REGIONAL MODELLING SYSTEM

Model Development Report

East Regional Model

Model Version 3

Údarás Náisiúnta Iompair
National Transport Authority

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Building Ireland's Future

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Abbreviations and Acronyms

AM	Morning peak
AMM	Active Modes Model
AVL	Automatic Vehicle Location
COCMP	Car Ownership / Competition Model
CCM	Car Competition Model
CDCU	Car Driver Car User
COM	Car Ownership Model
CSA	Census Small Area
CSO	Central Statistics Office
ED	Electoral Divisions
ERM	East Regional Model
FWPP	Free Workplace Parking
GDA	Greater Dublin Area
GTFS	General Transit Feed Specification
HBEB	Home-based Employers Business
HBEd	Home-based Education
HBEsc	Home-based Escort-to-education
HBFS	Home-based Food Shopping
HBO	Home-based Other
HBV	Home-based Social Visits
HBW	Home-based Work
HGV	Heavy Goods Vehicle
LDM	Long Distance Model
LT	Lunchtime
MWRM	Mid West Regional Model
NDFM	National Demand Forecasting Model
NHB	Non-Home-Based
NHBEB	Non-Home-Based Employers Business
NHBOT	Non-Home-Based Other
NHTS	National Household Travel Survey
NIRSA	National Institute of Regional and Spatial Analysis
NTA	National Transport Authority
NTEM	National Trip End Model
NUTS3	Nomenclature of Territorial Units for Statistics, level 3
OD	Origin-Destination
OGV	Ordinary Goods Vehicle (Type 1 or 2)
OP	Off-peak
OSi	Ordnance Survey Ireland
PCU	Passenger Car Units
PDAT	Planning Data Adjustment Tool
PM	Evening peak
PnR	Park and Ride
POWSCAR	Place of Work, School or College – Census of Anonymised Records
PPK	Cents per kilometre travelled
PPM	Cents per minute travelled
PSO	Public Service Obligation

PT	Public Transport
PTAM	Public Transport Assignment Model
RMS	Regional Modelling System
RMSE	Root Mean Square Error
RMSIT	Regional Modelling System Integration Tool
SAA	Secondary Analysis and Appraisal
SAPS	Small Area Population Statistics
SERM	South East Regional Model
SR	School Run time period
SWRM	South West Regional Model
UK TAG	UK Transport Analysis Guidance
TFI	Transport For Ireland
TII	Transport Infrastructure Ireland
TP	Time Period
WRM	West Regional Model

EXECUTIVE SUMMARY

Background to the Regional Modelling System

The National Transport Authority (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 by the NTA with the support Jacobs, SYSTRA and RAND Europe. The RMS comprises the National Demand Forecasting Model (NDFM); five large-scale, detailed, multi-modal regional transport models; and, a suite of Appraisal Modules. The five regional models comprising the RMS are focussed on the travel to-work areas for Dublin (represented by the East Regional Model (ERM)), for Cork (represented by the South West Regional Model (SWRM)), for Limerick (represented by the Mid-West Regional Model (MWRM)), for Galway (represented by the West Regional Model (WRM)) and for Waterford (represented by the South East Regional Model (SERM)).

The key attributes of the five regional models include; full geographic coverage of each region, detailed representations of all major surface transport modes including active modes, road and public transport networks and services, and of travel demand for five time periods (AM, 2 Inter-Peaks, PM and Off-Peak). The RMS encompasses behavioural models calibrated to 2016 Household Survey data that predict changes in trip destination and mode choice in response to changing traffic conditions, transport provision and/or policies which influence the cost of travel.

Purpose of the RMS

The NTA uses the RMS to help inform decisions required during strategy development and to assess schemes and policy interventions that are undertaken as part of its remit. The RMS has been developed to provide the NTA with the means to undertake comparative appraisals of a wide range of potential future transport and land use options, and to provide evidence to assist in the decision-making process. Examples of how the RMS can assist the NTA include testing new public transport schemes by representing the scheme in the assignment networks, testing demand management measures by, for example, changing the cost of parking or number of parking spaces within the regional model or testing the impacts of new land use by changing the planning data assumptions within the NDFM.

Update of the RMS to 2016

With the release and availability of the 2016 Census/POWSCAR[1] and 2017 National Household Travel Survey (NHTS) data sets the NTA embarked on an update of the RMS in 2017. As part of the RMS update a range of improvements to the main model components where identified and implemented. These improvements include improving and making changes to such elements as the NDFM, development of the Long-Distance

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[1] Place of Work, School or College – Census of Anonymised Records

Model, updated zoning, networks, and parking modules; best-practice discrete choice modelling using the NHTS and POWSCAR datasets to estimate the parameters of the behavioural models, improved model runtimes, and general model functionality improvements. The model represents a neutral weekday/month in 2016.

Key Modelling Features and Components of the RMS

Model Software:
The RMS is built within the following primary transport modelling software packages:
- Road Model is based on SATURN software; and
- NDFM, Public Transport Model and Choice Modelling components are built within the CUBE Voyager software.

Modelled Years:
- A base year of 2016 (to coincide with Census/POWSCAR and National Household data sets); and
- For forecasting, the RMS can represent any year for which land use and infrastructure provision assumptions can be provided.

Modes of Travel:
- Private vehicles – cars (distinguishing between car driver and car passenger) within the Demand Model;
- Public transport sub-modes (bus, rail, Luas, Metro);
- Park and Ride to/from designated locations;
- Active modes (walking and cycling);
- The model also includes representation of Goods vehicles (LGV and OGV); andTaxis, not a main mode within the choice models, but represented as a separate user (vehicle) class and based on a proportion of car trips within the 'Other' trip purpose.

Time Periods:
- AM Peak period covering the period between 07.00-10.00;
- Morning Inter-Peak covering the period between 10.00-13.00;
- Afternoon Inter-Peak covering the period between 13.00-16.00;
- PM Peak period covering the period between 16.00-19.00; and
- Off-Peak covering the period between 19.00-07.00.

Demand Segmentation:
- Home base journey purposes, such as:
    - Commute;
    - Education;
    - Escort to Education;
    - Shopping;
    - Visiting friends/relatives;
    - Employers business; and
    - Other (which combines all trip types not part of the above categories).
- Non-home-based trips, derived from the destinations of home-based trips;
- All home-based trips are segmented by car availability, which is a function of household car ownership and competition levels; and
- Access to free car parking (this segmentation is created within the initial stages of the Demand Model based on workplace parking capacities).

Zoning System:
The basic element of the RMS zoning system is the Census Small Area Population Statistics (SAPS) boundary system the associated data from the 2016 Census (supplied by the Central Statistics Office, CSO). Non-geographic zones, for examples airports and ports, whose trip patterns are not related to the standard demand segments (e.g. work, education, etc.) that comprise the Demand Model component of the regional models are represented by Special zones in the RMS.

Demand Model:
The Demand Model element of the RMS is a system of choice models which produce the assignment matrices from the input trip ends. Its key components include mode and destination choice models, the free workplace parking model, parking distribution model, and the park and ride model.

Model Development Summary

The model was developed, calibrated and validated in line with current transport modelling guidance, primarily from UK Department for Transport's Transport Analysis Guidance (TAG) and building on the work undertaken to deliver the 2012 RMS. Each model component was developed using the best available data, such as the 2016 Census, 2017 NHTS, latest traffic and passenger count data, standard PT timetable data formats such as General Transit Feed Specification (GTFS) and GPS-based journey time data. Overall, the level of calibration and validation achieved across each of the model components is of a high standard when considering the model of this scale and complexity.

The Road Assignment Model calibrates to a good standard when considering individual link counts. The target flow calibration and validation criteria are in line with UK TAG Unit M3-1 Section 3 Table 2. The Public Transport assignment model includes all the services that are coded in GTFS with the time period being modelled. Assignment parameters are set based on initial values provided by UK TAG Unit 3.2 and the Passenger Demand Forecasting Handbook (PDFH) v6.0. The responsiveness of the Demand Model has been established through realism testing as defined in UK TAG guidance using the standard three measures: change in car fuel, public transport fares and car journey time. The additional responsiveness provided by the parking models in the Regional Model enable a wide range of scheme and policy tests. Overall the level of calibration in the ERM is considered extremely good for a model of its scale and complexity.

Recommendations for Improvement

A number of areas have been identified where opportunities exist for further improvements in the RMS. These include more comprehensive collection of the key data used for model development, to investigate different approaches to matrix estimation in the road model to limit changes to the Demand Model matrices, reviewing how crowding is modelled in the public transport model and potentially to improve the assignment of walk and cycle trips in their respective transport networks.

1 Introduction

1.1 Background

The NTA has developed a Regional Modelling System (RMS) for the Republic of Ireland to assist in the appraisal of a wide range of potential future transport and land use options. The RMS comprises of several component models and tools, including:

- The National Demand Forecasting Model (NDFM);
- Five Regional Models; and
- Secondary Analysis and Appraisal Tools (SAA).

Each of the five regional models are focused on the travel-to-work areas of the major population centres of Dublin, Cork, Galway, Limerick, and Waterford.

This report details the development of the East Regional Model (ERM). The models were developed as part of the Modelling Services Framework (2013-2016), and the Transport Modelling Services Contract (2017-2020) by the NTA, Jacobs, SYSTRA and RAND.

Figure 1.1 shows the area covered by each of the five Regional Models.

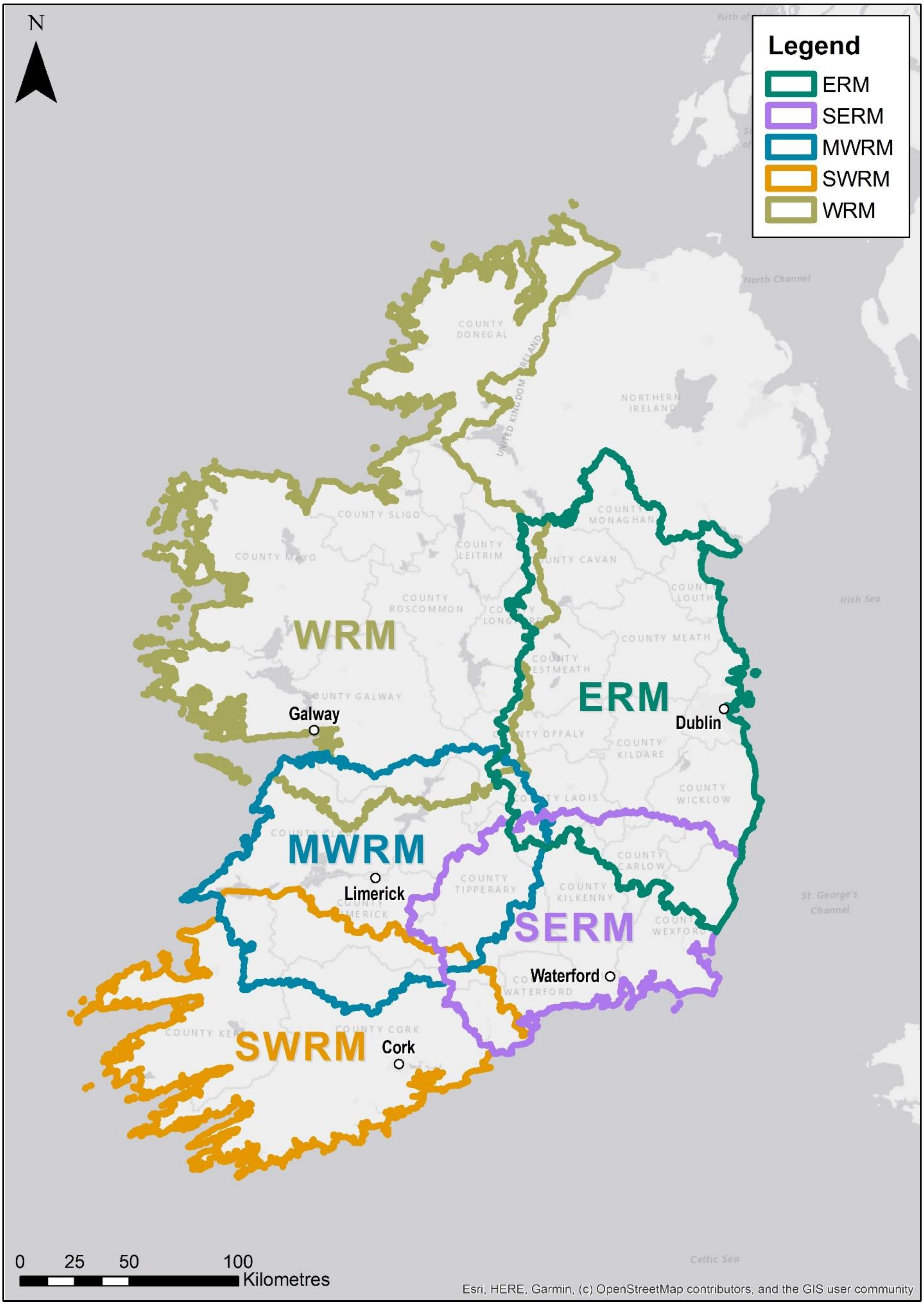


Figure 1.1 Regional Model Areas

1.2 Purpose of the Model

The NTA uses transport modelling to inform the decisions required during strategy development and assess schemes and policy interventions that are undertaken as part of its remit. The NTA remit includes but is not limited to:

- Preparation and regular review of the transportation strategy in the Greater Dublin Area (GDA);
- Adoption of an integrated implementation plan and a strategic traffic management plan;
- Financing the construction of public transport infrastructure;
- Promoting an integrated public transport network;
- Implementing integrated ticketing, fares and information schemes;
- Regulating fares and encouraging increased public transport use;
- Implementing demand management measures (excluding road pricing);
- Ensuring integration of land use and transport planning in Development Plans, Local Area Plans and Strategic Development Zones; and
- Developing traffic management plans in each of the following regions:
  - Cork City and Region;
  - Galway City and Region;
  - Limerick City and Region; and
  - Waterford City and Region.

Informed and robust decision making is essential to the NTA in order to ensure that we not only maximise the use and efficiency of our existing transport system, but also to ensure that any future investment and developments are complemented with the best transport solutions. The RMS has been developed to provide the NTA with the means to undertake comparative appraisals of a wide range of potential future transport and land use options, and to provide evidence to assist in the decision making process.

Examples of how the RMS can assist the NTA includes:

- Testing new public transport schemes by representing the scheme in the assignment networks;
- Testing demand management measures by, example, changing the cost of parking or number of parking spaces within the Demand Model; or,
- Testing the impacts of new land use by changing the planning data assumptions within the trip end model.

1.3 Structure of the Report

Due to the size and complexity of the RMS, this report covers many different topics regarding the model development, calibration and validation. However, it would be impractical to provide a detailed description of every model component and process as well as details on the calibration and validation processes. The various chapters of this report therefore provide a summary of their content, with links to more detailed technical notes and reports which can be referred to if further information is required. A complete list of all documents referenced in this report are provided in Annex 1.

To assist in locating the relevant information, this report has been structured to mirror the development of the model itself. The following description of each chapter is provided to indicate where information can be found, and a more detailed index is also provided at the back of this report:

- Chapter 2 provides an overview of the model structure and the main components, which are then described in detail later in the report. Also included is a summary of the National Demand Forecasting Model;
- Chapter 3 provides information about all data collected or used as part of the model development, calibration and validation. This includes all demand data related to the Demand Model, road model, Public Transport (PT) model and active modes model (e.g. Origin-Destination information, counts, journey times). Please note that network infrastructure data (e.g. number of lanes, road capacity, bus services) are described separately in the chapters relating to the road, PT and active modes (Chapters 7, 8 and 9, respectively);
- Chapter 4 describes the zoning system, including the criteria used to determine the zone boundaries, an overview of the hierarchical zone system and a description of the zone system relating specifically to the ERM area;
- Chapter 5 deals with the segmentation of the model demand. The model segmentation varies depending on the model component and at various times the demand may be classified according to journey purpose, user class, time period, etc. This chapter summarises the methods to determine which segments are used, as well as the level of segmentation applied to each model component;
- Chapter 6 deals with the Regional Demand element which uses the 24-hour all-mode segmented trip ends from the NDFM and uses a series of choice models to produce a series of demand matrices for each period and each mode which are output to the assignment models (described in the following three chapters). This chapter covers a large number of sub-models and processes, including:
    - Mode and Destination Choice;
    - Free Workplace Parking;
    - Park and Ride;
    - Parking Distribution;
    - Special Zones (Ports and Airports but can also cover other “non-standard” generators and attractors);
    - Taxis;

  - Goods Vehicles; and
  - Greenfield Sites.
- The road assignment model is described in Chapter 7. This covers the specification of the road model, standards for coding and methods for checking and validating the network. The chapter also provides details about the methods used to calibrate and update the assignment demand matrices;
- Chapter 8 covers similar information to the previous chapter, however, describes the PT model instead. This includes the definition of PT services, the procedures used for assignment as well as the derivation of model parameters such as those used to define values of time, crowding and fares;
- Chapter 9 summarises the development of the active modes model in a similar manner to the previous two chapters;
- Chapter 10 summarises the methods used to calibrate the Demand Model including the estimation of the choice models and other model components. This chapter importantly provides details around the final model parameters;
- Chapter 11 provides detailed results from the base ERM model demonstrating how well the model compares against observed values for a number of different metrics including, for example, mode share, trip length and traffic volumes;
- Chapter 12 provides the results of the three standard realism tests specified in appraisal guidelines, along with a number of bespoke sensitivity tests designed to test the performance of individual model components; and
- Finally, Chapter 13 provides a summary of the model development and calibration results and recommendations for future model enhancements.

As this report is intended to provide an overview summary of the model development and calibration, it is not possible to provide detailed technical descriptions of every component. Instead, further information on each aspect of the model can be found in the library of reference documents. As far as possible the relevant sections of the reference documents have been clearly sign posted throughout the report.

2 Model Structure

2.1 Overview of the Regional Modelling System

This chapter presents a brief overview of the RMS, which consists of:

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

The modelling approach is consistent across each of the regional models. The general structure of the regional models is shown below in Figure 2.1. The main parts of the regional modelling system are described below.

2.2 National Demand Forecasting Model Overview

The NDFM is an integrated suite of components that provide national level forecasts of daily travel demand produced by and attracted to each of the 18,641 Census Small Areas, and of inter-urban travel between most settlements with a population greater than 5,000.

There are five stages in the NDFM:

- Planning Data Adjustment Tool (PDAT);
- Car Ownership / Car Competition Model (COCMP);
- National Trip End Model (NTEM);
- Long Distance Model (LDM); and
- Regional Model System Integration Tool (RMSIT).

Further information on the NDFM is provided in Section 6.2 of this report. Each NDFM component is also more fully described in its own reference document, a link to which can be found in Section 6.2.

The NDFM interfaces with the Regional Models via the Regional Model Strategic Integration Tool (RMSIT) and the National Trip End Model (NTEM).

PDAT controls the planning data inputs to the core NDFM system and is used to amend these inputs.

COCMP estimates the number of cars owned in each CSA and subsequently categorises the number of households by levels of car ownership.

NTEM estimates the total daily travel demand at a Census Small Area level, which is adjusted to the zone based intra-region demand by the Regional Models.

The LDM calculates settlement-to-settlement trips across the island of Ireland allowing the number of trips between different regions (and to/from Northern Ireland) to be estimated, as well as providing consistency in the overlap areas.

RMSIT converts the private car, PT and HGV movements produced by the LDM and thus provides consistent flow data to each Regional Model boundary with respect to traffic moving into, through, and out of each region.

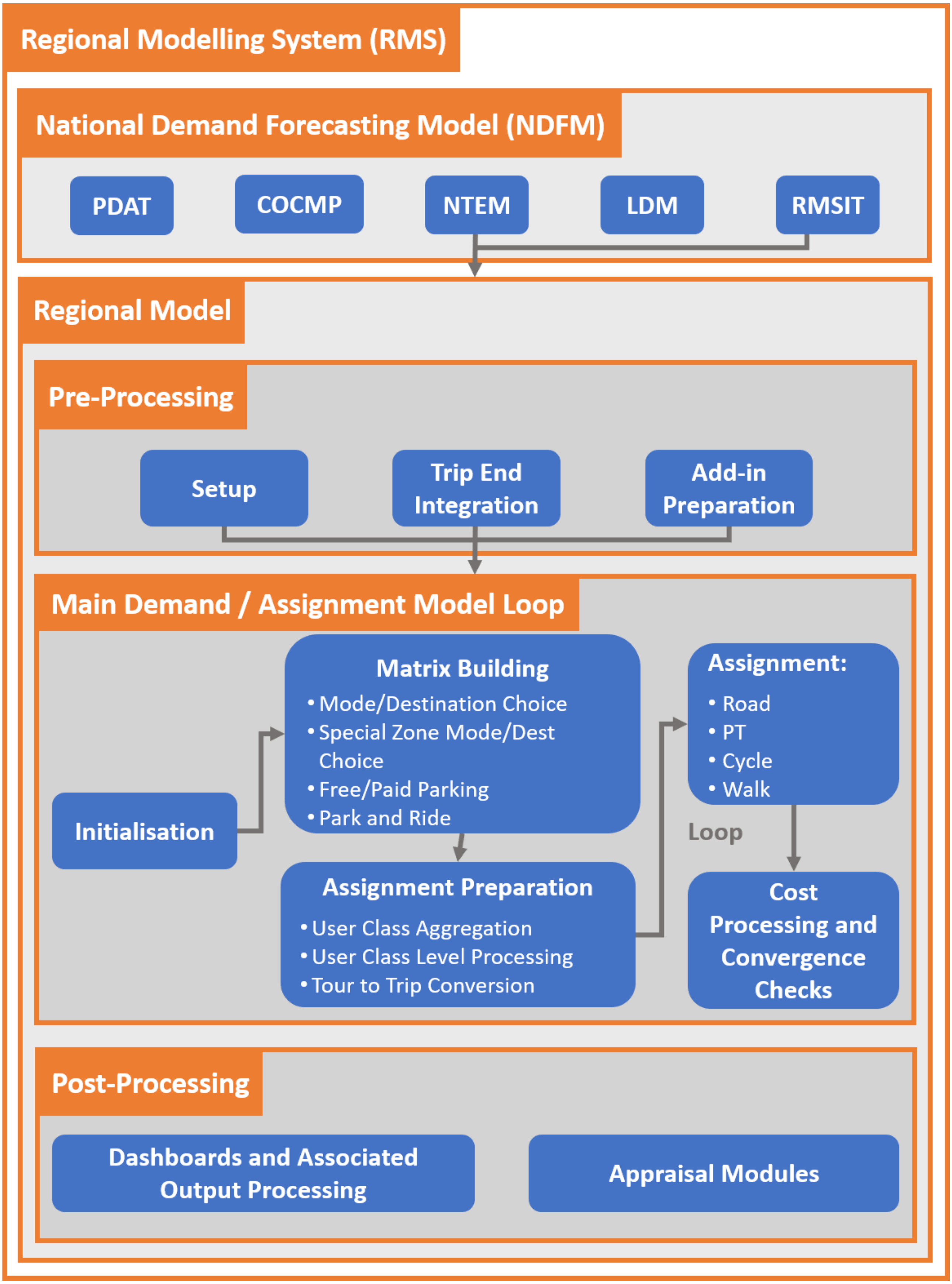


Figure 2.1 Regional Modelling System Structure

2.3 Regional Model Overview

The Regional Model is a set of travel choice models and assignment models that take NDFM outputs and apply them to the respective regional transport networks through a series of choice and assignment models. The model represents a neutral weekday/month in 2016.

A regional model is comprised of the following key elements.

2.3.1 Trip End Integration

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

2.3.2 Demand Model

The purpose of the Demand Model is to derive levels of trip making between zones by mode and time of day. A series of choice models derive each of these components in an iterative algorithm. A choice model is essentially a model of human behaviour which replicates as closely as possible observed behaviour. This behaviour can be mathematically described as function of travel costs. For example, the longer the trip the fewer people make it. Trends such as this are derived from data obtained from the National Household Travel Survey and the Place of Work, School or College – Census of Anonymised Records. These trends are assumed (and have been shown by extensive research) to remain largely constant over time.

2.3.3 Assignment Models

The Demand Model produces Road, Public Transport, and Active Modes travel demand matrices for the assignment models. The assignment models take transport networks and travel matrices as input and determine the route choice for every trip. The assignment models provide the cost of travel for each origin and destination pair back to the Demand Model, which then re-evaluates the travel choice estimates.

The Road Model includes capacity constraint, traffic signal delay and the impact of congestion.

The Public Transport (PT) Model 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.

The Active Modes model assigns walk and cycle trips using an all-or-nothing assignment. The model includes additional network elements such as footpaths and cycle routes.

2.4 Secondary Analysis and Appraisal

The Secondary Analysis and Appraisal (SAA) component of the RMS enables the use of Regional Model outputs in the analysis and appraisal of transport plans and policy proposals. The SAA 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.

3 Data

3.1 Introduction

Many components of the Regional Modelling System (RMS) are underpinned by information datasets such as road topography or observed datasets such as the National Household Travel Survey (NHTS).

Prior to updating the RMS, a workshop was held in November 2017 with the consultants and the NTA to review existing data sources used by the modelling suite. Much of the data used previously was sourced from the NTA DataStore, a bespoke database system containing travel survey data which is regularly updated. However, a number of other data sources which had been used were reviewed to ensure that they were still appropriate, and to review the data requirements of any proposed enhancement to the RMS.

The outcome from this workshop was the *Data Management Report*, which summarises the identified data types and sources, data gaps and the processed data sources. The identified data sources, their processing and checking, and any usage is outlined in the following sections.

3.2 Place of Work, School or College – Census Anonymised Records

3.2.1 Data Summary

The Place of Work, School or College – Census of Anonymised Records (POWSCAR) 2016 is a dataset from the National Census and provides details of where people live and work or go to school and approximate details about the usual mode used to commute and the time that they usually travel. The data is aggregated spatially to ensure that individual respondents cannot be identified.

3.2.2 Data Processing

Owing to the sensitive nature of this dataset, anyone with access to the data must be appointed as an Officer of Statistics. Furthermore, to provide additional protections to the dataset it was agreed that the data would only be stored on an isolated computer which only particular NTA staff members (who had been appointed as Officers of Statistics) could access.

This meant that a series of processing scripts had to prepared and tested using a dummy dataset, which could then be provided to the NTA in order for the data to be cleaned and processed in a secure manner. The outputs from each of these scripts would be aggregated datasets which could be disseminated more widely around the project team, but which still needed to be carefully managed. Although the datasets have been used to inform various aspects of the model, the datasets themselves cannot be provided to third parties and copies held by the consultants will be deleted at the end of the project.

As the data had already gone through extensive cleaning by the Central Statistics Office (CSO), additional cleaning of the data was generally limited to filtering of the dataset to remove any trips which did not start or end in the Republic of Ireland (e.g. cross-border commuters) and mobile workers (those with no fixed place of work). Additional processing was then undertaken to aggregate the data for input at various stages of the model, including deriving trip rates and average trip-lengths.

Further details on the scripts used for the cleaning and aggregation of data can be found in the sections of this report listed in the "Data Application" section below and in *POWSCAR Data Processing Note*.

3.2.3 Data Application

POWSCAR data is used to inform a number of different model elements. Due to the sensitivity of the data, it has been aggregated before inclusion in the model. Main purposes are:

- Zone System – define modelled area (see Chapter 4);
- Zone System – build zones with consistent level of transport demand (see Chapter 4);
- NDFM (see Chapter 6); and
- Demand Model parameters estimation (see Chapter 6).

3.3 Small Area Population Statistics

3.3.1 Data Summary

The Small Area Population Statistics (SAPS) 2016 is a dataset from the National Census and provides details of where people live and population structure. The data is aggregated spatially to ensure that individual respondents cannot be identified in 18,641 geographical polygons, named Small Areas (SA).

3.3.2 Data Processing

The data is available in a GIS shape file format with an attached detailed table.

3.3.3 Data Application

The SAPS provide the population figures that are used in the following RMS components:

- Zone System – Zones are aggregation of SAs and/or sub-SAs (see Chapter 4); and
- NDFM (see Chapter 6).

3.4 National Household Travel Survey

3.4.1 Data Summary

Between January and December 2017, the NTA undertook a National Household Travel Survey (NHTS) of nearly 6,000 households. The main purpose of the survey was to obtain essential information on all day travel patterns and travel behaviour across the country as a whole. This survey was a repeat of a similar household survey undertaken by the Authority between March and December 2012.

In addition to questions about the household, such as employment status and car ownership, the survey included a three-day travel diary recording details of all trips undertaken by household members.

3.4.2 Data Processing

Amárach Research undertook a rigorous data checking and cleaning process on behalf of the NTA. Their National Household Travel Survey 2017 Report[2] details their checking, cleaning and analysis.

As much of the data processing had already been undertaken by the survey company, only limited additional preparation of the dataset was required. This included applying the following checks to the trip diary data to ensure that the trip records were logical:

- Has a valid journey purpose, travel time, travel distance and means of travel been recorded?
- Has the respondent recorded a minimum of one outbound and one return trip on any given day?
- Is the trip record part of a logical sequence of trips on a given day?

The *NHTS Data Processing Note* summarises the additional data cleaning that was undertaken on the final dataset, presents the main findings from analysis of the NHTS 2017 travel diary data, and tracks significant changes to travel demand and travel behaviour in the intervening 5-year period between this survey and the previous NHTS in 2012.

The report concludes that survey samples are similar in 2017 to what they were in 2012, and that the survey represents a good representation of the national population. There was a major increase in persons who are full time employed, and a major decrease in persons who are part time employed or unemployed relative to the sample of respondents in the 2012 survey. As a result of this, weekday trips are now more concentrated in the AM and PM peaks than they were in 2012, while daily trip rates are on average 12 per cent lower than those obtained in the 2012 survey. The mode share and average trip distance are relatively unchanged when compared to the 2012 survey.

3.4.3 Data Application

The NHTS data has been used in a similar way to the POWSCAR data described above. The NHTS data covers more journey purposes than POWSCAR (which just captures commute and education trips), but only represents a sample of households. Aggregate data from the NHTS is used as calibration targets during estimation of the regional Demand Models (see Chapter 6).

[2] https://www.nationaltransport.ie/wp-content/uploads/2019/01/National_Household_Travel_Survey_2017_Report_-_December_2018.pdf

NHTS data has also been used to calculate average walking and cycling speeds within the active modes assignment model.

3.5 Valuations Data

3.5.1 Data Summary

Car Parking data was obtained from the Valuations Office for 2017. The Valuations Office is tasked with keeping an up-to-date inventory of commercial and industrial property, including car parking, for the purposes of applying business rates.

The Valuations Office kindly provided an extract from their database, which included an inventory of all commercial parking spaces, including private workplace parking and public off-street parking, for an area covering Dublin City Council, Dun Laoghaire-Rathdown County Council, Fingal County Council and South Dublin County Council.

It should be noted that the data is compiled through a variety of methods to ensure that the Valuations Office database is as complete as possible, but there will always be some omissions where the surveyors have been unaware of the existence of commercial parking. Furthermore, commercial rates are not applied to all parking spaces, so the data becomes unreliable outside of Dublin City Centre as out-of-town spaces are generally not included in the rateable value of a property. Similarly, the database will be incorrect where properties are exempt from business rates, for example healthcare facilities and charities.

3.5.2 Data Processing

The data from the Valuations Office is provided in a basic spreadsheet format with very little checking. The data was cleaned and processed using the following steps:

- Checks on descriptive fields to ensure that all data relates to car parks and not to other types of land-use;
- Conversion of quantitative fields to consistent units;
- Logic checks to spot anomalous values; and
- Allocation of individual car parks to the ERM zoning system.

The 2017 dataset was also compared to a similar dataset obtained in 2012. Details of the cleaning process and a summary of the comparison between the two datasets is presented in *Demand Data Processing Report.*

The note concludes that there are some significant differences between the dataset obtained in 2017 and the dataset provided in 2012, and that these differences should be considered when applying the data to the updated RMS.

3.5.3 Data Application

The data from the Valuations Office was used primarily to derive input data to the Free Workplace Parking Model. Details of how the data was processed for use in this model can be found in Chapter 6.

3.6 General Transit Feed Specification

3.6.1 Data Summary

The General Transit Feed Specification (GTFS) is a Public Transport dataset that aggregates information such as timetables, stop locations and public transport service routes. The NTA collects and publishes the GTFS data on their website for bus, rail and Luas routes operating in Ireland that can be downloaded as a series of comma separated value files.

GTFS data was downloaded from the NTA interface in September 2016 and in May 2017, which includes PT routes that were operating at the time.

3.6.2 Data Processing

For this project, we built a GTFS converter designed to convert PT data from the General Transit Feed Specification (GTFS) format into the software-specific format. More details on the process on how to use it are available in the *PT Model Development Report.*

Irish Rail and Luas GTFS files includes a list of stations with name and GIS coordinates. That information was converted into GIS shape files.

Rail PT routes (including Luas) were extracted from GTFS converter on Thursday 26/04/2016 (neutral weekday outside holidays, bank holiday weeks, closest to census day). Bus PT routes were extracted for Thursday 27/04/2017. The difference in the extraction dates comes from the September 2016 GTFS dataset, which contains the Dublin Bus summer timetable, not suitable to represent an average situation. Because GTFS datasets are not kept accessible, it wasn't possible to get April 2016 Bus GTFS data. It has then been decided to pick a similar day one year apart to extract Bus PT routes.

3.6.3 Data Application

The GTFS data, once converted, is fed into the "lines coder" process and generates the public transport service patterns for the public transport assignment model.

For each coded PT service, a theoretical (or timetable) journey time has also been extracted from GTFS and compared against modelled journey times during calibration.

In the coded PT network, Rail and Luas station location and distance between stations were also extracted from GTFS data.

3.7 LEAP Card Data

3.7.1 Data Summary

The Transport for Ireland LEAP Card is a method of payment for public transport services in Dublin, Cork, Galway, Limerick, Waterford, Sligo, Athlone, Kilkenny and Wexford. Card users "touch-on" to services when they board a PT service, and "touch-off" when they alight (except on buses, which are "touch-on" only), and therefore journey and fare information can be obtained.

3.7.2 Data Processing

LEAP Card data for a two-week period in September and October 2018 was obtained and analysed. Further information relating to the processing of the LEAP Card data can be found in *PT and Active Modes Data Processing Report.*

3.7.3 Data Application

LEAP Card data was used to support the calibration of the public transport components of the ERM by establishing the average fare paid (by operator), the number of transfers between operators and daily boarding distributions (by operator). Further details of how the data was used in the PT model can be found in Chapter 8. The LEAP Card data was also used to inform the time period to peak hour factors, as outlined in Chapter 5.

3.8 Topographical Road Network Data

3.8.1 Data Summary

HERE (formerly Navteq) provide mapping, navigation and location services. One of their data products is a topographical representation of the road network which is used by a number of navigation companies. This data product was used in the ERM as the basis of the road network structure.

3.8.2 Data Processing

The HERE 2016 dataset was imported into GIS, and multiple selection criteria were applied in order to select roads that would be included in the ERM road network. This included retaining any road above a certain function class, and road which carried a bus service, and any road that was of strategic importance. This process is detailed in the *Road Model Development Note*, which set out the level of detail retained in the initial network selection and the process of converting this information into a format compatible with the software-specific format required by the model.

3.8.3 Data Application

The processed HERE 2016 network formed the foundation for the road assignment model. This information was converted into a software-specific format usable by the road assignment model, and detailed coding added to the structure to represent the operation of each road and junction.

3.9 Rail Bridge Height Data

3.9.1 Data Summary

Irish Rail hold an inventory of each rail crossing bridge, with the dataset containing a bridge identification number, the underpass height restriction, the location of the bridge, the status of the rail line and details of the maintenance department responsible for that bridge.

3.9.2 Data Processing

The data provided by Irish Rail was mapped to the road network in GIS, and the various restrictions translated into a ruleset that can be applied in the road assignment model. Owing to a lack of vehicle height data from either the Road Safety Authority or TII, supporting data from the United Kingdom was used to determine that the average height of an OGV1 was 3.4 metres, and the average height of an OGV2 was 4.4 metres.

Roads passing under bridges with a height clearance of less than 3.4 metres were identified as having a full HGV (OGV1 and OGV2) ban, while roads passing under bridges with a height clearance of greater than 3.4 metres in height were only banned to OGV2. There were no restrictions related to bridges with a height clearance of greater than 4.4 metres unless otherwise signed on the ground.

Details of the data processing are included in the *Road Model Development Note*.

3.9.3 Data Application

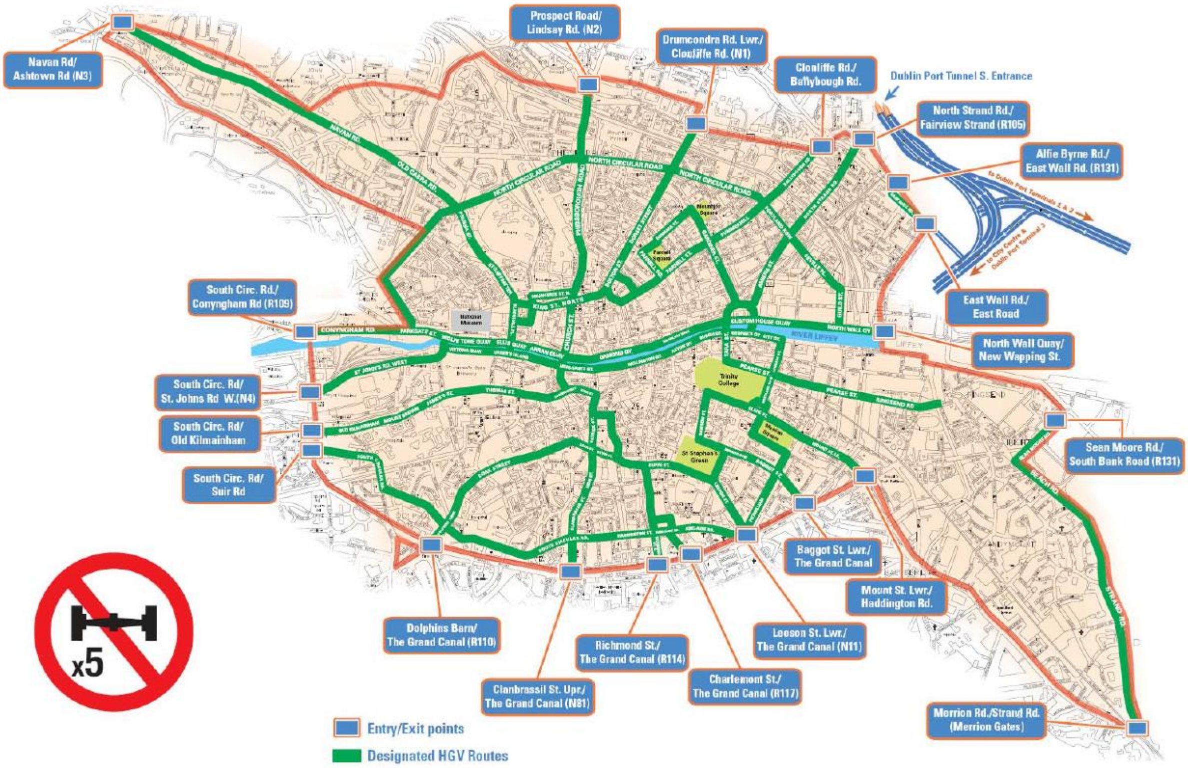
The bridge locations were matched to links in the road assignment model, and using the ruleset specified above the appropriate user classes were banned from accessing the road assignment link.

3.10 Heavy Goods Vehicle Restriction Data

3.10.1 Data Summary

Dublin has restrictions in place that prohibit goods vehicles from entering certain areas or using certain roads. This is most evident in residential areas where there is often a 3.5 tonne weight limit placed on vehicles. Dublin operates a permit-based system for accessing the city centre, as outlined on the Dublin City Council website[3]. Any vehicle with five or more axles is prohibited from entering a defined area without a permit. The area subject to the restriction is shown in Figure 3.1.

[3] http://www.dublincity.ie/hgv



Source: Dublin City Council

Figure 3.1 Dublin City 5-Axle Ban

Other vehicle restrictions were identified manually using street-level mapping and local knowledge where applicable.

3.10.2 Data Processing

Each identified vehicle restriction was mapped to a link within the road assignment model, and the correct vehicle restriction identified.

3.10.3 Data Application

The restrictions were coded into the road assignment model within the appropriate section of the input data files, which relates to restrictions and tolls. This ensures that HGV route choice is accurately reflected within the road assignment model. For further information please refer to Chapter 7.

3.11 Tolling Data

3.11.1 Data Summary

Transport Infrastructure Ireland through eToll[4] operate eleven toll roads in the Republic of Ireland, all of which are compatible with a tag-based system. The location of each toll is illustrated in Figure 3.2.

[4] https://www.etoll.ie/driving-on-toll-roads/information-for-visitors/

Source: eToll

Figure 3.2 Toll Road Locations

3.11.2 Data Processing

The eToll website specifies a toll for each tolled road, broken down by vehicle class, direction of travel and time of travel where this varies. This data was extracted in 2016 and has not been discounted. Each toll location was then mapped to a link in the road assignment model.

3.11.3 Data Application

The tolls were coded into the road assignment model within the appropriate section of the input data files in Cents. This ensures that toll costs are included in the cost of travel at the appropriate locations. For further information on how tolls are applied to the road model, please refer to Chapter 7.

3.12 Traffic Signal Data

3.12.1 Data Summary

Traffic signal data can be obtained from Urban Traffic Management Systems such as SCATS[5] (which is used in Dublin), SCOOT[6] or MOVA[7]. Such systems can adjust the phasing and duration of traffic signals to adapt to traffic flows, the purpose of which is usually to maximise network efficiency. The systems usually retain a log of signal timings and associated traffic counts, which can then be interrogated for use in the model.

Traffic signal data can also be obtained directly from on-site controllers or by manual observation of the traffic signal operation.

3.12.2 Data Processing

Regardless of the data source, the data was processed into a format that can be incorporated into the road assignment model. The average hourly operation of each junction was determined by assessing the duration and number of calls of each stage, and the junction tuning movements associated with each stage. Where stages were identical or infrequently called, these were merged with similar phases or removed from the dataset.

The output for the data processing was a stage plan, cycle time and stage timing for each signalised junction assessed. Where applicable, a global offset against the modelled hour start time, such as 0800, was also derived.

3.12.3 Data Application

Each signal controller was mapped to a junction in the road assignment model, and the signal phases mapped to applicable approaching arms and available turning movements. The calculated stage and cycle times were then coded to complete the definition of the signalised junction in the road assignment model. Further details on the coding of the signals can be found in the *Road Model Development Report*.

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[5] SCATS originated in Sydney and the name is an acronym for Sydney Coordinated Adaptive Traffic System
[6] SCOOT (Split Cycle and Offset Optimisation Technique) developed by TRL, coordinates timings between linked signals and is used in over 350 cities worldwide.
[7] MOVA (Microprocessor Optimised Vehicle Actuation) also developed by TRL, optimises timings at isolated junctions.

3.13 TII Traffic Count Data

3.13.1 Data Summary

TII operate a number of fixed long-term traffic counters across Ireland that record information on the volume of traffic by hour of day and by vehicle class, distinguished by the number of axles, with up to twelve vehicle classes being identified. This data is publicly available on the TII traffic count website[8].

3.13.2 Data Processing

The website can be interrogated to provide historic data covering a user-specified period. Volume of traffic by hour of day and by vehicle class was extracted for each weekday (Monday to Friday) in November 2016.

Once the data was formatted in a consistent manner a checking strategy, outlined in the *Road Model Data Processing Report*, was applied to the dataset to ensure accuracy. The strategy checked that:

- The data was accompanied by information to allow it to be mapped to the model network;
- All junction arms were accounted for;
- The tidality of the count was sensible;
- The count was proportionate to the data collected for the 2012 model (where available); and
- Neighbouring junctions showed similar traffic trends (where available).

Data was then joined to the road assignment model by assigning each count to a specific link within the model.

In total, 41 individual survey locations were processed. A summary of the data processing and checking is available in the *Road Model Data Processing Report*.

3.13.3 Data Application

The TII traffic count data was used in a number of ways during the development of the model. The initial usage was to derive a factor to take the time period matrices produced by the Demand Model and convert them to the specific assignment hours represented by the road model. This process is described further in *Peak Hour Specification Report*, with the calculated factors summarised in Chapter 7.

Selected data points were used to derive a factor that was applied to external zone traffic from the Long Distance Model (LDM). Further information on the LDM can be found in the *LDM Report*, while the factoring process is discussed further in Chapter 10.

The processed count data was divided into a calibration dataset, and an independent validation dataset. The calibration dataset was used to inform coding changes in the road

[8] https://www.tii.ie/roads-tolling/operations-and-maintenance/traffic-count-data/

assignment model, and during matrix estimation. The validation dataset was held independently, and was used to assess the validity of the road assignment. This is discussed further in Chapter 7, Chapter 10 and Chapter 11.

3.14 Other Traffic Count Data

3.14.1 Data Summary

Road-based traffic count data takes the form of either automatically counted data, or manually counted data, and can be collected either from fixed long-term counters (such as those which form the Transport Infrastructure Ireland traffic counter network), medium-term (usually temporary automated counters) surveys, or single day surveys. Surveys are typically classified by vehicle type, but this is not always the case. The data sources used are summarised below.

NTA DataStore

During the development of the previous 2012 RMS the NTA contacted all local authorities, such as Dublin City Council, Dun Laoghaire-Rathdown County Council, Kildare County Council etc, and requested that all traffic count data commissioned and held by the respective authorities be sent to the NTA for processing and collation in a national database. The DataStore provides a map-based interface where users can view survey information such as date of collection, survey duration and survey type. The user can also download a pre-formatted copy of the data and any associated plan image that would help the user identify the surveyed junction and arm designations.

SCATS

Additional traffic count information in Dublin was also extracted from the detector loops that form part of Dublin's SCATS system. November 2016 data was extracted for a total of 1,911 junction approaches and was provided as an all-vehicle total.

The *Road Model Development Report* summarises the checking of this data, and concluded that of the 1,911 data records obtained, 777 were suitable for inclusion in the ERM validation dataset. The location of these counts is summarised in 7.10.2.

Unprocessed Survey Data

Numerous data collection exercises have been commissioned by the NTA or other local authorities since the creation of the DataStore, and in many cases this data has not been processed and included in the DataStore as of yet. This data, such as surveys to assist in the appraisal of the Dublin MetroLink project were provided in the survey companies own format, and processed separately for inclusion in the RMS.

3.14.2 Data Processing

The initial step in processing the data was to convert it into a format that is compatible with the NTA's DataStore. This allows the data, regardless of its original purpose, to be used at a later date with minimal additional processing. The NTA DataStore retains information such as time of day, movement description and surveyed volume by vehicle class.

In terms of additional processing of the traffic count data for use in the development of the ERM, a series of additional screening processes were applied. Data collected before 2013 was excluded from the dataset. While UK TAG Unit M3.1, Section 8.1[9] suggests using all data newer than six years old, there has been substantial traffic growth in Ireland within that period. Therefore, limiting the age of data to a maximum of four years was more likely to produce a model which accurately replicated 2016 traffic volumes.

Once the dataset was cleaned, two data checking strategies were developed covering single day traffic counts and multi-day traffic counts. These are outlined in the *Road Model Data Processing Report*. The strategies checked that:

- The data was collected during a neutral month (February, March, April, May, October, November);
- The data was collected on a neutral day (Tuesday, Wednesday, Thursday);
- The data was accompanied by information to allow it to be mapped to the model network;
- All junction arms were accounted for;
- The tidality of the count was sensible;
- The count was proportionate to the data collected for the 2012 model (where available); and
- Neighbouring junctions showed similar traffic trends (where available).

Data was then joined to the road assignment model by assigning each junction and approach count to a specific link or turning movement within the model.

In total, 327 individual survey locations were processed, with observation years ranging from 2011 to 2018. A summary of the data processing and checking is also available in the *Road Model Data Processing Report*.

3.14.3 Data Application

The processed count data was divided into a calibration dataset, and an independent validation dataset. The calibration dataset was used to inform coding changes in the road assignment model, and during matrix estimation. The validation dataset was held independently, and was used to assess the validity of the road assignment. This is discussed further in Chapter 7, Chapter 10 and Chapter 11.

[9] Note that the guidance used was current at the time of the data processing and early stages of the model calibration, and had remained unchanged since 2013. TAG unit M3.1 was subsequently revised in May 2020 and guidance on the age of data was updated and moved to TAG unit M2.2

3.15 Luas Census Data

3.15.1 Data Summary

The Luas Census, undertaken in 2016, records passenger boardings and passenger alightings at every station, by service, on a neutral Thursday. The data is provided in the form of an Excel spreadsheet.

3.15.2 Data Processing

Before processing the data, several checks were undertaken. The first check was a comparison against the same dataset from 2012. Boardings and alightings at a station level were checked to ensure they are within 100 persons of 2012 values. The number of services in the census were also checked against the GTFS data to ensure all services were surveyed. Any difference between the two datasets was investigated.

Once checked the data was processed, associating each Luas stop name with a node in the ERM public transport network. Services were then filtered to retain only services for which the mid-journey time was within the modelled hours. Boardings and alightings were then summed at a station level for all time periods, and passenger flows by direction and time period calculated.

3.15.3 Data Application

The processed Luas data was used to calibrate the boardings and alightings and the line load flows in the public transport assignment model. This information was also used to calibrate various public transport parameters, discussed further in Chapter 10 and Chapter 11.

3.16 Rail Census

3.16.1 Data Summary

The NTA publish an annual Rail Census Report[10], which captures the number of individuals boarding and alighting at each station in the country on one day of the year, providing a “snapshot of usage and patronage across the country at all stations and on all services on this one date”. The data for the 2016 survey was collected on Thursday 17 November.

3.16.2 Data Processing

Before processing the data, several checks were undertaken. The first check was to compare the 2016 census data to that collected in 2012 and any differences, positive or negative, of greater than 25% in total patronage at any given station were investigated. The number of services reported within the survey were also compared to the number of services contained within the GTFS data.

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[10] https://www.nationaltransport.ie/wp-content/uploads/2013/10/NTA_Rail_Census_Report_2016_FINAL.pdf

The data was then processed such that every named station was attributed to a corresponding node in the ERM public transport assignment model. The census was also filtered to only contain services whose mid-journey time was within the modelled hours. The boardings and alightings at a station level for all modelled time periods were then summed, and passenger flows by direction and time period calculated.

3.16.3 Data Application

The processed Rail Census data was used to calibrate the boardings and alightings and the line load flows in the public transport assignment model. This information was also used to calibrate various public transport parameters, discussed further in Chapter 10.

3.17 Dublin Bus Boarding Data

3.17.1 Data Summary

A survey, recording the boardings on every Dublin Bus by stop and time of day was undertaken on Thursday 24 November 2016. The data was provided to the Consultants in comma separated value format.

3.17.2 Data Processing

The number of services surveyed was checked against the GTFS dataset, with any difference in the number of services greater than two investigated. The dataset was also compared against LEAP card data, with any difference in patronage greater than 20% investigated.

One the dataset was checked, boarding by stop, route and time of day were summarised. Dublin Bus stop IDs were then matched to public transport nodes within the public transport assignment model so that the data could be converted into a format usable by the public transport assignment model.

3.17.3 Data Application

The processed Dublin Bus boarding data was used to calibrate the Dublin Bus boardings in the public transport assignment model. This information was also used to calibrate various public transport parameters, discussed further in Chapter 10.

3.18 Regional Bus Survey

3.18.1 Data Summary

A regional bus service survey was commissioned by the NTA. The survey was carried out across Ireland between February and June 2017. The survey was split into five “lots”, containing a total of 203 locations. Each location was surveyed on a single day, from 0700 to 1900. For each bus surveyed, passengers boarding, alighting and an estimation of number of passengers on-board were recorded. The dataset was provided as a series of Excel spreadsheets.

3.18.2 Data Processing

A high-level check of the estimated daily boardings per service against route annual passenger totals was undertaken. Due to the number of assumptions made during this comparison, only large differences were investigated.

Once checked, all observations were collated into a single database. Count locations were then matched to links within the public transport assignment model, producing a list of links with associated observed bus occupancy for each observed time period.

3.18.3 Data Application

The processed regional bus passenger count data was used to calibrate the patronage of the regional bus services within the public transport assignment model. This information was also used to calibrate various public transport parameters, discussed further in Chapter 10.

3.19 Bus Éireann Annual Passenger Data

3.19.1 Data Summary

The Bus Éireann Annual Passenger dataset provides the total annual passengers on Bus Éireann Public Service Obligation (PSO) services for the years 2012 to 2016. This data was provided by the NTA from data provided by the service operators. A total of 289 routes were included, covering the urban routes of the regional cities of Cork, Limerick, Galway and Waterford. As this data set does not cover Dublin, it was not used in the development of the ERM model.

3.20 Annual Rail Ticket Data

3.20.1 Data Summary

The annual rail ticket sales dataset contains the total sum of all rail ticket sales, provided at the station-to-station level for 2016.

3.20.2 Data Processing

The annual ticket sales figures were compared with the 2016 Rail Census to identify any outliers or issues with the data. The rail stations were then matched to rail station nodes within the public transport assignment model, and a sub-matrix of annual ticket sales between stations was extracted.

3.20.3 Data Application

Modelled fares represent the average fare paid by a user class and takes account of the different ticket types. Ticket sales data has been used to calculate fares for the PT assignment model.

3.21 Tax Saver Rail Ticket Data

3.21.1 Data Summary

Rail-based Tax Saver ticket data was provided by the NTA and contains information relating to the number of tax saver tickets purchased for 2016.

3.21.2 Data Processing

The data was provided in a spreadsheet format, and was processed to allow the data to be included in the weighted average calculation of the rail fares for the RMS.

3.21.3 Data Application

Modelled fares represent the average fare paid by a user class and takes account of the different ticket types. Tax Saver data has been used during the calculation of the fares for the PT assignment model.

3.22 Dublin Canal Cordon Bus Passenger Counts

3.22.1 Data Summary

A bus passenger survey was undertaken for buses travelling inbound over the “Canal” Cordon over several neutral days in November 2016 between 0700 and 1000.

3.22.2 Data Processing

Checks were undertaken on the dataset to ensure that the passenger counts were of a similar magnitude to an equivalent dataset collected in 2011. Any differences of greater than 250 passengers per hour were investigated. The number of buses surveyed was also compared to the number of buses recorded in the Canal Cordon traffic count dataset.

Once checked, the location of the counts was matched to links within the public transport assignment model, producing a list of links with associated observed bus occupancy for each observed time period.

3.22.3 Data Application

The processed Canal Cordon bus passenger count data was used to calibrate the number of bus passengers entering the Canal cordon in the public transport assignment model. This information was also used to calibrate various public transport parameters, discussed further in Chapter 10.

3.23 Dublin Canal Cordon Active Modes Counts

3.23.1 Data Summary

As part of the Dublin Canal Cordon traffic survey Dublin City Council traffic is doing every year, walking and cycling were also recorded on neutral days in November 2016. The survey recorded the number of people walking and cycling across the Canal cordon (0700 to 1000 Inbound and 1600 to 1900 Outbound). Data was provided as a series of Excel spreadsheets.

3.23.2 Data Processing

The 2016 observed flows were checked against the observed flows from 2011 and 2012, with any difference greater than 25% investigated. The observed flows were then matched to links within the active modes assignment model.

3.23.3 Data Application

The processed Canal Cordon walking and cycling count data was used to validate the number of active trips entering the Canal cordon in the active modes assignment model.

3.24 Road Journey Time Data

3.24.1 Data Summary

Journey time data for the road model has been sourced from TomTom, who calculate journey times using vehicle position data from GPS-enabled devices, and provide this on a commercial basis to a number of different users. The NTA purchased a license to access the Custom Area Analysis dataset through the TomTom TrafficStats portal[11]. Travel time data downloaded from this portal is contractually-defined in terms of the availability of data and user-defined in terms of the data specification. The NTA has an agreement with TomTom to provide travel time information covering six areas of Ireland and for certain categories of road.

Further information on the extraction and processing of TomTom data can be found in the *Road Model Data Processing Report*. A special guide on how to interact with the TrafficStats portal to obtain further data can be found in the NTA Data Portal Guide.

Data is provided based on the area specified by the agreement; however, the date and time range of the data can be specified by the user. The selected date range averaged all weekday observations in February, March, April, May, October and November 2016, excluding holidays.

Data was provided for the following specific periods, selected to match the assignment model time periods:

- 0800 – 0900;
- 1200 – 1300;
- 1500 – 1600;
- 1700 – 1800; and
- 2000 – 2100.

The data is provided in the form of a GIS shapefile and accompanying travel time database file. The shapefile contains topographical details for each road segment, which is linked to the travel time database via a unique link ID. The database file then contains average and median travel time, average and median speed, the standard deviation for

[11] https://trafficstats.tomtom.com

speed, the number of observations and percentile speeds ranging from 5 to 95 for each link.

3.24.2 Data Processing

In order to compare the journey times of specific links and routes between the TomTom data and the road assignment model, the two datasets needs to be linked. After importing both the road assignment model and TomTom networks into the GIS environment, ensuring both datasets are in the same coordinate system, the selected routes can then be linked using a spatial join functionality. Further information on the spatial join can be found in the *Road Model Data Processing Report.*

Before applying the TomTom dataset to the models, it was checked to ensure that it was fit for purpose. A checking strategy, as outlined in *Road Model Data Processing Report*, was agreed with the NTA, and applied to the TomTom dataset. This checking strategy included checks of the number of observations that form the TomTom average time, and checks of travel times against both the 2012 TomTom dataset and Google Maps travel times.

The TomTom Custom Area Analysis dataset was processed to provide observed journey times against which the ERM road network could be validated. In total, 28 two-way routes were identified as routes of significant importance, of which 20 were previously collected manually by the NTA through their "moving car observer" data collection programme.

Once the TomTom data was processed and joined to the ERM road network, checking was undertaken in accordance with the TomTom data checking strategy. The outcome of these checks is summarised in the *Road Model Data Processing Report*.

3.24.3 Data Application

The processed journey time data was used to validate the road assignment model at an end-to-end travel time level, with intermediate segment travel times used to inform the calibration of the road assignment model. Further information about the journey time validation process can be found in Chapter 7 and Chapter 10.

3.25 Public Transport Journey Time Data

3.25.1 Data Summary

Public transport journey time data is available in the form of Automatic Vehicle Location (AVL) data. This dataset provides bus journey times between stops by route, and the provided datasets averaged all services running during weekdays in October and November 2016, excluding holidays.

Data was provided for the following specific periods, selected to match the assignment model time periods:

- 0800 – 0900;
- 1100 – 1200;
- 1500 – 1600;
- 1700 – 1800; and

- 2100 – 2200.

For the ERM, AVL data for 33 Dublin Bus and 3 Bus Éireann routes was extracted.

3.25.2 Data Processing

The dataset was provided as a series of Excel spreadsheets, and consisted of the bus journey times between stops by route.

The correspondence between the real bus stop location and the ERM nodes was done using a GIS process that joins each individual stop to the nearest model node. A visual check was undertaken to ensure each node represents the correct bus stop, particularly at modelled junctions.

Stop-to-stop time for each segment was allocated to the link or series of links to convert them to a modelled node-to-node time. In the case where there are non-stopping nodes in between stops the journey times were calculated as a proportion of distance between nodes.

The observed journey times were then checked against scheduled journey times to ensure they were within 25% of the scheduled journey time, with outliers investigated and discarded if there was low confidence in the data. In total, 30 Dublin Bus routes (out of 33) and 3 Bus Eireann (out of 3) were included in the PT model calibration.

The sample size for each route was also reviewed, with any route having a sample size of less than five records being excluded from the calibration dataset. In these instances, timetabled journey times were used to calibrate the route.

3.25.3 Data Application

The AVL information was used to calibrate the PT assignment model, by comparing the observed bus route journey time with modelled journey times.

The PT model includes runtime factors that can be applied to public transport services to better account for stopping frequency and the interaction with general traffic. The AVL data was also used to calculate these factors.

3.26 Train Capacity Data

3.26.1 Data Summary

Data pertaining to the planned train composition on every service running on a typical day in 2016 was provided by Irish Rail. This information also included additional information on typical carriage capacities and was provided as a series of Excel spreadsheets.

3.26.2 Data Processing

No specific check was undertaken on this dataset beyond a local knowledge review. The data was formatted to be compatible with the public transport model.

3.26.3 Data Application

Train capacity data was input to the public transport model (number of seats and total capacity) on a per service basis.

3.27 Greater Dublin Area Cycle Network

3.27.1 Data Summary

A GIS representation of the type and quality of cycling facilities within the Greater Dublin Area was provided to the modelling team by The NTA Cycle planner[12] team.

3.27.2 Data Processing

The GIS information was manually spot-checked against online mapping tools and local knowledge, with the GIS files manually amended where discrepancies were identified.

The data was then joined to the active modes network to inform the location of cycling facilities.

3.27.3 Data Application

The active modes network was manually adjusted by increasing cycling speeds to better reflect the provision of dedicated cycling facilities.

3.28 Other Data Sources

3.28.1 Summary

There are a number of other publicly available data sources that informed the model development, but that did not require processing or extensive quality checking. These are summarised in Table 3.1.

Table 3.1 Other Data Sources

Data Source	Data Type	Data Use
MyPlan (myplan.ie)	Web map portal providing spatial information relevant to the planning process in Ireland	Zone Definitions
GeoDirectory (geodirectory.ie)	Reference dictionary of addresses in Ireland	Zone Centroid Placement
Parkopedia (parkopedia.com)	Car park locations and capacities	Parking Distribution Capacity
Irish Revenue	Ireland rate of VAT and average tax	Road-based Generalised Cost

[12] https://www.transportforireland.ie/getting-around/by-bicycle/cycle-planner/

Data Source	Data Type	Data Use
UK TAG Databook[13]	Transport modelling and appraisal parameters	Road-based Generalised Cost
Project Appraisal Guidelines[14]	Transport modelling and appraisal parameters	Road-based Generalised Cost
Common Appraisal Framework[15]	Transport modelling and appraisal parameters	Road-based Generalised Cost
The AA[16]	Ireland historic average fuel prices Economic data Freight data	Road-based Generalised Cost

[13] UK TAG Databook, version dated November 2018 (available from National Archives) https://webarchive.nationalarchives.gov.uk/20181208064951/https://www.gov.uk/government/publications/tag-data-book

[14] Project Appraisal Guidelines, dated October 2016 (https://www.tiipublications.ie/)

[15] Due to changes in the Common Appraisal Framework during the model update, two different versions were used. 2012 values of time were taken from a draft version of CAF issued in Nov 2014 and were growthed to a 2016 base year using growth factors from the 2016 version of CAF (published in 2019)

[16] Values taken from October 2017 (https://www.theaa.com/~/media/the-aa/pdf/motoring-advice/fuel-reports/october-2017.pdf?la=en)

4 Zone System

4.1 Overview

The purpose of this chapter is to describe the development of and present the final 2016 East Regional Model (ERM) Zone System. The sections within this chapter cover the elements of the zone system, data inputs used and the development of the zone system.

The development of the ERM zone system is part of a general update of the ERM; other aspects of which are described in later chapters of this report, including:

- Chapter 7 – Road Model;
- Chapter 8 – Public Transport Model; and
- Chapter 10 – Regional Model Calibration and Validation.

The choice of zone system dictates the level of spatial resolution of a model, and hence the ability of the model to realistically represent the transport situation. The Regional Model zone systems take account of the following geographic features and model attributes:

- Natural barriers (rivers, railways, motorways or other major roads);
- Areas of similar land use that have clearly identifiable and unambiguous points of access onto the road network included in the model;
- Levels of zonal population, employment, and trip generation;
- Existing zone boundaries, where an existing model is being used as the basis for the new model; and
- Administrative and planning data boundaries (Census Small Areas [CSAs], Small Area Population Statistics [SAPS] and Electoral Divisions [EDs]).

Table 4.1 below outlines the key quantitative criteria used in the development of the ERM zone system. Further information on the development of the zone system is provided in the *Zones Report.*

Table 4.1 Target Quantitative Criteria

Criterion	Target	Comments
Population	0 < Population <3,000	Based on 2016 Census
Activity	500 < Activity < 3,000	Activity is the sum of POWSCAR 2016 productions & attractions
2040 Population	0 < Population < 3,000	National Planning Framework forecasts
2040 Work & School attractions	0 < Attractions <4,000	National Planning Framework forecasts
Land Use	Homogenous land uses	This can be estimated by examining permitted development as per e.g. the Dublin City Development Plan (using the MyPlan shapefile)
Size	< $50km^2$	
Intra zonal trips	No more than 5% of POWSCAR Activity levels	This means that no more than 5% of the daily trips produced by a zone are internal to the zone.

4.2 Elements of the Zone System

A Regional Model Zone System comprises the following elements:

- Geographic Zones:
  - These zones have boundaries and associated population, employment, and trip generation data. The main Demand Model performs its calculations at the geographic zone level; and
  - In the context of the Regional Modelling System (RMS), Geographic Zones may be defined as the set of geographic areas that divide the model region into similar areas of land use, that are associated with quantitative information describing the key trip generating properties of the area, e.g. its population and levels of employment, leisure, shopping etc.
- Route Zones;
  - Despite the name, “route zones” do not represent a geographic area. Instead they are connected to road and rail links at the edges of each regional model and are used to represent trips that are entering or leaving the model area;
  - Road, rail and bus trips which start and/or end outside of the model area are allocated to a route zone based on the road or rail link used to enter or leave the model area, regardless of the external area where they start or end their journey. For example, all trips which enter or exit the ERM via the M7 are allocated to the route zone representing the M7, regardless of whether they are travelling to Ennis, Limerick, Tralee or Killarney; and

  - The calculation of demand at route zones is handled by the Long Distance Model (LDM) as described in Section 6.2 and the Regional Modelling System Integration Tool (RMSIT) as described in Section 6.2. The LDM calculates demand between all settlements in Ireland and assigns the trips to major road and PT routes. RMSIT then aggregates trips from geographical zones outside of the model area to route zones based on the route taken.
- Special Zones;
  - The RMS provides a Special Zone module (see Section 6.9) to model surface access demand to and from Airports and Ports. The geographic zones in which such facilities are located are defined as “Special Zones” in the context of the overall zone system.
- Sectors.
  - The sector system aggregates model zones primarily to enable analysis and reporting at the sector rather than zone level. Each regional model is given a standard set of sectors that are used to improve some of the built-in reporting and analysis features throughout the RMS.

The ERM zone system is presented in Section 4.4 with respect to each of the above elements. The NTA Zone System Development presented in Section 4.5 includes further detail on the above aspects of the development of the zone system used in version 3 of the RMS.

Within the ERM, there are 1,953 zones, of which 1,907 are geographic zones, 39 are road route zones and 7 are rail route zones. There are also 3 special zones as part of the geographical zones.

4.3 Data Inputs

Data inputs used in the development of the ERM Zone System relate to travel demand (e.g. data that describe land uses or associated travel activity) and features of the region that inform appropriate boundary delineation and zone shape/size. This data is provided by a wide range of sources, which are discussed below.

Primary data sources are drawn from the 2016 Census, which provides many of the required zonal data inputs, such as detailed information on the population of Ireland and a comprehensive set of boundary systems that can be used as the building blocks for the zone system boundaries.

4.3.1 2016 Census Data

The relevant data used from Census 2016 includes CSAs and associated SAPS.

CSAs are compiled by the National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi) and in consultation with the Central Statistics Office (CSO). They typically contain between 50 and 200 dwellings and are nested within

ED boundaries and are generally comprised either of complete townlands or neighbourhoods.

SAPS are Census 2016 statistics produced for a range of geographical levels from state to CSAs. For zone system development, SAPS data linked to each of the 18,641 CSAs was used.

Figure 4.1 below shows CSAs within SAPMAP[17] for Dublin City, centred on Phoenix Park. This exemplifies an important point to note about Small Areas, which is that their size can vary depending on population density. Since they are defined to include between 50 and 200 households, their size increases in low population density areas, such as parks and areas of high employment.

[17] SAPMAP is a web-based tool provided by CSO to enable access to the Census datasets (http://census.cso.ie/sapmap/).

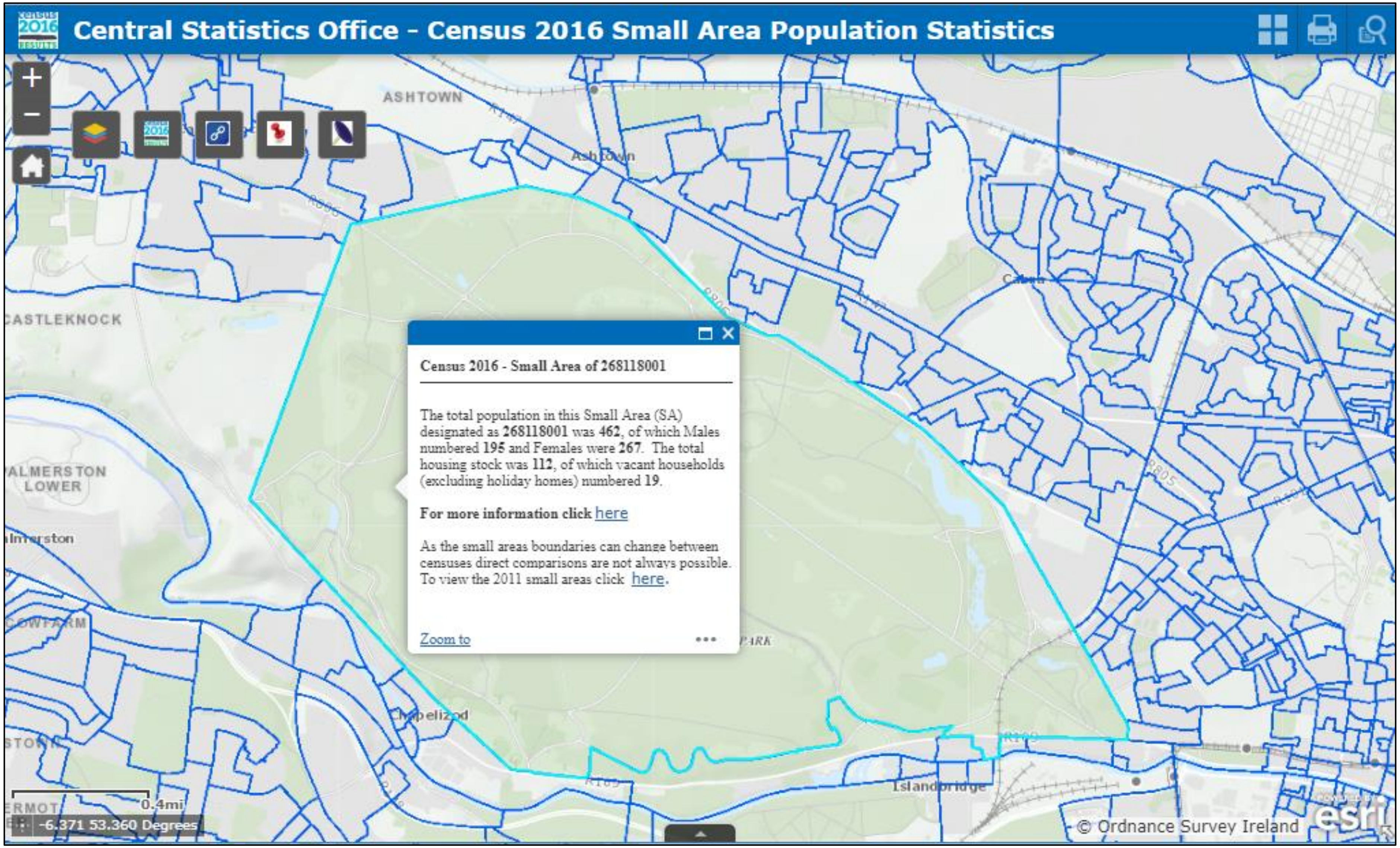

Figure 4.1 CSAs in SAPMAP Viewer

4.3.2 Electoral Divisions

EDs are the smallest legally defined administrative areas in the state. EDs are mostly contiguous but may bear little relation to natural community boundaries. There are 3,440 legally defined EDs in the State. 32 EDs with a low population have been amalgamated with neighbouring EDs for disclosure reasons giving the total of 3409 EDs which appear in the SAPS tables.

EDs are an important input to the zone system development process because, unlike CSAs, they do not change from Census to Census. They are therefore used to ensure consistency between different census data-sets.

Figure 4.2 below shows a similar view as above but with ED boundaries in red overlaid on the CSA boundaries (in blue). It is readily apparent that CSAs always nest neatly within an ED and do not overlap the red boundaries.

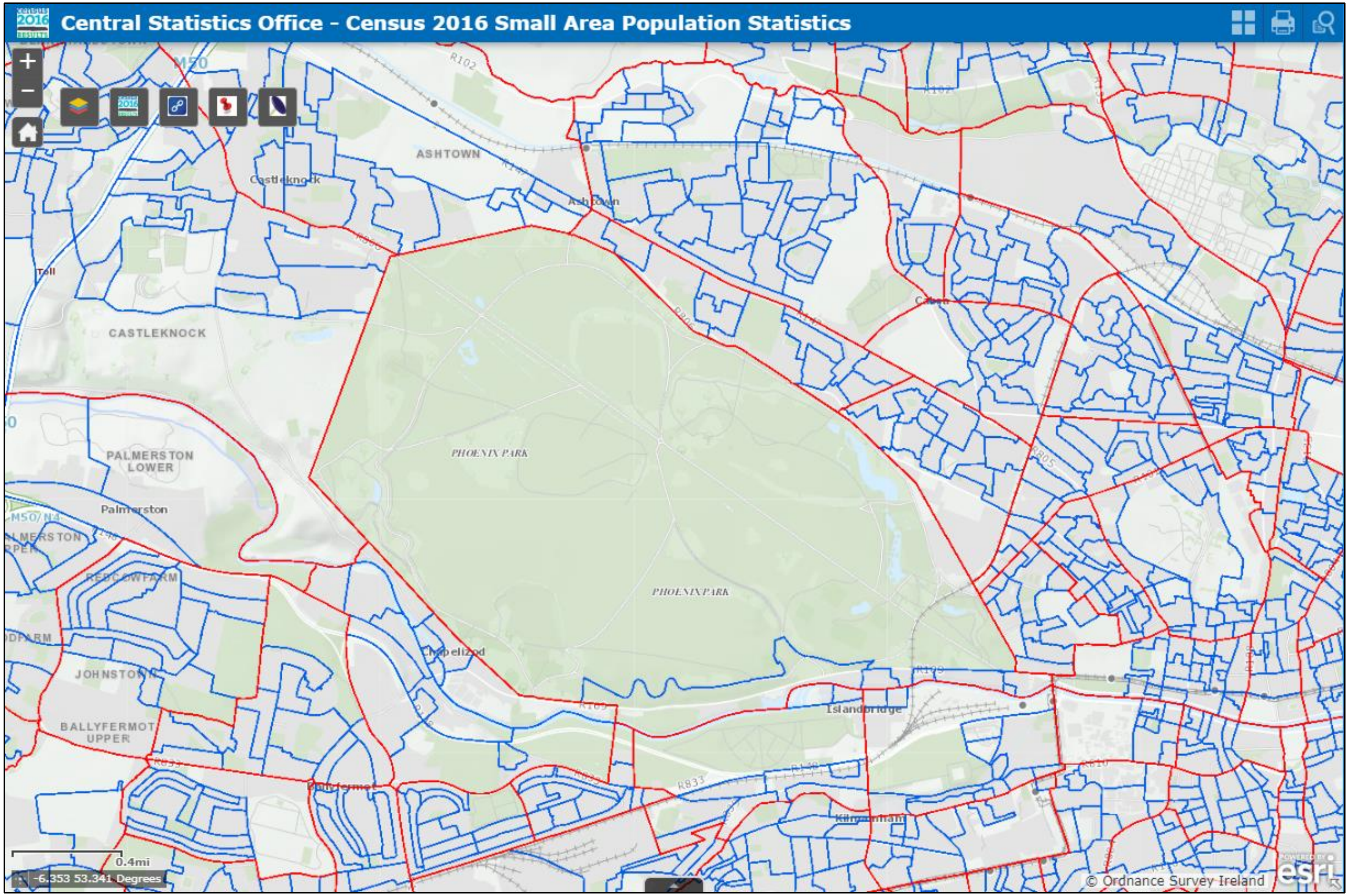

Figure 4.2 Electoral Divisions

4.3.3 POWSCAR

The Place of Work, School or College – Census of Anonymised Records (POWSCAR) covers persons who were enumerated and usually resident in Ireland on Census Night.

These data provide the location of the place of work, school or college, as coded for each person based on the reply to a question on the form, and therefore permit the calculation of trip making activities from home to places of work and school.

The CSO also provided a spatial extraction of the Census at the 1 kilometre grid level to enable more precise mapping of destinations than possible at the CSA level (which are larger for high employment but low population areas).

4.4 Zone System Development

4.4.1 Overview

The 2016 ERM Zone System used previous 2012 RMS as a starting point. The methodology followed the following steps:

- Combining the previous 2012 zone systems of each of the five regional models (e.g. ERM, South East Regional Model, South West Regional Model, Mid West Regional Model, West Regional Model) into a single National Zone System;
- Updating National Zone boundaries to be consistent with Census 2016 CSA boundaries;
- Re-evaluating model boundaries with respect to requirements for “model convexity” and revised commuter catchment areas;
- Evaluating zonal properties and adapting zones to maximise compliance with the target delineation criteria for each area; and
- Finalising the zone system for each Regional Model by allocating every zone in the National Zone System to one or more model areas.

Each of these stages is discussed in detail in the main *Zone Development Note* in Chapter 4 and explained in more detail below.

4.4.2 Zone Delineation Criteria

Zone delineation criteria provide a systematic means of developing zone systems by using various indicators which any zone can be classed as passing or failing. During its development, the zone system is adjusted so that the number of zones passing the various criteria is maximised. Applying this approach consistently for all zones in the country helps to ensure zone system consistency across all the model areas. The criteria are as follows:

- The number of people per Regional Model Zone should be between 0 and 3,000 for the base and future years[18];

[18] Population forecasts were obtained from the NTA consistent with the National Planning Framework 2040.

- The number of work and school trip productions should be between 500 and 3,000 in the base (based on observed data);
- The size of each zone is less than 50 square kilometres in area;
- There is a logical number of intrazonal trips in each zone, based on the mix and density of the land use;
- There are no irregular-shaped zones;
- The zone system structure is compatible with the base and future year road, public transport, and active modes networks;
- The zone system structure is compatible with Census, physical, political, and county boundaries such as Electoral Divisions and Census Small Areas;
- The zones are based on homogeneous land uses where feasible; and
- The zones consider future development plans.

Road, PT, and active modes also require that the centroid connectors (the links between zone centroids and the transport network) represent realistic access points for trips assigned to the respective networks. However, this is a network development rather than a zone system development task within the RMS.

4.4.3 National Zone System

Figure 4.3 shows all five of the 2012 RMS zoning systems combined to form the National Zone System. The zones are coloured according to the model area they fall within the 2012 RMS. The respective zone systems and the number of zones in each are as follows:

- East Regional Model (ERM – 1849 zones);
- Mid West Regional Model (MWRM – 454 zones);
- South East Regional Model (SERM – 571 zones);
- South West Regional Model (SWRM – 792 zones); and
- West Regional Model (WRM – 749 zones).

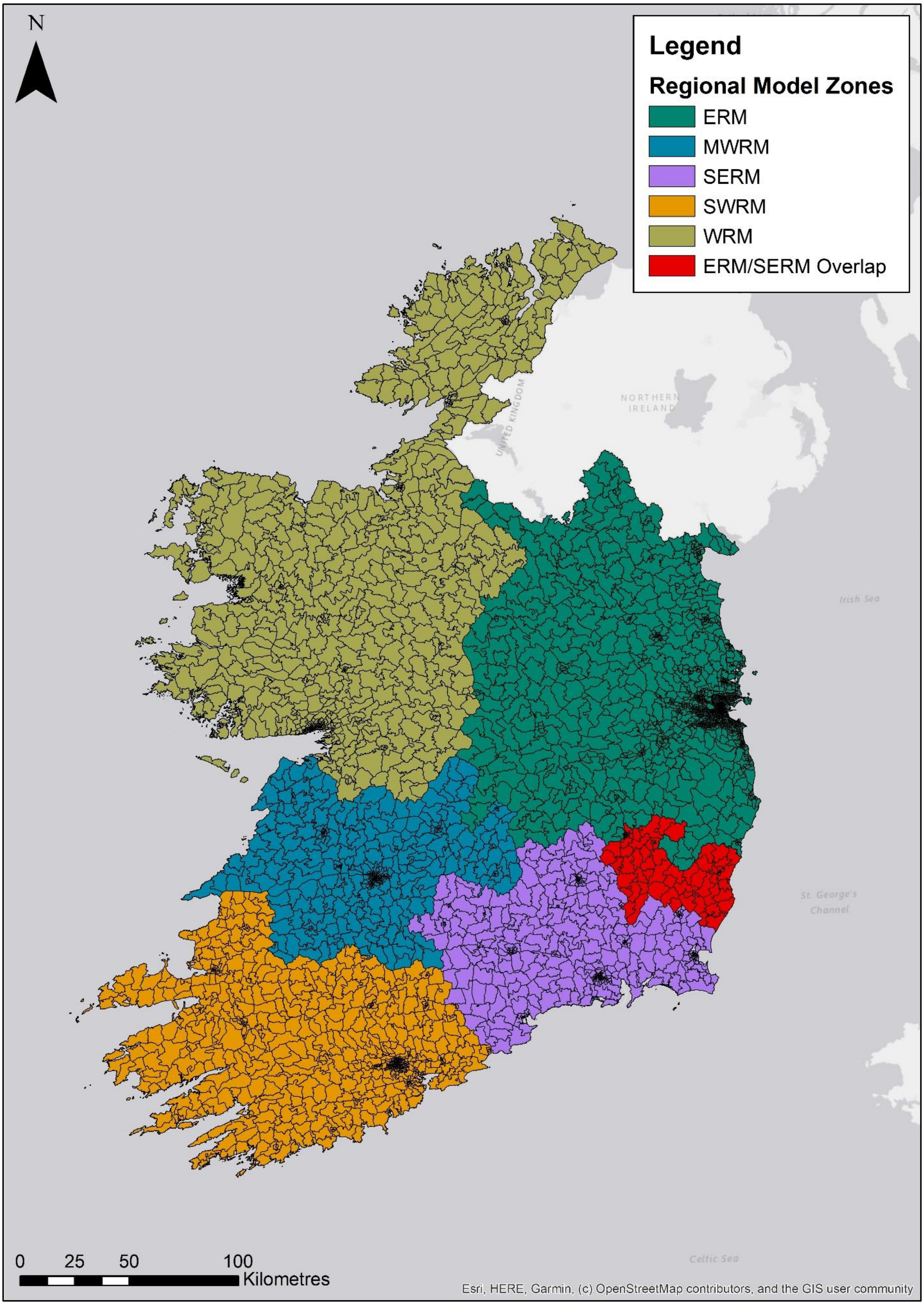

Figure 4.3 National Zone System (2012 RMS Zone Systems)

4.4.4 Model Area Redefinition

This section discusses the redefinition of the model area (and therefore by the ERM zone system) between the previous 2012 RMS (referred to as SWRM v2), and the updated 2016 RMS (ERM v3). The difference between the ERM zone system between the two RMS versions is shown in Figure 4.4.

Redefinition of the model area was undertaken in response to the following requirements:

- Minimising significant concave areas at the boundary by adding or removing zones (to minimise instances where the road and/or networks intersect irregularly with the model boundary); and
- Conforming the model area more closely to the observed commuter catchment of the Greater Dublin Area (GDA) based on POWSCAR original destination analysis to ensure all areas with a significant proportion of trips going to the GDA are included in the model.

Figure 4.4 shows the boundary position in both 2012 and 2016 ERM zone system versions. The updated zone system covers a slightly reduced area compared to ERM v2, particularly at its western edge where some zones have been removed. This reduction was justified by the catchment analysis that is shown in Figure 4.5, with EDs colour-graded by the percentage of total work trips that travel to Dublin city centre.

It is evident from the analysis shown that in the western part of ERM v2 there are a significant number of areas with less than 10% GDA bound trips (the selected threshold for including a zone in a model is that 10% or more of its trips go to the applicable commuter destinations of the model). The outcome of the catchment analysis, therefore, was to reduce the model area so that fewer of the zones outside the GDA commuter catchment area of influence are included, thus moving the western edge of the model moved inward towards Dublin in ERM v3.

A further significant change worth noting from ERM v2, arising from reducing the model's western extent, is the status of Athlone within the overall RMS. In RMS v2, Athlone straddled the ERM and WRM model boundaries, but was not satisfactorily represented in either model. In the general "v3" update to the overall RMS, this has been rectified by including Athlone in the WRM but not in the ERM, on the basis that significant regional towns should be represented well in only one regional model to avoid any doubt around which regional model to use.

Other significant changes include realignment of the southern ERM boundary to remove the concave areas present in the previous zone system.

Having redefined the model boundary, the road and PT networks were updated to include or exclude the relevant network detail to fully align with the new model area.

