FUEL COST TEST | NETWORK-BASED: SIMULATION + BUFFER LINKS ONLY PCU-KMS BASE | NETWORK-BASED PCU-KMS TEST | NETWORK-BASED UC ARC ELASTICITY | NETWORK-BASED TP ARC ELASTICITY | NETWORK-BASED ANNUAL ARC ELASTICITY | MATRIX-BASED: TOTAL EXCLUDING EXTERNAL-EXTERNAL MOVEMENTS PCU-KMS BASE | MATRIX-BASED PCU-KMS TEST | MATRIX-BASED UC ARC ELASTICITY | MATRIX-BASED TP ARC ELASTICITY | MATRIX-BASED ANNUAL ARC ELASTICITY | RUN DESCRIPTION | RESULTS ANALYSIS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R001 | AM | Employer's Business | 0.09% | Origin Constrained | -0.074 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 306,708 | 301,313 | -0.19 | -0.32 | -0.40 | N/A | | | | | **Run with redistribution only with median illustrative WebTAG lambda values.** | Slightly too high network-based outturn fuel cost elasticity. Scale of response for employer's business and other trip purposes too high. |
| | | Other | | Origin Constrained | -0.083 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 232,084 | 213,970 | -0.85 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 512,146 | 503,775 | -0.17 | | | | | | | | | |
| | IP | Employer's Business | 0.10% | Origin Constrained | -0.074 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 201,155 | 196,892 | -0.22 | -0.50 | | | | | | | | |
| | | Other | | Origin Constrained | -0.083 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 374,741 | 348,592 | -0.76 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 101,215 | 99,881 | -0.14 | | | | | | | | | |
| | PM | Employer's Business | 0.10% | Destination Constrained | -0.074 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 294,437 | 288,572 | -0.21 | -0.34 | | | | | | | | |
| | | Other | | Destination Constrained | -0.083 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 377,657 | 354,347 | -0.67 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | N/A | N/A | N/A | Yes | 100% | 110% | 413,667 | 407,848 | -0.15 | | | | | | | | | |
| R002 | AM | Employer's Business | 0.10% | Origin Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,774 | -0.07 | -0.18 | -0.22 | N/A | | | | | Run with redistribution only run with median illustrative WebTAG lambda values. **Cost damping added to lower overall response.** | Slightly too low network-based outturn fuel cost elasticity. Scale of response for commute perhaps a little too low.<br><br>Run with maximum illustrative values required to check possible increase in response. |
| | | Other | | Origin Constrained | -0.083 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 232,084 | 222,774 | -0.43 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 505,808 | -0.13 | | | | | | | | | |
| | IP | Employer's Business | 0.10% | Origin Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,559 | -0.08 | -0.24 | | | | | | | | |
| | | Other | | Origin Constrained | -0.083 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 374,741 | 362,074 | -0.36 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 100,230 | -0.10 | | | | | | | | | |
| | PM | Employer's Business | 0.10% | Destination Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 292,207 | -0.08 | -0.18 | | | | | | | | |
| | | Other | | Destination Constrained | -0.083 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 377,657 | 366,221 | -0.32 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 409,295 | -0.11 | | | | | | | | | |
| R003 | AM | Employer's Business | 0.09% | Origin Constrained | -0.106 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,026 | -0.09 | -0.26 | -0.32 | 552,734 | 544,410 | -0.16 | -0.36 | -0.55 | **Run with redistribution only run with maximum illustrative WebTAG lambda values.** Cost damping kept as in previous run. | Network-based fuel cost elasticity ok. Matrix-based outturn fuel cost elasticity showing slightly too strong response.<br><br>These results can be used to inform a finer calibration of the lambda parameters. |
| | | Other | | Origin Constrained | -0.133 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 232,084 | 218,060 | -0.65 | | | 327,495 | 295,781 | -1.07 | | | | |
| | | Commute | | Doubly Constrained | -0.113 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 503,211 | -0.18 | | | 577,298 | 568,401 | -0.16 | | | | |
| | IP | Employer's Business | 0.10% | Origin Constrained | -0.106 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 198,950 | -0.12 | -0.36 | | 349,066 | 342,506 | -0.20 | -0.64 | | | |
| | | Other | | Origin Constrained | -0.133 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 374,741 | 355,540 | -0.55 | | | 536,383 | 485,147 | -1.05 | | | | |
| | | Commute | | Doubly Constrained | -0.113 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 99,714 | -0.16 | | | 114,819 | 113,374 | -0.13 | | | | |
| | PM | Employer's Business | 0.10% | Destination Constrained | -0.106 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 291,435 | -0.11 | -0.26 | | 526,955 | 518,245 | -0.17 | -0.41 | | | |
| | | Other | | Destination Constrained | -0.133 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 377,657 | 360,393 | -0.49 | | | 529,503 | 486,488 | -0.89 | | | | |
| | | Commute | | Doubly Constrained | -0.113 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 407,491 | -0.16 | | | 462,265 | 456,207 | -0.14 | | | | |
| R004 | AM | Employer's Business | 0.12% | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,374 | -0.08 | -0.20 | -0.24 | N/A | | | | | **Run with redistribution only run with calibrated lambda values** based on previous runs. Cost damping kept as in previous run. | |
| | | Other | | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 232,084 | 222,006 | -0.47 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 504,399 | -0.16 | | | | | | | | | |
| | IP | Employer's Business | 0.07% | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,238 | -0.10 | -0.27 | | | | | | | | |
| | | Other | | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 374,741 | 361,044 | -0.39 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 99,932 | -0.13 | | | | | | | | | |
| | PM | Employer's Business | 0.10% | Destination Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 291,804 | -0.09 | -0.20 | | | | | | | | |
| | | Other | | Destination Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 377,657 | 365,372 | -0.35 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 408,360 | -0.14 | | | | | | | | | |
