REGIONAL MODELLING SYSTEM

Modelling Services Framework

Mid-West Regional Model

Road Model Development Report

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National Transport Authority

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Foreword

The NTA has developed a Regional Modelling System (RMS) for Ireland that allows for the appraisal of a wide range of potential future transport and land use alternatives. The RMS was developed as part of the Modelling Services Framework (MSF) by the National Transport Authority (NTA), SYSTRA and Jacobs Engineering Ireland.

The National Transport Authority's (NTA) Regional Modelling System comprises the National Demand Forecasting Model, five large-scale, technically complex, detailed and multi-modal regional transport models and a suite of Appraisal Modules covering the entire national transport network of Ireland. The five regional models are focussed on the travel-to-work areas of the major population centres in Ireland, i.e. Dublin, Cork, Galway, Limerick, and Waterford.

The development of the RMS followed a detailed scoping phase informed by NTA and wider stakeholder requirements. The rigorous consultation phase ensured a comprehensive understanding of available data sources and international best practice in regional transport model development.

The five discrete models within the RMS have been developed using a common framework, tied together with the National Demand Forecasting Model. This approach used repeatable methods; ensuring substantial efficiency gains; and, for the first time, delivering consistent model outputs across the five regions.

The RMS captures all day travel demand, thus enabling more accurate modelling of mode choice behaviour and increasingly complex travel patterns, especially in urban areas where traditional nine-to-five working is decreasing. Best practice, innovative approaches were applied to the RMS demand modelling modules including car ownership; parking constraint; demand pricing; and mode and destination choice. The RMS is therefore significantly more responsive to future changes in demographics, economic activity and planning interventions than traditional models.

The models are designed to be used in the assessment of transport policies and schemes that have a local, regional and national impact and they facilitate the assessment of proposed transport schemes at both macro and micro level and are a pre-requisite to creating effective transport strategies.

1 Introduction

1.1 Regional Modelling System

The NTA has developed a Regional Modelling System for the Republic of Ireland to assist in the appraisal of a wide range of potential future transport and land use options. The Regional Models (RM) are focused on the travel-to-work areas of the major population centres of Dublin, Cork, Galway, Limerick, and Waterford. The models were developed as part of the Modelling Services Framework by NTA, SYSTRA and Jacobs Engineering Ireland.

An overview of the five regional models is presented below in both Table 1.1 and Figure 1.1 Regional Model Areas

Table 1.1 List of Regional Models

Model Name	Standard Abbreviation	Counties
West Regional Model	WRM	Galway, Mayo, Roscommon, Sligo, Leitrim, Donegal
East Regional Model	ERM	Dublin, Wicklow, Kildare, Meath, Louth, Wexford, Carlow, Laois, Offaly, Westmeath, Longford, Cavan, Monaghan
Mid-West Regional Model	MWRM	Limerick, Clare, Tipperary North
South East Regional Model	SERM	Waterford, Wexford, Carlow, Kilkenny, Tipperary South
South West Regional Model	SWRM	Cork and Kerry

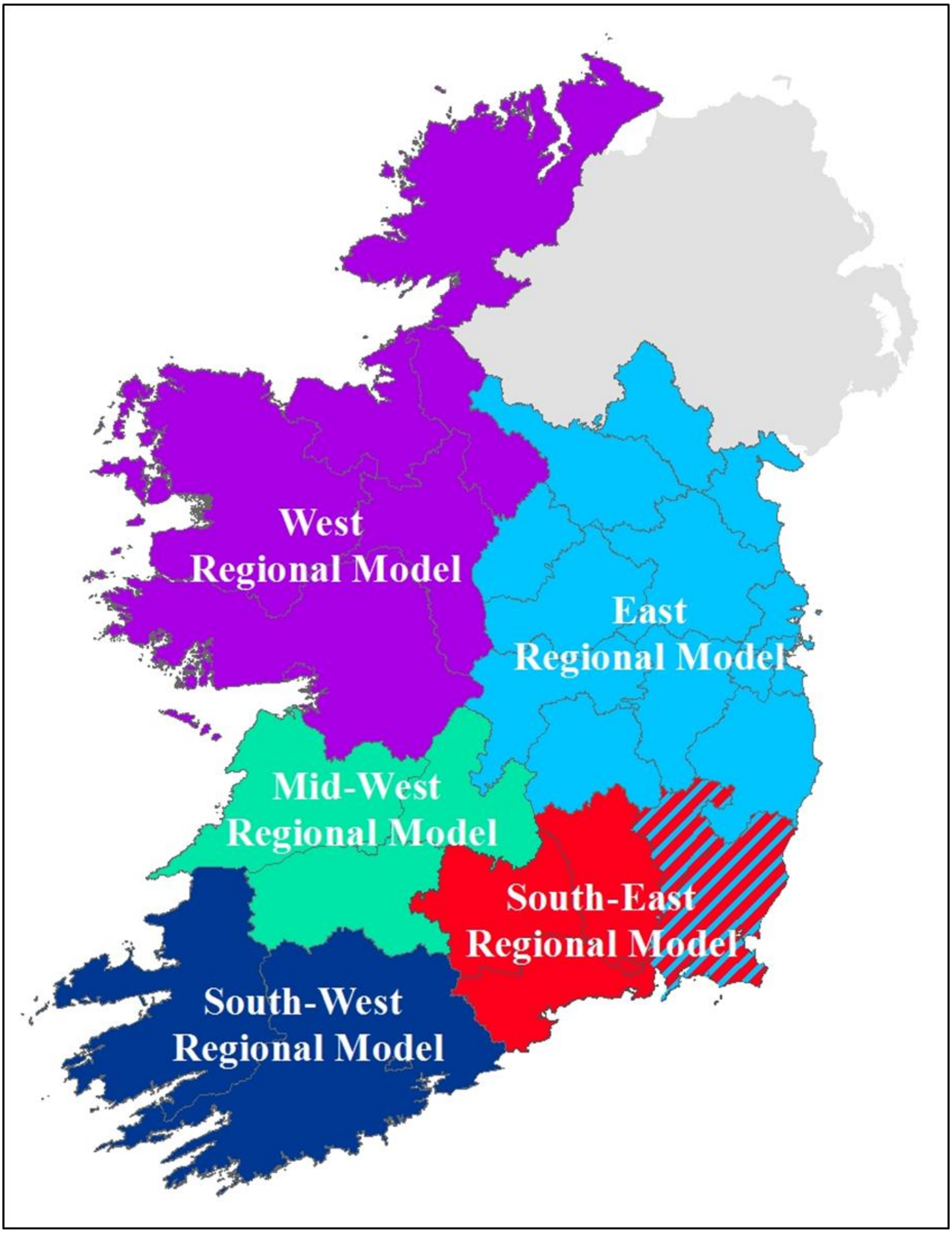

Figure 1.1 Regional Model Areas

1.2 Regional Modelling System Structure

The Regional Modelling System is comprised of three main components, namely:

- The National Demand Forecasting Model (NDFM);
- 5 Regional Models; and
- A suite of Appraisal Modules

The modelling approach is consistent across each of the regional models. The general structure of the MWRM (and the other regional models) is shown in Figure 1.2. The main stages of the regional modelling system are described below.

1.2.1 National Demand Forecasting Model (NDFM).

The NDFM is a single, national system that provides estimates of the total quantity of daily travel demand produced by, and attracted to, each of the 18,488 Census Small Areas. Trip generations and attractions are related to zonal attributes such as population, number of employees, geography, social conditions, income and other land-use data. See the NDFM Development Report for further information.

1.2.2 Regional Models (RM)

Each regional model is comprised of the following elements:

Trip End Integration

The Trip End Integration module converts the 24-hour trip ends as output by the NDFM into the appropriate zone system and time period disaggregation for use in the Full Demand Model (FDM)

The Full Demand Model (FDM)

The FDM processes travel demand as input and outputs origin-destination travel matrices by mode and time period to the assignment models. The FDM and assignment models run iteratively until an equilibrium between travel demand and the cost of travel is achieved.

See the RMS Spec1 Full Demand Model Specification Report, RM Full Demand Model Development Report and MWRM Full Demand Model Calibration Report for further information.

Assignment Models

The Road, Public Transport, and Active Modes assignment models receive the trip matrices produced by the FDM and assign them in their respective transport networks to determine route choice and the generalised cost for each origin and destination pair.

The Road Model assigns FDM outputs (passenger cars) to the road network and includes capacity constraint, traffic signal delay and the impact of congestion. See the RM Spec2 Road Model Specification Report for further information.

The Public Transport Model assigns FDM outputs (person trips) to the PT network and includes the impact of capacity restraint, such as crowding on PT vehicles, on people's perceived cost of travel. The model includes public transport networks and services for all PT sub-modes that operate within the modelled area. See the RM Spec3 Public Transport Model Specification Report for further information.

Secondary Analysis

The secondary analysis application can be used to extract and summarise model results from each of the regional models.

1.2.3 Appraisal Modules

The **Appraisal Modules** can be used on any of the regional models to assess the impacts of transport plans and schemes. The following impacts can be informed by model outputs (travel costs, demands and flows):

- Economy;
- Safety;
- Environmental;
- Health; and
- Accessibility and Social Inclusion.

Further information on each of the Appraisal Modules can be found in the following reports:

- Economic Module Development Report;
- Safety Module Development Report;
- Environmental Module Development Report;
- Health Module Development Report; and
- Accessibility and Social Inclusion Module Development Report.

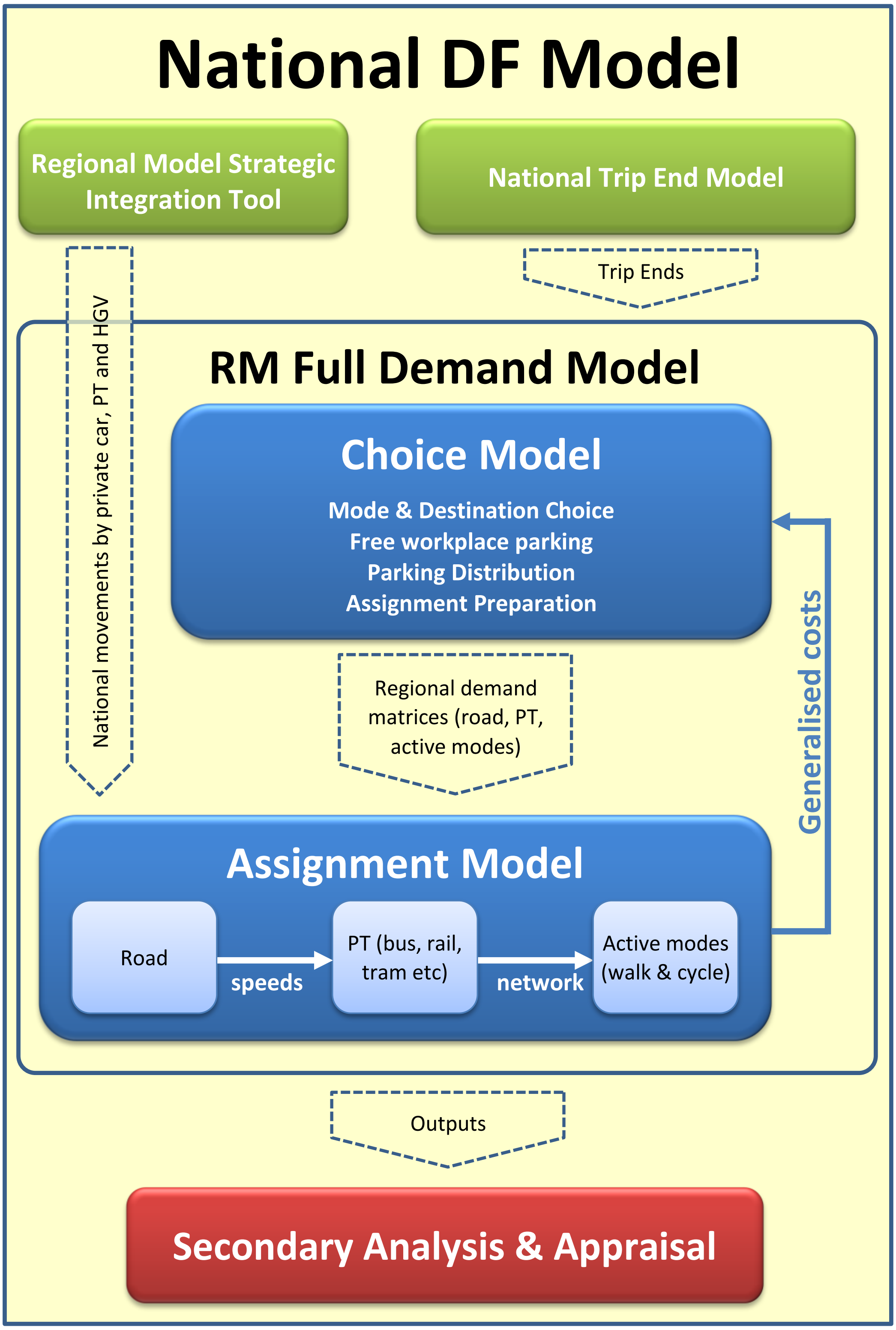

Figure 1.2 RMS Model Structure

1.3 MWRM Road Model Overview

1.3.1 RMS Road Model Specification

The Regional Modelling System Road Model Specification Report (*RM Spec2 Road Model Specification Report*) was used as a guide for the development of the MWRM Road Model. This specification report provides an overview with regard to:

- RMS Road Model Structure & Dimensions;
- RMS Road Network Development Approach;
- RMS Road Network Coding within SATURN;
- RMS Definition of Demand Segments for Road Model;
- RMS Road Model Assignment Methodology; and
- RMS Road Model Calibration & Validation Process.

1.3.2 Structure of RMS Road Model

Figure 1.3 provides an overview of the RMS Road Model (RM) structure. This shows the principal function of the RMS RM to represent the relationship between supply and demand through an assignment procedure and where data is an essential input to all elements of the model. This also shows the relationship with the RMS model components. The RM structure is the same for all five regional models.

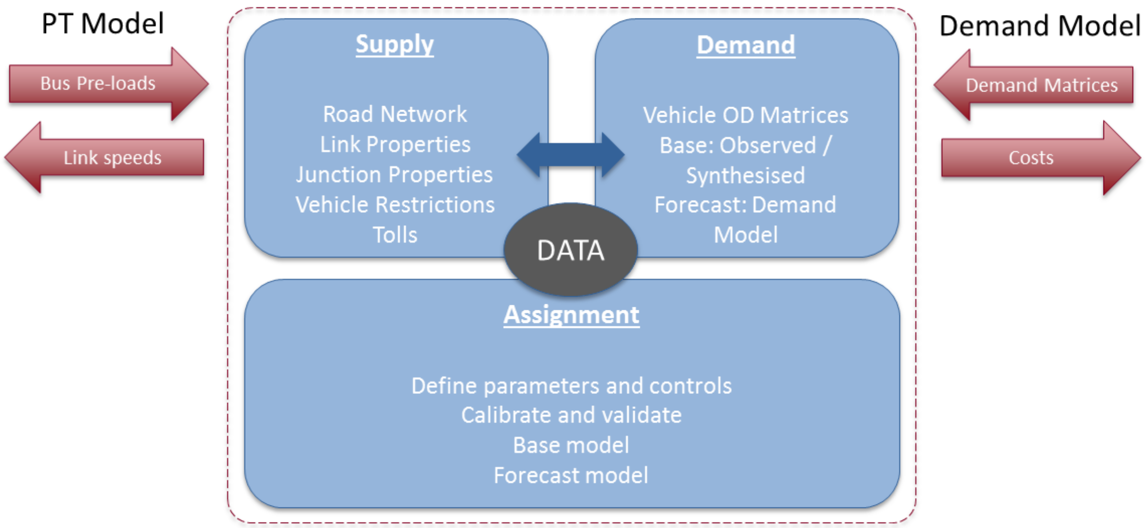

Figure 1.3 RMS RM Structure Overview

1.3.3 The Purpose of the Road Model

The purpose of the Road Model (RM) is to assign road users to routes between their origin and destination zones. The RM is sufficiently detailed to allow multiple routes between origins and destinations, and accurately model the restrictions on the available route choices.

Typical outputs from the RM that can be used directly for option development, design and appraisal include:

- vehicle flows on links;
- vehicle journey times along pre-defined routes; and
- cost of travel for economic appraisal.

1.3.4 Linkages with Overall MWRM Transport Model

The development of the RM includes a number of inter-dependencies with other elements of the RMS. These linkages are discussed in later sections where relevant and can be summarised as follows.

- Inputs to the RM
  - Zone System, defining zonal boundaries for the RM;
  - Travel demand matrices provided by the FDM;
  - Pre-load bus volumes provided by the PT Model;
- Outputs from the RM
  - Provision of assigned RM network to PT Model; and
  - Provision of generalised cost skims to FDM.

1.3.5MWRM Zone System

The Road Model zone system is the same as the zoning system specified for the overall MWRM as described in the “MWRM Zone System Development Report”. The zone system has been designed to include 456 zones and is shown in Figure 1.4.

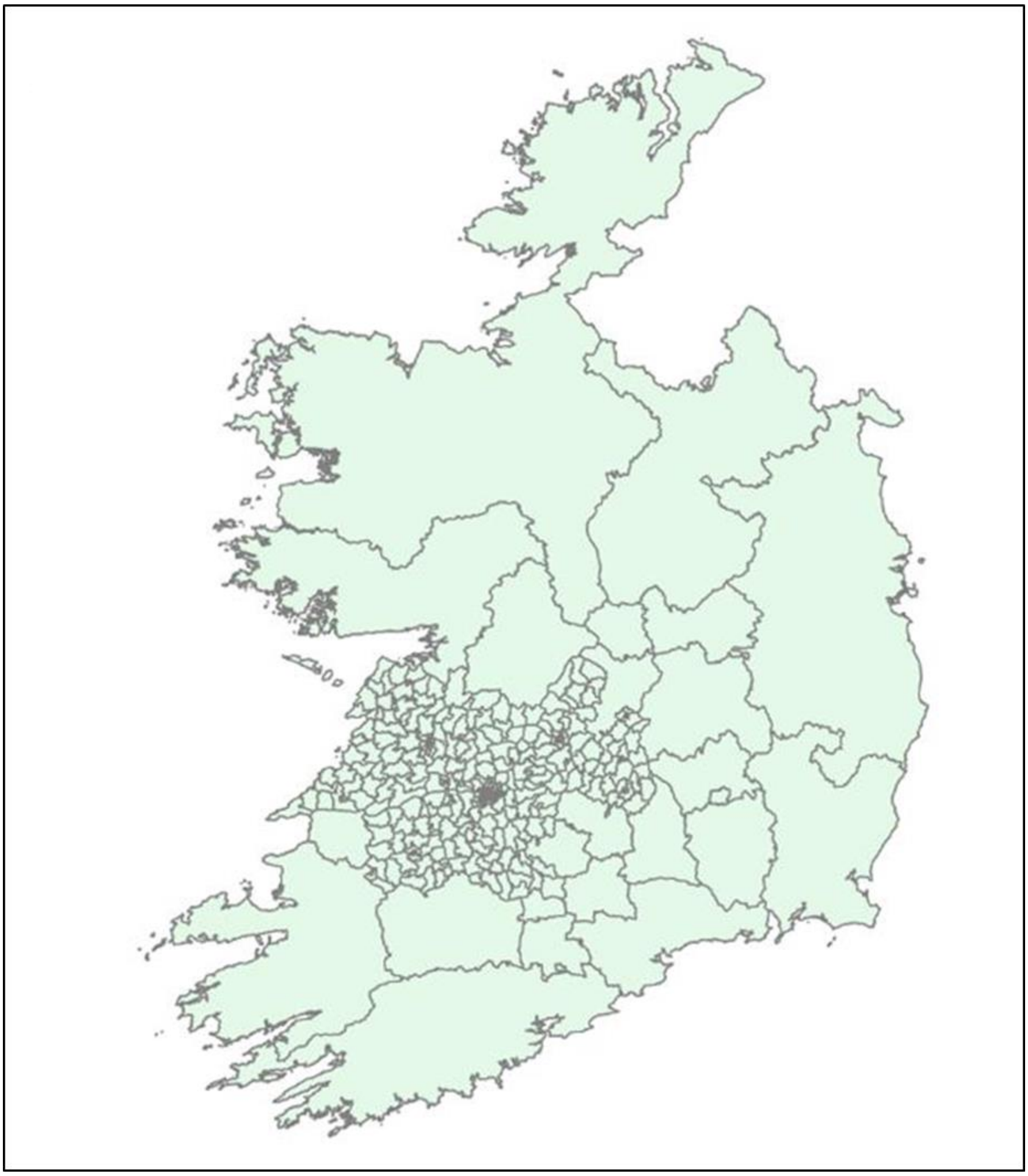

Figure 1.4 Zone System – v1.6

The key zone system statistics include:

- Total zones: 456:
  - Clare zones: 131;
  - Limerick zones: 220;
  - Tipperary zones: 81;
  - Special Use zones: 2; and
  - External zones: 22.

This high level of zonal detail allows the road model to be modelled to a greater degree of accuracy. Increased zonal density in urban areas such as Limerick City allows for the accurate representation of walk times for users wishing to access public transport. This allows the cost of travel by PT, and associated modal split, to be calculated with greater accuracy within the model.

1.3.6 Software

All demand and Public Transport model components are implemented in Cube Voyager version 6.4. SATURN version 11.2.05 is used for the Road Model Assignment. The main Cube application includes integration modules that are responsible for running SATURN assignments and performing the necessary extractions.

1.4 This Report

This report focuses on the Development, Calibration and Validation of the Road Model component of the Mid-West Regional Model (MWRM). It includes the following chapters:

- **Section 2: Road Model Development:** This chapter provides information on the network dimensions, network development and initial assignment checks undertaken prior to calibration and validation;
- **Section 3: Matrix Development:** This chapter outlines the hierarchy of User Classes used in the MWRM Road Model and describes the process of development of travel matrices for these User Classes prior to the model calibration process;
- **Section 4: Data Collection and Review:** This chapter outlines where the data used to calibrate and validate the MWRM was sourced;
- **Section 5: Road Model Calibration:** This chapter details the process of calibration and assignment of the Road Model;
- **Section 6: Road Model Validation:** This chapter sets out the specification and execution of the Road Model validation process; and
- **Section 7: Conclusion and Recommendations:** This chapter provides a summary of the development, calibration and validation of the Road Model. It also provides recommendations for future versions of the model.

2 Road Model Development

2.1 Introduction

Section Two summarises the specification of the road model development process undertaken prior to calibration and validation.

2.2 MWRM Road Network Development

2.2.1 Overview

The initial Mid-West Regional Model (MWRM) network was produced from HERE[1] geographic data using the methodology developed for the ERM, as outlined in "RD TN14 Network Development Task Report". The HERE GIS layer is provided in the "Irish National Grid" projection. Node and link data from the HERE GIS layer was also processed, taking the GIS information such as link speed, link length and number of connecting arms at junctions and converting this information into SATURN node coding. This skeleton network coding was then used as a foundation for the manual coding of each simulation junction in the highway model.