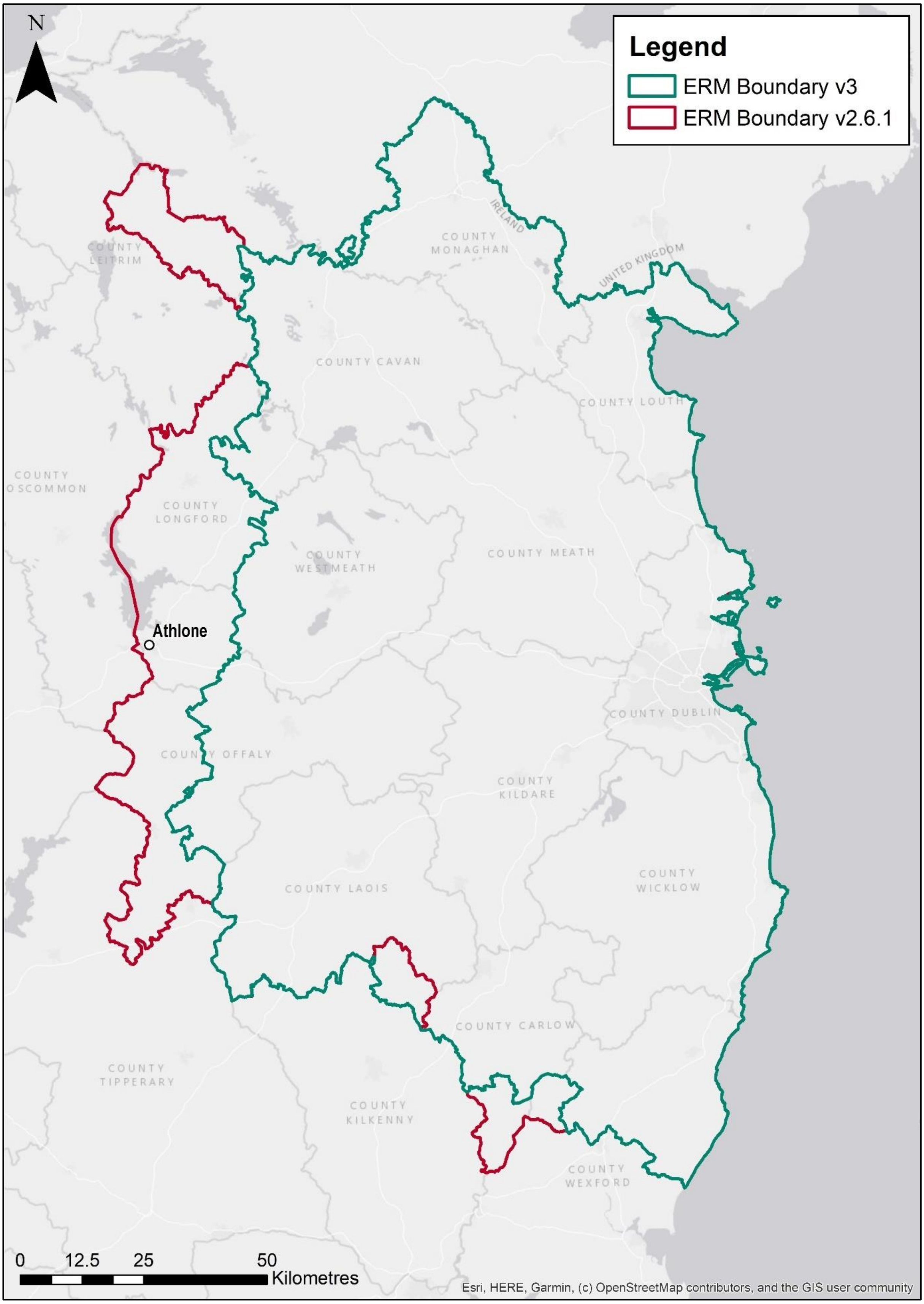

Figure 4.4 Updated ERM Model Boundary

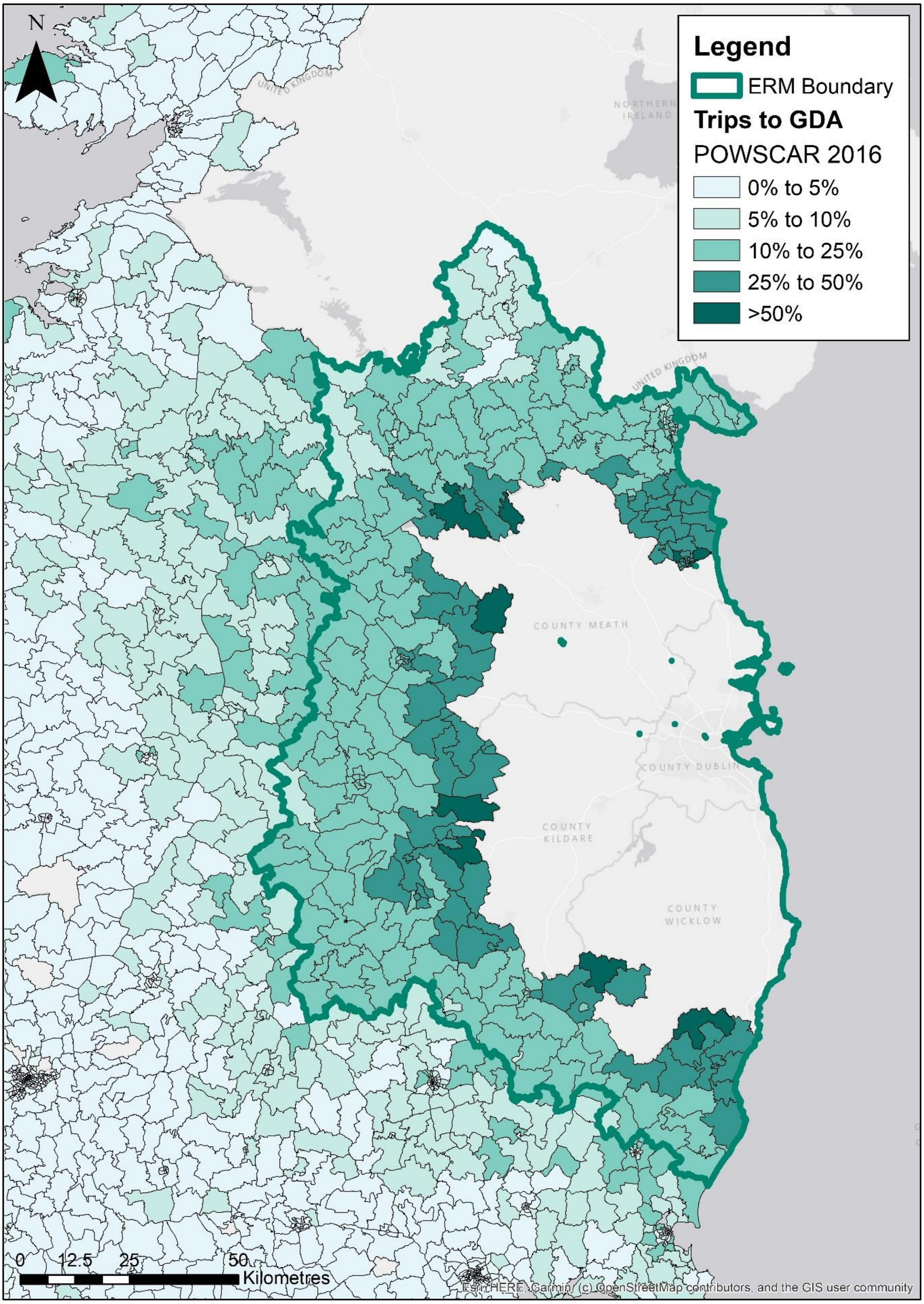

Figure 4.5 Percentage of POWSCAR Trips 2016 to Greater Dublin Area

4.4.5 Zone Centroids

Zonal transport demand is loaded and unloaded to the network at single points, named centroids. A centroid represents a geographical point within a zone, positioned in relation to the population and jobs within the zone. Centroids are linked to the network by centroid connectors, which are part of the networks (road, public transport and active modes)[19].

The centroid position influences the connector length(s), and therefore has an impact on associated travel costs.

The centroid positioning methodology is as follows:

- Intersect the zone polygons with the set of Geodirectory[20] address points (residential and commercial); then
- Calculate zone centroid coordinates as the weighted average of the Geodirectory addresses associated with the zone:
  - $\text{Xcentroid} = \frac{(X_1\text{GeoDir1} + X_2\text{GeoDir2} + \cdots)}{(\text{no.of GeoDir addresses in the zone})}$; and
  - $\text{Ycentroid} = \frac{(Y_1\text{GeoDir1} + Y_2\text{GeoDir2} + \cdots)}{(\text{no.of GeoDir addresses in the zone})}$.

The location of the centroid in a zone is thus located at the mean centre of GeoDirectory addresses in the zone.

Figure 4.6 exemplifies the outcome for the south Fingal area. The red crosses denote the location of the zone centroids and the grey fill is comprised of address points. The relationship between address points and centroid positions can be clearly seen, for example, for zones that are more heavily developed (i.e. have more address points) in one part than another, the centroid location is closer to the developed part of the zone. This is due to the use of the mean centre of addresses approach.

It should be noted that address points are not weighted by their size; therefore, in a zone where there is a dominant location relative to other address points within the zone, the centroid does not get moved to represent where most loading would occur.

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[19] Zone centroid connectors provide the link between each zone's centroid and the transport network. These connectors differ for each mode to reflect the different routes used by trips to access each mode's transport network. For further information on centroid connectors, please refer to Section 7.8 for the Road model, Section 8.11 for the PT model and Section 9.7 for the Active Modes model.

[20] Geodirectory was jointly established by An Post and Ordnance Survey Ireland and manages a definitive reference dictionary for all 1.9 million buildings that receive post in the Republic of Ireland

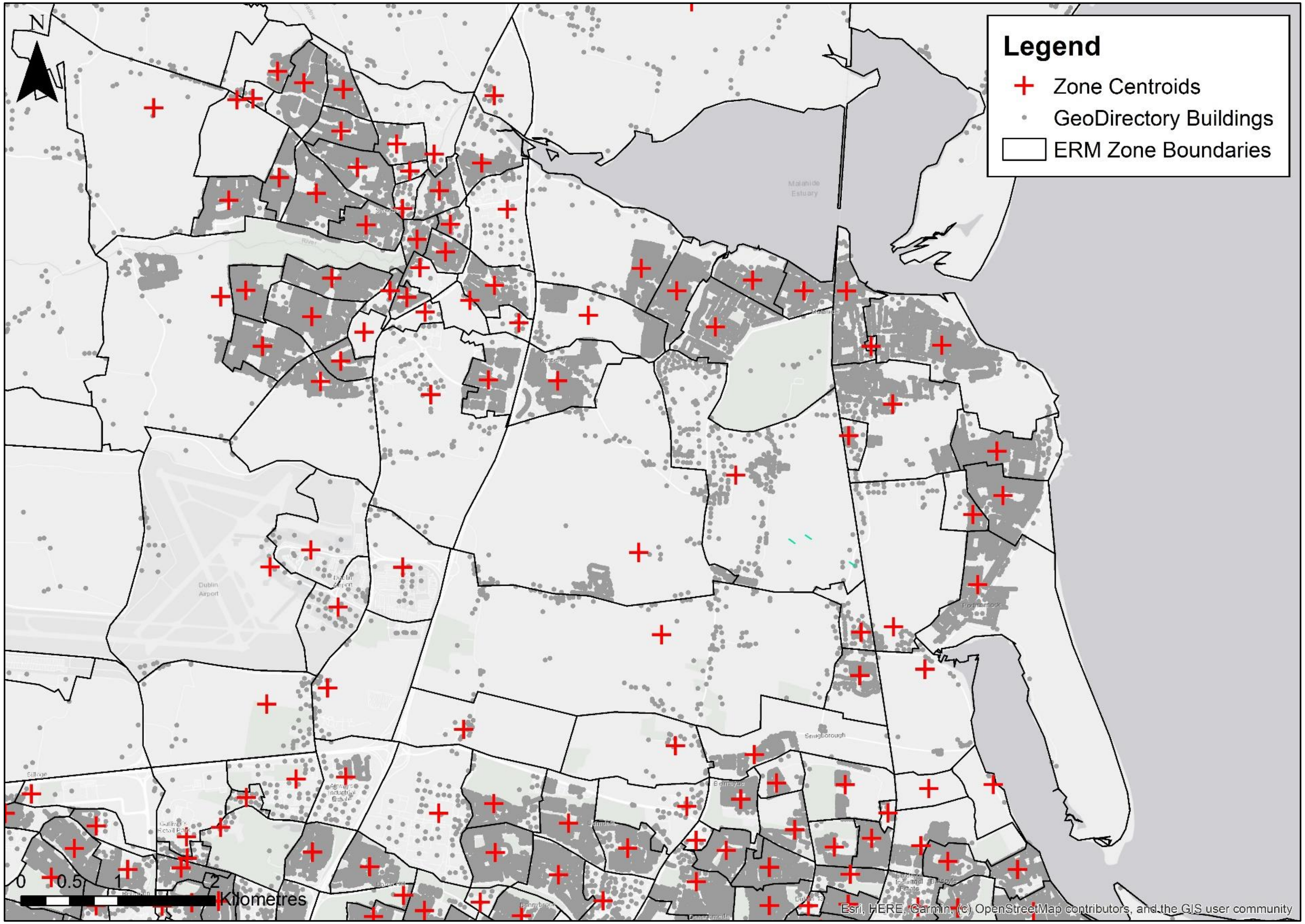


Figure 4.6 Zone Centroid Positioning to GeoDirectory Address Points

4.5 Final East Regional Model Zone System

4.5.1 Overview

This section presents the ERM v3 zone system through a series of maps and figures. It consists of 1,953 zones including:

- 1,907 Geographic Zones (Figure 4.7 and Figure 4.8);
  - Of these, 3 are defined as Special Zones (see Figure 4.12).
- 39 road route zones (see Figure 4.9);
- 7 rail route zones (see Figure 4.10); and

Figure 4.7 ERM Zones (City Centre)

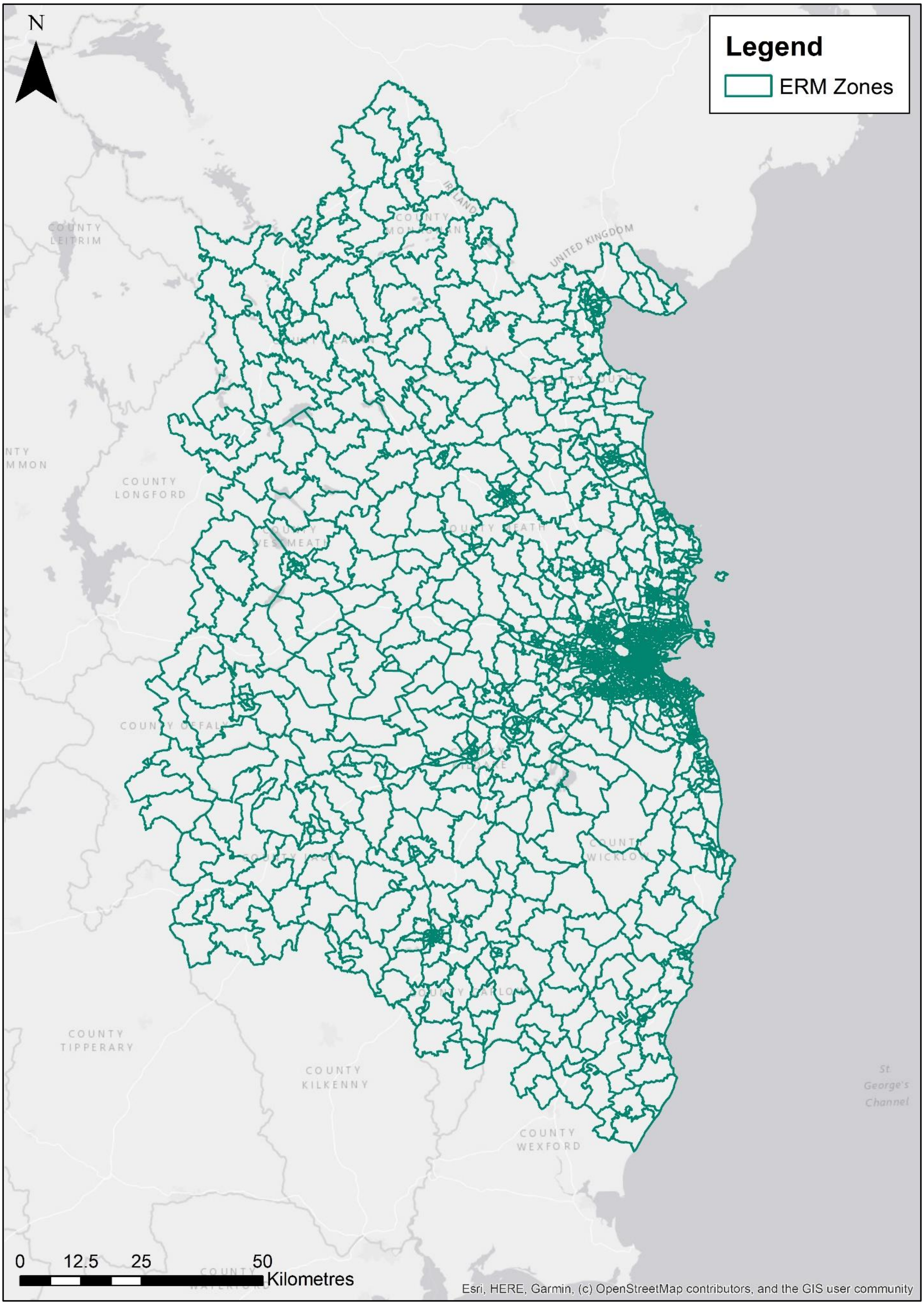


Figure 4.8 ERM Zone System v3 (Full Model Area)

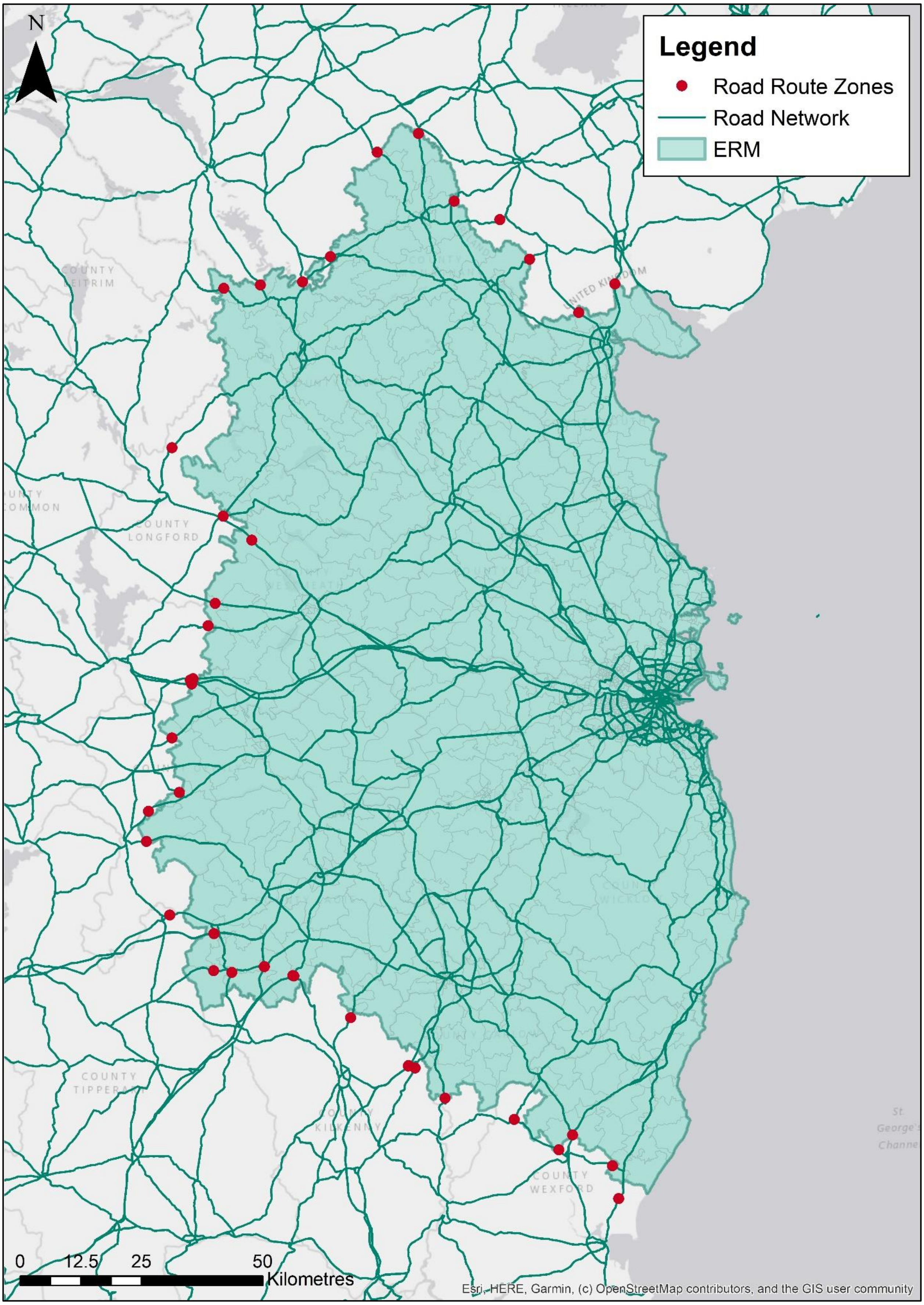


Figure 4.9 ERM Road Route Zones

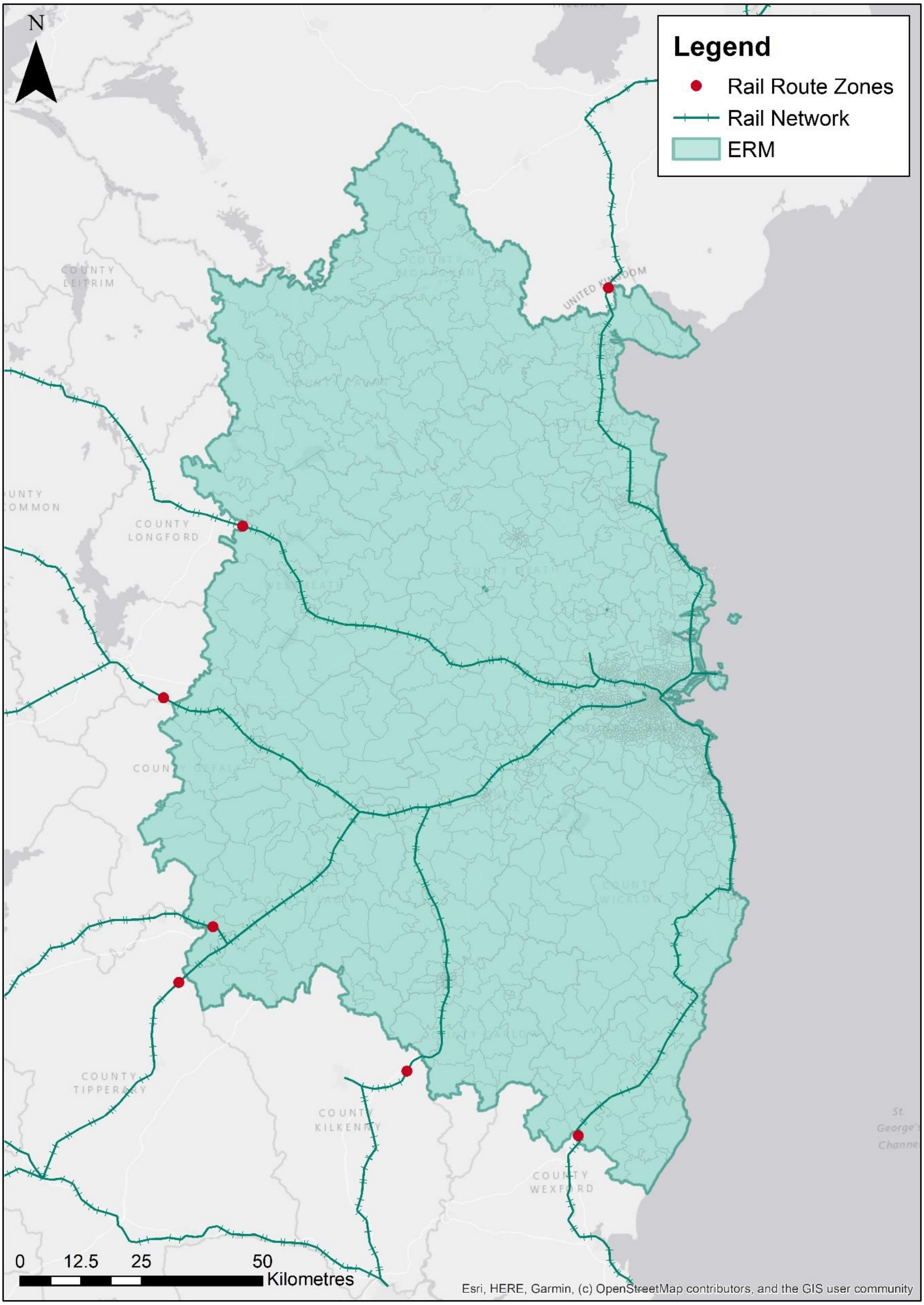


Figure 4.10 ERM Rail Route Zones

4.5.2 ERM Zone Numbering

The RMS uses both hierarchical and sequential zone numbering systems. The hierarchical system takes into consideration all 5 of the regional models (to ensure that each model has its own unique zone with no overlap), whilst the sequential zone system starts from 1 for all regional models. Hierarchical numbers are unique within the national zone system. Any new zones that are created would be added to national zone system with a unique hierarchical number.

The ERM's sequential zone numbering system is defined from 1 upwards as follows:

- 1 to 1,907: Geographic zones within the modelled area;
- 1,908 to 1,946: Road route zones; and
- 1,947 to 1,953: Rail route zones.

The hierarchical system is defined as follows:

- 2,000 to 39,258 and 58,521 to 59,852 are zones within the modelled area. The second range has been inherited from the ERM's previous hierarchical system, which assigned a different number range to zones that overlapped with the SERM in the previous RMS version;
- 90,001 to 90,039: Road route zones; and
- 95,001 to 95,007: Rail route zones.

Figure 4.11 shows the ERM zone system categorised by hierarchical number range. No changes have been made to the hierarchical system since ERM v2. This means that the numbering which currently applies in ERM v3 is still based on ERM v2, which was based on the ERM v2 sectoring system. While any sectoring system can be readily made compatible with the updated zoning system, the ERM v2 sectoring system is the primary one. The primary ERM v3 sectoring system is described in Section 4.5.4.

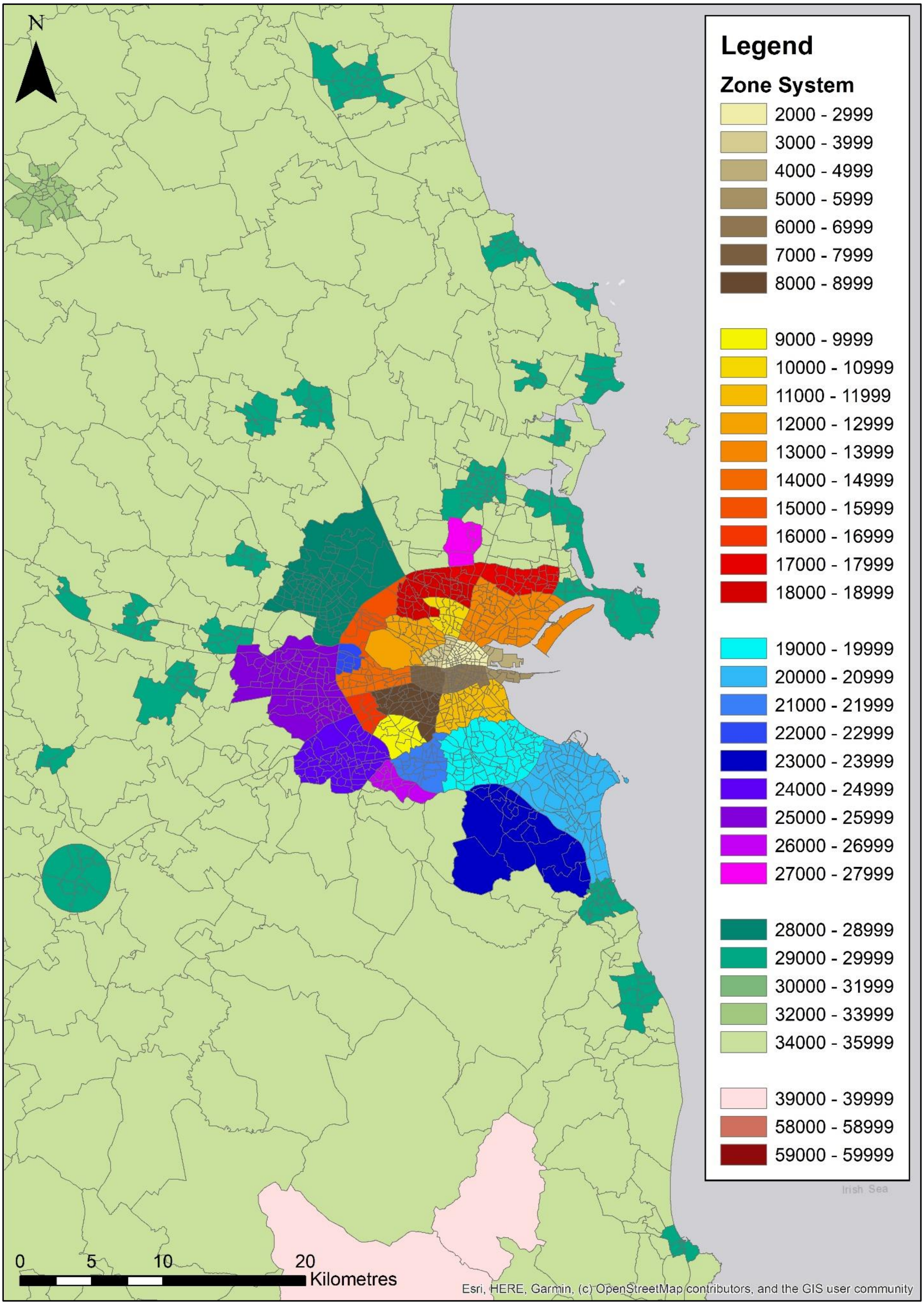


Figure 4.11 ERM Hierarchical Numbering System

4.5.3 ERM Special Zones

The ERM zone system includes a number of "Special Zones" that include port/airport demand that is not produced by the standard Demand Model. Any trips (individuals or HGVs) that go through an airport or a port with an oversea origin or destination are included in these zones. More information can be found in Section 6.9.

There are 3 Special Zones in the ERM:

- Dublin Airport: 27,000 (hierarchical) – 908 (sequential);
- Dublin Port: 4,002 (hierarchical) – 82 (sequential); and
- Dun Laoghaire Port: 20,013 (hierarchical) – 639 (sequential).

The locations of ERM's special zones are shown in Figure 4.12.

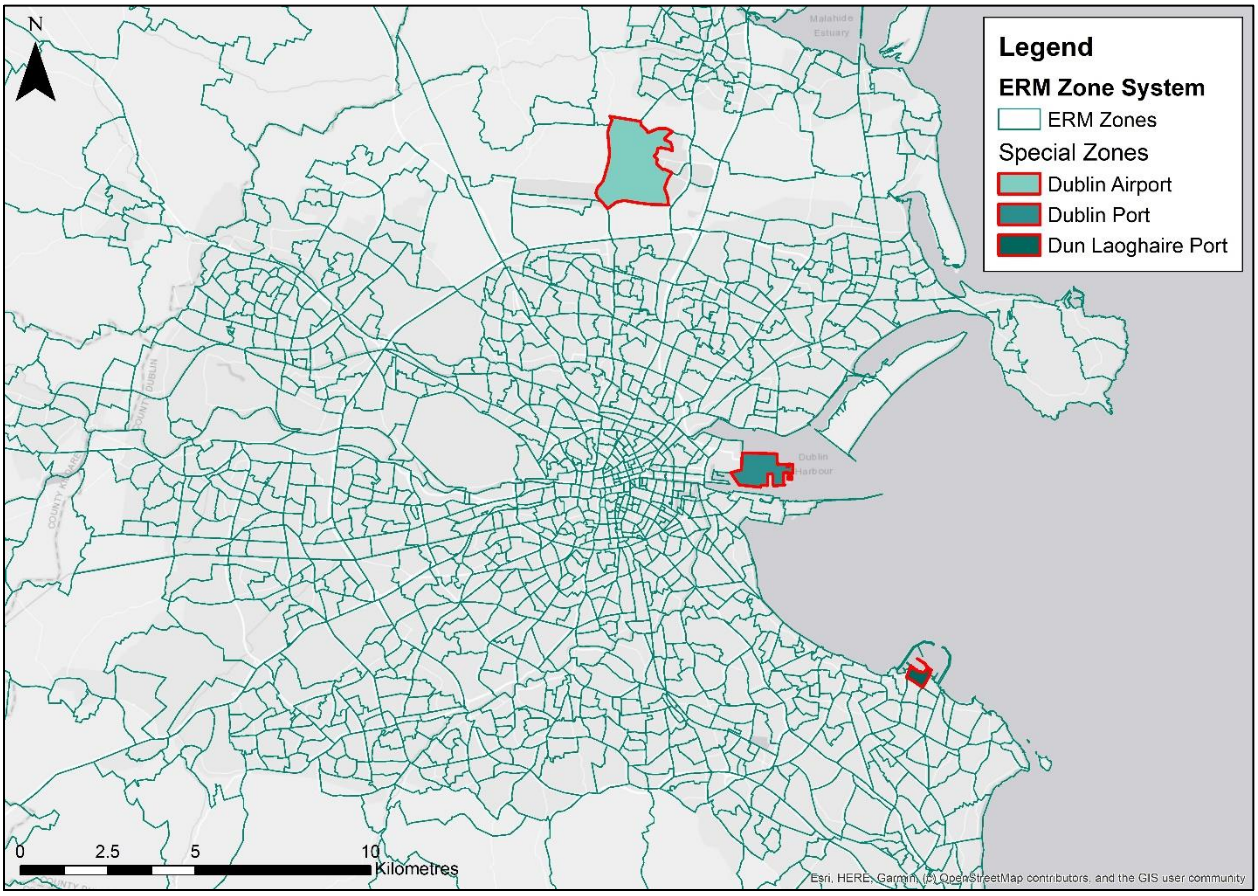


Figure 4.12 Special Zones in the ERM

4.5.4 ERM Sector System

The ERM consists of 39 sectors, comprised of 38 geographic sectors (as shown in Figure 4.13) and one non-geographic (virtual) sector. Depending on context, the non-geographic sector is either defined as the sum of all demand passing through road and rail route zones (e.g. for assignment modelling) or the sum of all demand outside the ERM model area (e.g. in the NDFM).

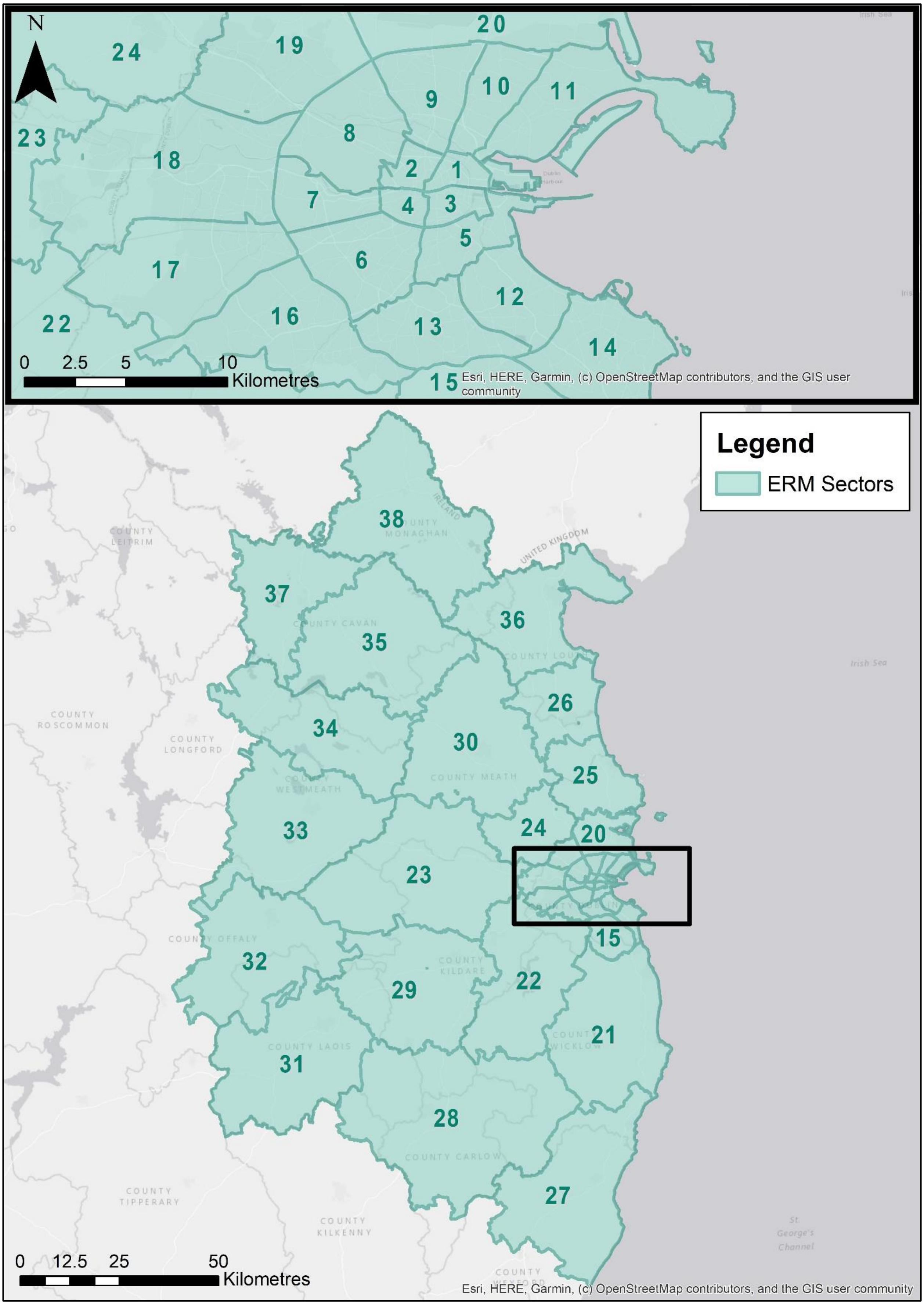


Figure 4.13 ERM Sector System

4.5.5 Zone System Compliance

Table 4.1 lists the key quantitative criteria applied to the set of National Zones contained within the ERM model area defined above. Table 4.2indicates the level of compliance within the ERM, based on the number of zones which meet each criterion. Previous development versions of the regional zone system are shown in the table to illustrate how compliance has increased or decreased with successive iterations of the zone system.

In the table, NZS refers to National Zone System. The columns represent the compliance of successive versions of the NZS with the target quantitative criteria established in Table 4.1. The final column represents the final, complete, NZS; this column is given the dual designation NZS V1.3/ERM v3, since the final ERM zone system is a subset of the final national system.

The GIS plots in Figure 4.14 to Figure 4.19 show the geographic distribution of zones passing or failing some of the criteria set out above.

Table 4.2 ERM Zone System Compliance Rates

Zone System:	NZS v0.5		NZS v0.51		NZS v0.52		NZS v0.53		NZS v0.54		NZS V0.55		NZS V1.3/ ERM v3	
# Zones:	1849		1836		1859		1891		1892		1892		1907	
Criterion	Pass	% Pass	Pass	% Pass	Pass	% Pass	Pass	% Pass	Pass	% Pass	Pass	% Pass	Pass	% Pass
Population 2016 < 3000	1735	93.8%	1726	94.0%	1750	94.1%	1785	94.4%	1786	94.4%	1786	94.4%	1819	95.4%
Activity 500 - 3000	1480	80.0%	1496	81.5%	1518	81.7%	1537	81.3%	1539	81.3%	1539	81.3%	1565	82.1%
Population 2040 < 4000	1647	89.1%	1635	89.1%	1665	89.6%	1695	89.6%	1696	89.6%	1696	89.6%	1732	90.8%
Work Attr 2040 < 4000	1795	97.1%	1792	97.6%	1816	97.7%	1849	97.8%	1850	97.8%	1850	97.8%	1866	97.9%
School Attr 2040 < 4000	1834	99.2%	1828	99.6%	1851	99.6%	1883	99.6%	1884	99.6%	1884	99.6%	1900	99.6%
Size < 50km^2	1657	89.6%	1653	90.0%	1676	90.2%	1708	90.3%	1709	90.3%	1709	90.3%	1769	92.8%

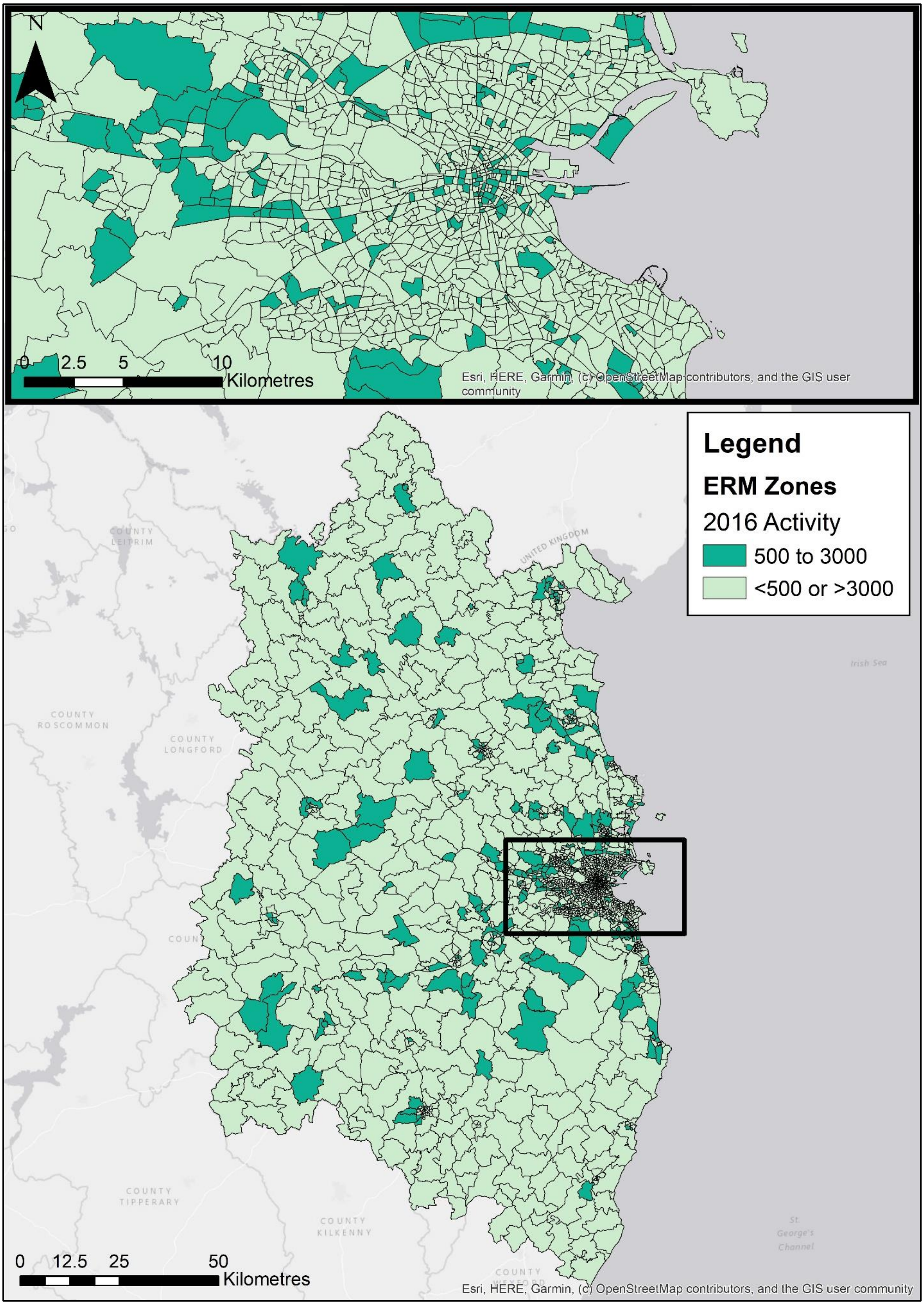


Figure 4.14 ERM Activity Criterion

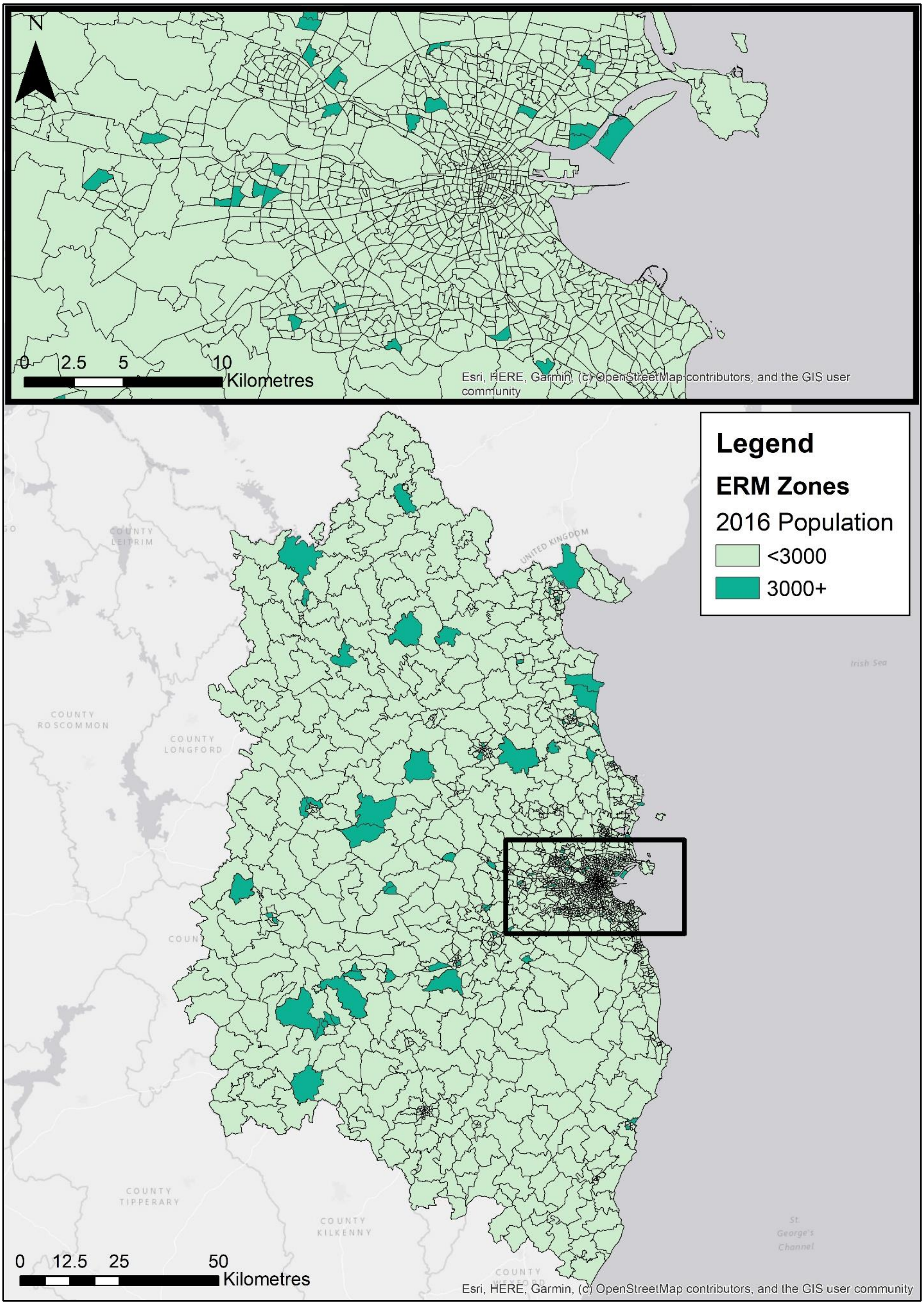


Figure 4.15 ERM Population Criterion

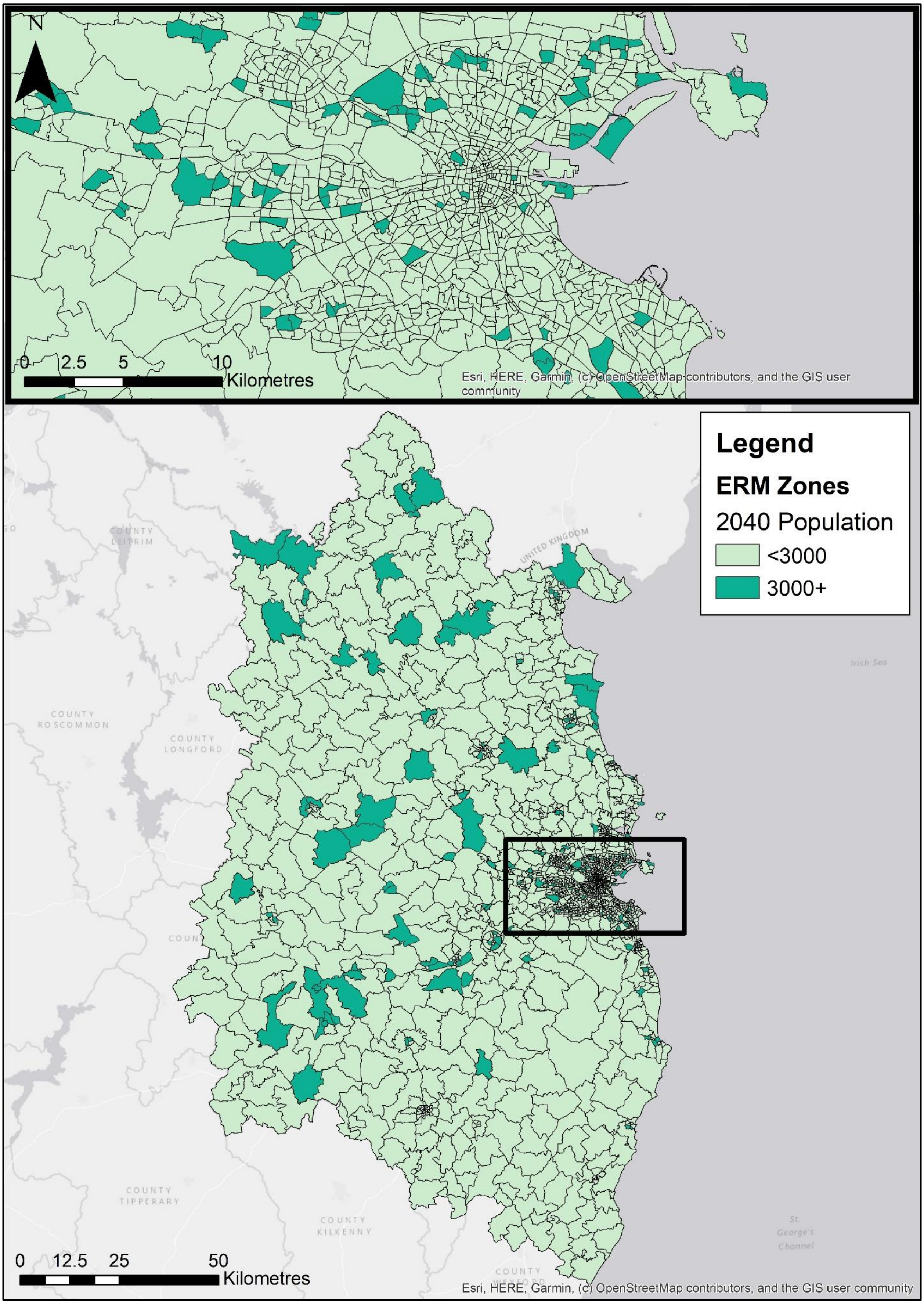


Figure 4.16 ERM Population 2040 Criterion

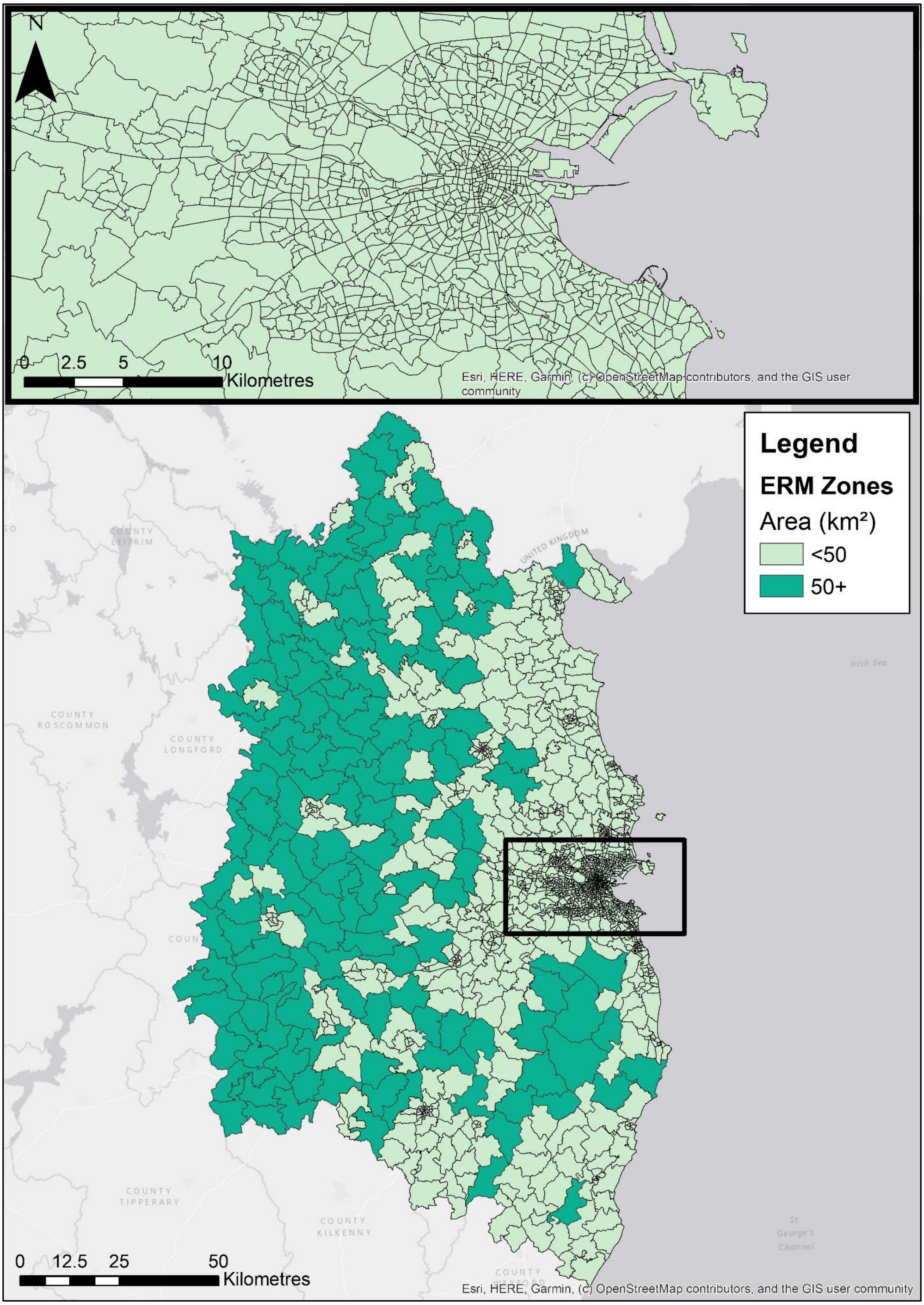


Figure 4.17 ERM Zones Size Criterion

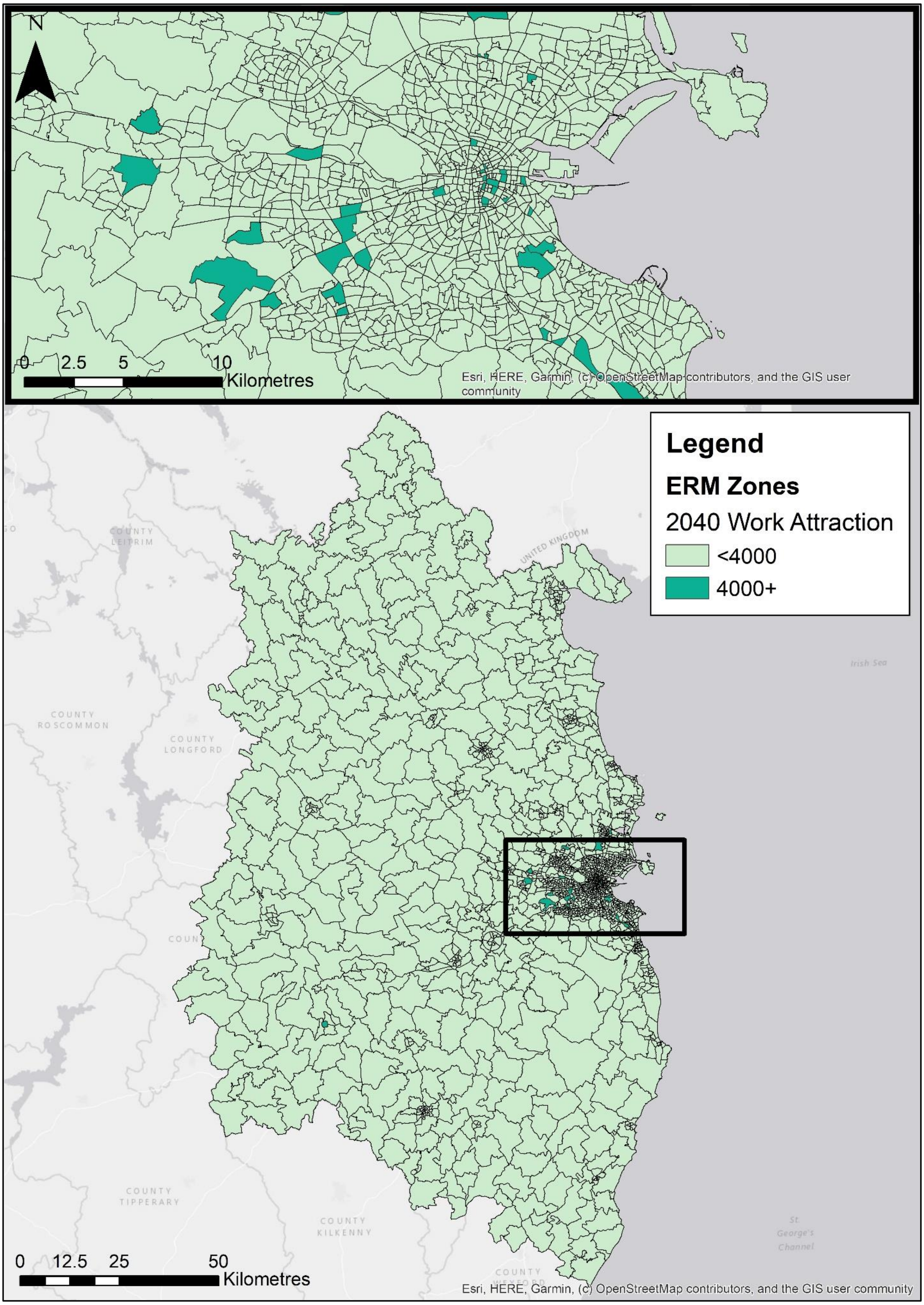


Figure 4.18 ERM Work Attraction Criterion

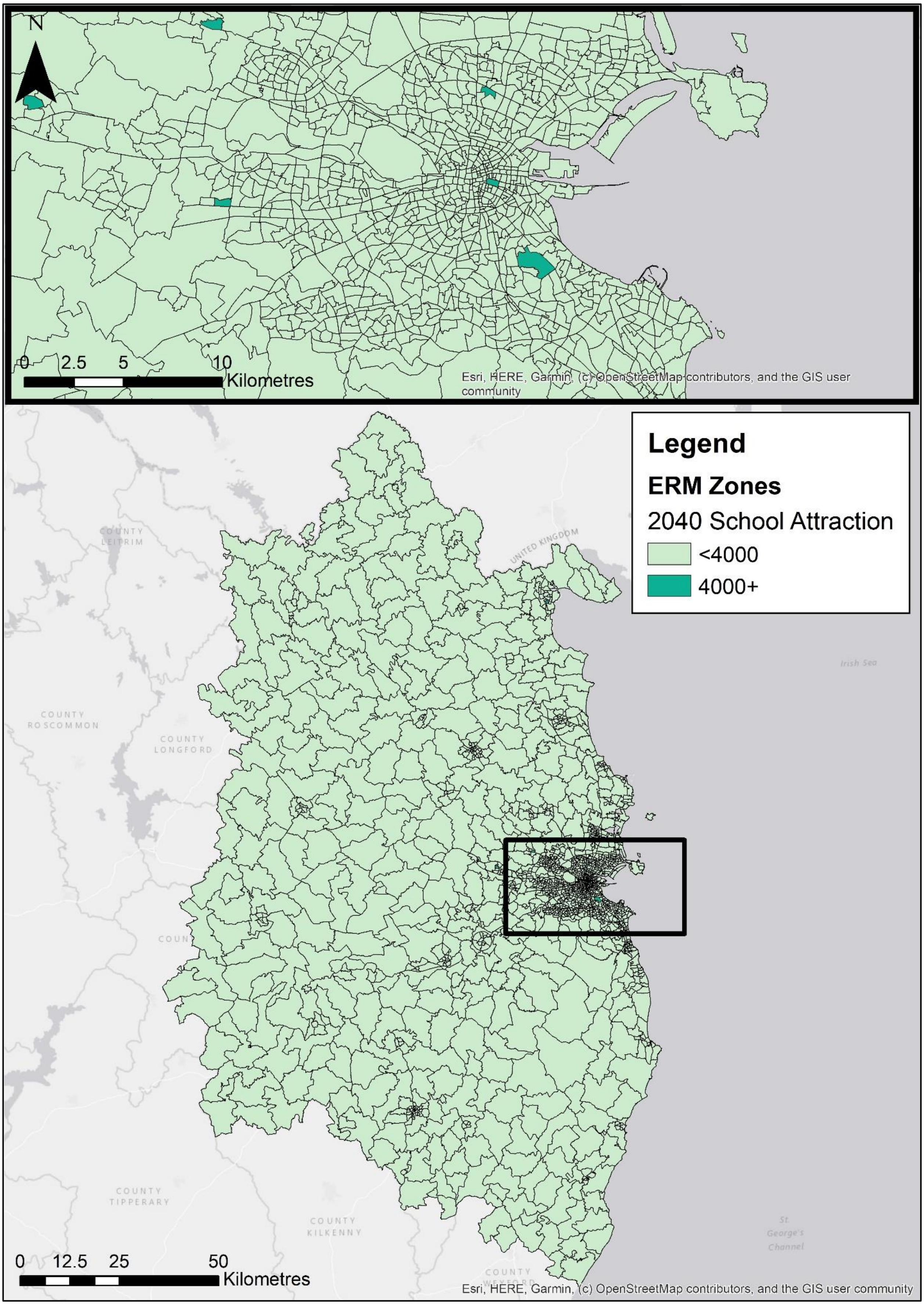


Figure 4.19 ERM School Attraction 2040 Criterion

4.6 Linkages to Regional Model

The zone system is linked to the regional model via the below components:

- Trip End Integration;
  - This process converts National Trip End Model (NTEM) trip ends from the CSA level to the zoning system of the regional model.
- Route Zones Long Distance to Regional Model Correspondence file:
  - This file is an input to RMSIT (see Section 6.2); and
  - It associates the route zone links in the ERM to corresponding links in the LDM. The RMSIT is responsible for converting LDM demand (see Section 6.2) to the relevant regional model zone system. It defines the association between both road and rail long-distance links at the corresponding location on the regional model boundary.

5 Model Dimensions

5.1 Introduction

This chapter provides a summary of the dimensions considered within the model including units, definitions and details of the level of segmentation used in the development of the Regional Modelling System (RMS).

5.2 Standard Units

Different components of the Demand Model work at different levels of detail, and hence different units are used. However, for the majority of the Demand Model, trips are in units of person trips travelling within a given time period.

Some of the key exceptions to this rule are as follows:

- Travel demand used in all road assignment models are in units of Passenger Car Units (PCU). For personal travel, PCU are equivalent to vehicles within the assignment model i.e. one car is one PCU;
- All assignments relate to an average peak hour rather than the period (for instance cost and demand matrices, network flows etc.);
- Tours relate to combinations of periods (further detail on that is provided in Section 5.6); and
- During the Trip End Integration stages of the regional model, productions and attractions are in units of 24-hour trip ends (average weekday person travel trips), prior to being disaggregated to their relevant tours and attractions within the mode choice and destination choice components.

Generally, costs units which refer to tour costs (i.e. in form of generalised cost matrices) are the average cost across both legs of each tour. As an example, if it costs 30 generalised minutes to travel-to-work and 40 generalised minutes to travel home, the average cost for the tour would be 35 generalised minutes.

For non-home-based trips or single legs where only a single cost is considered in the first place this obviously means that there is no need to average. For complete clarity, if the cost to travel in a non-home-based trip is 30 minutes, the model perceives it as 30 minutes.

5.3 Demand Segmentation

Different components of the model require the sub-division of travel demand into various classifications; however, the most prevalent sub-divisions are by demand segment and user class.

Demand segments are used to categorise trips into meaningful segments where there is a notable difference in travel choice primarily relating to mode choice or destination choice. User classes represent combinations of vehicle type, purpose and person type and are more important for route choice in assignment models where a clear difference exists in how they will be modelled such as value of time or free fares. User classes for Road, PT and active modes models are defined in Section 7.3, 8.6, and 9.4 respectively.

An extensive scoping exercise was undertaken prior to model development which considered the balance between:

- An increased number of demand segments which could lead to over-complexity, low samples of data, and increased runtimes; against
- A reduced number of demand segments which might not efficiently capture the full complexity of different travel patterns and travel behaviour, and therefore might fail to respond adequately during forecasting.

The key principles of this scoping exercise were to ensure that:

- Chosen segments should reflect significant variations of value of time, availability of travel options or sensitivity of travel choices;
- Each segment should represent a significant proportion of overall demand;
- The model should consider different levels of segmentation at different stages of the modelling process, with only the relevant segmentation retained at each step; and
- The model should include segmentation of demand by journey purpose, Home-Based (HB) vs Non-Home-Based (NHB), access to free parking and car availability segmentation.

This scoping led to implementing a refined level of disaggregation in the main mode and destination choice model. This disaggregation includes 33 segments of personal travel classified by overall journey purpose / user class, car availability, and in some cases an optional third level of segmentation such as:

- Type of “other” trip;
- Job class (blue collar or white collar);
- Education level; and
- Employed / unemployed.

At a more aggregated level, the model also includes user classes that equate to the level of detail used in the assignment models. This can be further expanded to consider true tour and one-way purposes (user classes not being used for one-way employer’s business and one-way other trips).

It should be noted that, with the exception of trips to/from ports and airports, tourists are not explicitly modelled by the RMS.

A description of the demand segmentations used in the ERM is provided in Table 5.1.

Table 5.1 Demand Segmentation Description

DS	Purpose (1-29 are home-based)	Car Availability	Third Level of Segmentation	Code	User Class
1	Commute	Available	Blue collar	COM_BC_CAV	COM
2	Commute	Available	White collar	COM_WC_CAV	COM
3	Commute	Not available	Blue collar	COM_BC_NCA	COM
4	Commute	Not available	White collar	COM_WC_NCA	COM
5	Education	Available	Primary	EDU_P_CAV	EDU
6	Education	Available	Secondary	EDU_S_CAV	EDU
7	Education	Available	Tertiary	EDU_T_CAV	EDU
8	Education	Not available	Primary	EDU_P_NCA	EDU
9	Education	Not available	Secondary	EDU_S_NCA	EDU
10	Education	Not available	Tertiary	EDU_T_NCA	EDU
11	Escort to education	Available	Primary	ESC_P_CAV	OTH
12	Escort to education	Available	Secondary	ESC_S_CAV	OTH
13	Escort to education	Available	Tertiary	ESC_T_CAV	OTH
14	Escort to education	Not available	Primary	ESC_P_NCA	OTH
15	Escort to education	Not available	Secondary	ESC_S_NCA	OTH
16	Escort to education	Not available	Tertiary	ESC_T_NCA	OTH
17	Other	Available	Employed	OTH_CAV	OTH
18	Other	Available	Non-working	OTH_CAV	OTH
19	Other	Not available	Employed	OTH_NCA	OTH
20	Other	Not available	Non-working	OTH_NCA	OTH
21	Shopping – food	Available	Employed	FSH_CAV	OTH
22	Shopping – food	Available	Non-working	FSH_CAV	OTH
23	Shopping – food	Not available	All	FSH_NCA	OTH
24	Visit friends / relatives	Available	Employed	VIS_CAV	OTH
25	Visit friends / relatives	Available	Non-working	VIS_CAV	OTH
26	Visit friends / relatives	Not available	All	VIS_NCA	OTH
27	Emp Business	All	All	EMP_All	EMP
28	All	Available	Retired	RET_CAV	RET
29	All	Not Available	Retired	RET_NCA	RET
30	One-way business	Available	All	NHBEB_CAV	NHBEB
31	One-way business	Not available	All	NHBEB_NCA	NHBEB
32	One-way other	Available	All	NHBOT_CAV	NHBOT
33	One-way other	Not available	All	NHBOT_NCA	NHBOT

The Home-based demand segments are shaded in olive green (segments 1-29). It should be noted in Table 5.1 that there are seven user classes identified in these demand segments. These are used to convert to meaningful aggregations during assignments, where in general the different user classes will have different costs passing through the model.

The two user classes Non-Home-Based Employers Business (NHBEB) and Non-Home-Based Other (NHBOT), are not assigned separately but are, in general, assigned as part of the EMP and OTH user classes. The reason for splitting these out in the Demand Model is that they relate to single trips rather than tours, and therefore only use a cost relating to trips rather than the average for a tour.

For further details regarding demand segmentation then please refer to the link to *Demand Segmentation Report*.

5.4 Mode Segmentation

There are five modes used within the ERM as detailed in Table 5.2 below. For more information about segmentation by mode, please refer to the Chapters 7, 8 and 9, and to the link to *Demand Segmentation Report.*

Table 5.2 Regional Model Modes

Mode	Standard Abbreviation	Notes
Road	Car	From the main Demand Model these include all personal trips (which include taxis) but the road assignment also includes goods trips (more information can be found in Chapter 7).
Public Transport	PT	Public transport trips include trips made on bus, rail, Luas, or new PT modes as assigned in the PT assignment model. The PT assignment is described in more detail in Chapter 8
Park and Ride	PnR	After the Park and Ride model, these trips are differentiated into individual road and PT legs and so are never assigned as PnR or are distinguishable from other road or PT trips
Walk	Wlk	Walk trips are made up of a combination of pure end-to-end walk trips and also the walk component of Parking Distribution trips (see Chapter 6 for more information on Parking Distribution and Chapter 9 for details of the walk assignment). Walk trips do not include the walk components of public transport trips which are generated and assigned during the PT assignment (see Chapter 8).
Cycle	Cyc	Cycle forms part of the active modes assignment which is described in Chapter 9

5.5 Time Period Segmentation

The ERM represents trips over a full 24-hour period, representing an average neutral weekday. This 24-hour period is divided into five time periods within the model, as shown in Table 5.3.

Assignment models are considered using a peak hour rather than a period, and the definitions for those peak hours are also provided.

For further information regarding time periods, please see the Link to *Peak Hour Specification Report*.

Table 5.3 Regional Model Time Periods

Time Period	Standard Abbreviation	Demand Model Period	Demand Model Duration	Road Assignment Model Peak Hour	PT Assignment Model Peak Hour	Active Assignment Model Peak Hour
Morning peak	AM	0700 – 1000	3 hours	0800 – 0900	0800 – 0900	0800 – 0900
Lunch time	LT	1000 – 1300	3 hours	1200 – 1300	1200 – 1300	1200 – 1300
School run	SR	1300 – 1600	3 hours	1500 – 1600	1500 – 1600	1500 – 1600
Evening peak	PM	1600 – 1900	3 hours	1700 – 1800	1700 – 1800	1700 – 1800
Off-peak	OP	1900 – 0700	12 hours	2000 – 2100	2000 – 2100	2000 – 2100

It is noted that the off-peak assignments are not calibrated or validated for any of the modes (road, PT, or active).

5.6 Tour Segmentation

Tours are combinations of trips which represent an entire journey from home and back to home. Two types of tours are included in the model – i.e. simple tours and complex tours. A simple tour is where someone leaves home to go somewhere, and then returns directly home from that location, and thus consisting of two trips. An example of a simple tour (the regular commute to work) is shown diagrammatically in Figure 5.1.

A complex tour is an expanded tour where a traveller makes a series of journeys before returning home again. Hence, a complex tour comprises the following legs (i.e. trips):

- A From Home trip;
- At least one Non-Home-Based trip; and
- A Return Home trip.

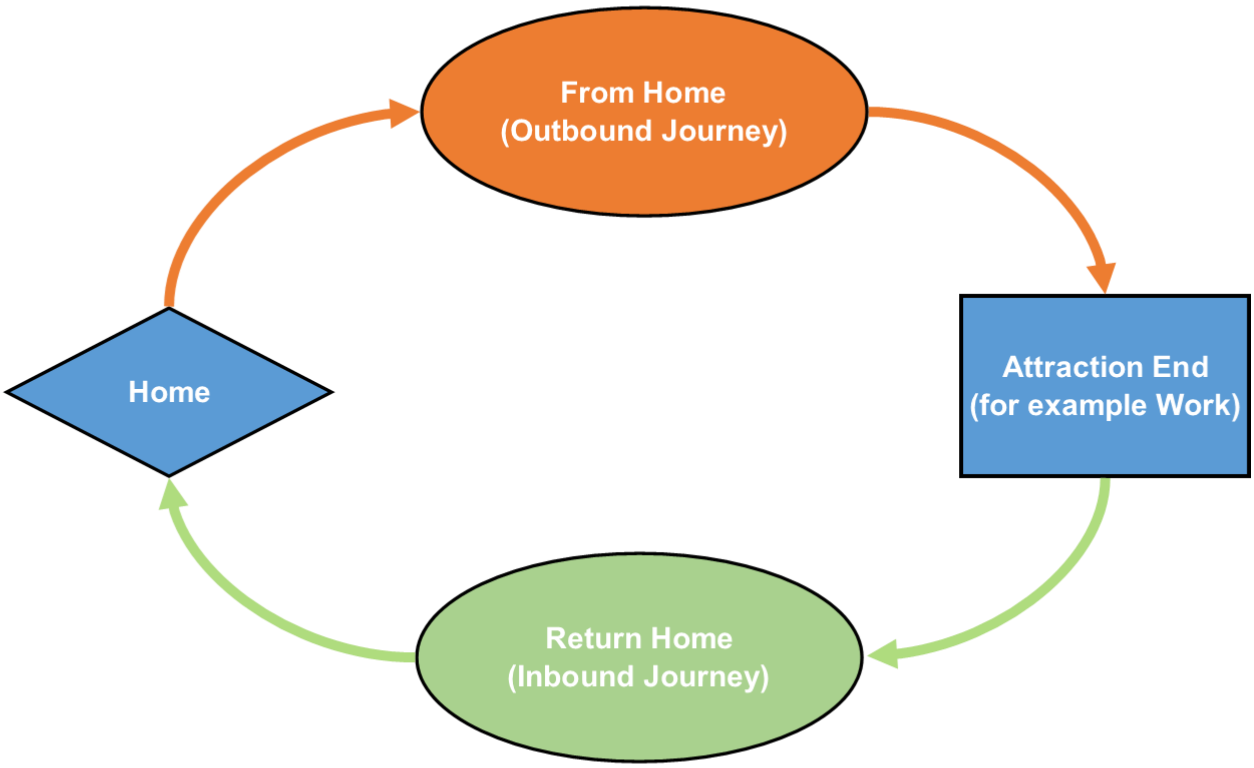


Figure 5.1 "Simple tour"

An example of a complex tour comprising three trips is shown graphically in Figure 5.2.

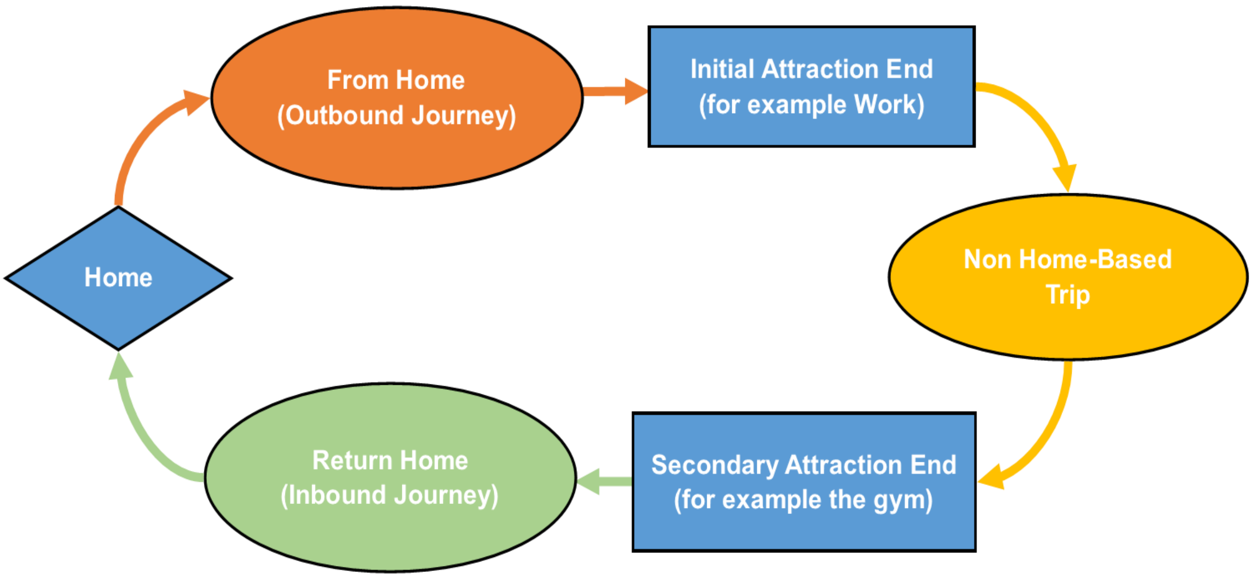


Figure 5.2 "Complex Tour"

A standard naming convention has been adopted throughout the model, where a tour is identified by the From Home (outbound) and Return Home (inbound) trips and their associated time periods, as shown in Table 5.4.

Table 5.4 Tour Notation and Tour Type, by Time Period

Outbound \ Inbound TP	AM	LT	SR	PM	OP
AM	1 (1)	2 (1)	3 (1)	4 (1)	5 (1)
LT	6 (2)	7 (1)	8 (1)	9 (1)	10 (1)
SR	11 (2)	12 (2)	13 (1)	24 (1)	15 (1)
PM	16 (2)	17 (2)	18 (2)	19 (1)	20 (1)
OP	21 (3)	22 (3)	23 (3)	24 (3)	25 (1)

There are three areas in this table:

- Tour type 1 shown with a white fill, which identifies tours which are modelled;
- Tour type 2 shown with an **olive** fill, which identifies tours which are not modelled; and
- Tour type 3 shown with a **blue** fill, which identifies tours which are only modelled for commute.

Early in model development process, an analysis of the 2012 National Household Travel Survey (NHTS) was undertaken to identify how many trips were in each of these tours involved overnight travel away from home. As expected, there were a very low number of overnight tours for the vast majority of purposes. The clear exception was commute, which had a number of observations highlighting individuals that went to work in the OP time period and returned the next day, and hence these trips are retained within the modelling.

The purpose of excluding the blue and olive highlighted areas (dependent on purpose) is primarily to reduce model runtimes and file sizes used – where the reduction from 25 to 16 tours has a potential saving of 36% in both.

Further detail regarding tours can be found in the *Trips and Tours Data Review Report*.

6 Regional Demand Model

6.1 Demand Model Structure

6.1.1 Wider Model Structure

As described in Chapter 2, the Regional Modelling System (RMS) is comprised of two main components:

- The National Demand Forecasting Model (NDFM) which provides national level forecasts of daily travel demand ("trip ends") produced by and attracted to each of the 18,641 Census Small Areas, as well as matrices of inter-regional trips; and
- Five regional models which take the outputs from the NDFM and apply them to the respective regional transport networks through a series of choice and assignment models.

This report describes the East Regional Model (one of the five regional models), and so does not provide detail on the NDFM as this is described in a number of other in-depth reports (links to which can be found in the following section). However, it is important to understand the source of the trip ends used by the East Regional Model (ERM) and so a summary of the NDFM is provided below in Section 0.

6.1.2 Overview

This chapter describes the "Demand Model" component of the ERM, which is actually a collection of several sub-models and processes. In combination, these models and processes, take all-day travel demand from the NDFM in the form of trip ends, and output origin-destination travel matrices by mode and time period to be used by each of the assignment models.

The trip matrices are calculated using travel costs skimmed from an assignment undertaken in a previous iteration using a loop mechanism. Figure 6.1 shows the Demand Model / assignment loop structure. The Demand Model consists of the following stages, which have all been developed in Cube Voyager (version 6.4.2):

- Pre-processing stages;
    - Trip End Integration: Converts the 24-hour trip ends supplied from NDFM into the appropriate zone system and time period disaggregation for the ERM. This process is described in Section 6.3 of this chapter; and
    - Add-in Preparation: Takes the inter-regional trip matrices from NDFM, factors it if necessary, and converts it into the zone system and time period disaggregation required by the ERM. In addition, it also reads in internal goods movements and adjust the internal regional trip ends to account for the inter-regional trips. This process is described in Section 6.4 of this chapter.

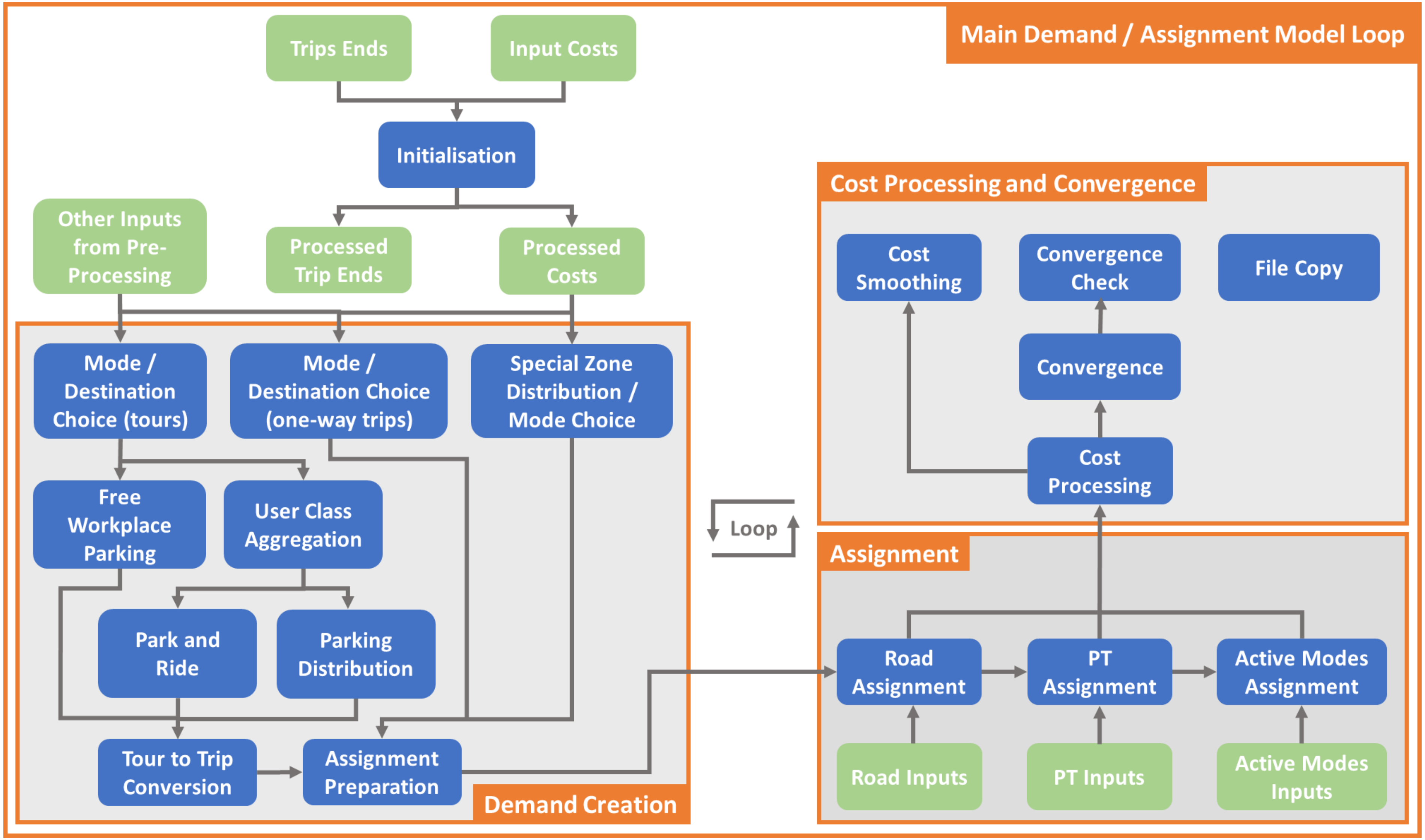


Figure 6.1 Main Demand / Assignment Loop

- Demand / assignment loop;
    - Mode and Destination Choice: Calculates where each production trip end will match with an attraction trip end, and by what mode the trip will be made, given the time when the trip will take place. The process is described in Section 6.5 of this chapter;
    - Free Workplace Parking: For journey purposes which may have access to free workplace parking, the initial mode and destination choice does not include parking charges. This module takes the initial output car demand and decides whether it can be accommodated in the available free workplace parking spaces. For the proportion of the car matrix which cannot be accommodated, and for the corresponding proportions of the other mode matrices, it undertakes a secondary mode split including parking charges. The Free Workplace Parking model is described in Section 6.6 of this chapter;
    - Park and Ride: Takes the trips assigned to Park and Ride during the mode and destination choice stage and works out which Park and Ride site they will use. The process used to calculate the Park and Ride site choice is described in Section 6.7 of this chapter;
    - Parking Distribution: This allows car trips to park remotely from their destination, which is critical where parking capacity is limited. The module gives car trips the choice to park in alternative zones, based on the total trip cost. It outputs the car and walk legs of each trip as well as information to be used in the calculation of the generalised costs. The Parking Distribution model is described in Section 6.8 of this chapter;
    - Special Zone Trip Distribution and Mode Choice: Calculates the trip distribution and mode used for trips to zones such as ports and airports which cannot be derived directly from the standard destination and mode choice stages. This is described in Section 6.9 of this chapter;
    - Taxi: This external model calculates the number of taxi trips as a proportion of car trips, based on the origin/destination of the trips. The output trip matrix produced by this process is retained as a separate user class for the road assignment model, which treats taxi vehicles differently to private vehicles. The derivation of the taxi matrix is described in Section 6.10;
    - Goods Vehicles: Goods vehicles do not behave in the same way as other trips with regards to trip generation and distribution. They are also subject to more stringent restrictions with regards to which roads they can use. This external model produces light and heavy goods vehicle matrices for use in the road assignment model and is described in Section 6.11;
    - Greenfield Sites: The standard destination and mode choice models assume trip-making behaviour in the future will be similar to current observed behaviours. However, where there are large changes in land-use, this assumption is no longer valid. The Greenfield Sites module allows the user to apply new assumption or to make adjustments to zones where large

developments or other major changes are expected to take place. This process is described in Section 6.12; and
- Assignment Preparation: This module undertakes a number of transformations on the output demand matrices to convert them for use in the assignment models. This includes aggregating journey purposes into user classes, splitting tour-based trips, into separate outbound and return legs, adding in the additional matrices (inter-regional trips, taxis, goods vehicles, specials zones, etc), and applying vehicle occupancy and period to peak hour factors as appropriate. It also applies incremental adjustments. The process is described in Section 6.13 of this chapter.

The demand/assignment loop is run for a set number of loops defined by a catalog key (*{Max Dem Loops}*) and convergence is monitored throughout by calculation of the %GAP statistic. Further discussion on the level of convergence achieved in a base year can be found in Section 11.2.3.

The next step in the overall modelling process is to assign the new matrices to the road, PT and active modes networks. The assignment process is described in Chapters 7 (for Road), 8 (for PT) and 9 (for Active Modes).

Following assignment, the Demand Model has one final process which needs to be run and that is to convert the cost skims (time, distance, monetary costs) from the assignment model and to convert this into aggregate, generalised cost which can be used in the next iteration of the Demand Model. This conversion process is described in Section 6.14.

6.2 Trip Generation

6.2.1 Overview

The ERM receives its trip ends and inter-regional demand from the National Demand Forecasting Model, the general structure of which is shown in Figure 6.2.

There are five main processes in the NDFM which contribute to the calculation of a regional model's trip ends and inter-regional demand:

- **Planning Data Adjustment Tool (PDAT)**, which controls the planning data inputs to the core NDFM system. The planning data consists of a range of variables related to the population by CSA, such a total population, age bands, employment status etc. PDAT is used to amend planning data to represent the combination of general changes over time and the relevant land-use planning scenarios. Further details can be found in the *PDAT Report*;
- **Car Ownership/Car Competition Models (COCMP)**, which estimates the number of cars owned in each CSA and subsequently categorising the number of households in each CSA with no car, the number of households with fewer cars than adults and the number with at least as many cars as adults. Further details on both models can be found in the *Car Ownership Report*;

- **National Trip-End Model (NTEM)**, which converts the planning data into person trips by car availability for each of 33 demand segments. Further details of the model can be found in the *NTEM Report*;
- **Long Distance Model (LDM)**, which derives:

  Residents travel demand by mode between settlements and ports/airports;
  Visitors travel demand by mode between settlements and ports/airports; and
  Goods vehicle demand between settlements and ports.

  Further details of this model can be found in the *LDM Report*; and
- **Regional Model Strategic Integration Tool (RMSIT)**, which works out which trips from the LDM travel demand matrices would be "inter-regional" (i.e. travelling into, out of, or through each of the regional models). It then converts this inter-regional travel demand into the relevant zone systems of the regional models. Details of this tool can be found in the *RMSIT Report*.