| R005 | AM | Employer's Business | 0.10% | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,375 | -0.08 | -0.22 | -0.26 | 552,734 | 546,306 | -0.12 | -0.28 | -0.42 | **Run with redistribution only run with better calibrated lambda values** based on previous runs. Cost damping kept as in previous run. | Result is good for network-based and matrix-based outturn fuel cost elasticity. Commuter response slightly on the weak side, but ok. These parameters can be used if no frequency response as proxy for mode choice is required. |
| | | Other | | Origin Constrained | -0.095 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 232,084 | 221,494 | -0.49 | | | 327,495 | 303,821 | -0.79 | | | | |
| | | Commute | | Doubly Constrained | -0.110 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 503,264 | -0.18 | | | 577,298 | 568,614 | -0.16 | | | | |
| | IP | Employer's Business | 0.08% | Origin Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,241 | -0.10 | -0.28 | | 349,066 | 343,438 | -0.17 | -0.48 | | | |
| | | Other | | Origin Constrained | -0.095 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 374,741 | 360,385 | -0.41 | | | 536,383 | 498,610 | -0.77 | | | | |
| | | Commute | | Doubly Constrained | -0.110 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 99,738 | -0.15 | | | 114,819 | 113,396 | -0.13 | | | | |
| | PM | Employer's Business | 0.06% | Destination Constrained | -0.090 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 291,785 | -0.09 | -0.21 | | 526,955 | 519,388 | -0.15 | -0.32 | | | |
| | | Other | | Destination Constrained | -0.095 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 377,657 | 364,623 | -0.37 | | | 529,503 | 497,214 | -0.66 | | | | |
| | | Commute | | Doubly Constrained | -0.110 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 407,557 | -0.16 | | | 462,265 | 456,265 | -0.14 | | | | |
| R006 | AM | Employer's Business | 0.10% | Origin Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,100 | -0.09 | -0.24 | -0.28 | N/A | | | | | **Run with redistribution & frequency response with median illustrative lambda values.** Cost damping kept as in previous run. | Overall annual network-based outturn fuel cost elasticity is ok, but response of 'other' users is a little bit strong. |
| | | Other | | Origin Constrained | -0.083 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 232,084 | 221,134 | -0.51 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 501,688 | -0.22 | | | | | | | | | |
| | IP | Employer's Business | 0.07% | Origin Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,141 | -0.11 | -0.30 | | | | | | | | |
| | | Other | | Origin Constrained | -0.083 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 374,741 | 359,337 | -0.44 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 99,430 | -0.19 | | | | | | | | | |
| | PM | Employer's Business | 0.09% | Destination Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 291,591 | -0.10 | -0.24 | | | | | | | | |
| | | Other | | Destination Constrained | -0.083 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 377,657 | 363,720 | -0.39 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 406,155 | -0.19 | | | | | | | | | |
| R007 | AM | Employer's Business | 0.11% | Origin Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,099 | -0.09 | -0.24 | -0.27 | 552,734 | 546,239 | -0.12 | -0.28 | -0.39 | Run with redistribution & frequency response with median illustrative lambda values. **Cost damping increased marginally for 'other' users compared to previous run.** | Result is ok for network-based fuel cost elasticity. Matrix-based result shows strong response, which is sensible based on long distance ext-int trips. Sensible that response in IP is higher than peak response. Elasticities for individual user classes also sensible. |
| | | Other | | Origin Constrained | -0.083 | 0.05 | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 232,084 | 221,849 | -0.47 | | | 327,495 | 306,256 | -0.70 | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 501,685 | -0.22 | | | 577,298 | 566,411 | -0.20 | | | | |
| | IP | Employer's Business | 0.06% | Origin Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,137 | -0.11 | -0.28 | | 349,066 | 343,601 | -0.17 | -0.44 | | | |
| | | Other | | Origin Constrained | -0.083 | 0.05 | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 374,741 | 360,403 | -0.41 | | | 536,383 | 502,325 | -0.69 | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 99,430 | -0.19 | | | 114,819 | 112,946 | -0.17 | | | | |
| | PM | Employer's Business | 0.08% | Destination Constrained | -0.074 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 291,585 | -0.10 | -0.23 | | 526,955 | 519,494 | -0.15 | -0.31 | | | |
| | | Other | | Destination Constrained | -0.083 | 0.05 | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 377,657 | 364,648 | -0.37 | | | 529,503 | 500,325 | -0.59 | | | | |
| | | Commute | | Doubly Constrained | -0.065 | 0.05 | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 406,157 | -0.19 | | | 462,265 | 454,428 | -0.18 | | | | |
| R007x | AM | Employer's Business | 0.09% | Origin Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 306,708 | 304,736 | -0.07 | -0.17 | -0.21 | N/A | | | | | **Run with redistribution response only with median illustrative lambda values.** Cost damping kept as in previous run. This run was carried out in order to determine the amount of overall response that is due to the redistribution & frequency response separately. | This run was created to analyse the relative influence of each VDM response. 78% of total response (change in car veh-kms in network-based analysis) is due to redistribution and 22% due to trip frequency response. |
| | | Other | | Origin Constrained | -0.083 | N/A | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 232,084 | 223,200 | -0.41 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 512,146 | 505,728 | -0.13 | | | | | | | | | |
| | IP | Employer's Business | 0.06% | Origin Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 201,155 | 199,545 | -0.08 | -0.23 | | | | | | | | |
| | | Other | | Origin Constrained | -0.083 | N/A | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 374,741 | 362,892 | -0.34 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 101,215 | 100,225 | -0.10 | | | | | | | | | |
| | PM | Employer's Business | 0.09% | Destination Constrained | -0.074 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 294,437 | 292,200 | -0.08 | -0.17 | | | | | | | | |
| | | Other | | Destination Constrained | -0.083 | N/A | 30,000 | 0.55 | 30,000 | Yes | 100% | 110% | 377,657 | 366,983 | -0.30 | | | | | | | | | |
| | | Commute | | Doubly Constrained | -0.065 | N/A | 30,000 | 0.5 | 30,000 | Yes | 100% | 110% | 413,667 | 409,293 | -0.11 | | | | | | | | | |