2.2.2 Node Coding Convention

Each node was manually coded in accordance with "SA TN11 Regional Model Coding Guide" to ensure consistency across the simulated model area, as well as consistency with the other regional models being developed. Node numbering followed the hierarchical node numbering system developed for the Regional Models, as described in "SA TN07 Regional Model Hierarchical Numbering System".

2.2.3 Zone Centroid Convention

Zone centroid connection points were defined and coded in accordance with "SA TN11 Regional Model Coding Guide". Centroid locations within the public transport model were identical to the road model.

2.2.4 Public Transport Service Files

The public transport lines files generated as part of the Public Transport Model Development task were converted into a SATURN pre-load file within Cube Voyager, which assigns a timetabled volume of buses to turns and links in the SATURN model. This file is referenced at the network build stage, and buses are pre-loaded on to the SATURN network before general traffic is assigned.

[1] HERE Maps (http://maps.here.com), originally Navigation Technologies Corporation (NavTeq) provides mapping, location businesses, satellite navigation and other services under one brand.

Where a bus lane exists, the buses will utilise the bus lane and not be affected by link congestion. If no bus lane is present buses will use regular road space at a rate of one bus equals three passenger car units (PCU) and will be affected by link congestion. Other road users will subsequently be affected by the presence of the bus on the regular road space.

2.2.5Vehicle Restrictions

Bus lanes adjacent to general traffic lanes are fully represented within the road model. Due to a limitation within SATURN in which taxis cannot use a bus lane, bus-only links have been coded as general traffic links in the road model, with a ban in place to all traffic with the exception of taxis.

In the rare instance where taxis are not permitted to use a bus-only link these links have been coded as traditional bus-only links in SATURN, designated with a negative saturation capacity.

Limerick City & County Council enforces a 5-axle ban on residential streets where heavy good movements are inappropriate. Similarly, vehicles whose gross weight exceeds three tonnes are banned from many residential areas in Limerick City. These bans were included in the network development stage. These bans have been included in the road model through the use of turn penalties for the affected user classes.

2.2.6Tolling

There are several tolled roads within the MWRM modelled area. These are:

- Toll Plazas at Limerick Tunnel;
- Toll Plazas at Fermoy; and
- Toll Plazas at Portlaoise.

Tolling levels were taken from the Transport Infrastructure Ireland (TII) tolling information website[2].

The tolling levels are in 2012 prices, but are then factored to a cost base of 2011 to remain consistent with the calculated values of time.

2.2.7Ferry Charges

There is a ferry charge between Killimer and Tarbert. The ferry toll charge was also factored to a cost base of 2011 to remain consistent with the calculated values of time. The ferry crossing takes approximately 20 minutes and an additional boarding/departing penalty of five minutes was applied to the travel time of the link representing the ferry in the road model. The ferry charge value was obtained from the Shannon Ferries website[3].

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[2] http://www. tii.ie/roads-tolling/tolling-information/toll-locations-and-charges/

[3] http://www. shannonferries.com/

2.2.8Speed Flow Curves

Initial speed flow curves and mid-link capacities are specified in “SA TN11 Regional Model Coding Guide” and were implemented in the development of the supply networks. Speed flow curves were originally applied on all links in the simulation area. However, these were streamlined in line with other regional model areas. The speed flow curves were removed from Limerick urban area and applied south of the M7 / N18 and in the rural area outside of Moyross and Anacotty, including the buffer network.

During the network calibration and validation stage some amendments to the speed flow relationships were made. These amendments include changing the capacity index of the curve applied on an individual link or making changes to the shape (as defined by the power value), free-flow speed, speed at capacity or capacity per lane for a specific curve, which would be replicated across all links in the network with similar characteristics. Where a more significant change is deemed necessary, it is likely to be more appropriate to adopt an alternative speed flow relationship, for example after checking speed limit or road cross section.

Speed flow curves are not currently applied in the simulation area within Limerick City. Combining flow delay curves with simulated junction coding within congested urban areas can have the effect of double counting the delay experienced by traffic as they are delayed by the capacity of the link and the capacity of the junction. In an urban environment, delays are typically caused by junction capacity and not by link capacity.

Although speed flow curves are not currently applied in the simulation area within Limerick City, it may be necessary to add speed flow curves on some corridors with few junctions in future iterations of the model development, where it is shown to be necessary to incorporate a speed flow curve to improve journey time validation.

2.3 Assignment Model Preparation

2.3.1 Network Checking

A comprehensive set of network checks was undertaken before commencing calibration. These checks included:

- range of checks including saturation flows, free flow speeds, flares, etc;
- spot checking of junction coding;
- check that the right types of junctions are coded;
- check that all zones are connected;
- coded link distances versus crow-fly distance; and
- observed traffic volumes versus coded and calculated capacity in SATURN.

2.3.2 Assignment Parameter Updating

The vehicle operating cost (Price Per Kilometre, PPK) and value of time (Price Per Minute, PPM) components were calculated based on model outputs using the methodology outlined in the Galway Interim Model Development report.

The calculated PPK component takes the average simulated network speed as an input variable. Between model and matrix versions it is possible that the average network speed changes. Although changes in network speed will have a small impact on the calculated generalised cost components it is prudent to update the costs to reflect network performance on a regular basis during model development.

The calculated PPM component does not change with the average simulated network speed and is fixed for all assignments.

Although it is possible to adjust PPK and PPM to improve calibration of the road model, this is generally not undertaken as this may introduce an inconsistency with future year values of PPK and PPM which will have been calculated using the methodology used to calculate the base values.

3 Matrix Development

3.1 Overview

The unadjusted travel demand matrices derived from available data sources are referred to as prior matrices. Prior matrices were provided for the following user classes:

- User Class 1 - Taxi
- User Class 2 – Car Employer's Business
- User Class 3 – Car Commute
- User Class 4 – Car Education
- User Class 5 – Car Other
- User Class 6 – Light Goods Vehicles (LGV)
- User Class 7 – Other Goods Vehicle 1 (OGV1)
- User Class 8 – Other Goods Vehicle 2 (OGV2) Permit Holder
- User Class 9 – OGV2 Non Permit Holder

Prior matrices for all user classes were developed in accordance with "MWRM Full Demand Model Calibration Report". These matrices are an essential input into the development of the Road Model.

3.2 Prior Matrix Factoring

The prior matrices (referred to Section 3.1) represent travel demand over a three hour period (e.g. 0700 – 1000). However, for assignment in the Road Model, SATURN requires a travel demand matrix that represents a single hour. Several methodologies are available to factor the three hour travel demand matrix to a single hour, using a Period-to-Hour (PtH) factor.

Two common approaches to deriving this PtH factor are to divide the total matrix by the number of hours it represents in order to provide an average hourly travel demand matrix, or to factor the matrix to a specific hour, for example 0800 – 0900, using observed traffic count data.

A third methodology is to represent the "peak everywhere" by applying a single factor, derived from various data sources, with the aim of representing the worst traffic conditions at each point in the network simultaneously. Automatic Traffic Counter (ATC) data was used to derive factors for the MWRM in order to best represent the traffic conditions within Limerick. The method used for this is consistent with the method used for ERM, which is discussed further in the "FDM Scope3 Modelling Time of Travel" report. This factor represents the "flow" PtH factor, and the factors calculated from the ATC data are outlined in Table 3.1. These factors were applied to interim versions of the road model.

Table 3.1 MWRM RM Initial Period to Assigned Hour Factors

Time Period	Period to Hour Factor
AM Peak (0700 – 1000)	0.431
Inter Peak 1 (1000 – 1300)	0.333
Inter Peak 2 (1300 – 1600)	0.333
PM Peak (1600 – 1900)	0.385
Off Peak (1900 – 0700)	0.083

The “demand” PtH factor is based on the Household Travel Diary and represents the proportion of all trips which take place within the peak hour without regard to journey purpose. The “flow” PtH factors are generally lower than the “demand” factors as trips are travelling between a variety of origins and destinations and therefore pass the fixed observation points at different times. The result is that the flow profile is more evenly spread throughout the period compared to the demand profile.

The “flow” PtH factors were applied to all counts and, initially, to the assignment matrices. It was later recognised that, due to the way SATURN assigns trips to the network, the true PtH factor required to convert the 3-hour demand matrices into 1-hour assignment matrices is somewhere between the two factors. In practice there is no straightforward way to determine mathematically what the factor should be, prior to model calibration.

An iterative process was therefore required to vary the PtH factor within the upper and lower limits formed by the “demand” and “flow” PtH factors, until the overall level of demand matched the observed flows. The final PtH factors used in the MWRM are outlined in Table 3.2.

Table 3.2 MWRM RM Final “demand” Period to Assigned Hour Factors

Time Period	Period to Hour Factor
AM Peak (0700 – 1000)	0.629
Inter Peak 1 (1000 – 1300)	0.460
Inter Peak 2 (1300 – 1600)	0.513
PM Peak (1600 – 1900)	0.490
Off Peak (1900 – 0700)	0.083

3.3 Prior Matrix Checking

Comprehensive checks of the matrices were undertaken before commencing calibration. These checks included:

- comparing matrix trip ends against NTEM outputs;
- checking trip length distribution against observed data;
- checking implied time period splits by sector-pair;
- checking implied purpose splits by sector-pair; and
- comparing sectored matrices with total screen-line and cordon flows where possible.

These checks revealed no significant issues with the prior matrices. These matrices were then assigned to the latest version of the road model.

4 Data Collation and Review

4.1 Supply Data

As described in the “RM Spec2 Road Model Specification Report”, road link specification is based on the HERE GIS layer for the Republic of Ireland. The HERE data includes a number of data fields including: link lengths; road class; speed category; single / dual carriageway; and urban / rural characteristics.

This was used to create the initial road network. The simulation area was then coded with reference to the agreed coding guide.

Based on guidelines established for ERM and described in “SA TN11 Regional Model Coding Guide”, superfluous network detail was removed from the MWRM road network (the development of the MWRM road network pre-dated the finalisation of the ERM guidance).

Traffic signal stages and timing have been developed for Limerick City from:

- Split Cycle Offset Optimization Technique (SCOOT) database where available;
- Microprocessor Optimised Vehicle Actuation (MOVA); and
- proportional green time split based on observed traffic count / modelled flow if not available from SCOOT or MOVA.

4.2 Demand Data

4.2.1 Car Based Journeys

The Full Demand Model (FDM) processes the all-day travel demand from the National Trip End Model (NTEM) and outputs origin-destination travel matrices by mode and time period. These are then combined with matrices from the Regional Model Strategic Integration Tool (RMSIT) and passed to the appropriate assignment model to determine the route choice of the trips.

These matrices are calibrated against the POWSCAR[4] dataset and outputs of the NTEM. NTEM, which has been calibrated using the National Household Travel Survey 2012 (NHTS) travel diary data, provided origin and destination trip ends for each modelled time period for all other journey purposes and to corroborate with POWSCAR.

The sample sizes of the NHTS 2012 are too small to be used directly to calibrate matrices for individual zone to zone trip volumes. However, the NHTS can be used

[4] Place of Work, School, or College Census of Anonymised Records, part of the 2011 Census of Ireland

to estimate broader sector to sector totals, mode share, time of day profiles and time of day return factors.

4.2.2 Goods Vehicles

Goods vehicles are comprised of the following classes of vehicles:

- Light Goods Vehicles (LGVs): up to 3.5 tonnes gross weight, for example transit vans.
- Other Goods Vehicles 1 (OGV1): rigid vehicles over 3.5 tonnes gross weight with two or three axles, for example tractors (without trailers) or box vans.
- Other Goods Vehicles 2 (OGV2): rigid vehicles with four or more axles, and all articulated vehicles.

For the purposes of the regional models, these three classes have been divided into two groupings with different trip characteristics, bulk goods and non-bulk goods.

Bulk Goods Trips are defined as trips between locations such as ports, airports, quarries, major industrial sites, retail, and distribution centres. These trips will be made regardless of the cost of travel. As with ERM, they have been assumed to be made mainly by OGV2, with a proportion of OGV1. Bulk Goods Trips have been derived from RMSIT, with the local distribution of trips to destinations other than ports, airports and similar locations based on NACE survey data relating to industrial activities. A 70/30 split was used to disaggregate the Bulk Goods matrices between OGV1 and OGV2.

Non-Bulk Goods Trip Ends were estimated using linear regression based on factors estimated for the ERM. These were disaggregated between LGVs and OGV1 using an 84/16 split.

More detail on the goods vehicles matrices and their derivation is given “FDM Scope12 Base Year Matrix Building”.

4.3 Count Data

There are between 6,000 and 7,000 road traffic survey data records nationwide, comprised of manual classified counts, automatic traffic counts (ATC) and SCATS data, which were collated under the Data Collection task. The data was collated in 2014 and represents data from January 2009 to December 2014.

Figure 4.1 indicates the location of traffic count data that was collated.

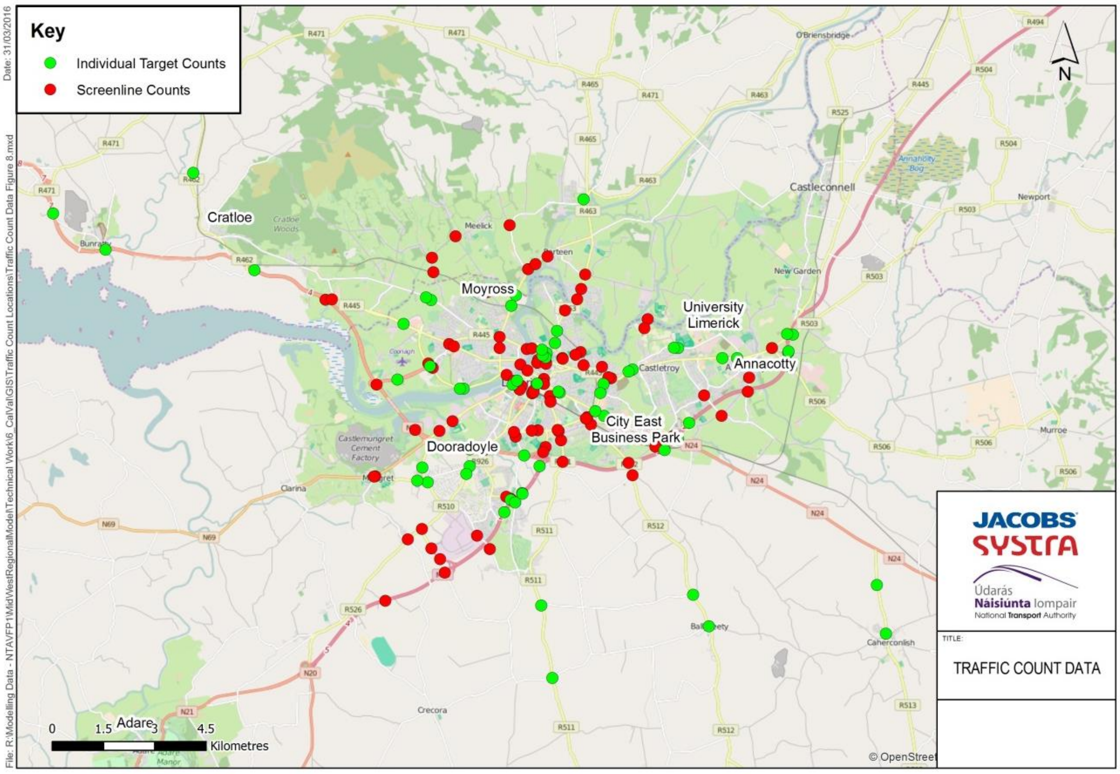

Figure 4.1 Location of Traffic Count Data

4.4 Journey Time and Queue Length Data

4.4.1 GPS-based Travel Time Data

The NTA purchased a license from TomTom[5] for their travel time product Custom Area Analysis (CAA). This product provides average travel time data on every road link within a given area over a specified time period. Details of the data acquisition and data processing are discussed in “MSF 011 TomTom Data Portal Guide” and “MSF 011 TomTom Data Extraction and Processing”.

The MWRM uses 2012 TomTom journey time data on 16 routes inbound and outbound, totalling 28 routes to be used while validating the model. There are three journey time categories that form a hierarchy of routes. Category 1 consists of the urban, national primary, motorway and arterial commuter. Category 2 comprises regional and secondary routes, while Category 3 include inter urban routes between regional towns.

TomTom data is available in both directions in all time periods. Figure 4.2 shows the routes.

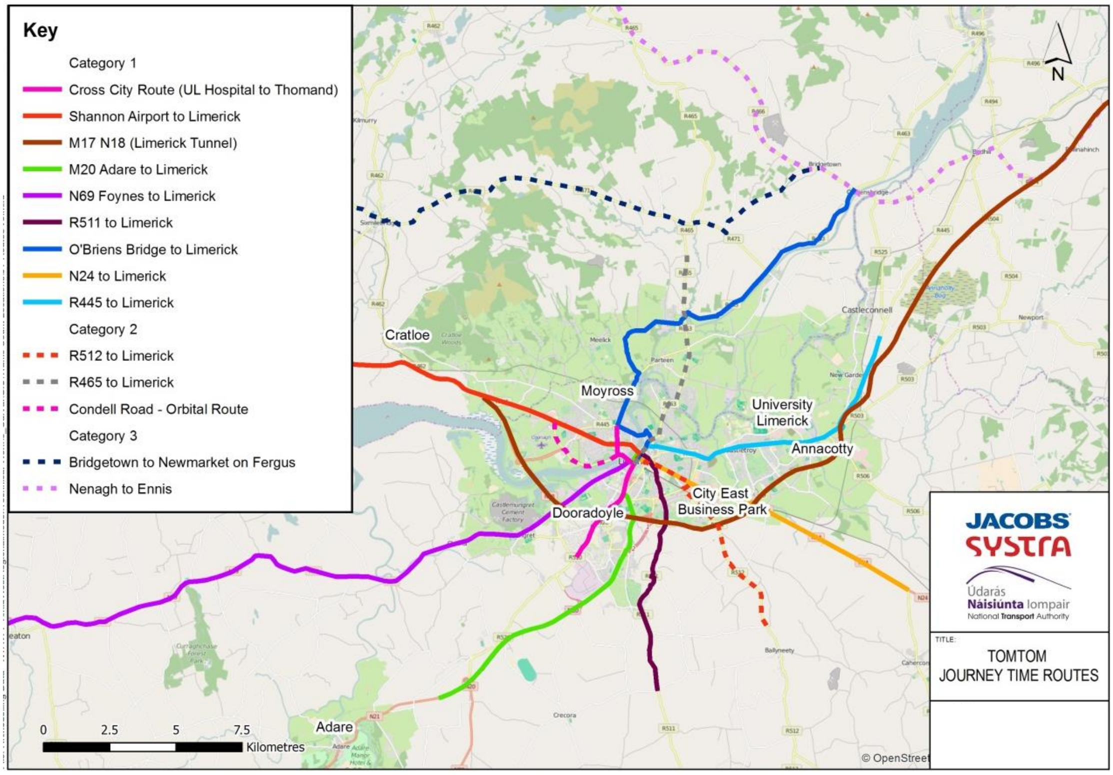

Figure 4.2 TomTom Journey Time Routes

[5] http://trafficstats.tomtom.com

Table 4.1 TomTom Journey Time Routes (16 Routes – inbound & outbound)

Route ID Number	Description
1	Cross City (UL Hospital to Thomand)
2	Shannon Airport to Limerick
3	M17 N18 Limerick Tunnel Inbound
4	M20 Adare to Limerick
5	N69 Foynes
6	R511 to Limerick
7	O'Briens Bridge to Limerick
8	N24 to Limerick
9	R445 to Limerick
11	R512 to Limerick
12	R465 to Limerick
13	Condell Road - Orbital Route
15	Bridgetown to Newmarket on Fergus
16	Nenagh to Ennis

Data is available at an hourly average level between 0700 and 1900, and at an average level for 1900 – 0700. The average travel times between 1900 and 0700 are split into two datasets, with a “quiet” off-peak covering 0100 – 0400 and the remainder of the off-peak (1900 – 0100 and 0400 – 0700) forming a second dataset.

Data was averaged over the neutral 2012 months of February, March, April, May, October and November, excluding weekends, public and school holidays within these months. This resulted in 112 days’ worth of observations which were averaged to form the TomTom travel time dataset. This number of observations is significantly in excess of what could normally be achieved through moving car observer type surveys, providing a more robust dataset with smaller variability and uncertainty.

The inbound and outbound direction for all routes is available and extracted in the AM (08:00 – 09:00), Inter-peak 1 (13:00 – 14:00), Inter-peak 2 (14:00 – 15:00) period, and PM peak period (17:00 – 18:00). A single hour of data was selected for the AM and PM peak periods after discussions with the NTA as this time period better represented the “peak” travel conditions across the network compared with alternative solutions, and aligned with the assignment model time periods and methods. An average time for Inter-peak 1 and Inter-peak 2 was also selected to align with the assignment model time periods and methods. This data was used to validate the final MWRM road model.

4.4.2 Queue Length Data

Where available, queue length data was used to confirm that queuing occurs at the correct locations in the model network. However, owing to potential ambiguity regarding the definition of a queue in a survey and the definition of a queue within SATURN, no attempt was made to match the observed queue length in anything other than general terms.

5 Road Model Calibration

5.1 Introduction

This chapter sets out the specification and execution of the model calibration process. This includes the incorporation and application of matrix estimation.

5.2 Assignment Calibration Process

5.2.1 Overview

The assignment calibration process was undertaken for the assignment of the MWRM and matrices through comparisons of model flows against observed traffic counts at:

- Individual links (i.e. link counts); and
- Across defined screenlines.

5.2.2 Calibration

Calibration is the process of adjusting the MWRM RM to ensure that it provides robust estimates of road traffic assignment and generalised cost before integrating it in to the wider demand model. This is typically achieved in iteration with the validation of the model to independent data.

The UK's Department for Transport's Transport Analysis Guidance (TAG) unit M3-1 advises that the assignment model may be recalibrated by one or more of the following means:

- Remedial action at specific junctions where data supports such as;
  - Increase or reduction in turn saturation capacity;
  - Adjustment to signal timings;
  - Adjustment to cruise speeds;
- Adjustments to the matrix through matrix estimation as a last resort;

TAG indicates that the above suggestions are generally in the order in which they should be considered. However, this is not an exact order of priority but a broad hierarchy that should be followed. In all cases, any adjustments must remain plausible and should be based on a sound evidence base.

Calibration is broadly split in to two components; matrix calibration and network calibration. Matrix calibration ensures the correct total volume of traffic is bound for certain areas through the use of sector analysis, while network calibration ensures the correct traffic volumes on distinct links (roads) within the modelled area. Table 5.1 outlines the matrix estimation change calibration criteria, as specified in TAG Unit M3-1, Section 8.3, Table 5.