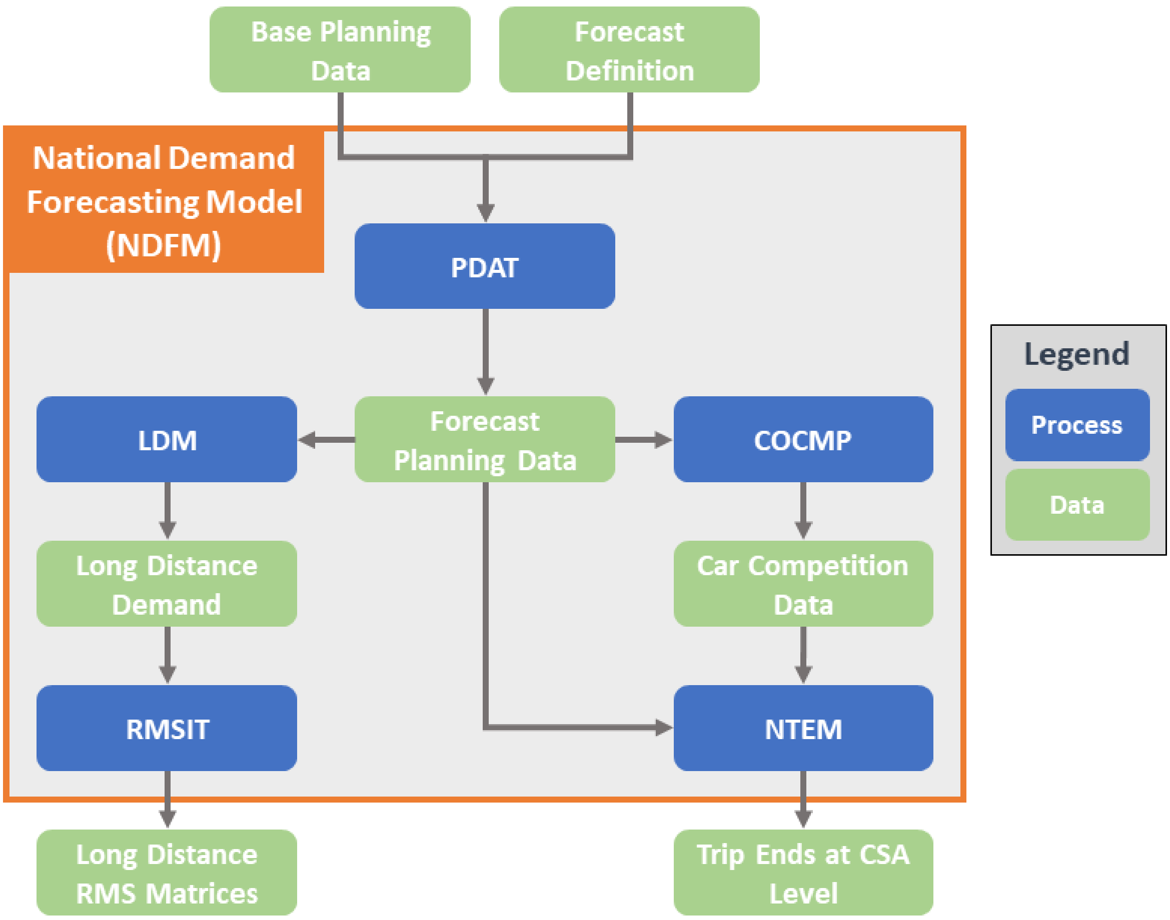


Figure 6.2 National Demand Forecasting Model overview

6.2.2 Trip Ends

Trip Ends produced by NDFM are in units of 24-hour productions and attractions by car availability at the CSA level for the following journey purposes:

- Work (HBW);
- Employer's business (HBEB);
- Education (HBEd);
- Escort-to-education (HBEsc);
- Social visits (HBV);
- Food shopping (HBFS);
- Other (HBO); and
- Non-Home Based (NHB).

Each trip end of the home-based purposes represents one end of a tour (which itself represents two legs of a return journey). For non-home based and one-way purposes, each trip end represents one end of a single trip. The regional models convert from CSAs to Zones in the Trip End Integration stage (as described below in Section 6.3).

6.2.3 Special Zone Demand

In the RMS, Special Zones are non-geographic zones of transport demand whose trip patterns are different from demand in the rest of the modelled area. Although Special Zones could, in principle, include a range of hard-to-model locations, at present they include only airports and ferry ports.

The NDFM includes base year travel patterns and forecasting functions that supply the demand to and from Special Zones (i.e., ports and airports) for each of the regional models.

The Special Zone module is described in more detail in Section 6.9.

6.2.4 Inter-Regional Demand

Inter-regional trips are those that have one or both ends located outside of the regional model (and where part of the trip takes place within the regional model). As described in Section 4.2, the external ends of the trips are aggregated to route zone defined by the point at which the trip enters or leaves the regional model. The inter-regional demand is provided by the NDFM as an origin-destination matrix for each route zone defined in the regional model.

The inter-regional demand is converted from the LDM settlement-to-settlement matrices by the RMSIT process which undertakes aggregation of the external trip ends to route zones and disaggregation of internal trip ends to the regional model zone system. Once the inter-regional demand has been converted by the RMSIT, the resultant trips are referred to as "external trips" within the regional Demand Model structure.

Further details about inter-regional demand and the LDM model can be found in the LDM Report.

6.3 Trip End Integration

6.3.1 Overview

The Trip End Integration stage, which is shown diagrammatically in Figure 6.3, takes 24-hour trip ends generated by the NDFM (specifically the National Trip End Model) and converts these for use in the ERM. This process involves:

- Conversion of the NTEM trip ends from CSAs to the zoning system of the ERM; and
- Conversion into 33 demand segments used in the regional model (which are listed in Table 5.1).

The conversion from CSA to the ERM zone system requires a user-defined correspondence file which defines the link between the two zone systems, including the proportion of each CSA to be associated with a given zone where the CSA is to be split between two or more zones. CSA to zone proportions are based on population for home-based productions, and employment or school places for attractions.

For further details regarding the Trip End Integration files and process then please refer to the *Demand Specification Report*.

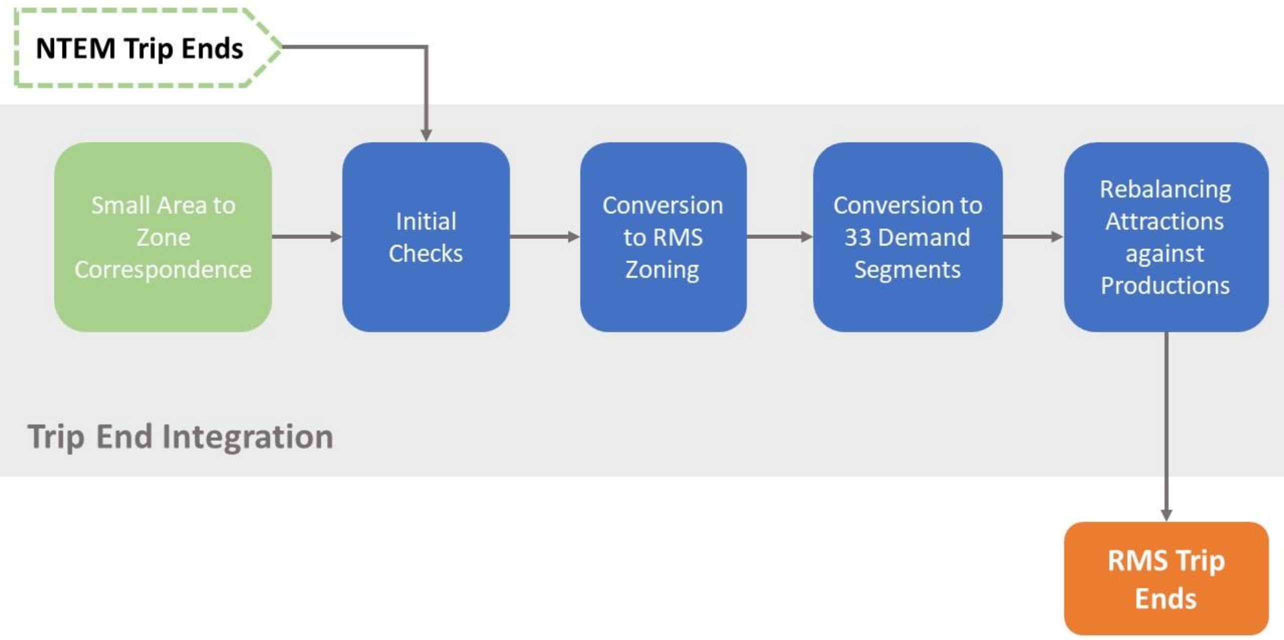


Figure 6.3 Trip End Integration

6.4 Add-in Preparation

6.4.1 Overview

The purpose of the Add-In Preparation stage is to process external trips which are generated by the Regional Model System Integration Tool (a component of the NDFM).

External trips represent inter-region movements, which cross boundaries between the regional models and so cannot be calculated internally in the regional Demand Models.

The processing of external trips during the Add-in Preparation stage involves:

- Conversion of external trips from time periods to ERM model hours;
- Conversion from person trips to vehicles; and
- Optional factoring to limit the amount of external traffic relative to internal traffic.

Furthermore, the Add-in Preparation stage adjusts trip ends (from the Trip End Integration stage) to ensure that external trips are not double counted. This is done by removing the number of external trips from the trip ends for each internal zone. Note that, although the external trips are split by time period, the internal trip ends remain at a 24-hour level at this stage.

The overview of the Add-In Preparation stage is shown in Figure 6.4.

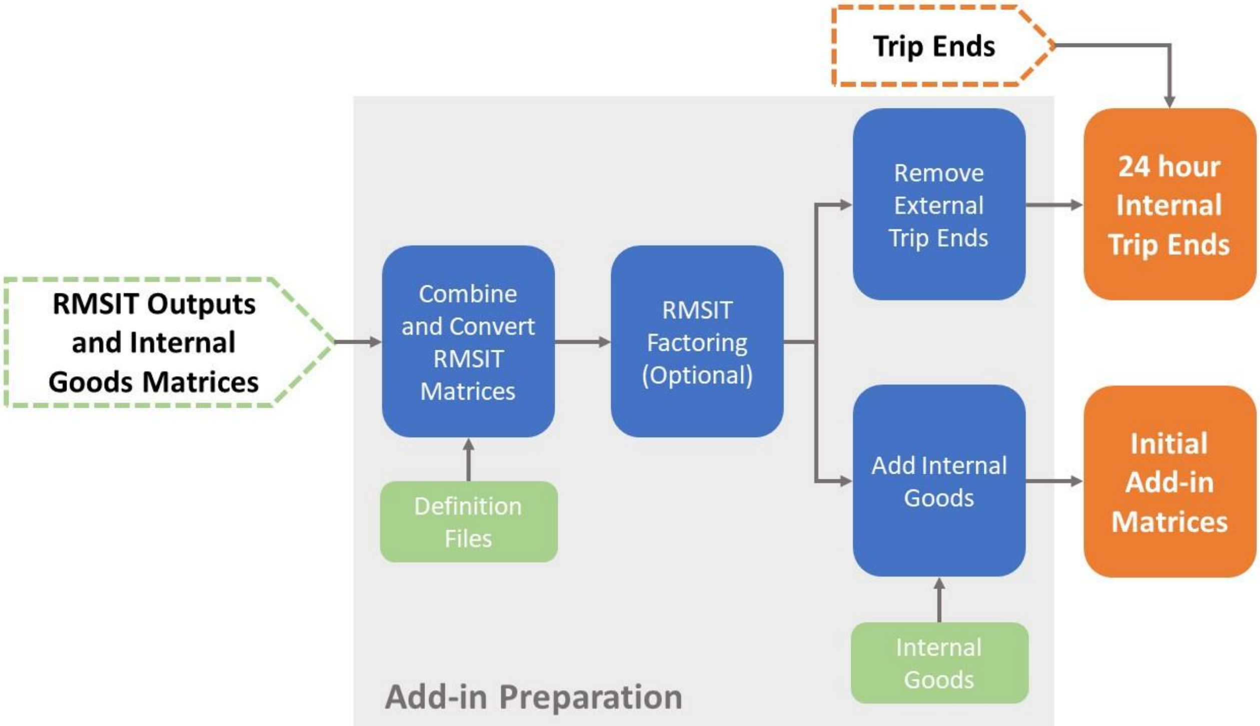


Figure 6.4 Add-in Preparation

The external trip matrices include long-distance goods vehicle movements as well as journeys made by car, bus and rail. Internal goods vehicles (i.e. those taking place entirely within the regional model area) are added to the long-distance goods vehicles. The combined goods vehicles matrices will be added to the assignment matrices during the final stage of the Demand Model.

The external trip matrices are in units of person-trips and so it is also necessary to convert trips made by car from persons to vehicles and then to PCUs. CDCU and PCU factors used in conversion are detailed in Table 6.9 and Table 7.2 respectively.

For further information on the Add-in Preparation Stage, please refer to the *Demand Specification Report*

6.5 Mode and Destination Choice

6.5.1 Overview

The Mode and Destination Choice process is a standard component of any variable demand transport modelling process, specifically tackling the trip distribution and mode choice stages.

Within this model these stages have been implemented as a logit choice model which is a widely recognised approach within economics and transport modelling. More specifically, the model takes the form of a nested, or hierarchical, logit model with destination choice undertaken first, followed by mode choice (as shown in Figure 6.5 below). The model is set up in this way to facilitate later steps in the Demand Model process, such as the free workplace parking model. For further information on the form of the model and the analysis which was undertaken, please see the *Model Estimation Report*.

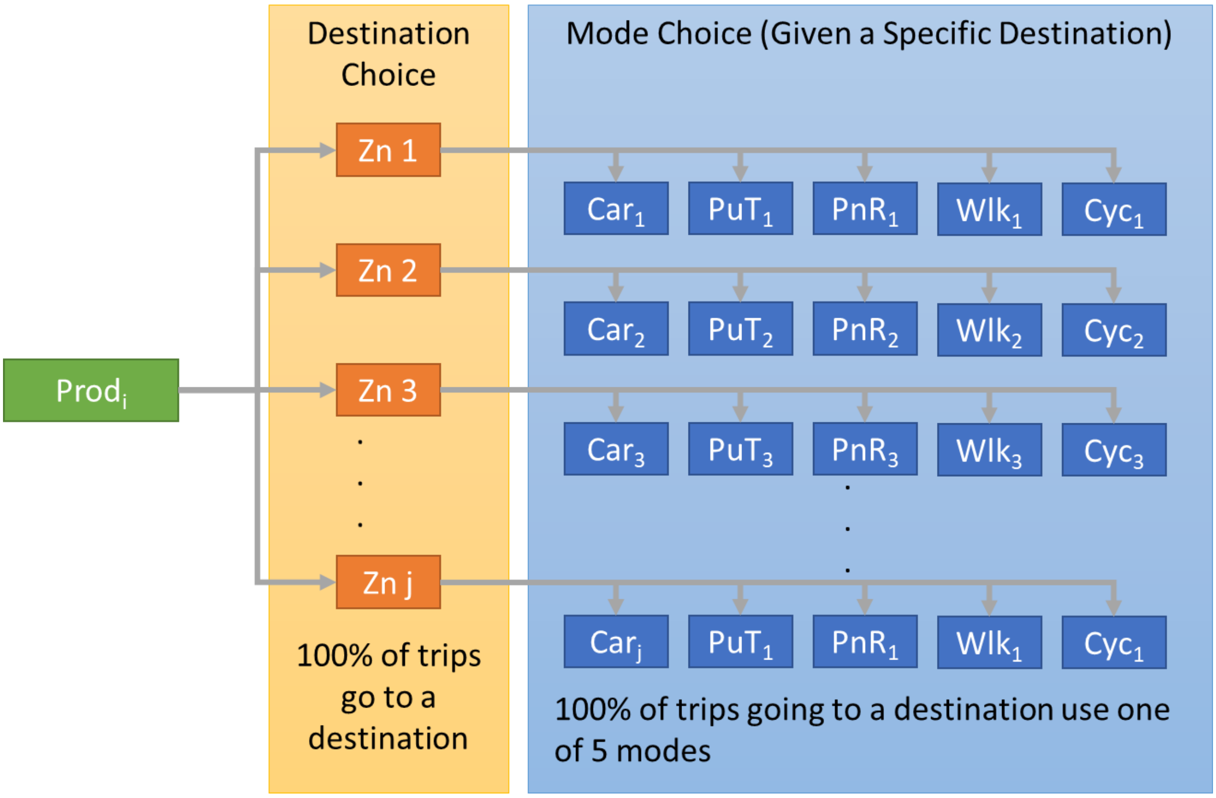


Figure 6.5 Logit Nesting within Choice Model

6.5.2 Mathematical Framework

The modelling framework of the Mode and Destination Choice process is based on the principle that a decision-maker chooses the travel mode and destination that yields greatest satisfaction or “utility”. A logit model is used to calculate the probability of use of the different choice alternatives, based on the difference in the utility of those choice alternatives.

The mode and destination choice model can be considered as an algorithm with the following steps:

- Read in generalised costs by mode, production and trip ends, and parameters;
- Derive utilities for mode choice;
- Derive utilities for destination choice;
- Derive probabilities for mode choice;
- Derive probabilities for destination choice; and
- Apply probabilities to trip ends to calculate trips by mode between zonal pairs.

Mode choice utilities for trips are defined as:

$$U_{ijm} = \alpha GC_{ijm} + \beta \ln(GC_{ijm}) + IZM_m IZ + ASC_m$$

Where:

m is the mode from full set M of car, PT, PnR, walk, and cycle;

U_{ijm} is the modal utility for travelling between zones i and j by mode m;

α, β, IZM_m and ASC_m are the utility function parameters, as follows;

α and β are scaling parameters which determine whether the relationship between utility and generalised cost is (α) or logarithmic (β);

IZM_m is an additional cost applied only to intrazonal trips and is used to correct any underrepresentation of intrazonal generalised costs;

ASC_m is the alternative specific constant and represents unquantified costs for that mode[21];

$GCijm$ is the generalised cost for travelling between zones i and j by mode m; and

IZ is a Boolean flag which is 1 if $i = j$ and 0 elsewhere.

The calculation of generalised cost is different for each mode. Further information on the derivation of generalised costs can be found in Sections 6.14, 7.9, 8.8 and 9.6.

Mode choice probabilities for trips are defined as:

$$P_{m|ij} = \frac{e^{-\lambda_M U_{ijm}}}{\sum_{m \in M} e^{-\lambda_m U_{ijm}}}$$

Where:

$P_{m \mid ij}$ is the probability of traveling by mode m between zones i and j; and

$\lambda_M > 0$ is the mode choice spread parameter.

[21] In logit models, if the utility of all modes is equal then the proportion of trips allocated to each mode would also be equal. In practice, when costs for car and PT are equal within the model, the observed data will indicate that more trips travel by car. This is generally understood to be because there are other factors influencing the mode choice decision which aren't quantified in the model (e.g. reliability of Public Transport). The ASC is therefore used to adjust the model to account for the unquantified costs and match the observed data.

Destination choice utilities for trips are composite utilities which represent the utility of travelling to each destination by any mode. They are defined using a logsum of the component mode choice utilities as follows:

$$U_{ij} = \frac{\ln\left(\sum_{m\in M} e^{-\lambda_M U_{ijm}}\right)}{-\lambda_M}$$

Where:

U_{ij} is the zonal utility for travelling between zones *i* and *j*, by any mode.

Destination choice probabilities for trips are defined as:

$$P_{j|i} = \frac{e^{-\lambda_d (U_{ij}+A_j)}}{\sum_{j\in J} e^{-\lambda_d (U_{ij}+A_j)}}$$

Where:

$P_{j\,|\,i}$ is the probability of traveling to destination *j* from zone *i*;

A_j is the 24-hour attraction for destination *j*; and

$\lambda_d > 0$ is the destination choice spread parameter.

Total trips are calculated by applying the mode proportion and destination proportion to the origin trip ends as follows:

$$T_{ijm} = Prod_i P_{j|i} P_{m|ij}$$

Where:

T_{ijm} are the modelled trips between zones i and j by mode m;

$Prod_i$ are the production trip ends for zone i; and

$P_{j/i}$ and $P_{m/ij}$ are the output probabilities from the destination and mode choice models which are described above.

Although both the mode and destination proportions can be applied to the trip ends at the same time, it is important to note that this is a hierarchical model (not a simultaneous model) as the destination choice function uses a composite utility from the mode choice model.

Double Constraint

It can be seen in the equation above that the calculation of total trips only considers the production trip ends and ensures that the total number of trips produced by a zone is constrained to the production trip end. However, although the probability of being attracted to a zone is influenced by the attraction trip end, the trip end does not form a constraint within the calculation of total trips. Consequently, it is unlikely that the number of trips attracted to a zone matches the trip end.

For many journey purposes, the lack of constraint at the attraction end is not an issue, as in reality, there usually isn't a constraint on the number of people who can, for example, visit a particular shopping centre. However, for work and education trips there is often a limit on the number of trips to a particular location, based on the number of jobs or the size of a school.

For these journey purposes, their destination choice model must also have a constraint on the attraction trip end; the model is then considered to be "doubly constrained" rather than "singly constrained". In practice, this means that an additional step is included in the calculations to ensure that both attractions and production totals are met; this step is a Furness process which is undertaken for trips by all modes, i.e. prior to applying a mode choice proportion.

During the Trip End Integration stage of the Demand Model process (Section 6.3), the total attraction trip ends by tour are matched to the overall productions so that a complete convergence is achievable during the Furness process, and so two different sets of attractions are considered during the destination choice process:

- 24-hour attractions within destination choice; and
- Balanced attractions within doubly constrained Furness process.

More information on the constraint mechanism and the Furness process can be found in the *Demand Specification Report*.

Parking Costs

For the journey purposes which are considered to have access to free workplace parking (i.e. work and education trips), the Mode and Destination Choice model does not include parking charges. Where necessary the Free Workplace Parking module undertakes a secondary mode split including parking charges. This is described in the following section (Section 6.6) of this chapter.

Tour-based and one-way demand segments

Previous versions of the model had separate modules that dealt with tour-based demand segments and one-way demand segments, whereas more recently this has been adjusted to include all demand segments within a single mode and destination choice framework. Matrices representing tour-based demand segments are stored in PA format, whereas matrices representing one-way and NHB demand segments are stored in OD format. The other key difference is that one-way trips only need to consider a single time period generalised cost rather than an average generalised cost. A key assumption here is that the parking cost duration for any one-way trip is 1.5 hours[22].

Calibration

6.5.3 Phase 1 Calibration

The mode and destination choice model is controlled by parameters introduced to the system for each demand segment, specifically:

- α parameters which are scalars applied to the generalised cost between zones;
- β parameters which are scalars applied to the natural log of the generalised cost between zones;
- Alternative Specific Constants (ASC) which are associated with the choice of mode;
- Intrazonal parameters (IZM) which are associated with reflecting the likelihood to travel within a zone rather than outside it; and
- Spread parameters for each nest (λ) which define the sensitivity to cost differentials between choices.

Each of these parameters were initially estimated using a multinomial logistic regression of the NHTS and POWSCAR datasets (separately for each demand segment) to provide initial parameters which can be used within the model.

This process was focussed on maximising the statistical significance of the parameters which relate costs with travel choices, and are evaluated based on a number of key criteria including:

- Mode share;
- Average generalised cost;
- Average trip length;
- Intrazonal proportions; and
- Statistical significance.

Model outputs based on the parameters derived through this process are not presented in this document. However, further information on the process and its outcomes can be found in the *Model Estimation Report*.

6.5.4 Phase 2 Calibration

Following from an initial estimation approach, it was noted that in some cases the model was not effectively capturing the key trends, or else there were reservations about the results. Reasons for this included:

- Lack of consistency in processes (estimation and ERM) including:
  - POWSCAR not identifying a return home time period for tour identification;

[22] See RMS Parking Specification Report Section 5.3.1 for further information on this assumption.

  - POWSCAR not matching the time period definitions for outbound time periods;
  - Blue collar and white collar disaggregation not being consistent between ERM/NHTS and POWSCAR due to differing segmentation;
  - POWSCAR not identifying car availability for a trip;
  - Likely errors in coding of the home end for tertiary education students in POWSCAR (parents' residence rather than term-time residence);
  - Low samples of observed data (particularly within the NHTS dataset); and
  - Errors or rounding in reporting.

To account for these, a secondary calibration process (called GoalSeek[23]) for the mode and destination choice models was developed to:

- Refine the observed targets;
- Recalibrate the parameters to better match the revised targets; and
- Correct for any model processes which were not captured in estimation (such as parking models).

The GoalSeek approach replicates a simplified version of the mode and destination choice model (on a 24-hour basis rather than individual tours in order to reduce runtimes). It then adjusts parameters so that observed targets are better matched for the following KPIs:

- Mode share, where the number of travellers using a certain mode is taken as a proportion of total travellers within the model at a set level of disaggregation (time period, demand segment, or user class as required);
- Average generalised cost, where the modelled generalised cost is multiplied for each cell in the matrix by the number of travellers and then divided by the number of travellers to generate a single number, based on the relevant section of the matrix at a set level of disaggregation (time period, demand segment, or user class as required); and
- Intrazonal proportions, where the number of travellers that stay within a zone (typically on a total matrix level) is compared against the total number of trips for the relevant section of the matrix at a set level of disaggregation (time period, demand segment, or user class as required).

These indicators are a subset of the KPIs considered during estimation, both trip length as well as statistical significance were excluded. Trip length is monitored but not explicitly targeted as part of this process (it is also worth noting that trip length is also not targeted in the initial estimation which is based entirely on generalised cost). The GoalSeek process does not involve a logistic regression or associated statistical significance measures.

Chapter 10 provides a description of the wider approach to calibration and how the two processes described here were applied. Chapter 11 details the performance of the model

[23] See Calibration Guide for further details.

following the calibration of the model, including the application of the GoalSeek algorithm. A more detailed description of the GoalSeek methodology and the more detailed outputs are reported in the *Calibration Guide.*

6.5.5 Summary

The mode and destination choice model is a core component of any variable demand transport model and has been implemented as a tour-based nested logit model with destination choice followed by mode choice.

While at its core it is a simple implementation of such a model, there are a number of additional mechanisms particularly related to parking costs which are included to allow it to effectively integrate with the rest of the Demand Model.

For further details regarding the Mode and Destination Choice process then please refer to the link to the *Demand Specification Report*.

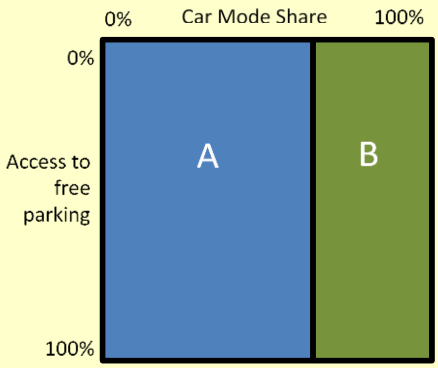
6.6 Free Workplace Parking

6.6.1 Overview

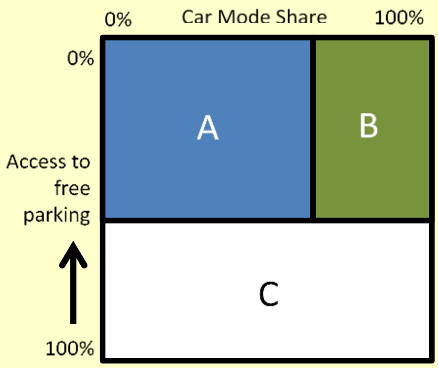
The Free Workplace Parking (FWPP) module was developed to replicate the choices that a traveller may face if the demand for free workplace parking is larger than the available supply, and allows the model to assess the impact of measures which may affect the number of free spaces for all destinations. The FWPP module applies to students parking at educational establishments as well as commuters parking at their place of work. It does not extend to business trips (i.e. Employers Business) where the availability of free visitor spaces is accounted for in the average parking charges. This choice process is shown diagrammatically in Figure 6.6.

Figure 6.6 Free Workplace Parking Stage

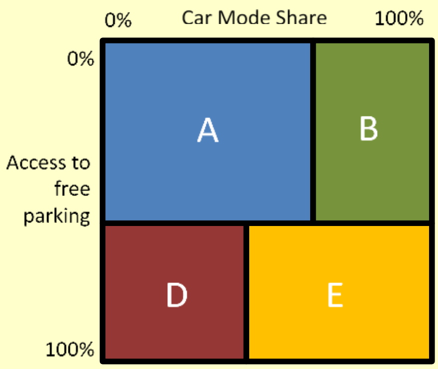
A diagrammatic representation of the how the FWPP module works is shown and described in Figure 6.7. Stage 1 of this process is undertaken by the Mode and Destination Choice Module while this module focusses on Stages 2 and 3.



Stage 1: Apply Mode split, assuming free parking for all
In the diagram to the left, the large square represents all of the “car-available” commuting trips to a particular destination zone.
The X axis represents the proportion of these trips which choose to travel by car, while the Y axis represents the proportion of trips with access to free parking.
In the first stage, the mode split is applied assuming everyone has access to free parking. Region A represents those trips which would be made by car in this event, and Region B represents those trips which would be made by other modes.



Stage 2: Calculate proportion of trips offered free parking
The proportion of trips with access to free parking is reduced, such that the number of trips made by car equals the estimated number of free parking spaces.
In the diagram, a horizontal line appears in the box denoting the proportion of trips with access to free parking. Those trips above the line (Regions A and B) have access to free parking, whereas those below the line (Region C) do not. As before, Region A represents car trips with access to free parking – the area of this region should match the number of free spaces.



Stage 3: Apply mode split to trips without access to free parking
The proportion of trips with no access to free parking (Region C in the diagram above) is subject to mode choice, but this time with parking charges included.
In the diagram, the former Region C is now split into two – Region D which represents trips made by car which pay for parking; and Region E which represents trips made by other modes that would not have had access to free parking. Regions A and B are unchanged from the previous stage. Regions B and E can be combined at this stage.

Figure 6.7 Free Workplace Parking Mathematical Framework

The FWPP module begins by calculating the occupancy for each zone for each time period, including the impact of spaces taken by earlier arrivals.

The number of trips which would travel by car to each zone (assuming that everyone has access to a free workplace parking space) has previously been calculated as part of the Mode and Destination Choice module. The number of person trips is converted into vehicles, which is then compared to the number of available spaces to establish the proportion of each car matrix which exceeds the available demand. The model then takes this proportion of the input matrices for all modes and applies revised mode split proportions based on costs which include parking charges. For cars, two matrices are taken forward to the later stages of the model: the proportion of the car matrix which can be accommodated by free parking; and the output from the revised mode split based on paid parking. For the other modes, the trips from both stages can be combined into a single matrix.

The amount of free workplace parking available to those arriving in each time period depends on the number of vehicles still in position from previous time periods. Figure 6.8 shows the tours which are considered to impact on occupancy in each time period (reading across the rows).

Inbound Time Period

Outbound Time Period

OB \ IB	AM	IP1	IP2	PM	OP
AM	1	2	3	4	5
IP1	6	7	8	9	10
IP2	11	12	13	14	15
PM	16	17	18	19	20
OP	21	22	23	24	25

AM IP1 IP2 PM OP

Figure 6.8 Free Workplace Parking Tour Grid

Since only a proportion of trips will have a free workplace parking space available, there is some uncertainty around how this would influence destination choice and hence whether to include the cost of parking in destination choice. It was agreed that the most appropriate choice was to use an average parking cost weighted by the proportion of trips with free workplace parking. The basis for this assumption is that it would provide a more logical response in future scenarios where the number of free spaces is changed.

This assumption only affects the destination choice. Within the mode choice stage (for journey purposes with access to free parking), the *initial* mode choice is based on not having to pay for parking; a secondary mode choice based on paid parking is then derived which is applied to the proportion of trips which do not have access to a free space. This results in three different cost matrices being required for those journey purposes with access to free workplace parking.

For journey purposes which don't have access to free parking, both the destination and mode choice is always based on costs which include parking charges.

A graphic of the choices involved is provided in Figure 6.9.

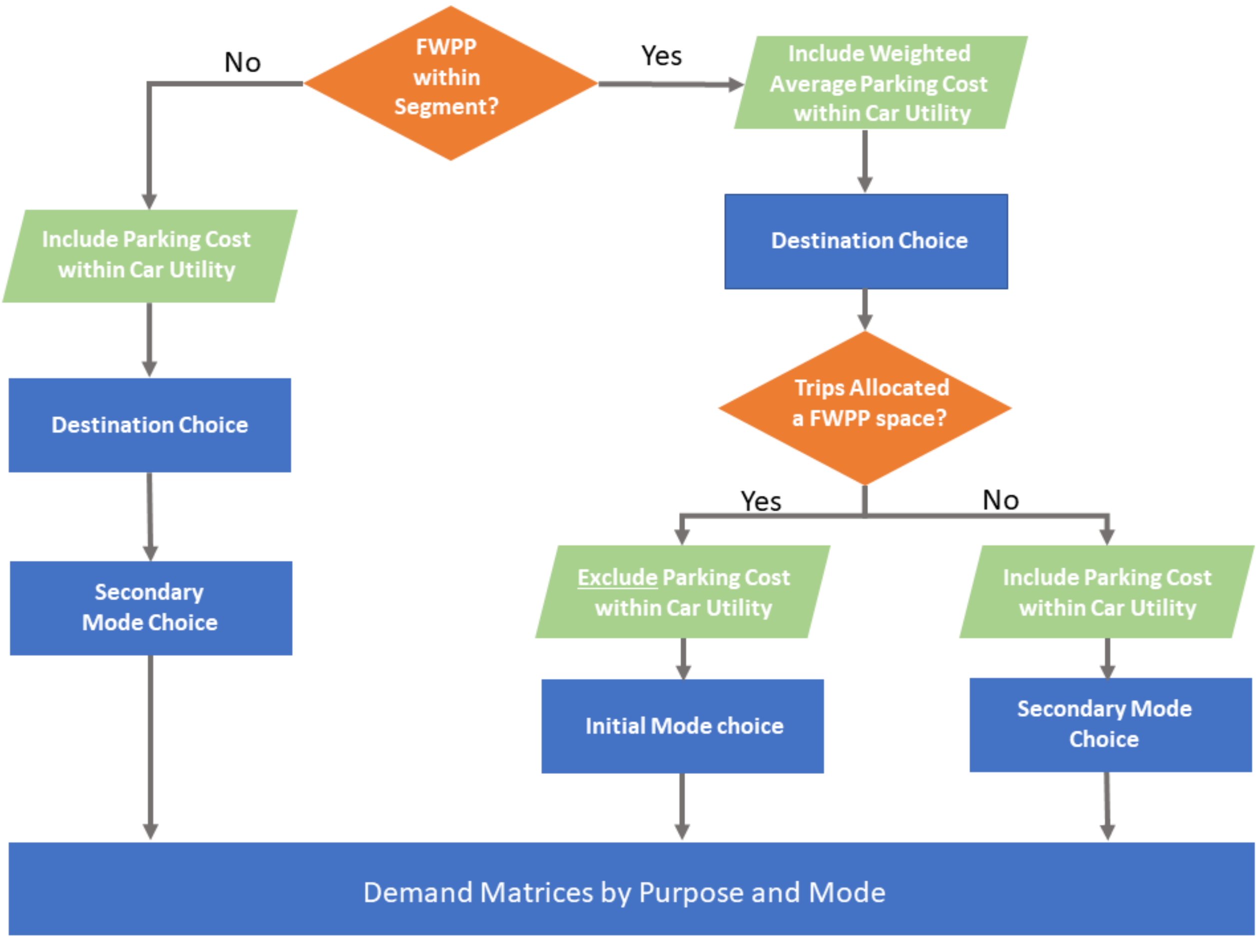


Figure 6.9 Description of Parking Inclusion within Choice Model

For further details regarding the Free Workplace Parking process then please refer to the *Parking Report*. For details of how the process was implemented please refer to the link to the *Demand Specification Report*.

6.6.2 Input Preparation

Data Source

There is no comprehensive record of the number of workplace car park spaces by location and it was therefore necessary to make several assumptions and combine inputs from four different sources to estimate the spaces available by model zones.

The four data sources used were:

- National Household Travel Survey (NHTS) responses;
- POWSCAR commute and education driver demand;
- Modelled commuter and education driver demand; and
- Valuation Office workplace parking space data (used as a confirmatory check only).

Information on the number of free workplace parking space is not directly available from any of the above data sources. However, using them all in combination and applying some assumptions enabled the derivation of an estimate of spaces for use in the model, as described below.

NHTS data was used to derive the proportion of commute and education drivers that had access to a free parking space (based on responses to a question on availability of free parking). This data could only provide proportion of trips with access to free parking and not absolute numbers. Due to the sample size, it was not possible to determine zonal or even sector based differential free parking proportions. Instead proportions were calculated for two areas: central Dublin (ERM sectors 1-4, which approximate to area within the canals); and the rest of the ERM. These two areas were treated separately to take account of lower rates of free parking provision in the city centre, compared with elsewhere.

Table 6.1 NHTS Free Workplace Parking Records

NHTS Records	Commute			Education		
Areas	Car	FWPP	% FWPP	Car	FWPP	% FWPP
All Regions	5,198	4,366	84%	1,670	1,354	81%
ERM	2,646	2,207	83%	591	512	87%
ERM Central Dublin (Sec1-4)	424	207	64%	10	4	40%
ERM Remainder	2,222	1,937	87%	581	508	87%

The percentage of car trips with access to free parking (as detailed in Table 6.1) was applied to the total car driver demand making commute or education trips. This yielded the estimated number of trips with access to a free space, which was assumed to equal the number of spaces available (this assumes that all free spaces are occupied).

The approach to deriving these spaces can therefore be described as:

$$Spaces_{z,p} = \frac{POWSCAR_{cardriver,z,p} \times NDFM_{Attr,z,p} \times NHTS_{FWPP,s,p}}{POWSCAR_{total,z,p} \times NHTS_{Car,s,p}}$$

Where:

$Spaces_{z,p}$ is the estimated number of free workplace parking spaces by user class (commute or education);

$POWSCAR_{cardriver,z,p}$ is the total number of POWSCAR destinations recorded in a zone by user class that travel regularly by car;

$NDFM_{Attr,z,p}$ is the total number of trip attractions by zone and user class.

$POWSCAR_{total,z,p}$ is the total number of POWSCAR destinations recorded in a zone by user class;

$NHTS_{FWPP,s,p}$ is the weighted sample of NHTS respondents by sector (not zone) which have access to free workplace parking identified in the survey; and

$NHTS_{Car,s,p}$ is the weighted sample of NHTS respondents by sector (not zone) which travel by car identified in the survey.

The total number of estimated FWPP spaces is detailed in Table 6.2 below.

Table 6.2 Summary of Estimated FWPP Spaces (by sector groupings)

	Commute			Education		
Areas	Cars	FWPP	% FWPP	Cars	FWPP	% FWPP
Central Dublin (Sec1-4)	50,192	31,467	62.7%	3,005	1,203	40.0%
Dublin Remainder (Sec 5-20)	214,592	174,152	81.2%	9,764	8,538	8787%.4%
ERM Remainder (Sec 21-38)	170,470	155,354	91.1%	6,772	5,921	87.4%
Total ERM (Sec 1-38)	435,254	360,973	82.9%	19,541	15,662	80.1%

The absolute number of free workplace parking spaces estimated in each zone from the method described above is shown in Figure 6.10 and Figure 6.11. The same data is presented as density plot in terms of free workplace parking spaces per square kilometre in Figure 6.12. These demonstrate the increasing provision of spaces in the east of the city centre.

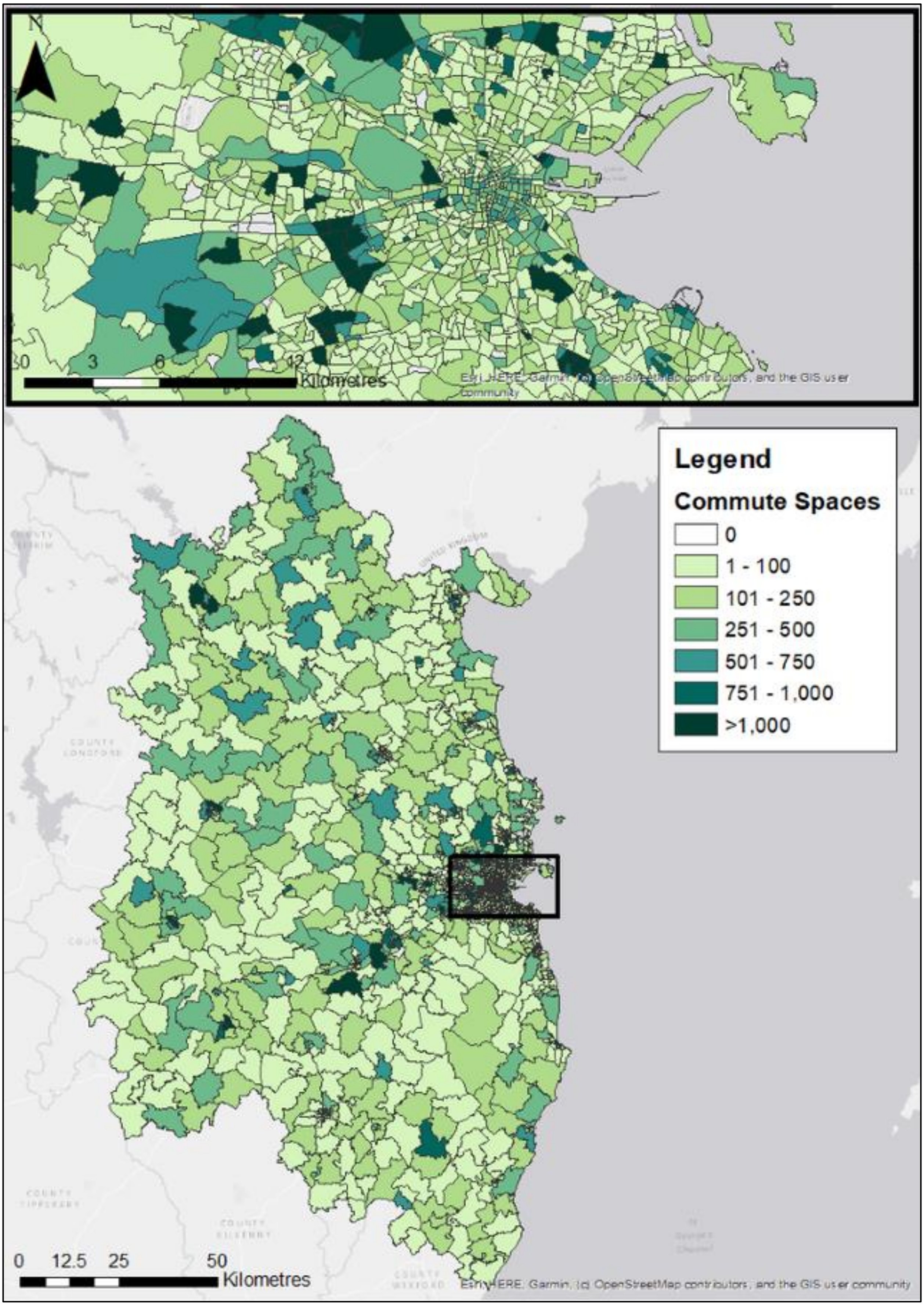


Figure 6.10 Free Workplace Parking Availability, Commuting (Absolute)

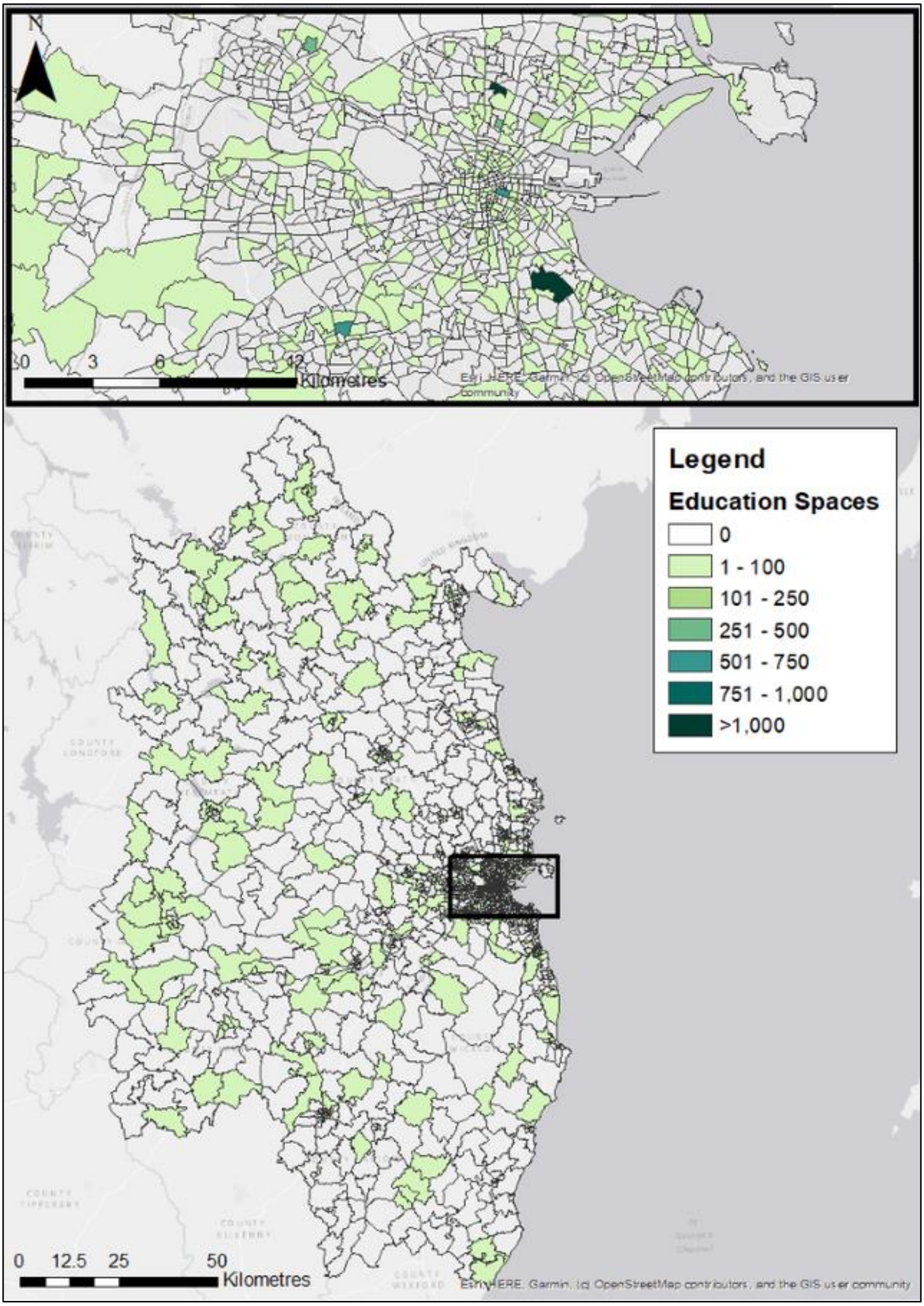


Figure 6.11 Free Workplace Parking Availability, Education (Absolute)

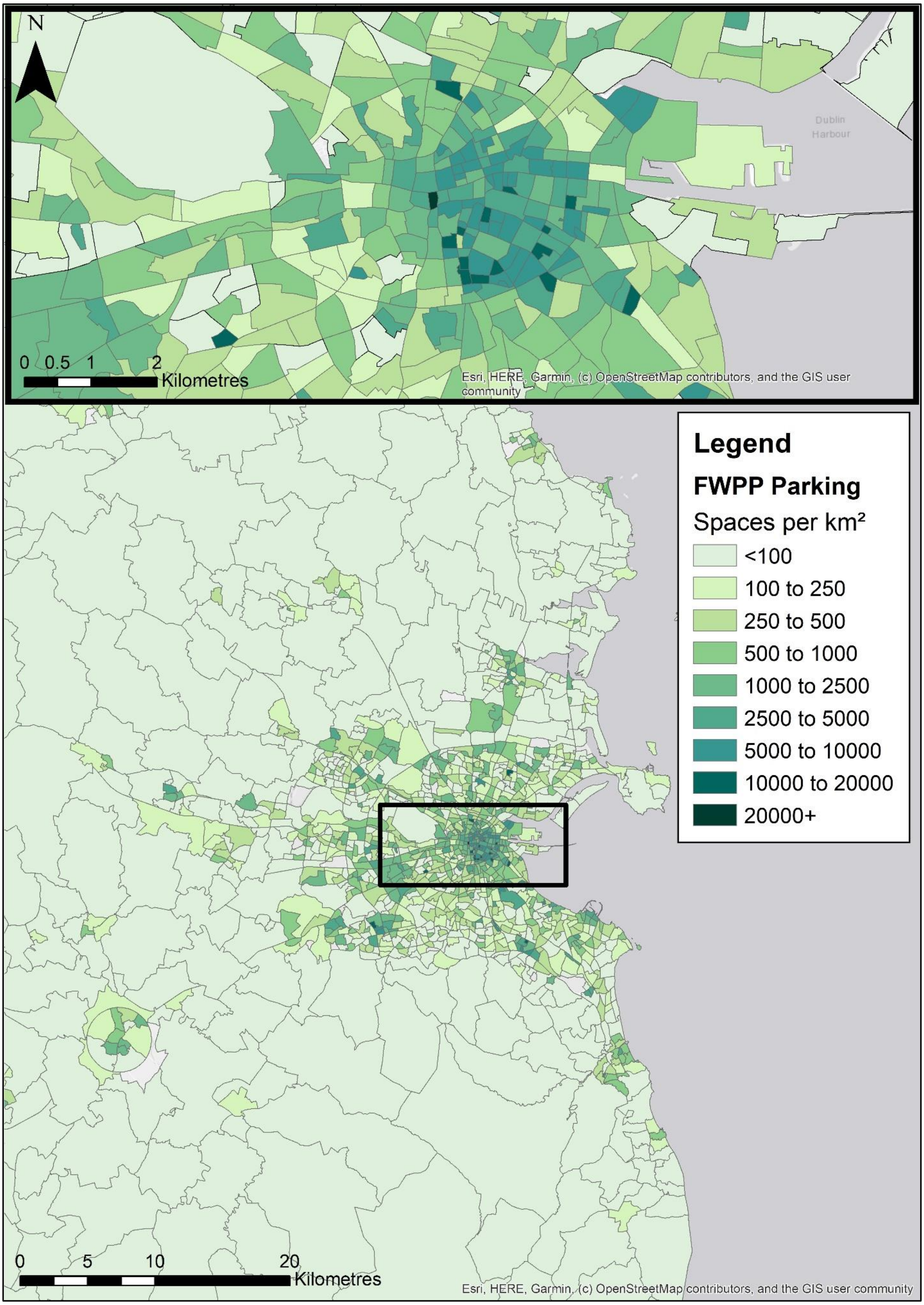


Figure 6.12 Free Workplace Parking Total Availability (Density)

6.6.3 Input Data Verification

As a check that the derived number of FWPP spaces were reasonable, the capacities were compared to data from the Valuation Office, originally collected for the application of business rates. This information is recorded for commute only as school and college parking is not rateable, and therefore detailed data is not collected by the Valuation Offices. Data was available for Dublin City, Dun Laoghaire-Rathdown County, Fingal County and South Dublin County Councils.

This data was available for 2012 and 2017 showing an approximate 3% increase in spaces over the five-year period. A linear interpolation was used to estimate the number of spaces in 2016 and these were compared to the spaces derived using the NHTS, POWSCAR and Model combination approach. The number of spaces estimated from the data is provided in Table 6.3, and the results of the comparison with the NHTS-derived numbers are shown in Table 6.4.

Table 6.3 Free Parking Spaces Recorded by Valuation Office

Council	2012	2017	5 Year Index (2012=100)	2016, Estimated	Annual Change
Dublin City	51,965	49,232	95	49,779	-547
Dun Laoghaire-Rathdown County	22,955	28,808	125	27,637	1171
Fingal County	19,469	20,576	106	20,355	221
South Dublin County	17,665	16,858	95	17,019	-161
Total	112,053	115,474	103	114,790	684

Within the central Dublin area, the number of spaces matched well. Valuation Office spaces represented 92% of the number estimated from the combined method. Outside of the central area however, the Valuation Office data seems to account for just half of the number of spaces estimated from the NHTS / POWSCAR data. Outside of the canal ring there appears to be a significant gaps and under-reporting of the full number of free spaces available in the Valuation Office data set.

Table 6.4 Valuation Office vs Estimated Free Parking Spaces (Commute only)

Area	Estimated	Valuation Office	Diff	Index (Est=100)
Central Dublin (Sectors 1-4)	31,467	28,964	2,503	92
Remaining area covered by Valuation Office (Sectors 5-20)	174,152	85,573	88,579	49
Total area (Sectors 1-20)	205,619	114,537	91,082	5

Assumptions inherent in the FWPP space estimate process are:

- NHTS average free parking provision proportions are applicable across whole areas. In the case of ERM two areas are specified: central Dublin (sectors 1-4) and the remaining zones (sectors 5-38);
- POWSCAR attractions (as opposed to demand) are factored to match trip ends across all modes combined;
- POWSCAR car driver mode share of total commute or education attractions is used;
- Valuation Office data is not used in preference to the factored POWSCAR approach because it appears to be missing significant numbers of spaces outside of Central Dublin. Central Dublin spaces match well between the two approaches; and
- No spare unused free workplace car parking spaces exist, i.e. all other spaces must be paid for. There could be some zones where such an excess is real; however, it is assumed they are not transferable to other users, and therefore the total represents the free space supply.

6.6.4 Validation

The proportion of trips with access to free parking for each zone was applied to the total number of commuting and education trips to determine the number of trips utilising free parking spaces. However, there was no observed occupancy data which could be compared with the modelled data to validate the performance of the model.

Therefore, the modelled occupancy by time period and zone/sector was summarised and engineering judgement was used to check that the results appeared reasonable. These results are presented in Section 11.2.8.

6.7 Park and Ride

6.7.1 Overview

The purpose of the Park and Ride module is to determine which Park and Ride site will be used by each Park and Ride trip and to calculate the associated car and PT trip legs.

Within this model, a Park and Ride (PnR) trip is one which uses road and then PT for an outbound trip and returns using the same set of modes in reverse. Park and Ride is currently only allowed at specific zones which offer formal Park and Ride. This includes dedicated car park sites associated with bus-based PnR, or at rail and Luas stations (with or without formal parking). It does not consider drivers who travel to a residential area to park and then get a bus on to their destination to avoid paying a parking charge.

6.7.2 Mathematical Framework

The Park and Ride module uses a standard logit choice to calculate, for each pair of zones, the proportion of PnR demand which uses each alternative PnR site, based on the cost to travel between the two zones via that site. The process is shown diagrammatically in Figure 6.13.

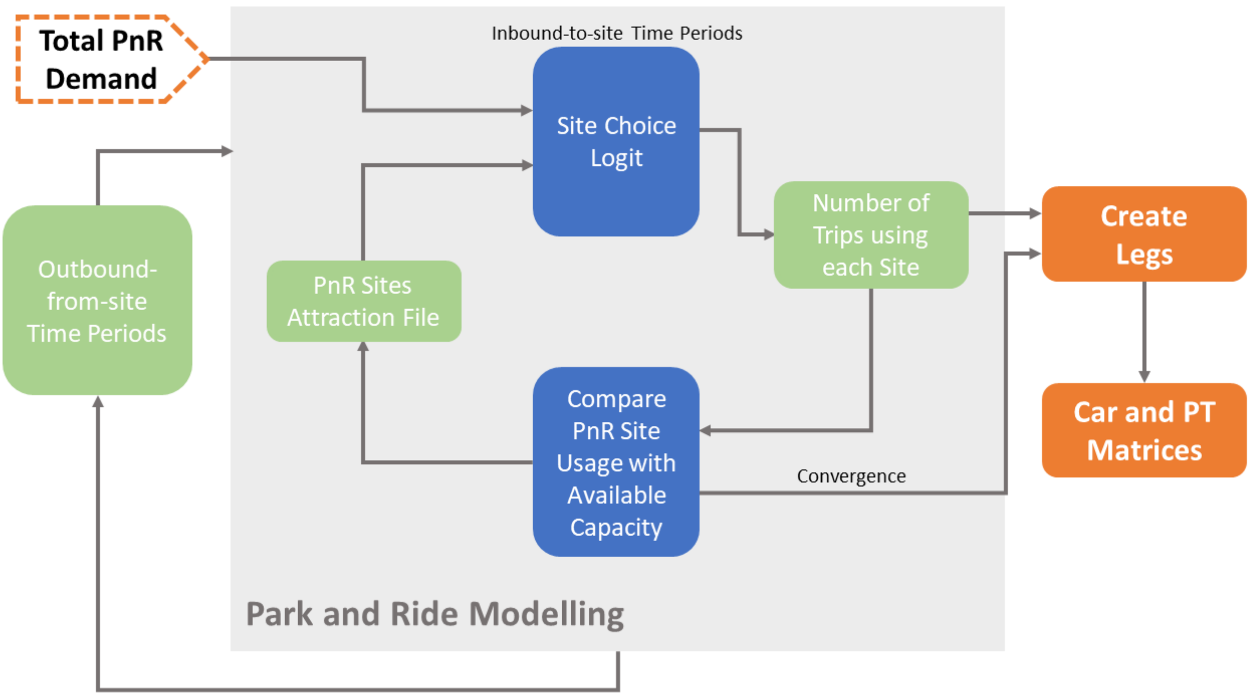


Figure 6.13 Park and Ride Model

The first stage is to create the total Park and Ride demand by adding together the demand from each user class[24]. Having obtained the total demand, the process then loops over the outbound-from-site time periods so as to process all tours leaving at the same time together.

For each outbound-from-site time period, the process enters a convergence loop in which it carries out site choice for each inbound-to-site time period separately. Site choice is based on the total trip cost from each origin zone to each destination zone via each permitted PnR site, which is calculated using the following equation:

$$PnRCost_{i,j,k} = CarCost_{i,k} + PTCost_{k,j} + ParkCost_k + Attr_k + Extra_k$$

Where:

$CarCost_{i,k}$ is the car cost associated with travel between the origin zone i and site k;
$PTCost_{k,j}$ is the PT cost associated with travel between site k and destination zone j;
$ParkCost_k$ is the cost of parking (per person trip) in site k;
$Attr_k$ is an additional calibration cost for site k which covers a range of variables which would affect the site's attractiveness (e.g. ease of connection to the local network); and
$Extra_k$ is a cost which increases as site k nears capacity.

[24] At this stage, the user class proportions are also calculated for each OD pair to allow the output to split back into individual user classes at the end of the module

To reduce the number of calculations required, both an origin and destination catchment are defined for each site. Origin catchments were originally defined as zones within 45 minutes' drive time of the site and catchments for bus and LUAS will be defined as the wider urban area which is associated with that service, such as Dublin City or Cork City. Catchments were then subject to a cleaning exercise to create contiguous areas and to ensure that travel choices were logical (for example, to remove destinations which could only be reached by a short PT trip and a long walk). Further details on the PnR site file and calibration of the site choice mechanism are provided in the *Parking Specification Report*.

The definition of catchments means that trips from zone i to zone j will only be given a choice between a subset of Park and Ride sites. Sites which are deemed illogical (i.e. where the cost to travel via the Park and Ride site is much higher than the direct travel cost) can be ignored in the site choice calculation below.

The probability that trips from zone i to zone j will choose site k is determined by the following calculation:

$$P_{k|i,j} = \frac{e^{-\lambda PnrCost_{i,j,k}}}{\sum_{k \in K} e^{-\lambda PnrCost_{i,j,k}}}$$

Where λ is the spread parameter.

The probability of choosing a particular site is then applied to the total number of Park and Ride trips between zone i and zone j, to get the number of trips using that site.

The total number of car arrivals and departures are summed for each site, allowing the occupancy to be calculated for each time period. The modelled occupancies for each site are compared to the available capacities, and where sites are overcapacity the "Extra" values are adjusted to discourage trips from using that site. The logit model is then re-run using the updated travel costs (including the revised "Extra" values) and the process is repeated iteratively until converge. The iterative loop is assumed to be converged when the changes in occupancy and "Extra" values fall below a pre-determined threshold or until a pre-set maximum number of loops is reached.

Having converged for one outbound-from-site time period the process then continues with the next until all five time periods are completed.

Once all five loops are completed the demand can be split back into user classes and individual trip legs (car from production zone to site and PT from site to attraction zone) can be created and the resulting matrices are passed forward to the Tour Aggregation stage.

For further details regarding the Park and Ride process then please refer to the *Parking Report*.

6.7.3 Park and Ride Input Preparation

The initial stage for defining model inputs is to allocate each Park and Ride site to the standard geographic zone where the site is located.

The Park and Ride model requires data about parking charges and capacities for each site. Parking charges are defined per day as the vast majority of sites offer unlimited parking for a fixed cost – this differs from the definition of parking charges in other model components which consider costs per hour.

Two types of parking are considered in this model, near and far. Near spaces are those which are directly operated by the site, for instance a rail station car park, while far spaces are those considered outside the site, but which travellers could still use in practice, such as parking on-street outside the station or at a nearby car park.

This is required as some locations already note that the number of vehicles using the station for Park and Ride exceed the formal capacity, and therefore the model must allow people to use other facilities.

It is possible to define a capacity for the informal far spaces which could be applied for example, at remote PnR site where parking outside of the formal parking area is limited. However, in practice this approach has not been used in the base year, and therefore all sites have a value of zero which assumes an infinite number of far spaces.

A summary of the parking charges and the number of spaces is provided in Table 6.5 and a map of the sites can be found in Figure 6.14.

Table 6.5 Park and Ride Site Data

Ref	Site Name	Model Zone	2019 Parking Charge (€/Hr)	Near Spaces	Far Spaces (Informal)
1	Adamstown	887	0.00	200	0
2	Athy	1225	4.00	90	0
3	Balally	562	5.00	421	0
4	Blackrock	584	6.00	70	0
5	Booterstown	577	4.00	130	0
6	Cheeverstown	818	2.00	312	0
7	Clondalkin_Fonthill	834	0.00	150	0
8	Clongriffin	497	0.00	400	0
9	Clontarf	405	4.00	117	0
10	Coolmine	918	4.00	170	0
11	Connolly	24	9.00	460	0
12	Dalkey_Station	660	4.00	70	0
13	Donabate	1105	4.00	210	0
14	Drogheda	1201	4.00	300	0
15	Dunboyne	1190	0.00	300	0
16	Enfield	1468	4.00	120	0
17	Gormanston	1400	4.00	137	0

Ref	Site Name	Model Zone	2019 Parking Charge (€/Hr)	Near Spaces	Far Spaces (Informal)
18	Hansfield	939	0.00	60	0
19	Heuston	189	9.00	480	0
20	Hazelhatch	1327	4.00	400	0
21	Howth	1051	0.00	10	0
22	Kilcoole	1618	0.00	15	0
23	Kildare	1221	4.00	260	0
24	Killiney	668	0.00	103	0
25	Laytown	1441	4.00	23	0
26	Leixlip	1636	4.00	40	0
27	Leixlip_Louisa_Bridge	1033	4.00	270	0
28	M3_Parkway	1338	0.00	1200	0
29	Monasterewin	1561	4.00	43	0
30	Mullingar	1796	4.00	60	0
31	Newbridge	1152	4.00	253	0
32	Portmarnock	1341	4.00	278	0
33	Red_Cow	809	4.00	727	0
34	Sallins	1314	4.00	260	0
35	Salthill_and_Monkstown	639	3.60	100	0
36	Sandyford	606	4.00	47	0
37	Shankill	674	3.00	100	0
38	Silver_Tankard	1486	0.00	20	0
39	Skerries	1117	4.00	200	0
40	Stillorgan	605	4.00	341	0
41	Sutton	1052	4.00	120	0
42	Garlow_Cross	1433	0.00	50	0
43	Ross_Cross	1351	0.00	50	0
44	Carrickmines	675	2.00	350	0
45	Navan	454	4.00	100	0
46	Kilmoon	1435	0.00	100	0
47	Bray	1012	4.00	100	0
48	Malahide	1070	4.00	100	0
49	Rusk_and_Lusk	1390	4.00	100	0
50	Greystones	1021	0.00	100	0
51	Maynooth	1332	4.00	100	0

Ref	Site Name	Model Zone	2019 Parking Charge (€/Hr)	Near Spaces	Far Spaces (Informal)
52	Balbriggan	1123	4.00	100	0

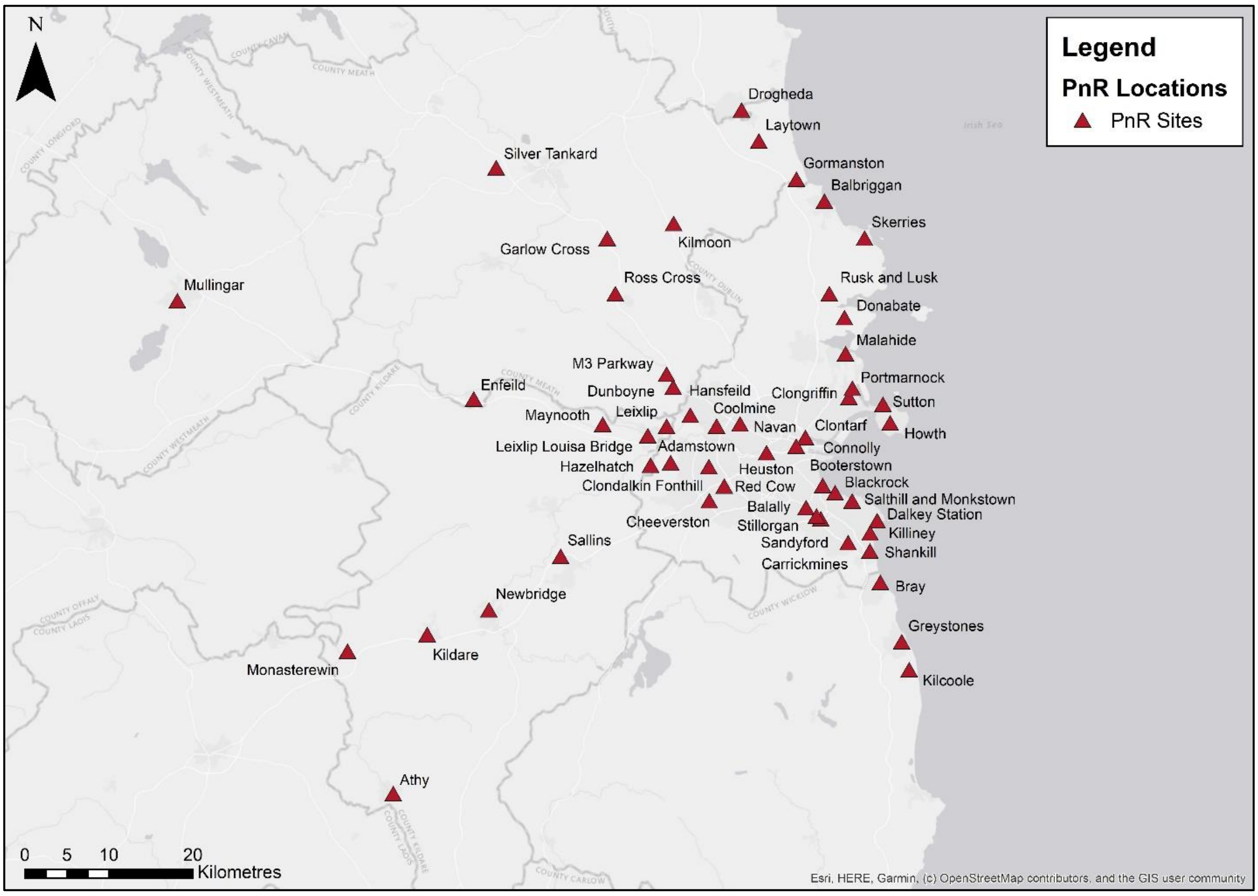


Figure 6.14 Park and Ride Site Locations

6.7.4 Preparation of Observed Data

Derivation of Site Occupancy

Observed occupancies by Park and Ride site were collected by Tracsis Traffic Data Ltd across a three-day period between 10th October 2015 and 22nd October 2015. Site occupancy was recorded at a single point in the day and the time was recorded. This meant that only a snapshot of the occupancy of each Park and Ride site was available ranging from survey times of 09:30 to 12:15.

It was necessary to derive an estimated occupancy for each site at the end of each time period in order to assess how well the forecasts matched these expected occupancies. It is acknowledged that the derivation of these estimated occupancies at the end of each time period boundaries can only be an approximation given the limited source data collected. Furthermore, the estimates occupancies have been based on assumptions which are applied across all Park and Ride sites and which in reality may vary between different locations.

These assumptions were based on observed NHTS tour proportions throughout the day as summarised in Figure 6.15. The coloured squares in the figure indicate which tours are assumed to be parked at a PnR site in each time period. For example, trips which arrive in the AM or LT time periods, but leave after the AM time period, are assumed to be parked at some point during the LT time period. The figures in the right hand column contain the sum of the tour proportions for each box (i.e. the proportion of all day traffic which are assumed to be parked in the relevant time period). These proportions can then be used to adjust the observed values. Arrivals in the off-peak are ignored hence the zero for that value.

OB \ IB	AM	LT	SR	PM	OP	Total	TP Usage
AM	4%	6%	5%	13%	3%	30.5%	30.5%
LT	0%	12%	9%	4%	1%	25.9%	52.2%
SR	0%	0%	9%	8%	2%	19.6%	53.9%
PM	0%	0%	0%	6%	5%	11.8%	42.2%
OP	0%	0%	0%	1%	11%	12.2%	
Total	4.4%	18.0%	23.7%	31.1%	22.8%	100%	

Figure 6.15 Park and Ride Occupancy Expansion

As an example, Adamstown had an observed 10% occupancy in the LT time period, which can be adjusted to estimate the occupancy in other time periods:

- AM: $10\% \times \frac{30.5\%}{52.2\%} = 6\%;$
- LT: $10\% \times \frac{52.2\%}{52.2\%} = 10\%;$
- SR: $10\% \times \frac{53.9\%}{52.2\%} = 10\%;$

- PM: $10\% \times \frac{42.2\%}{52.2\%} = 8\%$; and
- OP is zero.

This process enabled the occupancy to be estimated during each time period and these need to be adjusted to reflect the occupancy at the start of each time period. The final estimated occupancies were then compared to site use from the model and the results of this comparison can be found in Section 11.2.9.

Note that no capacity limit was placed on the estimated occupancy and, for a number of the smaller sites, the modelled maximum usage exceeded the number of spaces. However, this was also the case for several of the observed values.

Derivation of Park and Ride Geographical Travel Pattern

No data was available which captured the travel patterns of patrons who used individual Park and Ride sites, which potentially leaves a gap in any comparisons. To fill this gap, an estimate of travel pattern was made for each Park and Ride site to ensure that movements were considered appropriate.

This generally meant that there was a constrained set of origin zones for each site based on knowledge of the road network, available site usage, and site competition, while for destinations the zones were generally unconstrained. This reflects the assumption that most users of Park and Ride tend to use a reasonably local site to park but can then go anywhere (within reason) on the public transport network. The origin catchments for a number of larger sites are shown in Figure 6.16.

An exception to this rule was made for the following sites which are served by dedicated Luas services where passengers are less likely to interchange to other PT services. This results in a reduced destination catchment reflecting a more limited PT service:

- Ballaly;
- Carrickmines;
- Cheeverstown;
- Red Cow;
- Sandyford; and
- Stillorgan.

The destination catchment used for all Luas PnR sites is shown in Figure 6.17. The origin catchments of the “Red Line” PnR sites are shown in Figure 6.18 and those of the “Green Line” sites are shown in Figure 6.19.

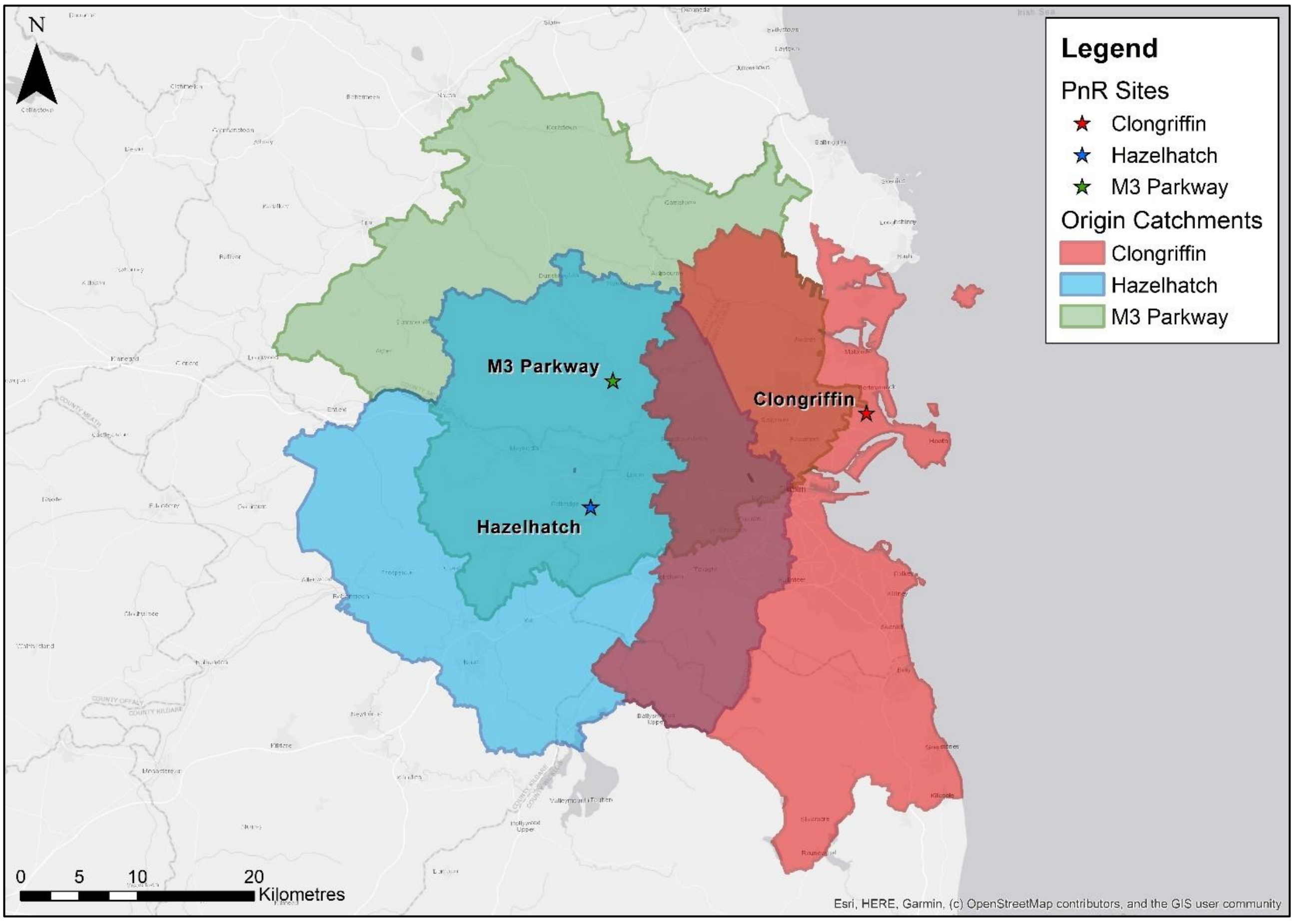


Figure 6.16 Park and Ride Origin Catchments (Example Non-Luas Sites)

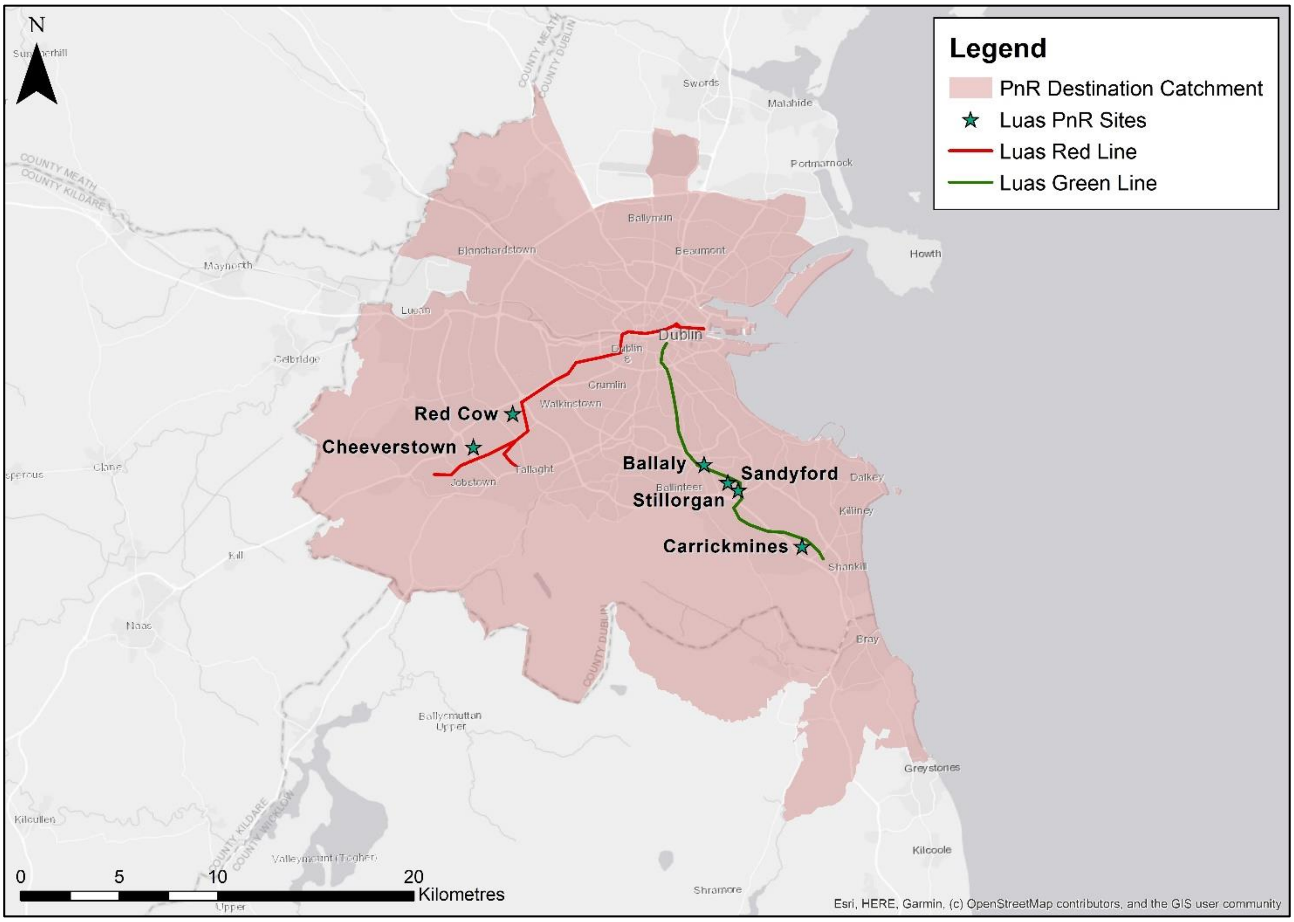


Figure 6.17 Park and Ride Destination Catchment (Luas Sites)

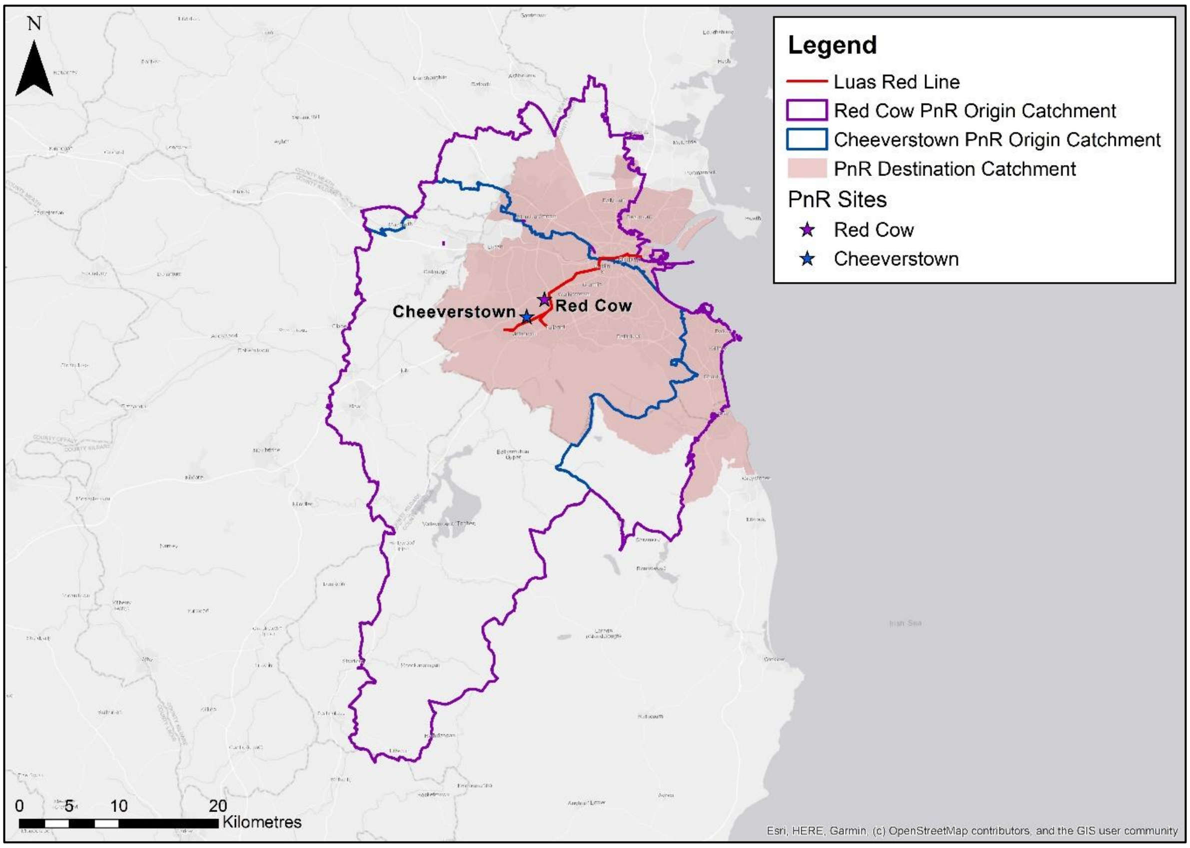


Figure 6.18 Park and Ride Origin Catchments (Luas Red Line Sites)

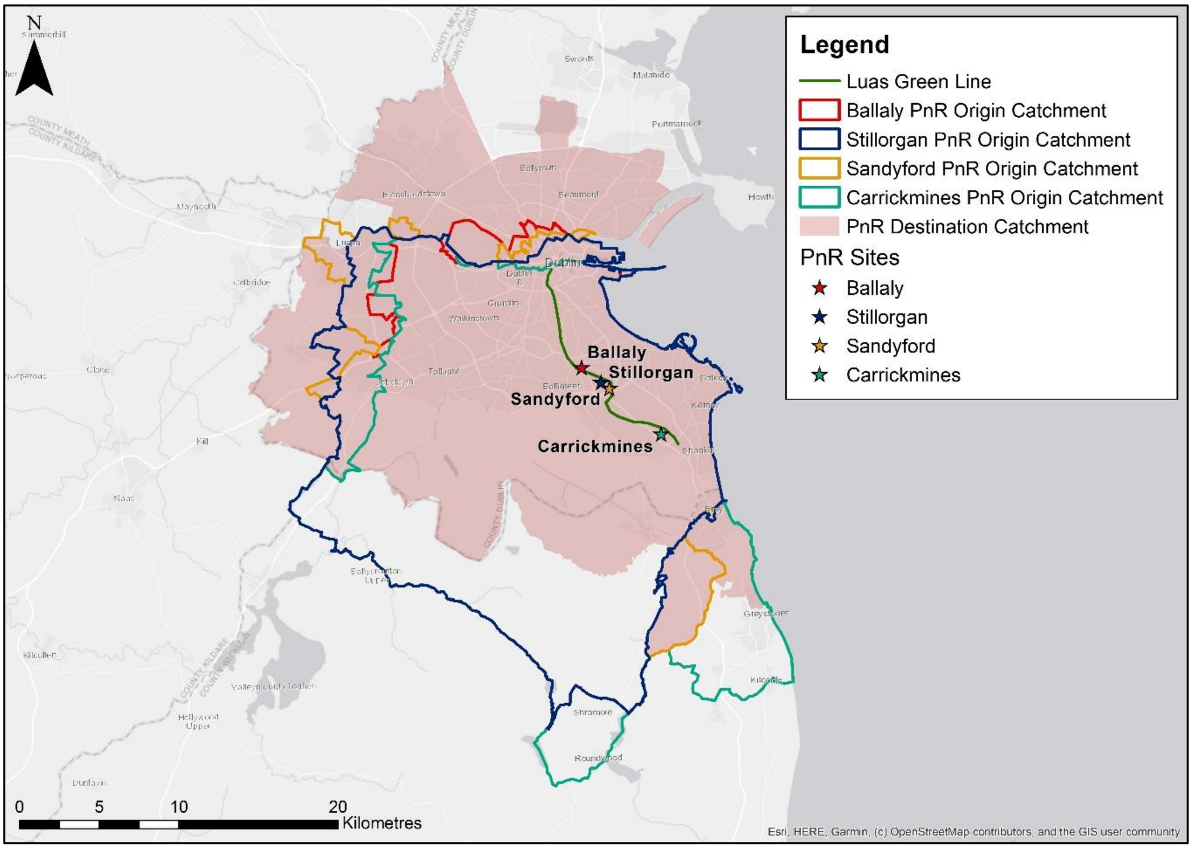


Figure 6.19 Park and Ride Origin Catchments (Luas Green Line Sites)

6.7.5 Calibration and Validation

Comparison of End to End Park and Ride Demand

As noted in the previous section, a set of estimated occupancies were created by expanding the observed data for each site. These were multiplied by estimates of demand and then aggregated across all sites, to give an overall estimate of PnR demand. This is directly comparable to the outputs from the Park and Ride model and an informal validation is undertaken to ensure that, at the highest level, the right level of demand and appropriate trip movements are being introduced to the Park and Ride module.

There are no acceptance criteria for these matrices given the large number of assumptions that are inherent in generating the “observed” targets, and it is further highlighted that leading transport guidance such as UK TAG does not provide any guidance on how close these matrices should compare.

6.8 Parking Distribution

6.8.1 Overview

Town and city centres, particularly the historic centres of large cities are acknowledged to have less parking supply than there is parking demand, particularly in certain areas. The usual response to this is for a proportion of travellers to switch mode or to travel to a different destination with less constraint. However, for some travellers a more logical response to limited parking availability is to park in another nearby location, with less constraint, and to walk to their final destination.

The Parking Distribution model component was developed both to simulate this behaviour, but also to provide travellers with an option to park remotely when there are other factors which may discourage parking in the destination zone. For example, parking in a neighbouring zone with cheap off-street parking to avoid expensive on-street parking at the destination, or parking outside the city centre to avoid delays crossing the canals.

The Parking Distribution model works similarly to Park and Ride by splitting road trips into two legs, which in this case are a road leg and a walk leg. An example is shown in Figure 6.20 below which illustrates what might happen if no parking was available at the ultimate destination: the traveller would park somewhere else (the red location) and walk the remaining journey.