# C2.2 Summary of Realism Testing

## Table C2.1: Summary of Realism Testing

| Category | Item | Guidance Document | TAG Unit M2 Reference (Jan 2014 Release) | M4 Model | Comment |
|---|---|---|---|---|---|
| Realism Testing | Cost Damping | Initial tests to be carried out without cost damping and should then be introduced if the need is demonstrated | 6.4.9 & 6.5.4 | ✓ | Initial fuel cost elasticity realism tests showed a need for cost damping |
| | Sensitivity Parameters (λ) | Values should lie within 25% of WebTAG median illustrative values | 6.5.6 | ✓ | Median illustrative λ values adopted |
| | | A record of all the changes made and their results should be kept and made available if requested | 6.5.6 | ✓ | All model runs recorded and archived |
| | Convergence | Convergence parameter should demonstrate that the solution is in close proximity to the true equilibrium and stable (%GAP < 0.1%) | 6.3.8 | ✓ | Model runs meet convergence criteria and solutions are stable |
| | Scaling Parameters (θ) | In the absence of mode choice response theta parameters for frequency response should be inflated as a proxy for mode choice | 4.7.3 | ✓ | θ parameters inflated as a proxy for mode choice and resulting effect on number of trips monitored in realism tests |
| | Car Fuel Cost Elasticity | A network-based and a matrix-based fuel cost test is to be carried out | 6.4.13 | ✓ | Both fuel cost elasticity tests have been carried out |
| | | Elasticity of car kilometres with respect to fuel cost should be between -0.25 and -0.35 | 6.4.17 | ✓ | Fuel Cost Elasticity: Network-based: -0.27; Matrix-based: -0.39. But matrix-based analysis includes long journeys which show a stronger response due to coarse zone system in external areas. |
| | | Annual average elasticities for employers' business trips should be near to -0.1, for discretionary trips near to -0.4 | 6.4.17 | ✓ | Outturn fuel cost elasticities show the correct trend by trip purpose |
| | | the pattern of all-purpose elasticities shows peak period elasticities which are lower than inter-peak elasticities | 6.4.17 | ✓ | Outturn fuel cost elasticities show the correct trend by time period |
| | Car Journey Time Elasticity | Journey time elasticities should be calculated using a single run of the demand model | 6.4.27 | ! | This test cannot be undertaken in Diadem |
| | | Journey time elasticities should be calculated from both a model run and on a matrix basis using times from the networks | 6.4.28 | ! | This test cannot be undertaken in Diadem |
| | | Elasticity of car trips with respect to journey time should be < -2.0 | 6.4.28 | ✓ | Using the crude method outlined in previous versions of WebTAG gives a journey time elasticity of -0.1 |
| | Sensitivity Testing | Sensitivity testing should be undertaken for sensitivity parameters that govern the individual demand mechanisms (i.e. the λ values) by increasing them by +50% of the mean | 6.6.2 | ✓ | Sensitivity test shows acceptable level of change to outturn network-based fuel cost elasticity (-0.38). |

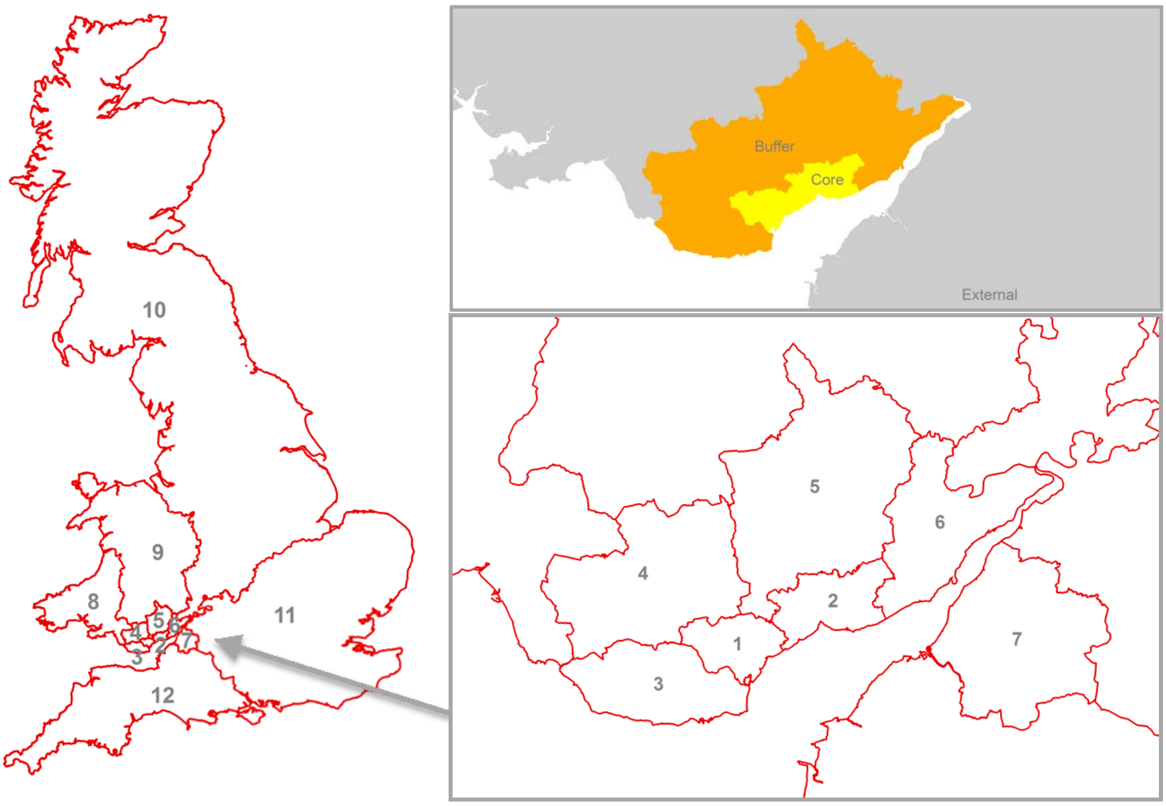
# C3 Spatial Analysis of Demand Response

Changes applied to the demand matrix by the VDM process need to be checked rigorously in order to give confidence in the realism of the results produced when using the adopted parameter values. A sector system, shown in Figure C3.1, was set up in order to undertake a spatial analysis of the demand response of run 'R007'. The changes in the demand matrix presented in this section are those resulting from a 10% increase in fuel cost as used in the fuel cost realism test. Relative increases are shown in green and relative reductions are shown in red.

The sector system reflects the following areas:

- Sector 1 & 2 represent the wider Cardiff and Newport area respectively. In the summarising results these sectors are referred to as the 'core' area.
- Sector 3 to 6 represent broadly a 30km cordon around the centre of Cardiff & Newport. The 30km boundary was selected because cost damping is applied to trips greater than 30km in length. These sectors are referred to as the 'buffer' area in the summarising sector analysis.
- Sectors 7 to 12 represent areas in the rest of Great Britain outside the 30km cordon. These are referred to as 'external' in the summary analysis. It should be noted that 'external' in this context does not refer to exactly the same as the long distance external zones for which demand is frozen.