Table 5.1 Significance of Matrix Estimation Changes

Measure	Significance Criteria
Matrix zonal cell value	Slope within 0.98 and 1.02; Intercept near zero; R^2 in excess of 0.95.
Matrix zonal trip ends	Slope within 0.99 and 1.01; Intercept near zero; R^2 in excess of 0.98.
Trip length distribution	Means within 5%; Standard Deviation within 5%.
Sector to sector level matrices	Differences within 5%

The comparison of the modelled vehicle flows also makes use of the GEH[6] summary statistic. This statistic is designed to be more tolerant of large percentage differences at lower flows. When comparing observed and modelled counts, focus on either absolute differences or percentage differences alone can be misleading when there is a wide range of observed flows. For example, a difference of 50 PCUs is more significant on a link with an observed flow of 100 PCUs than on one with and observed flow of 1,000 PCUs, while a 10 per cent discrepancy on an observed flow of 100 vehicles is less important than a 10 per cent mismatch on an observed flow of 1,000 PCUs.

The GEH Statistic is defined as:

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

Where, GEH is the Statistic, M is the Modelled Flow and C is the Observed Count.

Table 5.2 outlines the link calibration criteria as set out in TAG Unit M3-1, Section 3.2, Table 2.

Table 5.2 Road Assignment Model Calibration Guidance Source

Criteria	Acceptability Guideline
Individual flows within 100 veh/h of counts for flows less than 700 veh/h	> 85% of cases
Individual flows within 15% of counts for	> 85% of cases

[6] Developed by Geoffrey E. Havers (GEH)

flows from 700 to 2,700 veh/h	
Individual flows within 400 veh/h of counts for flows more than 2,700 veh/h	> 85% of cases
GEH < 5 for individual flows	> 85% of cases

Table 5.3 outlines the screenline calibration criteria as set out in TAG Unit M3-1, Section 3.2, Table 3.

Table 5.3 Road Assignment Model Screenline Calibration Guidance Sources

Criteria	Acceptability Guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines

5.3 Initial Generalised Cost Parameters

Initial generalised cost parameters applied were taken from the ERM as a starting point. This formed the basis for the first steps of model development. The initial generalised cost parameters are set out in the following four tables, with IP2 mirroring the initial costs of IP1 as there was no IP2 assignment undertaken at this stage. The generalised cost parameters have a base year of 2011 to remain consistent with the other model components and input values.

Table 5.4 Initial AM Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	58.82	17.58
UC2 – Car Employers Business	58.82	17.58
UC3 – Car Commute	21.70	9.29
UC4 – Car Education	42.82	9.29
UC5 – Car Other	21.09	9.29
UC6 – LGV	43.34	12.74
UC7 – OGV1	46.08	28.33
UC8 – OGV2 Permit Holder	44.40	51.84
UC9 – OGV2 (Other)	44.40	51.84

Table 5.5 Initial IP1 Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	52.96	16.51
UC2 – Car Employers Business	52.96	16.51
UC3 – Car Commute	21.55	8.85
UC4 – Car Education	27.83	8.85
UC5 – Car Other	24.38	8.85
UC6 – LGV	45.91	13.20
UC7 – OGV1	46.08	28.33
UC8 – OGV2 Permit Holder	44.40	51.84
UC9 – OGV2 (Other)	44.40	51.84

Table 5.6 Initial IP2 Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	52.96	16.51
UC2 – Car Employers Business	52.96	16.51
UC3 – Car Commute	21.55	8.85
UC4 – Car Education	27.83	8.85
UC5 – Car Other	24.38	8.85
UC6 – LGV	45.91	13.20
UC7 – OGV1	46.08	28.33
UC8 – OGV2 Permit Holder	44.40	51.84
UC9 – OGV2 (Other)	44.40	51.84

Table 5.7 Initial PM Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	60.02	16.36
UC2 – Car Employers Business	60.02	16.36
UC3 – Car Commute	21.42	8.67
UC4 – Car Education	43.76	8.67
UC5 – Car Other	27.49	8.67
UC6 – LGV	43.34	12.09
UC7 – OGV1	46.08	25.98
UC8 – OGV2 Permit Holder	44.40	47.54
UC9 – OGV2 (Other)	44.40	47.54

5.4 Road Model Network Progression

5.4.1 Overview

In total there were three iterations of the network data files used during the creation of the pre-assignment SATURN network (UFN). Each iteration consisted of an update to the network coding for the four assigned peak periods (AM, Inter-peak 1, Inter-peak 2 and PM) with the coding for Inter-peak 1 being replicated for the Off Peak network.

The main checks undertaken and adjustments made during the network development stage are outlined in the following sections.

5.4.2 RMS Rationalisation

Several Regional Models were being developed in parallel, with the ERM informing many model alterations during the development cycle. Many of these changes were related to assignment parameters which did not materially affect the assigned traffic volumes or patterns, but did ensure a consistently converged solution. The two changes with the largest effect as a result of developments on other Regional Models were the changes to the average PCU length, controlled by the parameter ALEX in SATURN, and the changes to the generalised cost assignment parameters.

5.4.3 Increase in Average PCU Length (SATURN Parameter ALEX)

The average PCU length parameter in SATURN, ALEX, was set to the default value of 5.75m as used in the 2006 Base version of the GDA model, and remained consistent at this level during the network development tasks. Further analysis by the NTA, including visual reviews of several aerial / satellite photographs suggested that the average PCU length has increased in recent years and is closer to 5.95m in length. The ALEX parameter was subsequently revised to 5.95 based on this recent research.

The increase in the average PCU length within SATURN reduces the stacking capacity of links, which in turn will increase the length of any queue, potentially beyond the end of a link, and can affect the link speeds as a result. This change had the effect of slowing down the modelled journey times, which was consistent with comparisons between the observed and modelled journey times.

5.4.4 Revised Cost Base

The Common Appraisal Framework (CAF) provides the largest proportion of information used during the derivation of the generalised cost assignment parameters; value of time (VoT) and vehicle operating cost (VOC). At the commencement the initial network development, the latest available information from the CAF provided costs with a base year of 2002. During the development of the road network, a draft version of the CAF was circulated which provided generalised cost parameters with a base cost year of 2011. A summary of all variables used during the development of the MWRM and their sources is presented in the "FDM Scope18 Regional Transport Model Exogenous Variables" report.

5.4.5 Initial Network Checks

In parallel with setting up and running the FDM, a detailed review of the network was carried out using the FDM produced matrix MWBY16_A9 issued in May 2016:

- **Junction turning counts and capacity checks:**
  Checks were undertaken to identify the junctions with counts greater than the modelled capacity. The network coding for these junctions was then reviewed to see how the capacity could be increased. For this purpose, flares and lane allocation were checked. The capacity was increased by adding flares or changing flares to extra lanes where necessary. For signalised junctions, signal timings and signal stages were reviewed. Where appropriate, green time adjustments were done. If this was not possible overall cycle time was increased. For some junctions, signal phases were re arranged.
- **Review of regional roads:**
  All the regional roads have been reviewed to check that the capacity and speed flow curves are consistent along each road. Speed flow curves were updated as below.
    - The speed flow curves on the R471 between Newmarket on Fergus and Bridgetown were revised to reflect the free flow speeds on this route and were reduced when passing through villages that have a signed lower speed limit.
    - The speed flow curves between Nenagh and Ennis were reviewed to reflect the road speeds. Amendments reflected the physical road

conditions and resulted in a reduction in free flow speeds on the links between Nenagh and Ennis.

- The review of the speed flow curves resulted in the removal of speed flow curves from urban areas in line with the ERM and other regional models. An urban area was defined which consisted of Moyross (in the east) to Annacotty (in the west) stretching down to the M7 (in the south). In this urban area, all speed flow curves were removed from links.

- **Over capacity links in buffer area:**
  Volume to capacity (V/C) and delay checks were carried out in the buffer area. No changes were made as a result of the checks.
- **Centroid connector review:**
  A review of centroid connectors was carried out to check that each centroid was correctly connected to the zones. Any unnecessary links were removed and the connectors were moved to appropriate links where required. 12 connectors were updated.
- **Exploded roundabout checks:**
  Exploded roundabouts, for example Shannonbridge Roundabout, were reviewed. Saturation flows were checked according to the inscribed circle diameter requirements set out in “SA TN11 Regional Model Coding Guide”. Capacity, V/C and delay checks were also undertaken. The coding of this junction was revised with more appropriate saturation flow and lane allocations, as per the Network Coding Guide.
- **Bus lane checks:**
  Bus lane coding for the Cork City area was reviewed. No corrections were identified to the coding representing the conditions on the ground.
- **Data checks:**
  A review of the observed data being used to calibrate and validate the model was undertaken to ensure that the data was processed and applied correctly. This exercise identified a gap in the M7 / R445 screenline, and an additional count was included to ensure a robust screenline along the M7 Screenline on the R445. A revised dataset was used on the Limerick Port Tunnel to provide more accurate observed data. The revised dataset used a wider, more robust sample of traffic counts for neutral months February, March and April in 2012.
- **Stress test:**
  110 per cent of the original matrix was assigned to the network and compared to the original network. Network checks were undertaken to identify any junctions that were now over capacity as a result of assigning the larger matrix (Figure 5.1 and Figure 5.2). Based on this, junction coding and refinement were corrected at sites highlighted in red below.

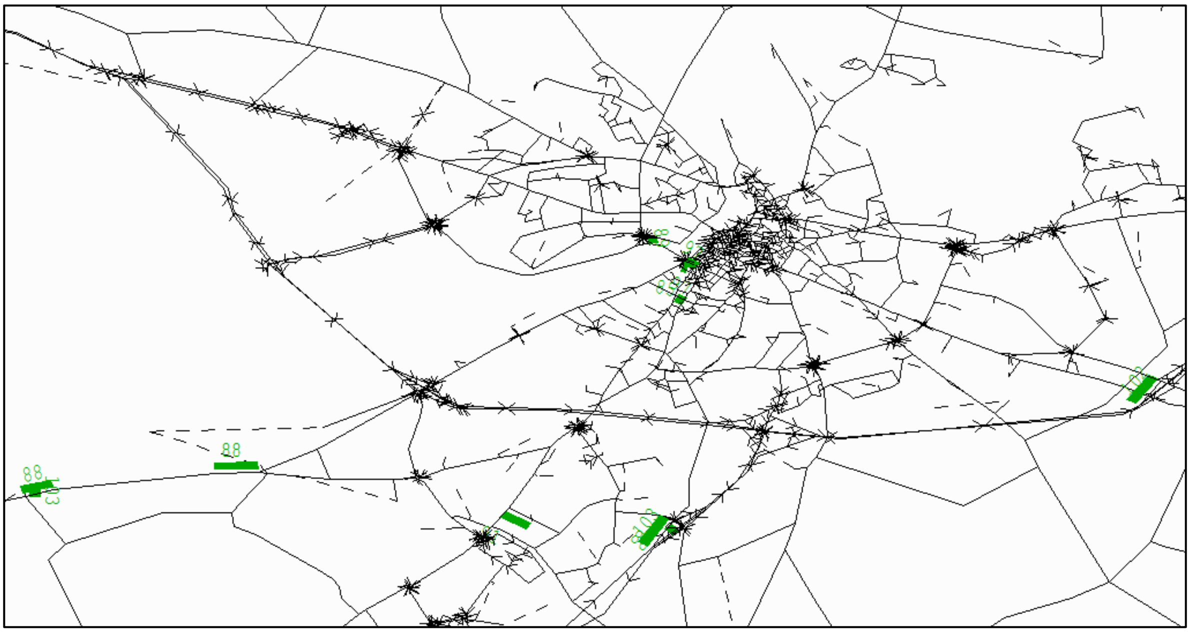

Figure 5.1 Original network with V/C above 85%

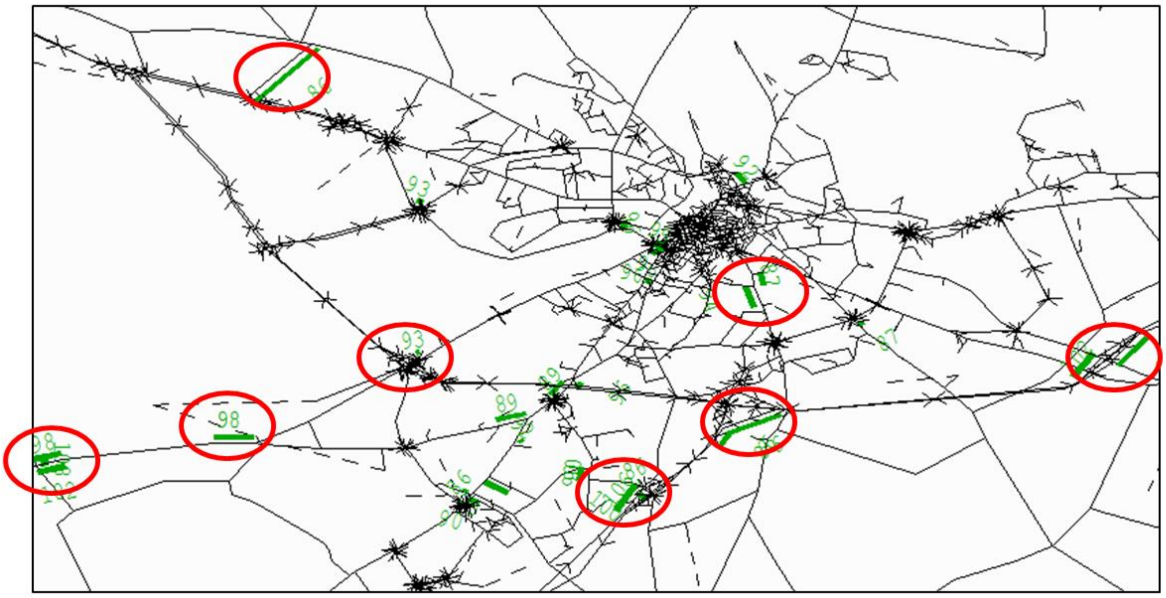

Figure 5.2 V/C in post stress test network

5.4.6 Period-to-Hour Factor

As outlined in Section 3.2, the PtH factors were adjusted during the development of the final model. These factors had the impact of varying the overall travel demand (matrix size) in each time period prior to any adjustment. The factors tended to increase during development, which in turn highlighted additional areas of the model that were weak and required review.

5.4.7 Detailed Network Audit

A detailed network audit was completed after all major changes had been applied to the model. The headline stats prior to the detailed audit are outlined in the following six tables, with detailed statistics included in Appendix A.

Table 5.8 Pre-audit Significance of Matrix Estimation Changes, AM Peak

Measure	Significance Criteria	UC1	UC2	UC3	UC4	UC5	UC6	UC7	UC8	UC9
Matrix zonal cell value	Slope within 0.98 and 1.02;	1.03	0.86	0.81	0.97	0.92	1.01	0.84		0.72
	Intercept near zero;	0.00	0.00	0.02	0.00	0.02	0.01	0.08		0.00
	R^2 in excess of 0.95.	0.78	0.70	0.68	0.79	0.84	0.61	0.50		0.67
Matrix zonal trip ends	Slope within 0.99 and 1.01;	1.06	0.87	0.78	1.01	0.91	1.03	1.09		0.71
	Intercept near zero;	0.04	0.99	9.32	0.04	9.22	1.02	1.09		0.71
	R^2 in excess of 0.98.	0.90	0.89	0.86	0.95	0.91	0.89	0.80		0.93
Trip Length Distributio n	Means within 5%;	-9%	-20%	-16%	-11%	-22%	-12%	-13%		-12%
	Standard Deviation within 5%.	-7%	-17%	-14%	-14%	-19%	-4%	-19%		3%

Table 5.9 Pre-audit Significance of Matrix Estimation Changes, Inter-peak 1

Measure	Significance Criteria	UC 1	UC 2	UC 3	UC 4	UC 5	UC6	UC7	UC8	UC9
Matrix zonal cell value	Slope within 0.98 and 1.02;	1.01	0.84	0.68	1.36	0.91	0.87	0.80		0.72
	Intercept near zero;	0.00	0.00	0.01	0.00	0.02	0.08	0.06		0.00
	R^2 in excess of 0.95.	0.71	0.68	0.70	0.74	0.83	0.47	0.60		0.71
Matrix zonal trip ends	Slope within 0.99 and 1.01;	1.06	0.88	0.66	1.20	0.90	1.01	0.95		0.69
	Intercept near zero;	0.12	0.55	2.14	-0.02	8.08	1.24	1.22		0.02
	R^2 in excess of 0.98.	0.84	0.88	0.93	0.97	0.88	0.85	0.84		0.93
Trip Length Distribution	Means within 5%;	-14%	-25%	-17%	-24%	-26%	-35%	-14%		-9%
	Standard Deviation within 5%.	-11%	-17%	-5%	-18%	-20%	-21%	-17%		2%

Table 5.10 Pre-audit Significance of Matrix Estimation Changes, Inter-peak 2

Measure	Significance Criteria	UC 1	UC 2	UC 3	UC 4	UC 5	UC 6	UC 7	UC 8	UC 9
Matrix zonal cell value	Slope within 0.98 and 1.02;	1.00	0.86	0.73	0.98	0.93	0.91	0.79		0.75
	Intercept near zero;	0.00	0.00	0.01	0.00	0.01	0.00	0.05		0.00
	R^2 in excess of 0.95.	0.80	0.67	0.72	0.89	0.88	0.84	0.60		0.75
Matrix zonal trip ends	Slope within 0.99 and 1.01;	1.02	0.86	0.69	0.98	0.91	0.63	0.91		0.72
	Intercept near zero;	0.13	0.68	4.28	0.05	7.31	1.98	1.14		0.02
	R^2 in excess of 0.98.	0.89	0.92	0.91	0.96	0.91	0.87	0.84		0.93
Trip Length Distribution	Means within 5%;	-14%	-21%	-18%	-12%	-23%	-28%	-15%		-9%
	Standard Deviation within 5%.	-11%	-14%	-9%	-15%	-18%	2%	-15%		3%

Table 5.11 Pre-audit Significance of Matrix Estimation Changes, PM Peak

Measure	Significance Criteria	UC 1	UC 2	UC 3	UC 4	UC 5	UC 6	UC 7	UC 8	UC 9
Matrix zonal cell value	Slope within 0.98 and 1.02;	1.03	0.79	0.80	1.05	0.89	0.95	0.89		0.73
	Intercept near zero;	0.00	0.00	0.04	0.00	0.04	0.01	0.03		0.00
	R^2 in excess of 0.95.	0.71	0.63	0.60	0.61	0.78	0.64	0.61		0.66
Matrix zonal trip ends	Slope within 0.99 and 1.01;	1.09	0.85	0.80	1.16	0.89	1.03	0.99		0.73
	Intercept near zero;	0.32	1.21	11.29	-0.12	15.39	0.80	0.77		0.02
	R^2 in excess of 0.98.	0.80	0.80	0.85	0.97	0.81	0.88	0.89		0.94
Trip Length Distribution	Means within 5%;	-10%	-24%	-18%	-12%	-26%	-11%	-11%		-11%
	Standard Deviation within 5%.	-7%	-17%	-14%	-9%	-19%	-8%	-12%		3%

It should be noted that there was no observed data available to derive the prior goods vehicles matrices. These were developed synthetically, and hence were unlikely to accurately represent the true travel patterns of heavy goods vehicles. This in fact makes the results summarised above look worse, with matrix estimation making particularly large changes to the LGV, OGV1 and OGV2 matrices across all time periods. However, even for the other user classes the differences between pre- and post-Matrix Estimation matrices generally exceed the significance criteria. At the zonal cell value, whilst the slope of the best-fit line through all data points for some user classes was within the range of 0.98 to 1.02, none of the R^2 values achieved the threshold value of 0.95. The same scale of change is noted at the trip end level and the changes to the trip length distribution also fall outside of the 5 per cent significance criteria with the majority user classes being shorter, as is often the case after matrix estimation. This indicates that the changes made during Matrix Estimation were larger than desired.

To address this, the XAMAX parameter in SATURN was reduced and trip end constraints were applied. The XAMAX parameter is discussed more fully in Section 5.8.1, but defines a maximum (or minimum) adjustment factor during Matrix Estimation. A lower value restricts the magnitude of the changes that can be made at a cell level during Matrix Estimation, while the trip end constraints were applied to further reduce the significance of the changes made during Matrix Estimation.

Table 5.12 Pre-audit Road Assignment Model Calibration

Measure	Acceptability Guideline	AM Peak	Inter-peak 1	Inter-peak 2	PM Peak
Individual flows within 100 veh/h of counts for flows less than 700 veh/h within 15% of counts for flows from 700 to 2,700 veh/h within 400 veh/h of counts for flows more than 2,700 veh/h	> 85% of cases	87% (201)	90% (190)	90% (189)	80% (187)
GEH < 5 for individual flows	> 85% of cases	87% (198)	87% (183)	86% (181)	79% (184)

Table 5.13 Pre-audit Road Assignment Model Screenline Calibration

Measure	Acceptability Guideline	AM Peak	Inter-peak 1	Inter-peak 2	PM Peak
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines	45%	45%	50%	30%

Table 5.12 indicates that the Road Assignment Model at the pre-audit stage meets the recommended criteria in each time period with the exception of the PM Peak.

Table 5.13 shows a similar pattern across the model screenlines, with the pre-audit stage model falling short of the criteria in each time period.

Reducing the XAMAX parameter and applying trip end constraints during Matrix Estimation to reduce the significance of matrix changes was anticipated to reduce the level of flow calibration achieved. The reason for this is that by restricting the matrix changes permitted during Matrix Estimation, the Matrix Estimation process may no longer make a large enough change to the prior matrices to meet the flow calibration criteria at as many locations.

To address this, an audit of the road model network coding was undertaken, which considered whether the coding could be improved at specific locations to improve the level of calibration pre-Matrix Estimation. This resulted in changes to access/ entry points to some zones, coding of a small number of junctions and speed-flow curves. A review of the target traffic counts used to calibrate the model was also carried out at this stage.

Table 5.14 shows the percentage difference between the Pre-ME2 and Post-ME2 for the matrix totals between the Pre Audit and the Final incremental PM matrix as an example. The table highlights the difference between the two sets of matrix totals demonstrating the impact of the change to XAMAX and the addition of trip end constraint. The result of the introduction of the XAMAX and the trip end constraint ensure that the user classes with the exception of Taxi do not significantly change.