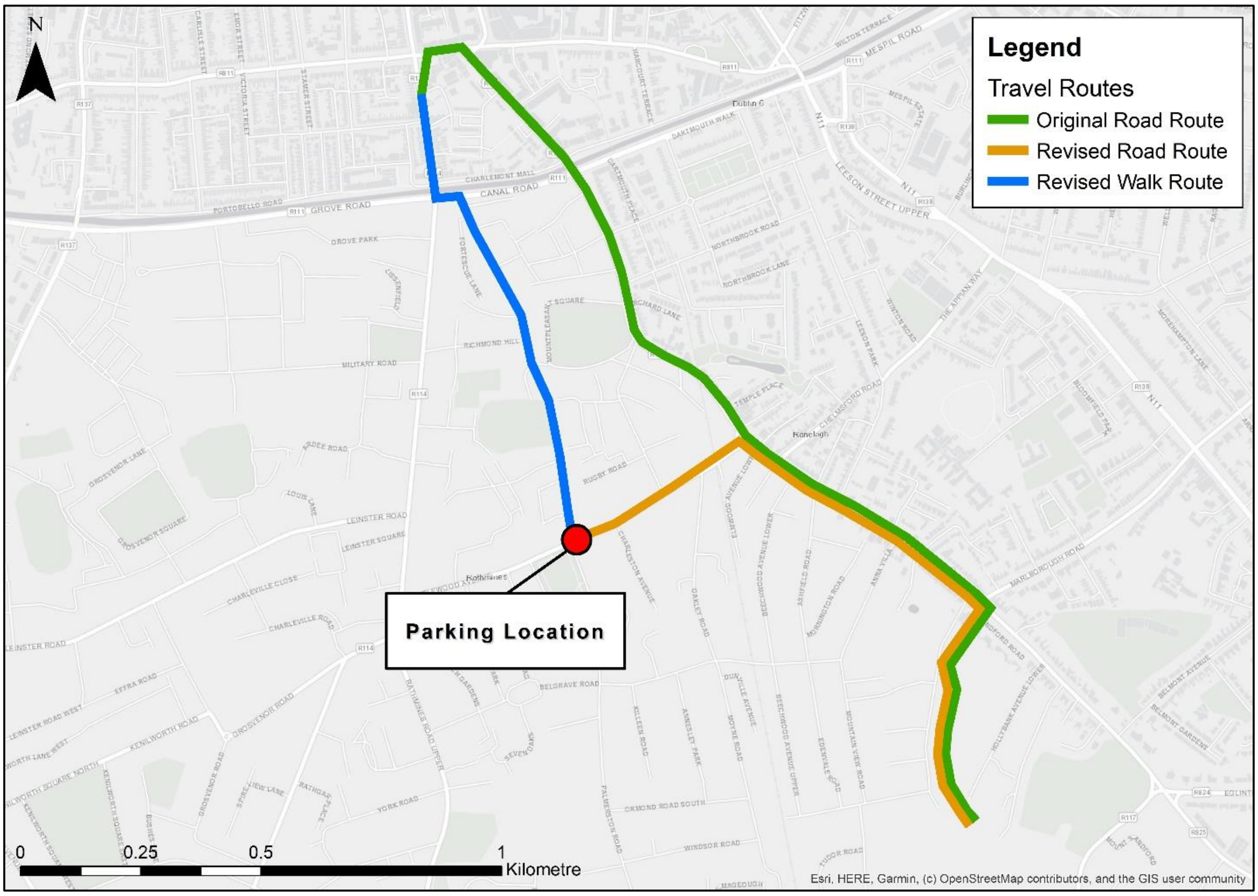


Figure 6.20 Parking Distribution Real World Example

The following sections provide a summary of the Parking Distribution model, and the processes required to prepare the model inputs. A more detailed description of the model processes can be found in the *Parking Report*.

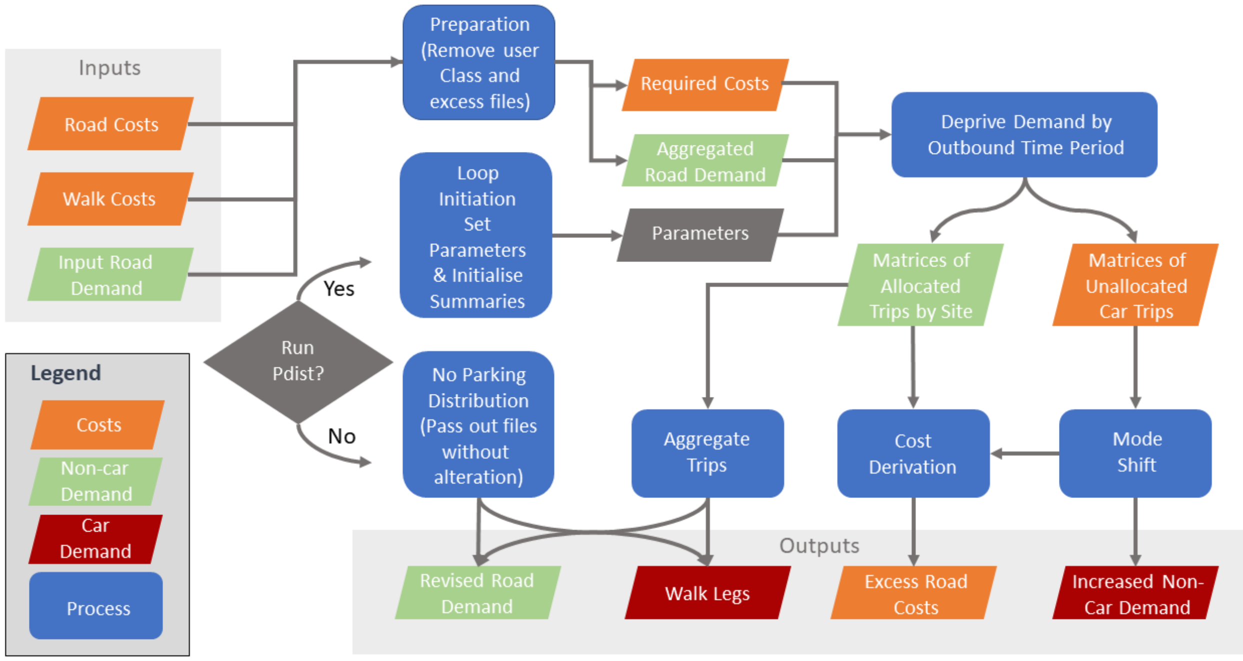


Figure 6.21 Parking Distribution Model Stages

The Parking Distribution model is composed by several stages as shown below in Figure 6.21 above. The figure shows processes as yellow boxes.

Preparation

The preparatory stage of the Parking Distribution model is used to simplify the number of calculations required by reducing the number of user classes considered through aggregation. The preparation step aggregates all demand into a generic user class by Tour and derives a proportion of trips for each initial OD pair by each user class, so that at the final stage of the process the aggregated demand can be split back out again.

The main component of the Parking Distribution model includes a looping mechanism which attempts to balance demand for parking in each zone with supply. On the first loop, parameters are initialised including the initial search times and space availability in each time period.

Derive Demand

The main process in the Parking Distribution calculates, for each pair of zones, the proportion of trips which park in each zone and for each outbound time period. A high-level flowchart of the processes is shown in Figure 6.22. This graphic shows some of the key inputs and outputs that transfer between the individual steps in the process. The available site capacity and matrices of unallocated demand (which is all demand on the first loop) are prepared in the loop initiation stage but are then subsequently overwritten on subsequent loops.

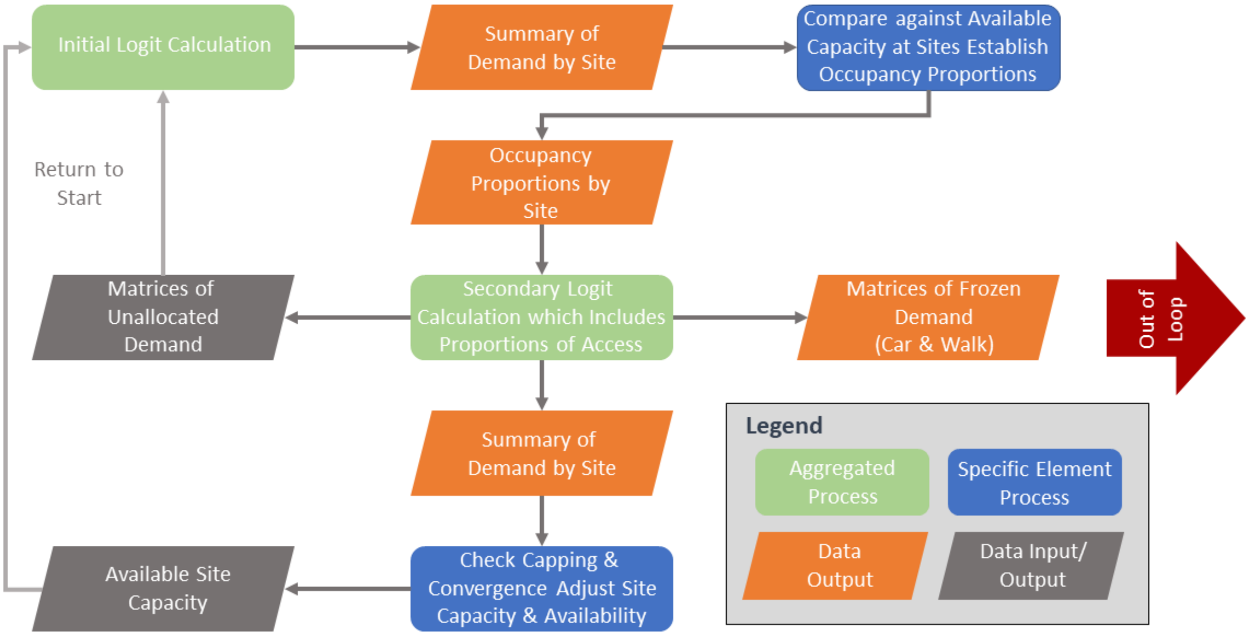


Figure 6.22 Parking Distribution Demand Derivation

The initial logit calculation and secondary logit calculation perform in the same way, however differ in terms of their outputs. The secondary calculation outputs demand as OD pairs whereas the initial calculation simply sums up the total demand for each parking zone so that it can be compared against the number of available spaces in the next stage; by restricting the detail of the outputs from the initial calculation, the model runs much faster.

The logit calculation seeks to proportionally allocate trips to intermediate parking zones[25] dependant on availability. The mathematical framework behind these decisions is laid out in the following section (Section 6.8.2).

Once the initial logit calculation has been undertaken and the demand is known for each site, this is compared against the available spaces. The available spaces are a running total of the number of spaces left unoccupied from earlier time periods i.e.

$$Available\ Spaces\ =\ Total\ Number\ of\ Spaces - Parked\ Vehicles$$

This clearly changes throughout the day and one of the key benefits of modelling tours is that the model can determine how many spaces are still available at different time periods.

Where demand exceeds the number of available spaces then only a proportion of demand can be accommodated. It is assumed here that every trip has equal opportunity to gain

[25] It should be noted that the group of “intermediate parking zones” includes all potential alternative parking destinations within the defined parking distribution area; this includes the destination zone itself (i.e. parking at the destination).

access to the available spaces, regardless of where they are originally coming from or going to, and consequently the proportion that obtain access can be derived as:

$$Access\ Proportion\ =\ minimum(1, [Available\ Spaces]/[Total\ Demand])$$

The secondary logit calculation undertakes the same calculations but also considers the proportion of travellers that get access to each zone. Demand at this point is split into:

- “Frozen” trips who gained access to a site and no longer have any decisions; and
- Unallocated trips who did not get access and thus still have to go through the next round of parking distribution.

The number of “frozen” trips should increase (and the number of unallocated trips reduce) on every iteration until specific convergence criteria are met. Once all trips have been allocated to a parking zone, the trips are split into their component car and walk legs, with the car leg travelling from the trip origin zone to the parking zone and the walk leg travelling from the parking zone to the trip destination zone.

If the iterative loop ends before all trips have been allocated to a zone, then the remaining unallocated demand is reallocated to another travel mode. This additional constraint mechanism is provided to ensure that on any individual main model loop, the Parking Distribution model does not output illogical results whereby the number of parked cars exceeds capacity. However, on subsequent iterations of the main demand-assignment model loop, the increased car costs associated with the over-allocated zones will influence the mode share (and destination choice to a lesser degree) in the main mode/destination choice model, resulting in there being fewer unallocated trips on the next full model loop.

Further details on all aspects of the Parking Distribution model can be found in the *Parking Report*.

6.8.2 Mathematical Framework

The Parking Distribution model calculates the probability of trips parking in a particular zone using a logit approach which compares the utility of all relevant choices and then applies that probability to the overall demand to work out the number of trips parking in each zone.

It is worth clarifying that the choice set that is being discussed is the set of zones considered within Parking Distribution on that loop – on the first loop this will be all those zones initially considered, but on subsequent loops and time periods the zones which are at capacity will be removed from the choice set, which helps to reduce model runtimes.

Utility in this element of the model is defined as:

$$U_{ijs} = \alpha R_{is} + \gamma W_{sj} + STime_s + Charge_s$$

Where:

U_{ijs} is the utility for trips between i and j via site s;

R_{is} is the road cost by tour origin i and site s;

W_{sj} is the walk cost by tour to travel between site s and destination j;

$STime_s$ is the search time for site s in generalised minutes based on occupancy which differs by arrival time period (described later in this section); and

$Charge_s$ is the personal charge for site s.

Where s and j are the same zone (i.e. the traveller chooses to park in their destination zone), then the walk cost is assumed to be zero.

The personal travel charge is defined as:

$$Charge_s = 60 \times \frac{PC_s \times duration}{2} \times \frac{CUCD}{VOT}$$

Where:

PC_s is the parking charge for site s in euro per hour;

$duration$ is the length of stay which is determined by the tour;

$CUCD$ is the car driver to car user factor; and

VOT is the value of time.

To derive the probability that trips will use an intermediate parking site to travel between two zones, the following formula is used:

$$P_{s|ij} = \frac{e^{-\lambda U_{ijs}}}{\sum_{s \in S} e^{-\lambda U_{ijs}}}$$

Where:

$P_{s\,|\,ij}$ is the probability that trips between zone i and zone j will park in intermediate parking site s;

λ is the spread parameter for Parking Distribution; and

S is the available choice set of sites.

Clearly the probability summed across all sites is equal to 1 for any given pair of i-j zones, so that no trips are lost in this mechanism.

Search Time Derivation

Search Time is modelled as a linear relationship between the percentage occupancy (which is capped at 100%) with an intercept of zero and a gradient of 0.15. A plot of the function is shown in Figure 6.23. The gradient is an assumption which yields an intuitive relationship between occupancy and search time, e.g. if spaces are all half-full an average search time of around 7.5 minutes is modelled, if they are 90% full, a search time of 13.5 minutes is modelled.

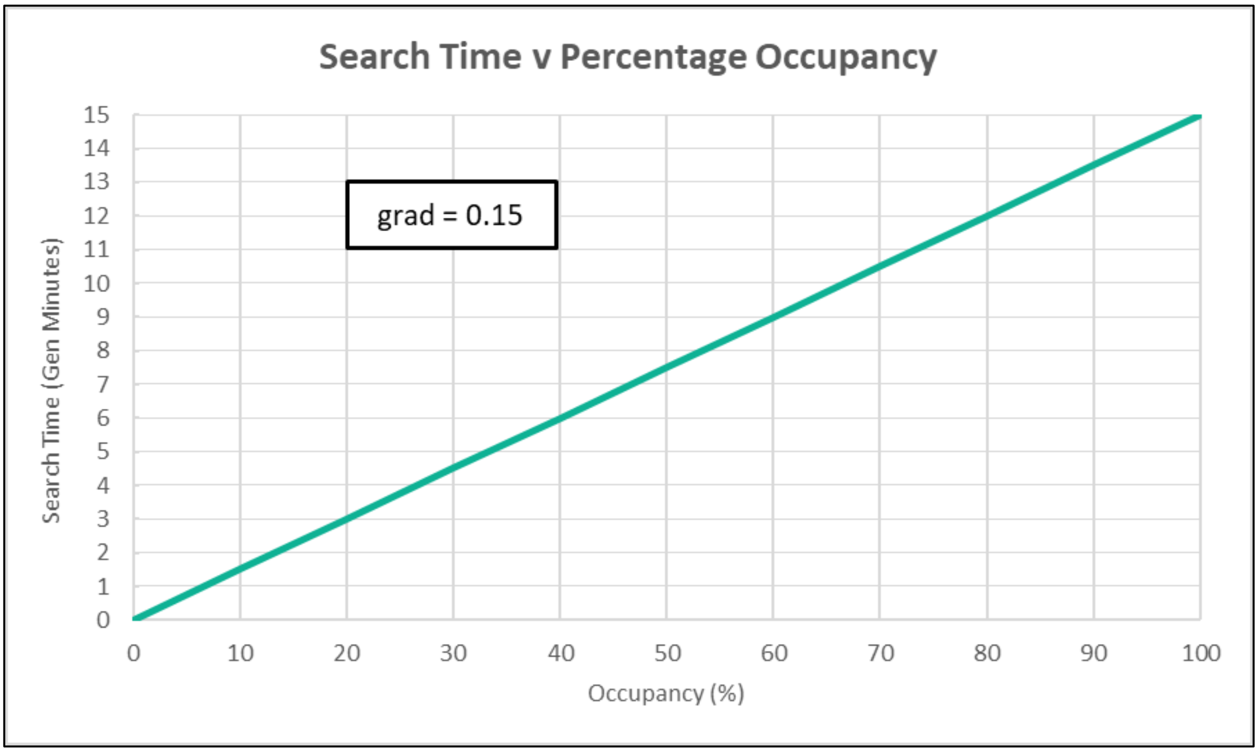


Figure 6.23 Search Time Function (Linear)

Stopping Criteria and Overcapacity Mode Shift

The stopping criteria for the Distribution stage of the model are as follows:

- No remaining unallocated demand;
- No available capacity; or
- A maximum iteration number is met (defined by the user).

The first criteria can be seen as the system converging, as all demand is allocated to a suitable parking space, and it is the most desirable outcome.

If there is no available capacity (second criteria) then this means that the maximum amount of demand has been allocated and therefore running further loops would not manage to achieve anything as there would be nowhere for travellers to park. If either of the second or third criteria are met, then the remaining unallocated demand is moved onto alternative travel modes. The mechanism to achieve this is to apply the existing mode choice proportions which are output from the Mode and Destination Choice model, but with the car mode removed from the choice set and the other mode shares increased pro-rata.

Further information on the mechanism can be found in the *Parking Report*. The number of loops will vary by year and scenario. Further discussion on model convergence can be found in Section 11.2.10.

Cost Derivation

The Parking Distribution model may allocate trips from a particular origin-destination zone pair to a number of different parking zones. Each parking zone will result in different costs incurred by the trip maker as car driving distances and times, search times, parking charges and walk times (to the final destination zone) will vary. Therefore, some average measure of car cost between each origin-destination zone pair needs to be passed back to the mode-destination choice model for use in the next Demand Model loop. A weighted average cost is used for this purpose and is derived using the following calculation.

The weighted average cost (which differs for each tour) is defined as:

$$Cost_{ij} = \left(\frac{\sum_{s \in S} Cost_{ijs} \times Demand_{ijs}}{\sum_{s \in S} Demand_{ijs}} \right)$$

Where:

$Cost_{ij}$ is the average utility to travel between zone i and zone j via any intermediate parking site (including parking in the destination zone);

$Cost_{ijts}$ is the overall utility to travel between zone i and zone j, parking in intermediate zone s (discussed below); and

$Demand_{ijts}$ is the number of trips between zone i and zone j and parking in intermediate zone s.

The cost here is the same used in the utility equations and is defined as:

$$Cost_{ijs} = Road_{is} + Walk_{sj} + (PCharge_s \times duration) + STime_s$$

Where:

$Road_{is}$ is the cost to travel by car between origin zone i and parking zone s;

$Walk_{sj}$ is the cost to travel by car between parking zone s and destination zone j;

$(PCharge_s\ X\ duration)$ is the cost to park per hour in parking zone s multiplied by the average parking duration (which is determined by the tour); and

$STime_s$ is the search time for parking zone s, which differs by arrival time period.

As in the utility equations, zones *s* and *j* can be the same zone, in which case the walk cost is assumed to be zero. The average overall costs (including parking charges and journey times via alternative zones) is then compared to the direct cost to travel by road (i.e. without any parking charges or intermediate parking zones) for every origin-destination zone pair. The resultant factor can then be used to adjust the road skims on the next iteration of the model, reflecting the impact of parking distribution on overall travel costs.

For further details regarding the Parking Distribution process then please refer to the *Parking Report*.

6.8.3 Input Preparation

The Parking Distribution model is applied to an area centred on the paid-parking, higher demand city centre area, extending to 249 zones model zones, as shown in Figure 6.24. The zones outside this central Dublin area are not included in the Parking Distribution model. Due to limitations in the software the maximum number of zones that can be included in the parking distribution model is 250.

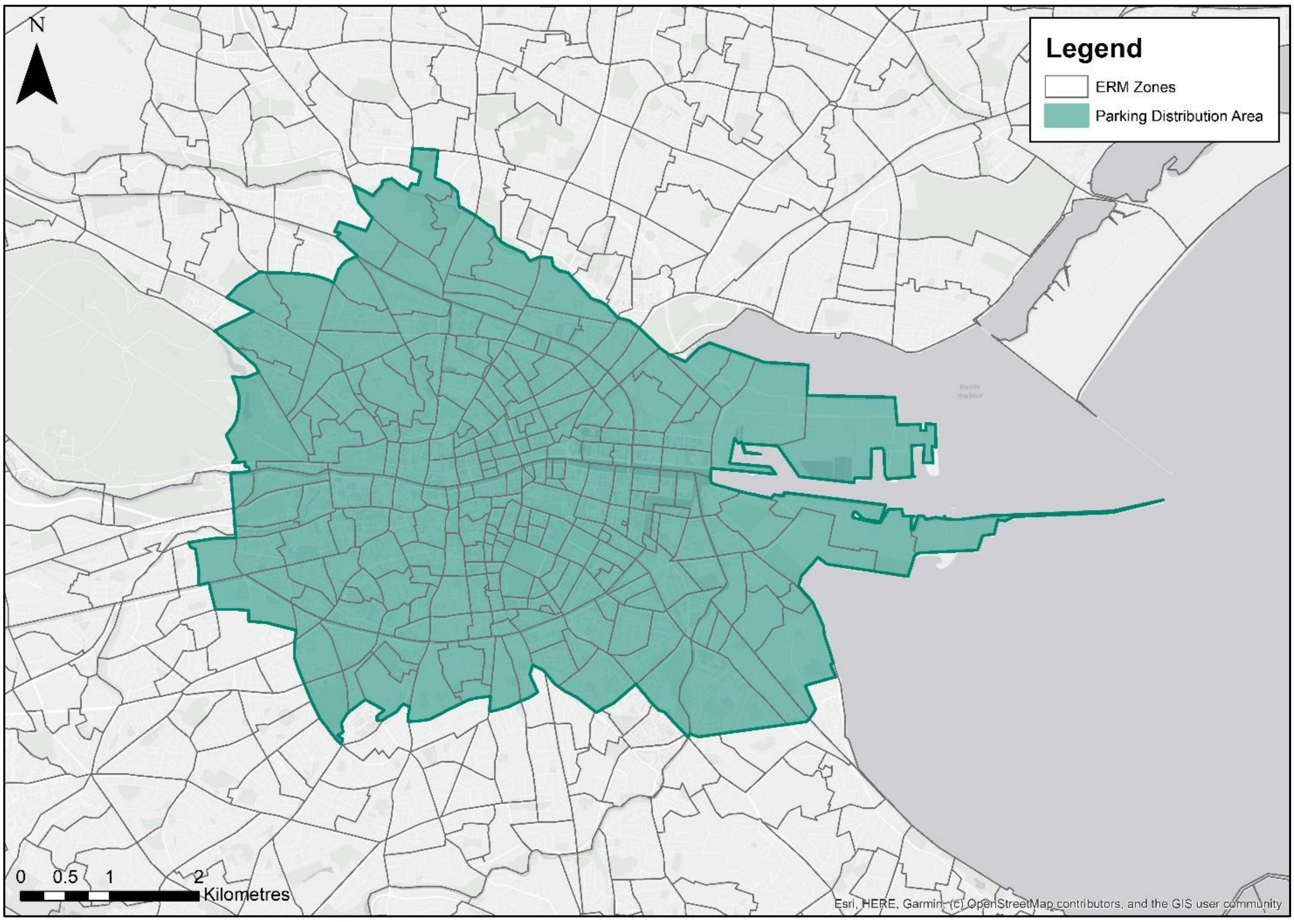


Figure 6.24 Parking Distribution Area

Note that there is no cap on the maximum walk length and all zones which are defined as part of the parking distribution area can be used as an alternative parking zone to any other zone in the area.

For every zone within the Parking Distribution area, the model requires a number of inputs such as parking charges and capacities.

Parking Capacity Data

The parking capacities of zones within the parking distribution area were derived from a number of sources including:

- For Multi-storey car parks, sources included the websites of the car park operators, Parkopedia[26] and Dublin City Council;

[26] Parkopedia is the world's leading parking service provider which contains detailed information on over 70 million parking spaces in 89 countries.

- For on-street parking within the parking distribution area, some of the locations of parking metres and the number of associated spaces were supplied by Dublin City Council; and
- Paid parking locations not included in the Dublin City Council data, as well as uncontrolled on-street parking capacity, were estimated.

The estimation of both undocumented paid parking and uncontrolled (or free) on-street parking capacity is described below.

Estimation of On-Street Parking Capacity

The estimation of parking capacity was performed by estimating the number of parking spaces per unit street length (excluding motorways, high speed national roads or pedestrianised streets) for a given zone. Zones were broadly categorised into two types based an analysis of the land use features within the zone. The Non-Residential category was defined to include industrial/non-retail commercial dominant, which tend to have fewer on-street parking facilities. The Residential category was defined to include zones with a residential/retail use, which have typically more on-street facilities. A road-length-to-space ratio was derived for each category by counting available capacity on a sample of streets using Google Street View.

Figure 6.25 and Figure 6.26 show the allocation of zones to each parking category. Note that categories were established within the M50, but capacities were only applied in the Parking Distribution area.

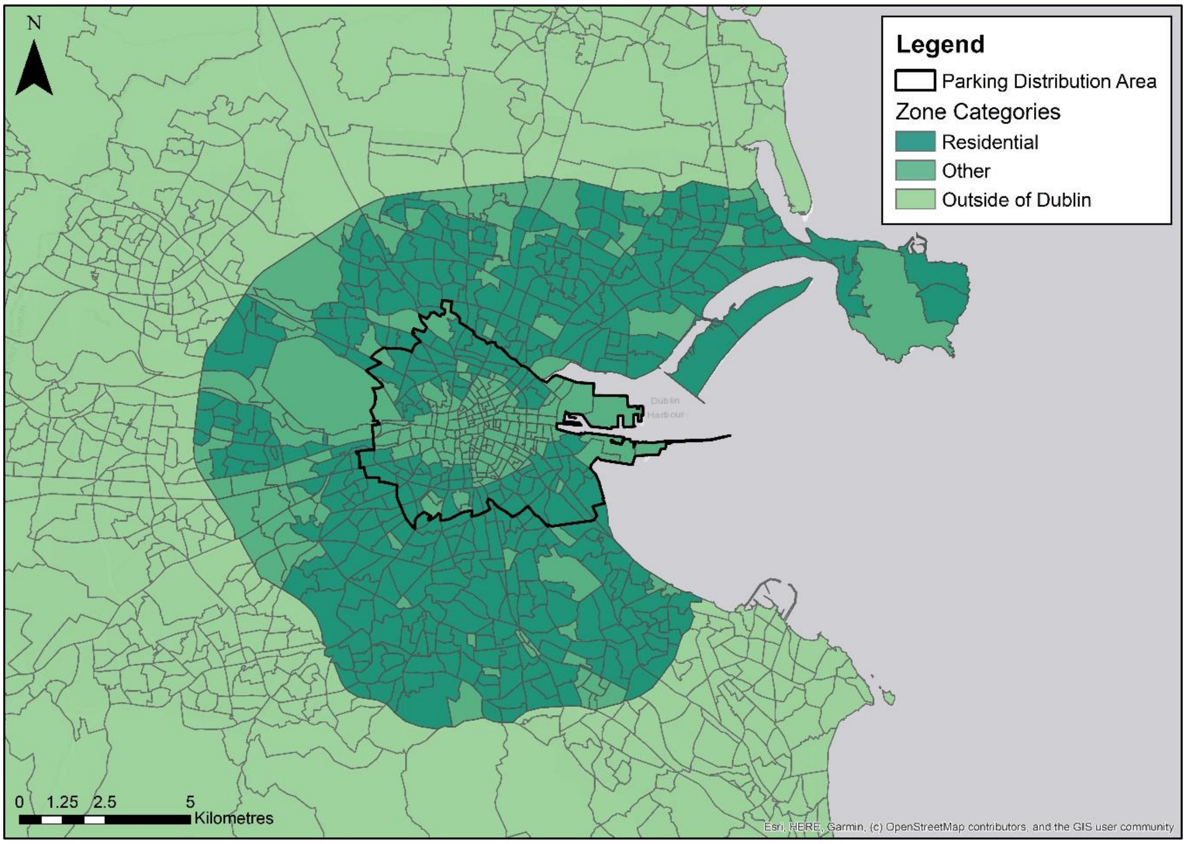


Figure 6.25 Parking Zone Category Definitions

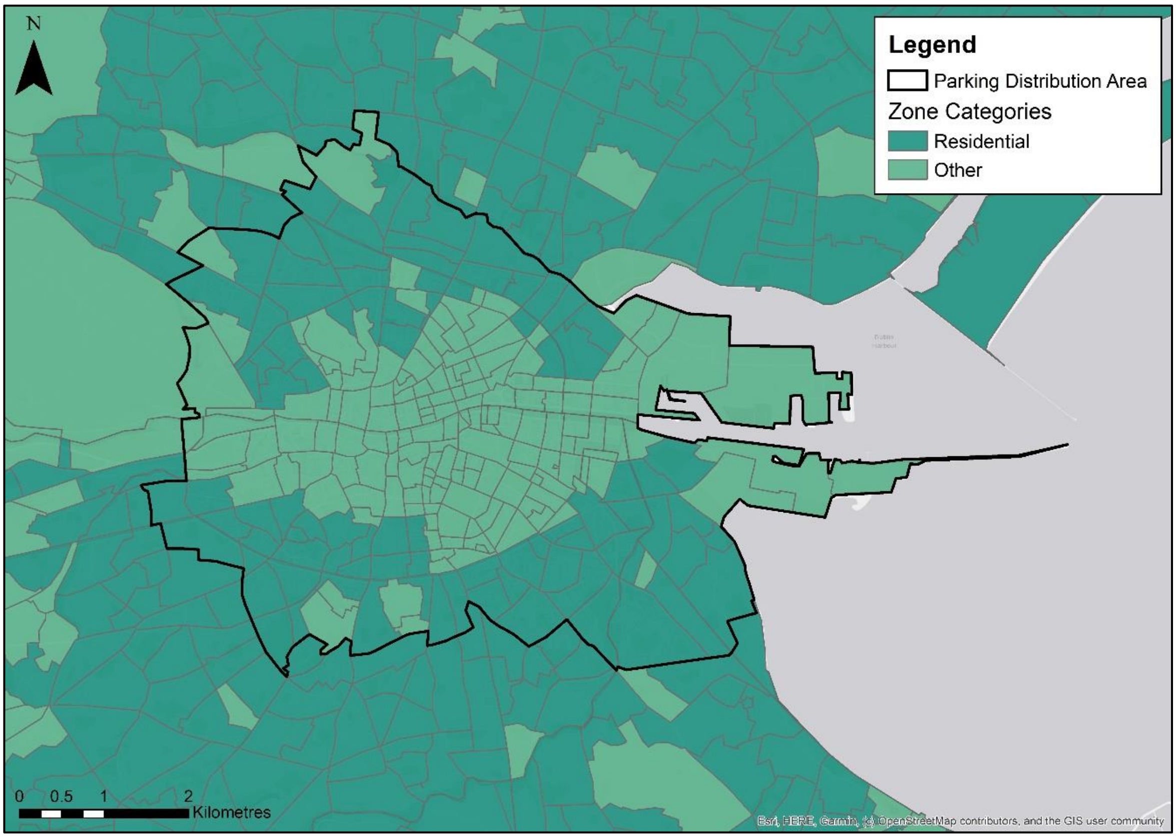


Figure 6.26 Parking Zone Category Definitions (City Centre view)

Based on the Street View analysis, residential areas are estimated to have approximately three times the number of on-street spaces per road kilometre than non-residential areas. The areas sampled and the estimated parking densities are shown in Table 6.6.

Table 6.6 On-Street Parking Capacity

Zone Category	Parking Capacity, Spaces/km	Example Zones Examined
Residential	78.1	Drumcondra / Stonneybatter / Portobello / Harold cross
Non-Residential (Other)	26.5	St Patrick Cathedral / City Centre / Usher Street / Around Connolly / City Quay / National Museum

Using a combination of multi-storey, known parking spaces and estimated uncontrolled spaces, the total number of parking spaces per zones was calculated as follows:

Maximum (known parking spaces, estimated free spaces) + multi-storey spaces

To take account of a proportion of the spaces calculated above being occupied before any new drivers attempt to use them, only a proportion of parking spaces were assumed to be available based on the same zone classification described above:

- Residential Area - 50% of parking spaces available; and

- Non Residential “Other” Area - 90% of parking spaces available.

The final available parking space capacity by zone is illustrated in Figure 6.27.

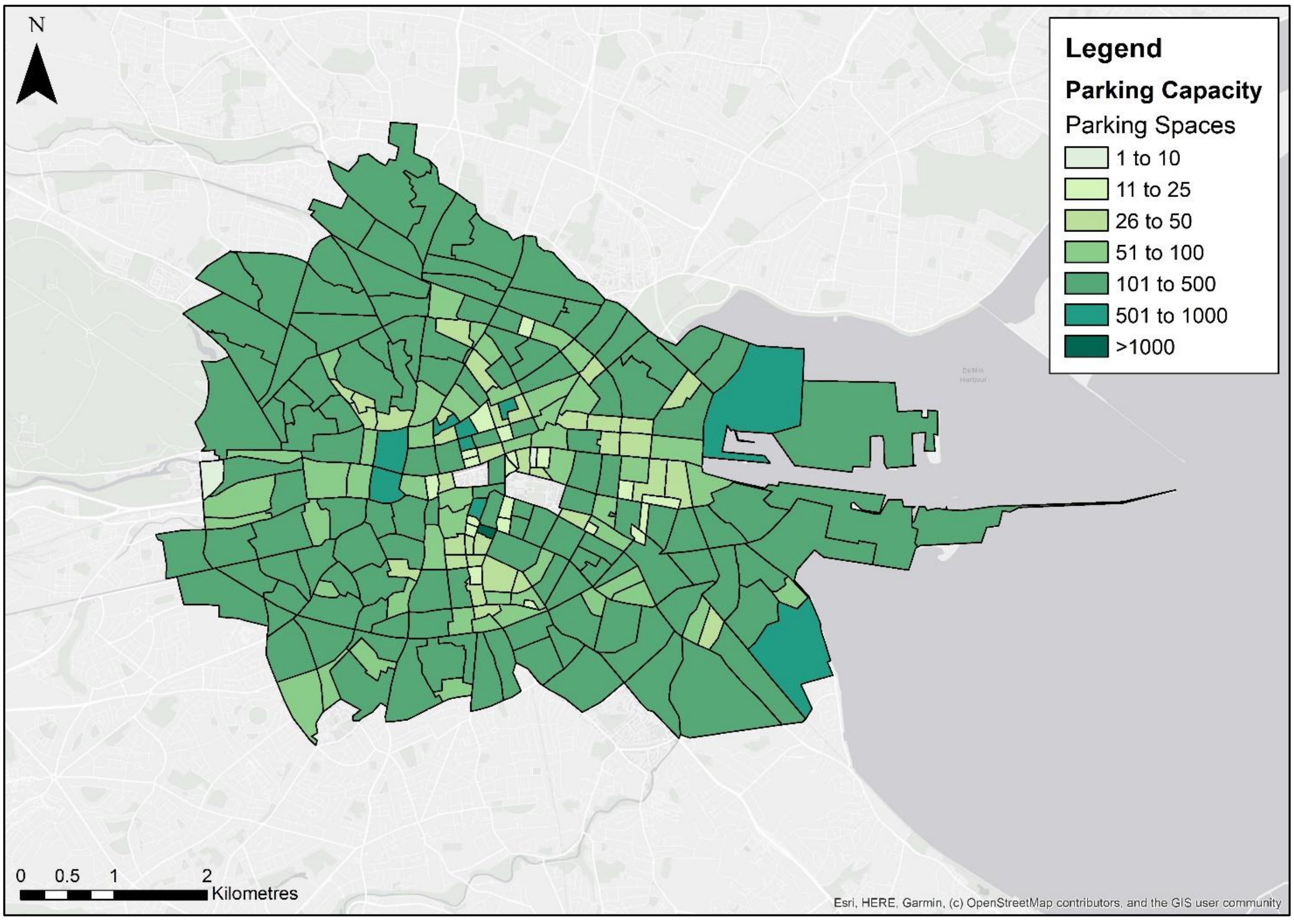


Figure 6.27 Parking Distribution Capacity by Zone

Average Parking Charge by Zone

An hourly charge for multi-storey parking for each zone has been calculated, based on the weighted average prices charged by the parking operators.

From this, a parking charge per zone has been calculated, as the weighted average charge between paid parking, multi-storey parking and free parking. In addition to providing an input to the parking distribution model, the calculated parking charges are also included in the road model assignment costs for all applicable destinations.

Details on the hourly parking charge by zone are provided in Figure 6.28.

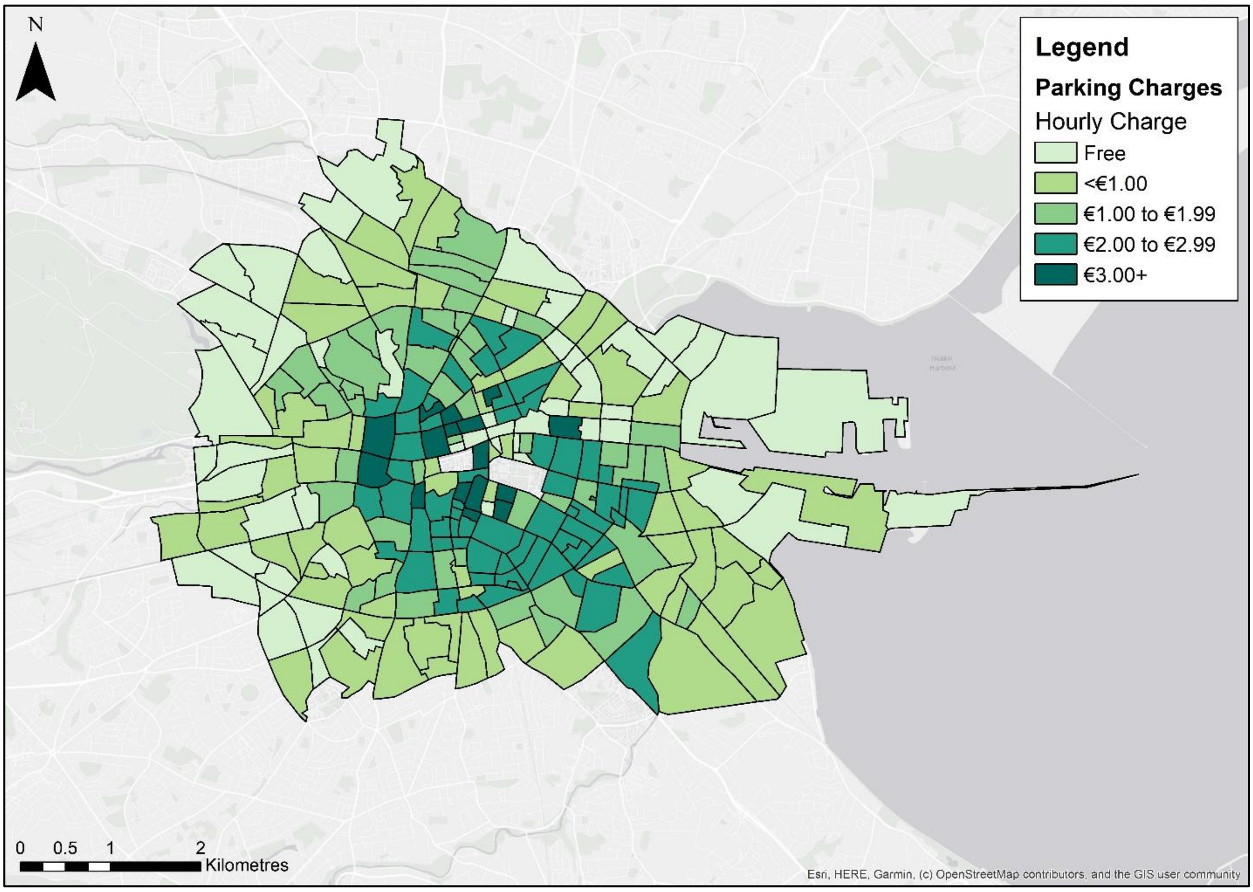


Figure 6.28 Hourly Parking Charge by Zone

6.8.4 Calibration and Validation

The Parking Distribution model is an algorithm which relies on a very limited number of parameters to function and is therefore not subject to any particular calibration. A list of parameters which can be adjusted as part of the calibration process is provided in Table 6.7.

Table 6.7 Parking Distribution Calibrated Parameters

Parameter	Base Year Value / Units	Description /Source
Lambda	-1.0	Spread parameter for logit model, set to most sensitive to essentially make travellers choose only the lowest cost choice.
Alpha	1	Weight on car legs (applied to car cost skim sans parking).
Gamma	1.5	Weight on walk legs, (applied to cost skim) and used to provide an additional prohibition to long walks – no source.
Gradient	0.15 (gen minutes / % occupancy)	As discussed in Chapter 7, a linear search time function has been introduced to incur a penalty if there is no space available.
Minimum Demand	0	Minimum number of trips remaining to be allocated before equilibrium reached, set to zero but had been set higher to evaluate runtimes.
Car Occupancy	1.18	Generic car occupancy (based on commute) which is applied to all user classes.
Value of Time	12.91 € per hour	Generic value of time used to convert parking charges to generalised minutes (based on commute) which is applied to all user classes.

No parking space occupancy data is available to check that the output from the Parking Distribution represents the actual use of parking capacity in the treated area. It is therefore difficult to confirm that the resultant model changes match the observed situation. However, the following checks have been undertaken to quantify the impact of the changes and to reassure that these changes are intuitive:

- Occupancy of Parking Spaces;
- Stability of Model Process; and
- Impacts on mode shares and subsequent effect on other assignment validation.

These results are presented in Section 11.2.10.

6.9 Special Zones

6.9.1 Overview

The purpose of the Special Zone stage is to calculate the distribution and mode choice of trips travelling to and from each special zone, which can't otherwise be modelled by the main Mode and Destination choice model. The Special Zone process is used predominantly to represent the travel choices of international passengers arriving at or departing from ports and airports, but its functionality could be extended to model any zone with atypical travel behaviours.

Ports and airports require a special approach to Demand Modelling, because they represent a gateway for an external demand from other countries. Demand associated with these zones cannot be predicted in a standard way (based on the land uses contained within them) as it depends on factors not included in the model, such as the range of flights and destinations available.

The Special Zones module takes the predicted total travel demand to and from each special zone (which is generated by the NDFM) and distributes this demand within the regional model area. Distribution within the Special Zones module works with four user classes:

- Residents on Employer's Business;
- Residents with Other journey purposes;
- Visitors on Employer's Business; and
- Visitors with Other journey purpose.

The Special Zones module also calculates mode share for the above user classes. Modes considered within Special Zones module include:

- Stay (Park) and Travel (only available to residents);
- Kiss and Travel;
- Car Hire (only available to visitors);
- Taxi; and
- Public Transport.

6.9.2 Modelling Process

An overview of the Special Zones Modelling process is shown in

Figure 6.29 and the following sections describe each of the stages within the process.

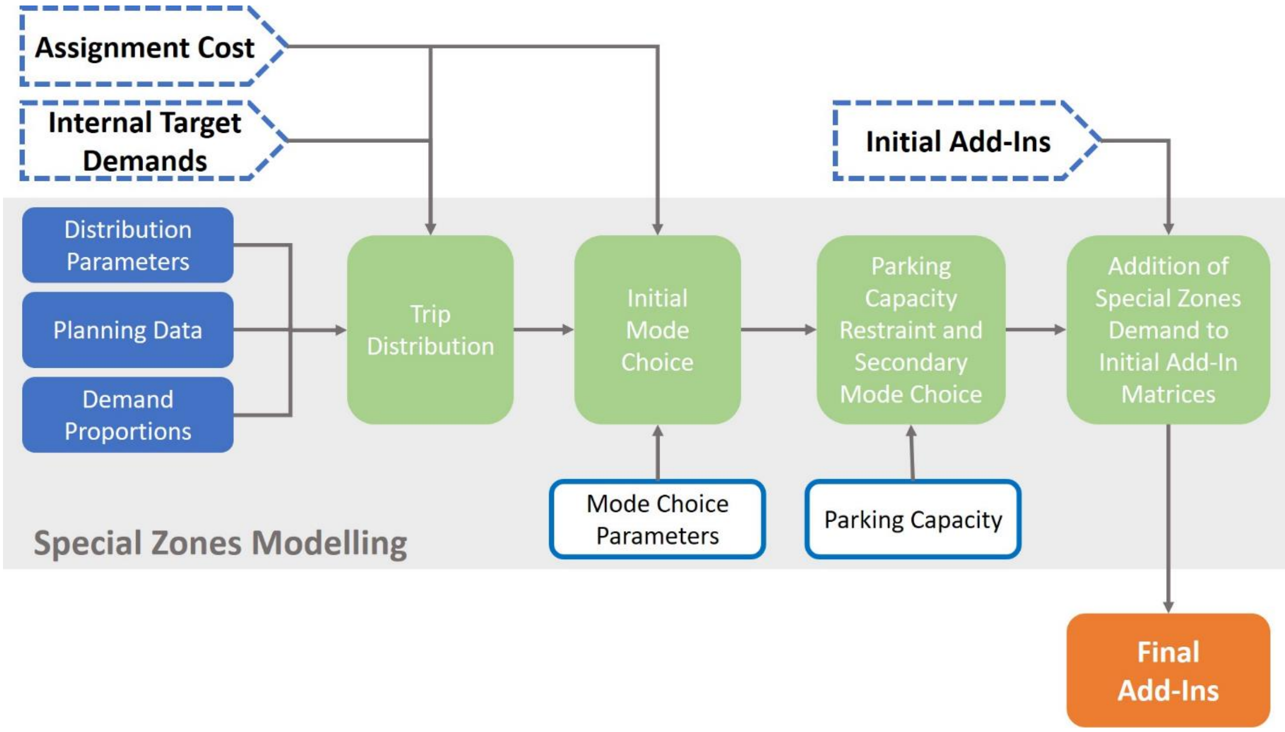


Figure 6.29 Special Zones Modelling

Trip distribution

The Trip Distribution stage derives distribution of passenger demand within regional model for each special zone located in that model. It consists of three substages:

- Planning data extraction;
- Cost extraction; and
- Application of a gravity model.

The planning data extraction stage involves reading input planning data at the CSA level (generated by NDFM), aggregation of these at the ERM zone level and extraction of total population, population in full time employment, job attractions and education attractions.

The cost extraction stage involves reading cost data generated by the ERM assignment models. The cost data is converted to utilities using the same calculation as in the standard Mode / Destination choice stages (described in Section 6.5.2), and using the values of time taken from the appropriate demand segment (i.e. employers business, or other).

The gravity model stage splits the total demand into individual time periods and user classes and then taking the costs, planning data and distribution coefficients, the model calculates the relative demand to each zone using the following equation:

$$T_{i,j} = \frac{(A_P P_i + A_F F_i + A_J J_i + A_E E_i)}{Cost_{i,j}}$$

Where:

A_p, A_f, A_j and A_e are coefficients which are applied to the different planning data;

P_i, F_i, J_i and E_i refer to total population, population in full time employment, job attractions and education attractions in zone i respectively; and

$Cost_{i,j}$ is the cost to travel between origin/destination i and special zone j.

These relative demands are then factored to the target demand.

Initial Mode Split

The purpose of the Initial Mode Split stage is to calculate the travel demand by each individual travel mode to/from the special zones. The procedure reads assignment cost, standard mode choice parameters and user defined inputs to calculate costs for the following modes:

- Stay (Park) and Travel;
- Kiss and Travel;
- Car Hire;
- Taxi; and
- Public Transport.

These costs are then converted to utilities using the standard model function (as described in Section 6.5.2). The ASC values used in the utilities calculation are specifically calibrated to the observed mode split at the individual airports.

The mode share is then calculated using the same mathematical framework as in the standard Mode Choice model stage, converting person trips to car trips as appropriate.

Capacity restraint and secondary mode split

The purpose of this stage is to redistribute Stay and Travel trips, where the level of demand for this mode exceeds parking capacity at the individual special zones.

Number of available parking spaces and average parking duration for each special zone is defined by the user.

Daily demand for parking is derived from the matrices generated in the Initial Mode Split stage and multiplying the number of Stay and Travel arrivals by the average stay length (in days) for each user class. The model works out the number of trips which cannot be accommodated and then redistributes the excess trips pro-rata across the other modes for each OD pair.

Addition of special zones demands to initial add-in matrices

The matrices generated by the secondary mode split stage are converted from the time period level to hourly matrices and then added to the other add-in matrices ready for inclusion with other demands at the Assignment Preparation stage (described in Section 6.13).

For further information on the Special Zones process, please see the *Special Zones Report*.

6.9.3 Input Preparation

The Special Zones module requires a number of inputs, including the:

- Total demand for each special zone;
- Time period and user class proportions for each special zone;
- Planning data, including population, job attractions and education attractions at CSA level;
- Parking data for each special zone, including number of available parking spaces and average duration of parking (in days); and,
- Other costs for each special zone such as parking charges, taxi fares and car hire costs.

This chapter discusses preparation of inputs for special zones located within the ERM area. Within the ERM area the following zones are considered as special zones:

- Dublin Airport (zone 908);
- Dublin Port (zone 82);
- Dun Laoghaire Port (zone 640); and
- Dundalk port (zone 1251).

Inputs for the Trip Distribution Stage

The total demand (in person trips) travelling to and from each special zone on an average weekday is generated by the NDFM. The proportion of trips travelling in each time period and segmentation by user class (Residents and Visitors) and trip purpose (Employer's Business and Other trip purposes) were derived from observed data for Dublin Airport. For the other special zones within the ERM area no observed travel pattern and mode share data were available and therefore the same demand proportions as derived for the Dublin airport were used.

Planning data for the standard zones, which are used as attraction weightings in the distribution model, include total population, population in full time employment, job attractions and education attractions. This data is generated by the NDFM.

Inputs for Initial Mode Choice

The mode choice function is a logit model which compares the utility to travel by each mode. The utility function is defined as:

$$\text{Utility} = \alpha \text{ x Cost} + \beta\text{x} \ln(Cost) + ASC$$

α and β parameters are extracted by the process from the main model, they are provided separately for car and PT, and separately Employer's Business and Other trip purposes; and

ASC constants are user-defined. For the Dublin Airport, these parameters were calibrated based on the passenger survey conducted in 2016. For the other special zones, the constants are based on calibration of the special zone model.

In addition to the travel cost for each mode, which are skimmed from the assignment models, the Cost variable also includes parking, car hire and taxi costs.

Cost associated with long-term parking (based on a daily parking charge times the average number of days parked) are based from observed data. Car hire costs are based on current typical daily hire rates, and have been adjusted as part of the model calibration. Taxi fares are calculated by applying a factor to car travel cost. The factor has been calculated to produce typical taxi fares to/from the airport, which can be adjusted as part of the model calibration.

Inputs for the Parking Capacity Restrain and Secondary Mode Choice Stage

The parameters regarding long-term car-parking capacities and average duration of stay are initially based on observed data, and have been adjusted as part of the calibration of the Special Zone model.

6.9.4 Calibration

This section describes the two separate steps of calibration as part of Special Zone modelling.

- **Trip distribution** – this involves estimation of distribution parameters associated with individual data fields from the NDFM planning dataset using the following approach:
  - Multiple linear regression was used to establish parametric relationships between demand and the characteristic variables;
  - Four data fields from the planning dataset have been selected as variables in the regression analysis; and
  - The variables have been selected using the backward elimination approach. Specifically, it starts with the four candidate predictors (planning data fields) and was repeated until only the significant predictor(s) were left in the model (predictors with P value less than 5%).

The final special zone trip distribution model form can be described by the equation below:

$$Trips = \frac{(A_1P_1 + A_2P_2 + \cdots + A_nP_n)}{C}$$

Where

$$P_1, \ldots, P_n = characteristic\ variables$$

$$A_1, \ldots, A_n = coefficients$$

$$C = cost$$

- The analysis was undertaken separately by the following segmentations:
  - User class: Residents and Visitors;
  - Trip purpose: Employer's Business and Other trip purposes;
  - Directions: to and from the airport; and
  - The entire 24-hour period.

In addition, it needs to note that the analysis has been:

- Undertaken for the entire 24-hour period;
- Undertaken only for Airport trips within the ERM model area;
- Undertaken for the Dublin airport only;
- Carried out at a sector level using the standard model sectors within Dublin and external zones or counties outside Dublin. This is due to low sample at zonal level and low granularity of data outside Dublin at sector level; and
- The output trip distribution matrices are at hourly level for each time period, due to the point at which special zone demands are fed into the level.

Mode split – once the output matrices have been produced from trip distribution, the initial mode split is calculated in line with the core Demand Model. The utilities and have been described in Section 6.5 above. Mode split for each mode is expressed as:

$$\frac{e^{\lambda\ X\ \ Utility_i}}{\sum_j e^{\lambda\ X\ Utility_i}}$$

where

λ parameters are extracted from the main model, for Employer's Business and Other trip purposes respectively; and

j and i represent the mode.

The calibration of mode split involves adjustment of the ASC constants. The ASC values were initialised to the main Demand Model's mode choice values, and further adjusted so that the model reproduced the observed mode split found in the passenger survey data at the Dublin Airport.

6.10 Taxi

It is important to consider taxis in the model as they can make up a significant proportion of vehicles on the network in certain areas and at certain times. The taxi module quantifies the impact of taxis and hackneys on the network. The initial scoping for the model recommended that taxis should be considered as a separate mode in the Mode and Destination Choice model, but there is insufficient data on the origin and destination of taxi trips (and particularly around empty and visitor taxi trips) to facilitate this. Instead, the decision has been made to focus on modelling the impact of taxis on other road users rather than the travel patterns of the taxis themselves.

The approach that has therefore been taken is to include taxi trips within the car mode during mode choice and then to generate a taxi matrix by taking a proportion of the car matrix (ensuring that the number and pattern trips changes in a similar way to cars, in response to changes in land use). In the base year, an initial taxi matrix is adjusted to match observed counts using matrix estimation, this estimated taxi matrix is used to calculate the proportions which are then applied for all model runs and scenarios subsequently.

6.10.1 Calculation Steps

Throughout the development and calibration of the Mode and Destination Choice model, all data related to taxis is combined with car data, including data from POWSCAR and the NHTS. This means that the “car” trips output from the Mode and Destination Choice model are considered to contain both car trips and taxi trips.

During development of the base year model, the initial proportion of overall car trips which are actually taxi trips is calculated initially from the NHTS data, and varies by geographic model sector and time period. These proportions are applied to the car matrix which is output from the Mode and Destination Choice model to produce a preliminary taxi matrix, and which is subsequently subject to matrix estimation so that it better matches observed taxi counts. Further information on this process is described in Chapter 7. The estimated taxi demand matrix is then compared again to the car matrix output from the Mode and Destination Choice model and a final taxi proportion matrix is calculated.

During the model runs, the final taxi proportion matrix is applied to the car matrix output from the Mode and Destination Choice model to produce a taxi trip matrix. In the base year, this will re-produce the estimated taxi trip matrix, but in forecasting the number of taxis will increase or decrease in proportion to changes in the car matrix. The taxi trip matrix is then subtracted from the input car matrix to produce an adjusted car trip matrix which excludes taxis. Both the taxi trip matrix and the adjusted car trip matrix are then taken forward to the road assignment stage (See Chapter 7).

Further information on Taxi modelling can be found in the *Taxi Scoping Report*.

6.11 Goods Vehicles

In a similar way to the Taxi model, goods vehicles are modelled in the ERM so that their impact on the road model can be represented, rather than as an attempt to understand the travel behaviour of the goods vehicles themselves.

Goods vehicle matrices come from two different sources: Long-distance goods vehicles are calculated as part of the Long Distance Model (part of the NDFM) and distributed within the ERM using a similar methodology to that used for long distance car trips, whereas short-distance goods vehicle trips (i.e. those trips wholly within the ERM region) are calculated using an external process and then combined with the long-distance trips before being passed to the road assignment model.

The Long Distance Model uses a gravity-based modelling approach (illustrated in Figure 6.30 to work out the number of trips travelling different settlements, based on the quantum of land use in those settlements and the distance between them. A similar method was initially attempted for short-distance trips, but the relationship between the number of trips and land use proved to be more complex than could be robustly represented by such a simple model.

Development of the short-distance goods vehicle matrices was undertaken using the gravity-based modelling approach to create a preliminary matrix. This matrix then underwent matrix estimation so that the modelled flows were a closer match to goods vehicle counts. The estimated matrix is now used directly in the base year model, and factored up in future years using exogenous factors to represent the expected growth in the number of goods vehicles. Further information on the Goods Vehicle process can be found in the *Goods Scoping Report*, while details about how the Goods Vehicle matrices are assigned to the road model can be found in Chapter 7. This model applies to OGV1 and OGV2 vehicle types whilst LGV prior matrices are inherited from the 2012 ERMv2 matrices and estimated to 2016 LGV counts. None of the goods vehicle classes serve as mode choices within the Demand Model (e.g. as transport option for personal business or commuting). Goods vehicles to/from ports are modelled by NDFM and explained in the LDM Report.

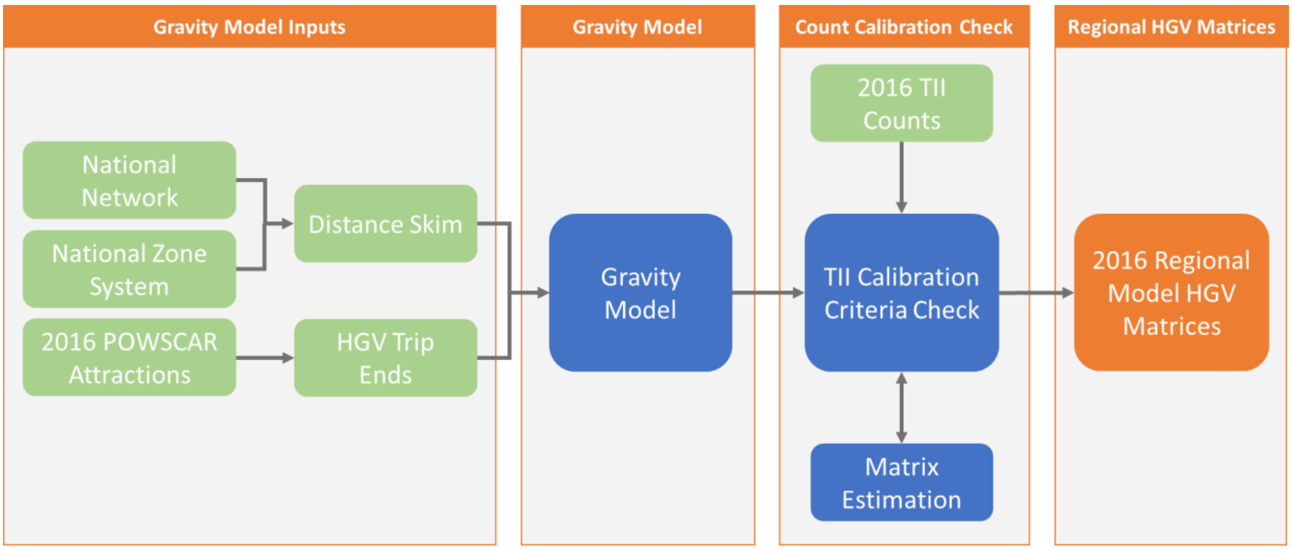


Figure 6.30 Long Distance Goods Matrix Development Methodology

6.12 Greenfield

6.12.1 Overview

The Greenfield module is used to model zones where there is a significant change in land-use between the calibrated base model and a forecast scenario. In these cases, the trip-pattern in the calibrated base model does not provide a robust basis for predicting the pattern of trips in that zone. Greenfield zones are usually those where there is a large increase in land-use, but can also apply where there is a significant decrease in land-use or there is another reason to believe that travel patterns may have changed. Examples might include:

- A new housing estate in an undeveloped zone;
- A large supermarket being planned in a zone which currently has no other shops;
- A new business park expected to bring large numbers of jobs to an out-of-town “rural” zone;
- The relocation of a large hospital; and
- Redevelopment of a housing zone which affects density or car-ownership.

The Greenfield Module offers three alternative methods:

- Greenfield Option 1 does not alter the output from the Mode/Destination Choice model for the Greenfield Zone, but triggers the incremental adjustment during the Assignment Preparation Stage (see Section 6.13) to be multiplicative rather than additive. This means that greenfield demand can be mimicked by placing appropriate factors in the incremental matrices;
- Greenfield Option 2 is probably the most-common approach to greenfield modelling, where a trip distribution pattern is copied from another “similar” zone and then scaled to the correct magnitude; and
- Greenfield Option 3 allows considerably more control on the trip distribution, by allowing the entire pattern to be user-specified, for example using a gravity model tailored to the relevant type of greenfield development and/or other information about the likely travel patterns.

The Greenfield module is triggered by a user input which identifies which zones are subject to the greenfield adjustment and which of the methods are to be used. For those zones using Greenfield Option 2, it is also necessary to specify which zone the trip distribution will be copied from and the relevant weights to apply to the trip distribution.

Additionally, for zones using Greenfield Option 3, the user must supply a file containing the origins and destinations by purpose for the particular greenfield development zone.

6.12.2 Calculation Steps

The steps taken within the Greenfield process differ for each option. For those zones where Option 1 is applied, there are no steps required at this stage, but instead the method of incremental adjustment will be changed during the Assignment Preparation stage (see Section 6.13).

Where Option 2 is used, the model will additionally require the output demand matrices from the Mode and Destination Choice model. From these matrices, the row and column which relate to the “donor” zone will be copied to row and column of the greenfield zone in the output matrix. The row and column are then factored by the weights specified in the control file.

Where Option 3 is used, the trips from the external trip distribution definition file will be copied directly into the output demand matrices.

For further information on the Greenfield process, please see the *Demand Specification Report*.

6.13 Assignment Preparation

6.13.1 Overview

The Assignment Preparation Stage converts the demand matrices (segmented by tour and journey purpose) into matrices that can be used by each of the assignment models (segmented by time period and user class). Specifically, it aggregates trips from various sources, splits two-way tours into one-way OD trips, converts to modelled hours and from persons to vehicles, processes greenfield demands, creates taxi matrices, adds incremental adjustments and outputs everything in the software-specific file format required for each assignment. The Assignment Preparation steps are shown in Figure 6.31.

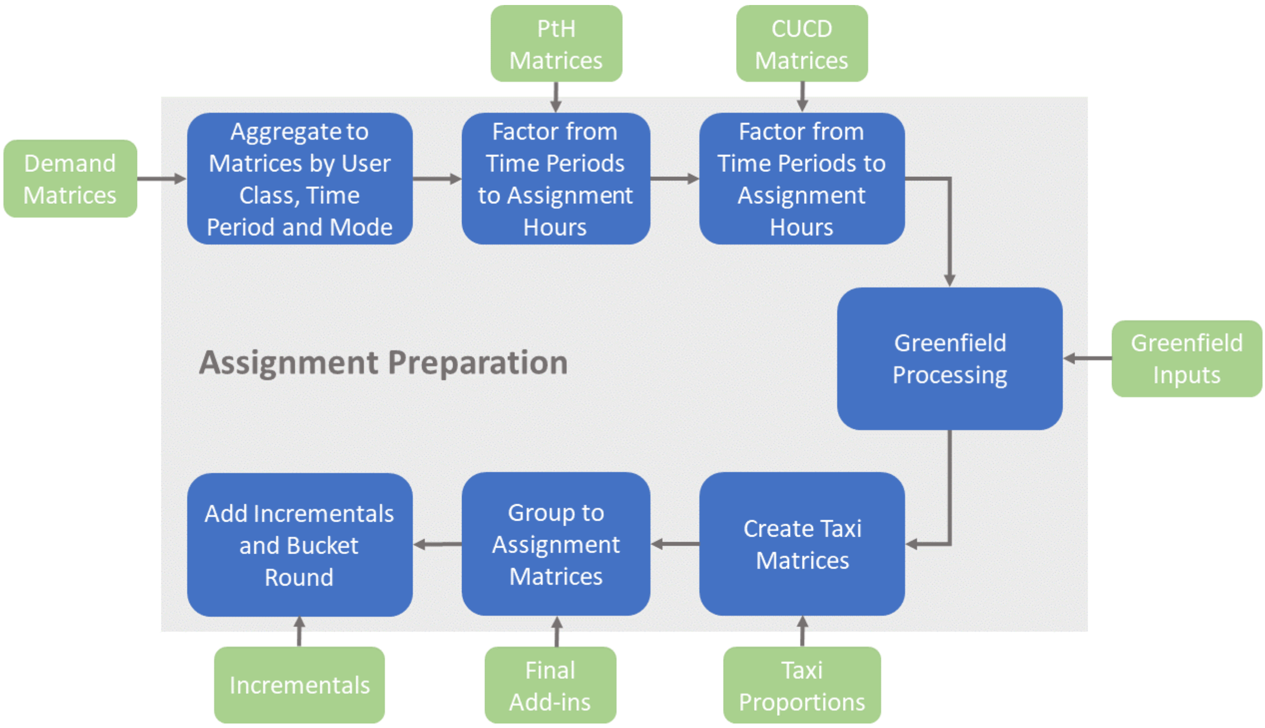


Figure 6.31 Assignment Preparation Stage

6.13.2 Calculation Steps

The first calculation step takes the demand matrices which are currently still segmented by journey purpose and combines them to provide a single matrix for each user class. Table 6.8 describes which journey purposes are aggregated to each of the user classes. Each of these user-class matrices has 20 layers giving each combination of mode (4) and time period (5).

As part of the same process, two-way tours are split into one-way trips representing the “from home” and “to home” legs, and aggregated to time period so that, for example, all tours that leave home in the AM time period (tours 1 to 5) are aggregated into a single matrix representing the AM “from home” trips. Similarly, all tours that arrive home in the PM time period (tours 4, 9, 14, 19 and 24) are aggregated into a single matrix representing the PM “to home” trips. The “to home” matrices are transposed to convert from PA to OD format and then the “from home” and “to home” matrices for each time period are added together.

Table 6.8 Relationship Between User Class and Journey Purpose

User Class	User Class Description	Person Type	Journey Purpose	Demand Segment IDs
UC1	Employer's Business	Non-retired	Employer's Business	27, 30, 31
UC2	Commute	Non-retired	Commute	1, 2, 3, 4
UC3	Other	Non-retired	Shopping, Escort, Visit, Other	11 to 26, 32, 33
UC4	Education	Non-retired	Education	5 to 10
UC5	Retired	Retired	All	28, 29

In the next two stages, Period to Hour factors are applied to convert from time periods to peak hours and Car User to Car Driver factors to convert the car matrices from persons to cars.

6.13.3 Period to Hour Factors

Period to hour factors are required to convert the Demand Model trips (by period) to standard hourly assignments. These factors have been derived from observed traffic, passenger and person count data and vary by mode. The factors are provided in Figure 6.32.

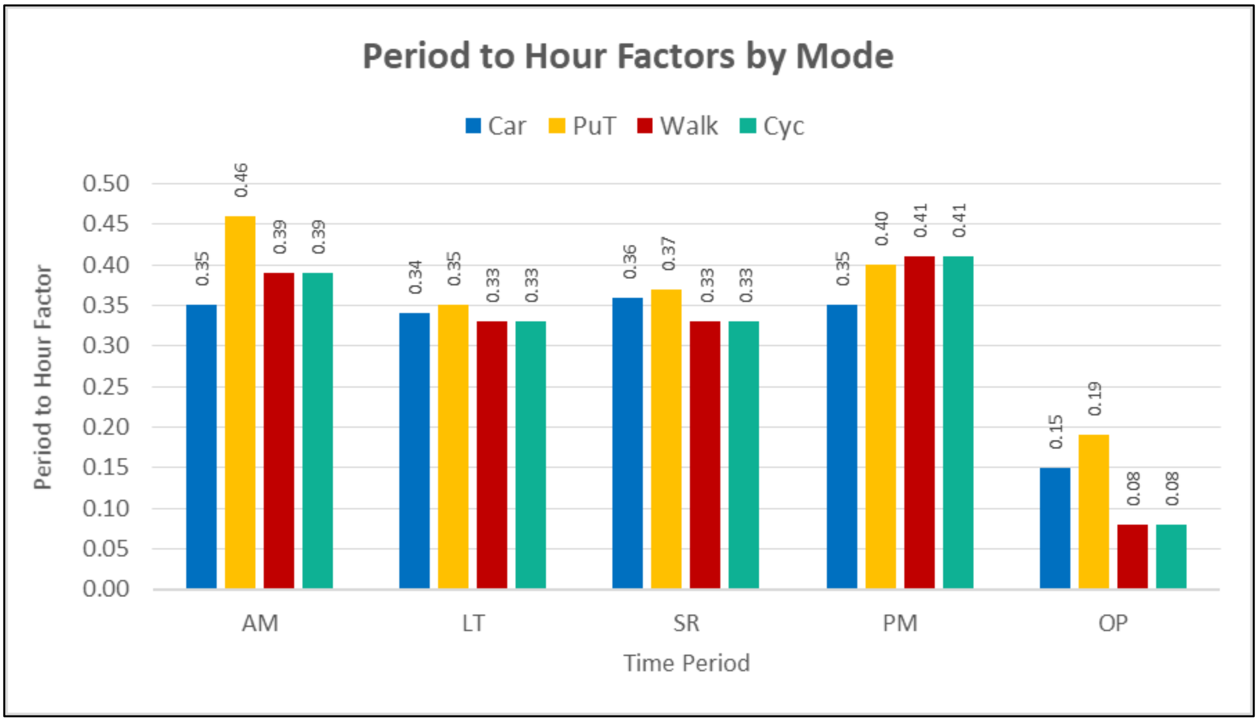


Figure 6.32 Period to Hour Factors by Mode

The derivation of these factors is discussed further in Section 0 and Section 8.5 for the road assignment factors and public transport assignment factors respectively, with further detail provided in the *Peak Hour Specification Report.*

6.13.4 Car Driver Car User Factors

As the Demand Model works in units of persons-trips and the road assignment model works in Passenger Car Units[27], it is necessary to convert the units of the Demand Model outputs before they can be input to the Road Assignment Model. These conversion factors (applied as divisors) were derived using the NTS and are provided by time period and user class, and are detailed in Table 6.9 (expressed in person trips to vehicle trips). Further explanation of the derivation of these factors is provided in the Demand Data Processing Report.

Table 6.9 Car Driver Car User Factors (CDCU)

Time Period	EMP	COM	OTH	EDU	RET
AM	1.078	1.046	1.097	15.633	1.114
LT	1.078	1.040	1.205	12.050	1.197
SR	1.078	1.061	1.171	19.200	1.236
PM	1.078	1.047	1.326	12.050	1.155
OP	1.078	1.042	1.319	12.050	1.393

It should be noted that in other models, a standard approach is to use vehicle occupancy which is similar to CDCU factors in concept. However, the magnitude of the factors themselves can be quite different. This is especially the case for education and illustrates the differences in the definitions assumed:

- Vehicle occupancy factors consider the total number of persons that typically travel in a car for a given purpose; but
- CDCU factors consider the probability that the person travelling for a purpose was a driver. For education trips, this yields an extremely high number given they are unlikely to be driving generally. Education car passengers will likely be driven by someone driving for another purpose (e.g. commute or escort-to-education). In this case, the driver’s trip is already included in the other trip purpose. In these cases, using a vehicle occupancy factor rather than a CDCU would assume all education passenger trips were driven by another education trip and lead to a double counting of vehicle trips across the two purposes.

[27] Equivalent to vehicles for personal travel

6.13.5 Add-in Matrices and Incremental Adjustment

In the next steps, Greenfield demands and Taxi matrices are added into the matrices. The processes to derive these demands are described in Sections 6.12 and 6.10.

The final stage in converting the demand matrices for assignment is to apply the incremental adjustment matrices (“incrementals”) and carry out bucket rounding. Incremental adjustment matrices are very small adjustments which are applied to the assignment matrices at a cellular level and account for small discrepancies in observed behaviour which can’t be explained at an aggregate level by the Demand Model. The incremental adjustment matrices are calculated as part of the model calibration process and further information about the derivation of the incremental adjustment matrices can be found in Section 10.4.2.

For zones where Greenfield Option 1 should apply, incrementals are applied in a multiplicative fashion to factor calculated demand levels. Zones using the other Greenfield options have already been adjusted by this stage and incrementals are not applied to these zones.

For all other zones, the incremental flags in the input incremental matrices are used to establish whether the incremental is of additive or multiplicative type and this information is used in combination with the input incremental value to adjust the calculated demand level.

Having obtained revised demands, the final step is to apply bucket rounding. Bucket rounding is applied individually to each user class, mode, and time period and ensures that there are no demands smaller than a cut-off value of 0.00001.

For each cell the demand smaller than the cut-off value is zeroed and the residues are collected until they aggregate to a value greater than or equal to the cut-off value. At this point the cut-off demand is added on to the value in the cell which has “filled the bucket” and the running residue total adjusted down to remove this amount before the process continues. There is no significant adjustment (more than the cut-off value) to any particular cell in the matrix.

To avoid bias towards particular columns which can occur (for example, if the process always starts from Zone 1), the bucket rounding procedure always starts from the intrazonal cell. Additionally, to avoid the loss of any residue remaining at the end of each row any outstanding residue is added to the last cell processed before starting on the next row.

For further information on the Assignment Preparation stage, please see the *Demand Specification Report*.

6.14 Generalised Cost Calculations

The generalised cost calculation module is run following the assignment models and convert the cost skims (time, distance, monetary costs) from each of the assignment model into tour-based generalised costs which can be used in the next iteration of the Demand Model. The module also calculates the additional costs for trips using Park and Ride or affected by Parking Distribution.

The first step in the process takes the cost skims for each mode and time period and calculates tour costs by averaging the direct and transposed values for each i, j combination. These are then aggregated by user class.

Tour costs for the Park and Ride mode are created by calculating the minimum average cost of Park and Ride use for each i, j pair. Although not every trip may choose to use this minimum cost site, this cost is considered to be valid for use in distribution and mode split.

Calculation of parking cost matrices uses the costs calculated by the Parking Distribution module (see Section 6.8.2) and the proportions of free- to paid-parking travellers derived in the FWPP module to calculate a weighted average cost for all travellers (paid and free - see Section 6.6.1). The average parking costs will be passed back to destination choice model.

Tour costs for all five modes are then aggregated to produce five purpose-specific matrices segmented by mode and tour.

The cost skims from the assignments and an approximate generalised cost for Park and Ride are also aggregated for use in the Convergence stage. This produces one matrix for each time period segmented by mode and user class.

Further information on the calculation of generalised costs can be found in the *Demand Specification Report.*

7 Road Model

7.1 Introduction

The purpose of the road assignment model is to accurately represent the physical road network and available route choice of road users. The road assignment model will be used for high level assessment and appraisal of road and public transport infrastructure projects, policy reviews and transport strategy development.

The purpose of the road assignment model within the East Regional Model (ERM) is to take a travel demand matrix produced by the Demand Model, assign it to an accurate representation of the road network, and provide the cost of travel to the choice components of the Demand Model, allowing the ERM to determine the time of day, mode and destination choices.

The initial development of the road assignment model is documented in *Road Model Development Note*, which details the creation of the assignment network responsible for representing road-based travel within each region. The development of the ERM road model is summarised in Section 7.7.

The road network was developed in SATURN (version 11.4.07H) and represents all major motorway, primary and secondary roads, as well as important connections between these roads through a combination of detailed (simulation) and less detailed (buffer) coding.

7.2 Model Coverage

7.2.1 Network Topology

The network topology was derived from the HERE (formerly Navteq) mapping layer. This dataset provided a detailed topographical representation of the road network that was processed and simplified for use within the model.

This process is detailed in the *Road Model Development Note*, which set out the level of detail retained in the initial network selection and the process of converting this information into a format compatible with the model. Further detail on the network selection is provided in the *Network Link Specification Report.*

The road network topology directly informs the public transport and active modes network topology. The public transport assignment model takes the road network and adds in rail-based infrastructure and station or stop pedestrian accesses, as well as any other walk-only links that can be used when interchanging between public transport services. Other links such as motorway links, are adjusted to prohibit walking or cycling.

7.2.2 Network Coverage

The ERM road network represents the area illustrated in Figure 7.1, modelled by a combination of detailed simulation network and buffer network. The extent of the simulation area was selected to broadly align with the Dublin Metropolitan Area and the counties of Dublin City, South Dublin, Dún Laoghaire–Rathdown and Fingal.

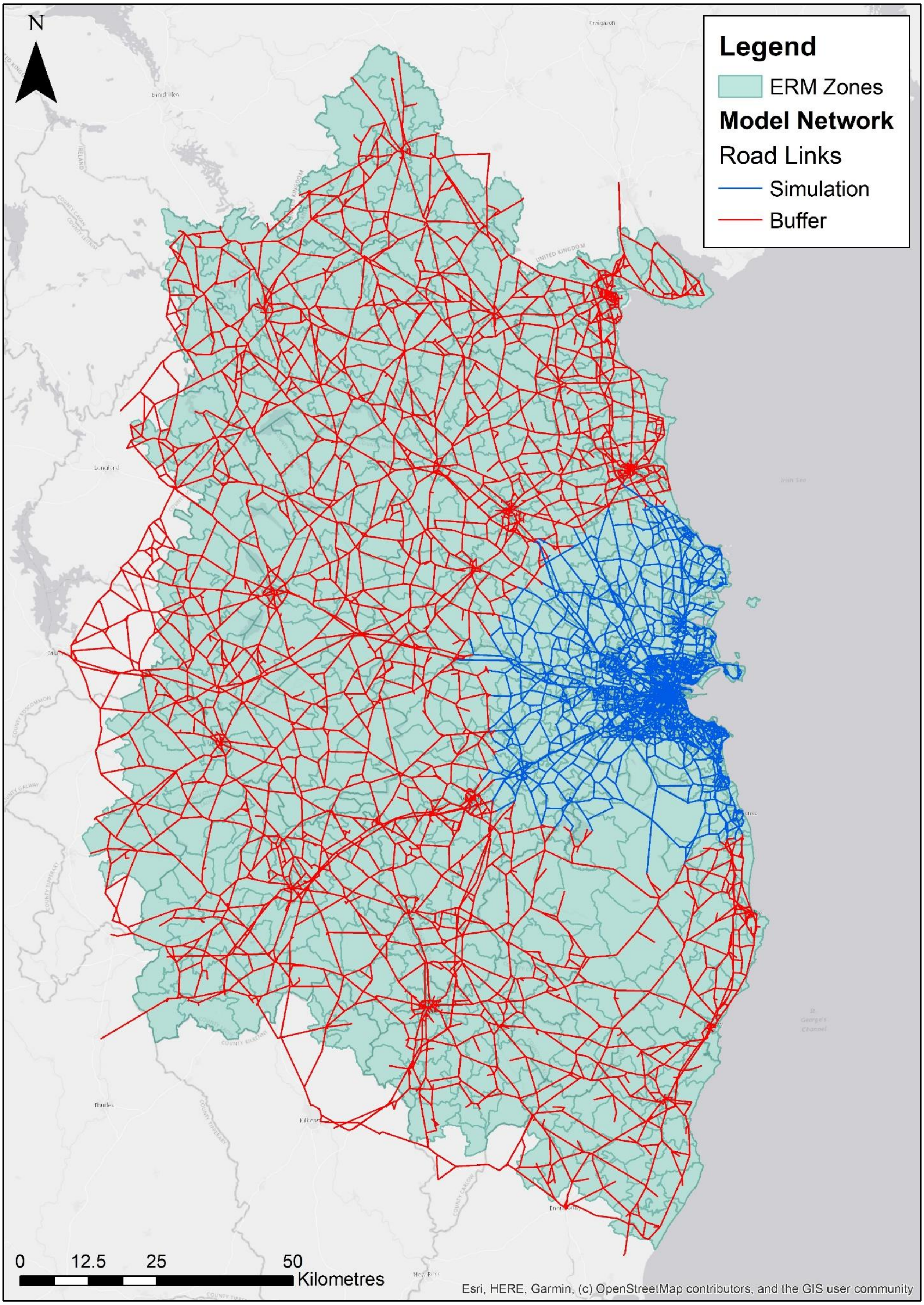


Figure 7.1 ERM Road Model Coverage

In some instances, the network extends beyond the model area to provide connectivity within the model that exists on the ground, such as the routes via Kilkenny to the south of the modelled area.

7.2.3 Zone Centroids

The zoning is consistent across all model components and all assignment models within the ERM. There are 1,953 model zones in the ERM, of which 1,907 are internal zones, 39 are road route zones and 7 are rail route zones. The zone system and route zone connections are set out in Chapter 4. Zone centroids are positioned using the GeoDirectory to locate the centroid point at the at the mean centre of addresses in the zone. All addresses are represented as a single point, so larger developments do not influence the centroid position more than smaller ones.

Time Periods

The ERM represents five average neutral weekday time periods, as set out in Section 5.5. These time periods represent multiple hours, and therefore require factoring to take them to the one-hour matrices assigned by the road model. The time periods, modelled hours and period to hour factors are presented in Table 7.1.

Table 7.1 Modelled Time Periods

Time Period	Standard Abbreviation	Demand Model Period	Assigned Hour	Period to Hour Factor
Morning peak	AM	0700 – 1000	0800 – 0900	0.352
Lunchtime	LT	1000 – 1300	1200 – 1300	0.343
School run	SR	1300 – 1600	1500 – 1600	0.362
Evening peak	PM	1600 – 1900	1700 – 1800	0.346
Off-peak	OP	1900 – 0700	2000 – 2100	0.152

The assigned model time periods were informed by analysis of road and public transport observed count data, with further information on the selection of these time periods detailed in the *Peak Hour Specification Report*. Hourly traffic data from the period of November 2016 was obtained for each TII automatic traffic counter (ATC) location within the ERM model boundary – both individual directions and two-way flows – and processed into two-way average weekday (Mon-Fri) flows per hour. The flow profile obtained from this data is illustrated in Figure 7.2.

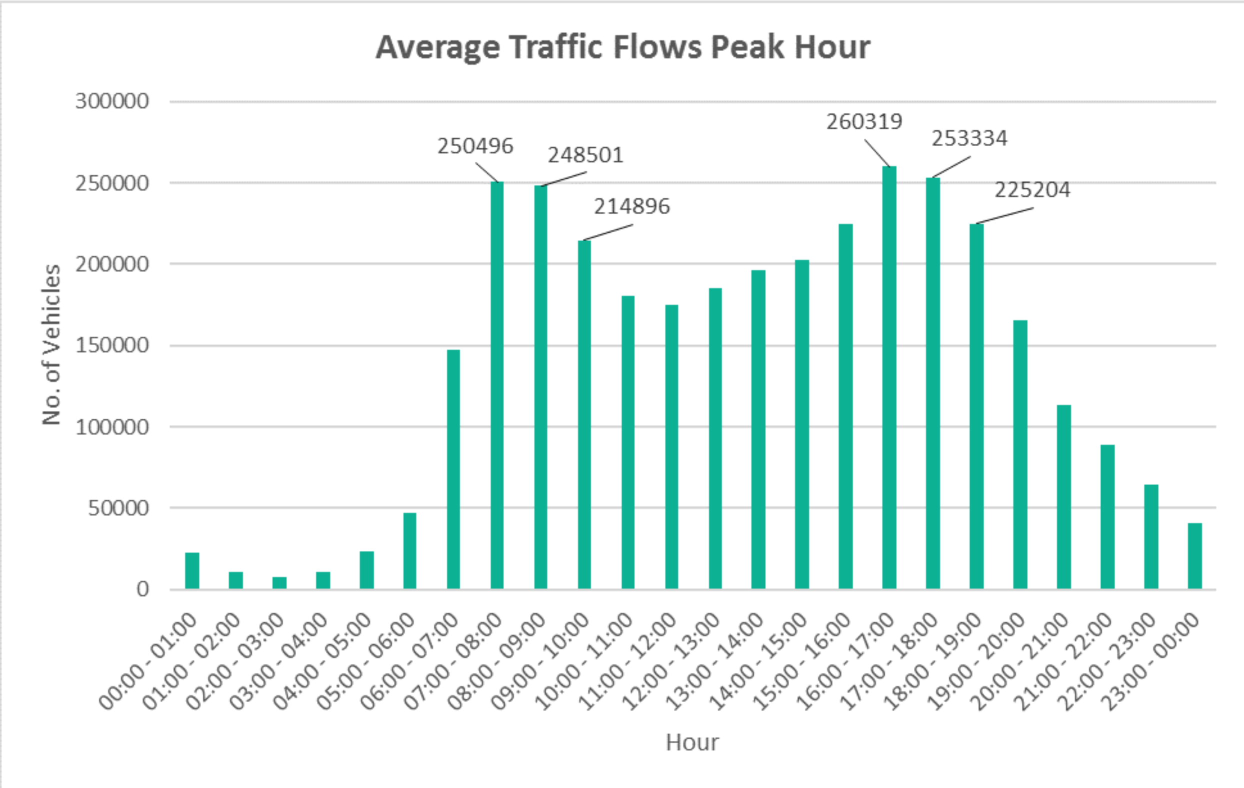


Figure 7.2 Average Traffic Flows Per Hour

The analysis of the data concluded that whilst the TII ATC data illustrated in Figure 7.2 demonstrated slightly higher flows during the 0700 – 0800 and 1600 – 1700 periods compared to the 0800 – 0900 and 1700 – 1800 periods, the 0800 – 0900 and 1700 – 1800 time periods were selected as the assignment hours. This aligned with the peak hours from the Luas boarding and alighting figures, and traffic data collected along the M50 screenline and at each River Liffey bridge consistently showed 0800 – 0900 and 1700 – 1800 were the peak hours for the AM and PM periods, respectively.

Furthermore, whilst the Irish Rail passenger counts displayed higher boarding and alighting figures between 1000 – 1100 during the LT period, the Luas boarding and alighting figures demonstrated an LT peak of 1200 – 1300. The Luas results are more consistent with the observations for this period, therefore 1200 – 1300 was selected for the LT period.

7.3 User Classes

The road assignment model represents ten user classes, as set out in Chapter 5. The represented user classes are also defined in Table 7.2. The model assigns traffic in passenger car units (PCU). The factor applied to convert a vehicle into a PCU is also detailed in Table 7.2.

Table 7.2 Road Assignment User Classes

User Class	Description	Vehicle Class	PCU Factor
User Class 1	Car Employer's Business	Car	1.0
User Class 2	Car Commute	Car	1.0
User Class 3	Car Other	Car	1.0
User Class 4	Car Education	Car	1.0
User Class 5	Car Retired	Car	1.0
User Class 6	Taxi	Car	1.0
User Class 7	LGV	LGV	1.0
User Class 8	OGV1	HGV	1.9
User Class 9	OGV2 Permit Holder	HGV	2.9
User Class 10	OGV2 Non-Permit Holder	HGV	2.9

Recent guidance on the application of PCU factors includes a consideration for road type and does not differentiate between rigid (OGV1) and articulated (OGV2) HGVs. In order to retain this level of detail PCU factors were sourced from the now superseded United Kingdom Department for Transport's Transport Analysis Guidance (UK TAG), Unit 3.5.9, Annex B, Table B4.

Each user class has, where possible, independently defined generalised cost components within the model (cents per minute travelled, PPM, and cents per kilometre travelled, PPK), and independently defined vehicle restrictions and tolling. Both of these components determine the route choice of that specific user class.

7.4 Assignment Method

The road assignment is undertaken in the SATURN SATALL module that applies a Wardrop User Equilibrium assignment to all user classes, iterating between network assignments and network simulations until an equilibrium, defined by user input termination parameters, is achieved. These parameters are defined in the Addendum.

7.5 Data Used

Development of the road network requires data from a wide variety of sources. Network topology and detailed information on road markings, permitted turns, traffic signal phasing and timings is required in order to represent the road network. Generalised cost parameters inform the route taken by each user class through the road network, while observed traffic count data and journey time data help calibrate and validate the model to known travel patterns.

For further information on data sources and data cleaning, please refer to Chapter 3.

7.6 Acceptability Criteria and Guidance

7.6.1 Trip Matrix Calibration / Validation

The measure used to assess the calibration or validation of the trip matrix is the difference between modelled and observed flows across designated screenlines. The recommended acceptability criterion to validate a trip matrix, as defined by the UK TAG Unit 3.1[28] Table 1 are specified in Table 7.3.

Table 7.3 Screenline Flow Criterion and Acceptability Guideline

Criterion	Acceptability Guideline
Difference between modelled flows and counts should be less than 5% of the counts	All or nearly all screenlines (i.e. 95%)

In the case of the ERM screenlines are being used to calibrate the trip matrix, and not to validate the trip matrix. As there is no specific criterion within UK TAG for the calibration of a trip matrix, the validation criterion outlined in Table 7.3 has been applied in this instance.