**Figure C3.1: Sector System used for VDM Response Check**



## Table C3.1: Demand Matrix Changes in Fuel Cost Realism Test

| *all units in PCUs* | | AM Peak | | | | Inter Peak | | | | PM Peak | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sector | Core | Buffer | Ext | Total | Core | Buffer | Ext | Total | Core | Buffer | Ext | Total |
| Employer's Business | Core | 13 | -2 | -13 | **-1** | 11 | -1 | -12 | **-2** | 13 | 7 | 1 | **21** |
| | Buffer | 8 | 2 | -7 | **3** | 4 | 1 | -7 | **-2** | -2 | 2 | -1 | **-1** |
| | Ext | 0 | -1 | -4 | **-5** | -1 | -1 | -2 | **-3** | -13 | -11 | -5 | **-29** |
| | Total | **21** | **-1** | **-24** | **-3** | **14** | **-1** | **-21** | **-7** | **-2** | **-3** | **-4** | **-9** |
| 'Other' | Core | 91 | -49 | -61 | **-20** | 118 | -70 | -75 | **-27** | 105 | 13 | 0 | **118** |
| | Buffer | 17 | 5 | -30 | **-8** | 24 | 5 | -49 | **-20** | -69 | 9 | -3 | **-63** |
| | Ext | -1 | 0 | -10 | **-11** | -3 | -5 | -11 | **-19** | -63 | -42 | -14 | **-119** |
| | Total | **106** | **-44** | **-101** | **-38** | **139** | **-70** | **-134** | **-65** | **-27** | **-20** | **-17** | **-63** |
| Commuter | Core | -19 | -29 | -28 | **-76** | -13 | -9 | -4 | **-25** | -24 | -37 | -14 | **-75** |
| | Buffer | -49 | -1 | 2 | **-49** | -8 | 0 | 0 | **-8** | -24 | -1 | 1 | **-25** |
| | Ext | -27 | 0 | 5 | **-22** | -4 | 0 | 1 | **-3** | -22 | -4 | 3 | **-23** |
| | Total | **-95** | **-30** | **-21** | **-147** | **-25** | **-9** | **-3** | **-37** | **-70** | **-42** | **-11** | **-123** |

## Table C3.2: Relative Demand Matrix Changes in Fuel Cost Realism Test

| | | AM Peak | | | | Inter Peak | | | | PM Peak | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sector | Core | Buffer | Ext | Total | Core | Buffer | Ext | Total | Core | Buffer | Ext | Total |
| Employer's Business | Core | 0.5% | -0.3% | -2.2% | **0.0%** | 0.5% | -0.2% | -2.7% | **-0.1%** | 0.3% | 0.7% | 0.2% | **0.4%** |
| | Buffer | 0.6% | 0.7% | -1.3% | **0.1%** | 0.7% | 0.3% | -2.0% | **-0.1%** | -0.3% | 0.5% | -0.2% | **-0.1%** |
| | Ext | 0.0% | -0.3% | -0.6% | **-0.3%** | -0.1% | -0.3% | -0.4% | **-0.3%** | -2.6% | -2.0% | -0.7% | **-1.6%** |
| | Total | **0.5%** | **0.0%** | **-1.3%** | **0.0%** | **0.5%** | **-0.1%** | **-1.7%** | **-0.1%** | **0.0%** | **-0.1%** | **-0.3%** | **-0.1%** |
| 'Other' | Core | 1.1% | -3.4% | -16.2% | **-0.2%** | 1.0% | -3.7% | -15.2% | **-0.2%** | 0.8% | 0.5% | 0.0% | **0.8%** |
| | Buffer | 1.1% | 0.6% | -9.3% | **-0.3%** | 1.1% | 0.4% | -8.4% | **-0.5%** | -3.0% | 0.8% | -0.7% | **-1.6%** |
| | Ext | -0.3% | 0.1% | -2.8% | **-1.1%** | -0.6% | -1.0% | -1.4% | **-1.1%** | -14.5% | -7.3% | -2.2% | **-7.3%** |
| | Total | **1.1%** | **-1.7%** | **-9.6%** | **-0.3%** | **1.0%** | **-2.0%** | **-7.4%** | **-0.3%** | **-0.2%** | **-0.5%** | **-1.1%** | **-0.3%** |
| Commuter | Core | -0.2% | -1.1% | -3.2% | **-0.6%** | -0.4% | -1.1% | -3.1% | **-0.6%** | -0.3% | -1.0% | -2.1% | **-0.6%** |
| | Buffer | -1.1% | -0.1% | 0.1% | **-0.7%** | -1.0% | 0.1% | -0.1% | **-0.6%** | -1.2% | -0.1% | 0.2% | **-0.7%** |
| | Ext | -2.8% | 0.0% | 0.9% | **-1.1%** | -2.7% | 0.0% | 0.7% | **-0.7%** | -3.0% | -0.3% | 0.8% | **-0.9%** |
| | Total | **-0.6%** | **-0.7%** | **-0.8%** | **-0.7%** | **-0.6%** | **-0.7%** | **-0.8%** | **-0.6%** | **-0.6%** | **-0.7%** | **-0.7%** | **-0.6%** |

Employer’s business users show approximately a 0.1% reduction in trips in response to a 10% increase in fuel cost throughout the day. For ‘other’ and commuter trips the overall reduction is around 0.3% and 0.7% respectively. This highlights that employer’s business trips are least sensitive and commuter trips are most sensitive to changes in travel cost.

The redistribution response for employer’s business and ‘other’ trips is origin constrained in the AM and inter peak. Consequently the change in origin totals is relatively balanced throughout the model, whereas for destinations a shift from external to core zones is evident for these trip purposes. The PM peak for these trip purposes is destination constrained and therefore the opposite pattern is evident with origins shifting from external to core zones. So, despite an increase in travel cost the number of trips internal to the core area increase to compensate for a reduction in trips between the core area and buffer and external areas.

For commuter trips the distribution response is doubly constrained. Therefore, the reduction in origin and destination totals is relatively balanced throughout all areas of the model. However, it is noticeable that there is a shift in trip patterns with a relatively high percentage reduction in trips between external and core and buffer and core compared to the much lower percentage reduction in trips internal to the core area. An increase in external-external trips is also evident. This is necessary to compensate for the redistribution of trips which have shortened in trip length by shifting one trip end from the external area to the buffer or core area.

Detailed outputs for each time period’s car user classes are shown in Table C3.3 to Table C3.11. They show a more detailed sector-to-sector breakdown of the shift in trip patterns. It should be noted that only percentage changes are illustrated. Movements that stand out as not following the trend are often due to very low total demand for these movements in the base year matrix. The core sectors 1 and 2 contain by far the most number of trips in the matrix. Therefore, even small percentage changes in these cells reflect potentially significant changes in terms of total trip numbers.