Table 5.14 PM Matrix Totals % Difference between Pre & Post ME2

% Difference between Pre & Post ME2	Taxi	Emp. Bus.	Commute	Education	Car Other	LGV	OGV1	OGV2
Final Matrix	3%	7%	2%	4%	2%	0%	0%	0%
Pre Audit Matrix	22%	7%	2%	11%	9%	19%	22%	-15%

5.5 Road Model Matrix Progression

5.5.1 Overview

For the MWRM five distinct versions of the prior matrices were produced, and each of these were assigned in order to provide updated network costs for further refinement of the synthetic component of the prior matrix development process. The five versions of the matrices are numbered one through to five in Figure 5.3 below, which illustrates the key processes involved in developing the final road model matrices for the MWRM. Note that not all of the steps that were undertaken are shown on this diagram.

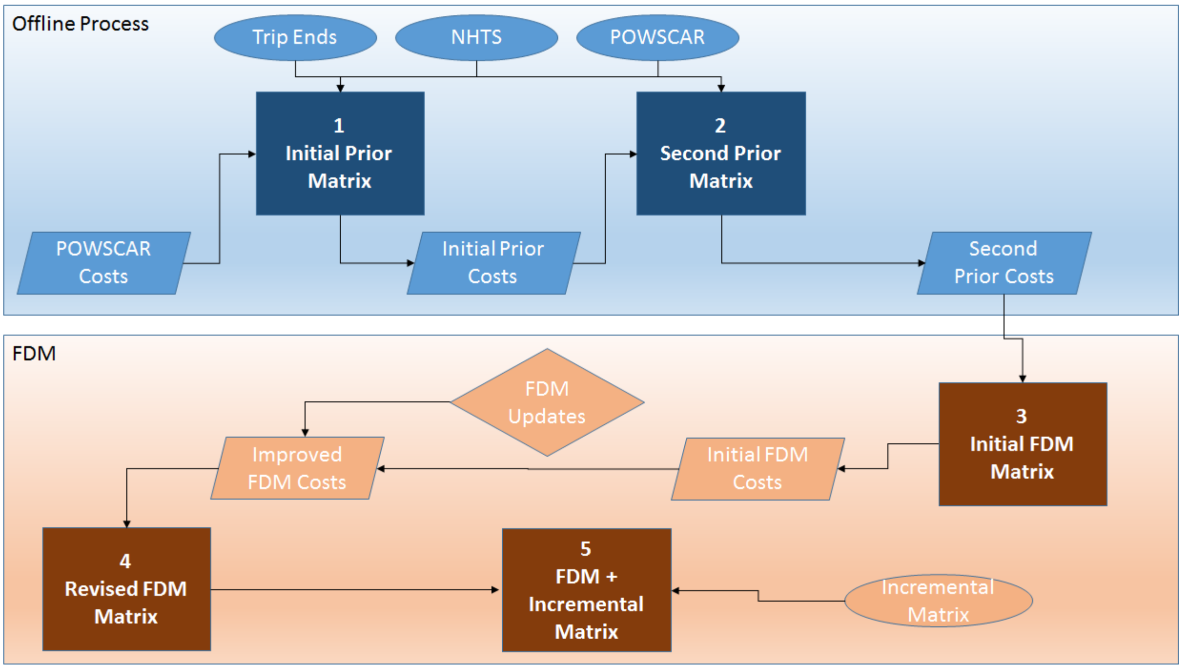

Figure 5.3 Road Model Matrix Development Process

5.5.2 1.Initial Prior Matrices

The initial prior matrices were created using the prior matrix process developed for ERM using NHTS, POWSCAR, Trip Ends and cost skims from approximate POWSCAR matrices. A detailed description of this is given in the “MWRM

Demand Model Calibration Report”. These matrices were assigned and costs extracted to give more accurate costs for input into the second iteration of the prior matrix development process. No updates to the network were made at this stage.

5.5.3 2.Second-Pass Prior Matrices

The second-pass prior matrices used costs extracted from the initial prior matrices to improve the matrices. These were assigned and limited comparisons with observed flows on strategic corridors suggested they provided a good starting point to create costs for the FDM. Costs were extracted from these assignments and used as costs for the first calibration of the FDM.

5.5.4 3.Initial FDM Matrices

The initial calibration of the FDM used the costs extracted from the Second-Pass Prior Matrices. One loop of the FDM was run to create road matrices for all time periods, and these were assigned and costs extracted. These costs were then used to recalibrate the FDM. Once this had been completed, one loop of the re-calibrated FDM was run to create road matrices, and these were assigned. A check of the AM assigned demand level with observed data for each of the screenlines showed that the demand from the FDM was low compared to observed flows on the network.

5.5.5 4.Revised Demand Model Matrices

As part of the calibration of the FDM, a number of assumptions were reviewed and changes made. This resulted in improved road assignment matrices which were taken forward as the starting point from which an incremental matrix was calculated. A description of the applied changes and these steps is given in the “MWRM Demand Model Calibration Report”.

5.5.6 Matrix Estimation

Matrix Estimation was undertaken on the final prior matrices using SATME2. SATME2 uses observed traffic count data and assigned road model paths to adjust the matrix. A maximum (or minimum) adjustment factor is defined by the parameter XAMAX. Traffic passing a particular point in the network where a traffic count is located can be factored by any number that lies between XAMAX and 1 / XAMAX. XAMAX has been set to 2 for cars and taxis, and 15 for goods vehicles due to the low confidence in the prior goods matrices. In this case, cars and taxis can be adjusted by a factor between 0.5 and 2. Goods vehicles can be adjusted by a factor between 0.001 and 15.

Further matrix estimation controls included applying a trip end constraint to the adjustments of + / - 10 per cent for all zone trip ends for cars (user classes 1 – 5).

SATME2 and the assignment module, SATALL, were run iteratively with the assigned paths and costs from the latest road assignment informing the next iteration of SATME2. The goods vehicle matrices were updated and retained between successive iterations, whereas the car input matrices remained constant throughout with the exception of the Taxi user class (UC1).

5.5.7 Incremental Matrix

The incremental matrix reflects those parts of the full travel behaviour pattern which have not been estimated by the demand model. This would include factors like:

- The choice of a school which gets particularly good exam results over another local school; or
- The choice of a journey by tram or train rather than bus which is made because the user can work more reliably on a tram or a train.

The incremental matrix includes all of these varied, hard to predict, behaviour patterns. In the base model it is used to adjust the matrices which are directly output from the demand model to match the calibrated base matrices and so produce a calibrated base network following assignment. In the future model it is intended to improve the predictive power of the model by adding in a contribution from the more unpredictable parts of the travel demand.

5.5.8 5.Final Incremental Matrix

Two types of incremental matrix are in use in the model:

- Additive incrementals, where the incremental matrices (whose values may be positive, negative, or a mix of the two) are added on to the matrices output by the demand model; and
- Multiplicative incrementals, where the incremental matrices are used to factor the matrices output by the demand model.

There is no reason in principal why each incremental could not be a mix of additive and multiplicative values but at present the model uses additive incrementals for the road and public transport matrices and multiplicative incrementals for the active modes. This is because the calibrated base matrices are considered to be much better defined in the road and public transport networks than is the case in the active modes model.

The additive incrementals are calculated by taking the best direct demand model output and finding the difference between this and the best calibrated base matrix on a cell by cell basis. The incremental matrix produced is added on to the best direct demand model output such that the final assignment output matches the calibrated base (in the base case).

As no detailed calibration of the active modes component was undertaken, the multiplicative incrementals are calculated to give the best overall fit to the total observed flow on any observed screenline. For example, if 100 trips were observed and the model with no incremental applied gave a value of 120 trips on that screenline then the incremental matrix would be set to a value of 100/120 in every cell such that once the incremental is applied the assignment model would mimic the 100 observed trips closely.

The final assignment matrices including the incremental adjustments are what the network calibration and validation assessments are based on. In relation to road travel, the incremental matrix only applies to car user classes; for goods vehicles the matrix estimated matrix was input directly as an updated version of the input internal goods matrix.

5.6 Final generalised cost parameters

The road assignment model was calibrated and subsequently validated using the generalised cost parameters set out in the following four tables.

Table 5.15 Final AM Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	58.82	17.69
UC2 – Car Employers Business	58.82	17.69
UC3 – Car Commute	21.70	9.34
UC4 – Car Education	42.82	9.34
UC5 – Car Other	21.09	9.34
UC6 – LGV	43.34	12.79
UC7 – OGV1	46.08	28.53
UC8 – OGV2 Permit Holder	44.40	52.21
UC9 – OGV2 (Other)	44.40	52.21

Table 5.16 Final IP1 Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	58.82	17.15
UC2 – Car Employers Business	58.82	17.15
UC3 – Car Commute	21.70	9.11
UC4 – Car Education	42.82	9.11
UC5 – Car Other	21.09	9.11
UC6 – LGV	45.91	13.39
UC7 – OGV1	47.87	28.68
UC8 – OGV2 Permit Holder	46.55	52.65
UC9 – OGV2 (Other)	46.55	52.65

Table 5.17 Final IP2 Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	58.82	17.32
UC2 – Car Employers Business	58.82	17.32
UC3 – Car Commute	21.70	9.17
UC4 – Car Education	42.82	9.17
UC5 – Car Other	21.09	9.17
UC6 – LGV	45.91	13.45
UC7 – OGV1	47.87	28.96
UC8 – OGV2 Permit Holder	46.55	53.17
UC9 – OGV2 (Other)	46.55	53.17

Table 5.18 Final PM Generalised Cost Values

User Class	Cents Per Minute	Cents Per Kilometre
UC1 – Taxi	58.82	17.26
UC2 – Car Employers Business	58.82	17.26
UC3 – Car Commute	21.70	9.15
UC4 – Car Education	42.82	9.15
UC5 – Car Other	21.09	9.15
UC6 – LGV	43.34	12.60
UC7 – OGV1	46.08	27.78
UC8 – OGV2 Permit Holder	44.40	50.84
UC9 – OGV2 (Other)	44.40	50.84

5.7 Road Model Network Calibration

5.7.1 Overview

This section details the calibration process and the level of calibration for the road assignment model across the four assigned peak periods.

In total, 234 observations have been used in the SATME2 procedure, of which 88 observations form part of the strategic screenlines.

Although TAG suggests that GEH values should be less than 5 for 85 per cent of cases, for a model of this size and complexity a range of standards suggest that it is common for larger GEH values to be accepted as showing a reasonable level of calibration when considered in full with the intended model application and other performance indicators. Acceptable models typically achieve the following criterion:

- GEH < 5 for 65 per cent of all sites
- GEH < 7 for 75 per cent of all sites
- GEH < 10 for 95 per cent of all sites

5.7.2 Traffic Count Locations

A detailed map showing the location of all traffic counts used during calibration is presented in Figure 5.4.

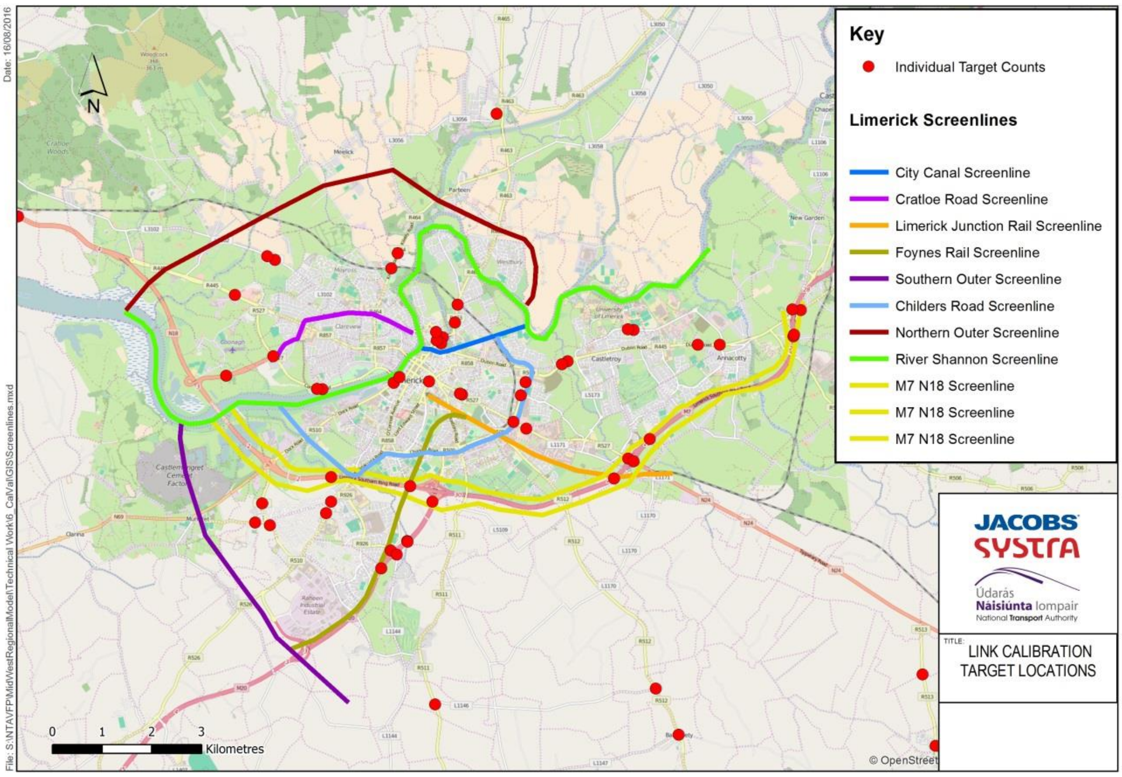

Figure 5.4 Link Calibration Target Locations

5.7.3 Individual link calibration criteria compliance – AM peak

There are a total of 234 individual link traffic counts used during the AM peak road model network calibration. Table 5.19 details the individual link count acceptability criteria.

Table 5.19 AM Link Flow Calibration

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	73% (171)
GEH < 5 for individual flows	> 65% of cases	70% (164)
GEH < 7 for individual flows	> 75% of cases	80% (187)
GEH < 10 for individual flows	> 95% of cases	89% (208)

The model statistics show that the individual link calibration for the AM peak road model does not meet the recommendations set out in TAG. However, in terms of GEH, it is close to passing all typical acceptability criteria set out in Section 5.7.1, with only the number of links with a GEH less than 10 failing to meet the recommended criteria by six per cent.

Detailed calibration results, highlighting specific links that pass or fail the recommended calibration criteria are included in Appendix A.

Four per cent of links (9) have a GEH in excess of 15. The location with the highest GEH is Ballinacurra Road / Childers Road. In this specific example, a GEH of 31.0 was recorded on the link, with the modelled demand far lower than the observed count data. Investigations into the poor performance of this link showed that there are no conflicting neighbouring target counts influencing matrix estimation and that the observed data is correct.

Traffic volumes both north and south of this location on the N18, Limerick Tunnel and other M7 sites perform well in terms of meeting the recommended calibration criteria. Another location with a poorly performing traffic count is on the M7 eastbound towards Junction 30 which has a GEH of 30.3. Further investigation indicated that the LGV and HGV modelled flows for this link compared well against the observed flows. The modelled traffic volume for combined car user classes is 712 vehicles compared to 1,990 observed car trips. There is a similar example of poor calibration on a nearby count on a link exiting the M7 (Junction 29) onto the off-slip which connects the M7 to the N24 / R527. The GEH value here is also quite high and further demonstrates that the demand is low in this area and can be attributed to underrepresentation of car-based trips. Another reason why the GEH is high at this location is due to the delay at the signalised junction from the off slip onto the R527.

The remaining GEH values in excess of 15 were reviewed, and with the exception of one these GEH values were recorded on links with lower modelled levels of traffic than observed. These include:

- R527 (inbound) 1496 observed, 844 modelled – GEH 19.1
- Athlunkard Street (WB) 327 observed, 45 modelled – GEH 20.6
- Lower Mallow Road (inbound) 305 observed, 1 modelled – GEH 24.5
- Bridge Street (SB) 69 observed, 327 modelled – GEH 18.4
- R512 Kilmallock Road (NB) 903 observed, 358 modelled – GEH 21.7

The high GEH value on Athlunkard Street can partially be attributed to the low observed levels of traffic. On Ballinacurra Road / Childers Road the inbound travel demand is low, which is reflected across all time periods. This can be attributed to the level of zone disaggregation in this area. There are seven zones along Childers Road at present, however there is potential for extra zones or additional zone connectors to represent traffic accessing retail units at the southwestern end of Childers Road. The high GEH at the R512 Kilmallock Road inbound is attributed to the low demand compared against the observed data. A nearby traffic count data on the R512 south of the M7 shows a well performing GEH. The low demand can be explained by the lack of zonal disaggregation on the R512 inside the M7.

5.7.4 Screenline calibration criteria compliance – AM peak

A total of nine two-way screenlines (inbound and outbound) were compared as part of the network calibration exercise.

Table 5.20 details the number of SATURN links forming each screenline, and the percentage difference between the total observed traffic volume across the screenline and the total modelled traffic volume across the screenline.

Table 5.20 AM Screenline Flow Calibration

Screenline	Number of Links	Modelled Difference
Northern Outer (Northbound)	6	7%
Northern Outer (Southbound)	6	-8%
Southern Outer (Inbound)	3	5%
Southern Outer (Outbound)	3	5%
River Shannon (Northbound)	6	1%
River Shannon (Southbound)	6	-11%
M7 N18 (Inbound)	8	-9%
M7 N18 (Outbound)	8	-4%
City Canal (Northbound)	4	2%
City Canal (Southbound)	4	4%
Limerick Junction Rail Screenline (Northbound)	3	-23%
Limerick Junction Rail Screenline (Southbound)	3	4%
Foynes Rail Screenline (Eastbound)	4	-24%
Foynes Rail Screenline (Westbound)	4	-5%
Childers Road (Outbound)	7	-3%
Childers Road (Inbound)	7	-24%
Cratloe Road (Northbound)	3	11%
Cratloe Road (Southbound)	3	-14%

44 per cent of the screenlines meet the recommended calibration criteria as set out in TAG Unit M3-1, which is below the recommended acceptability criteria of “all or nearly all” screenlines meeting the criteria, though a further four screenlines fail by less than five per cent.

The Cratloe Road and Foynes Rail Screenlines are the poorest performing screenlines. The Cratloe Screenline fails in both directions, on closer inspection the Cratloe Northbound Screenline fails by 1 per cent and the flows on the majority of the links pass. On the Southbound Screenline only one of the links has a GEH>5, this particular link has modelled flows on Condell Road which is lower than the observed which presents a weaker calibration in this area which can be explained by the low demand. The Foynes Rail Eastbound Screenline meets the GEH criteria on half the links with modelled flows lower than the observed flows along the R510 from M20 and Childers Road, this can be explained by the low demand in this area.

The Foynes Rail Westbound Screenline performs well, however does not meet TAG criteria by 0.2 per cent. Only one of the links fails to meet the individual criteria, but still has a GEH of less than 10.

5.7.5 Individual link calibration criteria compliance – Inter-peak 1

There are a total of 210 traffic counts used during the Inter-peak 1 road model network calibration. Table 5.21 details the individual link count acceptability criteria.

Table 5.21 Inter-peak 1 Link Flow Calibration

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	87% (182)
GEH < 5 for individual flows	> 65% of cases	82% (173)
GEH < 7 for individual flows	> 75% of cases	89% (186)
GEH < 10 for individual flows	> 95% of cases	94% (198)

The model statistics show that the individual link calibration for the Inter-peak 1 road model meets the recommendations set out in TAG, for link flow. In terms of GEH, it is close to passing all typical acceptability criteria set out in Section 5.7.1, with only the number of links with a GEH less than 10 failing to meet the recommended criteria by one per cent.

Detailed calibration results, highlighting specific links that pass or fail the recommended calibration criteria are included in Appendix A.

One per cent of links (3) have a GEH in excess of 15. Lower Mallow Street in the city centre has the highest GEH of any link in the Inter-peak 1 time period. In this specific example, a GEH of 21.7 was recorded. There is no modelled traffic on Lower Mallow Street eastbound from the Shannonbridge Roundabout in the Inter-peak 1 time period. The observed car traffic count is 190 cars. The coding of this link and the coding of upstream links are correct and allows for traffic to make use of this link. This link and approaching links do not have any banned movements that would obstruct traffic from reaching this part of the network. A comparison with the AM assigned network demonstrated that traffic can make use of this link and the assigned traffic on this link during the AM time period met the calibration criteria. In the AM peak, the main user classes representing movements on this link was the car commute and car other. There are three zones within a three hundred metre distance from the Shannonbridge roundabout. These three zones can be accessed more directly without requiring travel along Lower Mallow Street. These nearby zones would represent offices and places of employment therefore flows associated with these movements would tend to primarily occur during the AM and PM peaks. In the Inter-peak 1 time period there is very little delays in the city centre and it appears that only the most direct routes are utilised, therefore in this instance Lower Mallow Street experiences modelled flows of zero due to the lack of zones located within the immediate vicinity of this link, and the low delay in the Inter-peak 1 time period. This also occurs on Mallow Street.

The performance of the link leaving the N18 eastbound approaching the M7 (Junction 30) is poor. This also occurred in the AM peak period, and is evident in all time periods. The poor calibration can be attributed to the underrepresentation of commuter, education and car other trips in the prior matrix. The remaining GEH values in excess of 15 were reviewed, and these GEH values were recorded on links with lower modelled levels of traffic than observed. These include:

- Ballinacurra Road / Childers Road (inbound) 690 observed, 263 modelled – GEH 19.6.

The factors attributing to the poor calibration performance at this location is outlined in section 5.7.3.

5.7.6 Screenline calibration criteria compliance – Inter-peak 1

A total of nine two-way screenlines were compared as part of the network calibration exercise.

Table 5.22 details the number of SATURN links forming each screenline, and the difference between the total observed traffic volume across the screenline and the total modelled traffic volume across the screenline.

Table 5.22 Inter-peak 1 Screenline Flow Calibration

Screenline	Number of Links	Modelled Difference
Northern Outer (Northbound)	6	-7%
Northern Outer (Southbound)	6	-6%
Southern Outer (Inbound)	3	1%
Southern Outer (Outbound)	3	5%
River Shannon (Northbound)	3	7%
River Shannon (Southbound)	3	5%
M7 N18 (Inbound)	9	9%
M7 N18 (Outbound)	9	-6%
City Canal (Northbound)	4	-7%
City Canal (Southbound)	4	20%
Limerick Junction Rail Screenline (Northbound)	2	17%
Limerick Junction Rail Screenline (Southbound)	2	0%
Foynes Rail Screenline (Eastbound)	4	-18%
Foynes Rail Screenline (Westbound)	4	-20%
Childers Road (Outbound)	4	-10%
Childers Road (Inbound)	4	-6%
Cratloe Road (Northbound)	3	-2%
Cratloe Road (Southbound)	3	-2%

22 per cent of the screenlines meet the recommended calibration criteria as set out in TAG Unit M3-1, which is below the recommended acceptability criteria of “all or nearly all” screenlines meeting the criteria. However, a further nine screenlines fail by less than five percentage points. The Limerick Junction Rail and Foynes Rail Screenlines are the poorest performing screenlines. The Limerick Junction Rail Screenline fails in one direction (northbound). On closer inspection, there are only two links at this screenline and only one of the links fail due to percentage difference in flows of 331 per cent. This high percentage difference can be explained by low value numbers i.e. 15 observed vehicle trips compared to 65 modelled vehicle trips. The Foynes Rail Eastbound Screenline fails to meet the GEH criteria on just one link. The modelled flows are lower than the observed flows along Childers Road. This can be explained by the low demand in this area and this is evident in other time periods. The Foynes Rail Westbound Screenline performs well overall, however fails at Childers Road in the westbound direction.