Screenlines are typically made up of at least five links and are presented separately for each modelled time period.

7.6.2 Link Flow Calibration / Validation

When assessing link flow calibration and validation the measures used are absolute and percentage differences between modelled flows and observed flows, and GEH[29] statistic, which is a form of Chi-squared statistic that incorporates both relative and absolute errors. The GEH statistic is defined as:

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

Where:

M is the modelled flow; and
C is the observed flow.

The calibration and validation criteria and acceptability guidelines for link flows are specified in Table 2 of UK TAG Unit M3.1 and defined in Table 7.4.

[28] https://webarchive.nationalarchives.gov.uk/20191022084854/https://www.gov.uk/guidance/transport-analysis-guidance-webtag
[29] The GEH statistic is an industry-standard statistic which gets its name from the initials of its creator, Geoffrey E. Havers.

Table 7.4 Link Flow Criteria and Acceptability Guidelines

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

7.6.3 Journey Time Validation

The validation of journey times is assessed by the percentage difference between the modelled journey time and the observed journey time along predefined routes. Where a route is relatively short, differences in seconds can be considered, but this does not apply to any routes specified as part of the ERM model development.

The journey time validation criterion and acceptability guideline are specified in Table 3 of UK TAG Unit M3.1 and defined in Table 7.5.

Table 7.5 Journey Time Validation Criterion and Acceptability Guideline

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

7.6.4 Monitoring Changes Brought About by Matrix Estimation

The changes applied by matrix estimation are monitored to ensure that the prior matrix is not overly distorted. UK TAG Unit M3-1 outlines several criteria that should be considered, which are:

- Scatter plots of matrix zonal cell values, prior to and post matrix estimation, with regression statistics;
- Scatter plots of zonal trip ends, prior to and post estimation, with regression statistics;
- Trip length distributions, prior to and post estimation, with means and standard deviations; and
- Sector to sector level matrices, prior to and post matrix estimation, with absolute and percentage changes.

The significance criteria for each measure is outlined in Table 7.6.

Table 7.6 Significance of Matrix Estimation Changes

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

In addition to these criteria, the significance ratio of the trip length distribution before and after estimation was reviewed during all stages of matrix estimation. The coincidence ratio compares two mathematical functions - in this case two trip length distribution curves - for similarity. A coincidence ratio of one represents equality, therefore the significance criteria is “near one”.

7.6.5 Convergence Acceptability

Convergence describes the stability of the model assignment from iteration to iteration. The assignment models should be suitably stable as to not provide significantly different travel costs back to the Demand Model after each assignment loop.

The recommended acceptability criteria as set out in Table 4 of UK TAG Unit M3.1 for model convergence are defined in Table 7.7, where %GAP is the difference between costs along the chosen routes and those along the minimum cost routes, summed across the whole network, and expressed as a percentage of the minimum cost.

Table 7.7 Assignment Convergence Criteria and Acceptability Guidelines

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

To achieve the criteria set out in Table 7.7 a series of user-defined parameters are used to control the convergence of the assignment within the software. If the criteria are not met, then an additional parameter controls the maximum number of assignment / simulation loops that the software will perform while trying to meet the user-defined parameters. These parameters are defined in the Addendum.

7.7 Network Development

7.7.1 Introduction

The development of the road network is documented in *Road Model Development Note* and covers the works undertaken between the finalisation of the 2012 model and the completion of the 2016 network update task, including intermediate maintenance and analysis.

7.7.2 Network Structure

The model consists of a number of elements, as summarised in Table 7.8.

Table 7.8 ERM Road Model Elements

Element	Count
Zones	1,953
Simulation Nodes	10,846
Buffer Nodes	5,345
Model Links	48,418
Restricted Links	932
Bus Routes	688

7.7.3 Zone Connectivity

The zone system is discussed in Chapter 4, and is common to all model components.

All zones within the ERM connect to the wider assignment network via single links (spigots) that represent true zone access points connecting at physical junctions, such as a residential cul-de-sac or retail park entrance. The junctions are coded such that all turn capacities reflect the actual junction type and movement they represent.

Zone connectors are then used to link the zone centroids, positioned at the population-weighted centre of the zone, with the road network, using the spigots. Zone centroids and road model connection points are common to all modes, whereas each mode may have its own distinct set of additional connectors to represent non-motorised access and interchange links.

UK TAG Unit M3.1 recommends that the number of zone connectors for each zone is minimised so that traffic does not load at the periphery of the zone. The location and number of zone connectors has been chosen to reflect the actual routing decisions and delays encountered at the start and end of a car journey. Additional internal network was added where a zone legitimately had multiple entry or exit point from the network in order to provide more accurate route choice during the assignment process and subsequently more accurate costs when developing the demand matrices.

Further details concerning the coding of zone connectors and access links can be found in *Road Model Specification Report*, while the derivation and definition of the zoning system are detailed in Chapter 4.

7.7.4 Detailed Simulation Coding

The purpose of the simulated area within the model is to simulate junction delays from a given traffic pattern. Junctions are coded with accurate approach characteristics, such as distances, number of available lanes, existence of flares, and any junction operational properties such as signal timings and phasing. Each available movement is also given a turn saturation flow which determines the maximum number of PCU that can make a given turn, if unrestricted, in the modelled time period.

The detailed, simulated area of the ERM road assignment model covers the entirety of the Dublin Metropolitan Area, and extends into the rural hinterland, as illustrated in Figure 7.3.

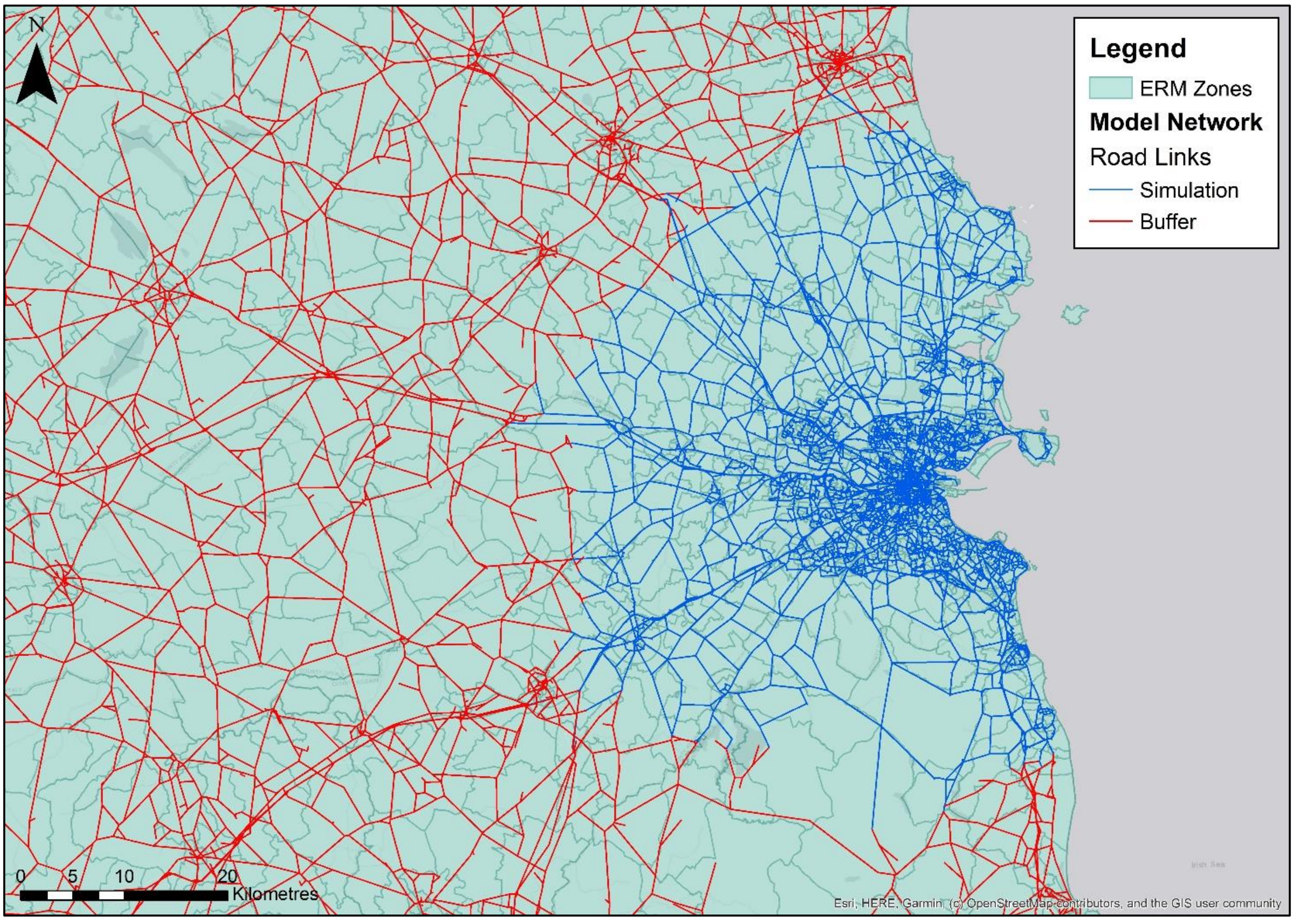


Figure 7.3 ERM Simulated Area

The simulation network was manually coded in accordance with *Road Model Coding Guide* which sets out the standardised turn saturation flows for priority, signalised, roundabout and merge junction types, standardised flow/delay curves and standardised network parameters. The standardised flow/delay curves are included in the Addendum.

7.7.5 Traffic Signals

The original source of the traffic signal timings and stage definitions for the ERM was the SCATS database, as outlined in Chapter 3. The SCATS database provides the stage plan, cycle time and stage timing for each signalised junction assessed.

Where a junction was not controlled by SCATS, synthetic signal data was produced, informed by street-level mapping, observed traffic flows (where available) and a basic ruleset that governed the overall cycle time which was dependent on the number approach arms and likely stages.

A register of synthetic traffic signal times was maintained which allowed for a wider range of changes to be applied at these locations. Changes to stage definitions and stage and cycle times were permitted at these locations where evidence, such as observed traffic counts or observed journey times, indicated that a change was required.

7.7.6 Vehicle Restrictions and Tolling

There are several types of vehicle restrictions applied to the ERM. These take the form of:

- Bus-only lanes;
- Bus-only links;
- Access restrictions based on time of day;
- Access restrictions based on vehicle weight;
- Access restrictions based on vehicle height, width or length;
- Access restrictions based on the number of vehicle axles; and
- Monetary tolling.

Detailed goods vehicle restrictions were coded as part of the input data files. These include representation of Dublin's HGV Management Strategy[30], more localised 3.5 tonne restrictions, particularly in residential areas and a representation of low bridges, narrow bridges and narrow turns as provided by Irish Rail.

Bus lanes and bus-only links are fully represented within the ERM, and were coded in accordance with *Road Model Coding Guide*. Vehicle restrictions are represented by banning particular user classes from making a turn or travelling along a link in the appropriate section of the input data files.

Tolling was applied based on the locations and values listed by eToll as outlined in Chapter 3. Tolling is represented in a similar way, but instead of banning a specific user class from making a turn or travelling along a link a user-defined monetary toll is added to

[30] http://www.dublincity.ie/hgv

the generalised cost of all traffic which choses to use the respective link. This typically varies by vehicle class and can vary by time of day.

7.7.7 Buffer Coding

The purpose of the buffer area coding is to provide route choice and accurate cost of travel information for more rural areas of the ERM.

The less detailed buffer coding consists of link-based data only, such as the length of the link and the relationship between the traffic volume of the link and the speed that the traffic will travel at.

The buffer network was manually coded in accordance with *Road Model Coding Guide* which sets out the standardised flow/delay curves. The same set of flow/delay curves are applied to both the simulation and buffer network.

7.7.8 Network Checking

Section 5.3 of UK TAG Unit M3.1 outlines the basic checklist that should be followed in order to minimise problems once the network has been coded. These include:

- Check of appropriate junction types;
- Check that the appropriate number of entry lanes have been coded and that flaring of approaches, where appropriate, are accounted for;
- Check that link and turn restrictions have been correctly identified;
- Check that one-way roads and no entries, if applicable, have been correctly specified;
- Check that saturation flows are appropriate;
- Check that link lengths, link types and cruise speeds for each direction of a link are Consistent, and that the second and third do not vary unjustifiably along series of links; and
- Compare crow-fly link lengths against actual lengths.

The above checks were undertaken and are reported in *Road Model Development Note*. Any coding errors identified by the above checks were addressed and included in the final road assignment model. A log of all coding changes is included in the Addendum.

7.7.9 Pre-calibration Checks

Section 5.4 of UK TAG Unit M3.1 also recommends that model calibration should not commence until the network has passed a series of basic checks. In the case of the ERM, these checks included:

- a review of the outcomes from the checks listed above to identify areas most affected by the model update;
- a review of the error logging included in the model log files;
- a review of key junctions; and
- a check of network connectivity, ensuring all trips can assign to the network and that route choice is sensible.

The review of the error logging and the check of network connectivity were undertaken and reported in *Road Model Development Note.* All network coding changes at this stage are still limited to error correcting, and as such all coding practices followed the guidance set out in the *Road Model Coding Guide*. A log of all coding changes is included in the Addendum.

7.8 Generalised Cost and Parameters

The assignment requires several parameters in order to determine route choice through the network, two of these being cents per minute (PPM) and cents per kilometre (PPK).

A tool was developed that takes in several national and industry-standard parameter and combines these with model performance statistics to derive a PPM and PPK value for each assigned user class, including HGVs. The inputs to this process, and their source are outlined in Table 7.9.

Table 7.9 Generalised Cost Parameter Inputs[31]

Parameter	Source
Average Tax	Irish Tax and Customs
Rate of VAT	Irish Tax and Customs
Journey purpose vehicle occupant resource cost	Common Appraisal Framework
Vehicle Occupancy	NHTS / Common Appraisal Framework
Vehicle Proportions	Project Appraisal Guidelines
Future values of time	Common Appraisal Framework
Average network speed (V)	Road Assignment
Fuel consumption parameters	UK TAG

The average network speed extracted from the model is an “all vehicle” speed and does not vary by user class. A generalised cost was derived for each user class in the assignment model, and this is updated automatically on each loop of the Demand Model. The generalised cost of travel in the model is defined as:

$$Generalised\ Cost = (PPM\ \times Travel\ Time) + (PPK\ \times Travel\ Distance) + Tolls$$

Where (per journey purpose):

$$Base\ Year\ Value\ of\ Time = Vehicle\ Occupancy \times Vehicle\ Occupant\ Resource\ Cost$$

$$PPM = Base\ Year\ Value\ of\ Time \times Future\ Values\ of\ Time$$

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[31] See Section 3.28 for details of data sources

$$Fuel\ Consumption = \frac{aFuel + (bFuel\ \times V) + (cFuel\ \times V)^2 + (dFuel\ \times V)^3}{V}$$

Where aFuel, bFuel, cFuel and dFuel are the fuel consumption parameters from UK TAG and V is the average assigned network speed.

$$Fuel\ Cost = Fuel\ Consumption\ (litres) \times Average\ Fuel\ Cost(cents\ per\ ltre)$$

$$Non\ Fuel\ Cost = aNonFuel + \frac{bNonFuel}{V}$$

Where aNonFuel and bNonFuel are the non-fuel parameters from UK TAG and V is the average assigned network speed.

$$PPK = Fuel\ Cost + Non\ Fuel\ Cost$$

7.9 Calibration and Validation Process

The overarching guidance used during the calibration of the road assignment model is the UK TAG, specifically UK TAG Unit M3.1 – Highway Assignment Modelling[32].

UK TAG Unit M3.1 provides guidance on the development of the road assignment model, the data required to code and check the network and the various stages of calibration and validation.

7.9.1 Network Calibration

Network calibration is the process of adjusting the initial network that has been sufficiently checked through the examination of preliminary assignments. Network calibration should be carried out before adjustments to the demand matrices are applied. the primary areas of focus for the network calibration are:

- areas where the observed traffic count exceeded the calculated capacity of a junction or movement;
- junctions where the calculated delay exceeded three minutes; and
- areas where modelled flows were either significantly higher or significantly lower than observed traffic count data.

The *Road Model Coding Guide* was used to guide network adjustments applied to the network with all changes applied to the network were justified and documented in a Coding Log, included in the Addendum.

[32] https://webarchive.nationalarchives.gov.uk/20191022084854/https://www.gov.uk/guidance/transport-analysis-guidance-webtag

7.9.2 Private Car Route Choice Calibration and Validation

Route choice calibration was undertaken at various stages of the network development process as route choice will be informed by any changes to zoning, network structure, network coding and trip matrices. The primary tools used to analyse route choice in the road assignment model are the use of minimum path routes and, later in the calibration process, fixed journey time routes. Further detail is provided in the *Network Development Process Report.*

The initial route choice review and calibration is documented in the *Road Model Development Note* where six key origin-destination pairs were examined and select link analysis was undertaken at ten key locations.

The six key origin-destination pairs were:

- Kimmage to Portobello;
- Raheny to Eastpoint Business Park;
- Drumcondra to Dublin Airport;
- Blanchardstown to Smithfield;
- Blackrock to Ballsbridge; and
- Dundrum to Ranelagh.

The ten select link analysis locations were:

- University College Dublin (UCD) main entrance;
- Dublin Airport M1 approach;
- Dublin Port Tunnel northbound and southbound;
- Inbound links on the N11, M11, N7 and N4; and
- Clockwise and anti-clockwise links on the M50.

No significant issues with private travel route choice were identified as a result of this check during the initial network development. These origin-destination pars and select link analysis points were assessed periodically during the model calibration stage.

As part of the route choice validation exercise UK TAG Unit M3.1 recommends assessing a number of routes proportional to the number of zones and number of user classes represented within the assignment model. For the ERM, with 1,953 zones and 10 user classes UK TAG Unit M3.1 suggests reviewing approximately 66 origin-destination pairs.

7.9.3 HGV Route Choice Calibration

In order to better calibrate HGV route choice, a larger weighting per kilometre travelled was calculated during the derivation of the generalised cost. To better match the available route choice for HGVs, detailed goods vehicle restrictions were also coded as part of the model input data files. These include representation of Dublin’s HGV Management

Strategy[33], more localised 3.5 tonne restrictions, particularly in residential areas and a representation of low bridges, narrow bridges and narrow turns as provided by Irish Rail.

HGVs were also coded with lower maximum speeds on Motorway, National and Regional roads to coincide with the legal speed limit of these vehicle types on these roads. This was achieved by using the CLICKS function within SATURN which can limit user-defined user classes to a different maximum speed on links with user-defined capacity indices.

HGV route choice was reviewed by assigning the goods user classes to the network and reviewing link loading. Changes applied during this review are detailed in a Coding Log, included in the Addendum.

7.9.4 Trip Matrix Calibration and Validation

The trip matrices generated by the Demand Model are commonly termed “prior” trip matrices. Analysis of the prior trip matrix was undertaken by comparing assigned flows with observed traffic counts. The aim of this comparison was to:

- Inform redevelopment of the prior matrices that would yield modelled flows that more closely match observed counts;
- Inform adjustments that can be applied to the assignment networks;
- Inform adjustments that can be applied to the trip matrices; and
- Identify the need for matrix estimation.

7.10 Assignment Calibration and Validation Data

7.10.1 Assignment Calibration

The road assignment was calibrated against screenline flows using the criteria set out in Section 7.6.1 and against individual link flows using the criteria set out in Section 7.6.2. Figure 7.4 and Figure 7.5 illustrate the location and extent of each screenline used during the calibration of the ERM.

[33] http://www.dublincity.ie/hgv

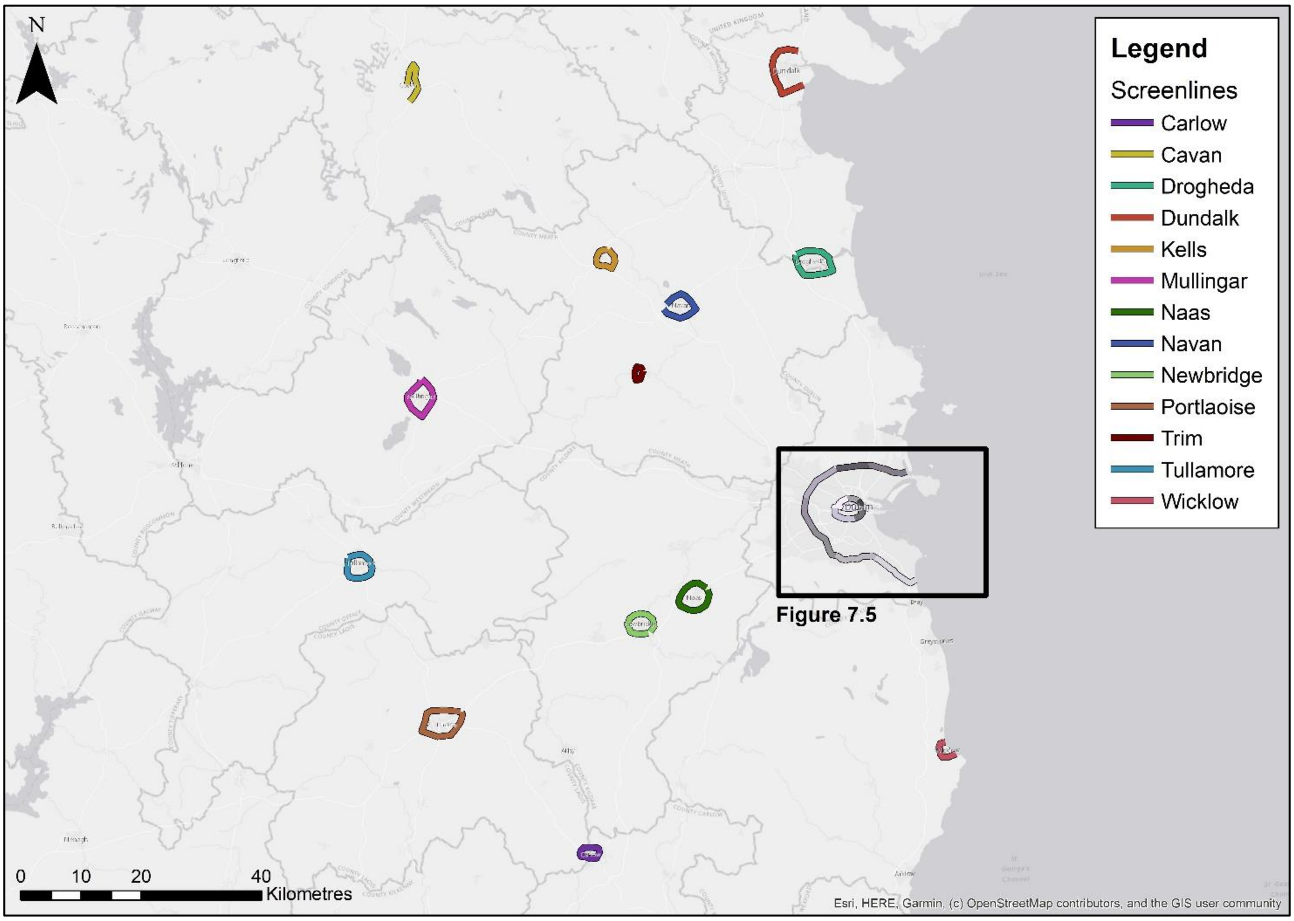


Figure 7.4 Road Assignment Screenlines (Calibration)

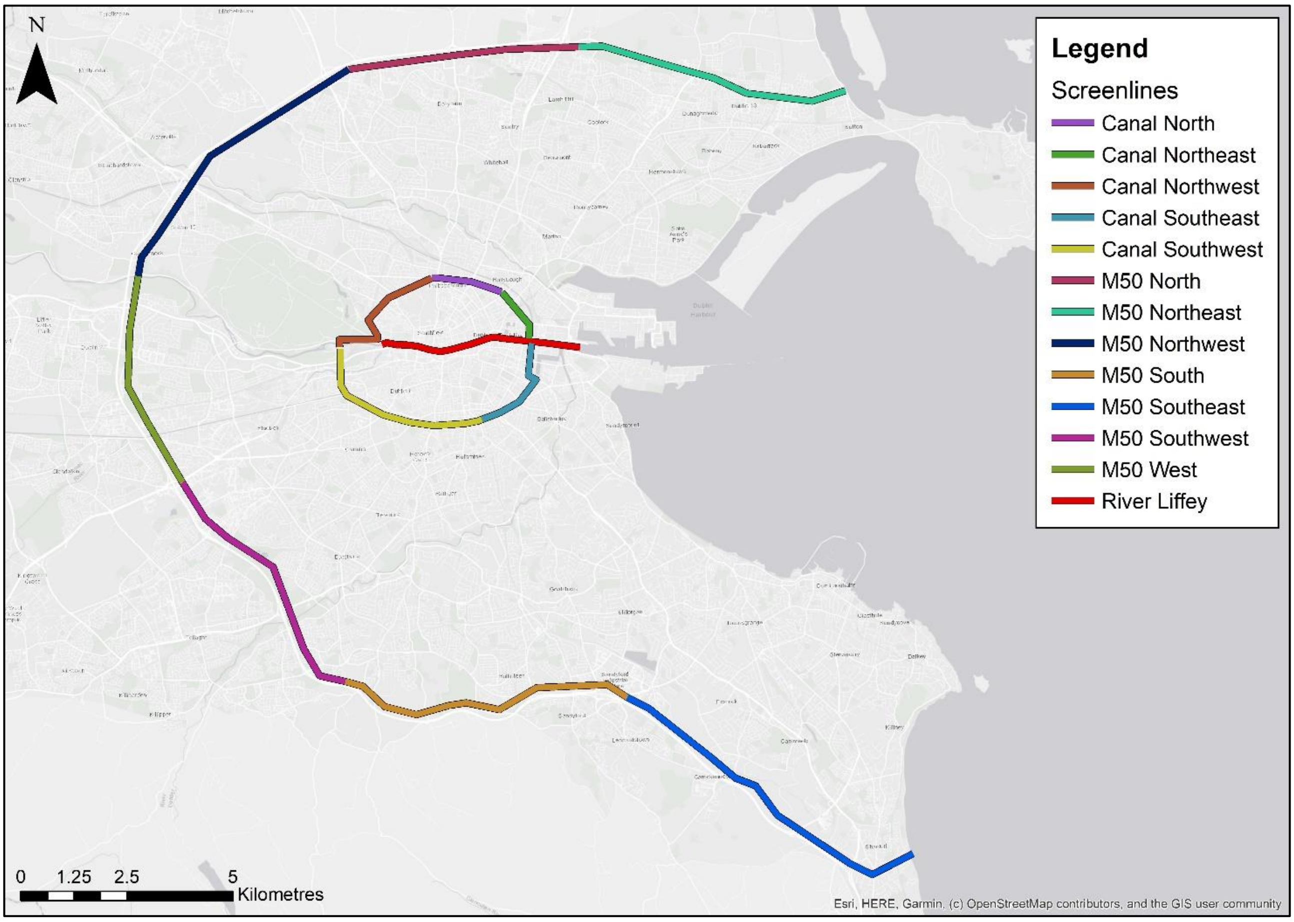


Figure 7.5 Dublin Road Assignment Screenlines (Calibration)

Figure 7.6 and Figure 7.7 detail the location of each individual link count used to calibrate the road assignment component of the ERM.

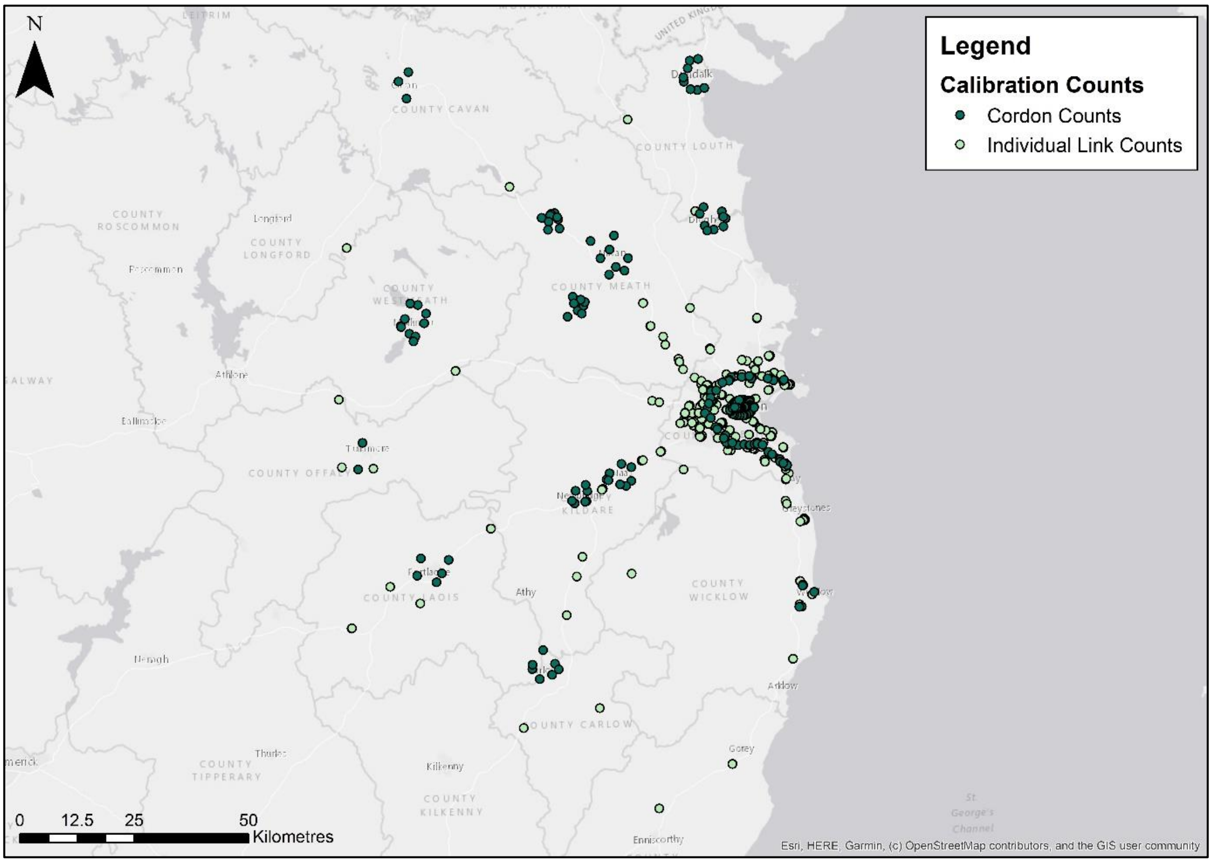


Figure 7.6 Road Assignment Individual Link Counts (Calibration)

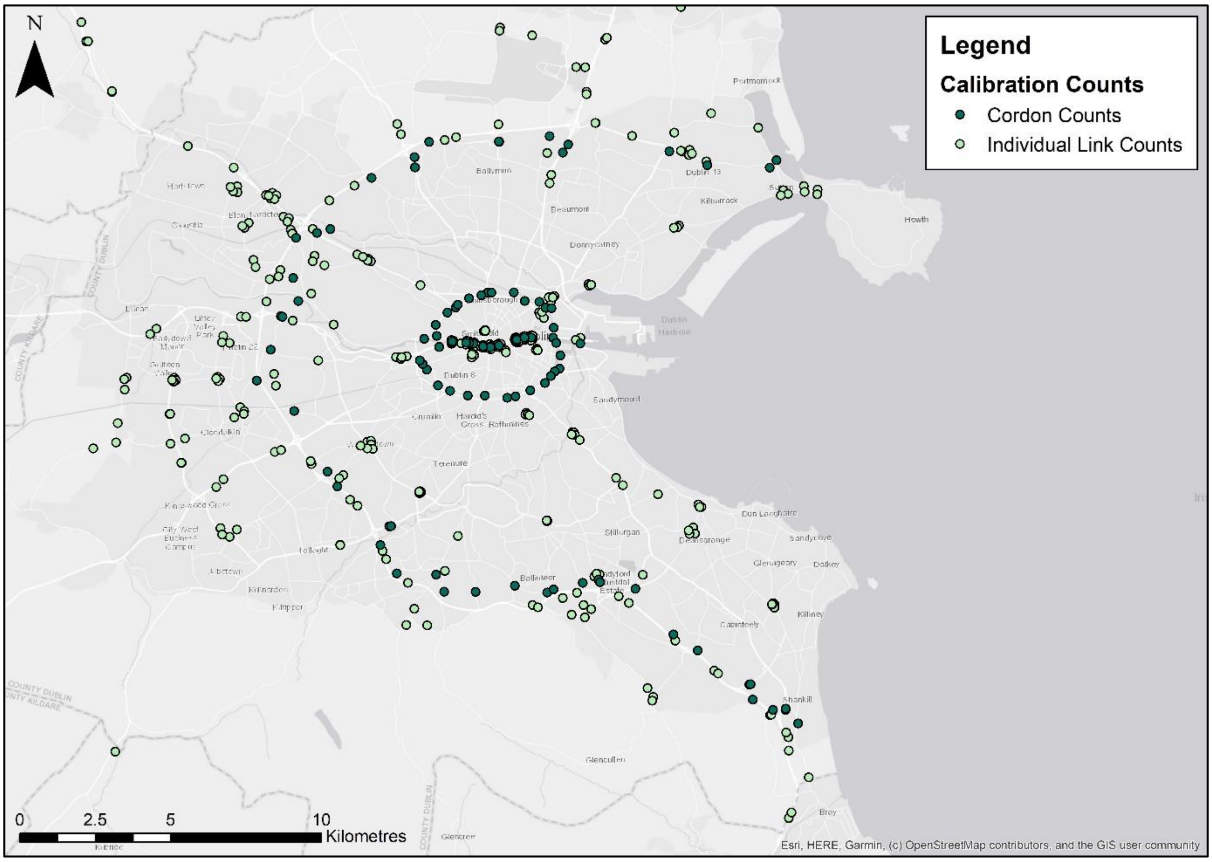


Figure 7.7 Dublin Road Assignment Individual Link Counts (Calibration)

All assignments are calibrated against 890 individual link counts, with the exception of the LT which has 686 counts and the OP which has 133. The LT has a reduced number as three locations were removed as the data was erroneous. The OP has less data as most surveys are undertaken between 0700 and 1900. Of these counts, in all time periods, 355 form the screenlines.

7.10.2 Assignment Validation

The road assignment was validated against 706 individual link flows using the criteria set out in Section 7.6.2 and against journey time validation criteria set out in Section 7.6.3. Figure 7.8 details the location of each individual link count used to validate the road assignment component of the ERM.

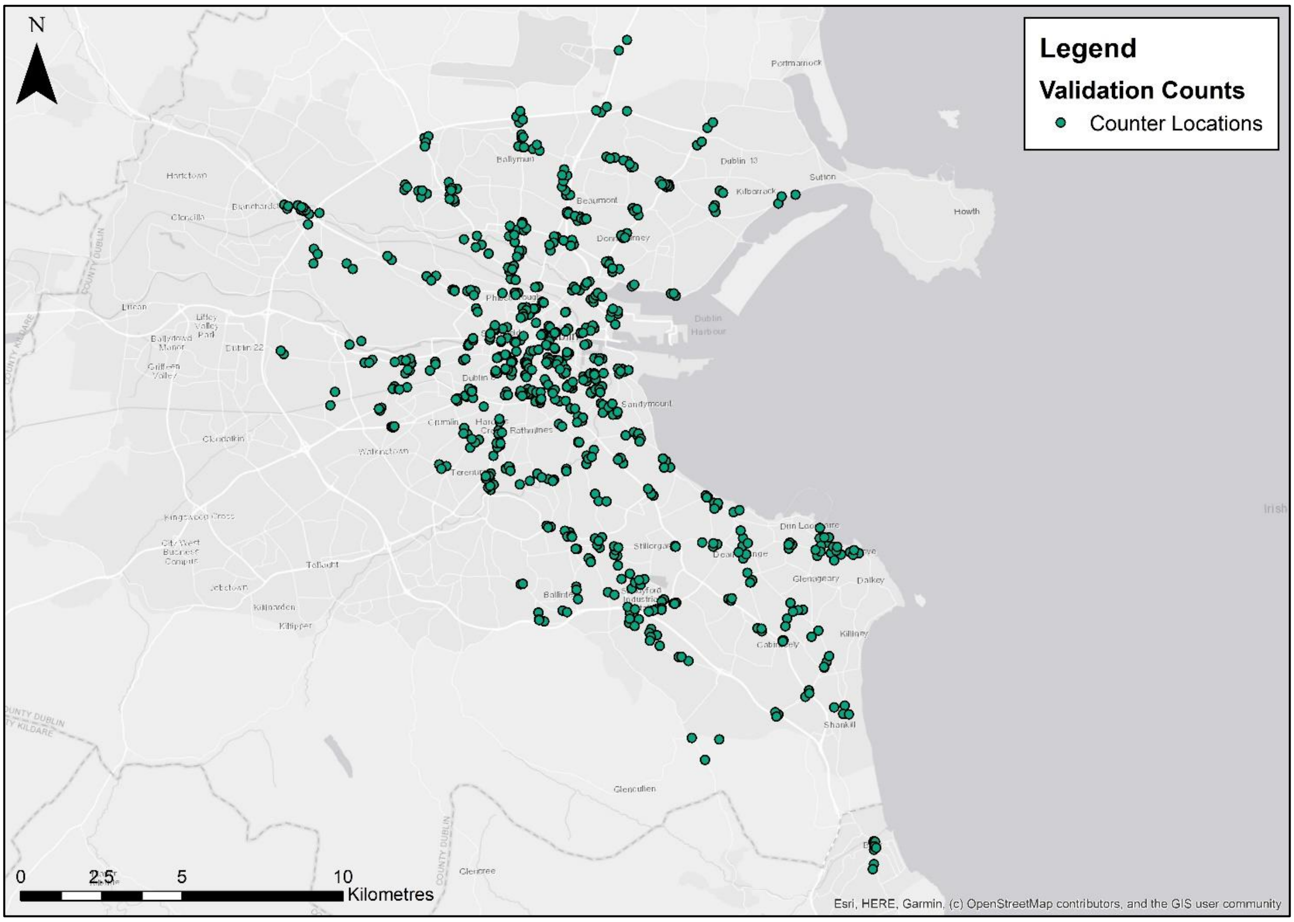


Figure 7.8 Road Assignment Individual Link Counts (Validation)

Figure 7.9 and Figure 7.10 detail the journey time routes that were used during the validation of the ERM.

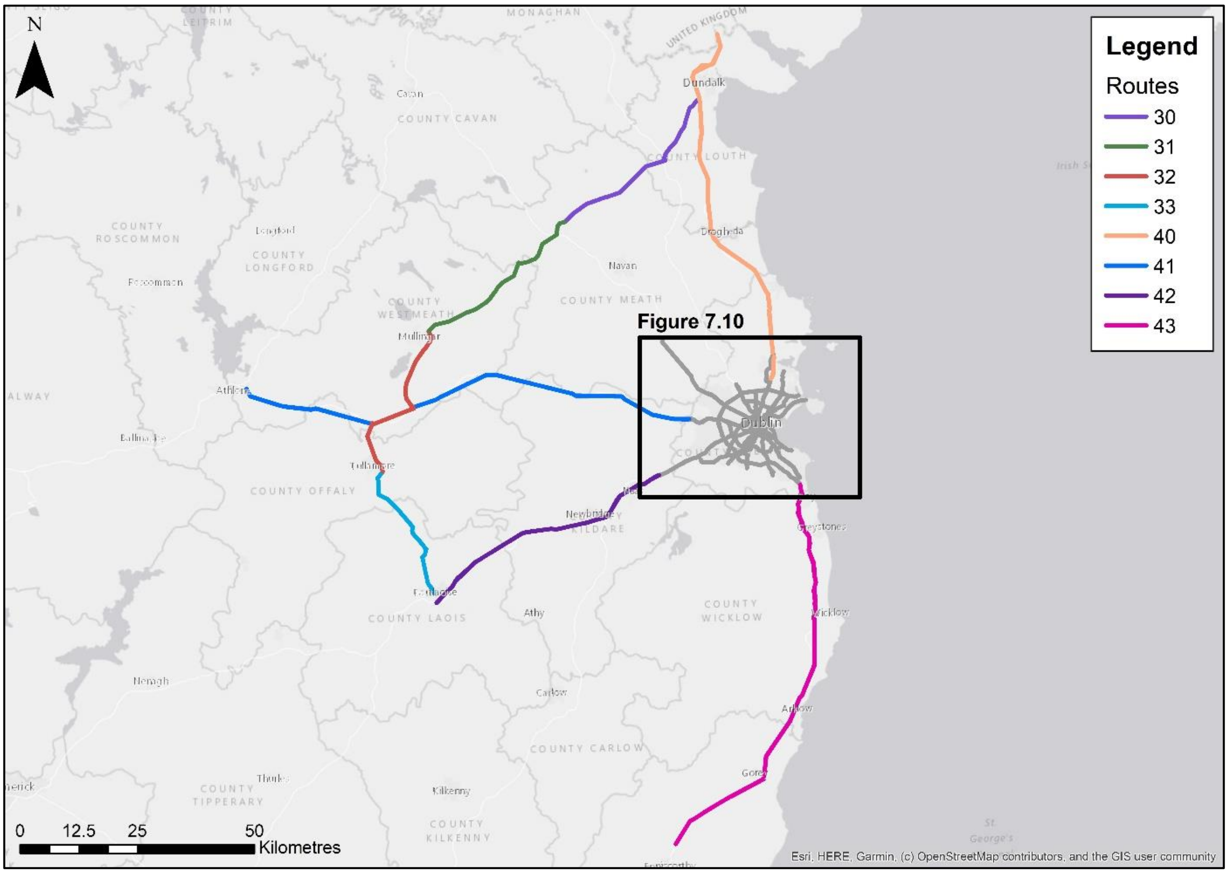


Figure 7.9 Road Assignment Journey Time Routes (Validation)

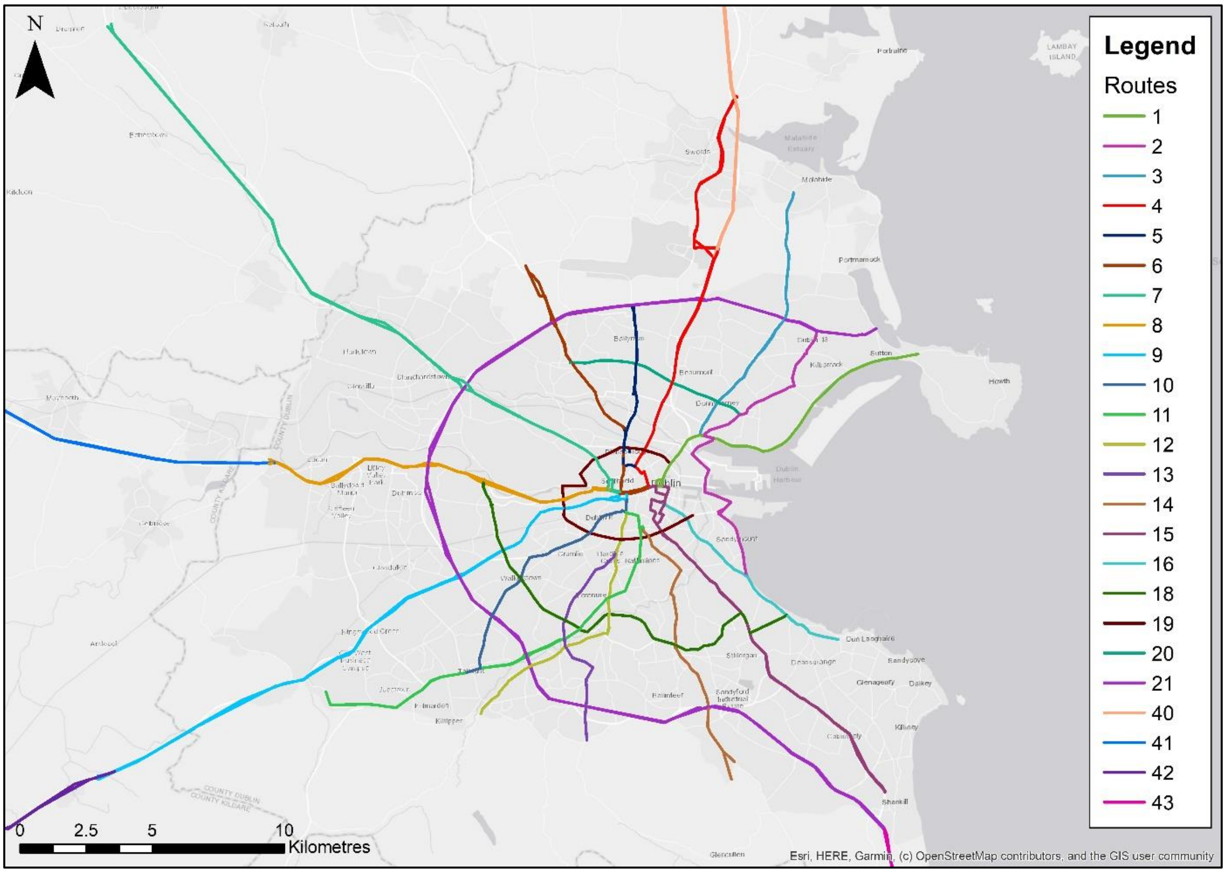


Figure 7.10 Dublin Road Assignment Journey Time Routes (Validation)

8 Public Transport Model

8.1 Introduction

This chapter describes the development activities undertaken on the ERM Public Transport Assignment Model (PTAM) as part of the overall calibration process. For a detailed description of the initial update of the ERM PTAM to the 2016 base, please see the *PT Network Development Report*, which includes detailed description of:

- A review of all model parameters e.g. time periods, fare systems, crowding curves etc.;
- Updates to the road, rail and walk networks; and
- Updates to bus and rail services.

The above document should be referenced in order to obtain the complete record of work undertaken to develop the 2016 ERM PTAM. The PTAM has been developed in Cube Voyager (version 6.4.2).

This section provides an overview of the key features of the PTAM, followed by description of the main activities undertaken to improve the model performance during the calibration of the ERM.

8.2 Public Transport Model Components

The PTAM is a system of networks, services data, assignment algorithms and parameters, and input trip matrices and requires as input. Its network is assembled by processes in the ERM from the following inputs:

- Road network links (copied directly from SATURN to Cube Voyager network format);
- Walking links (added to the road network to permit walk only paths and access to rail stations);
- Rail links; and
- Zone connectors (the connection points from zone centroids to the “physical” network).

Services are defined from Google Transit Feed Specification (GTFS), as descripted in the *PT Network Development Report*.

The Public Transport assignment algorithm implements a sequence of rules—network simplification and path building, route enumeration, route evaluation—to find an "approximate/feasible solution" close to the optimal solution. More detailed information on the assignment algorithm can be found in the "Public Transport Program" chapter of the Cube Voyager help documentation.

8.3 Model Area

There are 1,953 model zones in the ERM, of which 1,907 are internal zones, 39 are road route zones and 7 are rail route zones. The zone system is common to the Demand Model and each of the assignment models. This includes for a greater level of zonal density in urban areas such as Dublin enabling a more accurate representation of walk times for public transport users. This allows the cost of travel by PT, and associated modal split, to be calculated with a greater degree of accuracy within the model. The rail network, and the route zones are displayed below in Figure 8.1.

8.4 Public Transport Model Sub Modes

The PT sub modes included in the PTAM are as follows:

- DART;
- Other rail;
- Luas;
- Dublin Bus;
- Other bus;
- Bus Rapid Transit (not used in the base year); and
- Metro (not used in the base year).

For each sub-mode the model requires a specification of public transport operators, services and fare structure.

8.5 Time Periods

The time periods modelled in the ERM are detailed below, in line with the model segmentation detailed in Chapter 5, and are consistent with the other models. Each time period requires its own specific set of services as headways and journey times vary throughout the day.

- AM Peak (0800 – 0900);
- Lunch Time (1200 – 1300);
- School Run (1500 – 1600);
- PM Peak (1700 – 1800); and
- Off Peak (2000 – 2100).

The assigned model time periods were informed by analysis observed count data and further information on the time periods detailed in the Peak Hour Specification Report.

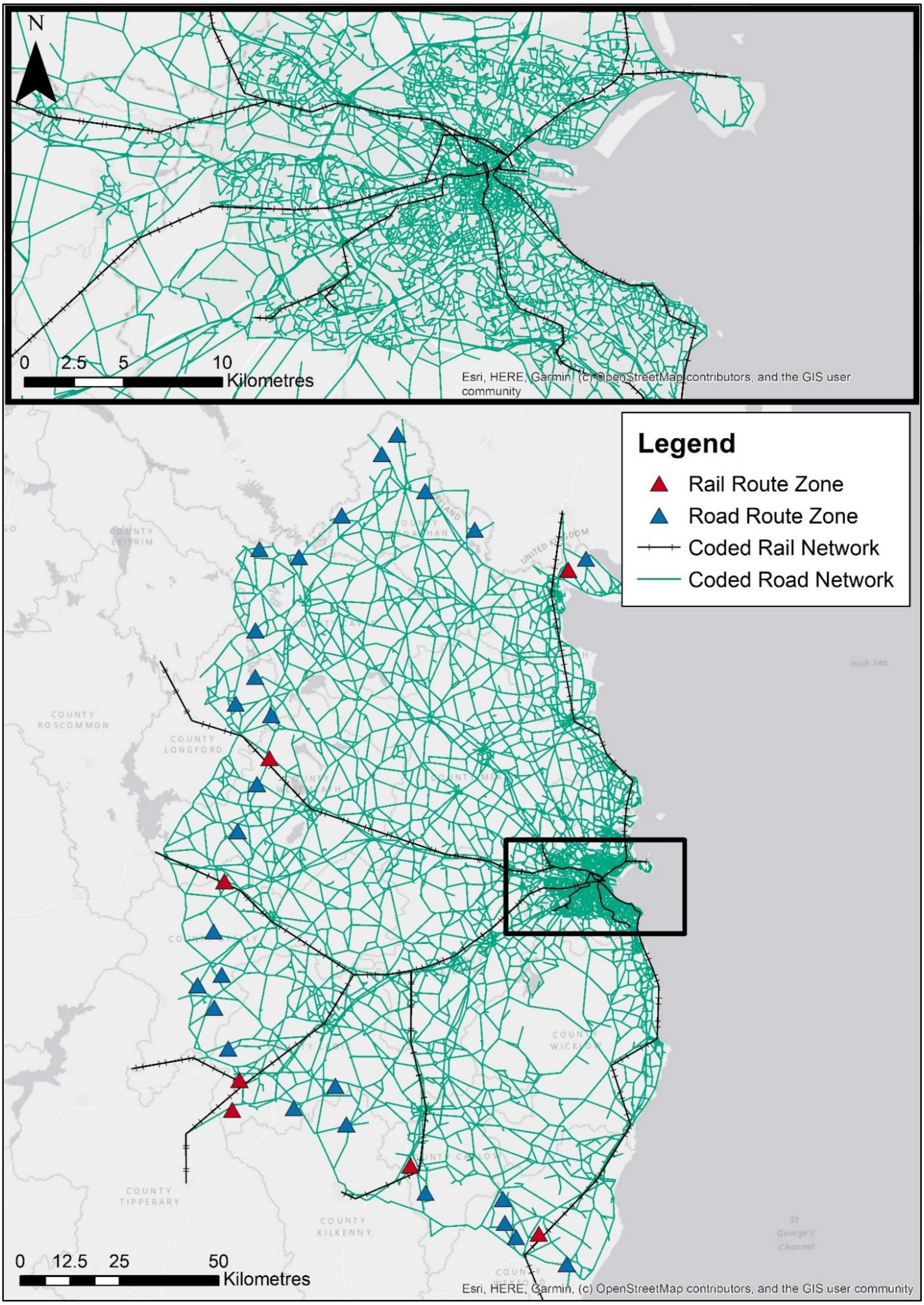


Figure 8.1 ERM Coded Network and Route Zones

8.6 User Classes

As different PT users experience and perceive very different costs in using PT services, the matrix of PT demand within the PTAM is split into the following user classes:

- Employer's Business: trips on employer's business;
- Commute: commuting trips between home and work;
- Other: all other journey purposes including shopping, visiting friends, escort to education etc., and one-way commuting trips;
- Non-Dedicated School (Education): primary and secondary school pupil trips on general PT services between home and place of education. Does not include contracted Department of Education school bus services; and
- Concessionary Travel (Retired): passengers eligible for free travel passes on PT through the Free Travel Scheme.

8.7 Assignment Method

The Public Transport assignment model (along with the Road and Active Modes) receives the trip matrices produced by the Demand Model and assigns them in their respective transport networks to determine route choice and the generalised cost for each origin and destination pair.

The PTAM assigns Demand Model 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.

The PTAM assigns trips to the PT network for five time periods across the full day. In the assignment process, public transport demand is represented by a single hour for each of the five time periods, and factors are used to convert the demand for the relevant period to a single hour for assignment purposes. Further details regarding the time periods is provided in Chapter 5 and in the *Peak Hour Specification Report*.

Figure 8.2 illustrates the key interfaces between the PTAM and other interdependent parts of the regional model. As shown, the PTAM's inputs are a mixture of user-defined inputs (including various parameter and network files etc.) and from the regional model (the road network and PT demand matrices). The PTAM assignment procedures generate costs skims which are fed back to the regional model when complete. The calculation steps in the PT assignment are identical for each of the five time periods modelled, but the input files will vary for each time period and each scenario.

The key steps within the PTAM are:

- Path enumeration which determines potential routes (or paths) through the PT network using combinations of appropriate services, and discarding illogical paths; and
- Route choice which compares the generalised cost of travel for each path, and then calculates the number of person trips using each one.

The calculation of the generalised cost of travel is based on the PT parameters described in Section 8.8 below, as well as the impact of capacity restraint (defined as crowding on PT services) on people's perceived cost of travel. Crowding costs are calculated using a separate sub-model which is described in the Section 0.

Access to the PT network is provided by non-transit legs. Non-transit legs are minimum-cost segments generated by the model to represent any leg of a route not undertaken on a PT service.

Further details on the structure of the PTAM can be found in the *PT Network Development Report*.

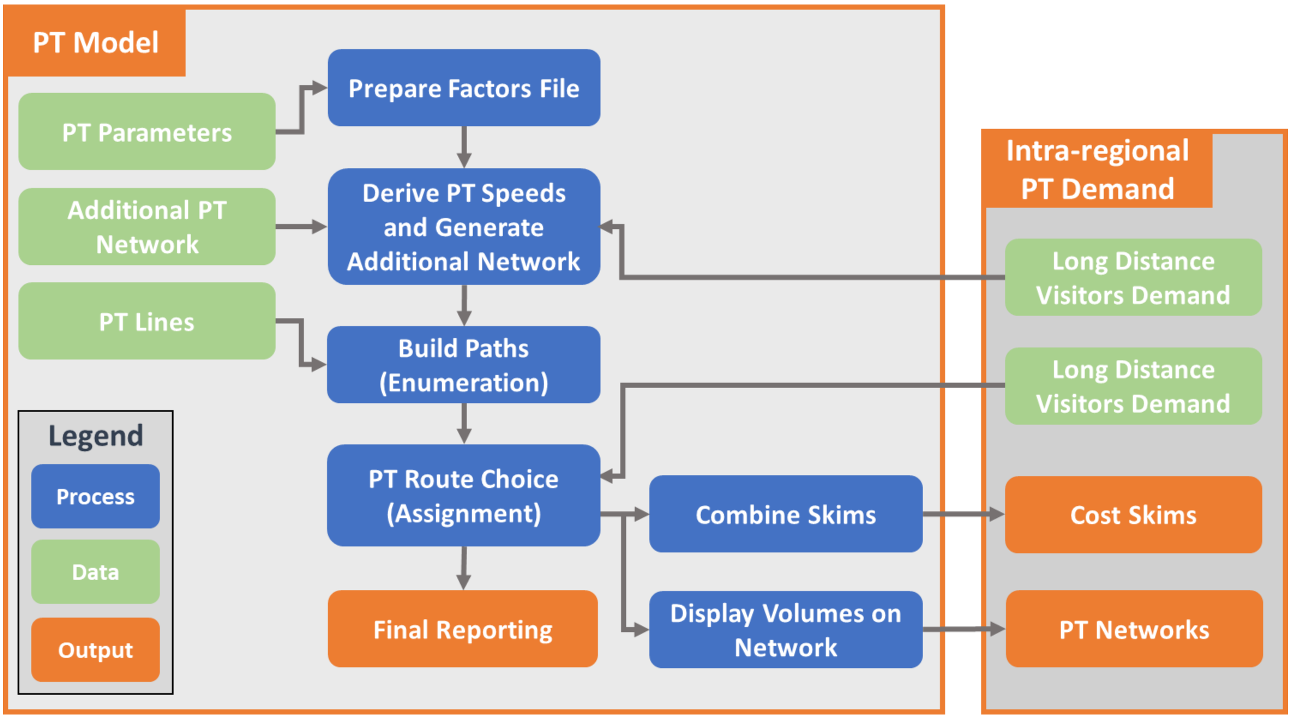


Figure 8.2 General PT Model Flow

8.8 Generalised Cost and Parameters

In order to assign PT person trips to the PT network, the PTAM must calculate the generalised cost of travel for each possible path through the network from trip origin to trip destination. As people perceive cost differently on the various stages of their journey (and between journeys on different modes and services), the PTAM uses weights and parameters to convert the objective journey costs into perceived costs. These weights and parameters are specified as inputs by the user and are adjusted as part of the model calibration process which is described in Section 8.11 below.

Network parameters can be classified in three main categories:

- PT access parameters – these relate to the access and egress parts of the trips (i.e. the part of the trip between the zone centroids and PT stops) and include weightings to be applied to the time spent walking to or from PT stops;
- PT journey parameters – these relate to the elements of generalised cost that make up the full PT journey time including wait time, fares paid (converted to units of time), in-vehicle time, boarding penalties and transfer penalties; and
- Route choice parameters – these relates to how the software calculates paths between zones and assigns the demand to the different routes. These parameters are normally kept the same for all five regional models and all scenarios and are not altered during the model calibration process.

It should be noted that the wait time parameter is implemented in the PTAM using a “wait curve” that defines the relationship between service headways and perceived wait times. In addition to accounting for people’s different perception of time while waiting, this curve also takes into account different behaviour exhibited depending on whether people are using frequent and infrequent services. In other words, people will just “turn up and go” for a frequent service but will try to time their arrival at a bus stop to coincide with an infrequent service to minimise wait time.

A list of the key parameters required (e.g. fares, value of time, walk time weights, in vehicle time, walk speed, boarding, wait factors and model choice sensitivity), along with their detailed description, value and source is provided in the main *PT Network Development Report*.

PT Fares

In order to calculate the generalised cost of travel for PT, the PTAM requires detailed information on fares in use throughout the ERM area and across the range of operators for bus, rail and Luas modes. In applying these to the generalised cost calculation, the PTAM converts these fares to units of time, using the value of time input parameter.

As part of the 2016 PTAM development, ticket sales and revenue data were obtained from the NTA and used to derive the fares, and fare structures, that should be applied to each of the PT operators within the model. The fares models for Luas and bus services are based on 2016 fare information. For rail fares, trips through the Dublin Short Hop Zone are also based on 2016 data, whilst inter-city rail (including DART and Irish Rail) are based on 2018 fares information.

Further information about the development of the fares model can be found in the Fares Modelling Report.

8.9 Crowding Model

The Crowding Model is the part of the PTAM and takes account of capacity restraint on PT services and the associated impact on the perceived cost of travel. The relationship between crowding (defined as the ratio of occupancy vs capacity) and the cost of travel is a derived input to the PTAM, and is referred to as a "crowding curve".

Crowding curves are implemented as multiplicative curves in the PTAM assignment procedures. Crowding factors are applied to the link journey time to represent the perceived journey time spent in crowded conditions relative to journey time at seated and standing capacity. It should be noted that all modelled occupants perceive the same crowding on a given section of the route, regardless of where they boarded.

After the initial assignment, the crowding curve is used to calculate a factor for each service which represents perceived crowding costs; this factor is then fed-back into route-choice process which adjusts the proportion of trips using each path in response to the change in costs. This in turn results in a different level of crowding on affected services, which alters the crowding factor and so the assignment must be undertaken iteratively until a stable solution is found.

Three different crowding curves are used, one for each PT sub-mode (i.e. Rail, Bus and Light Rail) and have been set as identical to those used in the 2012 Calibrated ERM. Crowding curves are implemented as multiplicative curves in the PT assignment procedures. For each level of utilisation, the free link journey time is multiplied by the appropriate adjustment factor to represent the perceived journey time spent in crowded conditions. It should be noted that all modelled occupants perceive the same crowding on a given section of the route, regardless of where they boarded. The measure of utilisation is expressed as the percentage of standing passengers as a proportion of the standing capacity. Utilisation is therefore zero until seated capacity is reached, and is 100% when the vehicle is at crush capacity, i.e. all standing room is taken.

8.10 Development and Calibration Data

A detailed description of the data sources used to development the ERM Public Transport Assignment Model is provided in Chapter 3 and in the main *PT Network Development Report*. In summary, the key data sources include:

- Network data;
    - ERM road network; and
    - Mapping (e.g. HERE maps).
- Public transport service data;
    - General Transit Feed Specification; and
    - Fleet data (e.g. bus types and characteristics by operator).
- Public transport fares data;
    - Ticket sales; and
    - Actual fares.
- Passenger and operational data;
    - National Heavy Rail Census 2016;
    - Luas Census 2016; and
    - Bus count data.

In developing both the road and public transport networks for all five regional models, extensive use was made of HERE maps. These provide a complete representation of both road and pedestrian networks, and include a detailed set of link attributes which can be used to identify road type, speed, and for example, pedestrian only links. While primarily used as an input to the road assignment model, these maps provide additional information to the PTAM on pedestrianised links.

The data used for model calibration includes bus speeds obtained from AVL data, PT boardings and alightings, whilst for model validation a separate set of observed data is used from different PT surveys and ticketing information.

8.11 Network Development

8.11.1 Road Network Input

The primary public transport network within the PTAM is taken from the ERM road model (which is coded using SATURN software) including information on:

- Link distances;
- Link capacities;
- Bus lanes;
- Bus speeds; and
- Congested network speeds.

8.11.2 Public Transport Network

In addition to the road network, the PT network also comprises a number of input components including specific links for walk, bus, rail and Luas, as well as zone connectors.

Walk-only links are used to represent segregated footpaths which wouldn't be present in the road network, as well as creating links to allow interchange between the road network (used for walk access/egress and bus services). In addition, it is also necessary to mark certain road links as "transit-only", which can be used by bus and other PT services but cannot be used as walk links to access or egress from the PT services. This category of link would be used to represent motorways and other roads where walking is prohibited, as well as the rail and Luas lines.

Bus links need to be added where there are bus-gates and bus-only roads as these will generally not be present in the road network. Furthermore, all one-way links inherited from the road model are converted to two-way; not only does this allow bus services using contra-flow bus lanes to be coded, but is also necessary to allow trips to walk either way down these roads when accessing PT services.

PT Services Definition

The PTAM incorporates a full representation of all public transport operators and services provided within the ERM modelled area. In coding public transport services, a standard procedure was used for all five regional models, based on General Transit Feed Specification (GTFS) data. GTFS defines a common format for public transportation schedules and associated geographic information. Data on all public transport services are made available in GTFS format on the Transport for Ireland (TFI)[34] website, including information on timetables, stop locations and routing. The PTAM uses the 2016 GTFS data directly to define public transport services in the model. An automated procedure was developed to convert from GTFS format to the format required by the PTAM. Further information on the conversion procedure can be found in the *PT Model Development Report*.

The following major public transport operators have been specified in the PTAM for the ERM:

- DART;
- Luas;
- Dublin Bus;
- Bus Eireann;
- Irish Rail (defined by corridor);
- Dublin Bus airport services;
- Bus Eireann airport services;

[34] GTFS data available at: https://www.transportforireland.ie/transitData/PT_Data.html

- BRT operator (not used in the base year); and
- Metro operator (not used in the base year).

In addition to the operators listed above, a number of private bus operators have also been specified, details of which can be found in the *PT Model Development Report*.

Zones and Zone Connectors

Public Transport zone connectors are inherited from the road network. An additional 80 connectors are added to the road connectors to represent more accurately PT access in certain areas.

Further details concerning the coding of Zone Connectors and access links can be found in the *PT Model Development Report* while the derivation and definition of the zoning system are detailed in Chapter 4.

Network Summary

Table 8.1 below gives a summary of the number of links by mode / type, zones and centroid connectors in the ERM.

Table 8.1 Summary of PT Network

PT Element	ERM Count
Rail Links	340
Active Modes Only Links	755
Road Links	36,999
Zone Connectors	5,101
Centroid Connectors	1,953
Geographic Zones	1,907
Road Route Zones	39
Rail Route Zones	7
Special Zones	3

8.12 Matrix Development

The PT trip matrix for the 2016 base year is a synthetic matrix created by the regional Demand Model.

During calibration of the PTAM, a matrix estimation process can be applied to the synthetic matrix to improve the goodness of fit across the modelled area. As described in Chapter 11, the differences that the matrix estimation process introduces to the demand matrix will reflect the slight variations in behaviour which aren't otherwise captured by the model. Subsequently, the differences can be applied to the output from the regional Demand Model as an "incremental adjustment" to improve the overall model performance.

This process is described in more detail under PTAM model calibration in Chapter 11.

8.13 Network and Assignment Checks

As part of the development and update of the PTAM in 2016, a series of network, assignment and quality assurances checks were undertaken. These included:

- Review of PT routes generated by the GTFS conversion process;
- Sense checking of observed data to be used in model calibration; and
- Preliminary assignment tests focusing on:
    - Lines without any PT demand;
    - Accessibility to PT services; and
    - Analysis of routing within the model.

These additional checks resulted in further revisions to the network coding and increased the quality of the network in advance of calibration.

8.13.1 PT Access

It is necessary to check that the PT assignment model can generate access legs between zones and the PT network. To do this, the Non-Transit leg file is used to extract the following indicators:

- Number of PT stops accessible;
- PT trip-ends by sub mode; and
- Weighted average PT access cost.

To determine zones without any access to PT in the model a demand matrix of zone-to-zone PT trips was derived from POWSCAR 2016 and assigned. School trips were not considered as school buses are not represented in the ERM.

Zones with a total of POWSCAR 2016 PT work trips over 50 (the sum of productions and attractions) but without PT access were reviewed and where possible fixed by adding a service or link.

Zonal maps of POWSCAR PT demand by sub mode were produced for sense checking (e.g. rail demand is expected to come from zones close to rail stations).

The number of accessible stops and access costs by zone were analysed to ensure that PT access parameters generate a reasonable representation of the situation.

Any significant under/over estimation in boardings at a particular stop can also draw attention to an area and lead to a review of zones connectors.

The slack parameter is defined as the maximum extra time a PT user can travel further than the time required to access to the closest stop, to access other PT services. Its purpose is to prevent PT users to travel far to access a service if there is already a stop nearby for the same mode. Slack parameter should be defined between 0min (closest stop only) and the maximum walk cost allowed.

- Modify the zone connectors;
- Modify the PT access parameters:
  - Maximum number of stops accessible by sub mode;
  - Maximum walk time to access a PT stop by sub mode; and
  - Value of the slack by sub mode.

The summary criteria which should be achieved during model validation is presented in **Error! Reference source not found.**.

Table 8.2 Access to Public Transport Validation Criteria and Acceptability Guideline

Criteria	Description of Criteria	Acceptability Guideline
1	Zones with more than 50 POWSCAR 2016 PT work trips (productions and attractions) have access to PT	> 95% of cases

Bus Journey Times

The first thing to calibrate in the PT assignment model is bus network speed. Having correct bus speed modelled is crucial to represent accurate bus journey times and therefore to have fair sub mode competition.

Bus journey times are calculated using congested speed from the road assignment. Several parameters are provided in the PT assignment model to enable calibration of bus journey times at the link level and at the route level. Modelled bus journey times are calculated as:

$$Bus\ Journey\ Time = \frac{Distance}{Car\ speed\ \times F1 \times F2 \times F3} \times\ Time\ Factor$$

Where

- F1 is a link-type (motorways, rural, urban etc.) factor;
- F2 is a geographical (sector-based or bespoken area) factor;
- F3 is a geographical and link-type factor; and
- Time Factor is a route type (express, all stops etc.).

For bus lanes, which are assumed to remain uncongested, speeds are obtained from a low-demand network assignment, i.e., where all links operate at their uncongested speed.

Bus dwell times are included in the observed data used to calibrate the modelled journey times. Time factors defined above represent bus dwell time.

Rail journey times are hard-coded in the model and directly extracted from GTFS data. Dwell times are included where this is available from GTFS. No action is required at the calibration stage on rail journey times unless there is evidence that they are not correctly coded.

8.13.2 Analysis

The following comparisons between model outputs and observed data were undertaken:

- End-to-end modelled Bus Journey Times V's Automatic Vehicle Location (AVL) observed data;
- End-to-end modelled Bus Journey Times V's Timetable data (General Transit Feed Specification or GTFS); and
- Stop-to-stop modelled Bus journey times to AVL observed data.

8.13.3 Calibration Actions

The following additional checks and calibration activities were undertaken on the PT model:

- Calculating modelled average bus speed on the entire route and investigating outliers (average modelled speed below 10kph or above 90kph);
- Calibrating link-type & geographical bus speed factors based on stop-to-stop journey time comparison (AVL vs modelled);

- Applying geographical bus speed factors (see PT Runtime Factors below for further detail); and
- Analysis of end-to-end bus journey times (modelled Vs observed for both AVL and timetable data) by time period and by type (urban, normal and express).

The summary criteria which should be achieved during model validation is presented in **Error! Reference source not found.**.

Table 8.3 Bus Journey Times Validation Criteria and Acceptability Guideline

Criteria	Description of Criteria	Acceptability Guideline
1	End-to-end modelled Bus Journey Times within +/-25% the observed journey times (AVL data)	> 85% of cases
	End-to-end modelled Bus Journey Times within +/-25% the scheduled journey times (GTFS data)	> 85% of cases

8.13.4 PT Runtime Factors

The following steps are undertaken to adjust modelled bus speeds to match the observed.

- Re-run the PT assignment with existing Time Factors set to 1;
- Compare the journey time output from the assignment to observed data (GTFS and AVL);
- The factors are calculated by dividing observed by modelled journey times and as average for each service group. Service groups were defined based on the corridors on which the buses are operating;
- Calculate factors based on AVL data when available, otherwise GTFS data is used;
- Factors are then applied to all PT lines in each service group; and
- Run PT assignment with the new factors.

8.14 PT services updates

8.14.1 Analysis

PT services coded have been extracted from GTFS data and checked when possible against independent sources of data (Census, boarding counts etc.). For each time period, services are included in the coding if their mid journey time is within the representative hour. This rule can be modified (mid journey time within the time period rather than the representative hour) on low frequency routes where lack of PT route creates connectivity issues. The process is however not 100% error proof and issues that can be identified during calibration are:

- Missing service: A service exists but is not coded in the PT network;
- Incorrect route: The coded PT line doesn’t follow the actual route; and
- Frequencies issues: The coded route has more/less services than the actual route.

PT lines coder can be amended to fix these issues. All modifications to be logged to track the origin of the error (GTFS data, lines coding process).

8.15 Time weightings and factors

In-vehicle time factors defined as a starting point are derived from stated preference surveys but can be modified during calibration process. In-vehicle time factors should only be modified when there is strong evidence that the correct sub-mode shares can be achieved by modifying them (for example 2 modes running in parallel, one overestimated and the other one underestimated, assuming the rest of the coding is correct). Coded services and zone connectors should be checked prior to modifying in-vehicle time factors.

Table below provides values for In-Vehicle Time factors, derived from the stated preference surveys (SWRM, SERM, MWRM and WRM) and the calibrated 2012 version of the ERM (ERM).

Table 8.4 In-Vehicle Time Factors to Commence Calibration

Regional Model	Rail IVT factor	Luas IVT factor	Bus IVT factor
ERM (Dublin)	1.30	1.00	1.50
SWRM (Cork)	1.00	1.00	1.26
SERM (Waterford)	1.00	1.00	1.00
MWRM (Limerick)	1.00	1.00	1.00
WRM (Galway)	1.00	1.00	1.13

8.15.1 Analysis

The analysis for IVT factor calibration is based on the boarding/alighting validation performance across PT sub-modes. The boarding figures help to identify whether there is a sub-mode which has unrealistic advantage over other sub-modes. This particularly applies where there are two sub-modes running on parallel routes. The analysis of assignment performance in these respects did not reveal any issues and therefore the values presented in Table 8.4 have been retained in the PTAM.

8.16 Interchange / boarding penalties

Interchange and Boarding penalties defined as a starting point are coming from UK TAG guidance but can be modified during calibration process. They should only be modified when there is strong evidence that the correct sub mode shares can be achieved by modifying them. Coded services and zone connectors should be checked prior to modifying boarding and interchange penalties.

The initial boarding and transfer penalties are presented in **Error! Reference source not found.** while the initial transfer penalties are presented in **Error! Reference source not found.**.

Table 8.5: Initial Boarding and Transfer Penalties

Regional Model	Boarding Penalty	Range allowed during calibration
All PT Modes	5 min	5 to 15min

Table 8.6 Transfer Penalties between PT Sub-Modes (minutes)

	DART	Irish Rail	Luas	Urban Bus	Other Bus	BRT	Metro
DART	15	15	15	15	15	15	15
Irish Rail	15	15	15	15	15	15	15
Luas	15	15	5	5	5	5	5
Urban Bus	15	15	5	15	5	5	5
Other Bus	15	15	5	5	5	5	5
BRT	15	15	5	5	5	5	5
Metro	15	15	5	5	5	5	5

8.16.1 Analysis

Similar to IVT factors in calibration, the boarding and transfer penalty calibration may be based on boarding/alighting validation performance across PT sub-modes. Based on the sub-mode analysis all values as presented in the table were retained during the calibration process.

8.17 Fare model

Fare models have been built for each regional model based on available data, broken by main sub modes (Rail, Urban Bus, Bus Eireann regional, Private Bus operators, Luas etc). Fares are 2016 fares in 2016 prices. The process aims to achieve a good reflection of the fare system, however the following two issues may be identified and rectified during calibration:

- Fare system not linked to PT line: No fare applied to journeys made on certain lines; and
- Inaccurate fare system for a route: the fare system used on a PT line is not the correct one.

9 Active Modes Model

9.1 Introduction

This chapter gives a summary description of the Active Modes Model (AMM) within the regional Demand Model. The development of the AMM is described in detail in the *ERM Active Modes Model Development Report.* The AMM has been developed in Cube Voyager (version 6.4.2).

The function of the AMM is to assign the walk and cycle trip matrices output from the regional Demand Model and to the walk and cycle networks. The position of the AMM within the general structure of the East Regional Model (ERM) and the wider Regional Model System is shown within Section 2.3.3.

9.2 Modes of Travel

There are two modes used within the AMM – walk and cycle. Walk trips are made up of a combination of pure end to end walk trips and also the walk component of Parking Distribution trips. Walk trips do not include the walk components of public transport trips.

9.3 Time Periods

The time periods modelled in the ERM are detailed below, in line with the model segmentation detailed in Chapter 5. Each time period can have its own specific network so that, for example, differences in traffic light phasing throughout the day can be modelled.

- AM Peak (0800 – 0900);
- Lunch Time (1200 – 1300);
- School Run (1500 – 1600);
- PM Peak (1700 – 1800); and
- Off Peak (2000 – 2100).

The assigned model time periods were informed by analysis of observed count data and further information on the time periods detailed in *Peak Hour Specification Report.*

9.4 User Classes

The following user classes are defined in the active modes assignment model, allowing for variations in value of time and other parameters:

- Employers Business: trips on employers’ business;
- Commute: commuting trips between home and work;
- Other: all other journey purposes including shopping, visiting friends, escort to education etc;

- Education: primary and secondary school pupil trips between home and school; and
- Retired: people past retirement age who will generally have lower values of time and lower walking and cycling speeds.

For further information on user classes, please refer to Chapter 5.

9.5 Assignment Method

The AMM is implemented in CUBE Voyager software and currently uses an “all-or-nothing” assignment. This means that for every origin-destination pair of zones, the lowest cost route is chosen and all trips between those two zones are assigned to that route. This method has been chosen as we currently have limited understanding of the factors that influence walk and cycle route choice. Further detail is provided in the *Active Modes Model Development Report.*

9.6 Generalised Cost and Parameters

The AMM network is the aggregation of the road and walking networks with identical node, link, zone connectors, and numbering convention.

Network speeds are established differently for the Walk and Cycle networks: Walking has adopted a relatively fixed and linear approach, whereas cycling has adopted a rule-based approach.

Specifically, walking speed is assumed to be at a constant rate of 5.1km/h, independent of link type, for Employee (EMP), Commuter (COM) and Others (OTH) user classes. In the case of the Education and Retired user classes, this default walk speed is factored (by 0.94 for EDU and by 0.92 for RET). Assignment is based on the shortest distance path.

For cycling, a rule-based system was developed during model specification to assign speeds based on link type. Hence, where information on Quality of Service, and/or descriptions of other characteristics (e.g. road type, presence of marked cycle lanes, etc.) is available, speeds of between 14.1km/h and 22.2km/h have been assigned based on the quality of the link. Similar to walking, assignment of cycle trips is based on the shortest path.

For both walking and cycling, no account of the impact of congestion has been taken in determining route choice.

The Active Modes Model outputs costs skims to the Demand Model, based purely on travel time. It should be noted that the AMM is not suitable for analysis of actual walking and cycling journeys, as there is insufficient representation of the on-the-ground conditions that influences the speed and routing of such trips.

9.7 Network Development

The AMM networks are based on the road network with the addition of walk and cycle only links.

The approach used to develop the active modes network is described in this section. Four main steps are identified and described in the sections below:

- Adding walk links;
- Coding cycle facilities in the network;
- Assigning cycle speeds (based on cycle facilities); and
- Connecting zone centroids.

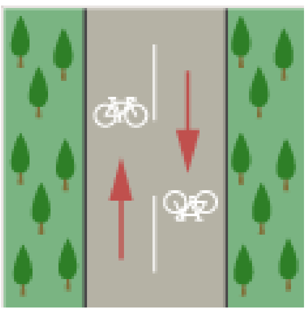
Further details on the development of the active modes network can be found in the *Active Modes Model Development Report.*

9.7.1 Adding Walk Links

To represent connections that are available to pedestrians, walk only links are added to the coded road network. These links were determined by comparing the ERM road network to an Open Street Map GIS layer, and extra links that were in the Open Street Map but missing from the coded road network were added. More attention has been paid to city centres (known pedestrian-only streets), parks, bridges (rail, road, river) and greenways. In addition to new walk links, new network nodes were added where required.

9.7.2 Coding Cycle Facilities in the Network

The NTA's Cycle Manual [35]is an important data source used to develop the cycle network within the AMM. The coding of different categories of cycle facilities in the model was checked against the classification of cycle facilities in the Cycle Manual – as illustrated in Figure 9.1 below. Six categories are defined, covering different types of cycling facilities. For the purposes of coding in the model, categories S1 (shared path with traffic) and C3 (on road cycle track) have been merged, as they represent a similar quality of cycle facility.

G1		Greenway: Cycle track independent from the road network

[35] https://www.cyclemanual.ie/

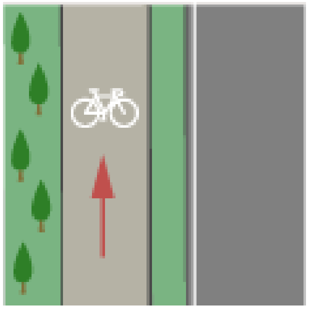
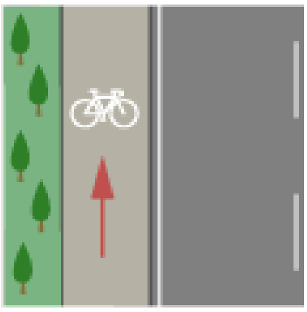
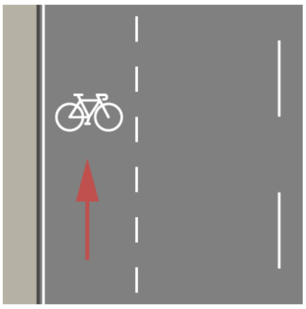
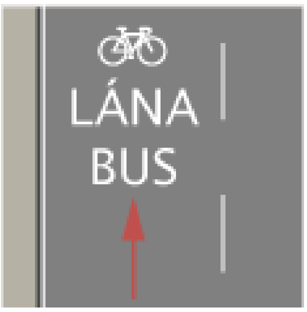
C1		Off-road cycle track separated from the road axis
C2		Off-road cycle track immediately adjacent to the road axis or on-road separated from the traffic
S1 / C3		On-road cycle track adjacent to traffic
S2		Shared track for cyclist and pedestrians
B1		Bus lane

Figure 9.1 Classification of Cycle Facilities in the NTA Cycle Manual

9.7.3 Assigning Cycle and Walking Speeds

The average cycle speed calculated from the 2017 National Household Transport Survey is 13.6km/h. This is the default cycle speed used in the model on links where there are no cycle facilities. On links where there is a cycle facility, the speed is increased depending on the quality and characteristics of the facility. Fully segregated cycle tracks are set to 19.9km/h, and this is the maximum cycle speed coded in the AMM. It should be noted that the coded speeds account for stopping at junctions. Table 9.1 Coded Network Speeds shows the cycle speeds coded for each link type. Figure 9.2 shows the cycle network for Dublin City Centre and it can be seen that most links are shown as grey (i.e. using the base network speed). Where cycle facilities exist, link speeds are increased as indicated by the colour of the link.

Table 9.1 Coded Network Speeds

Link Classification	2016 modelled speed (km/h) P1.5
Base network speed	13.6
B1/S2	16.8
S1/C3	18.3
C2	19.2
C1	19.5
G1	19.9

(*) Base network speed is calculated from the NHTS

The walking speed assigned to links is 5.1km/h except for the Education and Retired user classes, which are set to 4.8 and 4.7km/h respectively based on NHTS data for observed trips by these types of pedestrian.

9.7.4 Zone System and Zone Centroids

Zone connectors are used to link the zone centroids (which are positioned based on the population-weighted centre, as described in Chapter 4) with the active modes network. Zone centroids are common to all modes, whereas each mode will have its own distinct set of connectors. The location and number of zone connectors has been chosen to reflect the actual routing decisions and delays encountered at the start and end of a walk or cycle journey.

The active modes connectors are inherited from the road network (along with the Public Transport connectors). An additional 80 connectors are added to the road connectors to represent more accurately PT access in certain areas.

In the case of the active modes network the zone connector information is imported from the PT network. This is to ensure that there is consistency in the cost required to access the network when walking and seeks to reduce the risk of illogical mode choice results. However, it should be noted that zone connectors can be amended during the model calibration stage if required.

Further details concerning the coding of Zone Connectors and access links can be found in the *Active Modes Model Development Report* while the derivation and definition of the zoning system are detailed in Chapter 4.

9.7.5 Network Checks

The assignment of active modes trips to the network is checked to ensure that the walk and cycle flows are not using links they shouldn’t (e.g. motorways) and that cycle flows are more concentrated on cycle tracks etc. As discussed in the *Active Modes Model Development Report*, individual link flows are not calibrated, and direct matrix estimation is not used.

9.7.6 Pedestrian Flow Sense Checks

As illustrated on Figure 9.3 below, pedestrian trips do not use any of the motorway links which are banned for walking. There are more people walking in the centre of Dublin and further away from the central area the volume of walking trips reduces.