### Table C3.3: Relative Changes in Demand in AM Peak Business Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0% | 0.5% | -0.3% | -0.5% | 0.0% | -0.2% | -0.4% | -2.6% | -1.8% | -4.0% | -3.3% | -2.3% | **-0.1%** |
| 2 | 0.0% | 0.4% | -1.2% | -1.1% | -0.3% | 0.0% | -1.1% | -2.0% | 9.5% | -2.7% | -3.1% | -2.6% | **0.0%** |
| 3 | 1.4% | 0.5% | 0.0% | 0.0% | 0.5% | 0.3% | 0.2% | 0.0% | -0.9% | -1.5% | -2.0% | -1.7% | **-0.2%** |
| 4 | 0.8% | 1.5% | 0.0% | 1.4% | 0.5% | 6.0% | -0.1% | 0.0% | -0.8% | -2.6% | -2.9% | -2.4% | **0.3%** |
| 5 | 0.6% | 0.3% | -1.1% | -0.4% | 0.7% | 0.3% | 7.9% | -1.4% | -0.6% | -3.6% | -0.7% | -1.9% | **0.2%** |
| 6 | 0.3% | 0.9% | -0.4% | -0.6% | 0.2% | 1.1% | 0.3% | -2.1% | -2.1% | -2.5% | -3.2% | -2.7% | **-0.1%** |
| 7 | 0.1% | 0.0% | -0.5% | -0.6% | -0.1% | 1.0% | 0.7% | -1.6% | -0.5% | -0.3% | 0.0% | 0.0% | **-0.2%** |
| 8 | 0.7% | 0.6% | 0.0% | -4.4% | 0.3% | 0.5% | -0.6% | 0.0% | 0.0% | -0.9% | -1.1% | 0.1% | **-0.3%** |
| 9 | 0.5% | 0.0% | -1.0% | -0.3% | 1.1% | 0.9% | 0.3% | 0.0% | 1.4% | -1.5% | -1.2% | -0.5% | **-0.3%** |
| 10 | -0.4% | -0.2% | -0.6% | -0.4% | -0.3% | -0.3% | 1.0% | -1.1% | -0.9% | 5.4% | -0.4% | 0.5% | **-0.3%** |
| 11 | -0.3% | -0.1% | -0.5% | -0.7% | -0.2% | 0.1% | 0.2% | -1.1% | -0.7% | 0.0% | 0.0% | 0.0% | **-0.3%** |
| 12 | -0.4% | 0.1% | -0.9% | -0.7% | -0.1% | 0.1% | 0.3% | -1.4% | 2.6% | -0.6% | 0.0% | 0.0% | **-0.3%** |
| Total | **0.5%** | **0.4%** | **-0.6%** | **-0.6%** | **0.0%** | **0.6%** | **0.6%** | **-1.6%** | **0.1%** | **-2.5%** | **-2.1%** | **-1.3%** | **0.0%** |

### Table C3.4: Relative Changes in Demand in AM Peak 'Other' Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.3% | 0.0% | -4.3% | -5.4% | -3.4% | -7.5% | -10.1% | -13.8% | -11.6% | -21.5% | -19.0% | -16.7% | **-0.3%** |
| 2 | -2.2% | 1.1% | -10.4% | -8.9% | -2.0% | -3.0% | -10.3% | -15.9% | -13.2% | -17.3% | -20.8% | -16.6% | **-0.2%** |
| 3 | 3.4% | -2.5% | 0.0% | 0.0% | -5.0% | -3.8% | -8.1% | 0.0% | -13.6% | -24.0% | -11.3% | -11.9% | **-0.7%** |
| 4 | 1.2% | 4.0% | 0.0% | 0.0% | -1.6% | -3.1% | -5.4% | 0.0% | -18.5% | -13.7% | -9.0% | -11.6% | **0.5%** |
| 5 | -1.6% | 1.8% | -6.8% | -4.8% | -0.2% | 1.9% | -4.6% | -8.5% | -2.6% | -13.6% | -14.5% | -16.7% | **-0.4%** |
| 6 | -4.9% | 0.1% | -8.7% | -6.1% | -2.3% | 2.5% | -2.9% | -11.4% | -4.4% | -15.4% | -10.5% | -11.4% | **-0.5%** |
| 7 | -1.3% | 2.1% | 0.0% | 0.0% | -3.7% | 1.1% | 3.2% | -10.3% | -6.7% | -2.4% | 0.0% | 0.0% | **-0.9%** |
| 8 | 1.1% | -0.4% | 0.0% | -18.1% | 1.2% | -1.0% | -8.8% | 0.0% | 0.0% | -5.9% | -0.4% | -6.9% | **-1.1%** |
| 9 | -1.0% | 0.5% | 4.8% | 3.6% | 4.7% | 3.3% | -0.9% | -3.8% | 0.9% | 0.3% | -9.9% | -2.7% | **-1.1%** |
| 10 | -2.7% | 0.1% | -3.2% | -3.6% | -0.2% | -0.2% | 0.5% | -6.2% | -1.6% | 0.0% | -11.1% | 1.9% | **-1.3%** |
| 11 | -3.3% | -5.2% | -2.5% | -2.8% | -0.4% | -1.4% | 0.0% | 3.7% | -2.3% | -0.9% | 0.0% | 0.0% | **-1.5%** |
| 12 | -0.3% | 1.0% | 0.0% | 0.0% | 1.6% | 0.1% | -4.2% | -0.5% | -5.0% | -1.9% | 0.0% | 0.0% | **-1.2%** |
| Total | **1.2%** | **1.0%** | **-5.3%** | **-5.9%** | **-1.9%** | **0.6%** | **-3.5%** | **-8.7%** | **-8.0%** | **-13.9%** | **-13.8%** | **-11.4%** | **-0.3%** |