Similar to the eastbound direction, the modelled flows were lower than the observed flows at this location.

5.7.7 Individual Link Calibration Criteria Compliance – Inter-peak 2

There are a total of 210 traffic counts used during the Inter-peak 2 road model network calibration. Table 5.23 details the individual link count acceptability criteria.

Table 5.23 Inter-peak 2 Link Flow Calibration

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	83% (175)
GEH < 5 for individual flows	> 65% of cases	79% (166)
GEH < 7 for individual flows	> 75% of cases	85% (179)
GEH < 10 for individual flows	> 95% of cases	93% (196)

The model statistics show that the individual link calibration for the Inter-peak 2 road model narrowly fails to meet the recommendations set out in TAG for link flows. It does meet the GEH acceptability criteria set out in Section 5.7.1 for all cases except the number of links with a GEH less than 10 which fails to meet the recommended criteria by two per cent.

Detailed calibration results, highlighting specific links that pass or fail the recommended calibration criteria are included in Appendix A. Similar to Inter-peak 1 the area of the model where the calibration is weakest is Lower Mallow Street in the city centre. The reasoning behind the poor GEH value at this location is discussed in section **Error! Reference source not found.**. In summary the low travel demand can be attributed to no zone centroids within the vicinity and faster alternative routes to neighbouring zones without the need to utilise the link in question.

One per cent of links (3) have a GEH in excess of 15. As per all time periods the calibration of the link leaving the N18 eastbound approaching the M7 (Junction 30) is poor. The poor calibration can be attributed to the underrepresentation of commuter, education and car other trips as discussed previously in section 5.7.3. The remaining GEH values in excess of 15 were reviewed, and these GEH values were recorded on links with lower modelled levels of traffic than observed. These include:

- Ballinacurra Road / Childers Road (inbound) 743 observed, 292 modelled – GEH 19.8.

The factors attributing to the poor calibration performance at this location is outlined in section 5.7.3.

5.7.8 Screenline calibration criteria compliance – Inter-peak 2

A total of nine individual screenlines were compared as part of the network calibration exercise.

Table 5.24 details the number of SATURN links forming each screenline, and the difference between the total observed traffic volume across the screenline and the total modelled traffic volume across the screenline.

Table 5.24 Inter-peak 2 Screenline Flow Calibration

Screenline	Number of Links	Modelled Difference
Northern Outer (Northbound)	6	2%
Northern Outer (Southbound)	6	0%
Southern Outer (Inbound)	3	4%
Southern Outer (Outbound)	3	3%
River Shannon (Northbound)	3	1%
River Shannon (Southbound)	3	1%
M7 N18 (Inbound)	9	12%
M7 N18 (Outbound)	9	-5%
City Canal (Northbound)	4	0%
City Canal (Southbound)	4	6%
Limerick Junction Rail Screenline (Northbound)	2	18%
Limerick Junction Rail Screenline (Southbound)	2	2%
Foynes Rail Screenline (Eastbound)	4	-13%
Foynes Rail Screenline (Westbound)	4	-16%
Childers Road (Outbound)	4	-14%
Childers Road (Inbound)	4	-4%
Cratloe Road (Northbound)	3	-8%
Cratloe Road (Southbound)	3	-3%

56 per cent of the screenlines meet the recommended calibration criteria as set out in TAG Unit M3-1, which is below the recommended acceptability criteria of “all or nearly all” screenlines meeting the criteria. A further three screenlines narrowly fail to meet the criteria by less than five percentage points.

The Foynes Rail and Childers Road Screenlines are the poorest performing screenlines The Foynes Rail Eastbound Screenline fails to meet the recommended GEH criteria on just one link. The modelled flows are lower than the observed flows along Childers Road. This can be explained by the low demand in this area, which is evident in other time periods. The Foynes Rail Westbound Screenline performs well overall however fails at Childers Road in the westbound direction. Similar to the eastbound direction, the modelled flows were lower than the observed flows at this location. The Childers Road Outbound Screenline fails on one link at Dock Road with the remaining flows across the sceenline meeting the calibration criteria. On closer inspection, the combined flows crossing the screenline fail due to the low value flows i.e. 723 observed vehicle trips compared to 478 modelled vehicle trips which represents a 34 per cent difference in flows. The Childers Road Inbound Screenline towards the city centre meets the calibration criteria across all links.

5.7.9 Individual Link Calibration Criteria Compliance – PM Peak

There are a total of 234 traffic counts used during the PM peak road model network calibration. Table 5.25 details the individual link count acceptability criteria.

Table 5.25 PM Link Flow Calibration

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	76% (178)
GEH < 5 for individual flows	> 65% of cases	72% (169)
GEH < 7 for individual flows	> 75% of cases	80% (187)
GEH < 10 for individual flows	> 95% of cases	86% (201)

The model statistics show that the individual link calibration for the PM peak road model does not meet the recommendations set out in TAG. However, in terms of GEH, it is close to passing all typical acceptability criteria set out in Section 5.7.1, with only the number of links with a GEH less than 10 failing to meet the recommended criteria by 9 per cent.

Detailed calibration results, highlighting specific links that pass or fail the recommended calibration criteria are included in Appendix A.

Five per cent of links (11) have a GEH in excess of 15. The area of the model where the calibration is weakest is the N18 eastbound approaching the M7 (Junction 30). In this specific example, a GEH of 30.5 was recorded on the link. This link and the M7 off slip (Junction 29) perform poorly across all time periods; with section 5.7.3 outlining the reasoning behind the poor calibration of this link. In summary, the GEH value at this link is high due to the low demand between Junction 30 and 29 of the M7, and can be attributed to underrepresentation of commuter, education and car other trips within the demand matrices. Similar to the Inter-peak 1 and 2 time periods, the observed traffic count on the link at Lower Mallow Street in the city centre performs poorly. The reasoning behind the poor GEH value at this location is discussed previously in section **Error! Reference source not found.**. The remaining GEH values in excess of 15 were reviewed, and with the exception of one these GEH values were recorded on links with lower modelled levels of traffic than observed. These include:

- N85 (WB towards Ennis) 280 observed 824 modelled – GEH 23.2; and
- Ballinacurra Road / Childers Road (inbound) 832 observed 323 modelled – GEH 21.2.

Modelled demand in the Ennis area is greater than observed demand for all time periods. This issue becomes more acute at the N85 link count as outlined above. In the PM time period the modelled flows exceed a GEH value of 15 as outlined above. The matrices contain excess demand to and from Ennis. Ennis is located in the buffer network where junction delays are not modelled. Therefore, junctions may facilitate more traffic travelling across the link and through junctions than expected. A small number of capacity indices were revised to ensure traffic was routing correctly within Ennis, however the model still shows a higher level of demand in the Ennis area. This high demand can in part be attributed to trip generation undertaken by the Regional Model System Integration Tool (RMSIT) which is discussed in greater detail in the "MWRM Demand Model Calibration Report".

The factors attributing to the poor calibration performance at Ballinacurra Road / Childers Road is outlined in section 5.7.3.

5.7.10 Screenline Calibration Criteria Compliance – PM Peak

A total of nine individual screenlines were compared as part of the network calibration exercise.

Table 5.26 details the number of SATURN links forming each screenline, and the difference between the total observed traffic volume across the screenline and the total modelled traffic volume across the screenline.

Table 5.26 PM Screenline Flow Calibration

Screenline	Number of Links	Modelled Difference
Northern Outer (Northbound)	6	-12%
Northern Outer (Southbound)	6	-8%
Southern Outer (Inbound)	3	3%

Southern Outer (Outbound)	3	2%
River Shannon (Northbound)	6	-14%
River Shannon (Southbound)	6	-1%
M7 N18 (Inbound)	8	11%
M7 N18 (Outbound)	8	-11%
City Canal (Northbound)	4	-16%
City Canal (Southbound)	4	2%
Limerick Junction Rail Screenline (Northbound)	3	1%
Limerick Junction Rail Screenline (Southbound)	3	-5%
Foynes Rail Screenline (Eastbound)	4	-16%
Foynes Rail Screenline (Westbound)	4	-29%
Childers Road (Outbound)	7	-28%
Childers Road (Inbound)	7	-7%
Cratloe Road (Northbound)	3	-2%
Cratloe Road (Southbound)	3	-4%

39 per cent of the screenlines meet the recommend calibration criteria as set out in TAG Unit M3-1, which is below the recommended acceptability criteria of "all or nearly all" screenlines meeting the criteria. A further three screenlines narrowly fail to meet the criteria by less than five percentage points.

The Foynes Rail and Childers Road Screenlines are the poorest performing Screenlines. The Foynes Rail Eastbound Screenline fails to meet the recommended GEH criteria on just one link. The modelled flows are lower than the observed flows along Childers Road. This can be explained by the low demand in this area and this is evident in other time periods. The Foynes Rail Westbound Screenline performs well overall however fails at Childers Road in the westbound direction. Similar to the eastbound direction, the modelled flows were lower than the observed flows at this location. The Childers Road Outbound Screenline fails on five links, on closer inspection, the modelled flows crossing the screenline is much lower compared to the observed which results in weaker calibration in this part of the model as the PM outbound modelled trips from the city is lower. This can be explained by a low demand in this part of the model. The Childers Road Inbound Screenline fails on one link at Rebogue Road with the remaining flows across the sceenline meeting the calibration criteria. The combined flows crossing the screenline fails to meet the recommended criteria by 1.5 per cent. The 4568 observed vehicle trips compared to 4270 modelled vehicle trips which represents a 6.5 per cent difference in flows.

5.8 Road Model Matrix Calibration

5.8.1 Overview

Matrix estimation was undertaken on the final prior matrices, including constraints at a cellular and trip end level. These are discussed further in Section 5.5.6.

5.8.2 Calibration criteria compliance – AM Peak

Table 5.27 details the overall change in inter-zonal matrix size between the pre-estimation matrix and the post-estimation matrix. Intra-zonal matrix totals are not adjusted by matrix estimation and do not affect the assignment in SATURN.

Table 5.27 MWRM RM AM Peak Matrix Totals

User Class	Prior (PCU)	Post-Incremental (PCU)	Change (%)
TAG Criteria			Within 5%
Taxi	2,566	2,594	1%
Car Employers Business	3,458	3,450	0%
Car Commute	26,181	24,941	-5%
Car Education	1,459	1,408	-4%
Car Other	37,949	37,544	-1%
LGV	3,359	3,407	1%
OGV1	3,209	3,327	4%
OGV2 Permit Holder			
Other OGV2	241	241	0%

Overall, there is a reduction of two per cent in the matrix total, with the largest change applied to the Car Commute user class.

A table of sectored matrix differences is presented in Appendix B.

The changes to all user classes are of an acceptable level. GEH analysis was undertaken on the individual (non-zero) cells and their change between the pre-estimation and post-estimation values. 27 per cent of cells have a GEH value of less than 0.01, with 82 per cent of cells having a GEH value of less than 0.1. A graph illustrating the distribution of GEH values is shown in Figure 5.5 and Figure 5.6. Note the change in scale for both axes in Figure 5.6.

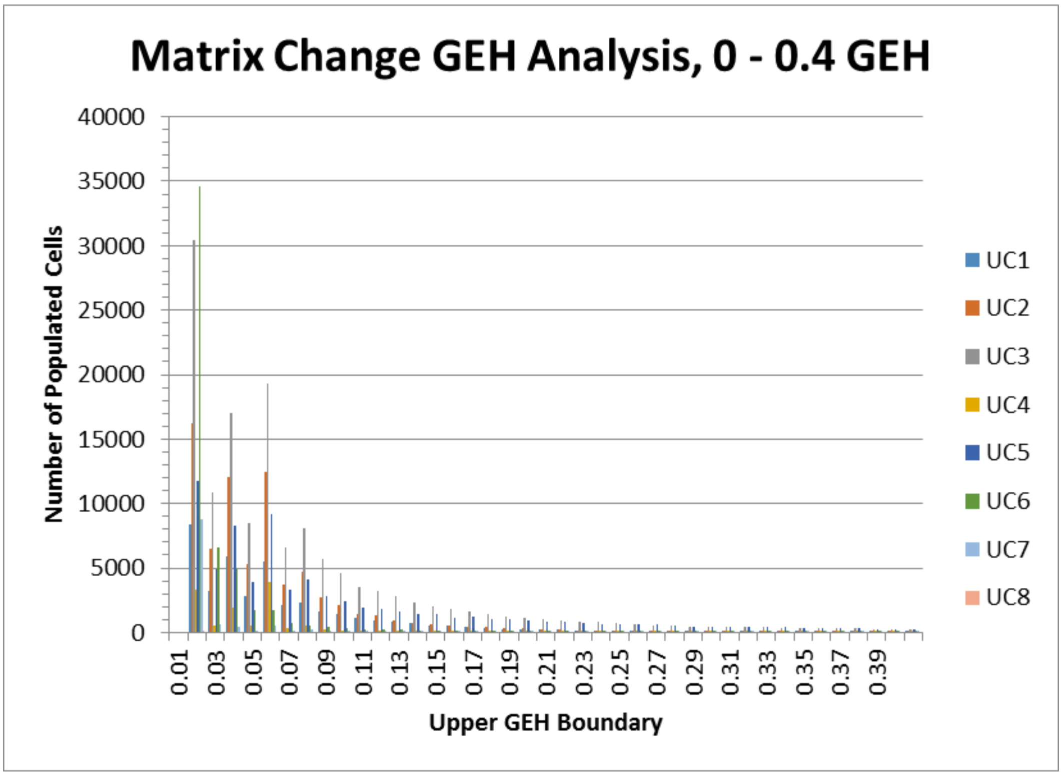

Figure 5.5 SATME2 AM Matrix Change GEH Analysis; 0 GEH to 0.4 GEH

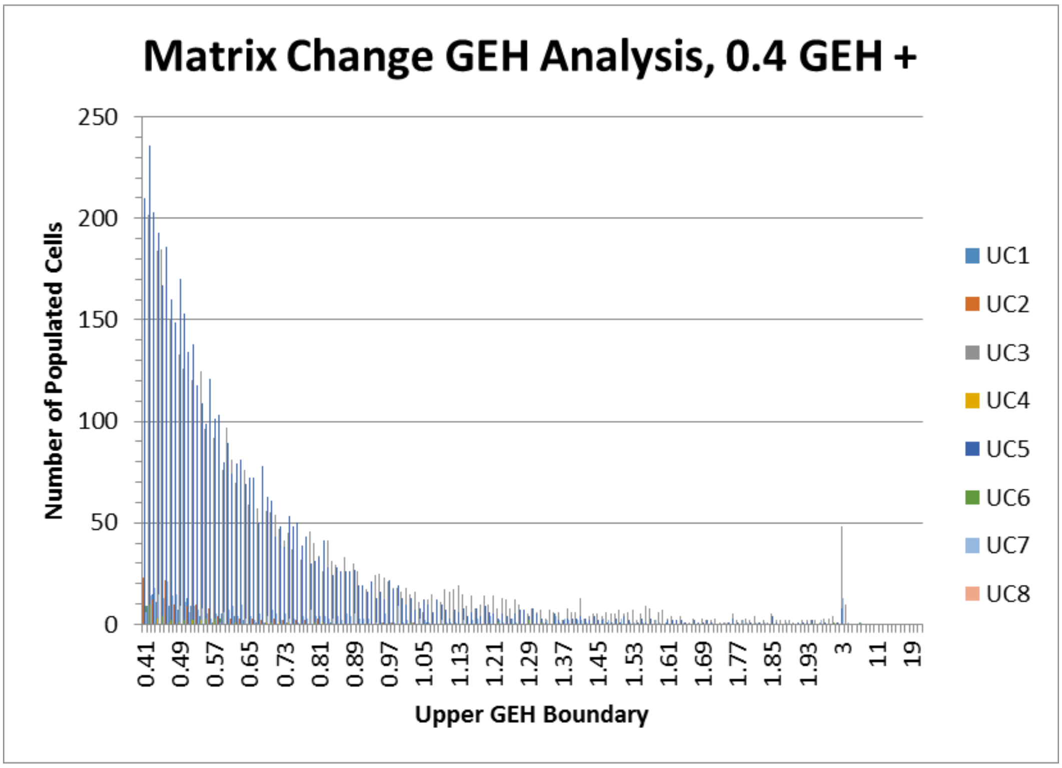

Figure 5.6 SATME2 AM Matrix Change GEH Analysis; 0.4 GEH Upwards

R^2 analysis was undertaken to further understand the matrix changes made by SATME2. Table 5.28 details the R^2 values for each individual user class. These are represented graphically in Appendix C.

Table 5.28 SATME2 AM Matrix Change R^2 Analysis

User Class	Cell R^2 Value	Cell Slope	Cell Y-Int
TAG Criteria	**> 0.95**	**0.98 - 1.02**	**Near 0**
Taxi	0.83	1.04	0.00
Car Employers Business	0.90	0.97	0.00
Car Commute	0.93	0.97	0.00
Car Education	0.95	1.03	0.00
Car Other	0.97	0.98	0.00
LGV	0.94	0.99	0.00
OGV1	0.94	0.97	0.02
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

TAG Unit M3-1, Section 8, Table 5 indicates that an acceptable R^2 value for individual matrix zonal changes is in excess of 0.95. Three of the user classes meet the recommended R^2 criteria, and of the five that do not pass, all have an R^2 value greater than 0.90, except for Taxi with a R^2 value of 0.83.

Trip End R^2 analysis was undertaken for each user class and summarised in Table 5.29.

Table 5.29 AM Trip End Matrix Change R^2 Analysis

User Class	Trip End R^2 Value	Trip End Slope	Trip End Y-Int
TAG Criteria	**> 0.98**	**0.99 - 1.01**	**Near 0**
Taxi	0.97	1.03	-0.12
Car Employers Business	0.97	0.98	0.23
Car Commute	0.99	0.92	2.49
Car Education	0.99	0.94	0.15
Car Other	0.99	0.97	2.05
LGV	0.99	1.01	0.05
OGV1	0.99	1.02	0.15

OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

The R^2 value for the trip ends is greater than 0.97 for all of the user classes. The trip end slope passes the TAG criteria for two of the user classes, with the other six only narrowly failing to meet the recommended criteria. Values for the y-intercept are between -0.12 and 2.49.

The matrix was compared against three prominent screenlines to determine whether or not the matrix broadly contains the correct number of trips. This check was undertaken on the M7 / N18, River Shannon and the Cratloe Road screenlines.

Table 5.30 MWRM RM AM Screenline Check

Screenline	Observed (Veh)	Model (Veh)	Difference (%)
TAG Criteria			**Within 5%**
M7 / N18 (Inbound)	5,322	4,866	-9%
M7 / N18 (Outbound)	3,448	3,313	-4%
River Shannon (Northbound)	3,223	3,243	1%
River Shannon (Southbound)	4,497	4,022	-11%
Cratloe Road (Northbound)	901	997	11%
Cratloe Road (Southbound)	1,616	1,398	-14%

Traffic levels across the M7 / N18 (Outbound) and River Shannon (Northbound) are within the acceptability criteria outlined in TAG unit M3-1. However, traffic crossing the remaining screenlines is not within the acceptability criteria. All screenlines are within 15 per cent of observed traffic levels.

Trip length distribution was also assessed as part of the matrix calibration process post-estimation. All of the eight user classes pass the criteria of a change in the mean trip length of less than 5 per cent, and seven pass the criteria of a change in the standard deviation of the trip length of less than 5 per cent as the “Car Other” user class fails through rounding only (5.2 per cent).

Table 5.31 Trip Length Distribution Analysis - AM

User Class	Mean Percentage Change	Standard Deviation Change
TAG Criteria	**< 5%**	**< 5%**
Taxi	-1%	-5%
Car Employers Business	-4%	-5%
Car Commute	-4%	-3%
Car Education	-4%	-4%
Car Other	-4%	-5%
LGV	-1%	-1%
OGV1	-1%	1%
OGV2 Permit Holder		
Other OGV2	0%	0%

Graphical representation of the trip length distribution changes at a user class level are presented in Appendix D.

5.8.3 Calibration criteria compliance – Inter-peak 1

Table 5.32 details the overall change in inter-zonal matrix size between the pre-estimation matrix and the post-estimation matrix. Intra-zonal matrix totals are not adjusted by matrix estimation and do not affect the assignment in SATURN.

Table 5.32 MWRM RM Inter-peak 1 Matrix Totals

User Class	Pre-Estimation (PCU)	Incremental (PCU)	Change (%)
TAG Criteria			**Within 5%**
Taxi	2,188	2,200	1%
Car Employers Business	2,003	1,996	0%
Car Commute	3,915	3,815	-3%
Car Education	134	134	0%
Car Other	30,804	30,609	-1%
LGV	2,443	2,460	1%
OGV1	2,715	2,806	3%
OGV2 Permit Holder			
Other OGV2	211	211	0%

Overall, there is a reduction of less than one per cent in the matrix total, with the largest percentage change applied to the Car Commute user class.

A table of sectored matrix differences is presented in Appendix B.

GEH analysis was undertaken on the individual (non-zero) cells and their change between the pre-estimation and post-estimation values. 26 per cent of cells have a GEH value of less than 0.01, with 87 per cent of cells having a GEH value of less than 0.1. A graph illustrating the distribution of GEH values is shown in Figure 5.7 and Figure 5.8. Note the change in scale for both axes in Figure 5.8.