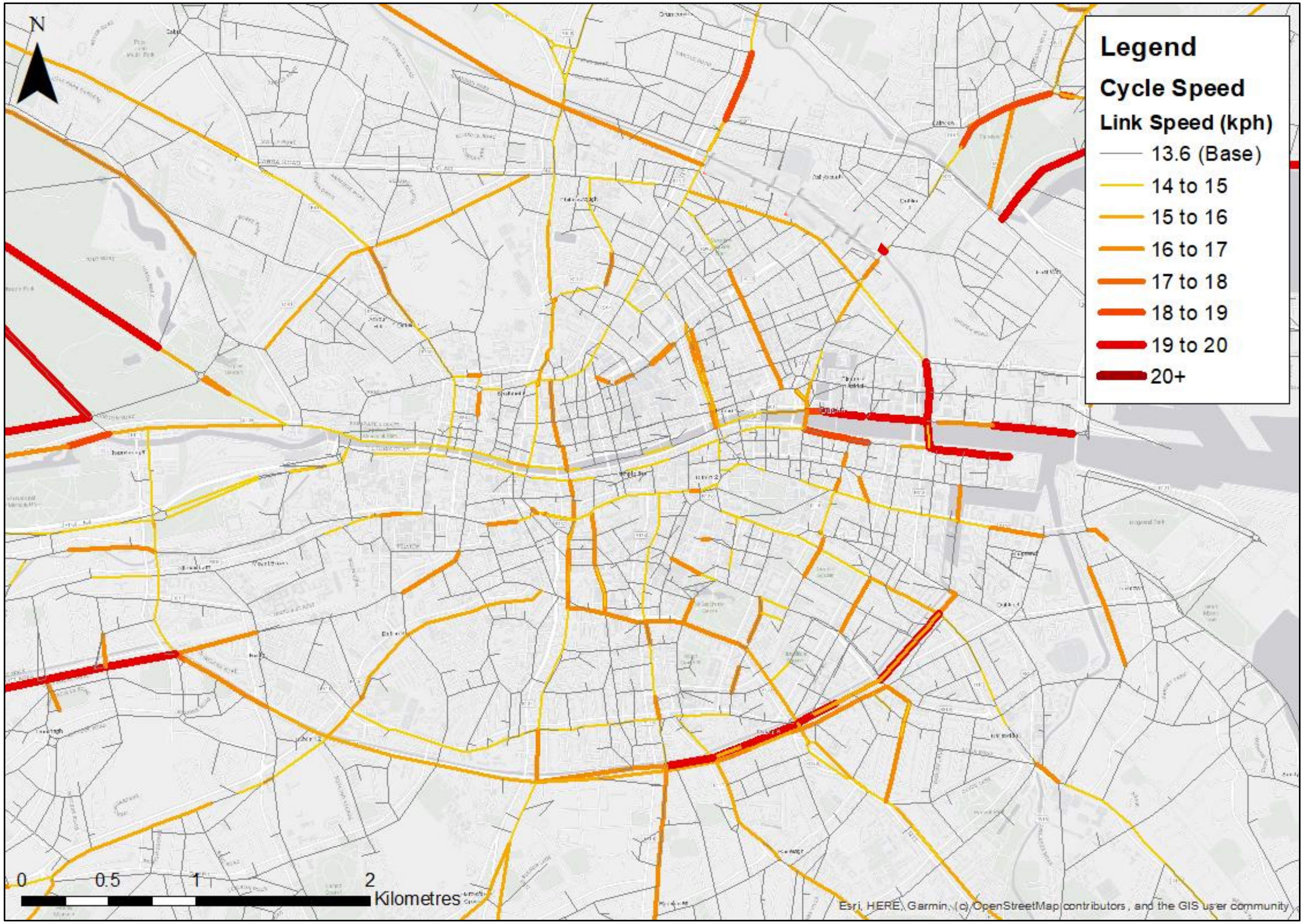


Figure 9.2 ERM Cycle Network and Cycle Speeds

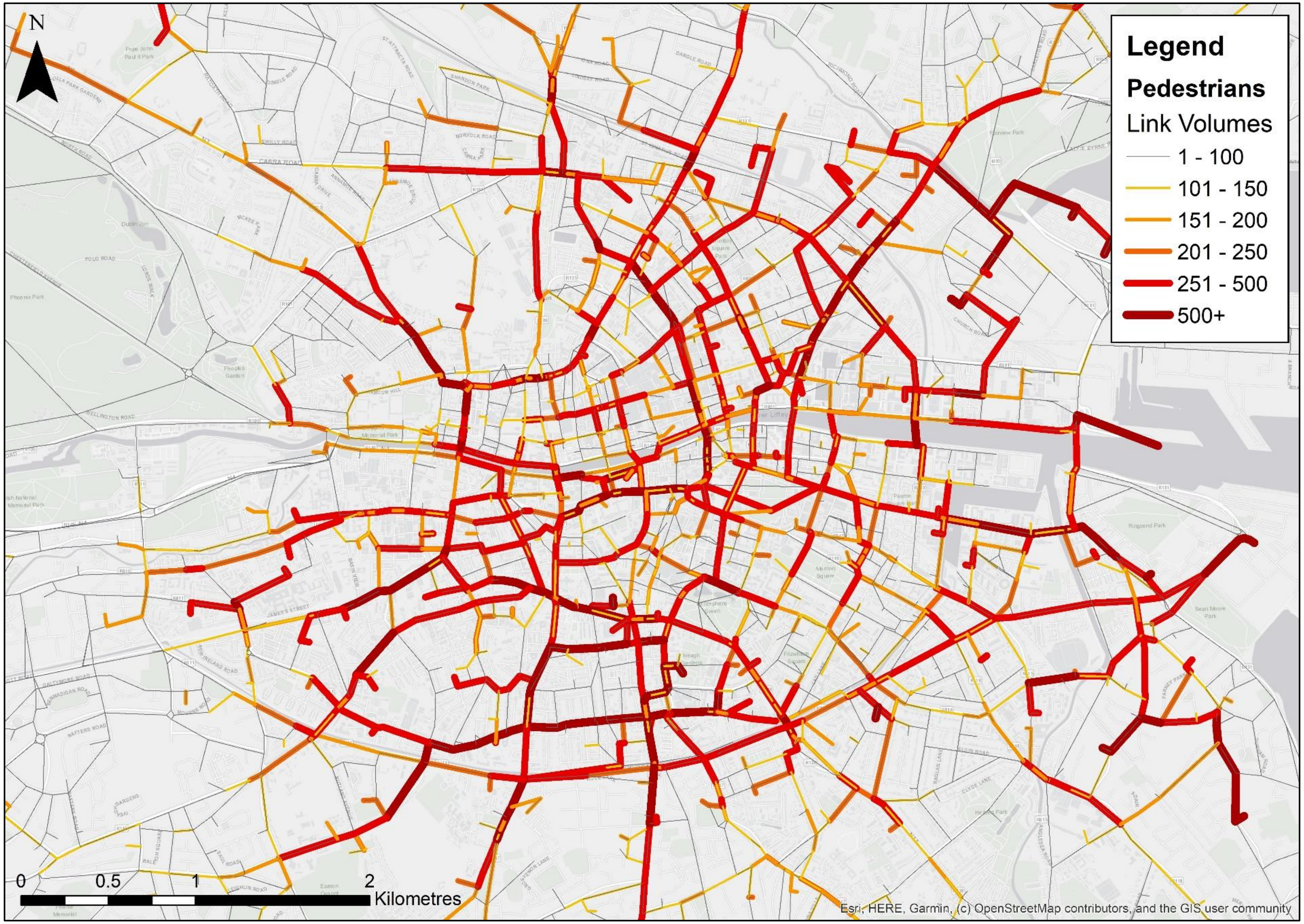


Figure 9.3 Pedestrian Sense Checks – Dublin City Centre

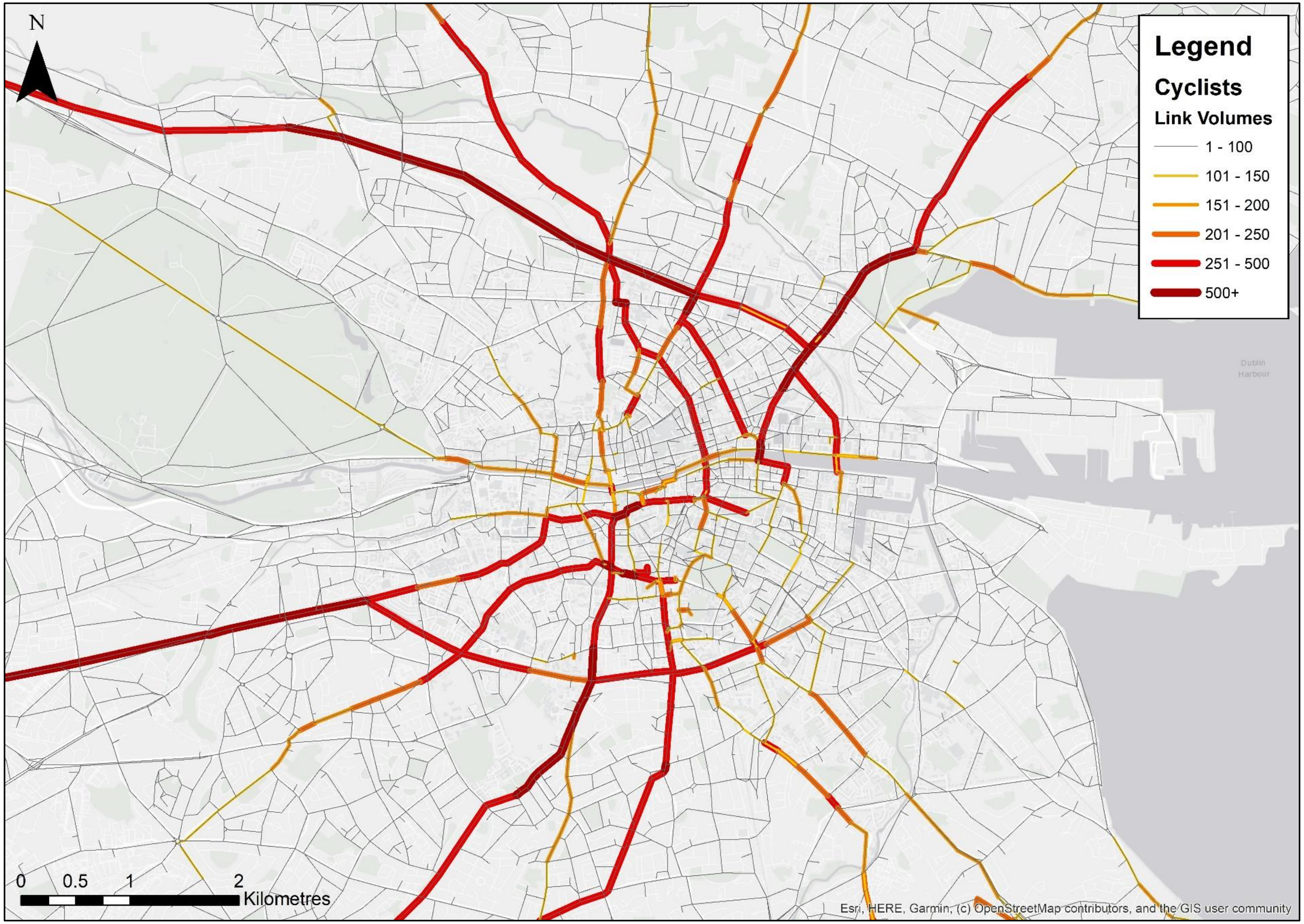


Figure 9.4 Cycling Sense Checks – Dublin City Centre

9.7.7 Cycling Flows Sense Checks

As illustrated in Figure 9.4 above, the predominant pathways for cycling in the city centre of Dublin follow the actual cycle network i.e. most cycle trips use the primary cycle network as described in the “Cycle Network Plan” (December, 2013).

9.8 Data Used

The development of the AMM required the use of data from various sources such as:

- HERE maps;
- NTA Cycle Manual[36];
- Cycle Planner Data;
- 2017 National Household Travel Survey (NHTS); and
- UK Transport Analysis Guidance (UK TAG).

Further reference on the data sources is presented in Chapter 3 of this report.

36 https://webarchive.nationalarchives.gov.uk/20191103014041/https://www.gov.uk/government/publications/webtag-tag-unit-m5-2-modelling-smarter-choices

10 Calibration and Validation

10.1 Introduction

This chapter presents the calibration and validation process applied to the development of the ERM. Calibration involves the derivation of parameters and refinement of modelling assumptions, either directly from observed data or through estimation to match samples of observed data using statistical principles. Assumptions and parameters may be refined to ensure that the model behaves appropriately. Model calibration and validation is undertaken in three main stages as follows:

- Parameter estimation, assumption or derivation against relevant data;
- Checking of responses against independent real data (realism testing); and
- Checking of responses to all its main inputs (sensitivity testing).

Discussion of the results presented in Chapter 11, while realism and sensitivity testing is provided in Chapter 12.

10.2 Calibration Overview

Calibration involves the adjustment of parameters used throughout the road, public transport and Demand Models, so that model predictions of observed behaviour and network characteristics are as “close to reality” as possible throughout the overall system.

Each NTA regional model is calibrated using the same approach, based on a set of best-available standards in use across the industry.

Table 10.1 Model Component Calibration Parameters shows the components of the overall model that are calibrated to observed data.

Table 10.1 Model Component Calibration Parameters

Main Component	Transport Features Modelled	Model inputs / parameters to calibrate
Demand Model	Aggregate groups of trip makers – by car availability, journey purpose, parking availability. Journey purpose splits; Mode splits; Time period proportions; Trip length distributions. Parking and Park and Ride.	Mode and destination choice. Park and Ride site choice.
Road Model	Traffic volumes for several user classes (car, goods, taxi). Journey times (a function of volume/capacity at junctions, queuing behaviour, traffic signalling, etc.).	Network configuration (capacities, speeds, junction layouts). Demand matrices (number of trips between zones).
PT Model	Passenger flows on bus, rail, and light rail. Journey times; Average fares; and Interchange.	Cost parameters (fares, boarding penalties, transfer penalties, in-vehicle time weightings, etc. Service speeds (timetabled or observed).
Active Modes Model	Walking and cycling networks; Walk speeds; and Cycle speeds.	Levels of walking / cycling through screenlines.

The next sections discuss the calibration of the components listed in the table in more detail.

The primary source of calibration guidance is UK TAG, however, a review of international guidance was also undertaken to select the most appropriate approaches for the particular model structure used in the ERM. Further information is available in the *Calibration Guide*.

In calibrating the demand and assignment models, the objective is to find, for every link in the network, an (observed) equilibrium point between demand and supply that is close enough to the true value assuming that we have a perfectly converged model, as illustrated in Figure 10.1.

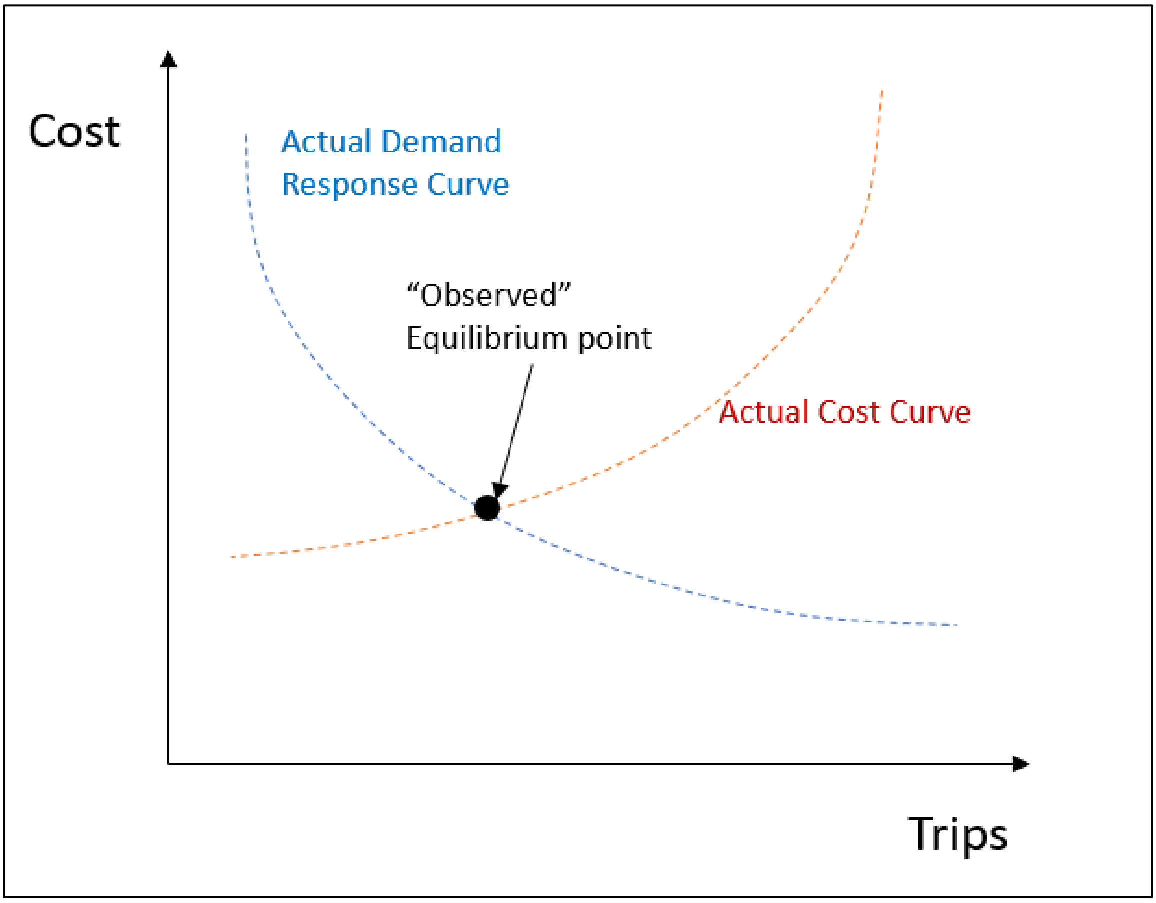


Figure 10.1 Demand and Cost Curves and Equilibrium Point

Figure 10.1 shows a familiar demand / supply curve. When costs are low, there is a greater demand for trips. But a greater demand leads to an increase in costs (through congestion or crowding). Within a stable transport system and over time, an equilibrium point is theoretically reached where the two curves balance each other. A key objective of the model calibration process is to ensure that this equilibrium point is the true point as observed through counts and surveys.

The level of calibration therefore needs to be compared against three separate measures:

- Comparison of key Demand Model indicators against observed data;
- Comparison of key assignment model indicators against observed data; and
- Stability of costs/demands between successive demand / assignment model loops.

The overall process of model calibration is illustrated in Figure 10.2.

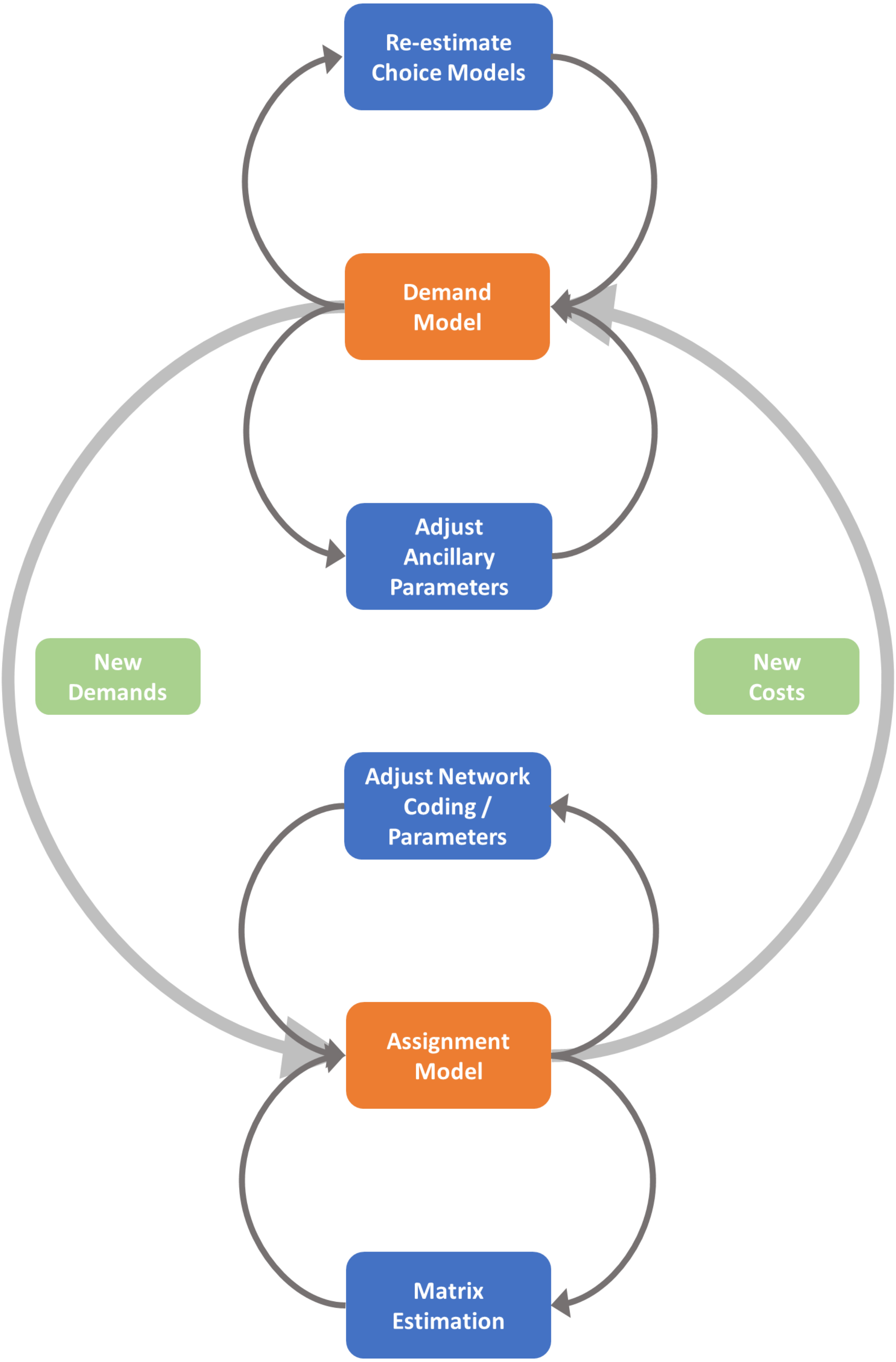


Figure 10.2 Overall Calibration Process

Phases of the Calibration Process

10.2.1 Overview

The regional model generates assignment matrices directly using the Demand Model, rather than using assignment matrices derived in a separate process as an entry point into the assignment/Demand Model cycle. The ERM model calibration involved a number of phases as follows.

- Phase 1 – Ensure model cycle completion using initial parameters taken from the previous version of the model;
- Phase 2 – Refine model control variables to match observations as closely as practicable; and
- Phase 3 - Lock down development elements of the ERM ready for application.

The elements undertaken within each phase are summarised below:

10.2.2 Phase 1

This is the preliminary stage of the calibration process. The objectives of this stage are to:

- Finalise as many model parameters and inputs as possible; and
- Optionally, stabilise costs by iteratively re-estimating the Demand Model.

Initialisation

The purpose of this phase was to run the model from start to finish without regard to any initial results to test its functionality, ensuring that all files exist in the correct format for subsequent adjustment. These files typically were converted through a rezoning process from the previous version of the model.

First run and subsequent review

Once the first set of checked parameters and inputs had been prepared it was run through the Demand Model to produce assignments. The travel costs were passed to the demand estimation and then also used to review whether all parameters look appropriate, e.g. period to hour factors, tour proportions.

10.2.3 Phase 2

In the second and longest phase, the assignment models continued to be improved at specific links, junctions or access points, to better reflect observed data. This included changing the coding of junctions in the Road Model to better reflect actual operation, making adjustments to saturation flows within specific ranges and the repositioning of zone connectors to give a more accurate representation of access to PT services. This process is iterative, with costs being fed back into the Demand Model on a regular basis so that the demand response can be captured correctly, and to ensure that unnecessary erroneous changes are not made to the networks based on erroneous or outdated demand.

Some associated Demand Model components (e.g. Parking models) were also calibrated by making large adjustments to initial assumptions (finer adjustments weren’t possible at this stage).

The objectives of this stage include:

- Calibration of the Road and PT assignment parameters;
- Make further improvements to the assignment model networks; and
- Adjust calibration of associated Demand Model functions (e.g. parking).

Main Development Cycle

At this point, the model development progressed as a feedback loop where model results were analysed, and potential solutions implemented. At the same time, cost stabilisation was introduced, reducing cost variations passed from one model demand estimation iteration to the next.

One approach that was used to generate preliminary assignment costs to feed parameter estimation (in the absence of calibrated assignment models) was to use trip matrix estimation, applied without any constraint on the level of adjustments that could be made to trip ends or matrix cells. The objective of this process was to improve journey times (and hence costs). This was applied to both road and PT modes. For active travel there was no need for this approach, because active generalised costs are not influenced by travel volumes (crowding etc.).

10.2.4 Phase 3

In this final pass, the main objective is to deliver a suitably calibrated/validated and robust model. This requires finer adjustments to the Road, PT and Active Modes models. In this phase there was a refinement to associated Demand Models, using the more accurate costs output from the assignment models. Sensitivity tests and realism tests were undertaken to demonstrate appropriate elastic response and model robustness and are discussed in more detail in Chapter 12.

Finalisation

Following the creation of final base year demand matrices, the validation of the resultant assignments was reviewed. A final matrix estimation pass was performed to account for any small discrepancies between the Demand Model output and the estimated “optimum” assignment demand matrix.

Incremental adjustment factors were derived to align base year synthetic matrices with those derived through matrix estimation. A final fixed set of base year costs was extracted for use as the starting point for all subsequent model (Demand/Assignment) loop applications.

Descriptions of the calibration mechanisms of the model components are given later in the chapter.

10.3 Demand Model Calibration and Validation

As discussed in Chapter 6, the Demand Model involves a complex process of interconnected mechanisms. The mechanisms need to be calibrated both in isolation and as part of the process. This is to ensure the Demand Model can produce effective demand matrices, which not only reflect travel demand in the base year, but also respond appropriately to changes in model inputs in a forecast scenario.

The main objective of this stage is to estimate and adjust the key parameters within the Mode Choice, Destination Choice, Parking and other components of the overall Demand Model to ensure a good fit of modelled outputs against observed data. The individual processes required to calibrate these components are described in Chapter 6.

Key Performance Indicators (KPIs) of this comparison include:

- Mode share by tour or time of day and geographic sector;
- Generalised cost distributions by mode and time period;
- Trip length distributions by mode and time period;
- Journey time distributions by mode and time period; and
- Overall trip ends going into and being output from the Demand Model by tour, time period, and total.

The main action taken during the calibration of the Demand Model was to adjust the choice parameters that affect Mode Choice and Destination Choice. The main sources of observed data used in the calibration of the Demand Model are the Census Place of Work, School or College – Census of Anonymised Records (POWSCAR) and the National Household Travel Survey (NHTS) datasets. The POWSCAR dataset contains fully observed trips and trip patterns tor travel to Work and Education, while the NHTS provides data on trip numbers, mode shares and trip-length distributions. The two datasets are also different as POWSCAR is collected and provided at population level, while NHTS is sample data.

The Mode Choice and Destination Choice parameters are first estimated using logit estimation which provides initial parameters but can struggle to provide robust results when entered into the Mode Choice and Destination Choice models for the following reasons:

- NHTS can have a small sample size for individual modes and demand segments which can lead to poorly estimated or completely missing parameters in some cases;
- The parameter governing average generalised cost for walk and cycle is combined to increase sample size meaning that they cannot be estimated independently;
- Intrazonal parameters are only estimated across all modes individually therefore not introducing mode specific variances to match targets;
- Any POWSCAR derivations are difficult to estimate with given a lack of car availability in the data set;

- POWSCAR also shows markedly different definitions and therefore trends when considering blue collar and white collar commute which leads to some level of incompatibility within the model;
- Double constraint is present in commute and education purposes in the Mode Choice and Destination Choice model which is not considered in an estimation context; and
- Target data is very restricted in that it cannot be aggregated from other models or from other purposes when sample size is low and instead must be restricted to the actual observations in that demand segment.

These challenges mean that in some cases parameters can be estimated, however the Mode Choice and Destination Choice models will fail to match target data of mode share, average generalised cost, and intrazonal proportions by mode when applied to modelled trip ends and costs as opposed to data samples.

An example of some standard results which were achieved for a single demand segment during estimation is provided in Table 10.2[37] and highlights some of the issues noted above, specifically:

- Low sample for walk and cycle;
- Inability to match both walk and cycle average generalised cost; and
- Difference between modelled and estimated results given the different input data (trip ends versus data sample).

Note also that Park and Ride (PnR) is not featured in the observed data set and therefore cannot have parameters estimated, which can happen for the other modes in specific demand segments such as escort to education for instance.

[37] Note that these values were from an intermediate point in development and do not reflect the final estimation or model results but are presented here as demonstration of process rather than reporting actual final values

Table 10.2 Example Summary of Estimation Performance

Variable	Mode	Observed	Estimated	Estimated - Observed	Modelled	Modelled-Observed
Ave Cost	Car	42.1	42.9	0.8	68.9	26.8
	PT	89.8	89.8	0.0	93.5	3.7
	PnR	-	-	-	-	-
	Walk	63.6	44.2	-19.4	40.5	-23.1
	Cycle	11.5	32.4	20.9	33.2	21.7
	Total	**47.7**	**47.7**	**0.0**	**69.6**	**22.0**
Actual Tours	Car	99	99	-	67,963	67,864
	PT	12	12	-	6,880	6,868
	PnR	-	-	-	-	-
	Walk	5	5	-	3,075	3,070
	Cycle	1	1	-	585	584
	Total	**117**	**117**	**-**	**78,503**	**78,386**
Mode Share	Car	84.6%	84.6%	0.0%	86.6%	2.0%
	PT	10.3%	10.3%	0.0%	8.8%	-1.5%
	PnR	0.0%	0.0%	0.0%	0.0%	0.0%
	Walk	4.3%	4.3%	0.0%	3.9%	-0.4%
	Cycle	0.9%	0.9%	0.0%	0.7%	-0.1%
	Total	**100.0%**	**100.0%**	**0.0%**	**100.0%**	**0.0%**

To account for these issues a further calibration process was introduced which replicated the Mode Choice and Destination Choice models in a simplified manner and allowed iteration to manipulate parameters and ultimately improve the KPIs reported in Section 11.2 (mode share, average generalised cost, trip length, and intrazonal proportion), commonly referred to as GoalSeek.

This process takes in consistent costs and trip ends with the Mode Choice and Destination Choice models but assumes that all trips are made within a single tour so as to reduce the complexity of calculations and therefore runtimes. For each user class a different tour has been selected as described in Table 10.3.

Table 10.3 GoalSeek Tour Assumptions

User Class	Outbound Time Period	Inbound Time Period	Tour / Time Period
EMP	AM	PM	4
COM	AM	PM	4
OTH	LT	SR	8
EDU	AM	SR	3
RET	LT	SR	8
NHBEB	AM		AM
NHBOT	AM		AM

At its simplest the process adjusts the α parameter for each mode in order to better match average generalised cost, the ASC values to match mode share, and the IZM values to match intrazonal proportions (see Section 6.5.2 for further detail on the mathematical framework of the Mode Choice and Destination Choice models). No change is introduced to either the lambda parameters or the beta parameters.

Table 10.4 shows the initial parameters that are obtained from estimation and a orange highlight is applied to those parameters where no data is available to derive a parameter. It is noted that where car is highlighted this is not actually an issue as they are all no car available demand segments and thus it is expected that there would be no observed data and the Mode Choice and Destination Choice models have been set up to account for this. As the beta parameters do not vary by mode only a single value is presented but in practice they are individually stated, and the same applies to the three different levels of lambda.

Table 10.5 highlights the final parameters that come out of the calibration process with a red highlight indicating an increase in value and a blue highlight indicating a reduction in a specific value. Table 10.6 further shows the percentage difference between estimated and calibrated parameters.

Table 10.4 Initial Estimated Parameters

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
COM_BC_CAV	1.00	0.51	1.00	1.25	1.25	0.00	0.00	88.11	99.00	50.45	131.87	-20.34	-20.34	-20.34	-20.34	-20.34	-0.03
COM_WC_CAV	1.00	0.51	1.00	1.25	1.25	0.00	0.00	88.11	99.00	50.45	131.87	-20.34	-20.34	-20.34	-20.34	-20.34	-0.03
COM_BC_NCA	1.00	1.00	1.00	3.30	3.30	0.00	99.00	0.00	99.00	-66.77	23.06	-15.35	-15.35	-15.35	-15.35	-15.35	-0.02
COM_WC_NCA	1.00	1.00	1.00	3.30	3.30	0.00	99.00	0.00	99.00	-66.77	23.06	-15.35	-15.35	-15.35	-15.35	-15.35	-0.02
EDU_P_CAV	1.00	1.00	1.00	0.69	0.69	0.00	0.00	99.00	99.00	9.43	99.00	2.93	2.93	2.93	2.93	2.93	-0.14
EDU_S_CAV	1.00	0.15	1.00	0.85	0.85	0.00	0.00	29.49	99.00	8.41	99.00	-9.93	-9.93	-9.93	-9.93	-9.93	-0.12
EDU_T_CAV	1.00	0.14	1.00	0.62	0.62	0.00	0.00	35.58	99.00	7.49	99.00	-6.47	-6.47	-6.47	-6.47	-6.47	-0.18
EDU_P_NCA	1.00	1.00	1.00	2.76	2.76	0.00	99.00	0.00	99.00	-148.50	99.00	96.02	96.02	96.02	96.02	96.02	-0.02
EDU_S_NCA	1.00	1.00	1.00	5.26	5.26	0.00	99.00	0.00	99.00	-195.97	31.76	13.37	13.37	13.37	13.37	13.37	-0.02
EDU_T_NCA	0.00	1.00	1.00	3.83	3.83	0.00	99.00	0.00	99.00	-169.37	50.52	21.12	21.12	21.12	21.12	21.12	-0.03
ESC_P_CAV	1.00	1.00	1.00	0.81	0.81	0.00	0.00	99.00	99.00	9.42	45.73	-1.75	-1.75	-1.75	-1.75	-1.75	-0.13
ESC_S_CAV	1.00	1.00	1.00	0.81	0.81	0.00	0.00	99.00	99.00	9.42	45.73	-1.75	-1.75	-1.75	-1.75	-1.75	-0.13
ESC_T_CAV	1.00	1.00	1.00	0.81	0.81	0.00	0.00	99.00	99.00	9.42	45.73	-1.75	-1.75	-1.75	-1.75	-1.75	-0.13
ESC_P_NCA	1.00	1.00	1.00	1.00	1.00	67.80	0.00	0.00	99.00	-154.56	99.00	66.16	66.16	66.16	66.16	66.16	-0.03
ESC_S_NCA	1.00	1.00	1.00	1.00	1.00	67.80	0.00	0.00	99.00	-154.56	99.00	66.16	66.16	66.16	66.16	66.16	-0.03
ESC_T_NCA	1.00	1.00	1.00	1.00	1.00	67.80	0.00	0.00	99.00	-154.56	99.00	66.16	66.16	66.16	66.16	66.16	-0.03
OTH_CAV	1.00	1.00	1.00	1.00	1.00	0.00	0.00	6.69	99.00	8.60	99.00	1.33	1.33	1.33	1.33	1.33	-0.10
OTH_CAV	1.00	1.00	1.00	1.00	1.00	0.00	0.00	99.00	99.00	6.07	51.79	0.22	0.22	0.22	0.22	0.22	-0.11
OTH_NCA	1.00	1.00	1.00	1.96	1.96	0.00	0.00	0.00	99.00	-32.38	68.57	5.49	5.49	5.49	5.49	5.49	-0.06
OTH_NCA	1.00	1.00	1.00	1.00	1.00	0.00	0.00	99.00	99.00	99.00	99.00	5.40	5.40	5.40	5.40	5.40	-0.04

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
FSH_CAV	1.00	1.00	1.00	1.00	1.00	0.00	0.00	31.12	99.00	45.49	99.00	-23.30	-23.30	-23.30	-23.30	-23.30	-0.04
FSH_CAV	1.00	1.00	1.00	1.00	1.00	25.26	0.00	0.00	99.00	17.99	109.56	51.68	51.68	51.68	51.68	51.68	-0.04
FSH_NCA	1.00	0.49	1.00	0.85	0.85	0.00	0.00	44.54	99.00	7.37	83.83	-15.29	-15.29	-15.29	-15.29	-15.29	-0.06
VIS_CAV	1.00	0.37	1.00	1.09	1.09	0.00	0.00	58.15	99.00	1.11	68.98	-5.62	-5.62	-5.62	-5.62	-5.62	-0.07
VIS_CAV	1.00	1.00	1.00	2.23	2.23	0.00	0.00	0.00	99.00	-63.13	52.88	-19.74	-19.74	-19.74	-19.74	-19.74	-0.04
VIS_NCA	1.00	1.00	1.00	1.81	1.81	0.00	0.00	0.00	99.00	-32.83	84.02	-2.55	-2.55	-2.55	-2.55	-2.55	-0.04
EMP_All	1.00	1.18	1.00	1.00	1.00	0.00	0.00	4.26	99.00	60.51	194.57	-16.41	-16.41	-16.41	-16.41	-16.41	-0.02
RET_CAV	1.00	0.21	1.00	1.06	1.06	0.00	0.00	93.37	99.00	8.97	94.37	-8.98	-8.98	-8.98	-8.98	-8.98	-0.06
RET_NCA	1.00	1.00	1.00	2.38	2.38	0.00	0.00	0.00	99.00	-69.39	68.12	-1.66	-1.66	-1.66	-1.66	-1.66	-0.04
NHBEB_CAV	1.00	1.00	1.00	1.00	1.00	11.91	0.00	29.68	99.00	99.00	99.00	3.15	3.15	3.15	3.15	3.15	-0.04
NHBEB_NCA	1.00	1.00	1.00	5.63	5.63	0.00	0.00	0.00	99.00	-96.62	28.84	-23.77	-23.77	-23.77	-23.77	-23.77	-0.02
NHBOT_CAV	1.00	0.13	1.00	0.42	0.42	0.00	0.00	47.34	99.00	22.79	67.53	-4.15	-4.15	-4.15	-4.15	-4.15	-0.12
NHBOT_NCA	1.00	1.00	1.00	2.72	2.72	0.00	0.00	0.00	99.00	-60.76	69.33	10.86	10.86	10.86	10.86	10.86	-0.03

Table 10.5 Final Calibrated GoalSeek Parameters

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
COM_BC_CAV	3.27	0.95	2.10	2.56	3.71	0.00	-58.70	123.15	-59.88	62.72	137.41	-0.69	63.24	37.15	9.66	29.83	-0.03
COM_WC_CAV	4.34	1.64	2.62	3.21	3.87	0.00	-25.88	40.34	-1.86	52.01	127.20	16.24	71.83	15.38	-0.03	33.79	-0.03
COM_BC_NCA	1.00	1.20	1.00	3.77	5.56	0.00	99.00	7.64	99.00	-68.22	21.96	-15.35	43.16	-15.35	-21.04	6.94	-0.02
COM_WC_NCA	1.00	2.05	1.00	4.93	5.78	0.00	99.00	-33.53	99.00	-77.04	44.51	-15.35	83.03	-15.35	14.32	66.19	-0.02
EDU_P_CAV	6.45	1.80	7.00	1.89	3.14	0.00	6.30	41.99	99.00	22.39	49.74	7.78	-2.93	48.53	-1.85	-4.52	-0.14
EDU_S_CAV	4.14	0.31	6.82	1.13	1.42	0.00	-8.46	35.80	99.00	17.97	46.78	30.32	13.52	18.53	-3.53	6.04	-0.12
EDU_T_CAV	7.00	1.92	7.00	1.17	2.86	0.00	1.06	-19.21	99.00	40.46	42.67	28.27	39.60	27.85	-15.32	-1.31	-0.18
EDU_P_NCA	1.00	6.73	1.00	8.76	8.76	0.00	99.00	-66.21	99.00	-225.34	135.09	96.02	-200.00	96.02	-55.61	-200.00	-0.02
EDU_S_NCA	1.00	2.55	1.00	7.37	11.23	0.00	99.00	-61.95	99.00	-173.13	35.91	13.37	78.36	13.37	18.17	63.24	-0.02
EDU_T_NCA	0.00	5.49	1.00	5.17	9.83	0.00	99.00	-151.26	99.00	-37.89	31.83	21.12	128.50	21.12	34.66	54.94	-0.03
ESC_P_CAV	3.48	0.32	7.00	1.35	2.06	0.00	3.58	99.03	99.00	8.08	43.49	12.48	5.88	56.11	9.05	12.76	-0.13
ESC_S_CAV	2.31	0.21	7.00	0.93	1.34	0.00	-3.17	99.01	99.00	11.72	46.60	18.09	23.52	57.07	13.73	23.74	-0.13
ESC_T_CAV	1.11	0.20	7.00	0.40	1.24	0.00	-14.19	99.00	99.00	23.19	46.15	20.41	28.26	54.83	8.81	25.40	-0.13
ESC_P_NCA	1.00	0.70	1.00	1.98	2.80	67.80	0.00	-67.20	99.00	-140.09	106.92	66.16	65.47	66.16	72.11	90.39	-0.03
ESC_S_NCA	1.00	0.63	1.00	1.28	1.88	67.80	0.00	-73.97	99.00	-138.09	107.18	66.16	159.40	66.16	91.63	138.80	-0.03
ESC_T_NCA	1.00	0.41	1.00	0.30	0.92	67.80	0.00	-75.27	99.00	-134.98	104.50	66.16	162.22	66.16	88.52	158.02	-0.03
OTH_CAV	1.18	0.42	7.00	0.85	1.16	0.00	13.03	23.00	99.00	3.77	85.36	-10.89	29.50	64.10	-0.54	-6.31	-0.10
OTH_CAV	1.31	0.40	7.00	0.86	1.10	0.00	10.90	77.67	99.00	8.01	46.07	-4.34	28.72	62.26	-6.89	-4.25	-0.11
OTH_NCA	1.00	0.63	1.00	1.27	1.85	0.00	0.00	14.31	99.00	-11.15	42.57	5.49	36.78	5.49	-13.66	-20.10	-0.06

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
OTH_NCA	1.00	0.97	1.00	2.37	2.91	0.00	0.00	86.36	99.00	52.60	149.62	5.40	71.29	5.40	10.39	-7.98	-0.04
FSH_CAV	5.00	1.72	7.00	2.78	5.18	0.00	5.10	36.34	99.01	22.03	115.61	-7.66	121.59	80.20	-10.81	-18.72	-0.04
FSH_CAV	3.25	1.45	7.00	1.42	3.67	25.26	-2.42	25.68	99.00	9.33	112.08	21.94	142.33	83.97	-15.19	4.84	-0.04
FSH_NCA	1.00	1.03	1.00	2.25	4.05	0.00	0.00	34.73	99.00	-1.33	95.79	-15.29	86.82	-15.29	10.97	-5.55	-0.06
VIS_CAV	1.17	0.41	7.00	1.58	1.61	0.00	-10.18	68.06	99.00	6.21	70.76	-6.11	47.68	76.95	-4.54	57.67	-0.07
VIS_CAV	2.12	0.78	7.00	2.96	3.01	0.00	-44.42	30.72	99.00	-37.74	61.68	-24.80	75.74	72.29	-5.67	92.51	-0.04
VIS_NCA	1.00	0.92	1.00	3.82	3.55	0.00	0.00	59.59	99.00	-33.08	64.40	-2.55	115.74	-2.55	21.67	130.74	-0.04
EMP_All	1.56	1.38	7.00	4.85	5.78	0.00	79.21	41.17	99.24	-23.82	187.30	-57.10	93.52	61.17	18.93	110.04	-0.02
RET_CAV	2.02	0.69	7.00	2.07	2.40	0.00	19.81	65.68	99.00	2.61	90.15	-1.13	28.28	67.77	4.47	7.89	-0.06
RET_NCA	1.00	1.11	1.00	3.01	3.93	0.00	0.00	18.30	99.00	-65.21	57.84	-1.66	43.34	-1.66	0.03	7.34	-0.04
NHBEB_CAV	0.37	0.64	7.00	3.63	3.14	11.91	59.05	31.03	99.00	31.80	106.70	-33.42	63.68	6.96	-16.78	92.59	-0.04
NHBEB_NCA	1.00	1.29	1.00	5.81	6.35	0.00	0.00	-10.74	99.00	-80.99	16.79	-23.77	97.48	-23.77	-28.41	136.76	-0.02
NHBOT_CAV	0.51	0.29	7.00	0.72	1.02	0.00	24.33	29.19	99.00	16.40	55.64	-12.61	23.61	1.22	-3.38	5.98	-0.12
NHBOT_NCA	1.00	1.06	1.00	4.16	4.48	0.00	0.00	9.99	99.00	-58.50	63.74	10.86	83.49	10.86	6.55	32.94	-0.03

Table 10.6 Percentage Differences in Mode and Destination Parameters

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
COM_BC_CAV	227%	86%	110%	105%	197%	-	-	40%	-160%	24%	4%	-97%	-411%	-283%	-147%	-247%	0%
COM_WC_CAV	334%	222%	162%	157%	210%	-	-	-54%	-102%	3%	-4%	-180%	-453%	-176%	-100%	-266%	0%
COM_BC_NCA	0%	20%	0%	14%	68%	-	0%	-	0%	2%	-5%	0%	-381%	0%	37%	-145%	0%
COM_WC_NCA	0%	105%	0%	49%	75%	-	0%	-	0%	15%	93%	0%	-641%	0%	-193%	-531%	0%
EDU_P_CAV	545%	80%	600%	174%	355%	-	-	-58%	0%	137%	-50%	166%	-200%	1556%	-163%	-254%	0%
EDU_S_CAV	314%	107%	582%	33%	67%	-	-	21%	0%	114%	-53%	-405%	-236%	-287%	-64%	-161%	0%
EDU_T_CAV	600%	1271%	600%	89%	361%	-	-	-154%	0%	440%	-57%	-537%	-712%	-530%	137%	-80%	0%
EDU_P_NCA	0%	573%	0%	217%	217%	-	0%	-	0%	52%	36%	0%	-308%	0%	-158%	-308%	0%
EDU_S_NCA	0%	155%	0%	40%	113%	-	0%	-	0%	-12%	13%	0%	486%	0%	36%	373%	0%
EDU_T_NCA	-	449%	0%	35%	157%	-	0%	-	0%	-78%	-37%	0%	508%	0%	64%	160%	0%
ESC_P_CAV	248%	-68%	600%	67%	154%	-	-	0%	0%	-14%	-5%	-813%	-436%	-3306%	-617%	-829%	0%
ESC_S_CAV	131%	-79%	600%	15%	65%	-	-	0%	0%	24%	2%	-1134%	-1444%	-3361%	-885%	-1457%	0%
ESC_T_CAV	11%	-80%	600%	-51%	53%	-	-	0%	0%	146%	1%	-1266%	-1715%	-3233%	-603%	-1551%	0%
ESC_P_NCA	0%	-30%	0%	98%	180%	0%	-	-	0%	-9%	8%	0%	-1%	0%	9%	37%	0%
ESC_S_NCA	0%	-37%	0%	28%	88%	0%	-	-	0%	-11%	8%	0%	141%	0%	38%	110%	0%
ESC_T_NCA	0%	-59%	0%	-70%	-8%	0%	-	-	0%	-13%	6%	0%	145%	0%	34%	139%	0%
OTH_CAV	18%	-58%	600%	-15%	16%	-	-	244%	0%	-56%	-14%	-919%	2118%	4720%	-141%	-574%	0%
OTH_CAV	31%	-60%	600%	-14%	10%	-	-	-22%	0%	32%	-11%	-2073%	12955%	28200%	-3232%	-2032%	0%
OTH_NCA	0%	-37%	0%	-35%	-6%	-	-	-	0%	-66%	-38%	0%	570%	0%	-349%	-466%	0%

Dem Seg	Alpha					Beta	ASC					IZM					Lambda
	Car	PT	PnR	Walk	Cycle	All	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle	All
OTH_NCA	0%	-3%	0%	137%	191%	-	-	-13%	0%	-47%	51%	0%	1220%	0%	92%	-248%	0%
FSH_CAV	400%	72%	600%	178%	418%	-	-	17%	0%	-52%	17%	-67%	-622%	-444%	-54%	-20%	0%
FSH_CAV	225%	45%	600%	42%	267%	0%	-	-	0%	-48%	2%	-58%	175%	62%	-129%	-91%	0%
FSH_NCA	0%	110%	0%	165%	376%	-	-	-22%	0%	-118%	14%	0%	-668%	0%	-172%	-64%	0%
VIS_CAV	17%	11%	600%	45%	48%	-	-	17%	0%	459%	3%	9%	-948%	-1469%	-19%	-1126%	0%
VIS_CAV	112%	-22%	600%	33%	35%	-	-	-	0%	-40%	17%	26%	-484%	-466%	-71%	-569%	0%
VIS_NCA	0%	-8%	0%	111%	96%	-	-	-	0%	1%	-23%	0%	-4639%	0%	-950%	-5227%	0%
EMP_All	56%	17%	600%	385%	478%	-	-	866%	0%	-139%	-4%	248%	-670%	-473%	-215%	-771%	0%
RET_CAV	102%	229%	600%	95%	126%	-	-	-30%	0%	-71%	-4%	-87%	-415%	-855%	-150%	-188%	0%
RET_NCA	0%	11%	0%	26%	65%	-	-	-	0%	-6%	-15%	0%	-2711%	0%	-102%	-542%	0%
NHBEB_CAV	-63%	-36%	600%	263%	214%	0%	-	5%	0%	-68%	8%	-1161%	1922%	121%	-633%	2839%	0%
NHBEB_NCA	0%	29%	0%	3%	13%	-	-	-	0%	-16%	-42%	0%	-510%	0%	20%	-675%	0%
NHBOT_CAV	-49%	123%	600%	71%	143%	-	-	-38%	0%	-28%	-18%	204%	-669%	-129%	-19%	-244%	0%
NHBOT_NCA	0%	6%	0%	53%	65%	-	-	-	0%	-4%	-8%	0%	669%	0%	-40%	203%	0%

In addition to the Mode Choice and Destination Choice components, the following components of the Demand Model were devised and refined during the Demand Model calibration process:

- Park and Ride Model - this model takes trips which have already been identified as using Park and Ride (based on minimum Park and Ride site costs) and allocates them amongst competing sites. This allows the two legs of their journey to be distinctly allocated to road and PT; and
- Parking Distribution Model - this is used to redistribute trips in locations where there are known constraints to parking and / or parking charges. It is used predominantly in urban centre locations to provide choice between expensive on-street parking and cheaper off-street parking.

In both cases, the modelled occupancy in each zone or PnR site can be adjusted until an acceptable match is made to the observed occupancy described in Section 6.8.4.

There is no standard industry guidance on the “acceptable” level of calibration for parking models, but given that parking occupancy can be considered as a “volume at a fixed point”, then criteria used to compare highway link flows can be adapted. Modelled and Observed occupancies are therefore compared using a combination of GEH, absolute, and percentage difference comparisons and it is considered that an acceptable model satisfies the following criteria:

- 85% of GEH values should be less than 5; and
- 85% of percentage differences should be within 15% or 10 vehicles, whichever is greater.

Park and Ride Routeing Review

In addition to the key review of modelled occupancy, routeing is considered at some of the larger sites to ensure that the trips which are using the site appear reasonable. It is noted, however, that there is no observed data available which can be used to verify these trips, and so any review is based solely on reasonable judgement.

10.4 Final Demand Model Preparation (Phase 3)

10.4.1 Overview

Once the model has been calibrated, there are a number of final calculations that need to be prepared, to produce factors and inputs which are used when the model is applied. These link the base year synthetic absolute demand matrices to those used in the final base year calibrated assignments.

The inputs are not calibrated during Demand Model development or calibration but do need to be calculated and stored for later model use. These consist of:

- Incremental adjustment matrices;
- Internal goods;

- Taxi proportions;
- Car Driver Car User Factors; and
- Period to Hour Factors.

With the exception of the incremental adjustment matrices and taxi proportions the other inputs can be calculated independently of the model calibration process and are described in Chapter 6.

10.4.2 Calculation of Incremental Adjustments

The ERM is an absolute model with an incremental adjustment, and so is capable of producing full internal demand matrices solely dependent on costs. However, the model is an aggregate model and the behaviours that it simulates are “average” behaviours across a wide geographical area. The model is unable to replicate small unobservable factors which may affect behaviours in localised areas.

To ensure that synthetic demand matrices match the observed base year traffic volumes, some form of adjustment is required to adjust the Demand Model outputs to match the assignment matrices which have been validated in the base year assignment models.

This also ensures that the costs from a base year assignment model are identical to those generalised costs contained in the base year parameters, thus improving model stability in both base and forecast scenarios.

These incremental adjustment matrices are a combination of additive and multiplicative corrections applied at zone pair level for each time period and user class in the assignment matrices, and are calculated as follows:

$$IA_{Add} = ASS_{TP,M,UC} - DM_{TP,M,UC}$$

$$IA_{Mult} = \frac{ASS_{TP,M,UC}}{DM_{TP,M,UC}}$$

$$IA_{Flag} = \begin{cases} 1 & 0.5 \leq IA_{Mult} \leq 2, (use\ IA_{Mult}) \\ 0 & 0.5 > IA_{Mult} > 2, (use\ IA_{Add}) \end{cases}$$

Where:

IA_{Add} is the additive incremental adjustment;

IA_{Mult} is the multiplicative incremental adjustment;

$ASS_{TP,M,UC}$ is the validated assignment matrix by time period, mode, and user class;

$DM_{TP,M,UC}$ is the output assignment matrix from the Demand Model by time period, mode, and user class; and

IA_{Flag} is a flag which indicates whether the model should apply an additive incremental for a zone pair (0) or multiplicative (1).

For absolute clarity where either $ASS_{TP,M,UC}$ or $DM_{TP,M,UC}$ is zero the additive factor would be applied.

There is no direct formal guidance which discusses the acceptable limits of these incremental adjustments, however, it is highlighted that in practice these are directly related to the difference between prior and post adjustment matrices for the assignment models. The prior/post matrix differences do have explicit acceptance criteria which can be used as a proxy for the acceptability of the incremental adjustment matrices and these criteria are evaluated and reported in Chapter 10.

10.4.3 Modelling Taxis

Taxi proportions are used within the model to section out a proportion of “other” user class trips and change their user class to Taxi.

While in previous model versions the proportion of trips was based on survey data such as NHTS, this could lead to conflicting results when compared against taxi counts on the road network.

As such, an alternative method for the derivation of taxi proportions has been included in this model version which is as follows:

- From the validated base year road assignment matrices, matrix estimate taxi as a separate user class to ensure that the matrix is an appropriate size to replicate traffic counts;
- Aggregate both taxi and other (user class) validated assignment matrices to sector pair level;
- At sector pair level, identify the applicable proportion calculated as:

$$Prop_{Taxi} = \frac{Taxi}{Other+Taxi} \text{ for each sector pair;}$$

- Copy the proportion for the sector pair to each zone pair within that relevant area of the matrix; and
- These proportions are assumed to remain constant over time. The absolute number of Other (and therefore Taxi) trips will vary.

As these proportions are already developed from validated assignments, there is limited benefit in trying to validate the proportions themselves for instance against NHTS as the samples tend to be quite small, however, checks are undertaken to ensure that the taxi proportions are reasonable, including:

- Consideration of overall magnitude; and
- Checks of trends by region e.g. urban should be higher than rural.

10.5 Road Model Calibration and Validation

10.5.1 Overview

The initial Road Model development, calibration and validation criteria, and calibration and validation data is set out in Section 7.7, Section 7.9 and Section 7.10 respectively. This section details the steps undertaken when calibrating the road model. The final calibration and validation of the model is presented in Chapter 11.

10.5.2 Network Updating

The initial stage of the calibration of the Road Model was to examine areas of excessive delay or areas of the model with very low flows relative to observed data. Among the actions taken at this stage were to examine and where necessary adjust:

- Junction coding;
- Turn saturation flows;
- Zone connectors – to ensure demand can access the appropriate junction / junctions; and
- SATURN assignment parameters – e.g. GAP acceptance.

There were several iterations of the road assignment model, with each one focussed on addressing a certain area of model performance. These are summarised in the following sections. All changes applied to the network during calibration were justified and documented in a Coding Log, included in the Addendum.

Count in Excess of Capacity Review

The network viewer can highlight locations where the input observed data is in excess of the calculated capacity for a given link. These plots were reviewed, and corrections applied to locations throughout the network.

In the majority of cases the lower capacity was either due to synthetic signals not accurately reflecting the observed operation of a signalised junction or an incorrect capacity index applied to the approaching link, artificially reducing the mid-link capacity below observed levels.

Journey Time Route Review

Each journey time route was reviewed in detail to ensure the correct number of lanes and turn allocations were provided at each junction. Capacity indices, or fixed network speeds where applicable, were also reviewed for accuracy.

At this stage several dedicated pedestrian crossings were added to the network to better reflect the delays experienced by traffic on many routes into and out of Dublin.

Capacity Index Review

The application of capacity indices was reviewed by plotting each type and overlaying this against a mapping background to ensure that each type of capacity index, such as a motorway capacity index, aligned with the road types they represent.

This review highlighted an issue in rural towns, where some rural locations were attributed with urban-type capacity indices based on posted speed limits and road capacity. This does not necessarily pose an assignment issue, and may result in the correct speed response, but may require consideration where a link type could be incorrectly inferred from the capacity index, such as in COBALT[38].

It was also identified that rural narrow country roads were being given a relatively high free flow speed and capacity in comparison to their actual operation. Investigation of other modelling solutions identified a capacity index that would be more suited to the road types than the capacity index currently being used. This capacity index, from Highways England's Regional Transport Models, was incorporated into future versions of the model where suitable locations for its application had been identified.

Review of Model Applications

The calibrated 2012 model has been used to assess a number of transport infrastructure and policy projects to date. With many of these projects focusing on individual corridors or areas, a significant amount of work has gone into ensuring the model is well represented in these areas by the respective project teams.

Changes applied by each application of the model were reviewed, and any applicable change was documented in the Coding Log and included in the latest road assignment network.

Areas of Poor Convergence

Model convergence statistics available within the network viewer, including the "10 worst" converged nodes, delays, capacities and flow, can highlight areas of the model that require further investigation. These tools were used to identify nodes or links whose performance was changing significantly from iteration to iteration.

Node and link delays were also examined to highlight locations with delays in excess of three minutes. These locations were reviewed and, where applicable, network corrections applied.

10.5.3 Prior Matrix Calibration Review

The model performance was then reviewed to determine whether or not a robustly calibrated road model was possible without adjustments to the prior matrices.

Table 10.7 details the individual link flow calibration prior to any matrix adjustment or matrix estimation being applied and indicates relatively poor model performance across all time periods.

[38] COBALT is UK Government software used to calculate the impact of accidents as part of an economic appraisal. https://www.gov.uk/government/publications/cobalt-software-and-user-manuals

Table 10.7 Road Model Prior Matrix Calibration (All Vehicle Types)

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	44%	39%	52%	71%
LT	41%	33%	45%	65%
SR	39%	34%	44%	59%
PM	40%	38%	50%	67%
OP	44%	41%	49%	65%

While individual link performance is a useful indicator at this stage, screenline performance provides a clearer picture of overall traffic volumes to and from larger areas. Table 10.8 sets out the screenline calibration performance prior to any matrix adjustment or matrix estimation being applied. This indicates that should the model accurately represent route choice through the modelled area the unadjusted demand matrix would not achieve the calibration criteria set out in UK TAG and summarised in Section 7.6.

Table 10.8 Road Model Screenline Prior Matrix Calibration (All Vehicle Types)

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
AM	19%	37%	23%
LT	17%	27%	25%
SR	10%	12%	12%
PM	15%	31%	21%

The results outlined in Table 10.7 and Table 10.8 suggest that matrix estimation was required in order to achieve higher levels of model calibration.

10.5.4 Matrix Factoring

Prior to undertaking matrix estimation, the level of modelled traffic flow was compared to observed traffic flows to determine whether any form of matrix factoring at either a global or broad sector level would improve the model performance.

At this stage it was identified that traffic flows to and from the route zones was on average higher than the observed levels. The demand to and from the route zones is produced by the LDM, and is not affected by changes in road costs unlike other elements of the demand matrices. As such, data from the TII static traffic counters detailed in Chapter 3 was used to derive a factor that was applied to traffic to and from the route zones. These factors are detailed in Table 10.9.

Table 10.9 Route Zone Factors

Time Period	Standard Abbreviation	Inbound Factor	Outbound Factor
Morning peak	AM	0.534	0.913
Lunchtime	LT	0.641	0.762
School run	SR	0.849	0.912
Evening peak	PM	0.858	0.791
Off-peak	OP	1.140	1.839

Ultimately, the factoring of traffic to and from route zones was not retained in the final calibrated model due to the complex and manual nature of the process. Instead, matrix estimation was allowed to adjust traffic to and from the route zones within the control parameters detailed in the following section.

10.5.5 Matrix Estimation

At the final stages of the calibration process, matrix estimation may be used, however, it is used with care and mainly to help stabilize costs rather than as a significant calibration tool.

Matrix estimation is the process of adjusting a matrix to better match observed traffic flows. Typically, a modelled flow is compared to an observation, with the observed flow divided by the modelled flow creating a balancing factor. This balancing factor is then applied to all origin-destination pairs that pass through that particular location so that the modelled flow will equal the observed flow. This is repeated iteratively until all modelled flows have been adjusted to match the observed flows.

Matrix estimation was undertaken using the SATURN modules SATPIJA and SATME2. SATPIJA determines which origin-destination pairs pass through each observed count location, and SATME2 adjusts the volume of these origin-destination pairs iteratively and within user-defined boundaries until each observed count location has the correct number of trips passing through it.

This process was repeated five times, with SATPIJA being run on the assignment of the estimated matrix, and the prior matrix being estimated using the updated SATPIJA information, ensuring that the estimated matrix is never re-estimated. This process is illustrated in Figure 10.3.

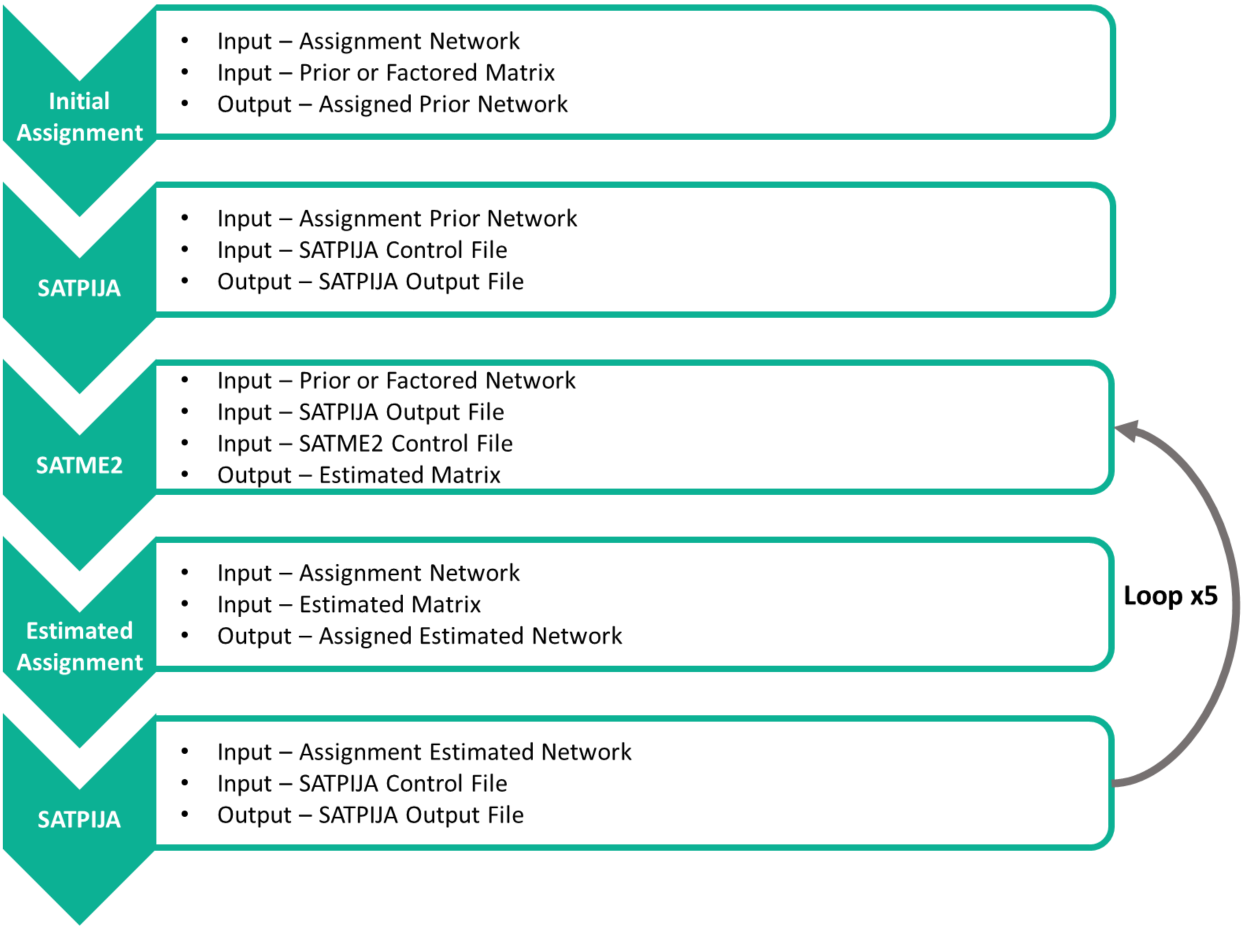


Figure 10.3 Matrix Estimation Process

The Car, LGV and HGV vehicle classes, as defined in Section 7.3, were estimated separately against their respective observed count data.

Matrix Estimation Controls

There are several levels of control that can be applied during the matrix estimation procedure. Trip ends or individual origin-destination pairs can be constrained or frozen, counts can be targeted individual or combined into screenline totals, and the balancing factor applied by matrix estimation can be reduced to limit the scale of the change applied.

When applying matrix estimation to the ERM, the maximum and minimum balancing factor that can be applied to any origin-destination pair is defined by a parameter (XAMAX) in the SATME2 control file. For the ERM this was set to 3 for Cars and 15 for both LGV and HGV. This limits the factor that can be applied to any Car origin-destination pair to 3 or 0.33 (1 / 3) and limits the factor that can be applied to any LGV or HGV origin-destination pair to 15 or 0.067 (1 / 15).

A trip end constraint of ±10% was applied to the car vehicle class in order to constrain distortions in the overall car trip ends, and to improve the model performance in relation to the significance of change criteria.

These constraints are tabulated in Table 10.10.

Table 10.10 Matrix Estimation Constraint

User Class	Description	Vehicle Class	XAMAX	Trip End Constraint
User Class 1	Car Employer's Business	Car	3	±10%
User Class 2	Car Commute			
User Class 3	Car Other			
User Class 4	Car Education			
User Class 5	Retired			
User Class 6	Taxi			
User Class 7	LGV	LGV	15	n/a
User Class 8	OGV1	HGV	15	n/a
User Class 9	OGV2 Permit Holder			
User Class 10	OGV2 Non Permit Holder			

10.5.6 Network Finalisation

Upon successful completion of the matrix estimation there were several iterations of the road assignment model, with each one focussed on addressing a certain area of model performance. These are summarised in the following sections.

All changes applied to the network during calibration were justified and documented in a Coding Log, included in the Addendum.

Fixed Speed Review

From detailed examination of flow bandwidth plots and minimum cost path routes, it was determined that the fixed link speeds coded for many areas inside the M50, made many residential areas attractive alternative routes. The initial free flow speed for many residential areas was coded as 40km/h. While this is below the legal 50km/h speed limit, it did not represent the true nature of many of these residential areas which have traffic calming, and on-street parking which reduces the natural speed of traffic. Residential areas were reviewed, with many changed to a lower speed to reflect measures that are in place on the ground to deter rat-running.

The fixed speed in residential areas was reduced based on a visual inspection, with a range of values applied to the network, ranging from 20km/h to 40km/h (unchanged) depending on the level of traffic calming or obstructions.

Airport Access Review

At all stages of the model development, the cost of travel between zones was reviewed. One area highlighted by this review as requiring more detailed analysis was access to Dublin Airport special zone. While this access was coded in accordance with the *Road Model Coding Guide*, the sheer volume of "kiss and fly" trips meant that the zone access points were over-capacity.

The Dublin Airport zone access was changed from a spigot-type approach as outlined in Section 7.7.9 to a link-based loading where the zone connects along the length of a link, resulting in no delay for traffic entering or exiting the zone. This better represents the drop-off and pick-up area at the airport.

Capacity Index Change

During the finalisation of the model calibration it became clear that the existing capacity indices available to the modelling team were becoming prohibitive. It was difficult, using the 12 primary capacity indices, to represent all road condition and speed combinations. There were also concerns over the age of the data used to derive these capacity indices.

After reviewing similar-scaled models in the United Kingdom it was decided that the ERM and the other regional models would adopt Highways England's Regional Transport Model (RTM) capacity indices. A like-for-like equivalence was created between the existing 12 capacity indices and the larger number available within the Highways England RTM. This was achieved by plotting each capacity index, and comparing the description of each capacity index. The like-for-like equivalence is detailed in Table 10.11.

Table 10.11 Capacity Index Equivalence

NTA ERM Capacity Index	Highways England RTM Capacity Index
Urban Central	Urban Central INT = 2
Urban Non-Central	Urban Non-central 50% Development
Suburban Narrow Collector	Suburban S2/S4 Typical Development
Suburban Distributor	Suburban S2/D2 Light/Typical Development
Suburban Narrow Distributor	Rural S2 6.5m Poor
Rural Narrow Country Road	Rural S2 Other Road (Slow)
Motorway	Rural Motorway
Dual Carriageway Near Motorway Std.	Rural All-Purpose
Wide National	Rural WS2 10m A Road
National / Regional	Rural S2 7.3m A Road (Older)
Regional	Rural S2 7.3m A Road (TD9/81)
Slip Road	Rural All-Purpose D2 50mph

This change resulted in an overall model improvement across all time periods.

Capacity Index Refinement

The Highways England Regional Transport Model capacity indices provide a flexibility in terms of speed limit, road quality, level of development and frequency of junctions. The initial like-for-like equivalence did not include this flexibility, but this was later added to allow more detailed calibration of the road assignment model. All Highways England RTM capacity indices were included within the model input data files and were available for use by the model development team.

Road Model Convergence Review

A key final check in the calibration process is to ensure that the Road Model has achieved a high level of convergence, i.e. travel costs have stabilized and an equilibrium between travel demand and costs has been obtained.

Model convergence was reviewed throughout development, calibration and validation with the final convergence statistics presented in Chapter 11.

10.6 Public Transport Model Calibration and Validation

The purpose of the PT Model is to allocate PT demand in a given time period (as output by the Demand Model) to PT services and routes operating between origin and destination zones. To do this, the PT Model must have a full representation of all PT lines, services and sub modes that operate throughout the modelled area. PT trips are the travel demand inputs to the PT Model, and the representation of PT lines and services are the supply inputs to the PT Model.

10.6.1 Calibration

As for the Road Assignment Model, the initial stages of the calibration of the PT Model concentrate of eliminating any obvious errors in the coding of the PT network and services shown up by the comparison of model outputs against observed data. A key initial stage is to compare modelled Bus speeds against observed speeds obtained from Automatic Vehicle Location (AVL) data and make adjustment to the representation of the network and services where required.

At a more detailed stage of the calibration process, modelled outputs are compared against observed PT line flows and boarding and alighting data, and PT assignment parameters are adjusted where this gives a better match.

As a final stage of the calibration process, matrix estimation may be used to adjust sectors of the matrix where travel demand is under or over-represented. Matrix estimation is used to make small changes only, because large distortions could prevent the model reaching a true equilibrium between demand and travel costs.

A full list of calibration statistics and the detailed list of criteria for the match of observed data and model outputs for the PT model are given in Chapter 8.

UK TAG unit M3-2, Oct 2013[39] sets out the following means of PT model calibration:

- adjustments may be made to the zone centroid connector times, costs and loading points;
- adjustments may be made to the network detail, and any service amalgamations in the interests of simplicity may be reconsidered;
- the in-vehicle time factors may be varied;
- the values of walking and waiting time coefficients or weights may be varied;
- the interchange penalties may be varied;
- the parameters used in the trip loading algorithms may be modified;
- the path building and trip loading algorithms may be changed; and
- the demand may be segmented by person (ticket) type.

UK 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.

10.6.2 Validation

The validation of the PT Model compares the modelled passenger flows with equivalent observed data across screenlines/cordons, boarding/alighting volumes at rail and Luas stations and on specific cross-network movements. Comparisons of annual ticket sales revenue and analysis of modelled loadings versus capacities are also undertaken. Bus journey times are also validated against observed data.

UK TAG unit M3-2 indicates that the following passenger flow validation criterion should be considered:

- Modelled PT flow should ideally fall within 15% of observed flow across appropriate screenlines; and
- Modelled PT flow should ideally fall within 25% of observed flow on individual links, except where observed flows are particularly low (less than 150), on individual links.

An exploration of non-UK guidance has been undertaken to determine if any other international calibration and validation standards would be appropriate for the ERM. Table 10.12 provides a summary of the available guidance for PT assignment model validation.

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[39] https://webarchive.nationalarchives.gov.uk/20191103110735/https://www.gov.uk/government/publications/webtag-tag-unit-m3-2-public-transport-assignment-modelling

Table 10.12 Public Transport Model Validation Guidance

Organisation	Location	Guidance	Description
UK Department of Transport	UK	UK TAG Unit M3.2 PT Assignment	UK guidance for transport appraisal Validation criterion for passenger flow comparisons
Florida Department of Transportation Systems Planning Office	Florida (US)	FSUTMS Principles of Model Calibration Validation	Guidelines on transport modelling calibration Guidelines for PT service times using root-mean-square error (RMSE)
ARUP - Hong Kong planning department	Hong Kong (China)	HK Transport Modelling Approach and Validation	Report on a multi modal transport model calibration Validation criterion for passenger flow comparisons though less onerous than UK TAG
CERTU	France	Modélisation des déplacements urbains de voyageurs - Guide des pratiques	Guidelines on Transport modelling in urban areas Validation criterion for passenger flow comparisons slightly more onerous than UK TAG but on a more limited sample

10.6.3 Journey time calibration

As outlined in the previous sub-section, the first step in calibration the PT Model is to undertake a comparison between modelled journey times and available observed data (GTFS and AVL). The calibration takes the post matrix estimation road network to take into account the impact of the estimation process.

The process begins by assigning PT demand on the estimated network with run time factors set to 1. The resulting bus run times are then compared to the observed data. Factors are then calculated at service group level, this can either be done by service types or service corridors (geographic locations), depending on the initial results. The factors are then applied in the service coding and PT assignment is rerun.

10.6.4 Prior matrix calibration review

The PT Model performance was reviewed to justify whether matrix estimation is required. The indicators used in the analysis are modelled flows and boardings. This analysis is based on the guidelines set out in TAG Unit M3.2 including the link flows validation criterion being within 25% of observed data for links with observed data higher than 150 passengers per hour as discussed in sub-section 10.6.1.

Table 10.13 PT Model Link flows validation summary (E3R12) and Table 10.14 PT Model Boardings validation summary (E3R12) below summarise the number of sites that met the link flows and boardings validation criteria respectively for ERM model run E3R12. These results suggest that PT matrix estimation is required to achieve a better validation performance based on the TAG guidelines.

Table 10.13 PT Model Link flows validation summary (E3R12)

	No of Sites (observed Flows >150 pass/h)				%Sites (within +/-25%)			
Time Period	**Dublin Bus**	**Rail**	**Luas**	**Total**	**Dublin Bus**	**Rail**	**Luas**	**Total**
AM	22	138	97	**257**	32%	43%	34%	**39%**
LT	0	120	71	**191**	n/a	36%	38%	**37%**
SR	0	105	81	**186**	n/a	12%	53%	**30%**
PM	18	147	95	**260**	56%	44%	38%	**43%**
OP	0	39	0	**39**	n/a	5%	n/a	**5%**

Table 10.14 PT Model Boardings validation summary (E3R12)

	No of Sites (observed Boardings >150 pass/h)				%Sites (within +/-25%)			
Time Period	**Dublin Bus**	**Rail**	**Luas**	**Total**	**Dublin Bus**	**Rail**	**Luas**	**Total**
AM	27	50	39	**116**	30%	42%	31%	**35%**
LT	13	5	10	**28**	8%	60%	50%	**32%**
SR	19	8	15	**42**	5%	13%	33%	**17%**
PM	49	21	25	**95**	24%	52%	48%	**37%**
OP	11	4	7	**22**	0%	25%	0%	**5%**

10.6.5 Matrix Estimation

Matrix estimation was used to further adjust the trip matrices to improve the validation performance. The matrix estimation for PT model was undertaken using a bespoke CUBE Analyst tool which were developed as part of RMS modelling framework. This tool uses observed link flows data as constraints which were then aggregated into screenlines counts. The parameters to constrain the changes in the estimation are defined as confidence intervals and these are applied at counts, trip ends, and matrix cell values level. These confidence intervals are presented in Table 10.15 PT Matrix estimation parameters below. The possible values range from 1-100, with observed PT counts being the benchmark and therefore is given a confidence interval of 100, and the other two components are given values relative to the PT counts with the lowest value of 5 given to Prior matrix cell values as they are produced by model estimation.

Table 10.15 PT Matrix estimation parameters

Component	Confidence Interval
Counts	100
Trip Ends	80
Matrix cell values	5

The estimation tool takes the loaded networks and prior demand matrices from the full Demand Model run as a starting point. It is worth noting that the loaded networks include the post Road matrix estimation network speed to better reflect the interactions between the two assignment models especially on the impact on network speed due to congestion. Prior to the estimation process the tool analyses the routes through defined screenlines to produce intercept files (ICP) which are then used in the estimation process to adjust the demand matrices. The adjusted demand matrices are then re-assigned to the network and the outputs are assessed to determine the impact of the estimation. The PT matrix estimation process is summarised in Figure 10.4 PT Matrix estimation workflow below.

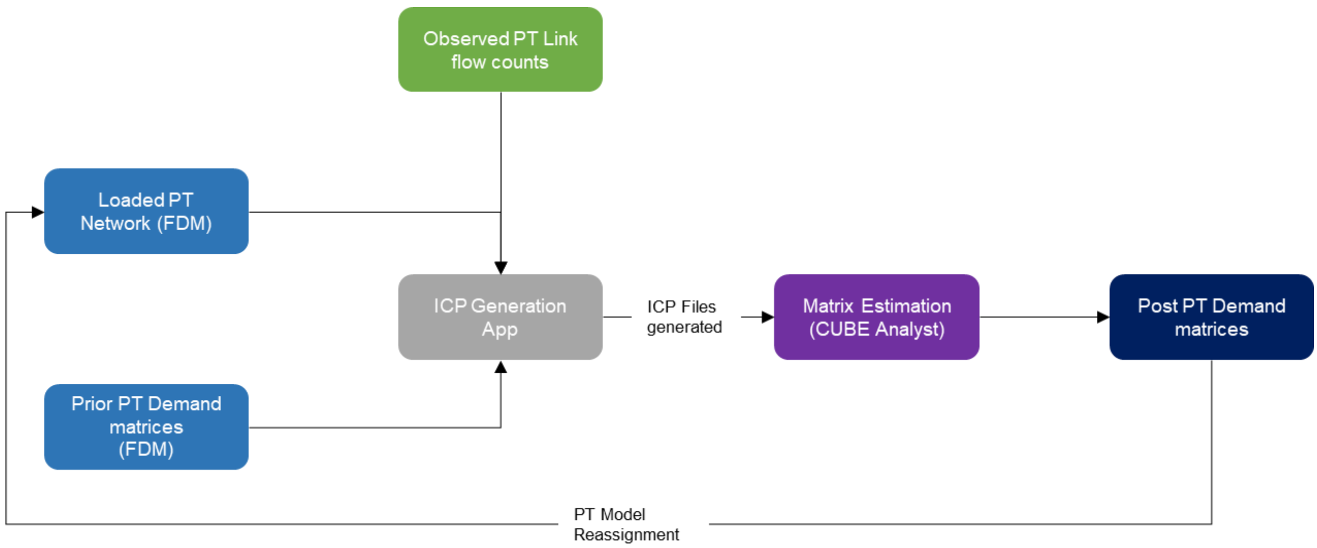

Figure 10.4 PT Matrix estimation workflow

10.7 Active Modes Model Calibration and Validation

A key initial stage of the calibration of the Active Modes Network is to examine the additional walk links inherited from the development of the PT network. These need to be reviewed if the connectors don't represent how people access the network for walking and cycling. For example, there may be areas with lack of network details. This would lead to overestimation of walk and cycle costs, that in turn would result in underestimation of walk and cycle demand. Hence, an essential initial check is to:

- Compare modelled Walk and Cycle mode shares to observed data; and
- Add network details and modify zone connectors in areas where modelled active modes demand is significantly lower than observed.

Walk and Cycle speeds used in the Active Modes model are calculated from the NHTS 2017. However, in the calibration process there may be a need to:

- Modify overall walk or cycle speed if modelled costs are obviously too low or high; and
- Modify cycle speed defined on cycle facilities to calibrate the assignment.

There is no official guideline on what walk and cycle assignments should achieve to validate flows against observed values. However, a good starting point is to use PT calibration criteria, bearing in mind that they might be difficult to achieve for walk and cycle.

A full list of calibration statistics and the list of criteria for the match of observed data and model outputs for the Active Modes model are given in Chapter 9.

10.8 Summary

This chapter has laid out the key assumptions and processes that were used to develop inputs to the Demand Model and also outlined how they were validated in practice, the results of which are covered in Chapter 11.

For each model component the approaches have been discussed, beginning with the overall approach to calibration of the ERM and the “phasing” approach to development.

The mode and destination choice model has been calibrated in multiple stages including an initial estimation following by an additional calibration to cover up acknowledged weaknesses in the approach such as small samples of observed data. The model results are then evaluated on a number of key criteria including mode share, average generalised costs, intrazonal proportions, and trip length distributions to establish the quality of fit against observed data.

Free workplace parking is discussed as being primarily algorithm-based rather than response-based as it simply compares capacity and demand before re-evaluating mode share (based on the original mode choice model with parking included) and therefore not reliant on calibration to any great degree. It is noted there is a significant lack of validation data which makes it impossible to evaluate whether it reflects the real world.

The Park and Ride model also suffers from a lack of data and is therefore reliant on a number of assumptions to prepare both data inputs into the model as well as “observed” data to be compared against and these assumptions and the outcome targets have been presented.

The Parking Distribution has been discussed in terms of the input data and the assumptions required to estimate parking capacity on a zonal level noting that specific observed data is not available at that level of detail, and the parameters which drive the approach have been described.

The additional processes and procedures to model ports and airports has been discussed in the section on Special Zones, covering the linkages to the NDFM where the target demand (magnitude of travellers) is first introduced and then the approach to calibration and validation of the distribution and mode choice models has been covered alongside preparation of the inputs to the model (parameters and definitions).

The approach to converting demand from the mode and destination choice models into assignment matrices is covered through the discussion on Period to Hour and CDCU factors which have been sourced from passenger count data and the NHTS respectively.

Finally, the process of closing the Demand Model loop through application of an incremental adjustment has been discussed.

11 Calibration and Validation Results

11.1 Calibration and Validation Overview

Calibration of the ERM Demand Model involves calibrating each of its sub-components, which include:

- Mode and Destination choice; this section discusses the calibration results of the various choice models, including the following:
    - Mode Choice – calibrated to observed mode shares;
    - Destination Choice – calibrated to observed trips and their associated modelled generalised costs;
    - Free Workplace Parking – calibrated to synthesised car parking occupancy and capacity data;
    - Park and Ride – calibrated to observed capacities and synthesised base travel patterns and daily usage profiles;
    - Parking Distribution – calibrated in the context of the overall model structure to provide a level of parking constraint in the base and redistribution from high-demand zones to zones with sufficient on-street and multi-story parking capacity;
    - Special Zones – calibrated both in the NDFM (see LDM Report) and the regional model to observed travel pattern data at the regional airports.;
- Road assignment model – calibrated using a range of observed traffic count and journey time data;
- Public Transport assignment model – calibrated using a range of observed traffic count and journey time data;
- Active modes assignment model – validated at the screenline level only; and
- Incremental adjustment.

This chapter presents the results of the overall calibration exercise for each of the above components.

11.2 Mode and Destination Choice

11.2.1 Overview

The Key Performance Indicators (KPIs) used to calibrate Mode and Destination Choice are:

- Mode Share;
- Generalised Cost Distribution; and
- Intrazonal proportions.

The performance of the calibrated ERM with respect to the above KPIs is discussed below.

11.2.2 Data Discussion

Two key data sources are used to provide comparison for the mode and destination choice model and indeed any demand comparisons: the 2017 National Household Travel Survey (NHTS); and the 2016 Place of Work, School or College - Census of Anonymised Records (POWSCAR). These are both very different sources of information and have particular strengths and weaknesses.

POWSCAR is a census data set which covers the population of Ireland and therefore includes a large amount of information and hence a high level of confidence. POWSCAR relates the locations that people work and live and is able to provide mode shares and very detailed generalised cost and trip length comparisons for instance once related to a model zone.

NHTS is a much smaller survey relating to a sample of 6,000 households but generally provides much more information and critically:

- Relates to actual journeys made;
- Can provide information on legs within a journey; and
- Covers all purposes rather than just commute and education.

It is important to recognise the impact of the differences between NHTS and POWSCAR as it is critical to any comparison between observed data and the model and expands across all comparison including average generalised costs, trip lengths and intrazonal proportions.

A comparison of each of the datasets across a number of key criteria within the ERM Demand Model context is presented in Table 11.1 to provide context on how they may differ.

Note that cleaning was undertaken on both datasets to remove records which were not fully specified i.e. records missing geographic references, records missing critical fields for alignment with time of day or demand segment, non-standard modes etc. Further information on the data cleaning exercise can be found in the *Data Management Report.*

Table 11.1 POWSCAR and NHTS Comparison within an ERM Demand Model Context

Item	POWSCAR	NHTS
Sample size	Full country population noting some missing values	Nationally 6,000 households, 10,289 individual diaries, 62,307 trips
Weekday identification	No information provided on whether a person makes a trip on a weekday or how often	Clear and concise definition of day of travel
Relates to trips	No, relates to people and their location of work	Identifies journeys and even legs of a journey
Identifies tours	Can only be assumed with large assumption on time of day and mode	Can link legs throughout the day based on diaries to identify tours
Purposes detail	Commute (COM) and education (EDU) only	All user classes, purposes, and demand segments can be identified for each record
Mode identification	Can identify main modes but not park and ride	Can identify all modes
Time of day	Limited information on normal time of travel, broken down into half hourly segments between 0630 and 0930 and then the rest of the day as a group	Start and end time for each leg of a journey
Demand segmentation: blue collar / white collar commute	Provides information on the job segmentation but is not the same	Definition for all demand segments (particularly blue- and white-collar commute) consistent with the ERM
Demand segmentation: car availability	No direct information on car availability, must be inferred based on comparison of household car ownership and number of residents	Clear and consistent definition for car availability for a journey
Demand segment: education level	Provides clear definition of education level (primary, secondary, tertiary)	Provides clear definition of education level (primary, secondary, tertiary)

As NHTS is a sample it has much less information available than the POWSCAR dataset, and it is important to recognise that when summarised it provides different information, particularly for mode shares when presented at various times of day.

Within this model POWSCAR was used as the source of data for calibration for COM and EDU purposes while NHTS was used for all others. The reason for this was the much larger sample size available from POWSCAR despite the issues noted above with correspondence between definitions in the data and the ERM usage.

This also means when comparisons are made against NHTS data there can be notable differences between the modelled results and the interpretations of the observed data and where possible summaries of both datasets are provided to allow contrast not only between modelled values but also the different observed data.

11.2.3 Demand Model Convergence (GAP Analysis)

As this model is an absolute model it should in practice be built to automatically converge in the base year. This is assisted by the inclusion of an incremental adjustment which effectively closes the loop between costs produced by assignment and the demand produced by the costs, but the presence of additional parking models which do not have such a fix in place means that there ultimately is some level of noise within the base.

As this will follow through to other scenarios a summary of the GAP analysis for a multi-loop base year is included below in Figure 11.1 and Table 11.2. A multi-loop base year is not standard practice and more importantly is not what is reported on in the rest of this document, and these results should not be considered a core element of a base year run.

The typical requirements laid out in UK TAG are that a model should achieve a GAP convergence of 0.1% although 0.2% would be acceptable in large models.

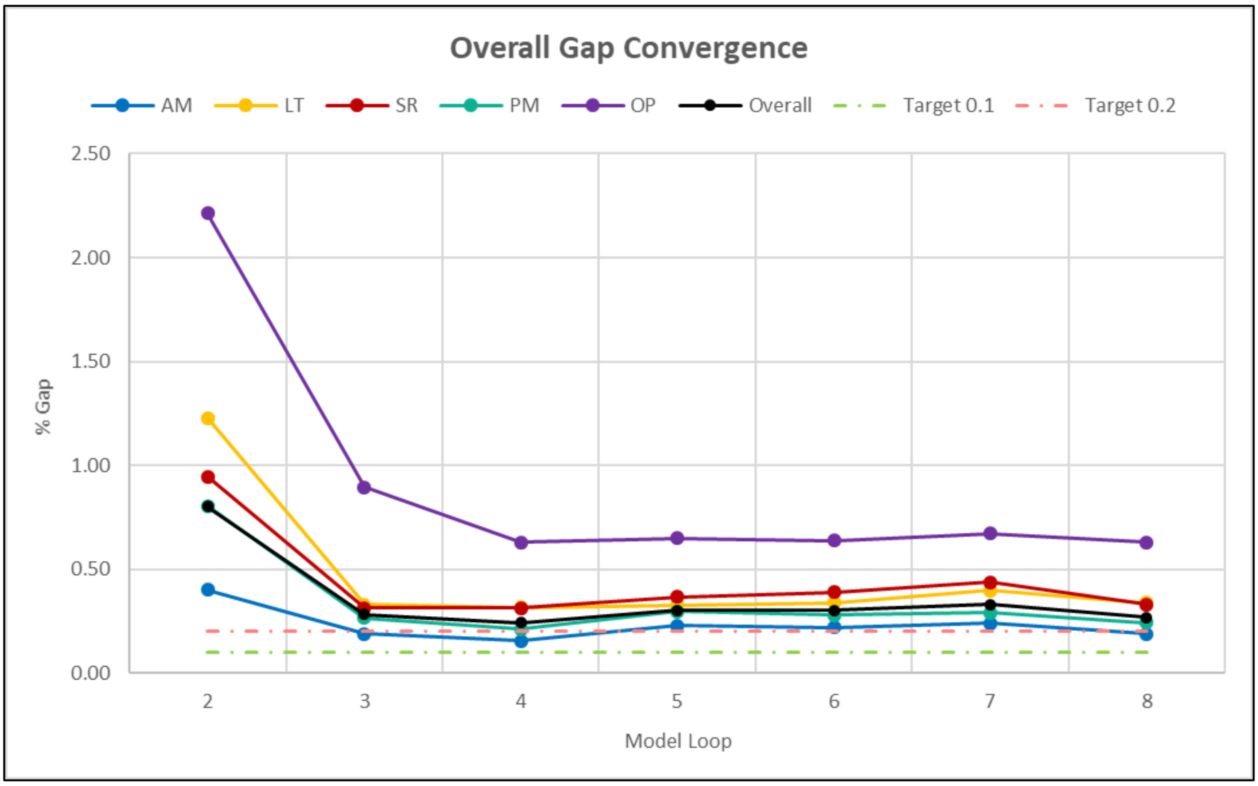

Figure 11.1 Overall GAP Convergence by Time Period

Table 11.2 Overall GAP Convergence by Time Period

Loop	AM	LT	SR	PM	OP	Overall
2	0.40	1.23	0.94	0.80	2.21	0.80
3	0.19	0.33	0.31	0.27	0.89	0.28
4	0.16	0.32	0.31	0.21	0.63	0.24
5	0.23	0.33	0.37	0.30	0.65	0.30
6	0.22	0.34	0.39	0.28	0.64	0.30
7	0.24	0.40	0.44	0.29	0.67	0.33
8	0.19	0.34	0.33	0.24	0.63	0.27

As is evident above, the model does not achieve the recommended value of 0.2% and also on the 5th iteration here can be seen to increase suggesting that the lowest value of 0.24 overall is the minimum that would be achieved and running for further loops is unlikely to dramatically reduce the GAP.