### Table C3.5: Relative Changes in Demand in AM Peak Commuter Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.1% | -2.1% | 0.9% | 0.2% | -2.7% | -7.1% | -5.2% | -1.0% | -2.9% | -4.0% | -3.2% | -3.4% | **-0.6%** |
| 2 | -2.3% | 0.1% | -3.0% | -1.4% | 0.2% | -3.3% | -3.7% | -2.0% | -3.4% | -3.1% | -2.2% | -1.8% | **-0.6%** |
| 3 | 1.1% | -3.8% | 0.0% | 2.3% | -3.0% | -6.4% | -3.9% | 0.0% | -3.2% | -4.9% | 0.6% | -1.8% | **-0.9%** |
| 4 | -0.3% | -0.9% | 1.4% | 8.0% | -0.7% | -4.2% | -1.6% | 2.6% | 0.7% | -0.9% | -0.7% | -0.7% | **-0.6%** |
| 5 | -2.5% | -0.4% | -0.3% | 0.0% | 1.9% | -0.6% | -2.3% | 2.2% | 2.9% | 1.2% | -0.4% | -0.8% | **-0.7%** |
| 6 | -5.3% | -2.2% | -4.4% | -3.4% | -1.5% | 1.1% | 0.9% | -1.8% | -1.1% | -2.5% | 0.3% | 0.5% | **-0.6%** |
| 7 | -4.0% | -2.4% | -1.3% | -0.1% | -1.9% | 1.5% | 1.0% | 0.7% | -0.5% | 2.1% | 0.0% | 0.0% | **-0.9%** |
| 8 | -1.2% | -2.1% | 0.0% | 0.0% | -0.2% | -3.0% | -0.4% | 0.0% | 3.1% | 0.1% | 0.0% | 1.3% | **-1.3%** |
| 9 | -3.2% | -3.4% | 0.0% | 0.1% | 3.1% | 0.6% | 0.4% | 6.0% | 4.4% | 2.7% | 2.0% | 0.9% | **-1.0%** |
| 10 | -4.4% | -4.1% | -0.7% | -1.0% | -1.3% | -1.6% | 0.5% | 2.2% | 2.2% | 0.0% | 2.9% | 0.7% | **-1.0%** |
| 11 | -4.0% | -2.8% | 0.9% | 0.6% | -0.7% | -0.4% | 0.9% | 0.0% | 3.6% | 14.2% | 0.0% | 0.0% | **-1.2%** |
| 12 | -3.2% | -2.3% | 0.0% | 0.5% | -0.6% | 0.1% | -0.8% | 2.1% | 2.1% | 2.1% | 7.0% | 0.0% | **-1.2%** |
| Total | **-0.7%** | **-0.6%** | **-0.7%** | **-0.6%** | **-0.7%** | **-0.7%** | **-0.8%** | **-0.7%** | **-0.8%** | **-0.8%** | **-0.7%** | **-0.8%** | **-0.7%** |

## Table C3.6: Relative Changes in Demand in Interpeak Business Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0% | 0.6% | -0.5% | -0.4% | -0.1% | -0.1% | -1.0% | -2.4% | -2.2% | -4.1% | -3.9% | -1.9% | **-0.1%** |
| 2 | -0.3% | 0.4% | -1.1% | -1.1% | -0.1% | 0.3% | -1.2% | -2.9% | -2.0% | -5.1% | -3.5% | -2.0% | **-0.1%** |
| 3 | 1.4% | 0.5% | 0.0% | -0.8% | 0.0% | -0.2% | -1.3% | 0.0% | -1.1% | -3.5% | -1.9% | -0.3% | **-0.2%** |
| 4 | 1.1% | 1.1% | 0.0% | 2.3% | 0.6% | 0.4% | 0.0% | -0.4% | -1.3% | -2.8% | -3.0% | -1.3% | **-0.2%** |
| 5 | -0.2% | 0.8% | -0.4% | -0.7% | 0.6% | 0.2% | -0.9% | -2.1% | -1.1% | -3.8% | -3.1% | -2.3% | **-0.1%** |
| 6 | -0.4% | 0.4% | -0.8% | -0.6% | 0.0% | 0.7% | 0.3% | -2.0% | -1.8% | -2.4% | -2.8% | -2.3% | **-0.1%** |
| 7 | -0.4% | 0.1% | -0.6% | -0.7% | -0.1% | 0.9% | 0.9% | -2.0% | -1.1% | -0.5% | 0.0% | -0.7% | **-0.2%** |
| 8 | 0.6% | 0.5% | 0.0% | -4.2% | 0.0% | -0.4% | -0.8% | 0.0% | -2.2% | -0.8% | -0.5% | -0.2% | **-0.3%** |
| 9 | 0.9% | 0.6% | -0.5% | -0.5% | 0.8% | -0.2% | -0.2% | -2.1% | 0.7% | -1.3% | -1.9% | -0.9% | **-0.3%** |
| 10 | -0.6% | -0.4% | -1.0% | -0.8% | -0.4% | 0.5% | 0.9% | -0.1% | -0.7% | 2.1% | -0.9% | 0.0% | **-0.3%** |
| 11 | -0.5% | -0.3% | -1.0% | -0.7% | -0.4% | -0.1% | 0.4% | -0.6% | 0.6% | 0.2% | 0.0% | 0.0% | **-0.3%** |
| 12 | -0.3% | 0.3% | -0.5% | -0.6% | -0.3% | 0.1% | 0.4% | -0.8% | -0.2% | -1.2% | 0.0% | 0.0% | **-0.3%** |
| Total | **0.5%** | **0.5%** | **-0.7%** | **-0.6%** | **0.0%** | **0.4%** | **-0.5%** | **-1.3%** | **-1.1%** | **-2.7%** | **-2.7%** | **-1.4%** | **-0.1%** |

## Table C3.7: Relative Changes in Demand in Interpeak 'Other' Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.5% | 0.0% | -3.5% | -4.3% | -4.4% | -7.6% | -9.8% | -12.4% | -12.0% | -19.8% | -19.4% | -15.0% | **-0.3%** |
| 2 | -3.1% | 0.9% | -9.0% | -8.1% | -2.6% | -3.7% | -9.8% | -15.6% | -15.0% | -18.5% | -21.8% | -15.6% | **-0.1%** |
| 3 | 4.2% | -0.9% | 10.9% | -3.1% | -2.0% | -2.9% | -3.0% | 0.0% | -13.5% | -15.2% | -15.4% | -8.2% | **-0.7%** |
| 4 | 3.0% | 2.0% | 0.0% | 17.9% | -0.6% | -2.4% | -4.4% | -13.5% | -6.3% | -13.9% | -13.4% | -11.4% | **-0.7%** |
| 5 | -2.9% | 1.5% | -6.5% | -4.7% | 1.4% | -0.6% | -6.8% | -10.9% | -3.2% | -12.3% | -15.6% | -10.5% | **-0.4%** |
| 6 | -3.4% | -0.2% | -6.0% | -4.4% | -0.4% | 1.8% | -1.0% | -7.7% | -6.1% | -10.9% | -12.6% | -7.3% | **-0.4%** |
| 7 | -1.2% | 0.4% | -4.8% | -2.8% | -1.4% | 1.7% | 4.8% | -8.3% | -6.5% | -2.7% | 0.0% | -12.8% | **-0.8%** |
| 8 | 2.8% | 2.5% | 0.0% | -4.4% | 2.2% | -1.2% | -5.2% | 0.0% | -2.7% | -5.3% | -1.4% | -4.4% | **-1.2%** |
| 9 | -1.7% | 1.6% | -2.5% | -1.8% | 3.4% | 0.7% | -0.1% | -2.6% | 0.4% | -3.3% | -6.1% | -3.5% | **-1.0%** |
| 10 | -4.8% | -2.3% | -6.6% | -5.2% | -1.8% | -0.9% | 2.2% | 1.1% | 3.1% | -9.5% | -3.3% | 3.7% | **-1.2%** |
| 11 | -3.2% | -2.2% | -5.1% | -3.3% | -3.0% | -0.4% | 0.9% | 1.4% | -6.4% | 1.7% | 0.0% | 0.0% | **-1.3%** |
| 12 | -1.9% | -0.2% | -4.5% | -4.4% | -1.5% | 0.9% | 2.2% | -3.6% | 1.4% | 2.4% | 0.0% | 0.0% | **-1.1%** |
| Total | **1.2%** | **0.9%** | **-5.3%** | **-5.0%** | **-2.1%** | **-0.5%** | **-2.9%** | **-5.1%** | **-7.7%** | **-11.5%** | **-11.2%** | **-8.3%** | **-0.3%** |