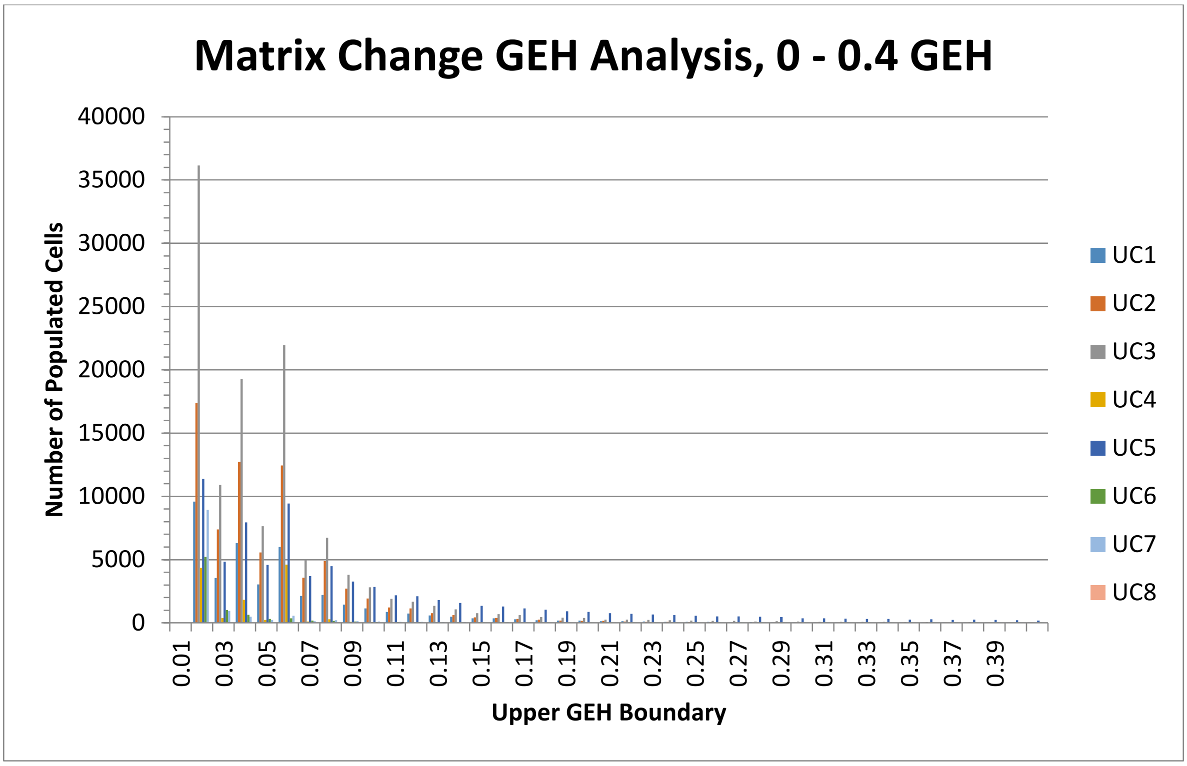

Figure 5.7 SATME2 IP1 Matrix Change GEH Analysis; 0 GEH to 0.4 GEH

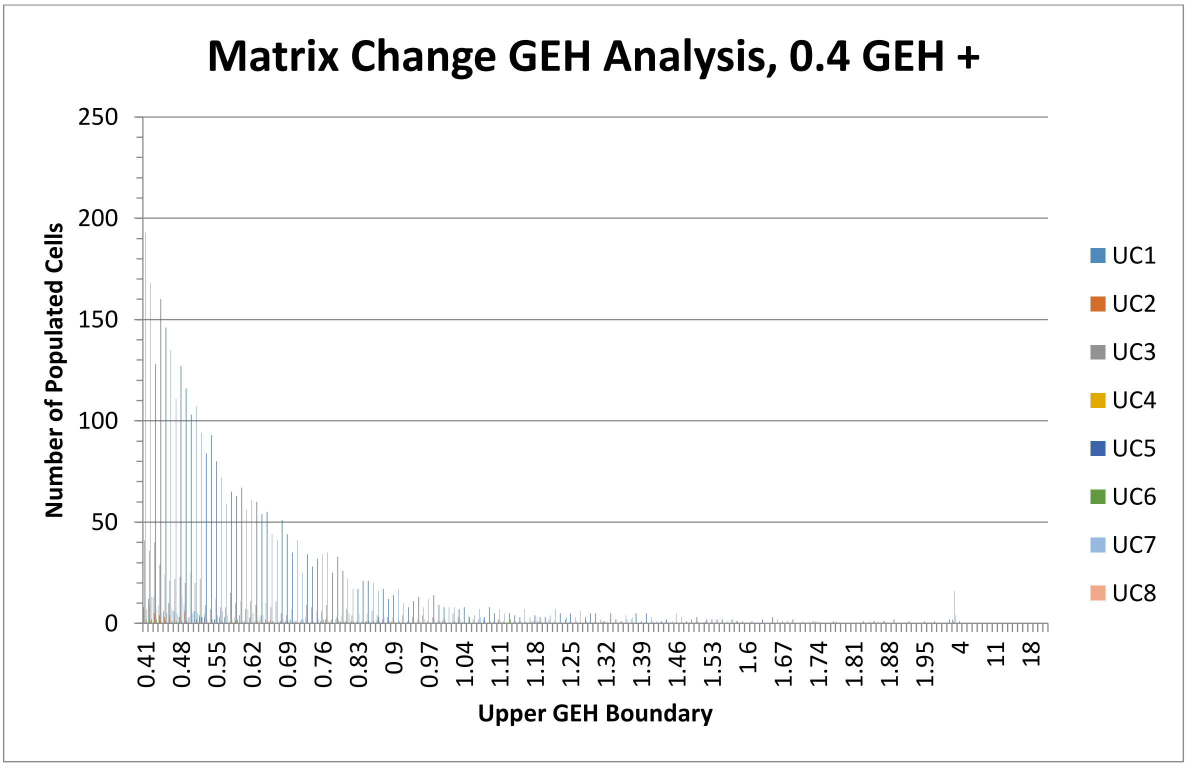

Figure 5.8 SATME2 IP1 Matrix Change GEH Analysis; 0.4 GEH Upwards

R^2 analysis was undertaken to further understand the matrix changes made by SATME2. Table 5.33 details the R^2 values for each individual user class. These are represented graphically in Appendix C.

Table 5.33 SATME2 IP1 Matrix Change R^2 Analysis

User Class	Cell R^2 Value	Cell Slope	Cell Y-Int
TAG Criteria	**> 0.95**	**0.98 - 1.02**	**Near 0**
Taxi	0.83	1.02	0.00
Car Employers Business	0.92	0.97	0.00
Car Commute	0.87	0.95	0.00
Car Education	0.94	0.99	0.00
Car Other	0.97	0.98	0.00
LGV	0.99	1.02	0.00
OGV1	0.98	1.04	0.00
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

Four of the user classes meet the recommended R^2 criteria, and of the four that do not pass, all have an R^2 value greater than 0.83.

Trip End R^2 analysis was undertaken for each user class and summarised in Table 5.34.

Table 5.34 IP1 Trip End Matrix Change R^2 Analysis

User Class	Trip End R^2 Value	Trip End Slope	Trip End Y-Int
TAG Criteria	**> 0.98**	**0.99 - 1.01**	**Near 0**
Taxi	0.99	0.98	0.15
Car Employers Business	0.98	0.97	0.16
Car Commute	0.97	0.94	0.34
Car Education	0.99	0.98	0.01
Car Other	0.99	0.98	1.50
LGV	1.00	1.00	0.01
OGV1	1.00	1.02	0.09
OGV2 Permit Holder			

Other OGV2	1.00	1.00	0.00

The R^2 value passes the TAG criteria for six user classes, with the remaining user classes (Car Employers Business) and (Car Commute) narrowly failing the TAG criteria. Four of the user classes pass the TAG criteria for trip end slope, while a further three only narrowly fail. Values for the y-intercept are between 0.00 and 1.50.

The matrix was compared against three prominent screenlines to determine whether or not the matrix broadly contains the correct number of trips. This check was undertaken on the M7 / N18, River Shannon and the Cratloe Road screenlines.

Table 5.35 MWRM RM IP1 Screenline Check

Screenline	Observed (Veh)	Model (Veh)	Difference (%)
TAG Criteria			Within 5%
M7 / N18 (Inbound)	2,647	2,889	9%
M7 / N18 (Outbound)	2,782	2,606	-6%
River Shannon (Northbound)	834	890	7%
River Shannon (Southbound)	885	932	5%
Cratloe Road (Northbound)	716	702	-2%
Cratloe Road (Southbound)	1,000	985	-2%

Traffic levels across the Cratloe Road and River Shannon (Southbound) screenlines are within the acceptability criteria outlined in TAG unit M3-1. However, traffic crossing the River Shannon (Northbound) and M7 / N18 screenlines are not within the acceptability criteria. All screenlines are within 10 per cent of observed levels.

Trip length distribution was also assessed as part of the matrix calibration process. All user classes pass the criteria of a change in the mean trip length of less than 5 per cent, and all eight user classes pass the criteria of a change in the standard deviation of the trip length of less than 5 per cent.

Table 5.36 Trip Length Distribution Analysis – IP1

User Class	Mean Percentage Change	Standard Deviation Change
TAG Criteria	**< 5%**	**< 5%**
Taxi	-3%	0%
Car Employers Business	-2%	0%
Car Commute	0%	3%
Car Education	-3%	-1%
Car Other	-4%	-3%
LGV	0%	1%
OGV1	-1%	0%
OGV2 Permit Holder		
Other OGV2	0%	0%

Graphical representation of the trip length distribution changes at a user class level are presented in Appendix D.

5.8.4 Calibration criteria compliance – Inter-peak 2

Table 5.37 details the overall change in inter-zonal matrix size between the pre-estimation matrix and the post-estimation matrix. Intra-zonal matrix totals are not adjusted by matrix estimation and do not affect assignment in SATURN.

Table 5.37 MWRM RM Inter-peak 2 Matrix Totals

User Class TAG Criteria	Pre-Estimation (PCU)	Incremental (PCU)	Change (%) Within 5%
Taxi	2,458	2,492	1%
Car Employers Business	3,340	3,297	-1%
Car Commute	8,633	8,349	-3%
Car Education	550	529	-4%
Car Other	37,148	36,899	-1%
LGV	2,657	2,656	0%
OGV1	2,757	2,876	4%
OGV2 Permit Holder			
Other OGV2	254	254	0%

Overall, there is a reduction of 0.8 per cent in the matrix total, with the largest numerical change applied to thr Car Commute user class. The largest percentage change is applied to the Car Education user class.

A table of sectored matrix differences is presented in Appendix B.

GEH analysis was undertaken on the individual (non-zero) cells and their change between the pre-estimation and post-estimation values. 29 per cent of cells have a GEH value of less than 0.01, with 85 per cent of cells having a GEH value of less than 0.1 and 100 per cent of cells having a GEH value of less than 1.0. A graph illustrating the distribution of GEH values is shown in Figure 5.9 and Figure 5.10. Note the change in scale for Figure 5.10.

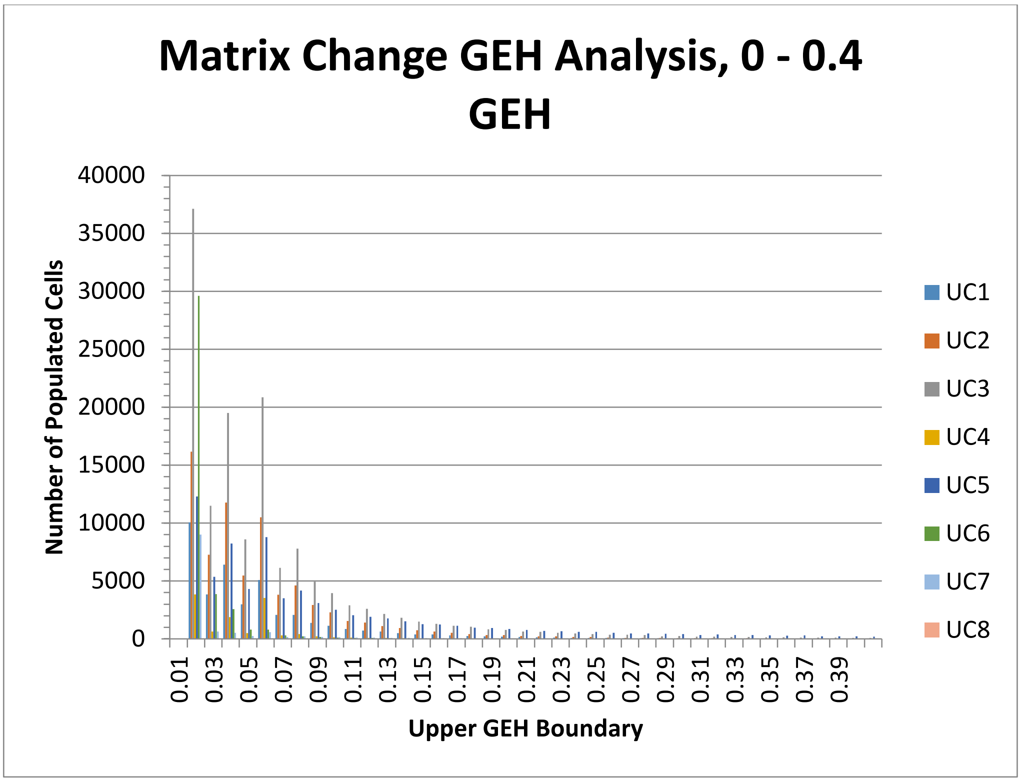

Figure 5.9 SATME2 IP2 Matrix Change GEH Analysis; 0 GEH to 0.4 GEH

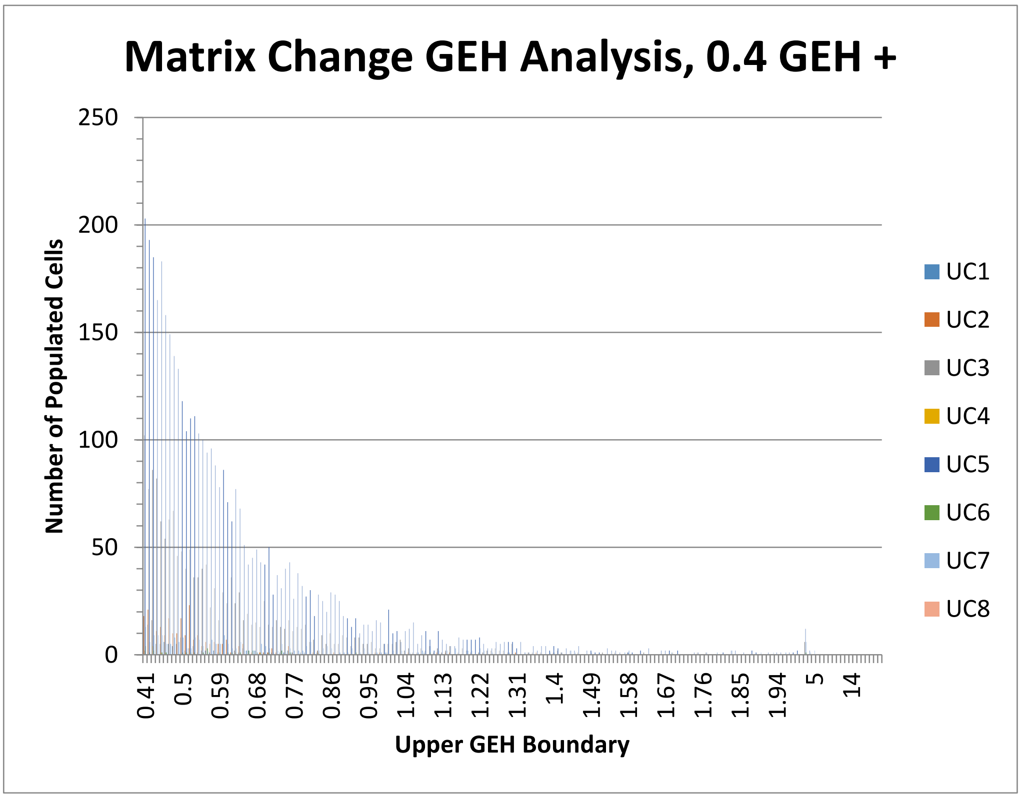

Figure 5.10 SATME2 IP2 Matrix Change GEH Analysis; 0.4 GEH Upwards

R^2 analysis was undertaken to further understand the matrix changes made by SATME2. Table 5.38 details the R^2 values for each individual user class. These are represented graphically in Appendix C.

Table 5.38 SATME2 IP2 Matrix Change R^2 Analysis

User Class	Cell R^2 Value	Cell Slope	Cell Y-Int
TAG Criteria	**> 0.95**	**0.98 - 1.02**	**Near 0**
Taxi	0.93	0.99	0.00
Car Employers Business	0.91	0.95	0.00
Car Commute	0.90	0.95	0.00
Car Education	0.96	0.94	0.00
Car Other	0.98	0.98	0.00
LGV	1.00	1.00	0.00
OGV1	0.96	1.04	0.00
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

Five user classes meet the recommended R^2 criteria, with the pass criteria being a R^2 value in excess of 0.95.

Trip End R^2 analysis was undertaken for each user class and summarised in Table 5.39.

Table 5.39 IP2 Trip End Matrix Change R^2 Analysis

User Class	Trip End R^2 Value	Trip End Slope	Trip End Y-Int
TAG Criteria	**> 0.98**	**0.99 - 1.01**	**Near 0**
Taxi	0.98	1.02	-0.07
Car Employers Business	0.98	0.96	0.28
Car Commute	0.98	0.92	1.00
Car Education	0.99	0.94	0.05
Car Other	0.99	0.97	2.43
LGV	1.00	0.99	0.08
OGV1	1.00	1.02	0.13
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

The R^2 value passes the TAG criteria for seven user classes with the eighth (Car Commute) failing due to rounding. The trip end slope passes for four of the eight user classes. Values for the y-intercept near zero are between -0.07 and 2.43.

The matrix was compared against three prominent screenlines to determine whether or not the matrix broadly contains the correct number of trips. This check was undertaken on the M7 N18, River Shannon and the Cratloe Road screenlines. Table 5.40 details the total traffic crossing the screenlines.

Table 5.40 MWRM RM IP2 Screenline Check

Screenline TAG Criteria	Observed (Veh)	Model (Veh)	Difference (%) Within 5%
M7 N18 (Inbound)	2,849	3,192	12%
M7 N18 (Outbound)	3,766	3,560	-5%
River Shannon (Northbound)	1,052	1,063	1%
River Shannon (Southbound)	1,013	1,022	1%
Cratloe Road (Northbound)	908	837	-8%
Cratloe Road (Southbound)	1,116	1,083	-3%

Traffic levels across the Cratloe Road (Southbound), M7 N18 (Outbound) and the River Shannon screenlines are within the acceptability criteria outlined in TAG unit M3-1. However, traffic crossing the M7 N18 (Inbound) and Cratloe Road (Northbound) are not within the acceptability criteria. All screenlines are within 12 per cent of observed traffic volumes.

Trip length distribution was also assessed as part of the matrix calibration process. All user classes pass the criteria of a change in the mean trip length of less than 5 per cent, and all eight user classes pass the criteria of a change in the standard deviation of the trip length of less than 5 per cent.

Table 5.41 Trip Length Distribution Analysis – IP2

User Class	Mean Percentage Change	Standard Deviation Change
TAG Criteria	< 5%	< 5%

Taxi	-2%	0%
Car Employers Business	-2%	1%
Car Commute	-2%	2%
Car Education	-2%	-1%
Car Other	-3%	-2%
LGV	-1%	0%
OGV1	-1%	0%
OGV2 Permit Holder		
Other OGV2	0%	0%

Graphical representation of the trip length distribution changes at a user class level are presented in Appendix D.

5.8.5 Calibration criteria compliance – PM peak

Table 5.42 details the overall change in inter-zonal matrix size between the pre-estimation matrix and the post-estimation matrix. Intra-zonal matrix totals are not adjusted by matrix estimation and do not affect assignment in SATURN.

Table 5.42 MWRM RM PM Peak Matrix Totals

User Class	Pre-Estimation (PCU)	Incremental (PCU)	Change (%)
Taxi	1,785	1,891	6%
Car Employers Business	1,816	2,038	12%
Car Commute	20,056	20,534	2%
Car Education	604	621	3%
Car Other	28,879	29,904	4%
LGV	2,828	2,841	0%
OGV1	2,507	2,650	6%
OGV2 Permit Holder			
Other OGV2	319	319	0%

The overall matrix size increases by three per cent as a result of matrix estimation, with the largest percentage change (12 per cent) being applied to Car Employer's Business. The largest numerical change is applied to Car Other.

A table of sectored matrix differences is presented in Appendix B.

GEH analysis was undertaken on the individual (non-zero) cells and their change between the pre-estimation and incremental values. 28 per cent of cells have a

GEH value of less than 0.01, with 81 per cent of cells having a GEH value of less than 0.1 and 100 per cent of cells have a GEH value less than 1. A graph illustrating the distribution of GEH values is shown in Figure 5.11 and Figure 5.12. Note the change in scale for both axes in Figure 5.12.