While this is below the UK TAG recommendation it must be highlighted that the overall complexity of the model is far from standard, particularly with the noted parking models which can change both demand and costs. In comparison, most transport models only allow a changing cost element to come from assignment and demand allocation is generally simpler. It is further noted that despite results being presented here for all time periods, the guidance does not explicitly state that each time period of subset of demand must meet the target of 0.2% or lower, only that overall the model should achieve this, but it is worth noting where the less convergent elements are for potential appraisal purposes.

A summary of the GAP after 5 iterations is provided in Table 11.3 and Table 11.4 noting that this would not be expected to be as low in a forecast year for instance.

Table 11.3 Base Year GAP After 8 Iterations by Mode

Mode	AM	LT	SR	PM	OP
Road	0.39	0.65	0.59	0.41	0.94
PT	0.14	0.23	0.27	0.19	0.41
Walk	0.07	0.04	0.05	0.06	0.01
Cycle	0.12	0.08	0.13	0.10	0.01

Table 11.4 Base Year GAP After 8 Iterations by User Class

UC	AM	LT	SR	PM	OP
EMP	0.66	0.86	0.91	0.75	1.52
COM	0.14	0.53	0.54	0.18	0.71
OTH	0.14	0.21	0.20	0.19	0.35
EDU	0.20	0.15	0.19	0.21	0.10
RET	1.07	0.70	1.16	1.30	2.52

Further discussion of convergence takes place in Chapter 13 – Forecasting and provides a better comparison of what could reasonably be expected through typical model use.

11.2.4 Mode Shares

Correctly replicating observed mode shares is critical to the overall Demand Model calibration. The mode share estimates directly inform the total number of trips by mode in units of person trips per time period for a typical 24-hour weekday.

The Demand Model is interrogated at the following stages to establish and report on the modelled mode shares:

- Directly after Free Workplace Parking, at demand segment level; and
- At assignment level, with units converted back into person trips per period, by user class (using the same factors which converted them to assignment level in the first place).

The level of detail differs at these points; the first allowing the most disaggregated comparison of mode share at the demand segment level (e.g. white-collar car-available commute), and the second at assignment stage being more aggregate, at the user class level (e.g. commute). The latter comparison also includes additional changes to modes share introduced by the Parking Distribution and Park and Ride (PnR) models.

As described in Chapter 6, two mode choice steps are performed in the model, prior to and following the application of Free Workplace Parking (FWPP). These are applied independently to the commute and education car available segments of travel demand. As overall mode share is affected by the application of Free Workplace Parking, it is necessary to report on the calibration of mode choice after the FWPP stage is completed and the aggregate mode share by demand segment is available. Details of the calibration of mode choice at the assignment stage of the model are presented later in this chapter.

Demand Segment Comparison

A demand segment comparison between observed and modelled mode shares is provided in Table 11.5, including the total number of tours by demand segment (or trips for segments 30-33, see Chapter 5 for further details on demand segmentation). A discussion of the results follows the table.

In addition, Table 11.6 provides a comparison of the expanded synthesised tours and the modelled tours, as well as a summary of the sample that generated the mode shares. There are some critical points to note:

POWSCAR does not have a consistent interpretation of car availability with the NHTS and so additional processing must take place to split among demand segments and therefore the sample that is reported here is for the combined car available and non-car available segments such that for example DS01 + DS03 sample size is reported in both, and this continues for all the POWSCAR purposes (DS01-DS10).

POWSCAR also cannot identify Park and Ride trips so these values have been developed within the car available commute demand segments (DS01 and DS02) to give the correct overall number of tours that are expected to arrive within the Park and Ride model, hence there is no sample associated with these. The mode share for other modes is maintained with the same ratio as the synthesised data above.

The Root Mean Square Error (RMSE) value provided in the table is derived as follows:

$$RMSE = \sqrt{\frac{\sum_{m \in M}(Observed - Modelled)^2}{5}}$$

Where:

m is the mode from the set of modes M;

$Observed$ is the observed mode share or estimated tours;

$Modelled$ is the modelled mode share or modelled tours; and

The 5 in the denominator is the number of modes.

Table 11.5 Demand Segment Mode Share Comparison – Post Free Workplace Parking

Demand Segment	Purpose	Total Tours[40]	Observed Mode Share					Modelled Mode Share					RMSE
			Car	PT[41]	PnR[42]	Walk	Cycle	Car	PT	PnR	Walk	Cycle	
DS01	COM	111,909	98.2%	0.0%	1.8%	0.0%	0.0%	97.9%	0.1%	1.9%	0.1%	0.0%	0.2%
DS02	COM	381,647	93.5%	2.8%	1.8%	1.2%	0.8%	96.1%	1.9%	1.2%	0.6%	0.3%	1.3%
DS03	COM	46,649	0.0%	38.7%	0.0%	44.9%	16.4%	0.0%	38.0%	0.0%	46.0%	16.0%	0.6%
DS04	COM	148,728	0.0%	52.5%	0.0%	32.6%	14.9%	0.0%	51.0%	0.0%	34.0%	15.0%	0.9%
DS05	EDU	158,585	94.0%	1.3%	0.0%	4.4%	0.3%	92.8%	0.0%	0.0%	6.8%	0.4%	1.3%
DS06	EDU	101,982	61.7%	18.7%	0.0%	17.3%	2.3%	85.4%	7.2%	0.0%	7.1%	0.5%	12.7%
DS07	EDU	24,784	54.1%	30.2%	0.0%	10.9%	4.9%	81.3%	11.1%	0.0%	6.0%	1.7%	15.1%
DS08	EDU	94,240	0.0%	21.3%	0.0%	73.9%	4.8%	0.0%	4.0%	0.0%	92.0%	4.0%	11.2%
DS09	EDU	64,312	0.0%	48.9%	0.0%	45.2%	5.9%	0.0%	48.0%	0.0%	48.0%	4.0%	1.6%
DS10	EDU	38,525	0.0%	65.7%	0.0%	23.7%	10.6%	0.0%	55.0%	0.0%	35.0%	10.0%	7.0%
DS11	OTH	91,076	91.8%	0.0%	0.0%	7.9%	0.3%	91.0%	0.0%	0.0%	9.0%	0.0%	0.6%
DS12	OTH	42,503	97.8%	0.0%	0.0%	2.3%	0.0%	97.0%	0.0%	0.0%	3.0%	0.0%	0.5%
DS13	OTH	5,484	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DS14	OTH	55,675	0.0%	2.7%	0.0%	97.3%	0.0%	0.0%	3.0%	0.0%	97.0%	0.0%	0.2%
DS15	OTH	27,115	0.0%	2.7%	0.0%	97.3%	0.0%	0.0%	3.0%	0.0%	97.0%	0.0%	0.2%
DS16	OTH	5,533	0.0%	2.7%	0.0%	97.3%	0.0%	0.0%	2.0%	0.0%	98.0%	0.0%	0.4%
DS17	OTH	193,613	83.5%	2.3%	0.0%	13.4%	0.8%	82.0%	3.0%	0.0%	15.0%	0.0%	1.1%
DS18	OTH	153,841	86.2%	0.4%	0.0%	12.6%	0.8%	85.0%	0.0%	0.0%	14.0%	1.0%	0.9%
DS19	OTH	89,066	0.0%	19.1%	0.0%	72.7%	8.3%	0.0%	19.0%	0.0%	73.0%	8.0%	0.2%
DS20	OTH	73,017	0.0%	29.3%	0.0%	65.2%	5.5%	0.0%	29.0%	0.0%	65.0%	5.0%	0.3%
DS21	OTH	65,150	91.5%	1.4%	0.0%	7.1%	0.0%	91.0%	1.0%	0.0%	7.0%	1.0%	0.5%
DS22	OTH	51,846	91.6%	0.0%	0.0%	8.0%	0.4%	91.0%	0.0%	0.0%	8.0%	0.0%	0.3%
DS23	OTH	53,834	0.0%	9.3%	0.0%	89.9%	0.9%	0.0%	9.0%	0.0%	90.0%	1.0%	0.2%
DS24	OTH	37,715	98.8%	0.0%	0.0%	1.2%	0.0%	99.0%	0.0%	0.0%	1.0%	0.0%	0.1%
DS25	OTH	30,642	96.7%	1.1%	0.0%	2.2%	0.0%	97.0%	1.0%	0.0%	2.0%	0.0%	0.2%
DS26	OTH	12,405	0.0%	18.2%	0.0%	66.7%	15.2%	0.0%	18.0%	0.0%	67.0%	15.0%	0.2%
DS27	EMP	138,747	82.4%	9.2%	0.0%	7.8%	0.7%	86.0%	9.0%	0.0%	5.0%	0.0%	2.1%

[40] 24-hour person tours / trips
[41] Public Transport
[42] Park and Ride

Demand Segment	Purpose	Total Tours[43]	Observed Mode Share					Modelled Mode Share					RMSE
			Car	PT[44]	PnR[45]	Walk	Cycle	Car	PT	PnR	Walk	Cycle	
DS28	RET	91,756	88.4%	1.5%	0.0%	9.7%	0.5%	89.0%	1.0%	0.0%	9.0%	0.0%	0.5%
DS29	RET	33,825	0.0%	18.2%	0.0%	77.7%	4.1%	0.0%	18.0%	0.0%	78.0%	4.0%	0.2%
DS30	NHBEB	37,818	87.1%	8.6%	0.0%	4.3%	0.0%	90.0%	8.0%	0.0%	1.0%	1.0%	2.0%
DS31	NHBEB	16,067	0.0%	53.3%	0.0%	33.3%	13.3%	0.0%	53.0%	0.0%	34.0%	13.0%	0.4%
DS32	NHBOT	336,254	87.1%	4.3%	0.0%	7.9%	0.8%	90.0%	3.0%	0.0%	7.0%	0.0%	1.5%
DS33	NHBOT	187,352	0.0%	45.8%	0.0%	46.3%	7.9%	0.0%	45.0%	0.0%	47.0%	8.0%	0.5%
	Total	3,001,695	60.4%	13.3%	0.3%	23.1%	2.9%	62.0%	11.6%	0.2%	23.6%	2.6%	1.1%

[43] 24-hour person tours / trips
[44] Public Transport
[45] Park and Ride

Table 11.6 Demand Segment Tour Comparison – Post Free Workplace Parking

Demand Segment	Purpose	Total Tours[46]	Estimated Tours					Observed Sample Size					Modelled Tours / Trips				
			Car	PT[47]	PnR[48]	Walk	Cycle	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle
DS01	COM	111,909	109,898	-	2,014	-	-	435,387	117,063	-	70,139	33,139	109,640	67	2,059	157	34
DS02	COM	381,647	356,809	10,610	6,870	4,389	2,939	78,946	13,607	-	15,070	5,742	366,770	7,290	4,656	2,175	1,030
DS03	COM	46,649	-	18,063	-	20,956	7,632	435,387	117,063	-	70,139	33,139	-	17,728	-	21,460	7,464
DS04	COM	148,728	-	78,051	-	48,544	22,145	78,946	13,607	-	15,070	5,742	-	75,850	-	50,567	22,309
DS05	EDU	158,585	149,070	2,030	-	7,041	460	141,856	23,133	-	80,252	5,157	147,104	48	-	10,816	634
DS06	EDU	101,982	62,836	19,075	-	17,629	2,302	59,743	46,852	-	43,307	5,655	86,606	7,587	-	7,190	458
DS07	EDU	24,784	13,400	7,468	-	2,692	1,206	20,431	38,703	-	13,956	6,255	20,142	2,737	0	1,481	409
DS08	EDU	94,240	-	20,083	-	69,681	4,476	141,856	23,133	-	80,252	5,157	-	3,770	-	86,701	3,770
DS09	EDU	64,312	-	31,530	-	29,146	3,771	59,743	46,852	-	43,307	5,655	-	30,938	-	30,938	2,578
DS10	EDU	38,525	-	25,320	-	9,130	4,089	20,431	38,703	-	13,956	6,255	-	21,197	-	13,489	3,854
DS11	OTH	91,076	83,617	-	-	7,168	282	583	-	-	50	2	82,879	-	-	8,197	-
DS12	OTH	42,503	41,547	-	-	956	-	87	-	-	2	-	41,228	-	-	1,275	-
DS13	OTH	5,484	5,484	-	-	-	-	42	-	-	-	-	5,484	-	-	-	-
DS14	OTH	55,675	-	1,492	-	54,183	-	-	3	-	140	-	-	1,670	-	54,005	-
DS15	OTH	27,115	-	727	-	26,389	-	-	1	-	-	-	-	813	-	26,302	-
DS16	OTH	5,533	-	148	-	5,384	-	-	-	-	5	-	-	111	-	5,422	-
DS17	OTH	193,613	161,705	4,453	-	25,963	1,491	436	12	-	70	4	158,762	5,808	-	29,042	-
DS18	OTH	153,841	132,657	615	-	19,338	1,231	432	2	-	63	4	130,765	-	-	21,538	1,538
DS19	OTH	89,066	-	16,985	-	64,733	7,348	-	37	-	141	16	-	16,922	-	65,018	7,125
DS20	OTH	73,017	-	21,394	-	47,607	4,009	-	80	-	178	15	-	21,175	-	47,461	3,651
DS21	OTH	65,150	59,593	925	-	4,632	-	193	3	-	15	-	59,287	652	-	4,561	652
DS22	OTH	51,846	47,475	-	-	4,163	207	228	-	-	20	1	47,180	-	-	4,148	-
DS23	OTH	53,834	-	4,980	-	48,381	474	-	21	-	204	2	-	4,845	-	48,451	538
DS24	OTH	37,715	37,278	-	-	437	-	85	-	-	1	-	37,338	-	-	377	-
DS25	OTH	30,642	29,630	337	-	674	-	88	1	-	2	-	29,722	306	-	613	-

[46] 24-hour person tours / trips
[47] Public Transport
[48] Park and Ride

Demand Segment	Purpose	Total Tours[49]	Estimated Tours					Observed Sample Size					Modelled Tours / Trips				
			Car	PT[50]	PnR[51]	Walk	Cycle	Car	PT	PnR	Walk	Cycle	Car	PT	PnR	Walk	Cycle
DS26	OTH	12,405	-	2,255	-	8,270	1,879	-	6	-	22	5	-	2,233	-	8,311	1,861
DS27	EMP	138,747	114,258	12,695	-	10,878	902	126	14	-	12	1	119,322	11,100	-	6,937	-
DS28	RET	91,756	81,066	1,330	-	8,900	468	1,221	20	-	134	7	81,663	918	-	8,258	-
DS29	RET	33,825	-	6,149	-	26,282	1,394	-	106	-	453	24	-	6,088	-	26,383	1,353
DS30	NHBEB	37,818	32,940	3,252	-	1,626	-	81	8	-	4	-	34,037	3,025	-	378	378
DS31	NHBEB	16,067	-	8,568	-	5,355	2,142	-	8	-	5	2	-	8,515	-	5,302	2,089
DS32	NHBOT	336,254	292,776	14,358	-	26,564	2,556	1,939	95	-	176	17	302,628	10,088	-	23,538	-
DS33	NHBOT	187,352	-	85,826	-	86,669	14,857	-	104	-	105	18	-	84,308	-	88,055	14,988
	Total	3,001,695	1,812,040	398,722	8,884	693,762	88,258						1,860,558	345,789	6,715	708,544	76,713

* "-" in the table indicates no data or not applicable.

49 24-hour person tours / trips
50 Public Transport
51 Park and Ride

This comparison shows a strong correspondence in the majority of demand segments, although there are some notable exceptions.

For trips on Home-based Employers Business (HBEB, DS27), the model overestimates travel by car, and underestimates travel by walking by around 3.7%, and this trend continues throughout the model generally. This suggests there is a difficulty matching mode share at the same time as matching average generalised costs and intrazonal proportions. It should also be noted that there is limited data available from the NHTS (153 records) for this demand segment, which makes the target mode share for Employer's business less reliable.

The most notable exceptions are in Home-based Education tours (HBEd, DS5-10) where there are large differences in ERM and observed mode share between car, PT, and walk for individual demand segments.

A summary of Table 11.6 aggregated by user class is provided in Table 11.7 below and highlights that the Demand Model at this stage provides a reasonable modal share comparison, considering:

- Overall mode share is within 2% for all modes;
- For employer's business trips, the model overestimates car mode share, but this segment is a relatively low proportion of overall demand (~5%); and
- For trips to education, the model overestimates car and underestimates PT by 10-20% - it is noted that the low ratio of cars to people for education trips means that this error will have less of an impact on the road model.

Table 11.8 shows a similar comparison of modelled and observed trips at the assignment stage, noting the observed values here are derived as the mode share from the relevant data source expanded to the total number of trips in the model (24-hour weekday average persons). This shows a consistent trend to Table 11.7, but with less of a discrepancy for education trips.

For clarity the total number of trips are not the same, as the Parking Distribution and Park and Ride models both expand tours into complex tours with multiple legs by different modes, hence there are more overall trips in the assignment models than measured in other locations.

This table also notably includes POWSCAR (24-hour) comparisons for COM and EDU and highlights quite clearly how different the two datasets actually are when considered at an overall level.

Table 11.9 provides a comparison of modelled and observed mode shares broken down by time period across the day. In addition, POWSCAR does not record the trip timing outside 0630 to 0930, and hence a 24-hour value is the only data provided. By contrast, modelled and NHTS trips refer to travel by all demand segments.

Table 11.7 Mode Share by User Class – Post Free Workplace Parking

User Class	Tours	Car		PT		PnR		Walk		Cycle	
		Observed	Modelled	Observed	Modelled	Observed	Modelled	Observed	Modelled	Observed	Modelled
EMP	138,747	82%	86%	9%	8%	0%	0%	8%	5%	1%	0%
COM	688,944	68%	69%	15%	15%	1%	1%	11%	11%	5%	4%
OTH	988,516	61%	60%	5%	6%	0%	0%	32%	33%	2%	2%
EDU	482,429	47%	53%	22%	14%	0%	0%	28%	31%	3%	2%
RET	125,581	65%	65%	6%	6%	0%	0%	28%	28%	1%	1%
NHBEB	53,885	61%	63%	22%	21%	0%	0%	13%	11%	4%	5%
NHBOT	523,606	56%	58%	19%	18%	0%	0%	22%	21%	3%	3%
Total	3,001,706	60%	62%	13%	12%	0%	0%	23%	24%	3%	3%

Table 11.8 Comparison of Modelled and Synthesised Trips by User Class

Time Period	Source	Car	PT	Walk	Cycle	Car	PT	Walk	Cycle
24H	Model	63%	12%	23%	2%	3,642,292	708,449	1,306,178	139,408
24H	NHTS	66%	10%	20%	4%	13,095	1,974	4,069	729
24H	POWSCAR	59%	19%	18%	4%	738,874	239,696	227,262	56,690
EMP	Model	83%	11%	5%	1%	343,282	45,130	22,035	2,810
EMP	NHTS	77%	12%	10%	1%	273	43	36	4
COM	Model	70%	16%	10%	4%	1,052,472	232,847	150,197	61,836
COM	NHTS	71%	12%	10%	6%	4,242	737	623	370
COM	POWSCAR	67%	17%	11%	5%	516,774	131,737	86,513	39,246
OTH	Model	60%	9%	29%	2%	1,574,739	232,268	764,079	48,200
OTH	NHTS	68%	6%	23%	2%	5,388	493	1,846	168
EDU	Model	49%	19%	30%	2%	497,988	190,033	300,173	23,364
EDU	NHTS	54%	17%	25%	4%	1,617	502	760	129
EDU	POWSCAR	45%	22%	29%	4%	222,100	107,958	140,750	17,443
RET	Model	68%	3%	27%	1%	173,811	8,171	69,694	3,198
RET	NHTS	60%	8%	30%	2%	1,576	199	804	58
24H	Model	63%	12%	23%	2%	3,642,292	708,449	1,306,178	139,408
24H	NHTS	66%	10%	20%	4%	13,095	1,974	4,069	729
24H	POWSCAR	59%	19%	18%	4%	738,874	239,696	227,262	56,690

Table 11.9 Comparison of Modelled and Synthesised Trips by Time Period

Time Period	Source	Mode Share				Tours[52] / Sample[53]			
		Car	PT	Walk	Cycle	Car	PT	Walk	Cycle
24H	Mod	63%	12%	23%	2%	3,642,292	708,449	1,306,178	139,408
24H	NHTS	66%	10%	20%	4%	13,095	1,974	4,069	729
24H	POWSCAR	59%	19%	18%	4%	738,874	239,696	227,262	56,690
AM	Mod	62%	14%	22%	3%	1,053,763	230,184	372,843	43,620
AM	NHTS	70%	11%	16%	4%	4,210	651	951	220
LT	Mod	62%	10%	26%	2%	557,864	90,566	232,280	18,280
LT	NHTS	56%	10%	31%	3%	1,740	300	952	90
SR	Mod	61%	9%	28%	2%	719,584	106,916	329,966	22,138
SR	NHTS	67%	7%	24%	2%	2,510	269	909	56
PM	Mod	63%	16%	18%	3%	859,691	216,366	240,446	40,110
PM	NHTS	66%	13%	16%	6%	3,179	607	757	275
OP	Mod	68%	10%	20%	2%	451,391	64,417	130,642	15,260
OP	NHTS	66%	7%	23%	4%	1,456	148	500	89

[52] Period level person trips
[53] For NHTS and POWSCAR these values represent the initial sample of data used to derive a mode share

These tables show a close correspondence between modelled and observed mode shares with a few notable exceptions.

- Modelled EMP mode share is overestimated by 6% which predominately comes from walk trips in contrast;
- OTH car trips are under-estimated by 8% which appears to trade from walk; and
- RET trips are overestimated in the model by 8%, mostly trading from PT.

It is notable that two of the user classes which show large discrepancies are those which include non-home-based trips (EMP and OTH) which may indicate that there is not a correct match in home-based and non-home-based trips which means that when aggregating trips there is a discrepancy present at the higher level that is not there at the detailed level, particularly given the strong comparison of these user classes in Table 11.7.

There are also some differences by time period where there seem to be trades between car and walk, with an 8% underestimation of car in the AM, 6% overestimation of car in the LT, and 6% overestimation of car in the SR.

The model shows little variation of mode share throughout the day at this level of detail while NHTS has much more variation, potentially indicating that trends are not being replicated effectively with costs alone, particularly given the generally high sample sizes throughout the NHTS data by time period. However, this could instead indicate unseen biases in the data such as different distributions of user class throughout the day or a lack of representation of enough people to capture trends effectively, particularly in how tour distributions are derived (the likelihood of a trip being made at various times of day dependent on purpose).

Overall modelled mode shares are close to the model across the different time periods, and user classes and in the small number of exceptions the expected impact has been discussed and highlighted.

11.2.5 Average Generalised Cost and Generalised Cost Distributions

Average generalised cost (GC) can be used as an indicator of model fit, as generalised cost is the main variable used in the logit models to allocate trips to particular modes and destinations (rather than, for instance, trip length or journey time).

Generalised cost is the composite function of the two typical resources required in making a trip (money, time). The concept of generalised cost is used widely in variable demand modelling and it is heavily related to the “disutility” of travelling.

Utility microeconomic theory is widely applied in Demand Modelling estimating the probability of a choice from a set of choices. It should be noted that travelling is rarely the purpose of a trip. Therefore, the generalised cost or the combination of money and time expresses the disutility (negative utility) for making a trip.

The inclusion of both time and money attributes mean that generalised cost captures more elements of travel and therefore provides a more comprehensive comparison when trying to compare or replicate choices than simple distance or journey time which can both miss key elements from the decision-making process.

In order to derive a synthesised average generalised cost i.e. the representative single value that on average reflects the overall disutility of a traveller's journey, the NHTS or POWSCAR data is first allocated to the model zone system at both origin and destination end in order to find an average generalised cost from the model, thus ensuring that the approach is consistent with the modelled values. Skimmed model cost matrices are extracted directly from the relevant assignment software.

In the case of skimmed road costs, these are defined as minimum path costs with generalised cost defined as a linear combination:

$$GC = PPM \times T + PPK \times D + M$$

Where:

GC is the cost in units of Pence;

T is time in units of minutes (including any time penalties);

D is distance in kilometres;

M is monetary charge in Pence;

PPM is a user-defined parameter specifying "Pence Per Minute"; and

PPK specifies "Pence Per Kilometre".

Within the PT assignment model generalised cost is taken from the skimmed composite cost matrix supplied directly by Cube software which is defined as representing the total utility of the trip including the choices available to the traveller. The software defines these skim calculations as a single expected cost overall from origin to destination based on each decision point in the trip and varying with the type of choice:

- Walk choices;
- Transit choices;
- Alternative alighting points; and
- Walk and transit choices.

These are further expanded upon in the Cube help manual:

'For origins close to the destination, the costs are usually simple. For example, at the start of the egress leg, the cost of the leg is the cost to reach the destination.

At points further from the destination, where there are alternative routes, the process combines the costs to form a single value for the expected cost to destination from a single point.

For multileg trips, the process computes the expected cost to the destination for each leg, working away from the destination. Computed at decision points using the composite-cost formula, the cost includes walk, transit, and wait times.

At choices between walking and alighting transit, the process uses logit models. The logit composite cost formula combines costs, producing a single value that represents the set of alternatives:

$$GC = \frac{-1.0}{\lambda}\left[\sum_{alt} e^{-(\lambda ECD_{alt})}\right]$$

Where:

GC *is the cost in units of minutes;*

λ *is a scale parameter which reflects the traveller's sensitivity to cost differences; and,*

ECD_{alt} *is the expected generalised cost to destination via a particular alternative.*

At choices between transit alternatives, the process computes the cost to the destination by adding the cost of the transit leg (including boarding and transfer penalties) and the expected cost to the destination from the end of the transit leg. Then, the process combines the values for the transit alternatives into a single value for the expected cost from the node to the destination. This is calculated as the average of the costs associated with each alternative (weighted by the probability of passengers taking the alternative).

In calculating the transit element of the expected cost to destination, the process applies an additional condition to ensure that adding (or improving) services does not increase costs. Specifically, the process examines each service operating between a pair of boarding and alighting points and includes the service if the resulting reduction in wait time exceeds the resulting increase in travel time. The process ensures that the expected time to the destination from the boarding node improves when a service is included in the set of attractive alternatives. This set of services is known as the basic choice set.' [54]

Within the active model the generalised cost is simply the journey time taken to travel via the shortest path from an origin to a destination using fixed speeds across the network and noting no impact of congestion.

It is further noted that additional assumptions have been introduced to the intrazonal costs which are considered within the models as assignments typically do not provide them. These assumptions are:

- Road intrazonal costs are taken to be 40% of the lowest cost to an available zone, capped at 24 minutes;
- PT intrazonal costs are 40% of the lowest cost to an available zone; and
- Active intrazonal costs are calculated as 40% of the lowest cost to an available zone, capped at 30 minutes.

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[54] Cube version 5.4.2 help manual, *Public Transport Program > Theory > Route-evaluation process > Deriving cost used*

For clarity, the average generalised cost is not based in any way on self-reported trip length or journey time as can be found in the NHTS dataset. It is further noted that while the model is in units of tours, the average generalised cost from the data refers to the home-based (outward only) leg of a tour, or the one-way trip.

A comparison of average generalised cost by mode between modelled and synthesised is provided in Table 11.10.

Table 11.10 Comparison of Modelled and Synthesised Average Cost by Demand Segment (Generalised Minutes)

Demand Segment	Total Tours	Car		PT		PnR		Walk		Cycle		Root Mean Square Error
		Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod	
DS01	111,909	19.0	18.6	99.0	98.5	100.0	74.6	22.0	21.8	15.0	15.0	17.0
DS02	381,647	23.0	22.1	101.0	100.3	100.0	84.1	21.0	19.7	19.0	18.6	10.7
DS03	46,649	-	-	99.0	100.2	-	-	22.0	21.7	15.0	14.9	0.8
DS04	148,728	-	-	101.0	100.4	-	-	21.0	20.9	19.0	18.8	0.4
DS05	158,585	4.0	4.3	91.0	29.5	-	-	13.0	9.8	8.0	5.9	41.2
DS06	101,982	8.0	7.4	109.0	178.9	-	-	18.0	16.3	12.0	14.1	46.8
DS07	24,784	15.6	8.6	106.8	67.3	-	-	35.0	31.5	12.2	21.3	27.6
DS08	94,240	-	-	91.0	21.0	-	-	13.0	16.8	8.0	28.0	48.8
DS09	64,312	-	-	109.0	114.4	-	-	18.0	19.6	12.0	16.3	4.7
DS10	38,525	-	-	106.8	68.7	-	-	35.0	23.8	12.2	20.5	27.1
DS11	91,076	4.0	5.3	91.0	85.0	-	-	13.0	13.4	8.0	8.3	4.1
DS12	42,503	8.0	8.2	109.0	134.2	-	-	18.0	18.2	12.0	12.2	16.9
DS13	5,484	15.6	15.0	106.8	111.7	-	-	35.0	35.5	12.2	12.3	3.3
DS14	55,675	-	-	91.0	90.9	-	-	13.0	13.3	8.0	8.5	0.4
DS15	27,115	-	-	109.0	110.2	-	-	18.0	18.0	12.0	12.0	0.8
DS16	5,533	-	-	106.8	96.2	-	-	35.0	31.0	12.2	11.2	7.6
DS17	193,613	16.5	16.2	81.1	81.7	-	-	21.2	21.2	14.5	14.6	0.5
DS18	153,841	14.3	14.1	81.1	81.6	-	-	17.9	17.9	14.5	14.6	0.4

Demand Segment	Total Tours	Car		PT		PnR		Walk		Cycle		Root Mean Square Error
		Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod	
DS19	89,066	-	-	81.1	81.5	-	-	21.5	21.5	14.5	14.5	0.3
DS20	73,017	-	-	81.1	81.4	-	-	19.9	20.0	14.5	14.6	0.2
DS21	65,150	9.7	10.8	63.9	64.3	-	-	17.1	17.4	7.2	9.0	1.5
DS22	51,846	10.8	11.0	63.9	64.3	-	-	17.7	17.8	7.2	8.1	0.7
DS23	53,834	-	-	63.9	64.2	-	-	16.0	16.1	7.2	8.2	0.7
DS24	37,715	24.7	24.5	101.4	102.7	-	-	16.6	16.5	16.9	16.9	0.8
DS25	30,642	25.0	24.7	101.4	102.6	-	-	16.6	16.6	16.9	16.9	0.8
DS26	12,405	-	-	101.4	102.6	-	-	16.6	17.0	16.9	17.1	0.8
DS27	138,747	45.9	43.7	87.7	88.3	-	-	16.9	17.7	12.7	14.5	2.0
DS28	91,756	16.9	17.0	74.9	75.4	-	-	16.6	16.5	13.6	13.5	0.4
DS29	33,825	-	-	74.9	74.7	-	-	18.1	18.2	13.6	13.8	0.2
DS30	37,818	50.1	46.2	87.7	88.3	-	-	7.9	8.7	12.7	12.9	2.7
DS31	16,067	-	-	87.7	88.7	-	-	13.2	13.5	12.7	13.0	0.7
DS32	336,254	30.5	30.5	95.7	88.2	-	-	19.2	19.3	14.7	14.7	5.0
DS33	187,352	-	-	95.7	97.0	-	-	16.5	16.8	14.7	15.0	0.9

* “-“ in the table indicates no data or not applicable.

The vast majority of modes and demand segment comparisons show a very close correspondence between the modelled average generalised cost and the synthesised target but there are a few notable differences:

- Education segments (DS05-DS10) in general show large discrepancies highlighted by large RMSE values which are typically associated with large variances in the PT cost results and target;
- DS01 and DS02 (commute car available) show a high RMSE which is primarily focussed on the difference between the Park and Ride target and model result; and
- DS12[55] and DS16[56] show a high RMSE which is related to the on the difference between the PT target and model result.

There are a number of potential reasons that could be the cause for the differences in education segments, with some of the key possibilities as follows:

- The model only includes a single hour representation of PT services and thus might exclude services which are outside the peak, leaving many education trips without access to a valid service;
- The model does not include specific school bus services which would in reality be used and hence the cost would be impossible to match; and
- There is a recognised element of error in recording the home end of a tertiary education trip where the term-time home is not what is recorded, thus POWSCAR would not accurately record the typical journey being made.

It is worth highlighting that a large difference in the average PT generalised cost might be considered more acceptable than other modes given the high values in comparison to other modes (typically over 100 generalised minutes).

In addition to demand segment comparisons, the aggregated purposes are also considered as they are closer to what the assignment models will use, as reported in Table 11.11. Again, the aggregation of education does not hide the fact that there are some differences as discussed above at demand segment level.

[55] Home-based escort to education secondary level, car available
[56] home-based escort to education tertiary level, no car available

Table 11.11 Average Generalised Cost (GC) by Purpose

Purpose	Total Demand[57]	Car Average GC		PT Average GC		Walk Average GC		Cyc Average GC	
		Syn[58]	Mod[59]	Syn	Mod	Syn	Mod	Syn	Mod
EMP	138,747	45.9	43.8	87.7	88.0	16.9	17.7	12.7	14.5
COM	688,932	15.8	11.7	100.5	90.8	21.2	21.2	18.1	18.1
OTH	988,516	9.2	9.3	83.5	83.8	18.2	18.3	12.3	12.6
EDU	482,428	3.8	3.0	99.3	69.9	17.6	16.3	9.9	15.6
RET	125,581	12.4	12.4	74.9	75.0	17.0	16.9	13.6	13.6
NHBEB	53,885	35.2	32.4	87.7	88.1	9.5	10.1	12.7	12.9
NHBOT	523,606	19.6	19.6	95.7	90.8	18.2	18.4	14.7	14.8
Total	3,001,694	14.0	12.8	92.0	84.3	18.5	18.4	13.7	14.9

The average generalised cost comparisons provide reassurance at a certain level of detail that the model behaves appropriately, but it is also important to compare the overall distribution of generalised costs as two different distributions can have the same average generalised cost and could describe very different sets of trips.

Figure 11.2 provides a comparison of the full generalised cost distribution, and in general shows a good match of modelled and observed values, with some notable differences.

For Road trips, the model tends to have too few very short distance trips and overestimates trips in the 10 to 20-minute range, in comparison to both POWSCAR and NHTS, but could be due to the changes introduced by the Parking Distribution model.

For Walk trips, the model tends to provide a reasonable comparison between the NHTS and POWSCAR distributions which would be expected given certain demand segments were calibrated to each dataset. Both modelled and synthesised distributions include an odd spike at 30 minutes - this is most likely due to a capping mechanism in the cost calculations for active modes where intrazonal trips are assumed to be less than or equal to 30 minutes.

The model also overestimates shorter Cycle trips (less than 10 minutes) but is clear that the sample is relatively low in NHTS (1,950 records) and shows definite spikes rather than a smooth curve which may indicate that not enough data is available to produce a curve which can be taken with complete confidence.

[57] 24-hour weekday average person trips
[58] Synthetic targets
[59] Modelled

Although presented in the same charts, POWSCAR must be noted as only containing COM and EDU purposes and therefore is not necessarily straight-forward to compare against all-purpose definitions, however, its large sample size means it is considered to be an absolutely critical comparison which should be presented.

It must also be highlighted that comparisons of average generalised cost are favourable at demand segment level and only show a notable difference in COM at user class level which may indicate that the composition of trips by user class is different between NHTS and the model, something which is evident from the mode share comparisons and will mean that despite matching average GC at the demand segment level, aggregation of this type will not lead to a perfect match.

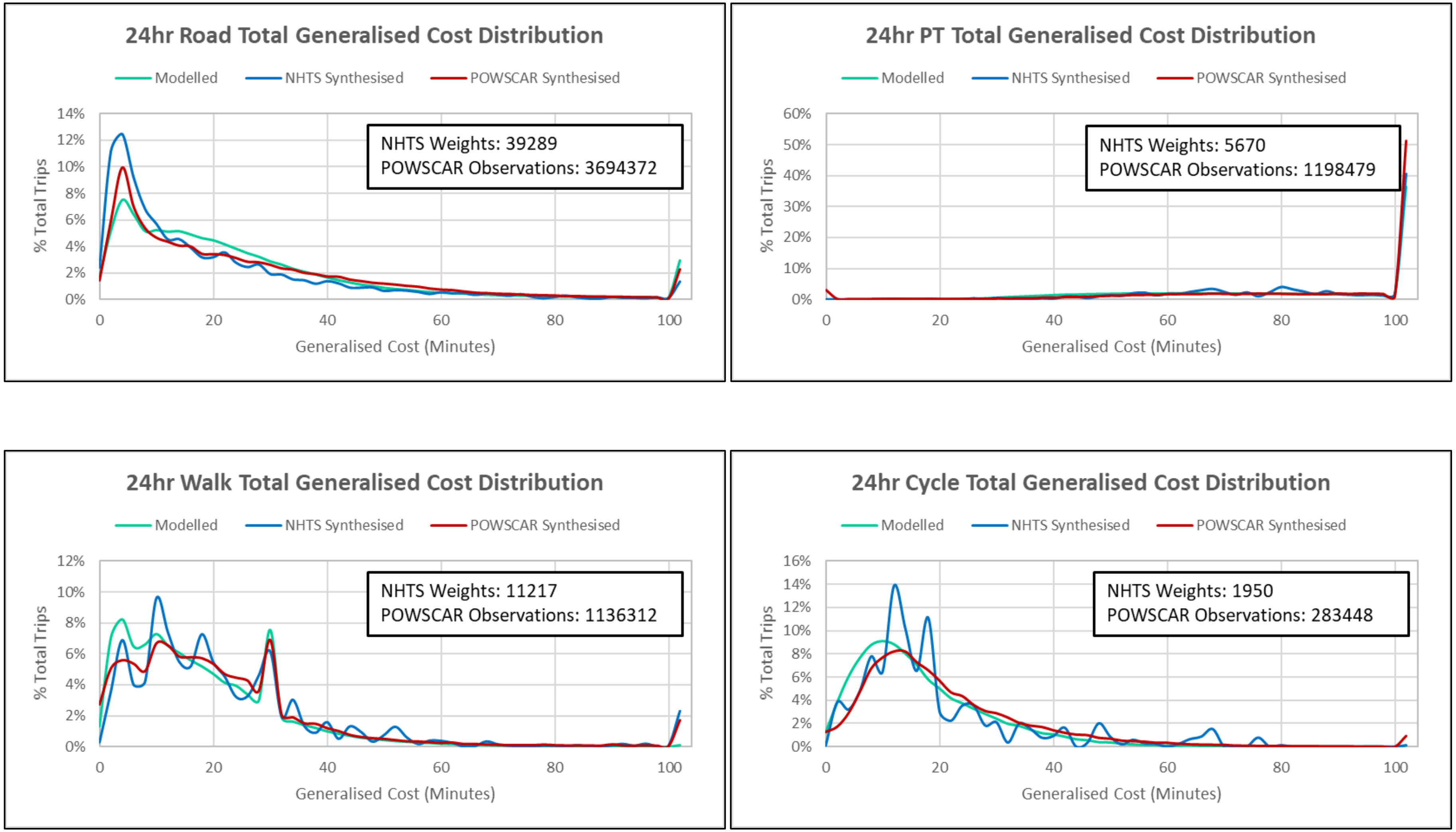


Figure 11.2 24-Hour Generalised Cost Distribution by Mode

11.2.6 Average Trip Length and Distributions

While not directly calibrated, a comparison of modelled versus observed average trip length and trip length distribution is a widely accepted measure of model fit. This comparison is reported in this section in a similar manner to generalised cost.

In order to provide a consistent trip length for comparison, the NHTS data is first allocated to the model zone system at both origin and destination end and average distances are extracted from the model skims to produce a synthesised average trip length and associated distribution.

Hence, the average distance is not based in any way on self-reported trip length as can be found in the NHTS and POWSCAR datasets.

A comparison of average trip length by mode showing how each demand segment matches model results and observed targets is provided in Table 11.12 and presented graphically in Figure 11.3, while aggregated derived values by purpose are reported in Table 11.13.

It is noted that these results are not directly produced by the ERM and are based on the GoalSeek analysis (see *Calibration Guide* for further information on that process), but comparisons of generalised cost between the GoalSeek procedure and the output ERM are very similar. Hence it has been deemed appropriate here to provide only GoalSeek results.

Table 11.12 Synthesised and Modelled Average Tour/Trip Length by Demand Segment and Mode

Demand Segment	Purpose	Trips / Tours[60]	Car Syn	Car Mod	PT Syn	PT Mod	Walk Syn	Walk Mod	Cycle Syn	Cycle Mod
DS01	COM	111,909	26.2	10.5	14.8	12.3	7.9	2.0	7.0	3.7
DS02	COM	381,647	33.4	12.2	27.6	15.9	11.1	1.9	10.5	4.9
DS03	COM	46,649	26.2	0.0	14.8	11.8	7.9	1.9	7.0	1.4
DS04	COM	148,728	33.4	0.0	27.6	16.5	11.1	1.8	10.5	3.1
DS05	EDU	158,585	12.0	4.6	14.0	23.5	4.3	1.4	2.6	2.5
DS06	EDU	101,982	16.5	5.8	22.4	9.9	5.3	1.7	4.3	2.9
DS07	EDU	24,784	30.6	14.7	30.8	20.3	12.7	3.1	14.7	3.5
DS08	EDU	94,240	12.0	0.0	14.0	9.8	4.3	2.2	2.6	8.1
DS09	EDU	64,312	16.5	0.0	22.4	13.0	5.3	1.8	4.3	7.7
DS10	EDU	38,525	30.6	0.0	30.8	14.5	12.7	2.9	14.7	1.4
DS11	OTH	91,076	4.4	3.6	0.0	12.2	1.8	1.4	2.0	2.0
DS12	OTH	42,503	6.2	5.6	0.0	12.1	1.0	1.7	0.0	2.9
DS13	OTH	5,484	4.5	10.9	0.0	9.4	0.0	3.0	0.0	2.9
DS14	OTH	55,675	0.0	0.0	3.0	10.4	2.1	1.4	0.0	2.2
DS15	OTH	27,115	0.0	0.0	20.0	13.6	0.0	1.8	0.0	3.0
DS16	OTH	5,533	0.0	0.0	0.0	12.6	2.4	3.2	0.0	3.0
DS17	OTH	193,613	9.7	11.6	12.3	8.2	3.0	2.0	3.6	3.6

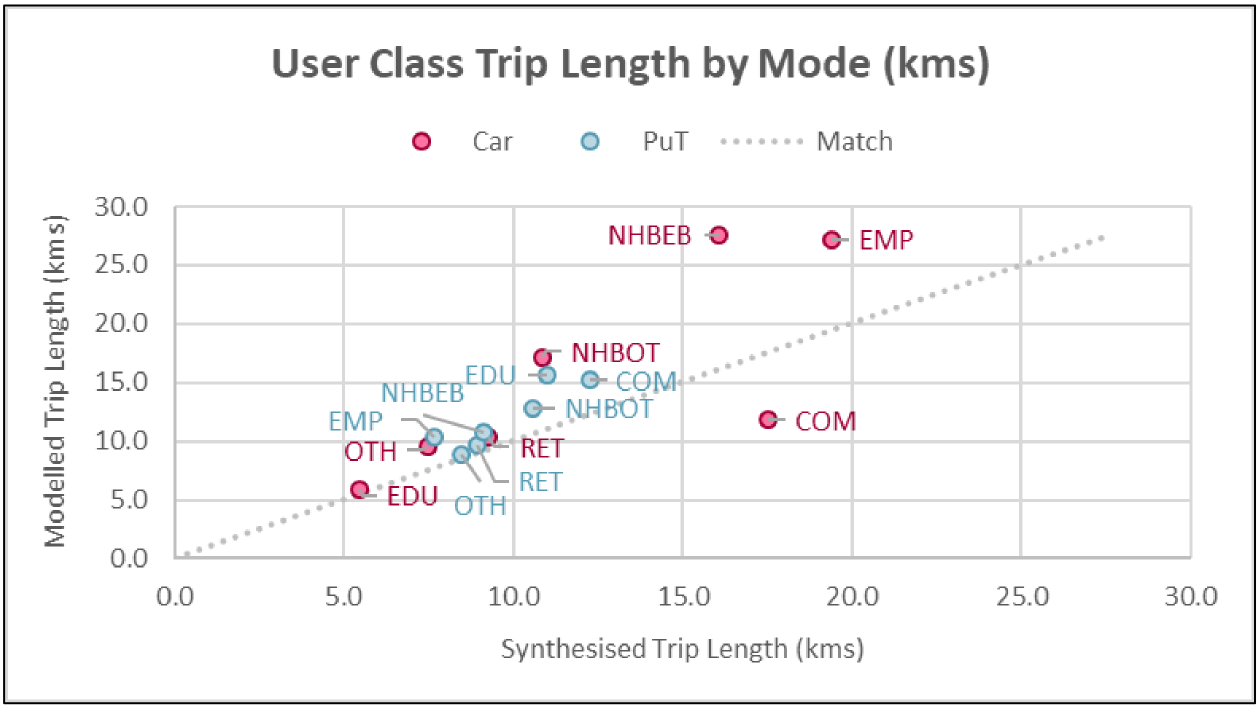
[60] Weekday average 24-hour person tours / trips

Demand Segment	Purpose	Trips / Tours[60]	Car Syn	Mod	PT Syn	Mod	Walk Syn	Mod	Cycle Syn	Mod
DS18	OTH	153,841	9.3	9.8	7.6	8.2	2.6	1.7	2.4	3.6
DS19	OTH	89,066	0.0	0.0	7.9	8.0	2.5	2.0	3.7	3.6
DS20	OTH	73,017	0.0	0.0	9.5	8.0	2.7	1.8	4.8	3.6
DS21	OTH	65,150	6.8	7.3	17.7	5.2	2.0	1.7	0.0	2.3
DS22	OTH	51,846	6.6	7.6	0.0	5.2	2.1	1.8	3.0	2.1
DS23	OTH	53,834	0.0	0.0	4.0	5.2	2.1	1.5	2.0	2.1
DS24	OTH	37,715	14.5	16.8	0.0	12.0	1.0	1.6	0.0	4.1
DS25	OTH	30,642	17.9	17.1	22.0	12.0	1.6	1.6	0.0	4.1
DS26	OTH	12,405	0.0	0.0	9.5	12.1	2.2	1.6	4.3	4.1
DS27	EMP	138,747	19.8	27.2	8.2	10.4	3.3	1.7	4.0	3.6
DS28	RET	91,756	9.7	10.4	15.0	9.8	2.3	1.5	5.9	3.3
DS29	RET	33,825	0.0	0.0	8.2	9.4	2.1	1.6	4.4	3.4
DS30	NHBEB	37,818	16.5	27.6	12.5	10.8	1.2	1.2	0.0	3.1
DS31	NHBEB	16,067	0.0	0.0	6.9	10.9	2.2	1.4	4.0	3.1
DS32	NHBOT	336,254	11.3	17.1	13.6	13.7	2.4	1.8	6.4	3.6
DS33	NHBOT	187,352	0.0	0.0	8.9	11.3	2.3	1.6	4.2	3.7

Table 11.13 Average Tour/Trip Length by User Class

Purpose	Total Demand [61]	Car Ave Trip Length (kms)		PT Ave Trip Length (kms)		Walk Ave Trip Length (kms)		Cycle Ave Trip Length (kms)	
		Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod
EMP	138,747	19.4	27.2	7.7	10.4	2.8	1.7	3.5	3.6
COM	688,944	17.5	11.8	12.2	15.2	2.3	1.9	5.7	4.1
OTH	988,516	7.5	9.5	8.5	8.8	1.9	1.8	3.5	3.1
EDU	482,429	5.5	5.9	11.0	15.7	2.3	1.9	3.0	4.3
RET	125,581	9.3	10.4	8.9	9.7	1.7	1.5	4.3	3.3
NHBEB	53,885	16.1	27.6	9.1	10.8	1.2	1.3	3.5	3.1
NHBOT	523,606	10.9	17.1	10.6	12.8	1.9	1.7	4.8	3.6
Total	3,001,706	10.8	12.0	10.1	12.2	2.1	1.8	4.2	3.6

[61] 24-hour weekday average person trips



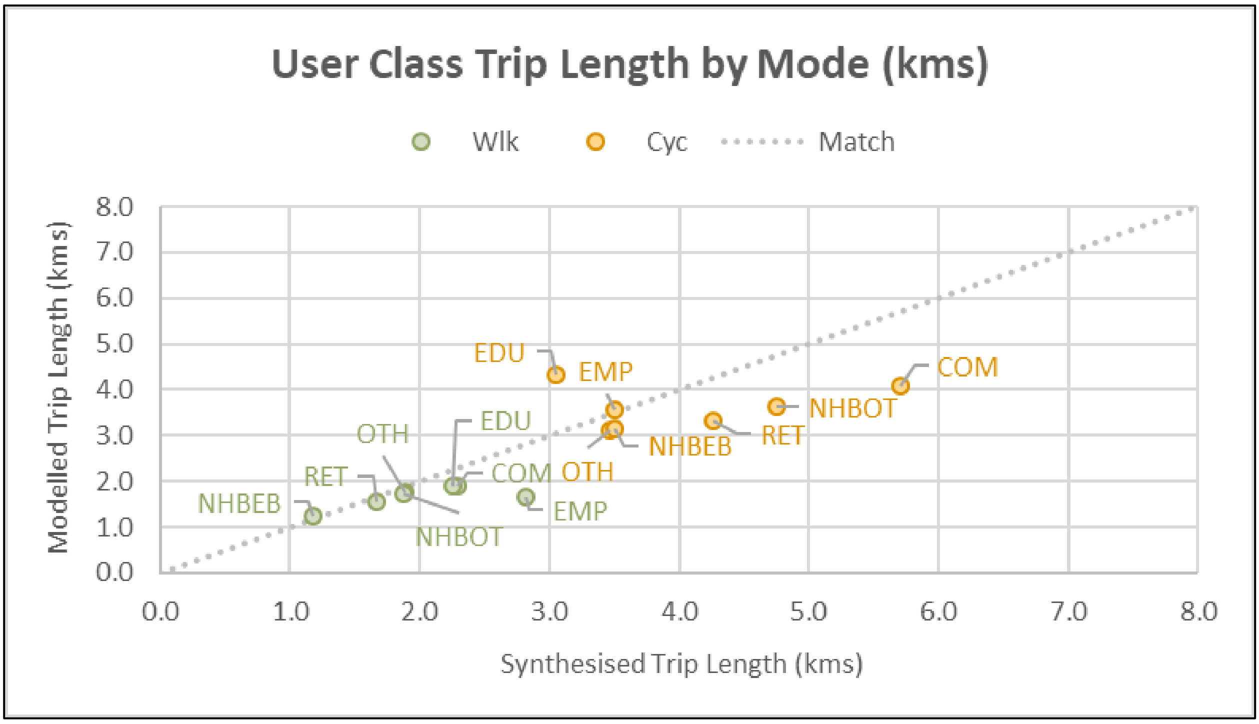


Figure 11.3 Average Trip Length by User Class and Mode

It is clear that there are larger disparities in average trip lengths than there are in generalised costs across the vast majority of demand segments and user class comparison, although with exception they are not typically large in magnitude.

EMP and NHBEB show large over-estimations in average trip length within the model for car trips and are clearly evident visually in Figure 11.1. Car is almost always over-estimated to some degree with the exception of COM trips, and this may suggest that

Parking Distribution could be one of the causes as it breaks a tour into multiple journeys and given its influence in the city centre is predominately focussed on EMP and COM trips.

PT trips can be seen to overestimate the average trip length in the model but to a lesser degree than road and the worst matches are COM and EDU, and for EDU trips in particular it was recognised even with the average generalised cost considered in 11.2.5 that the model struggled to accurately replicate PT trips, and the potential causes are still applicable here:

- The model only includes a single hour representation of PT services and thus might exclude services which are outside the peak, leaving many education trips without access to a valid service;
- The model does not include specific school bus services which would in reality be used and hence the cost would be impossible to match; and
- There is a recognised element of error in recording the home end of a tertiary education trip where the term-time home is not what is recorded, thus POWSCAR would not accurately record the typical journey being made.

Walk and cycle trips generally show a favourable comparison in terms of the differences although it is recognised that percentage differences would be much greater given the relatively low values of average trip lengths.

Potentially the most important thing to consider here is that the ERM is calibrated to generalised cost, not trip length, and this suggests there is a disparity between the generalised costs and the trip lengths as calculated in the model as it does not appear that both can be matched at the same time using these metrics.

The average trip length comparisons provide reassurance at a general level of detail that the model behaves appropriately, but as with the generalised costs comparison, a comparison of modelled and observed trip length distributions was also undertaken.

Figure 11.4 provides a comparison of modelled and observed trip length distributions. It shows a very comparable match for PT, walk, and cycle trips although it is noted that there are disparities between POWSCAR and NHTS which mean the model lies somewhere between them given how it has been calibrated to both. The car distribution highlights a tendency to have longer trip lengths than either POWSCAR or NHTS would suggest.

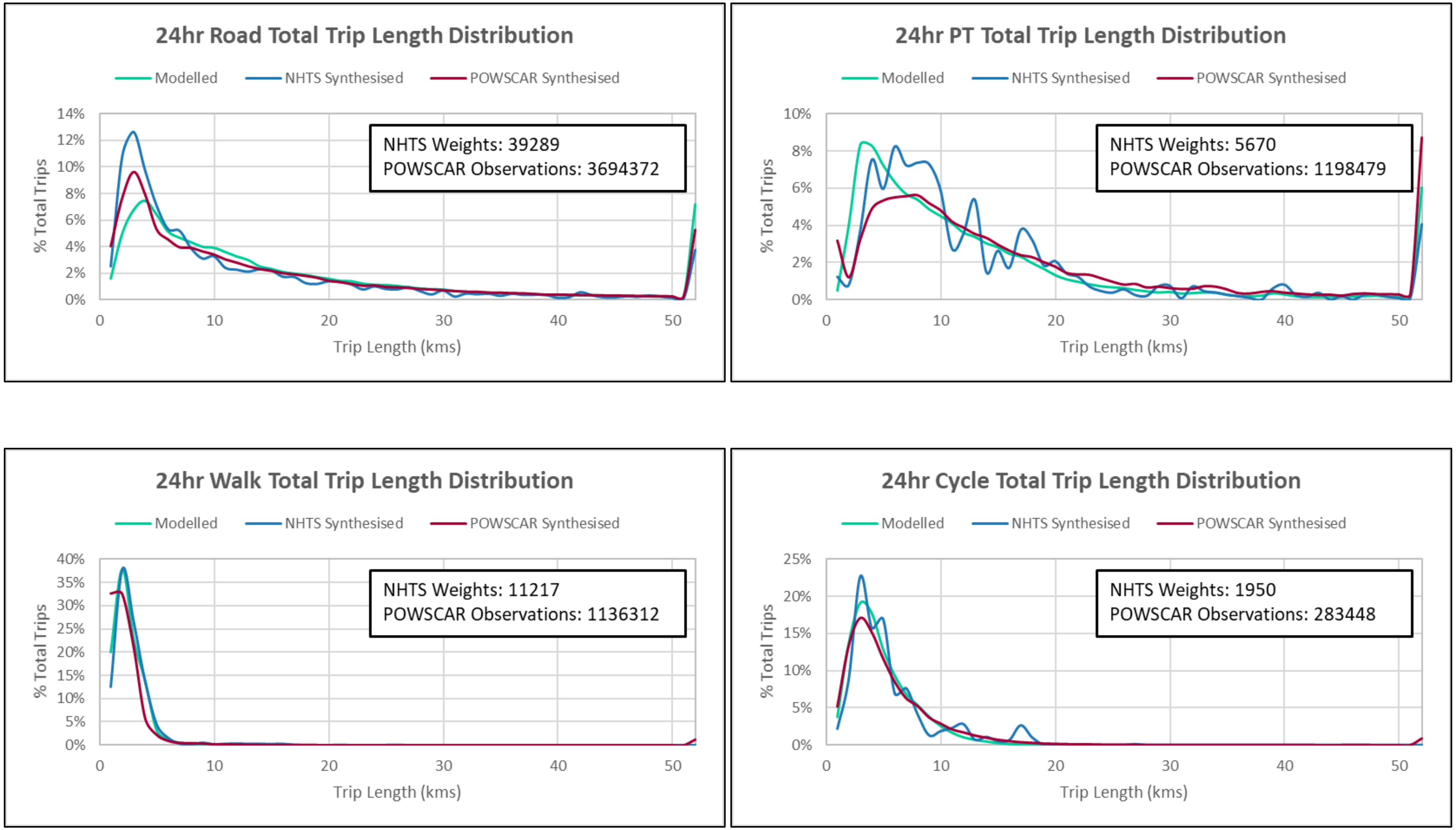


Figure 11.4 24-Hour Trip Length Distribution by Mode

11.2.7 Intrazonal Proportions

Intrazonal trips are trips that are internal to a particular zone and are not assigned on the network. Hence the percentage of intrazonal trips or more importantly their absence from total trip ends have a significant impact on congestion in the road model and crowding in the PT model. Therefore, it is important that the model reproduce the correct volumes of observed intrazonal trips in order to ensure a good representation of actual congestion on the road network and crowding on the PT network.

In this comparison, observed intrazonal proportions are calculated by aligning the NHTS and POWSCAR data with the model zone system at both the origin and destination end. Then both observed and modelled proportions are calculated as:

$$IZProp_{mp} = \frac{IntraTrips_{mp}}{Trips_{mp}}$$

Where:

$IZProp_{mp}$ is the proportion of intrazonal trips;

$IntraTrips_{mp}$ is the number of trips which do not leave the zone by mode m and purpose p; and

$Trips_{mp}$ is the total number of trips by mode m and purpose p.

The Root Mean Square Error (RMSE) value provided in the table is derived as follows:

$$RMSE = \sqrt{\frac{\sum_{m \in M}(Observed - Modelled)^2}{5}}$$

Where:

m is the mode from the set of modes M;

$Observed$ is the observed intrazonal proportion;

$Modelled$ is the modelled intrazonal proportion; and

5 is the number of modes.

Table 11.14 Demand Segment Intrazonal Proportion Comparison
(Post Free Workplace Parking)

Label	Purpose	Trips / Tours[62]	Synthesised Intrazonal Proportion				Modelled Intrazonal Proportion				RMSE
			Car	PT	Walk	Cycle	Car	PT	Walk	Cycle	
DS01	COM	111,912	7.5%	1.1%	22.2%	5.7%	7.6%	1.1%	22.7%	6.0%	0.3%
DS02	COM	381,655	3.5%	0.3%	15.5%	1.3%	3.5%	0.5%	23.4%	2.3%	4.0%
DS03	COM	46,651	0.0%	1.1%	22.2%	5.7%	0.0%	1.3%	24.4%	6.6%	1.2%
DS04	COM	148,725	0.0%	0.3%	15.5%	1.3%	0.0%	0.6%	15.8%	1.6%	0.3%
DS05	EDU	158,585	21.4%	18.7%	33.4%	15.3%	35.1%	88.4%	66.7%	58.3%	45.3%
DS06	EDU	101,841	6.9%	1.0%	19.2%	3.3%	3.2%	4.3%	73.3%	28.2%	30.0%
DS07	EDU	24,769	0.9%	0.3%	10.0%	1.2%	0.9%	1.0%	49.0%	8.4%	19.8%
DS08	EDU	94,240	0.0%	18.7%	33.4%	15.3%	0.0%	96.3%	34.3%	40.0%	40.7%
DS09	EDU	64,453	0.0%	1.0%	19.2%	3.3%	0.0%	1.6%	20.0%	4.6%	0.8%
DS10	EDU	38,539	0.0%	0.3%	10.0%	1.2%	0.0%	2.8%	15.4%	4.0%	3.3%
DS11	OTH	91,076	21.4%	18.7%	33.4%	15.3%	23.8%	22.4%	34.2%	16.0%	2.6%
DS12	OTH	42,503	6.9%	1.0%	19.2%	3.3%	8.2%	1.1%	20.4%	3.5%	1.1%
DS13	OTH	5,484	0.9%	0.3%	10.0%	1.2%	0.9%	0.2%	7.5%	0.9%	1.3%
DS14	OTH	55,675	0.0%	18.7%	33.4%	15.3%	0.0%	19.9%	33.3%	15.3%	0.6%
DS15	OTH	27,115	0.0%	1.0%	19.2%	3.3%	0.0%	1.1%	19.2%	3.2%	0.1%

[62] Weekday average 24-hour person tours / trips

Label	Purpose	Trips / Tours	Synthesised Intrazonal Proportion				Modelled Intrazonal Proportion				RMSE
			Car	PT	Walk	Cycle	Car	PT	Walk	Cycle	
DS16	OTH	5,533	0.0%	0.3%	10.0%	1.2%	0.0%	0.2%	9.2%	1.1%	0.4%
DS17	OTH	193,613	14.0%	0.8%	27.1%	20.5%	15.5%	0.8%	27.5%	20.8%	1.1%
DS18	OTH	153,841	12.5%	0.8%	47.6%	20.5%	13.6%	0.8%	47.9%	20.7%	0.8%
DS19	OTH	89,066	0.0%	0.8%	30.5%	20.5%	0.0%	0.8%	30.5%	20.5%	0.0%
DS20	OTH	73,017	0.0%	0.8%	23.0%	20.5%	0.0%	0.9%	23.0%	20.6%	0.0%
DS21	OTH	65,150	15.0%	0.0%	40.0%	33.3%	16.0%	0.5%	40.3%	33.6%	0.7%
DS22	OTH	51,846	14.5%	0.0%	55.0%	33.3%	14.9%	0.4%	55.4%	33.6%	0.4%
DS23	OTH	53,834	0.0%	0.0%	23.5%	33.3%	0.0%	0.2%	23.5%	33.3%	0.1%
DS24	OTH	37,715	3.5%	0.0%	32.0%	0.0%	3.8%	0.2%	32.7%	0.2%	0.4%
DS25	OTH	30,642	5.7%	0.0%	32.0%	0.0%	6.1%	0.4%	32.6%	0.4%	0.5%
DS26	OTH	12,405	0.0%	0.0%	32.0%	0.0%	0.0%	0.5%	32.1%	0.4%	0.3%
DS27	EMP	138,747	2.4%	0.0%	16.7%	0.0%	1.9%	0.5%	16.4%	0.7%	0.6%
DS28	RET	91,756	8.9%	1.6%	31.3%	9.7%	8.8%	1.7%	32.1%	10.1%	0.4%
DS29	RET	33,825	0.0%	1.6%	30.7%	9.7%	0.0%	1.7%	30.7%	9.7%	0.0%
DS30	NHBEB	37,818	2.5%	0.0%	50.0%	0.0%	2.2%	0.3%	49.7%	0.4%	0.3%
DS31	NHBEB	16,067	0.0%	0.0%	40.0%	0.0%	0.0%	0.6%	40.1%	0.6%	0.4%
DS32	NHBOT	336,254	8.7%	0.5%	30.7%	5.7%	7.0%	0.5%	29.7%	5.4%	1.3%
DS33	NHBOT	187,352	0.0%	0.5%	25.7%	5.7%	0.0%	0.8%	26.1%	5.9%	0.3%
Total	Total	3,001,706	6.5%	3.0%	26.8%	9.6%	7.1%	9.5%	32.0%	13.9%	4.7%

These values have been aggregated and are presented at a user class level in Table 11.15. The comparisons in this table are based on assignment model units and will differ to those presented in the previous table, which are in person units. As noted, the education segment shows notable differences but other purposes show a high level of correspondence between modelled and synthesised values.

Table 11.15 Intrazonal Proportions by Journey Purpose

Purpose	Tours	Car Intrazonal %		PT Intrazonal %		Walk Intrazonal %		Cycle Intrazonal %	
		Syn	Mod	Syn	Mod	Syn	Mod	Syn	Mod
EMP	138,747	2.4%	1.9%	0.0%	0.5%	16.7%	16.4%	0.0%	0.7%
COM	688,944	3.2%	3.2%	0.5%	0.7%	17.0%	21.7%	2.3%	3.0%
OTH	988,516	9.0%	9.9%	3.2%	3.8%	33.0%	33.3%	18.8%	19.1%
EDU	482,429	8.5%	12.3%	10.2%	49.3%	25.4%	50.5%	9.3%	34.3%
RET	125,581	6.5%	6.4%	1.6%	1.7%	31.2%	31.7%	9.7%	10.0%
NHBEB	53,885	1.7%	1.5%	0.0%	0.4%	47.0%	46.8%	0.0%	0.4%
NHBOT	523,606	5.6%	4.5%	0.5%	0.6%	28.9%	28.4%	5.7%	5.6%
Total	3,0001,706	6.5%	7.1%	3.0%	9.5%	26.8%	32.0%	9.6%	13.9%

11.2.8 Free Workplace Parking Results

Free Workplace Parking (FWPP) is a component of the model that allows travellers to re-evaluate their mode choice response based on whether they have to for parking. On the initial mode choice reported above, free parking is assumed for the two purposes that allow FWPP – i.e. commute and education. In this next section of the model, any travellers who did not get a space are then given the option of choosing their mode again with the knowledge of whether or not they have to pay for parking.

In order to evaluate the performance of the FWPP component of the model, model data was extracted for:

- The level of FWPP uptake by time period; and
- The resultant mode shifts.

It should be noted that no observed data exists for the actual levels of uptake of FWPP by time period. Hence, the review of this component of the model is restricted to an evaluation of the how realistic is the model's response for the above two measures. In addition, the number of available spaces is considered less relevant in the context of this model than the proportion of trips who gain access to FWPP.

The figures below (Figure 11.5 to Figure 11.10) show the proportions of access by trip attraction to free workplace destinations for the AM, LT, and SR time periods i.e. the percentage of car travellers who gained access to a free workplace parking space within that time period.

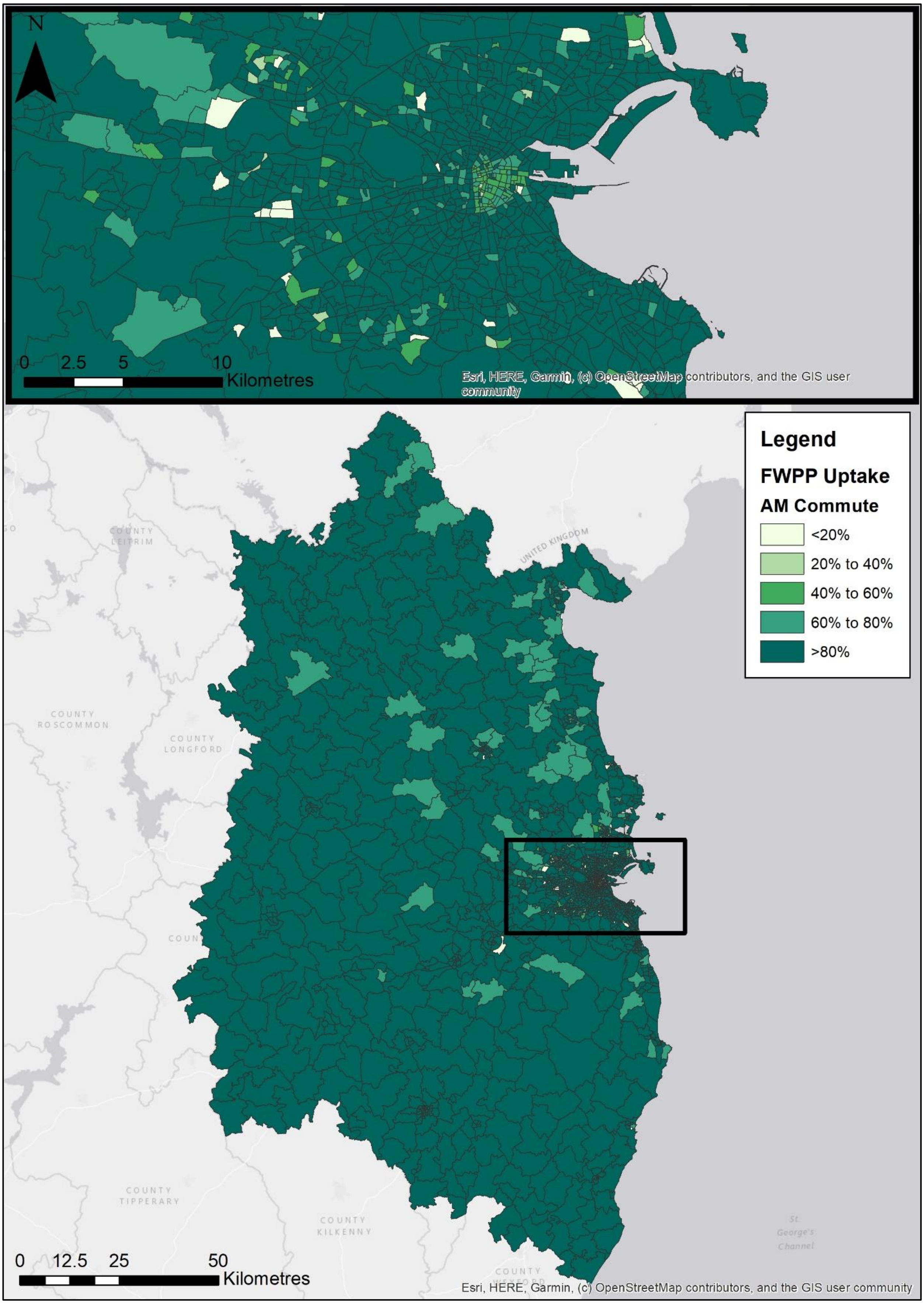


Figure 11.5 AM FWPP Uptake, Commute (Proportion, Model Area and Dublin)

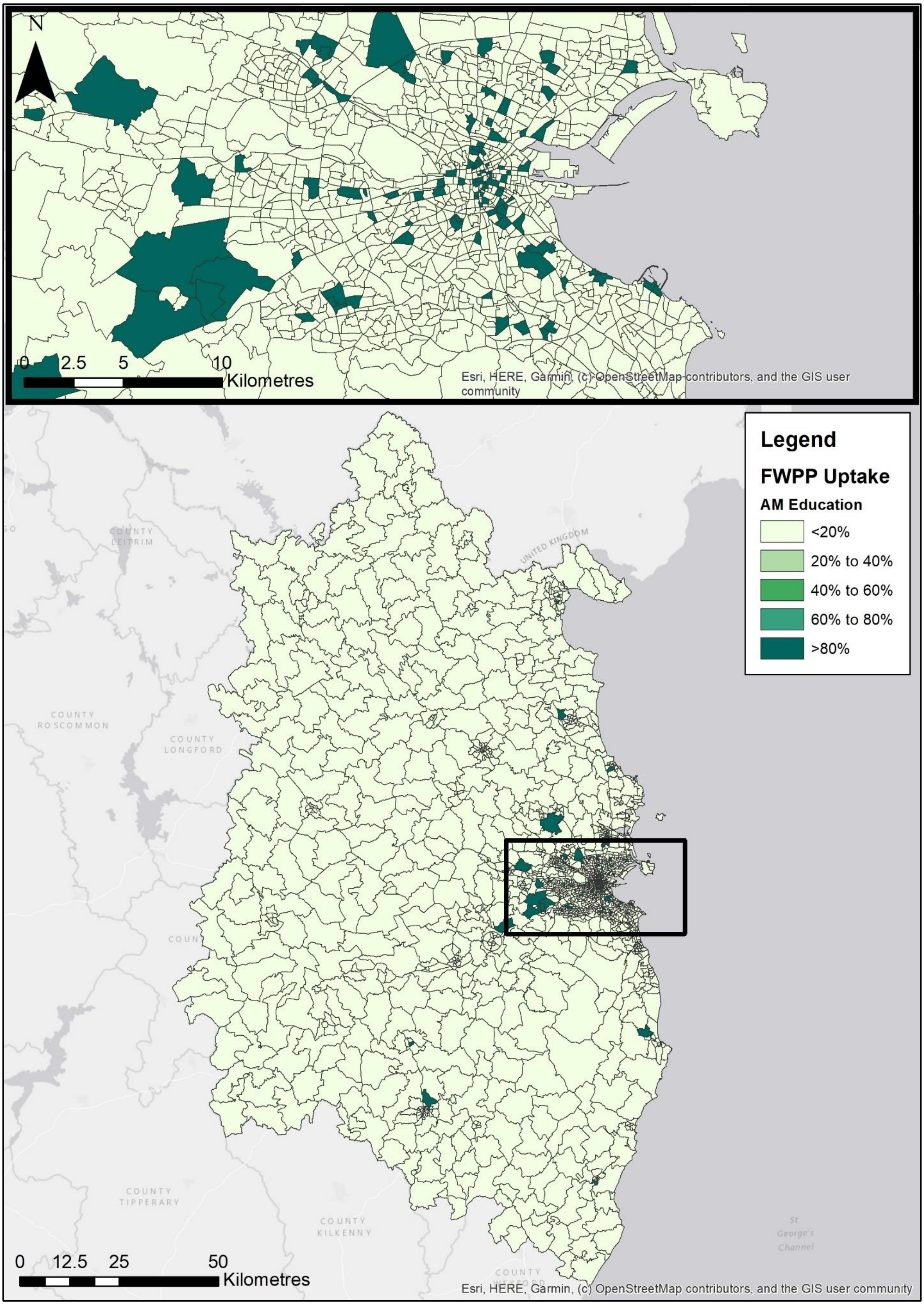


Figure 11.6 AM FWPP Uptake, Education (Proportion, Model Area and Dublin)

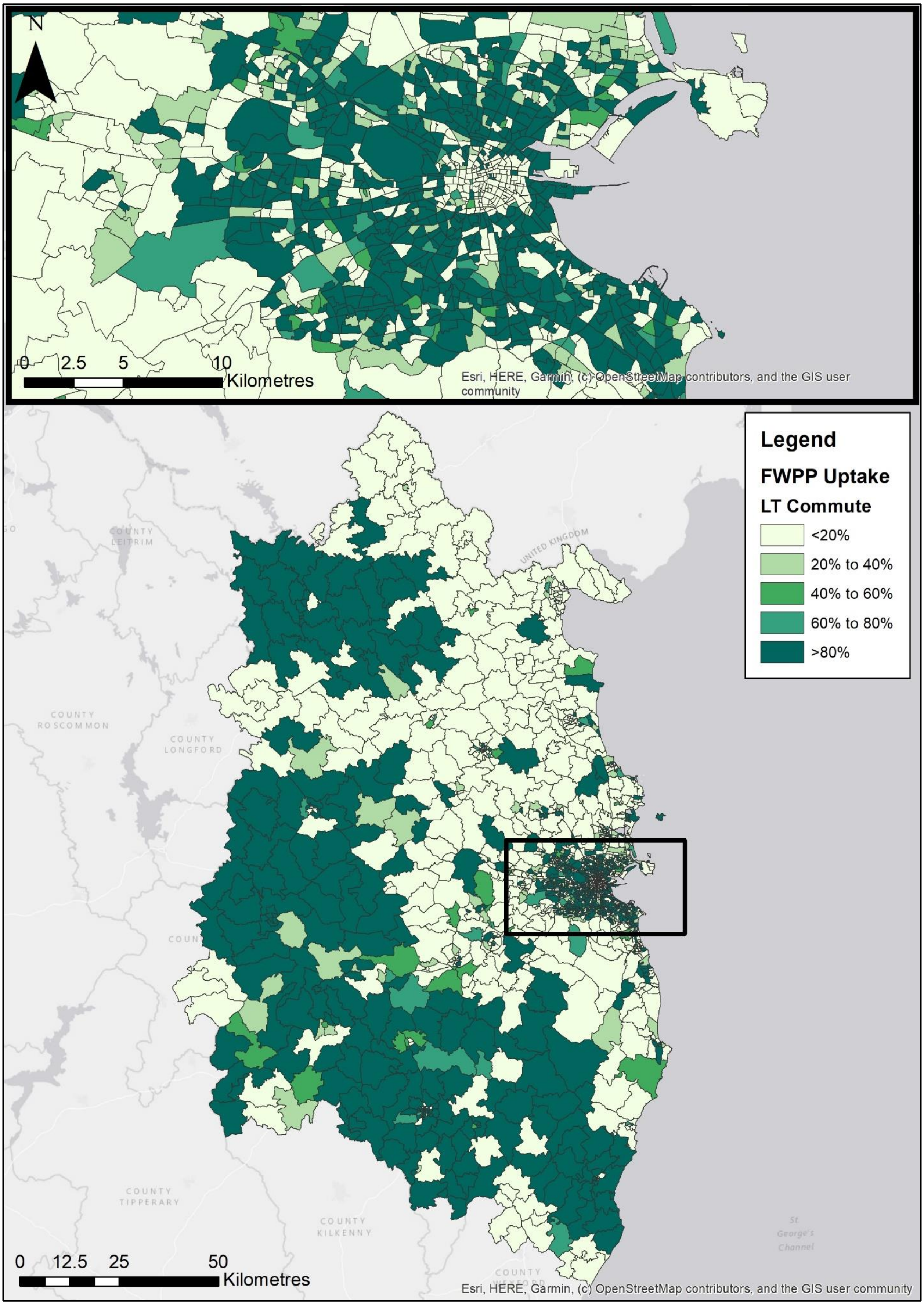


Figure 11.7 LT FWPP Uptake, Commute (Proportion, Model Area and Dublin)

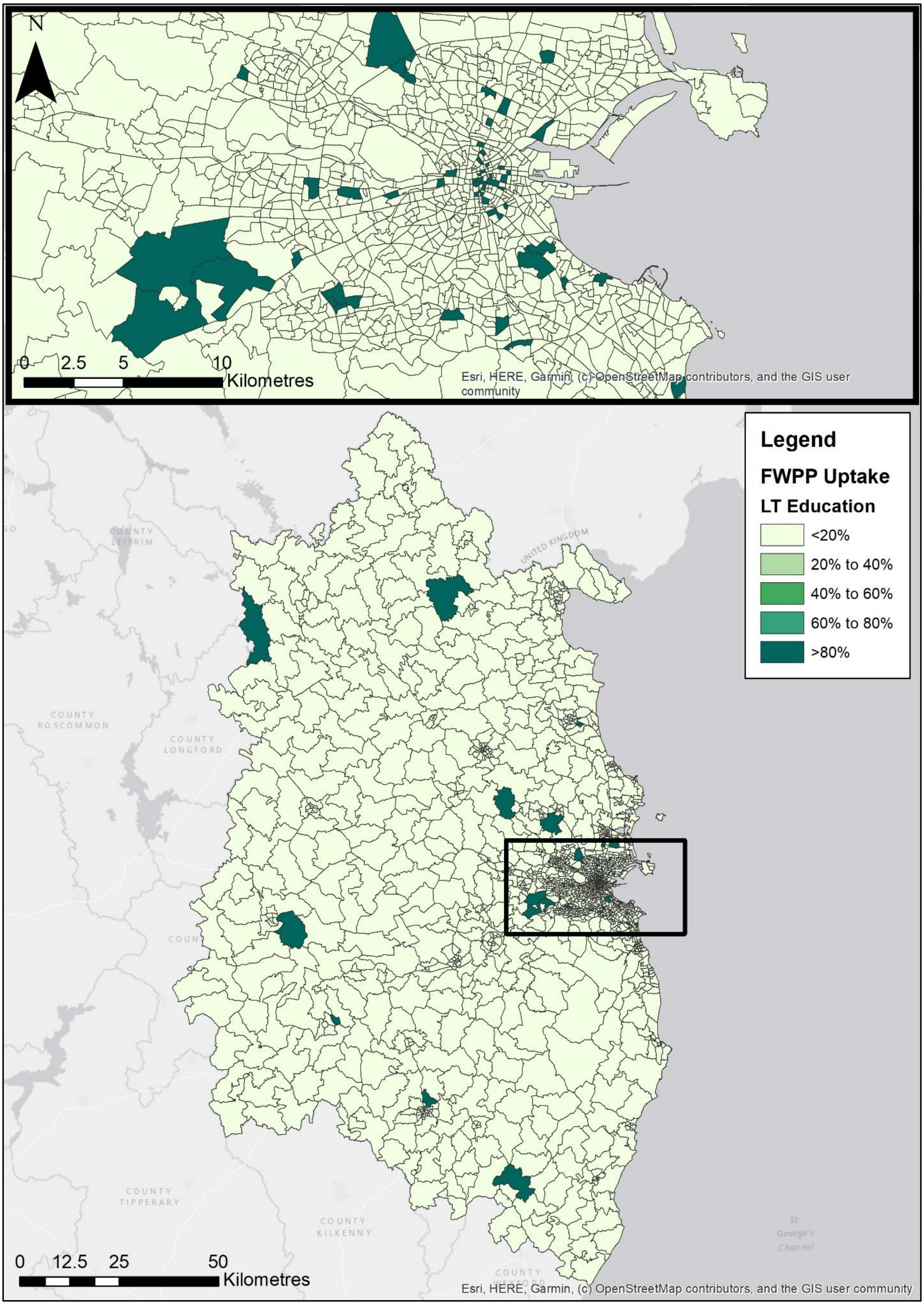


Figure 11.8 LT FWPP Uptake, Education (Proportion, Model Area and Dublin)

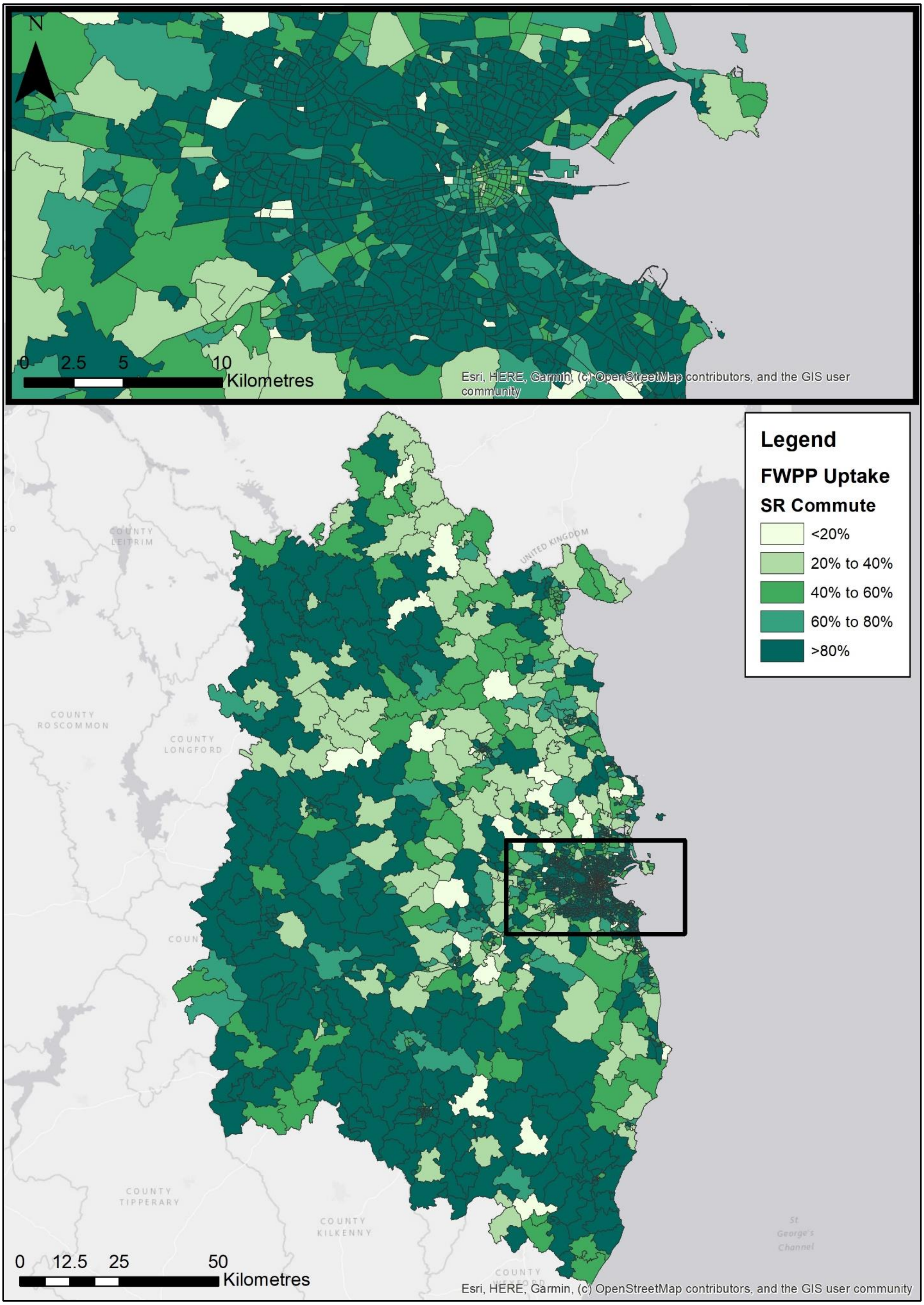


Figure 11.9 SR FWPP Uptake, Commute (Proportion, Model Area and Dublin)

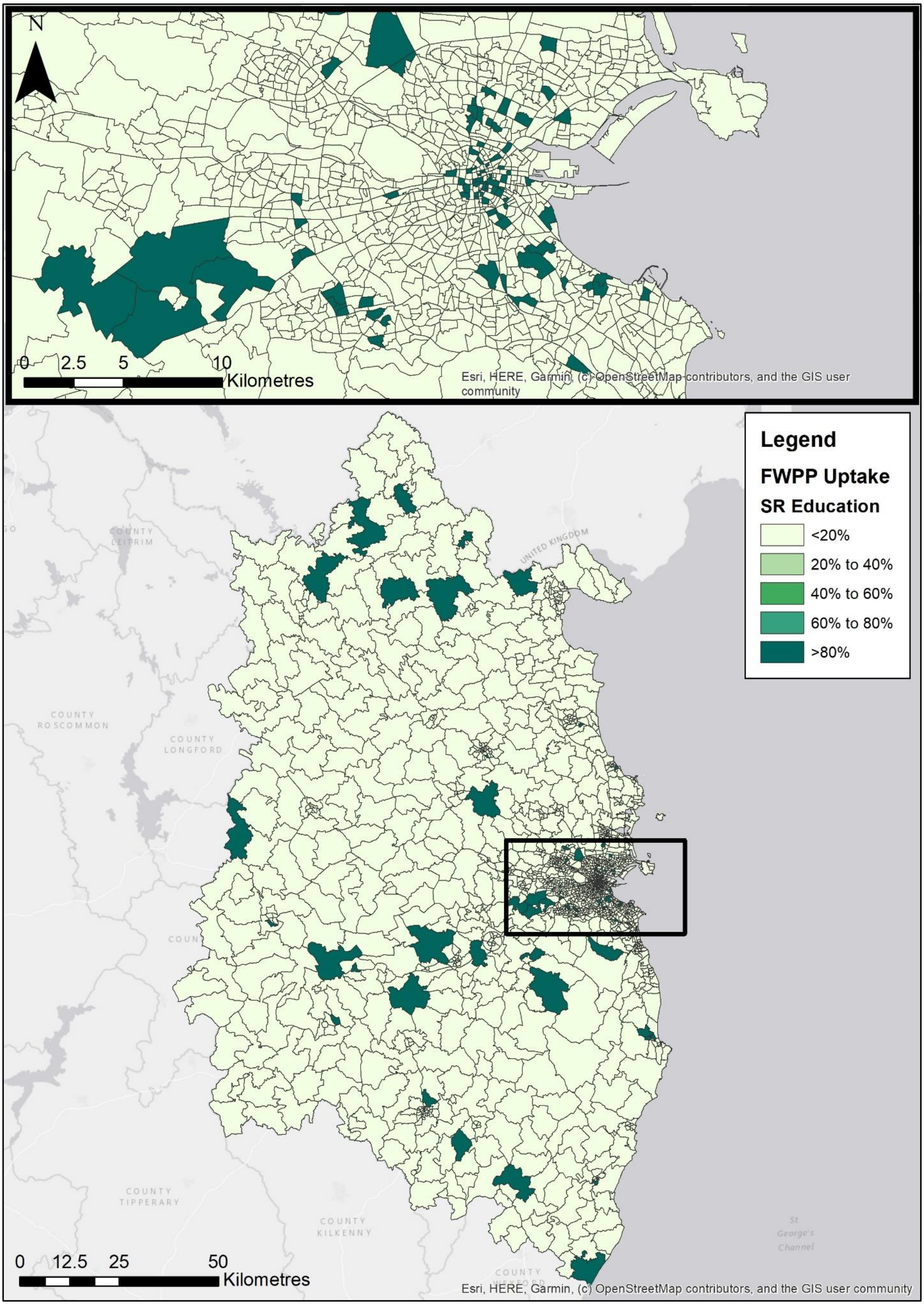


Figure 11.10 SR FWPP Uptake, Education (Proportion, Model Area and Dublin)

These figures show that in general the AM time period has large areas where there is limited constraint on parking, and in excess of 80% of trips gain access to Free Workplace Parking. However, moving towards the urban areas in Dublin, there are some zones where not all trips gained access to FWPP (orange, yellow and green zones).