## Table C3.8: Relative Changes in Demand in Inter Peak Commuter Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.7% | -2.3% | 1.1% | 0.3% | -2.6% | -6.7% | -5.0% | -1.5% | -1.8% | -3.4% | -4.4% | -4.9% | **-0.4%** |
| 2 | -3.0% | -0.3% | -2.3% | -2.1% | -0.6% | -2.4% | -3.4% | -2.3% | -2.7% | -4.7% | -1.8% | -3.3% | **-0.7%** |
| 3 | 0.4% | -2.4% | 0.0% | 0.0% | 1.1% | -7.4% | -2.6% | 0.0% | 0.0% | -3.6% | 0.0% | -1.7% | **-0.8%** |
| 4 | -0.4% | -1.5% | 4.3% | 15.3% | -0.6% | -5.0% | -0.9% | 0.0% | 3.3% | -0.6% | 1.4% | 0.0% | **-0.9%** |
| 5 | -3.6% | 0.0% | -2.2% | -1.1% | 1.7% | -2.1% | -4.3% | -0.2% | 1.0% | -1.8% | 2.6% | -2.1% | **-0.7%** |
| 6 | -6.4% | -1.8% | -3.5% | -3.3% | -0.5% | 0.8% | 1.7% | -1.8% | -2.3% | -0.6% | -0.5% | 0.6% | **-0.4%** |
| 7 | -4.1% | -1.7% | -2.1% | -0.1% | -0.5% | 0.8% | 0.3% | -0.1% | -2.0% | 0.2% | 0.0% | 0.0% | **-0.6%** |
| 8 | -1.5% | -2.0% | 0.0% | 14.3% | 1.5% | -1.9% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | **-0.8%** |
| 9 | -2.1% | -2.4% | 2.5% | 3.2% | 5.6% | -2.7% | 2.2% | 4.1% | 4.0% | 2.4% | -2.4% | 0.0% | **-0.6%** |
| 10 | -5.8% | -2.8% | -4.3% | -0.4% | 1.6% | -1.3% | 1.1% | 1.1% | 2.8% | 0.0% | 2.9% | 1.6% | **-0.6%** |
| 11 | -2.8% | -1.3% | -4.0% | -0.5% | -1.5% | -0.8% | 13.3% | 2.0% | 0.0% | 3.2% | 0.0% | 0.0% | **-1.0%** |
| 12 | -4.0% | -2.4% | 1.0% | 0.6% | -0.5% | -0.6% | -1.6% | -0.4% | 0.0% | 0.5% | 0.0% | 0.0% | **-0.8%** |
| Total | **-0.7%** | **-0.6%** | **-0.6%** | **-0.6%** | **-0.6%** | **-0.8%** | **-0.8%** | **-0.8%** | **-0.8%** | **-0.9%** | **-0.7%** | **-0.8%** | **-0.6%** |

## Table C3.9: Relative Changes in Demand in PM Peak Business Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.9% | -0.1% | 1.4% | 1.1% | 0.2% | -0.2% | 0.0% | 0.8% | 0.6% | -0.2% | -0.3% | 0.1% | **0.6%** |
| 2 | 0.6% | 0.2% | 0.8% | 0.9% | 0.6% | 0.7% | 0.6% | 0.6% | 0.7% | -0.1% | -0.1% | 0.5% | **0.3%** |
| 3 | -0.6% | -1.6% | 0.0% | 0.3% | -1.7% | -1.2% | -0.4% | 0.0% | -0.6% | -0.7% | -0.8% | -0.3% | **-0.9%** |
| 4 | -0.5% | -0.9% | 0.0% | 1.1% | -0.7% | -0.5% | -0.4% | -1.0% | 0.1% | -0.6% | -0.6% | -0.4% | **-0.6%** |
| 5 | -0.2% | -0.2% | 0.4% | 0.9% | 0.3% | 0.9% | -0.3% | 0.3% | 0.6% | -0.1% | -0.2% | -0.1% | **0.0%** |
| 6 | -0.9% | 0.3% | 0.4% | 0.1% | 0.5% | 1.2% | 1.0% | -0.2% | 1.1% | -1.4% | 0.1% | 0.6% | **0.5%** |
| 7 | -1.1% | -1.4% | 0.0% | 0.0% | -0.7% | 0.2% | 0.0% | -1.0% | -0.1% | 0.7% | 0.9% | 1.2% | **-0.4%** |
| 8 | -2.3% | -1.3% | 0.0% | 0.0% | -1.6% | -1.8% | -1.5% | 0.0% | -1.0% | -1.0% | -0.7% | -1.1% | **-1.3%** |
| 9 | -2.1% | -2.8% | -1.3% | -1.3% | -0.1% | -1.9% | -0.6% | 0.0% | 0.0% | -0.5% | -0.4% | -0.7% | **-1.0%** |
| 10 | -4.0% | -3.0% | -1.4% | -3.4% | -3.0% | -4.5% | -0.1% | -1.2% | -0.6% | 5.4% | -0.1% | -0.4% | **-2.3%** |
| 11 | -4.2% | -3.2% | -2.0% | -3.3% | -3.0% | -2.9% | 0.0% | -0.5% | -1.8% | -1.0% | 0.0% | 0.0% | **-2.5%** |
| 12 | -2.4% | -2.8% | -1.4% | -2.4% | -2.1% | -1.7% | 0.0% | 0.1% | -1.0% | 0.2% | 0.0% | 0.0% | **-1.4%** |
| Total | **-0.1%** | **0.0%** | **-0.2%** | **-0.2%** | **-0.1%** | **-0.1%** | **-0.2%** | **-0.2%** | **-0.2%** | **-0.3%** | **-0.3%** | **-0.3%** | **-0.1%** |