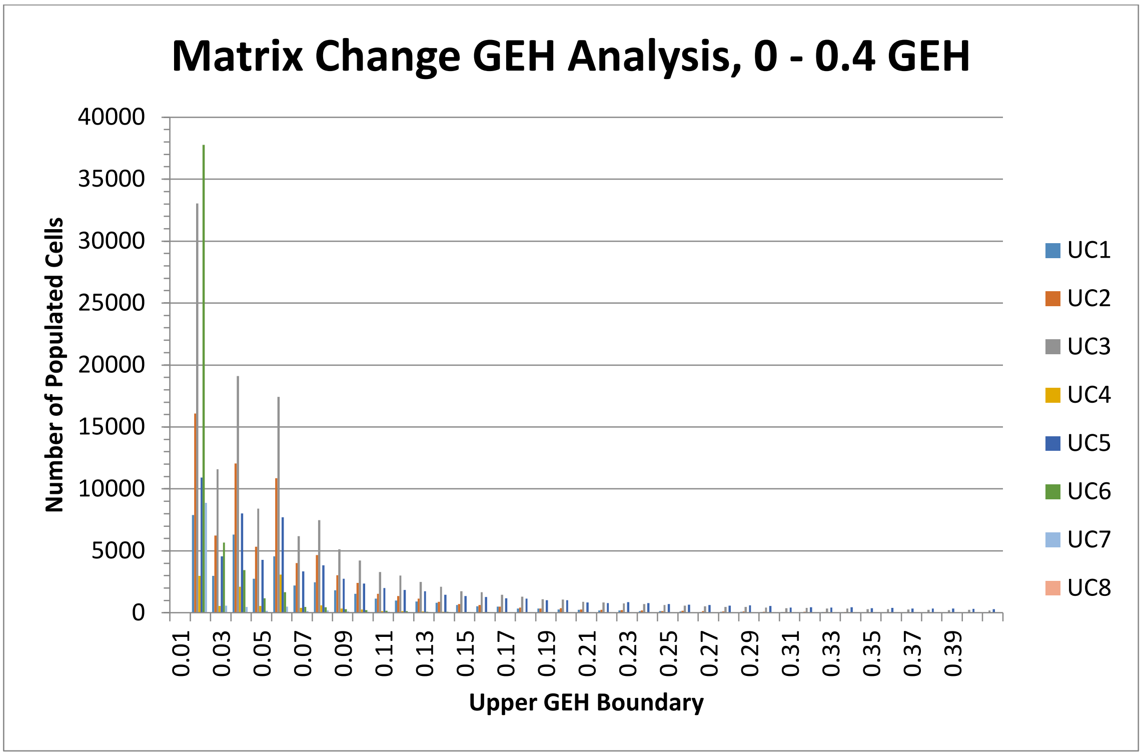

Figure 5.11 SATME2 PM Matrix Change GEH Analysis; 0 GEH to 0.4 GEH

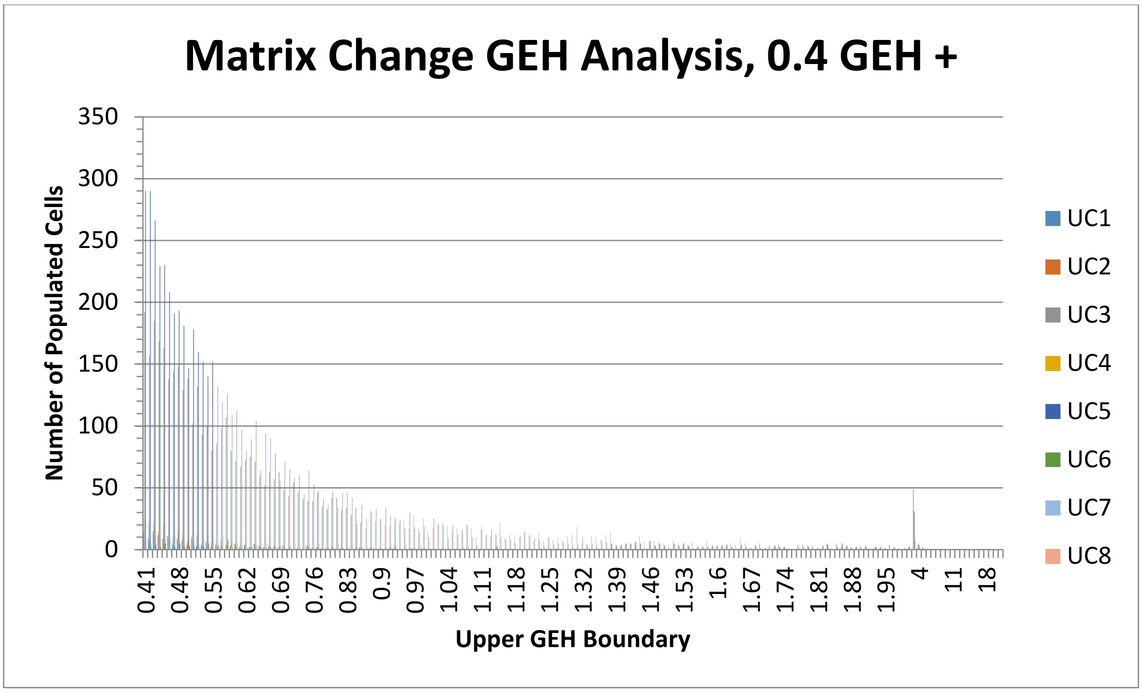

Figure 5.12 SATME2 PM Matrix Change GEH Analysis; 0.4 GEH Upwards

R^2 analysis was undertaken to further understand the matrix changes made by SATME2.

Table 5.43 details the R^2 values for each individual user class. These are represented graphically in Appendix C.

Table 5.43 SATME2 PM Matrix Change R^2 Analysis

User Class	Cell R^2 Value	Cell Slope	Cell Y-Int
TAG Criteria	**> 0.95**	**0.98 - 1.02**	**Near 0**
Taxi	0.69	1.09	0.00
Car Employers Business	0.84	0.96	0.00
Car Commute	0.90	0.95	0.01
Car Education	0.83	0.81	0.01
Car Other	0.96	0.97	0.01
LGV	0.98	1.01	0.00
OGV1	0.96	1.03	0.01
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

Four of the user classes pass the R^2 test, and one further user class, “Taxi” fails to meet the TAG criteria.

Trip End R^2 analysis was undertaken for each user class and summarised in Table 5.44.

Table 5.44 PM Trip End Matrix Change R^2 Analysis

User Class	Trip End R^2 Value	Trip End Slope	Trip End Y-Int
TAG Criteria	**> 0.98**	**0.99 - 1.01**	**Near 0**
Taxi	0.97	1.10	-0.24
Car Employers Business	0.96	1.03	0.32
Car Commute	0.98	0.95	3.37
Car Education	0.99	1.10	-0.14
Car Other	0.98	0.99	2.64
LGV	1.00	1.00	0.01
OGV1	0.99	1.03	0.17
OGV2 Permit Holder			
Other OGV2	1.00	1.00	0.00

Five user classes pass the R^2 criteria for trip ends, with the three user classes, “Taxi”, “Car Employers Business” and “Car Commute” narrowly failing to meet the TAG criteria. Three user classes pass the TAG criteria for trip end slope. All y-intercept values are between -0.24 and 3.37.

The matrix was compared against three prominent screenlines to determine whether or not the matrix broadly contains the correct number of trips. This check was undertaken on the M7 N18, River Shannon and the Cratloe Road screenlines. Table 5.45 details the total traffic crossing the screenlines.

Table 5.45 MWRM RM PM Screenline Check

Screenline	Observed (Veh)	Model (Veh)	Difference (%)
TAG Criteria			**Within 5%**
M7 N18 (Inbound)	3,549	3,927	11%
M7 N18 (Outbound)	5,718	5,083	-11%
River Shannon	4,448	3,815	-14%

(Northbound)			
River Shannon (Southbound)	3,447	3,416	-1%
Cratloe Road (Northbound)	1,248	1,221	-2%
Cratloe Road (Southbound)	1,327	1,268	-4%

Traffic levels across the River Shannon (Southbound) and Cratloe Road screenlines are within the acceptability criteria outlined in TAG unit M3-1. All screenlines are within 14 per cent of observed traffic volumes.

Trip length distribution was also assessed as part of the matrix calibration process. Seven of the eight user classes pass the criteria of a change in the mean trip length of less than 5 per cent, with one further user class “Car Education” failing. Six user classes pass the criteria of a change in the standard deviation of the trip length of less than 5 per cent, with one of the remaining user classes “Taxi” narrowly failing due to rounding.

Table 5.46 Trip Length Distribution Analysis – PM

User Class	Mean Percentage Change	Standard Deviation Change
TAG Criteria	**< 5%**	**< 5%**
Taxi	4%	-5%
Car Employers Business	-2%	-5%
Car Commute	-2%	-1%
Car Education	13%	10%
Car Other	0%	-3%
LGV	-1%	-1%
OGV1	-1%	1%
OGV2 Permit Holder		
Other OGV2	0%	0%

Graphical representation of the trip length distribution changes at a user class level are presented in Appendix D.

5.9 Calibration summary

5.9.1 Overview

Table 5.47 details the status of each component of the calibration process for each modelled period.

Table 5.47 Model Calibration Status

Component	AM Status	IP1 Status	IP2 Status	PM Status
Individual Link Flows	Fail	Pass	Fail	Fail
Individual Link GEH <5 (TAG)	Fail	Fail	Fail	Fail
Individual Link GEH <5 (65%)	Pass	Pass	Pass	Pass
Individual Link GEH <7 (75%)	Pass	Pass	Pass	Pass
Individual Link GEH <10 (95%)	Fail	Fail	Fail	Fail
Screenlines	Fail	Fail	Fail	Fail
Matrix Cell R^2 Analysis	Fail	Fail	Fail	Fail
Trip End Analysis	Fail	Fail	Pass	Fail
Matrix Trip Length Distribution	Pass	Pass	Pass	Pass

5.9.2 Traffic count observations

It is difficult to assess the calibration of traffic flows within Limerick City Centre due to the exact representation of car parking within the prior matrix development process. Although trip origins are likely to be accurate, the destination of the vehicle as opposed to the driver or passenger may not be suitably represented, and should not be sufficiently altered automatically by means of matrix estimation.

At the 24-hour level, there is a reasonable correspondence between observed and modelled traffic at the two outer screenlines (Northern Outer and Southern Outer). At the screenline locations in the city centre (River Shannon, M7 N18, City Canal, Limerick Junction, Cratloe Road) there is also a reasonable correspondence between observed and modelled traffic. Two screenlines (Foynes Rail and Childers Road) modelled traffic is still slightly lower compared to observed flows.

Overall the modelled screenline counts are slightly higher than the observed traffic counts. The Childers Road Screenline performs the worst in the AM time period with the observed flows exceeding the modelled flows by approximately 24 per cent. In the PM time period, the Childers Road Screenline also performs the worst with the observed flows exceeding the modelled flows by approximately 28 per cent. The Foynes Rail Screenline is the worst performing screenline during the inter peaks with the modelled flow approximately 38 to 16 per cent lower than observed flows.

Within the City Centre the highest GEH values were all located on Lower Mallow Street and Ballinacurra Road / Childers Road and are listed below:

- AM – GEH 31.0 Ballinacurra Road / Childers Road;
- IP1 – GEH 21.7 Lower Mallow Street;

- IP2 – GEH 20.9 Lower Mallow Street ; and
- PM – GEH 22.1 Lower Mallow Street.

The Ballinacurra Road / Childers Road has a high GEH in the northbound direction across the four time periods. There is a significant difference between the modelled and observed flows with modelled flows being underrepresented on this link. This can be explained due to the low demand in this area as a result of the lack of zone connectors on Childers Road. Lower Mallow Street is the worst performing GEH for the remaining time periods, due to low modelled traffic flows, this is discussed previously in sections **Error! Reference source not found.**, 5.7.7 and 5.7.9.

Outside the City Centre, the area around Ennis does not calibrate well due to issues in the way that the travel demand is generated by RMSIT and used within the FDM.

5.9.3 Matrix observations

Comparing the pre- and post-estimated matrices shows that the inter-zonal combined matrix total for the five car user classes (User Class 1 to 5) changes by around one per cent. The largest individual car user class change was observed in the Car Commute user class (User class 3) which changed by three per cent.

POWSCAR observed data informed the development of “Car Education” and “Car Commute” matrices, and therefore smaller changes to these matrix components were anticipated. The largest change in the observed components occurs in the AM Peak period where the “Car Commute” matrix reduced by six per cent. This was due to the overall size of the “Car Commute” user class and the way in which the “Car” vehicle class was estimated.

5.9.4 Trip Length Distribution Observations

Analysis of each modelled time period results in the same conclusion regarding the influence that matrix estimation is having on the prior matrices. As with many implementations of a matrix estimation solution, SATURN has generated shorter distance trips in order to meet the specified target traffic flows instead of generating longer distance trips. This has the effect of reducing the mean trip length distribution and the standard deviation of trips within the estimated matrices.

It should be noted that the increases in shorter distance trips are not of a significant level, but the trend is worth highlighting.

5.9.5 Calibration observation summary

Table 5.48 outlines the key calibration observations and indicates which modelled time periods the observation relates to.

Table 5.48 Model Calibration Identified Issues

Issue	AM Peak	IP1	IP2	PM Peak
Bridge Street (NB) modelled traffic flow is high – City Canal			○	○
Bridge Street (SB) modelled traffic flow is high – City Canal	○	○	○	
Lower Mallow Street (EB) modelled traffic flow is low	○	○	○	○
Mallow St O'Connell St (WB) modelled traffic flow is low	○	○	○	○
N85 (EB) modelled traffic flow from Ennis is high	○	○		○
N85 (WB) modelled traffic flow towards Ennis is high	○	○	○	○
M7 (EB) modelled traffic flow is low	○	○	○	○
Jnc 29 M7 (slip onto R527 NB) modelled traffic flow is low	○	○	○	○
Ballinacurra Rd / Childers Rd (NB) modelled traffic flow low	○	○	○	○

6 Road Model Validation

6.1 Introduction

This chapter sets out the specification and execution of the model validation process. This includes the source of calibration criteria, application of these criteria, comparison of the model outputs with these criteria and commentary on this.

6.2 Assignment validation process

6.2.1 Overview

Model validation is the process of comparing the assigned traffic volumes against data that was kept independent of the calibration process, comparing modelled versus observed journey times and comparing trip length distribution of pre- and incremental matrices. Validation serves as an essential quality check on the calibrated road model. It is recommended that modelled flows and counts should be compared by vehicle type and time period if possible.

6.2.2 Validation Criteria

Model validation is the process of comparing the assigned traffic volumes against data that was independent of the calibration process, comparing modelled versus observed journey times and comparing trip length distribution of pre- and incremental matrices. It is recommended that modelled flows and counts should be compared by vehicle type and time period if possible.

Table 6.1 outlines the screenline validation criteria as set out in TAG Unit M3-1, Section 3.2, Table 1.

Table 6.1 Road Assignment Model Screenline Validation Criteria

Criteria	Acceptability Guideline
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines

Table 6.2 outlines the journey time validation criteria as set out in TAG Unit M3-1, Section 3.2, Table 3.

Table 6.2 Road Assignment Model Journey Time Validation Criteria

Criteria	Acceptability Guideline
Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher than 15%)	> 85% of routes

6.2.3 Traffic volume comparison

The following data sources are available for the traffic volume comparisons:

- Permanent ATCs operated by TII; and
- Individual link and junction turning counts.

Individual link validation was undertaken against the same acceptability criteria as set out previously.

6.2.4 Journey times

Observed journey time data is available for a number of major roads within the MWRM through the TomTom dataset. The routes previously defined for the moving car observer surveys were retained for the validation of the MWRM. These routes constitute eight two-way radial routes, plus two two-way orbital routes.

AM Peak travel times were taken as being the average observed link times between 0800 and 0900. Inter-peak 1 travel times were taken as being the average observed link times between 1000 and 1300, with Inter-peak 2 travel times being the average observed link times between 1300 and 1600. PM Peak travel times were taken as being the average observed link times between 1700 and 1800.

TAG Unit M3-1, Section 3.2.10 states that modelled journey times should be within 15 per cent of the observed end to end journey time, or within one minute if higher.

6.3 Traffic volume validation

6.3.1 Overview

Permanent ATC’s operated by the NRA and Individual link and junction turning counts were utilised as an independent dataset to validate the model. From this data it is possible to validate the SATURN model against an all-vehicle total across 50 links.

6.3.2 Traffic count locations

A detailed map showing the location of the three screenlines used during validation is presented in Figure 6.1.

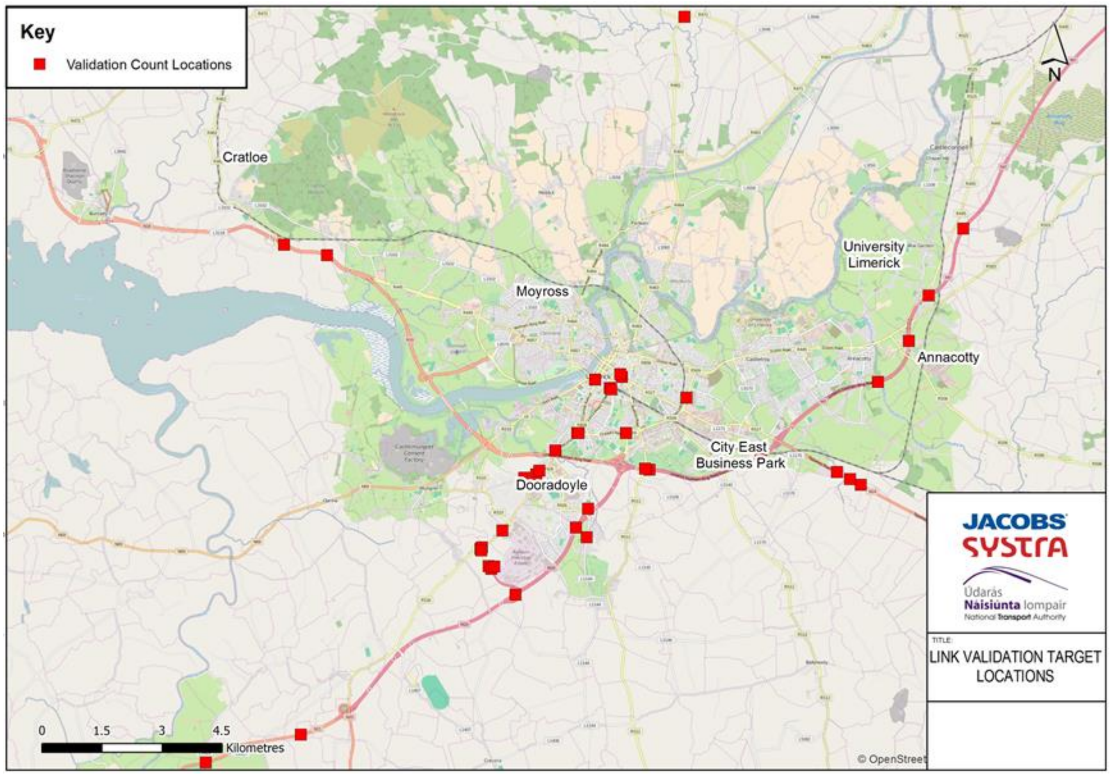

Figure 6.1 Link Validation Target Locations

6.3.3 Validation criteria compliance – AM Peak

The validation statistics of the AM Peak model when compared against the individual link count validation criteria are outlined in Table 6.3.

Table 6.3 AM Link Flow Validation

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	44% (22)
GEH < 5 for individual flows	> 65% of cases	32% (16)
GEH < 7 for individual flows	> 75% of cases	56% (28)
GEH < 10 for individual flows	> 95% of cases	72% (36)

Across the 50 count locations in the AM Peak, 44 per cent (22) pass the TAG flow validation criteria. 32 per cent of links have a GEH of less than 5. However, slackening the criteria to include GEH values of less than 10 yields a 72 per cent pass rate, which remains below the TAG recommendation of 85 per cent of links. The areas of poorest validation are to the south-west of Limerick (N21 Adare, R510 Ballycummin Ave), the M7 to the west of the City Centre (M7 between Junction 28 & 29 and M7 near Wood Road bridge) and at certain City Centre locations south of Limerick (Raheen Industrial Estate, Crescent Shopping Centre, Roxboro Shopping Centre).

Detailed validation results, highlighting specific links that pass or fail the recommended validation criteria are included in Appendix E.

In general, modelled traffic volumes are lower than observed traffic volumes. There were specific traffic volume differences that warranted further investigation, and these are discussed in more detail in Section 6.5.

6.3.4 Validation criteria compliance – Inter-peak 1

The validation statistics of the Inter-peak 1 model when compared against the individual link count validation criteria are outlined in Table 6.4.

Table 6.4 IP1 Link Flow Validation

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	50% (25)
GEH < 5 for individual flows	> 65% of cases	48% (24)
GEH < 7 for individual flows	> 75% of cases	58% (29)
GEH < 10 for individual flows	> 95% of cases	78% (39)

Across the 50 count locations on the Inter-peak 1, 50 per cent (25) pass the TAG flow validation criteria. 48 per cent of links have a GEH of less than 5. However, slackening the criteria to include GEH values of less than 10 yields a 78 per cent pass rate. This remains below the TAG recommendation of 85 per cent of links passing validation, and below the typical acceptability criteria of 95 per cent of links with a GEH value of less than 10.

As with the AM Peak model validation, the areas of poorest validation are to the south of the City Centre (Ballyclough Avenue, South Circular Road, N18, Childers Road).

Detailed validation results, highlighting specific links that pass or fail the recommended validation criteria are included in Appendix E.

There were specific traffic volume differences that warranted further investigation, and these are discussed in more detail later in Section 6.5.

6.3.5 Validation criteria compliance – Inter-peak 2

The validation statistics of the Inter-peak 2 model when compared against the individual link count validation criteria are outlined in Table 6.5.

Table 6.5 IP2 Link Flow Validation

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	46% (23)

GEH < 5 for individual flows	> 65% of cases	42% (21)
GEH < 7 for individual flows	> 75% of cases	58% (29)
GEH < 10 for individual flows	> 95% of cases	70% (35)

Across the 50 count locations in the Inter-peak 2, 46 per cent (23) pass the TAG flow validation criteria. 42 per cent of links have a GEH of less than 5. However, slackening the criteria to include GEH values of less than 10 yields a 70 per cent pass rate. This remains below the TAG recommendation of 85 per cent of links passing validation, and below the typical acceptability criteria of 95 per cent of links with a GEH value of less than 10.

As with the AM Peak and Inter-peak 1 model validation, the areas of poorest validation are to the south of the City Centre and the M7, including R510 Ballycummin Ave, N18 and South Circular Road. Detailed validation results, highlighting specific links that pass or fail the recommended validation criteria are included in Appendix E. There were specific traffic volume differences that warranted further investigation, and these are discussed in more detail later in Section 6.5.

6.3.6 Validation criteria compliance – PM peak

The validation statistics of the PM Peak model when compared against the individual link count validation criteria are outlined in Table 6.6.

Table 6.6 PM Link Flow Validation

Criteria	Acceptability Guideline	Model Statistics
Link Flow	> 85% of cases	50% (25)
GEH < 5 for individual flows	> 65% of cases	42% (21)
GEH < 7 for individual flows	> 75% of cases	50% (25)
GEH < 10 for individual flows	> 95% of cases	64% (32)

Across the 50 count locations in the PM Peak, 50 per cent (25) pass the TAG flow validation criteria. 42 per cent of links have a GEH of less than 5. However, slackening the criteria to include GEH values of less than 10 yields a 64 per cent pass rate, which remains below the TAG recommendation of 85 per cent of links passing validation.

As with the AM Peak, IP1 and IP2 model validation, the areas of poorest validation are to the south of the City Centre and the M7, including R510 Ballycummin Ave and South Circular Road. Detailed validation results, highlighting specific links that pass or fail the recommended validation criteria are included in Appendix E. There were specific traffic volume differences that warranted further investigation, and these are discussed in more detail in Section 6.5.

6.4 Journey time validation

6.4.1 Overview

The NTA purchased access to the TomTom Custom Area Analysis (CAA) product, which provides historical journey time data. The application of this data is a shift away from the traditional moving observer approach. The benefit of using TomTom data is that there is an abundance of journey time routes available with a larger sample of observations which can be used to determine the typical journey times on a particular route or link.

6.4.2 Journey Time Routes

Appropriate journey time routes were identified from the TomTom data and agreed with the NTA. The journey time routes cover the main arterial routes into the city centre (Category 1) and origins and destinations from the main regional roads towards Limerick (Category 2). A detailed map of each journey time route is presented in Figure 4.2, in Section 4.4.1.

Further TomTom Journey time data and analysis is included in Appendix F.

6.4.3 Validation Criteria Compliance – AM Peak

Of the 28 journey time routes, 86 per cent (24) pass TAG criteria, which exceeds the TAG recommendation of 85 per cent of routes passing the criteria. Figure 6.2 details the validation of each route.

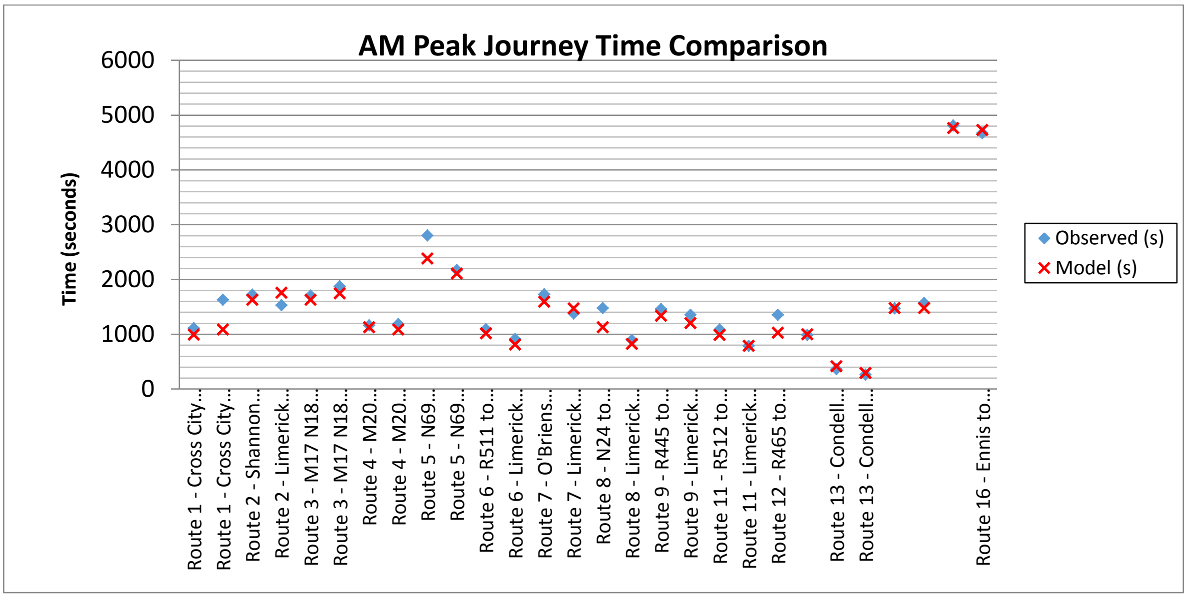

Figure 6.2 AM Peak Journey Time Comparison

Further details are included in Appendix F, with detailed analysis of any significant issues discussed in Section 6.5.

6.4.4 Validation Criteria Compliance – Inter-peak 1

Of the 28 journey time routes, 82 per cent (23) pass the TAG criteria, which falls slightly short of the TAG recommendation of 85 per cent of routes passing the criteria. Figure 6.3 details the validation of each route.

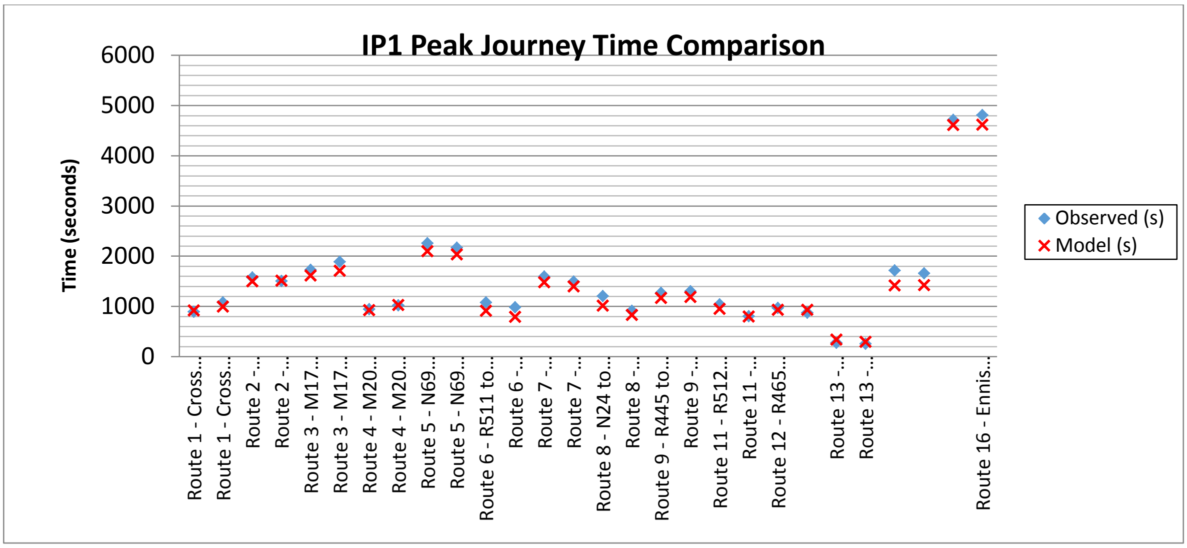

Figure 6.3 Inter-peak 1 Journey Time Comparison

Further details are included in Appendix F, with detailed analysis of any significant issues discussed in Section 6.5.

6.4.5 Validation Criteria Compliance – Inter-peak 2

Of the 28 journey time routes, 86 per cent (24) pass the TAG criteria, which exceeds the TAG recommendation of 85 per cent of routes passing the criteria. Figure 6.4 details the validation of each route.

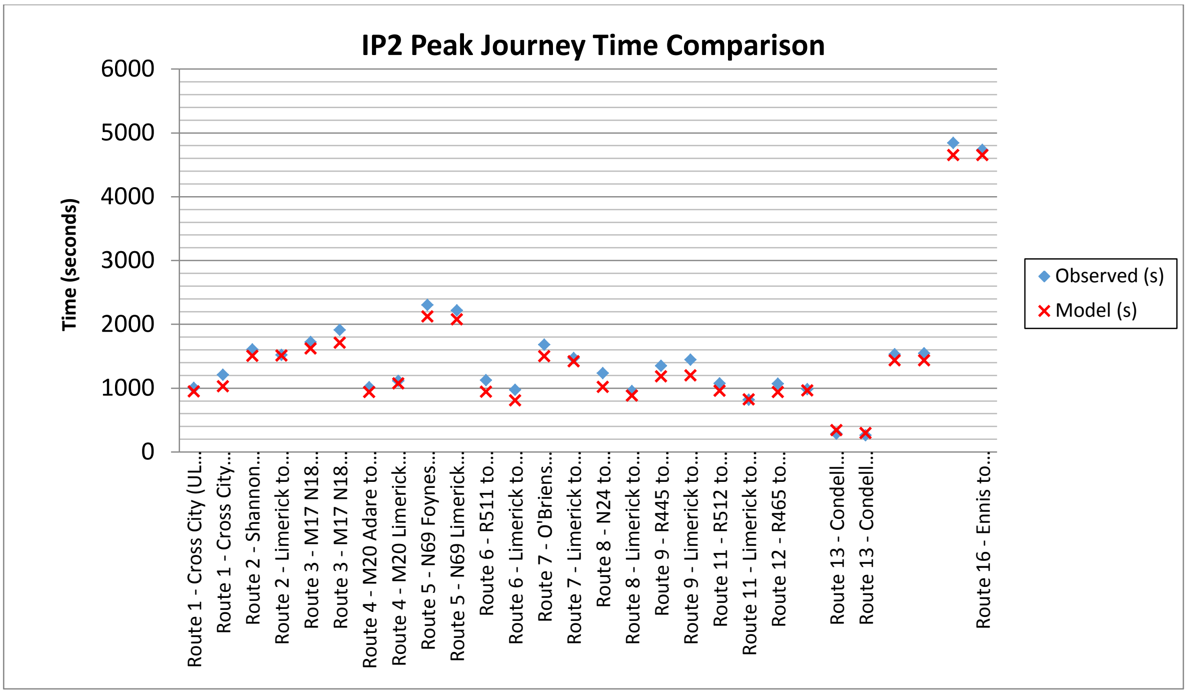

Figure 6.4 Inter-peak 2 Journey Time Comparison

Further details are included in Appendix F, with detailed analysis of any significant issues discussed in Section 6.5.

6.4.6 Validation Criteria Compliance – PM Peak

Of the 28 journey time routes, 79 per cent (22) pass the TAG criteria, which falls slightly short of the TAG recommendation of 85 per cent of routes passing the criteria. Figure 6.5 details the validation of each route.

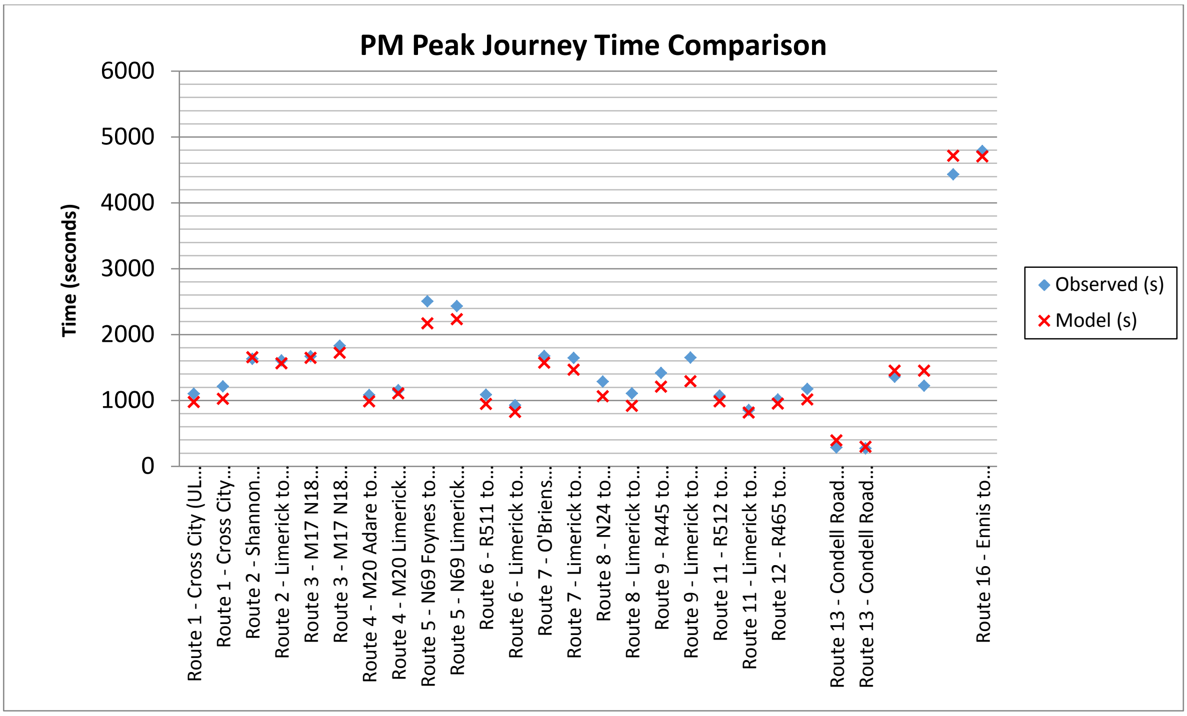

Figure 6.5 PM Peak Journey Time Comparison

Further details are included in Appendix F, with detailed analysis of any significant issues discussed in Section 6.5.

6.5 Validation summary

6.5.1 Overview

Table 6.7 details the status of each component of the calibration process for each modelled period.

Table 6.7 Model Validation Status

Component	AM Status	IP1 Status	IP2 Status	PM Status
Individual Link Flows	Fail	Fail	Fail	Fail
Journey Times	Pass	Fail	Pass	Fail

6.5.2 Traffic count observations

Validating traffic levels within Limerick City Centre is challenging for a number of reasons. The representation of car parking is likely to cause some challenges; although trip origins are likely to be accurate, the destination of the vehicle as opposed to the driver or passenger may not be suitably represented, and should not be automatically altered sufficiently during the matrix estimation process. For this reason, vehicular flows in the vicinity of large parking areas in the City Centre are likely to be underrepresented in the model.

The traffic count locations chosen for inclusion in the validation dataset were selected to provide a consistent coverage of observations into and through

Limerick City centre. Despite this, as a regional model which covers a significant area outside of the Limerick urban area, the representation of final destinations (as noted above) may be an issue in some cases. However, without another comprehensive validation dataset (equivalent to the SCATS data used for ERM) this was considered the most appropriate dataset available at the time of the development of the model.

6.5.3 Journey Time Observations

Comparing the modelled journey times to the observed data in the AM Peak, four journey time routes fail; one modelled end to end journey time is too slow compared with observed data with the remaining three routes too fast compared to observed journey times. Looking at these in more detail, it is clear that most of the routes that do not pass the calibration criteria are as a result of the model failing to replicate the observed delay at a small number of junctions. For example, Route 8 (N24 to Limerick) along N24 towards Limerick does not replicate the observed delay between the N24 and the R527.

Modelled journey times in the Inter-peak 1 period generally compare very well with the observed times and only five routes narrowly fail. In the Inter-peak 2 period the match is also very good as four of the routes only narrowly fail. In the PM Period, modelled journey times are generally faster than the observed TomTom journey times.

Some routes do not meet the validation criteria across more than one modelled time period. These are:

- Route 6 outbound: R511 to Limerick Inbound;
- Route 8 inbound: N24 to Limerick; and
- Route 13: Condell Road - Orbital Route.

Two of these routes (Route 6 & 8) travel through Limerick City Centre. The remaining route (Route 13) fails due to too much delay within the model at Condell Road / Shelbourne Road Lower.

It should also be noted that the TomTom journey times for the AM and PM peak have been taken for the time periods 8-9am and 5-6pm respectively, whereas the road assignment matrices output from the FDM and the traffic counts are created by factoring a 3-hour peak period to a 1-hour peak, rather than modelling a specific hour. In the two inter-peak time periods, both the TomTom journey times and road assignment matrices and traffic counts are the average of the 3-hour period.

6.5.4 Validation Observation Summary

Table 6.8 outlines the key validation observations and indicates which models the observation relates to. It quickly shows the number of routes where modelled times are too fast and too slow for all time periods. Appendix F summarises the TomTom Journey Time Data and Analysis in more detail.

Table 6.8 Model Validation Identified Issues

Issue	AM Peak	IP1	IP2	PM Peak
Journey times routes too quick	◯ (3)	◯ (4)	◯ (4)	◯ (4)
Journey times routes too slow	◯ (1)	◯ (1)		◯ (2)
Low City Centre validation	◯	◯	◯	◯
Increase in short distance trips	◯	◯	◯	◯

7 Conclusion and recommendations

7.1 Summary

The Mid-West Regional Model has been developed to assist the NTA with the assessment of current and future network performance, and the appraisal of local and strategic transport infrastructure projects and investments. This report has presented the development of the road model element of the Mid-West Regional Model.

7.2 Road Model Development

The model network was in a strong position prior calibration and validation commencing due to previous work undertaken. The road model network and the assignment parameters as well as the demand model have been enhanced considerably during the task. The model makes best use of the available information at the time of model inception through to this version of the model being completed. As part of the calibration and validation process the model network was adjusted to better reflect observed data. However, further improvements could be made for future model versions to improve model calibration and validation.

7.3 Road Model Calibration

The model calibrates reasonably well, although each assigned user class does not meet all of the recommended guidelines set by the UK's TAG. These recommended criteria are summarised in Table 7.1, Table 7.2 and, Table 7.3 representing a review of the change in demand and also a comparison of observed and modelled traffic levels.

Table 7.1 outlines the matrix estimation change calibration criteria, as specified in TAG Unit M3-1, Section 8.3, Table 5, and a summary of the results obtained from each peak period model.

Table 7.1 Significance of Matrix Estimation Changes

Measure	Significance Criteria	AM Peak	Inter-peak 1	Inter-peak 2	PM Peak
Matrix zonal cell value	Slope within 0.98 and 1.02;	0.97 to 1.04	0.95 to 1.04	0.94 to 1.04	0.81 to 1.09
	Intercept near zero;	0 to 0.02	0	0 to 0	0 to 0.01
	R^2 in excess of 0.95.	0.83 to 1	0.83 to 1	0.90 to 1	0.69 to 1
Matrix zonal trip ends	Slope within 0.99 and 1.01;	0.92 to 1.03	0.94 to 1.02	0.92 to 1.02	0.95 to 1.10
	Intercept near zero;	-0.12 to 2.49	0 to 1.50	-0.07 to 2.43	-0.24 to 3.37
	R^2 in excess of 0.98.	0.97 to 1	0.97 to 1	0.98 to 1	0.96 to 1
Trip length distribution	Means within 5%;	-4% to 0%	-4% to 0%	-3% to 0%	-2% to 13%
	Standard Deviation within 5%.	-5% to 1%	-3% to 3%	-2% to 2%	-5% to 10%
Sector to sector level matrices	Differences within 5%	27/196	40/196	35/196	16/196

The “Car Other” user class meets the recommended WebTAG recommended criteria for matrix zonal change in all four modelled time periods. In the AM Peak period and Inter-peak 2 period the matrix zonal cell changes for “Car Education” meets the WebTAG recommended criteria, with R^2 values of 0.97 and 0.96 respectively. The slope for “Car Other” and “LGV” met the TAG criteria with values of 0.98 and 0.99.   In the Inter-peak 1 period the R^2 value for “LGV” also meet the TAG recommended criteria.

The slope for “Car Employers Business” and “Car Commute” fell narrowly outside the recommended range of between 0.98 and 1.02 in the Inter-peak 1, Inter-peak 2 and PM Peak time periods. “Car Education” also fell narrowly outside the recommended ranges in the Inter-peak 2 time period.

In the PM peak period the matrix zonal cell changes for “Car Commute” and “Car Education” are close to the TAG recommended criteria, with R^2 values of 0.90 and 0.83 respectively.

The intercept value for both cells and trip ends is considered to be "near zero" for each user class across all time periods.

Table 7.2 outlines the link calibration criteria as set out in TAG Unit M3-1, Section 3.2, Table 2, and the level of calibration achieved in each specific period model.

Table 7.2 Road Assignment Model Calibration Guidance Source

Criteria	Acceptability Guideline	AM Peak	Inter-peak 1	Inter-peak 2	PM Peak
Individual flows within 100 veh/h of counts for flows less than 700 veh/h within 15% of counts for flows from 700 to 2,700 veh/h within 400 veh/h of counts for flows more than 2,700 veh/h	> 85% of cases	73% (171 of 234)	87% (182 of 210)	83% (175 of 210)	76% (178 of 234)
GEH < 5 for individual flows	> 85% of cases	70% (164 of 234)	82% (173 of 210)	79% (166 of 210)	72% (169 of 234)

Although the AM peak period does not meet the TAG recommended criteria for either individual flows or GEH, it is close to passing the criteria for individual flows, with 73 per cent of links passing. Considering a more typical range of GEH values, assessing the number of links with a GEH of 7 or less, and 10 or less, results in 80 per cent and 89 per cent of links respectively, which is considered to be sufficient.

The Inter-peak 1 period meets the criteria set out in TAG for individual flows but falls narrowly short of the GEH criteria. Extending the analysis of GEH to assess the number of links with a GEH of 7 or less, and 10 or less, results in 89 per cent and 94 per cent of links, respectively.

The Inter-peak 2 period falls narrowly short of meeting the criteria set out in TAG for individual flows, with 83 per cent and just narrowly fails to meet the criteria for GEH, with 79 per cent of links. Extending the analysis of GEH to assess the number of links with a GEH value of 7 or less, and 10 or less, results in 85 per cent and 93 per cent of links, respectively.

In the PM peak period, the model fails to meet the recommended criteria as set out in WebTAG. Extending the GEH analysis to assess the number of links with a GEH of 7 or less, and 10 or less, results in 80 per cent and 86 per cent of links respectively, which is considered to be sufficient.

Table 7.3 outlines the screenline calibration criteria as set out in TAG Unit M3-1, Section 3.2, Table 3, and the level of calibration achieved in each specific period model.

Table 7.3 Road Assignment Model Screenline Calibration Guidance Sources

Criteria	Acceptability Guideline	AM Peak	Inter-peak 1	Inter-peak 2	PM Peak
Differences between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines	44%	22%	56%	39%

No peak period meets the criteria set out in WebTAG, with the Inter-peak 2 period being the best performing period at 56 per cent.

In the AM peak 44 per cent of screenlines are within 5 per cent of the observed traffic flows. Four additional screenlines are within 9 per cent, and the remaining screenlines are all within 25 per cent of the observed total traffic flows.

The Inter-peak 1 period has 22 per cent of screenlines meeting the TAG recommended criteria of total modelled screenline flows within 5 per cent of observed. Ten additional screenlines are within 10 per cent, and all screenlines are within 20 per cent of the observed total traffic flows.

The Inter-peak 2 period has 56 per cent of screenlines meeting the TAG recommended criteria of total modelled screenline flows within 5 per cent of observed. Three additional screenlines are within 10 per cent, and all screenlines are within 18 per cent of the observed total traffic flows.

The PM peak has 39 per cent of screenlines within 5 per cent of the observed traffic flows. Three additional screenlines are within 8 per cent, and the remaining screenlines are all within 29 per cent of observed traffic flows.

Careful consideration was given to each criterion during the calibration and validation exercise such that the level of matrix change was balanced against the observed traffic volumes and observed journey times. Calibration of the car vehicle type is very strong across all time periods.

“Taxi”, “Car Other”, “LGV” and “HGV” calibrate to a lesser extent, however this was anticipated owing to the synthetic nature of the input matrices, and the lack of disaggregated observed traffic data, particularly for “Taxi”.

Trip length distribution analysis and cellular GEH analysis of the matrix estimation changes indicates that the matrix estimation procedure has not excessively altered the observed user class data.

7.4 Road Model Validation

Despite traffic volume validation not meeting TAG criteria in the AM Peak, the journey times compare reasonably well against TomTom data, with 86 per cent of routes meeting the WebTAG criteria of modelled journey times being within 15 per cent of observed journey times. 96 per cent of journey time routes are within 25 per cent of the observed journey times.

Journey time validation for the IP1 period narrowly fails to meet the TAG criteria with 82 per cent of journey times being within 15 per cent of observed journey times, and all of the routes are within 25 per cent of the observed journey times.

In the IP2 period, 86 per cent of the journey time routes meet the TAG criteria, and 100 per cent of the routes are within 25 per cent of the observed journey times.

In the PM peak, 79 per cent of the journey time routes meet the TAG criteria, and 96 per cent are within 25 per cent of the observed journey times.

7.5 Recommendations

At present the values of time and the vehicle operating costs applied during the road model assignment are user defined within the SATURN data files prior to the final assignments. These are based on the best available model information at the time to inform the parameter calculations. The model information used is the average simulation network speed, which does not vary significantly between model versions of the same scenario. However, there are improvements to this process that could be applied to add further functionality.

A procedure could be written that takes the average network speed and re-calculates the vehicle operating cost between iterations / loops of the demand model. This would provide a more stable solution between model iterations should the network and information be refined or updated in the future. This would also ensure that the vehicle operating costs were updated in future year scenarios; a process which currently relies on user intervention.

Appendix A

Calibration Results

Appendix B

Matrix Sector to Sector Differences

Appendix C

R^2 Analysis Graphs

Appendix D

Trip Length Distribution Analysis

Appendix E

Individual Link Validation Results

Appendix F

Journey Time Analysis

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