## Table C3.10: Relative Changes in Demand in PM Peak 'Other' Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.2% | -3.0% | 3.8% | 2.2% | -2.8% | -5.7% | -0.2% | 2.7% | 2.6% | -2.4% | -3.6% | -2.1% | **0.9%** |
| 2 | -0.6% | 0.8% | -0.8% | 0.8% | 1.0% | 0.0% | -0.2% | 2.4% | 2.3% | -1.2% | -1.1% | 0.7% | **0.7%** |
| 3 | -2.4% | -8.5% | 0.0% | 0.5% | -2.9% | -7.7% | -4.0% | 0.0% | -2.1% | -3.3% | -5.0% | -3.7% | **-3.6%** |
| 4 | -4.2% | -6.5% | 0.0% | 0.0% | -2.9% | -6.0% | -1.7% | 0.0% | 3.9% | -3.4% | -6.3% | -2.2% | **-4.7%** |
| 5 | -3.5% | -1.7% | -2.4% | -0.9% | 0.9% | -0.9% | 0.0% | 3.7% | 4.6% | -1.5% | -1.2% | -2.0% | **-1.5%** |
| 6 | -7.3% | -3.5% | -0.7% | -4.3% | 0.1% | 2.2% | 2.5% | -1.2% | -0.4% | 0.7% | -4.1% | 2.7% | **-0.3%** |
| 7 | -9.9% | -8.8% | -3.9% | -4.7% | -5.4% | -1.4% | 0.0% | -0.7% | -2.4% | 0.7% | 0.0% | 0.0% | **-3.5%** |
| 8 | -13.0% | -15.8% | 0.0% | 0.0% | -10.5% | -9.5% | -6.4% | 0.0% | -2.3% | -0.3% | 2.3% | -3.5% | **-5.0%** |
| 9 | -13.3% | -11.2% | -9.5% | -8.5% | -1.2% | -6.7% | -1.5% | -3.0% | 0.5% | -3.2% | -3.1% | 0.8% | **-6.8%** |
| 10 | -18.7% | -24.0% | -15.2% | -15.3% | -12.1% | -8.8% | -2.2% | -3.1% | -6.1% | 0.0% | 0.0% | -1.2% | **-11.4%** |
| 11 | -19.0% | -19.1% | -7.5% | -12.6% | -14.0% | -14.2% | 0.0% | -8.2% | -3.4% | 8.4% | 0.0% | 0.6% | **-12.6%** |
| 12 | -14.5% | -14.8% | -10.4% | -9.6% | -9.1% | -8.2% | 0.0% | -3.7% | -7.5% | 0.7% | 2.2% | 0.0% | **-8.5%** |
| Total | **-0.3%** | **-0.1%** | **-0.7%** | **-0.6%** | **-0.4%** | **-0.4%** | **-0.8%** | **-1.1%** | **-1.0%** | **-1.1%** | **-1.1%** | **-1.1%** | **-0.3%** |

## Table C3.11: Relative Changes in Demand in PM Peak Commuter Trips

| Sector | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0% | -2.2% | 1.0% | 0.0% | -2.3% | -6.4% | -3.3% | -0.9% | -2.2% | -3.6% | -3.3% | -2.8% | **-0.5%** |
| 2 | -1.9% | -0.1% | -1.9% | -1.4% | -0.2% | -2.6% | -1.6% | -1.8% | -1.8% | -5.0% | -2.0% | -1.8% | **-0.6%** |
| 3 | 0.8% | -3.8% | 0.0% | 0.0% | -0.9% | -5.9% | -1.2% | 0.0% | 0.0% | 0.9% | -0.4% | -0.2% | **-0.8%** |
| 4 | -0.2% | -1.9% | 0.0% | 7.7% | 0.1% | -5.1% | -1.3% | 0.0% | -0.3% | -1.8% | 0.3% | 0.2% | **-0.9%** |
| 5 | -2.4% | -0.1% | -0.8% | -0.5% | 1.0% | -0.9% | -1.1% | 0.2% | 2.9% | 0.2% | 0.0% | -1.4% | **-0.7%** |
| 6 | -5.8% | -2.9% | -3.7% | -3.6% | -0.9% | 0.6% | 1.5% | -1.6% | -0.4% | -3.2% | -0.2% | 0.1% | **-0.6%** |
| 7 | -4.5% | -2.6% | -1.2% | -1.0% | -1.7% | 0.4% | 0.0% | 0.3% | -0.8% | 0.3% | 4.9% | 0.0% | **-0.8%** |
| 8 | -1.8% | -2.2% | 0.0% | 1.5% | -0.3% | -2.4% | 0.5% | 0.0% | 4.3% | 0.4% | 1.6% | 0.9% | **-1.2%** |
| 9 | -1.9% | -3.0% | -2.5% | 0.5% | 1.9% | -1.9% | 1.2% | 3.5% | 4.2% | 0.2% | 1.4% | 0.0% | **-1.0%** |
| 10 | -4.4% | -3.9% | -0.3% | -0.3% | 0.0% | -4.1% | 2.4% | 2.9% | 2.1% | 0.0% | 8.8% | 1.8% | **-1.1%** |
| 11 | -3.5% | -1.8% | 0.0% | -1.6% | -1.2% | -0.6% | 0.0% | 0.0% | 1.9% | 1.5% | 0.0% | 6.2% | **-1.1%** |
| 12 | -3.8% | -2.9% | -0.3% | 0.5% | -0.7% | -0.9% | 0.0% | 1.3% | -0.5% | 0.2% | 0.0% | 0.0% | **-1.0%** |
| Total | **-0.6%** | **-0.6%** | **-0.6%** | **-0.6%** | **-0.6%** | **-0.8%** | **-0.7%** | **-0.7%** | **-0.7%** | **-0.9%** | **-0.8%** | **-0.7%** | **-0.6%** |