Considering the later LT time period, it is evident that a large number of the spaces have already been taken by the AM occupants, hence there are many more zones where a higher proportion of travellers do not gain access to FWPP.

In the later SR time period, most zones have capacity for FWPP as shown in the SR charts. This shows that there is less parking constraint in the system for the SR time period as there is less demand trying to access these locations later in the day, and additional spaces have now become available. The PM time period shows almost complete accessibility to FWPP with only a few locations showing less than 80% access for COM trips.

While the section above discusses the potential access to a space, the model also includes a response to not getting a free space and therefore having to pay for parking. This response is a mode shift without a destination choice (as it is assumed that nobody will travel to an alternative location at this point).

Table 11.16 highlights the overall change in car trips by time period and purpose as a response to lack of free parking. This shows a modest change in mode by time period with an increased shift in the LT time period (a response to the reduced availability). It is highlighted that the mode shift response does not assume that the user did not take the car, but that they had to pay for parking. Hence the modal shift is relatively muted in contrast with the lack of parking availability.

Table 11.16 Change in Car Tours from Free Workplace Parking

Time Period	Commute			Education		
	Original	Post FWPP	% Change	Original	Post FWPP	% Change
AM	401,878	400,117	-0.44%	253,725	243,975	-3.84%
LT	23,793	23,542	-1.06%	5,666	5,565	-1.79%
SR	9,023	8,976	-0.52%	2,949	2,832	-3.98%
PM	5,856	5,856	0.00%	1,094	1,076	-1.64%
OP	37,902	37,902	0.00%	412	406	-1.63%
Total	478,452	476,393	-0.43%	263,847	253,854	-3.79%

Table 11.17 highlights which modes these trips change to for the first two time periods only, noting an overall change in trips is zero on the right. General trends are that:

- Shifting to PT is the likeliest option for commuters, followed by Park and Ride, suggesting an overall longer set of tours where walking and cycling are not valid options; and

- Education trips tend to go towards walking in the AM and PT in the LT time periods, likely a reflection of the different times of day and general trip lengths of the different levels of education.

It is noted that Park and Ride is only available in this model to commuters, hence the lack of shift for education tours.

Table 11.17 Summary of Mode Shift Response to Free Workplace Parking

Time Period	Purpose	Car	PT	PnR	Walk	Cycle	All Modes
AM	COM	-1,761	834	650	167	110	0
AM	EDU	-9,750	1,838	-	7,425	487	0
AM	Total	-11,511	2,672	650	7,591	597	0
LT	COM	-251	80	112	43	16	0
LT	EDU	-101	46	-	47	8	-0
LT	Total	-352	127	112	90	24	-0

As mentioned above, there is no validation data to compare the modelled usage of FWPP to observed data. However, considering the results and analyses presented above the model appears to be performing intuitively and producing a reasonable response.

11.2.9 Park and Ride

Park and Ride is a separate mode within the model and is subject to a distinct choice component that distributes trips between different Park and Ride sites. This model has been evaluated using the following metrics:

- Input demand; and
- Demand at each Park and Ride site by time period.

Park and Ride Input Demand Comparison

In general terms, the model shows a total 14,519 tours using Park and Ride in comparison with an expected / observed 14,608 persons actually using this mode.

Figure 11.11 breaks down this comparison of modelled and observed Park and Ride trips by the twenty-five different tours in the model and shows a close match is obtained across all tours. This means that the model is reasonably replicating the actual level of usage of each Park and Ride site.

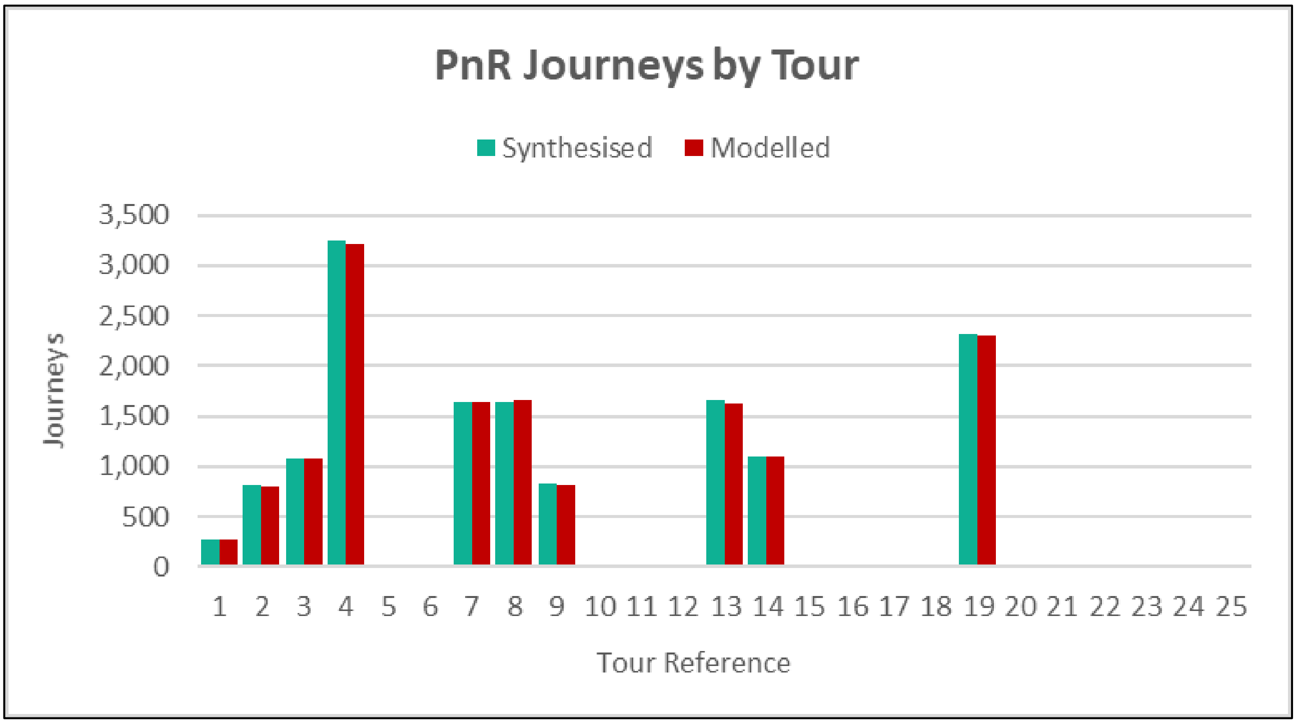


Figure 11.11 Park and Ride Tours (Journeys) by Tour

Park and Ride Demand by Site

As discussed in Section 6.7.5, usage of Park and Ride sites can be considered in the same way as a link flow past a point, and hence the calibration can be evaluated using either GEH or percentage difference against known occupancies. Table 11.18 gives the percentage of Park and Ride sites calibrating within different GEH bands across three time periods, while Table 11.19 gives the same calibration data in terms of percentage difference bands.

For clarity the GEH criteria is defined as:

$$GEH = \sqrt{\frac{(Observed - Modelled)^2}{(Observed + Modelled)}}$$

Where:

$Observed$ is an observed or in this case synthesised traffic flow; and

$Modelled$ is modelled traffic flow.

Table 11.18 Park and Ride GEH Summary Across All Sites

Band	Number of Sites			Proportion of Sites		
	AM GEH	LT GEH	SR GEH	AM GEH	LT GEH	SR GEH
GEH<=1	22	21	23	42.3%	40.4%	44.2%
1<GEH<=3	23	24	22	44.2%	46.2%	42.3%
3<GEH<=5	3	4	5	5.8%	7.7%	9.6%
GEH>5	4	3	2	7.7%	5.8%	3.8%
Total	52	52	52	100.0%	100.0%	100.0%

Table 11.19 Park and Ride Percentage Difference Summary Across All Sites

Label	Number of Sites			Proportion of Sites		
	AM % Diff	LT % Diff	SR % Diff	AM % Diff	LT % Diff	SR % Diff
Diff<-25%	7	4	7	13%	8%	13%
-25%<Diff<=-10%	7	7	5	13%	13%	10%
-10%<Diff<=0	18	16	17	35%	31%	33%
0<Diff<=10%	8	12	11	15%	23%	21%
10%<Diff<=25%	4	6	5	8%	12%	10%
Diff>25%	8	7	7	15%	13%	13%
Total	52	52	52	100%	100%	100%

Comparisons of the modelled versus synthesised occupancies at the end of the three time periods are provided in Figure 11.12 to Figure 11.14 with synthesised target occupancies on the x-axis and modelled demand occupancies (in persons) on the y-axis. These charts would be expected to show a linear trend along the line x=y should the model perfectly match the synthesised targets. This shows that the model has a tendency to overestimate demand for some Park and Ride sites and underestimate demand for others. It is noted that the slope of the correlation is generally around 1 and there is a low intercept in each time period as expected.

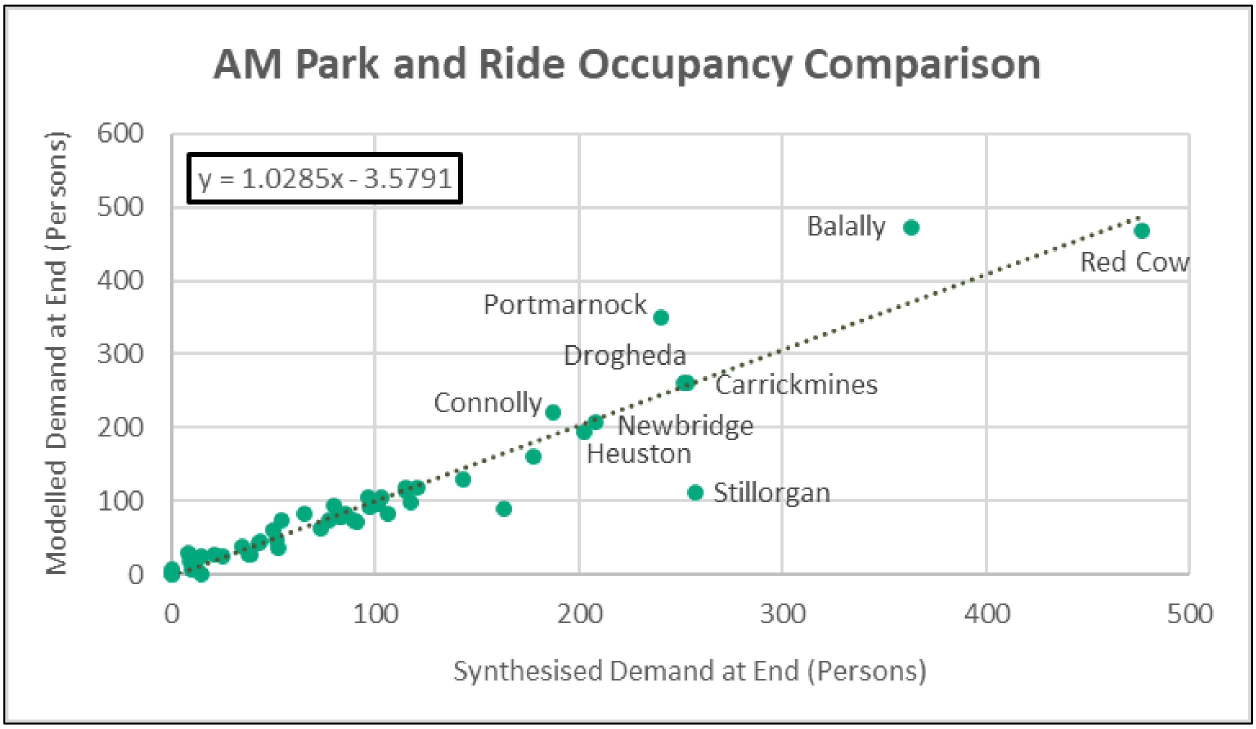


Figure 11.12 AM Park and Ride Occupancy Comparison

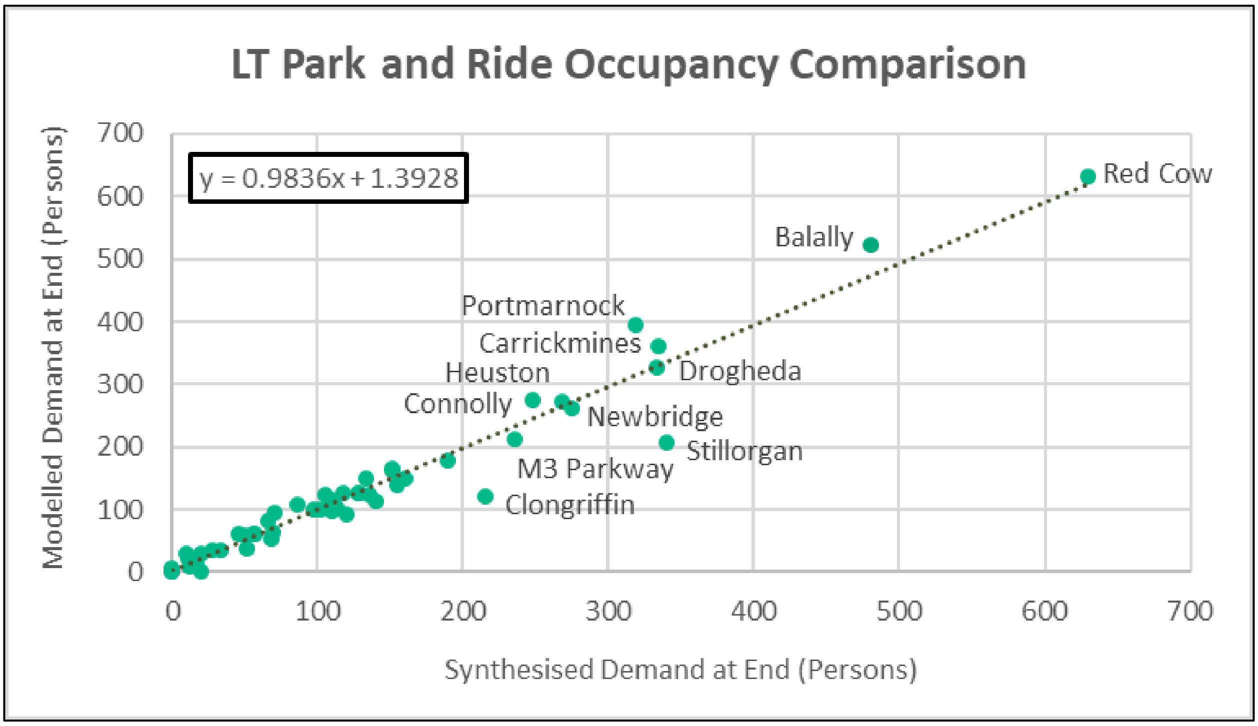


Figure 11.13 LT Park and Ride Occupancy Comparison

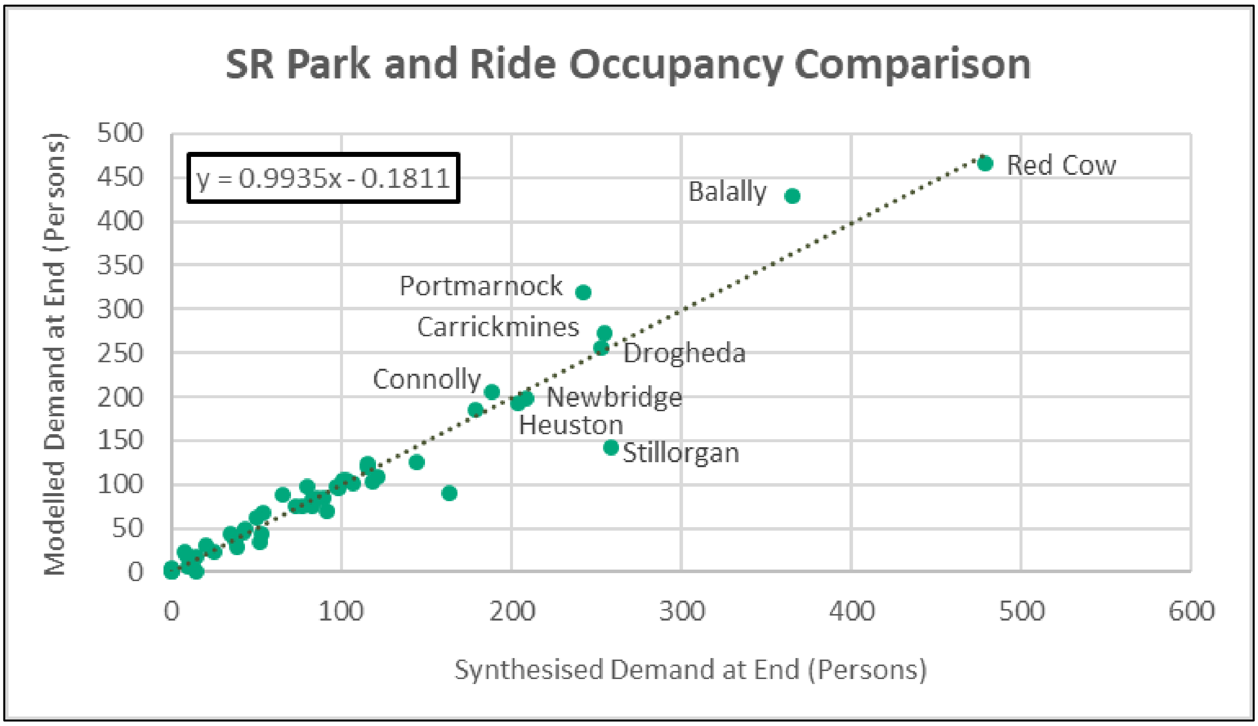


Figure 11.14 SR Park and Ride Occupancy Comparison

These comparisons can also be shown spatially to evaluate where the key issues lie, with GEH comparisons shown for each time period in Figure 11.15, Figure 11.16 and Figure 11.17 and percentage difference comparisons shown in Figure 11.18 to Figure 11.20. It should be noted that the PM period is omitted - this is because Park and Ride sites would be expected to be nearly empty at the end of the PM period, and hence would not be expected to give a valid or necessarily useful comparison.

The GEH comparisons show that a comparable match of modelled and synthesised data is typically achieved at most sites in all time periods. The percentage difference comparisons indicate a clear trend within the model to overestimate trips using Park and Ride sites in urban areas in contrast with rural sites.

It is likely this trend is due to the general weights on the road and PT legs of each journey. Despite the fact that the model applies site specific Park and Ride weights to help correct this issue, the calibration data shown in Figure 11.15 to Figure 11.20 suggests that the model has passengers travelling by car to Park and Ride sites closer to their final destination than is evidenced based on the observed Park and Ride site occupancy data.

It is further noted that some particular corridors do tend to be over-estimated (those in the south-west and south-east) in contrast with those in other areas (the north-west).

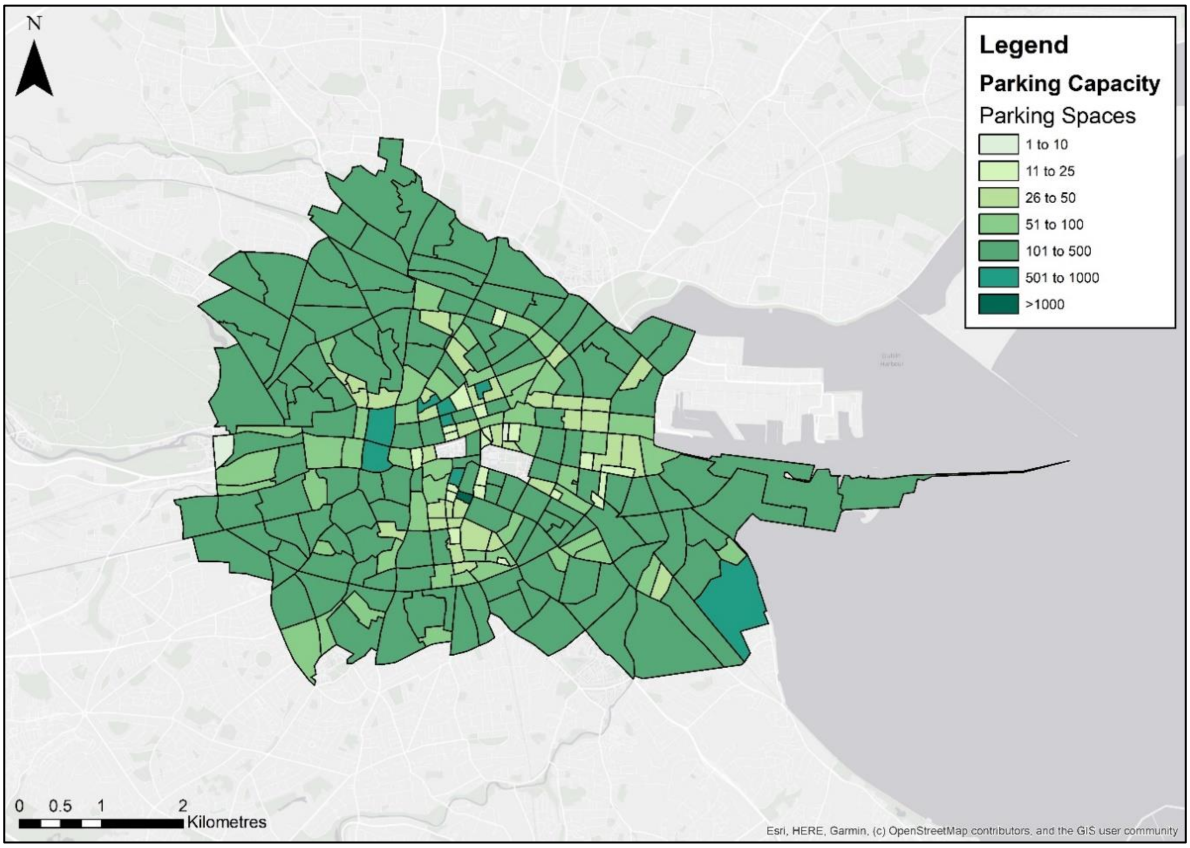


Figure 11.15 AM Park and Ride GEH Comparison by Site

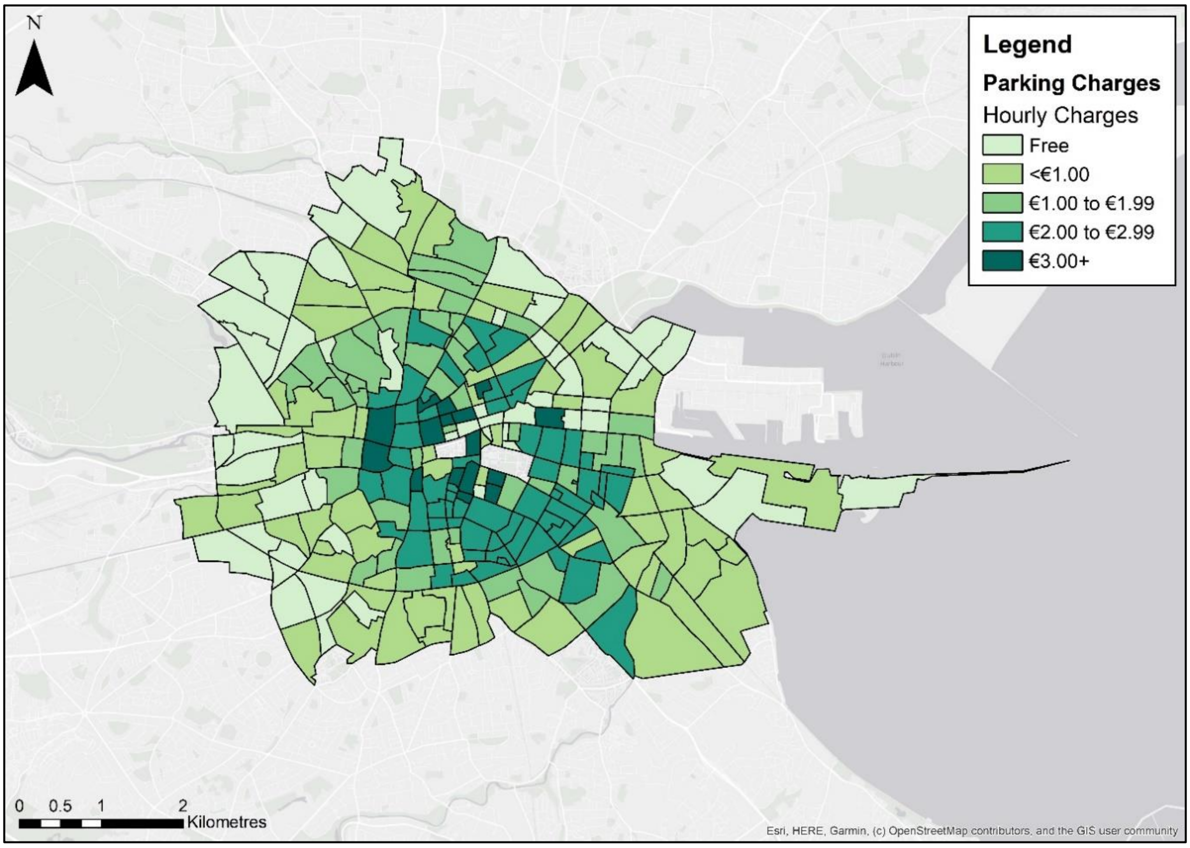


Figure 11.16 LT Park and Ride GEH Comparison by Site

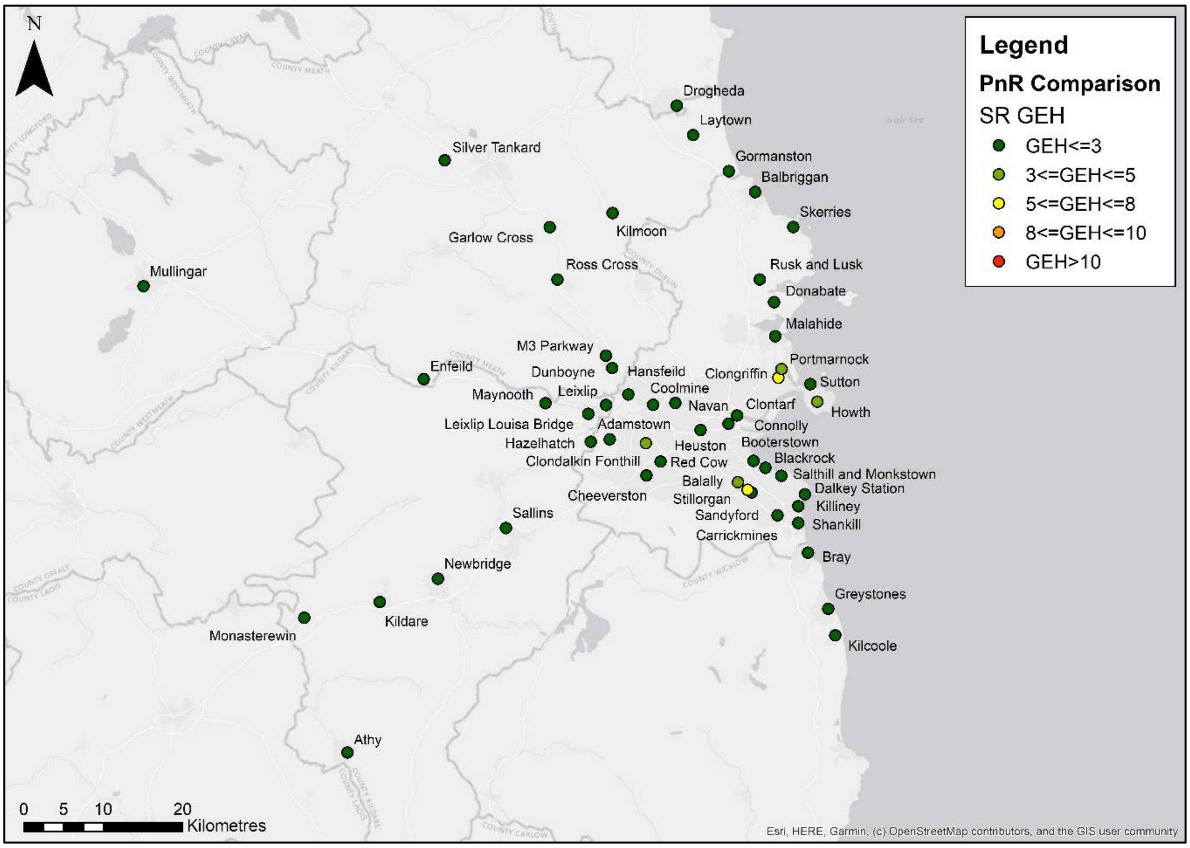


Figure 11.17 SR Park and Ride GEH Comparison by Site

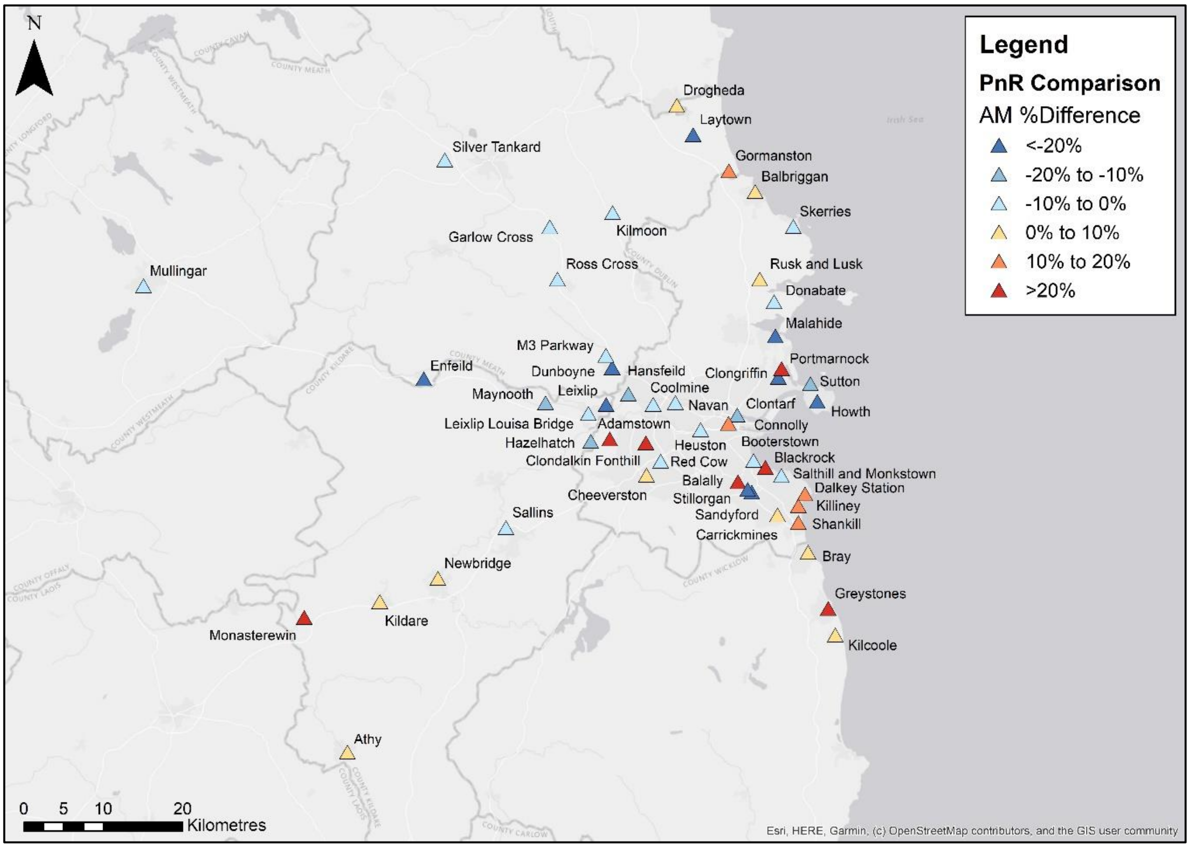


Figure 11.18 AM Park and Ride % Difference Comparison by Site

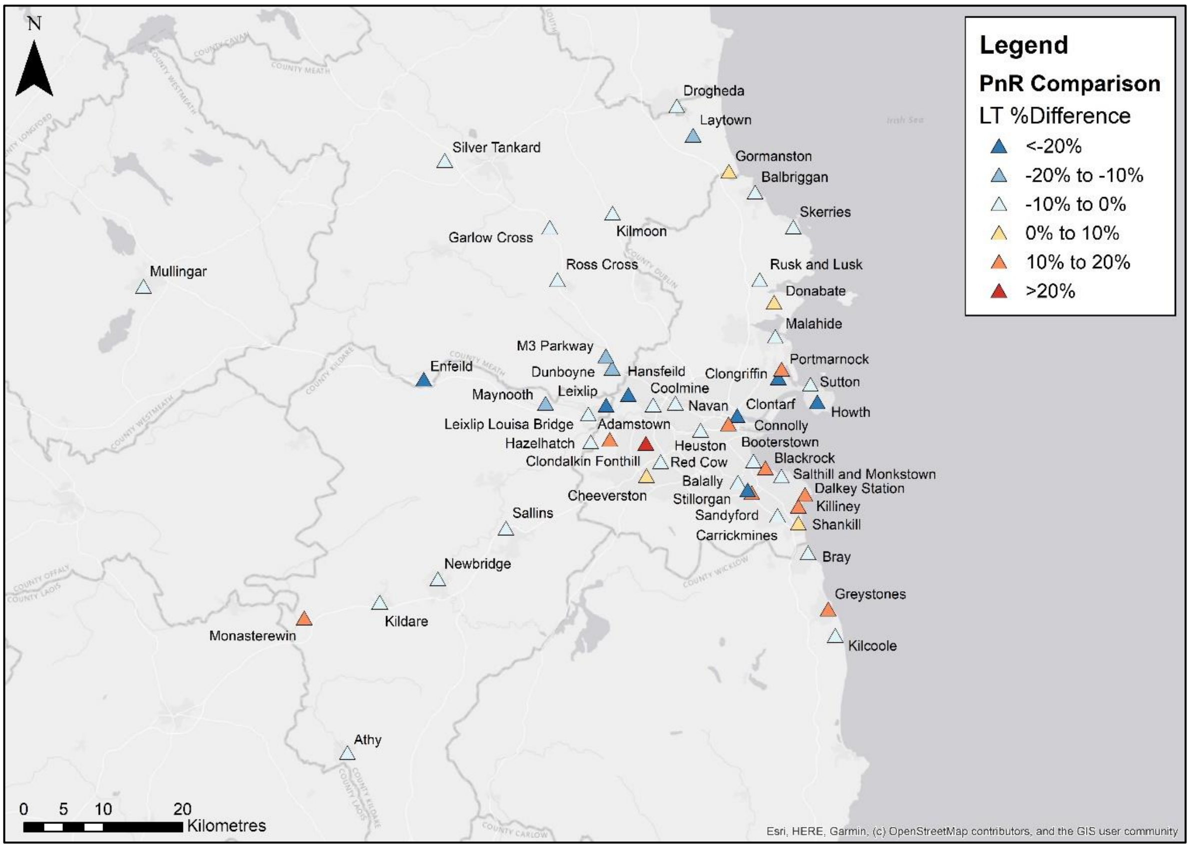


Figure 11.19 LT Park and Ride % Difference Comparison by Site

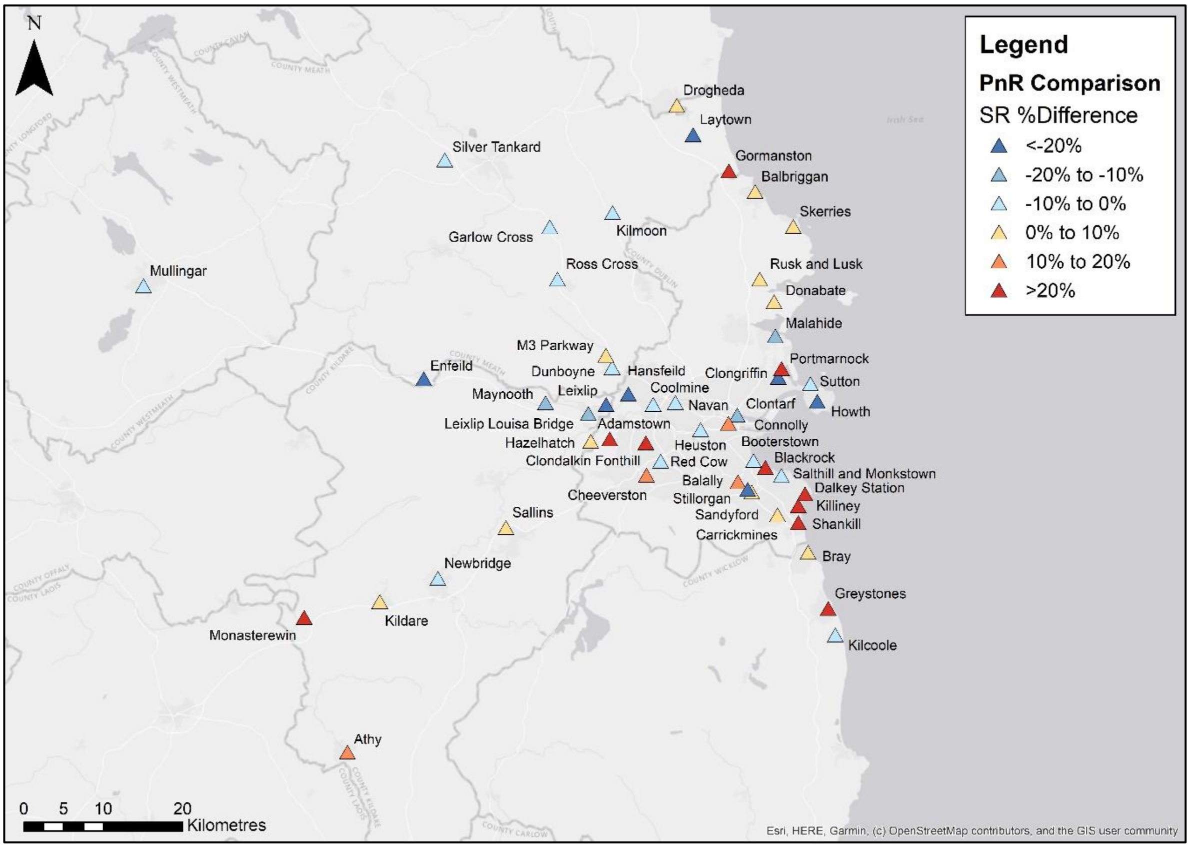


Figure 11.20 SR Park and Ride % Difference Comparison by Site

Site by Site Comparison

A comparison (GEH and percentage difference) of modelled and synthesised Park and Ride usage for each site in the three calibrated time periods is provided below in Table 11.20.

Table 11.20 Park and Ride Site Calibration (Demand in Persons)

Ref	Site	AM Mod	AM Obs	AM GEH	AM %Diff	LT Mod	LT Obs	LT GEH	LT %Diff	SR Mod	SR Obs	SR GEH	SR %Diff
1	Adamstown	23.1	14.7	1.9	58%	27.7	19.4	1.7	43%	16.7	14.8	0.5	13%
2	Athy	11.5	43.1	6.0	-73%	18.8	57.1	6.2	-67%	10.0	43.4	6.5	-77%
3	Balally	496.3	363.1	6.4	37%	535.4	480.6	2.4	11%	432.8	365.6	3.4	18%
4	Blackrock	70.2	53.5	2.1	31%	92.0	70.8	2.4	30%	65.7	53.8	1.5	22%
5	Booterstown	75.0	82.8	0.9	-9%	105.1	109.6	0.4	-4%	76.2	83.4	0.8	-9%
6	Cheeverstown	30.6	42.3	1.9	-28%	45.7	55.9	1.4	-18%	33.5	42.6	1.5	-21%
7	Clondalkin Fonthill	30.1	7.8	5.1	287%	32.7	10.3	4.8	219%	25.7	7.8	4.4	229%
8	Clongriffin	61.0	163.0	9.6	-63%	82.3	215.8	10.9	-62%	63.5	164.1	9.4	-61%
9	Clontarf	94.7	117.3	2.2	-19%	116.5	155.3	3.3	-25%	92.6	118.1	2.5	-22%
10	Coolmine	115.8	120.8	0.5	-4%	144.8	159.8	1.2	-9%	104.1	121.6	1.6	-14%
11	Connolly	216.0	187.2	2.0	15%	303.9	247.7	3.4	23%	211.5	188.4	1.6	12%
12	Dalkey Station	57.3	50.0	1.0	14%	79.5	66.2	1.6	20%	60.1	50.4	1.3	19%
13	Donabate	74.6	100.9	2.8	-26%	117.7	133.6	1.4	-12%	80.7	101.6	2.2	-21%
14	Drogheda	111.4	251.9	10.4	-56%	158.6	333.4	11.1	-52%	98.1	253.6	11.7	-61%
15	Dunboyne	63.4	106.1	4.6	-40%	87.4	140.4	5.0	-38%	75.7	106.8	3.3	-29%
16	Enfield	10.1	38.8	5.8	-74%	15.7	51.4	6.2	-69%	9.9	39.1	5.9	-75%

Ref	Site	AM Mod	AM Obs	AM GEH	AM %Diff	LT Mod	LT Obs	LT GEH	LT %Diff	SR Mod	SR Obs	SR GEH	SR %Diff
17	Gormanston	13.9	20.7	1.6	-33%	17.2	27.4	2.2	-37%	14.0	20.8	1.6	-33%
18	Hansfeild	42.8	51.8	1.3	-17%	49.8	68.5	2.4	-27%	32.1	52.1	3.1	-38%
19	Heuston	191.9	202.7	0.8	-5%	248.7	268.3	1.2	-7%	182.1	204.1	1.6	-11%
20	Hazelhatch	45.8	73.3	3.6	-37%	70.8	97.0	2.9	-27%	52.6	73.8	2.7	-29%
21	Howth	0.8	14.7	5.0	-94%	2.0	19.4	5.3	-90%	1.5	14.8	4.7	-90%
22	Kilcoole	15.5	25.0	2.1	-38%	19.7	33.1	2.6	-41%	11.4	25.2	3.2	-55%
23	Kildare	24.2	114.7	10.9	-79%	48.0	151.8	10.4	-68%	20.7	115.5	11.5	-82%
24	Killiney	35.7	34.5	0.2	4%	52.5	45.7	1.0	15%	39.7	34.7	0.8	14%
25	Laytown	2.8	12.9	3.6	-79%	7.7	17.1	2.7	-55%	3.1	13.0	3.5	-76%
26	Leixlip	6.0	9.5	1.3	-37%	8.3	12.6	1.3	-34%	5.4	9.6	1.5	-43%
27	Leixlip Louisa Bridge	97.4	143.2	4.2	-32%	138.6	189.5	4.0	-27%	93.6	144.2	4.6	-35%
28	M3 Parkway	108.0	177.7	5.8	-39%	147.2	235.2	6.4	-37%	126.4	178.9	4.2	-29%
29	Monasterewin	3.6	8.6	2.1	-59%	5.0	11.4	2.2	-56%	3.1	8.7	2.3	-64%
30	Mullingar	57.4	76.8	2.4	-25%	73.6	101.6	3.0	-28%	55.7	77.3	2.7	-28%
31	Newbridge	113.2	207.9	7.5	-46%	152.0	275.1	8.4	-45%	102.2	209.3	8.6	-51%
32	Portmarnock	313.4	240.6	4.4	30%	368.5	318.5	2.7	16%	284.5	242.3	2.6	17%
33	Red Cow	400.3	476.1	3.6	-16%	545.9	630.2	3.5	-13%	399.2	479.4	3.8	-17%
34	Sallins	53.5	97.5	5.1	-45%	75.4	129.0	5.3	-42%	53.6	98.1	5.1	-45%
35	Salthill and Monkstown	75.7	82.8	0.8	-9%	94.5	109.6	1.5	-14%	72.7	83.4	1.2	-13%

Ref	Site	AM Mod	AM Obs	AM GEH	AM %Diff	LT Mod	LT Obs	LT GEH	LT %Diff	SR Mod	SR Obs	SR GEH	SR %Diff
36	Sandyford	24.8	38.0	2.3	-35%	52.5	50.2	0.3	5%	32.7	38.2	0.9	-14%
37	Shankill	83.7	79.4	0.5	5%	110.6	105.0	0.5	5%	86.3	79.9	0.7	8%
38	Silver Tankard	0.1	0.0	0.5	0%	0.3	0.0	0.8	0%	0.1	0.0	0.5	0%
39	Skerries	90.1	114.7	2.4	-21%	129.5	151.8	1.9	-15%	95.0	115.5	2.0	-18%
40	Stillorgan	99.1	257.0	11.8	-61%	183.4	340.2	9.7	-46%	129.1	258.8	9.3	-50%
41	Sutton	54.5	88.8	4.1	-39%	93.6	117.6	2.3	-20%	62.9	89.4	3.0	-30%
42	Garlow Cross	0.7	0.0	1.1	0%	1.3	0.0	1.6	0%	0.6	0.0	1.1	0%
43	Ross Cross	0.4	0.0	0.8	0%	0.7	0.0	1.1	0%	0.3	0.0	0.8	0%
44	Carrickmines	214.8	253.0	2.5	-15%	318.7	334.9	0.9	-5%	231.4	254.7	1.5	-9%
45	Navan	5.1	0.0	3.2	0%	5.4	0.0	3.3	0%	4.0	0.0	2.8	0%
46	Kilmoon	0.2	0.0	0.6	0%	1.6	0.0	1.8	0%	0.6	0.0	1.1	0%
47	Bray	92.0	96.6	0.5	-5%	104.4	127.9	2.2	-18%	81.2	97.3	1.7	-17%
48	Malahide	23.4	52.4	4.7	-55%	40.9	69.4	3.8	-41%	27.7	52.8	4.0	-48%
49	Rusk and Lusk	83.2	102.5	2.0	-19%	97.6	135.7	3.5	-28%	83.1	103.2	2.1	-20%
50	Greystones	50.4	65.2	1.9	-23%	64.3	86.2	2.5	-25%	49.1	65.6	2.2	-25%
51	Maynooth	55.8	90.6	4.1	-38%	70.6	119.9	5.1	-41%	51.6	91.2	4.7	-43%
52	Balbriggan	65.1	85.4	2.3	-24%	80.1	113.0	3.4	-29%	62.3	86.0	2.7	-28%

Park and Ride Notes

Park and Ride has been shown to have a majority of sites with low GEH when used as a comparison of synthesised and modelled usage. However, the lack of specific Park and Ride data is a significant weakness in the model and leads to reduced confidence in the level of fit of the model in some areas.

It is recommended that additional data be sought for future updates, as highlighted in Table 11.21 below.

Table 11.21 Future Park and Ride Recommendations

Item	Benefit
Additional time period occupancy data	Reduces the reliance on NHTS for establishing tour approximations to provide increased confidence in comparisons
Further data on purpose	Model assumes commute is sole source for Park and Ride due to lack of data, leading to general trends of all day parking
Improved mode choice mechanism	Logit models can struggle to replicate small proportions, and Park and Ride may be better represented using an alternative approach such as proportions and elasticities
Adjustments made to weights on costs	Model tends to overestimate usage of urban sites which may be a sign of preferring road to PT legs
Incremental to align initial demand should be removed	The less reliance on general correction factors within the model, the cleaner the response from the primary mechanisms

11.2.10 Parking Distribution

As discussed in Chapter 6, the Parking Distribution model takes a fixed set of demand inputs and then redistributes trips to designated parking locations within the modelled area covered by Parking Distribution. As there is no observed data available on usage of parking locations across the day, the key metrics of performance of the parking distribution model are analysing the:

- Initial and final uptake of demand;
- Occupancy by time period;
- Modal shift; and
- Convergence.

Initial and final uptake of demand

Demand within Parking Distribution can be considered using a number of metrics, but arguably provides the best context when considered beside capacity as absolute numbers of users or people seeking access provide little context without awareness of the available capacity. These items are discussed as follows:

The figures below (Figure 11.21 to Figure 11.24) graphically shows parking demand and percentage of parking capacity used at parking locations for the first four time periods in the day – it is assumed that there is negligible impact of parking in the off-peak and therefore this time period is not reported.

Each figure shows four metrics, defined as follows:

- Available Spaces (in Persons). This is the capacity available at the beginning of the time period, and excludes those spaces that have already been taken in an earlier time period;
- Initial demand (Persons) is that demand which aims to arrive within a given time period, but may not still be present at the end of that time period;
- Initial demand as a percentage of the available spaces; and
- Final Access Demand as a percentage of available capacity. This is the final percentage of available capacity used following the redistribution of trips (to eliminate over-capacity demand at parking locations) by the parking distribution model.

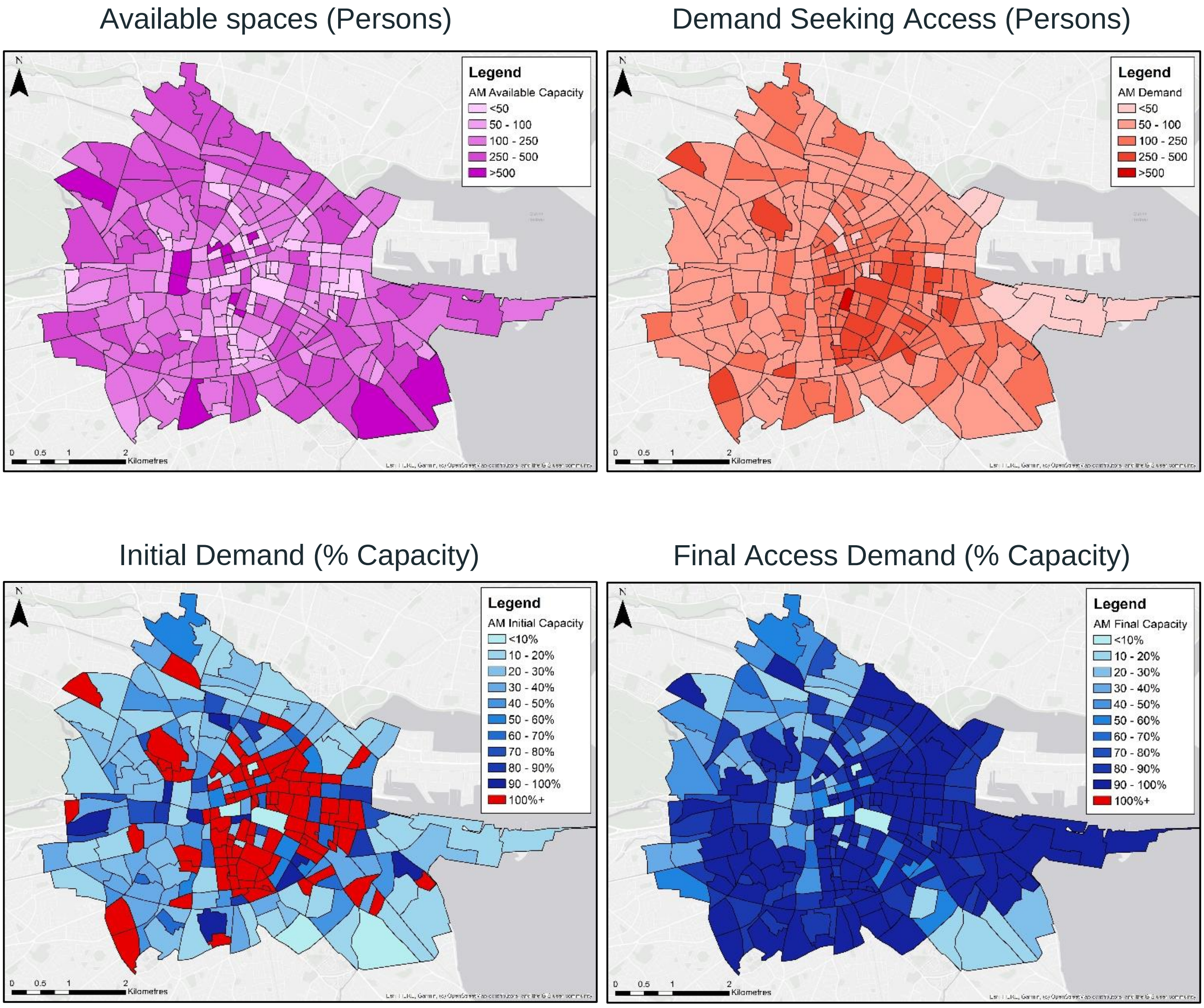


Figure 11.21 AM Parking Distribution Demand and Capacity by Time Period

From the AM plots, it can be seen that there is a substantial initial demand in the AM, and this exceeds capacity in many cases (bottom left chart). The Parking Distribution algorithm then redistributes these trips, such that there are no overcapacity zones at the end of the process as evidenced in the bottom right with lack of red areas.

There is also a clear trend for the fully occupied zones to be located near to the initial overcapacity areas, showing that the model will redistribute locally rather than send trips further away if possible.

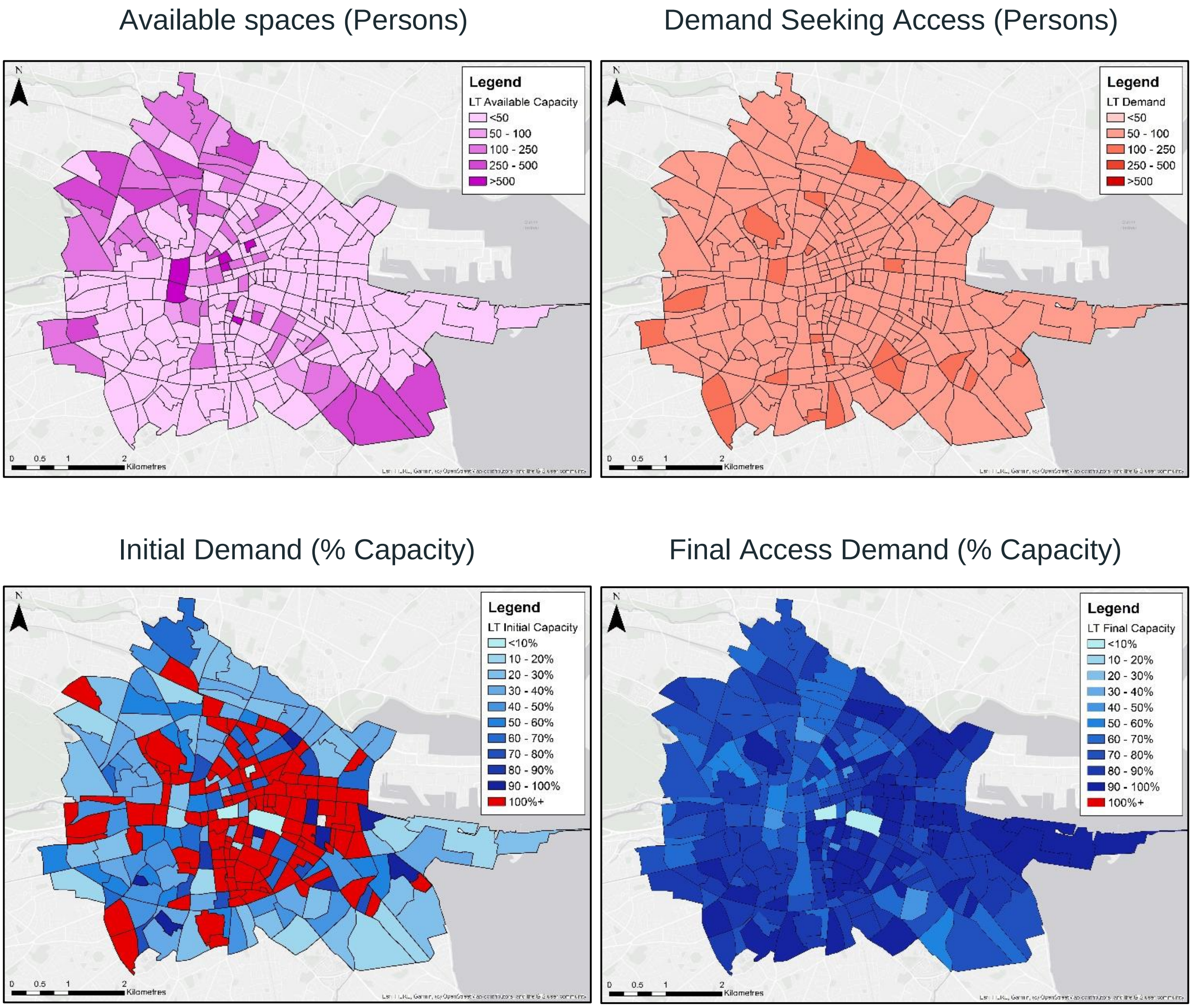


Figure 11.22 LT Parking Distribution Demand and Capacity

The LT time period should be considered in relation to the preceding AM period. It is clear from Figure 11.22 that there is significantly less available capacity at the start of the process (top left, more light areas than AM) which is due to spaces being taken during the AM time period and there is a correspondence between the final allocated demand in the AM and the available spaces.

There is also less demand overall trying to access the area in these time periods (top right) but more zones that will be overcapacity without redistribution (bottom left). Again, the process can be seen to redistribute as in the AM in the bottom right chart, noting there are more areas of high capacity at the end of the LT time period than the AM.

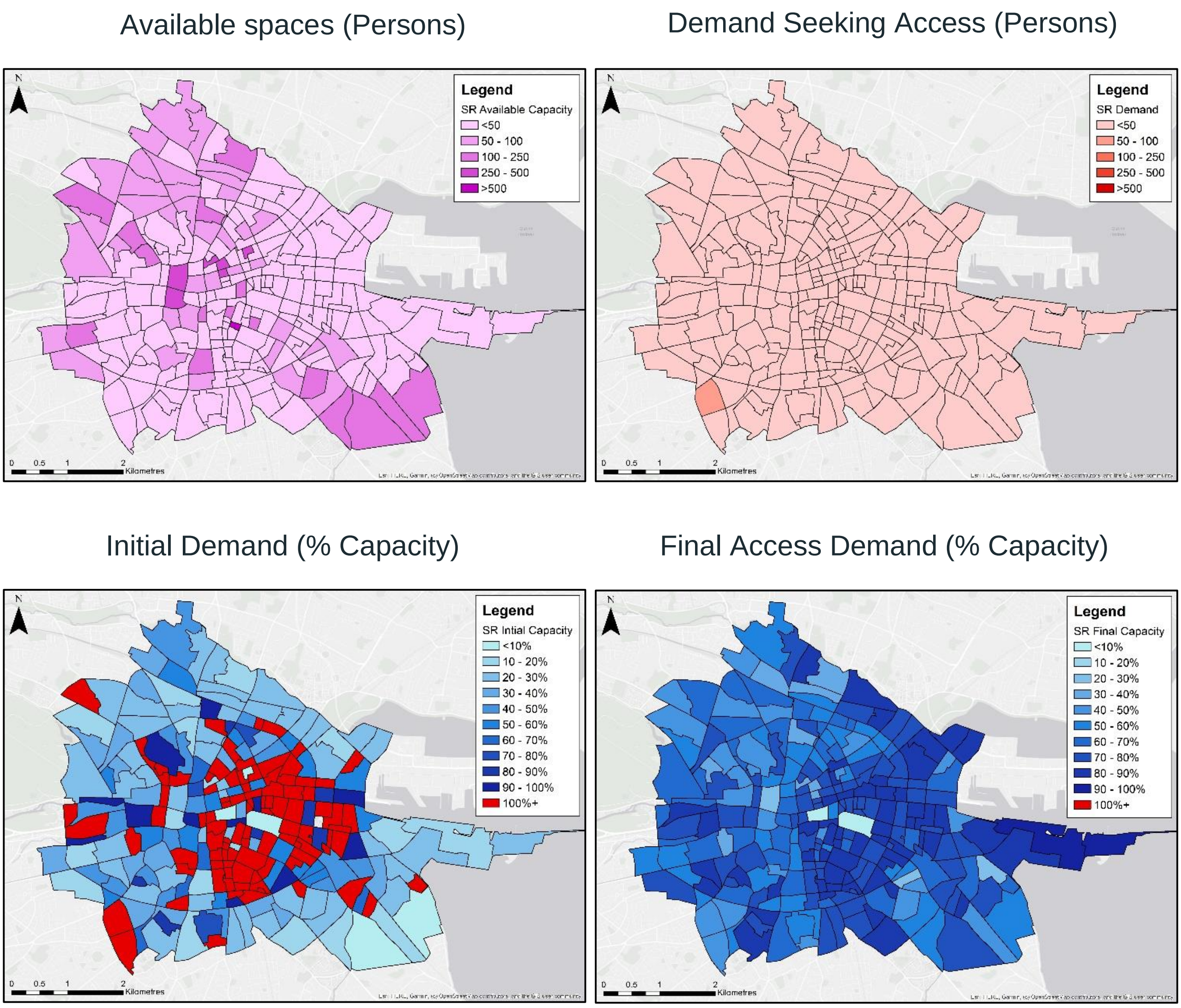


Figure 11.23 SR Parking Distribution Demand and Capacity by Time Period

The SR time period shows significantly less demand arriving in the area than in the earlier time periods but a similar number of available spaces at the start, indicating that there is still a large amount of demand that has stayed throughout the day from earlier periods.

The reduced demand leads to less zones being overcapacity in the first instance and generally less demand at the final stage.

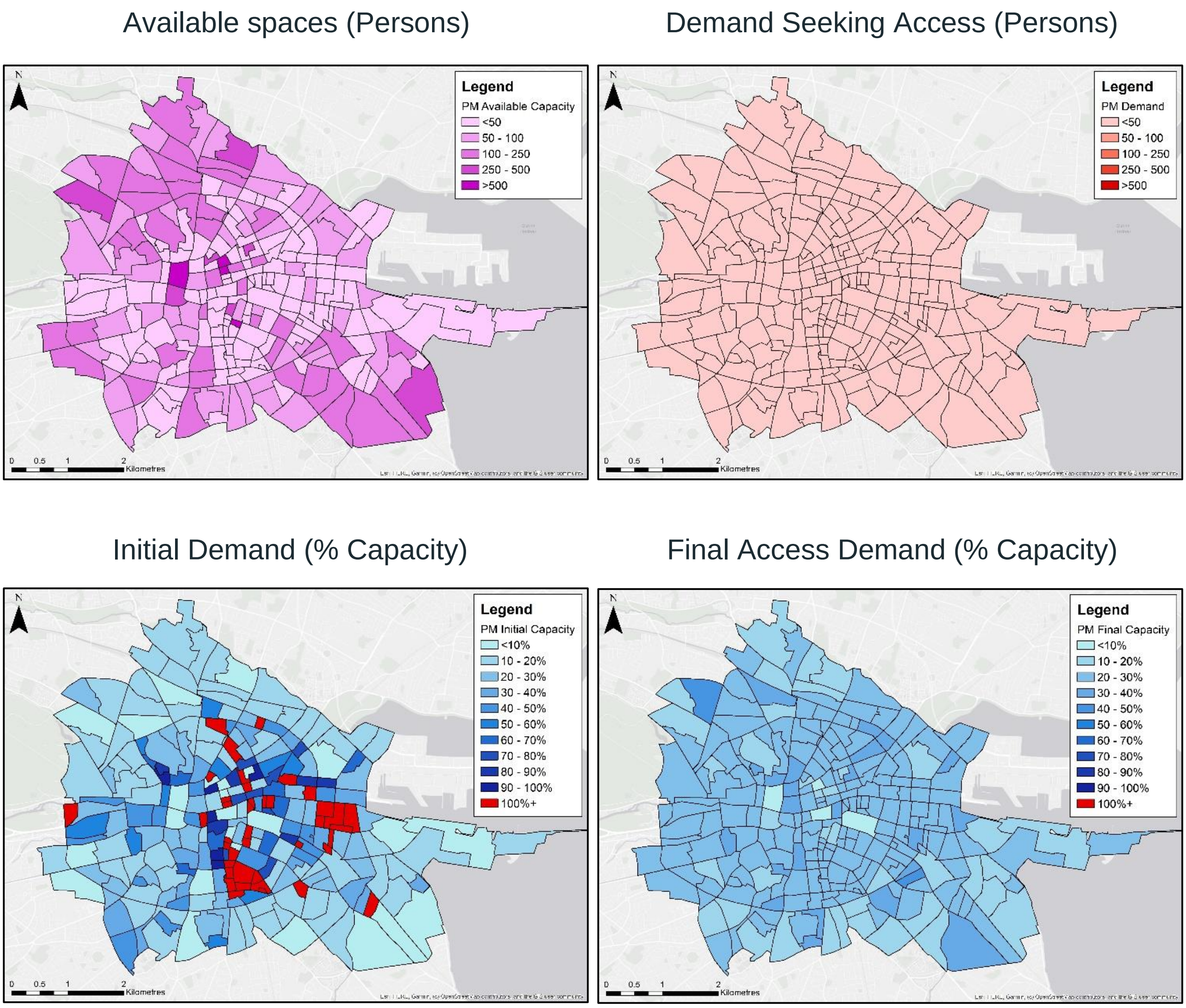


Figure 11.24 PM Parking Distribution Demand and Capacity by Time Period

The PM time period shows similar trends to the SR period, with a number of spaces already taken and much less demand arriving than in earlier time periods. However, as expected, the PM period has less overcapacity areas both initially and finally following redistribution.

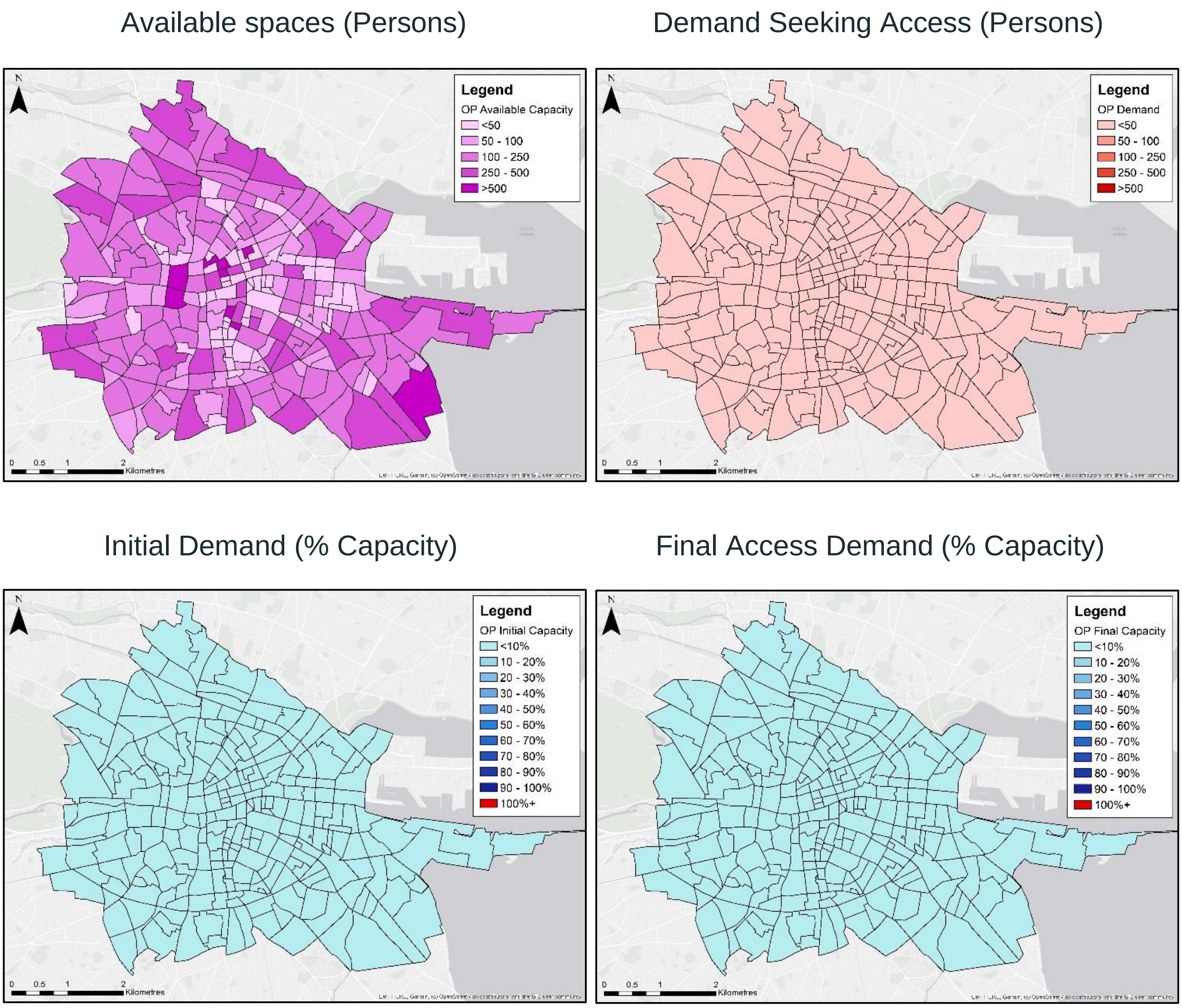


Figure 11.25 OP Parking Distribution Demand and Capacity by Time Period

The OP time period shows very small numbers of trips entering the area and there is sufficient capacity in all zones to allow for trips to complete their journey in the ideal location.

Occupancy by time period

Table 11.22 gives a summary of the overall occupancy of all parking locations by time period, and this information is shown graphically in Figure 11.26.

Table 11.22 Parking Distribution by Time Period (Persons)

Time Period	Total Spaces	Initial Spaces	Arrivals	Leavers	Occupancy At End	% Occupancy At End
AM	46,794	46,794	32,169	2,644	29,525	63%
LT	46,794	17,269	17,269	11,137	35,657	76%
SR	46,794	11,137	8,766	15,011	29,412	63%
PM	46,794	17,382	9,129	28,260	10,281	22%
OP	46,794	36,513	7,605	17,885	0	0%

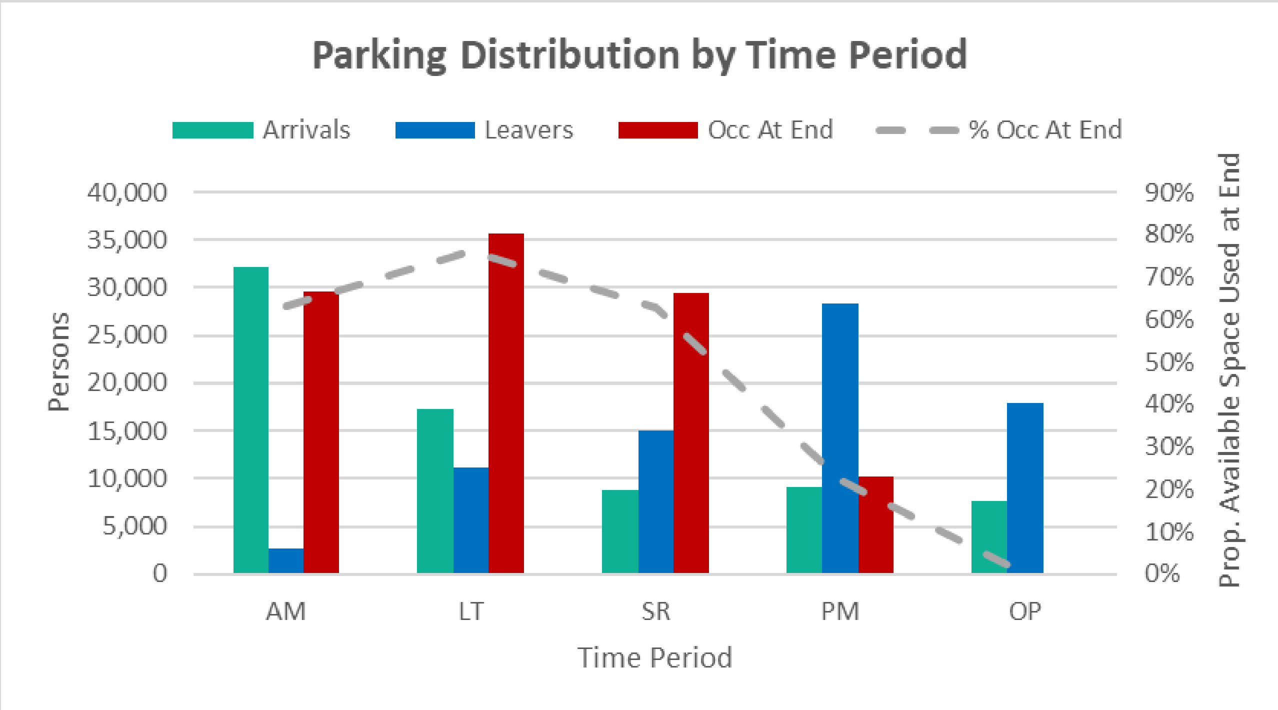


Figure 11.26 Graphical Parking Distribution by Time Period (Persons)

Convergence

Convergence of the Parking Distribution model is achieved when all demand has been redistributed and no parking location has demand in excess of capacity. This redistribution is managed through two separate mechanisms:

- An initial allocation which allows any demand which terminated their journey in a zone with available capacity to park there; followed by
- A secondary allocation mechanism that uses logit choice to choose from all available sites.

Table 11.23 shows the first phases of convergence of the Parking Distribution model by time period. It shows that in each time period the model convergence quickly allocated a majority of demand although still requires a number of loops which suggests there is a large amount of constraint being experienced within the area. It is also noted the LT time period actually exceeds the number of spaces so there are 3,286 persons who cannot access a space in the desired area and therefore are shifted on to other modes.

Table 11.23 Parking Distribution Convergence Reporting (Persons)

Time Period	Number of Loops	Overall Demand	Initial Allocation	Allocated End Loop 1	Allocated End Loop 2	Allocated End Loop 3	Unable to be allocated
AM	7	32,168	21,118	24,823	27,915	30,126	-
LT	5	17,270	6,716	13,418	15,329	16,849	3,286
SR	6	8,766	5,228	6,871	7,564	8,136	-
PM	5	9,128	6,778	8,467	9,014	9,102	-
OP	1	7,605	7,223	7,605	7,605	7,605	-

Modal shift

There are 3,286 tours that shift mode due to their inability within the mod to access a space in the LT time period. These are summarised by user class in Table 11.24. The vast majority of trips shift to either PT or walk which would be expected given they are the predominate modes of travel excluding car. There are variances by user class such as a larger proportion of EMP and COM tours shifting to PT than in OTH but this is to be expected given the type of trips which were originally being made and which from Sections 11.2.5 and 11.2.6 could be seen to travel longer distances and have higher generalised costs, which means PT is therefore a more likely option as a replacement journey.

Table 11.24 LT Mode Shift Summary by User Class and New Mode (Persons)

New Mode	EMP	COM	OTH	EDU	RET	Total
PT	575	212	1,011	38	35	1,872
Walk	45	86	943	69	24	1,166
Cycle	5	66	158	15	5	248
Total	625	364	2,112	122	64	3,286

11.2.11 Special Zones

This section outlines the calibration of the Special Zones module for the ERM further to the model setup and calibration approach outlined in Section 6.9. The methodology and results of calibration process can be found within the *Special Zones Report*.

Objectives

The Special Zone module estimation and calibration was to improve the estimated model and to reflect new Passenger Survey data. An overview of the model development and calibration work described in the above reports is provided in this section.

Passenger Survey

The main source for parameter estimation and model calibration was passenger survey at the Dublin Airport, which was conducted in late 2016.

In the passenger survey, all passengers were surveyed on arrival at Dublin Airport (survey at departure area of the airport).

Each record was assigned to a time period grouping (AM, IP, PM or OP), a geographic region, a code indicating passenger type (resident / visitor) and trip purpose (employer's business / other). Information about the return trip (Irish and Northern-Irish residents) and about the original outbound trip (visitors) was also recorded.

Calibration of Trip Distribution

Calibration of trip distribution has involved estimation of gravity model parameters associated with individual data fields from the NDFM planning dataset. Multiple linear regression was used to establish parametric relationships between demand and the characteristic variables. Four variables from the planning data have been selected as variables:

- Total population;
- Population in full time employment;
- Jobs; and
- Education places.

The regression analysis was:

- Undertaken separately for each user class (Residents and Visitors) and trip purpose (Employer's Business and Other trip purposes);
- Undertaken separately for two directions (to the airport and from the airport);
- Undertaken only for Airport trips within the ERM model area;
- Undertaken for the entire 24-hour period (Initially proposed to be undertaken by 5 time periods in line with the Full Demand Model: AM, LT, SR, PM and OP;
- Undertaken iteratively using the backward elimination approach. Specifically, it starts with the four candidate predictors (planning data fields) and was repeated until only the significant predictor(s) were left in the model (predictors with P value less than 5%); and
- Undertaken for the Dublin airport only.

The three data source used in this process are:

- Passenger survey by Dublin Airport in 2016;
- Costs from the calibrated base run; and
- NDFM planning dataset for demographic information by Census Small Areas (CSA).

Due to a low sample at zonal level, and granularity of data outside Dublin at sector level, the regression analysis has been carried out at a sector level, using the standard model sectors within Dublin and external zones or counties outside Dublin.

In addition, due to the point at which special zone demands are fed into the process, its output matrices are at hourly level for each time period, as opposed to period level.

The final special zone trip distribution model form can be described by the equation below:

$$Trips = \frac{(A_1P_1 + A_2P_2 + \cdots + A_nP_n)}{Ci, j}$$

Where

$$P_1, \ldots, P_n = characteristic\ variables;$$

$$A_1, \ldots, A_n = coefficients;\ and$$

$$C_{i,j} = cost\ between\ zones\ i\ and\ j.$$

The results of regression have made sure that only statistically significant variables have entered the model form by segmentation. For example, trips to Airport in the PM is predicted by population in full time employment, whereas to the Airport in the same time period is predicted by Jobs. This is logical and opposite to the observation in the AM – in the PM, employees would travel to the airport for home-bound flights, whereas employed residents will be returning from the airport to home.

For the other special zones within the ERM area no observed travel pattern and mode share data were available and therefore the same distribution coefficients as derived for the Dublin airport were used.

Calibration of Mode Split

Once the trip distribution modelling has been carried out for the Special Zone, the initial mode split is calculated in line with the mode function adopted in the core Demand Model. There are four airport modes defined in the modelling, where trips are made with:

- Private cars that park at the special zone;
- Private cars that do not park at the special zone;
- Taxi or private hires; and
- Public transport.

The costs to travel in Special Zone is based on the generalised cost from the network skims and adjusted for the modes above. Those costs are then used to express utilities in the standard choice model form in line with the core Demand Model.

Calibration of mode split involved adjustment of the ASC values. The ASC values were initialised to the main Demand Model's mode choice values, and further adjusted so that the model reproduced the observed mode split found in the passenger survey data at the Dublin Airport. For the other special zones within the ERM area, the ASC values remain at their standard main Demand Model values.

Calibration Results

Calibration of the travel patterns from regions of the model results are presented for Dublin Airport only, because for the other special zones in the ERM area (i.e. Dublin Port) data.

The calibration summaries and figures presented below present only trips to Dublin Airport as the observed data is more reliable in this direction[63].

The trip distribution results are presented in terms of aggregated sectors as follows: Dublin, Dublin suburbs, and the rest of internal ERM area, which was split into three areas (North, East and South).

Comparison of observed and estimated trip distribution for trips to the Dublin Airport is shown in Figure 11.27.

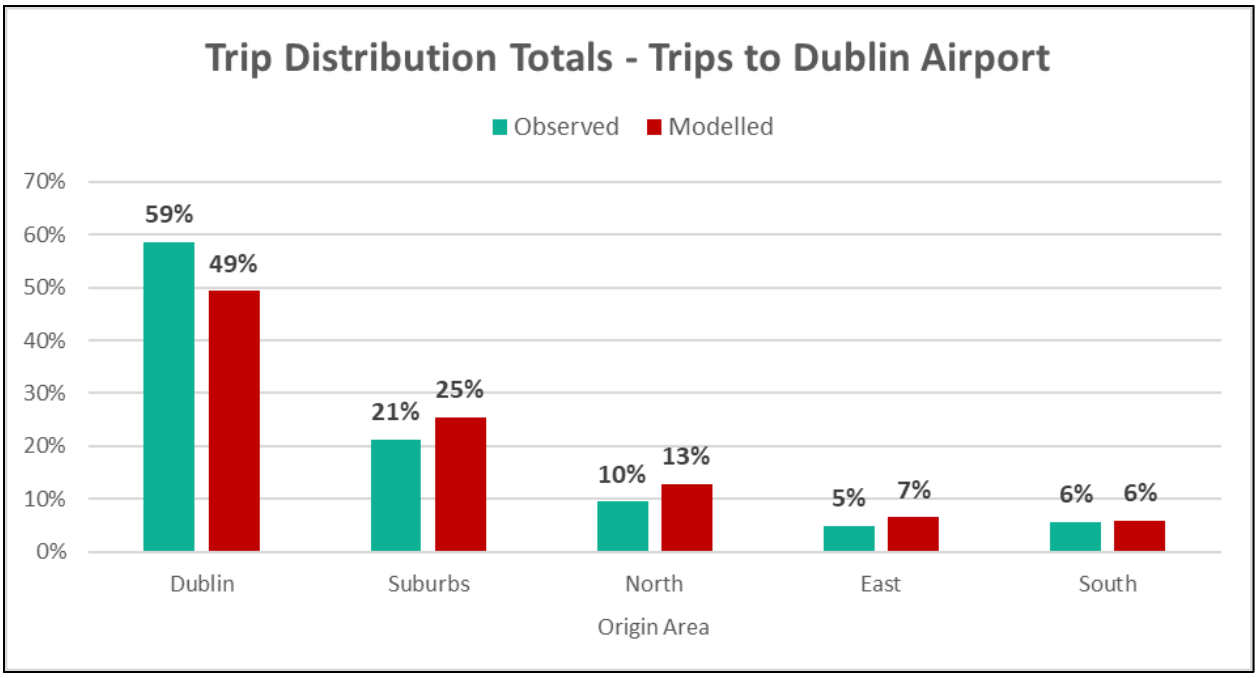


Figure 11.27 Calibration of Special Zones – Trip Distribution

[63] This is probably caused by the way the survey was carried out: travellers were interviewed in the departure hall, and it is assumed that during the interview, the information about trip to the airport was recorded as a priority and with greater confidence than information about the trip from the airport.

Comparison of observed and estimated trip distribution by user class (for trips to the Dublin Airport) is shown in Figure 11.28.

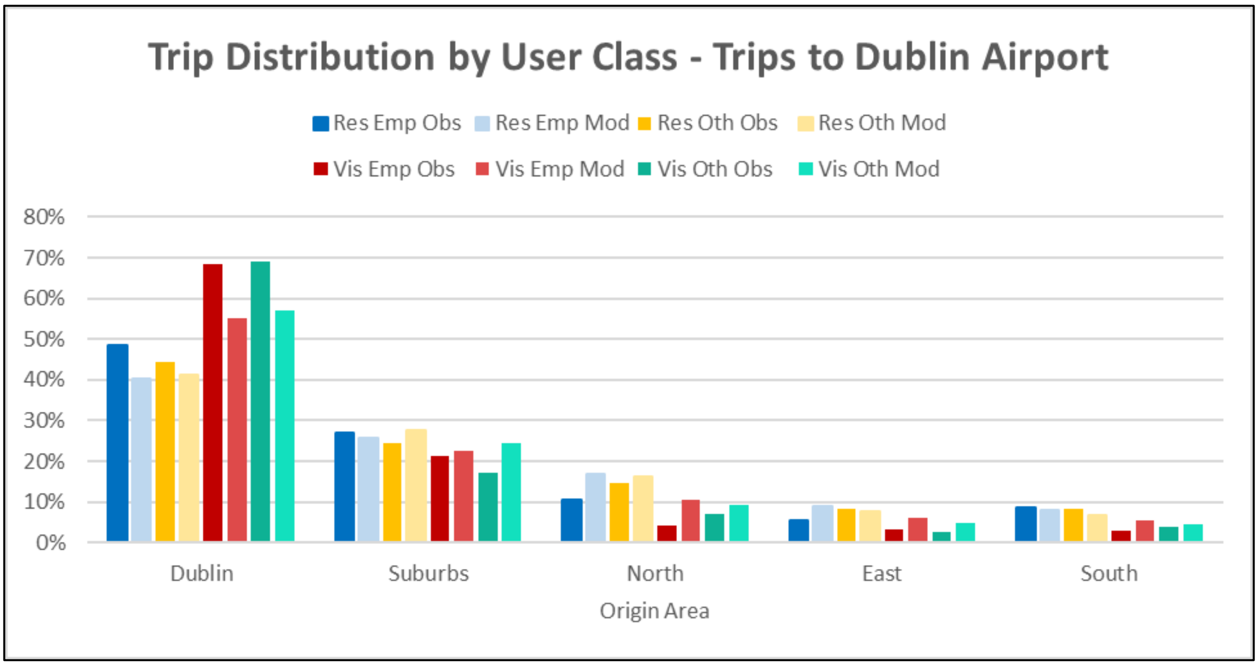


Figure 11.28 Calibration of Special Zones – Trip Distribution by User Class

The Suburbs are generally over-estimated as destinations from Dublin Airport, while Dublin (City Centre) is underestimated, especially for the visitors, suggesting a potential for improvement in the modelled distribution. This may be achieved by exploring the use of other planning data variables; e.g. for visitors, the model uses total job attractions to calculate distribution, however using other attraction variables such as hotel capacities could result in better match between observed and estimated distribution.

Comparison of observed and estimated mode share for trips to the Dublin Airport is shown in Figure 11.29.

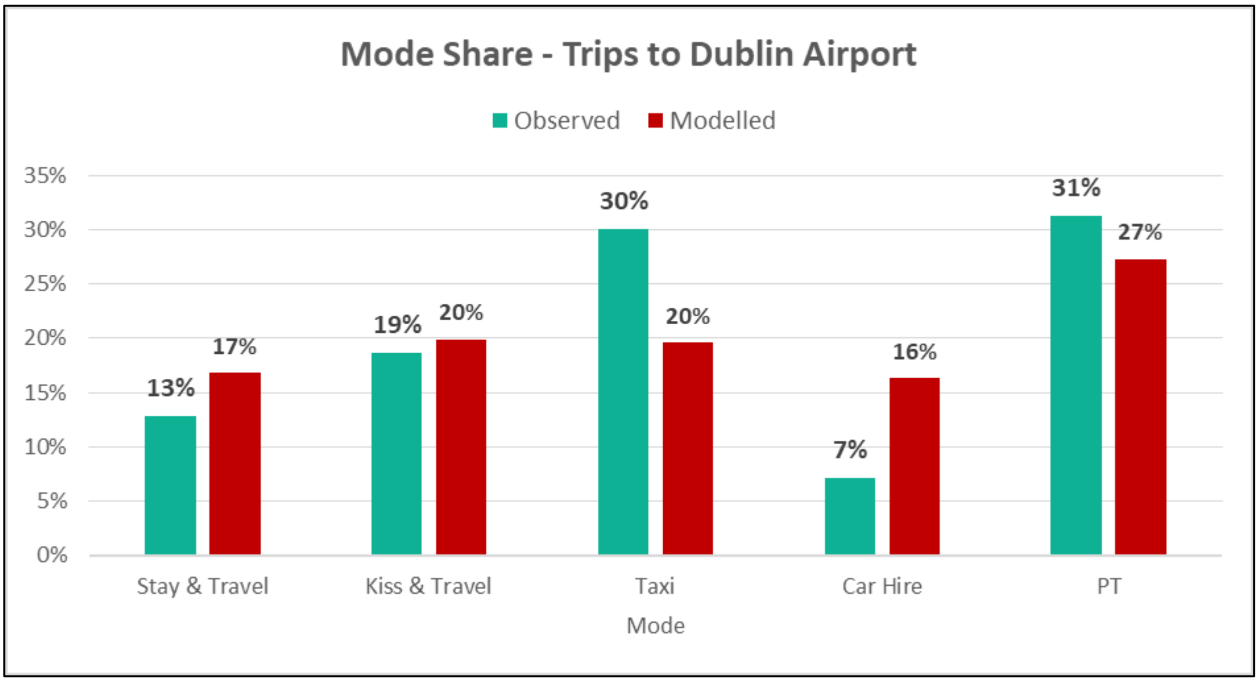


Figure 11.29 Dublin Airport Mode Share Comparison

Comparison of observed and estimated mode share by user class for trips to the Dublin Airport is shown in Figure 11.30.

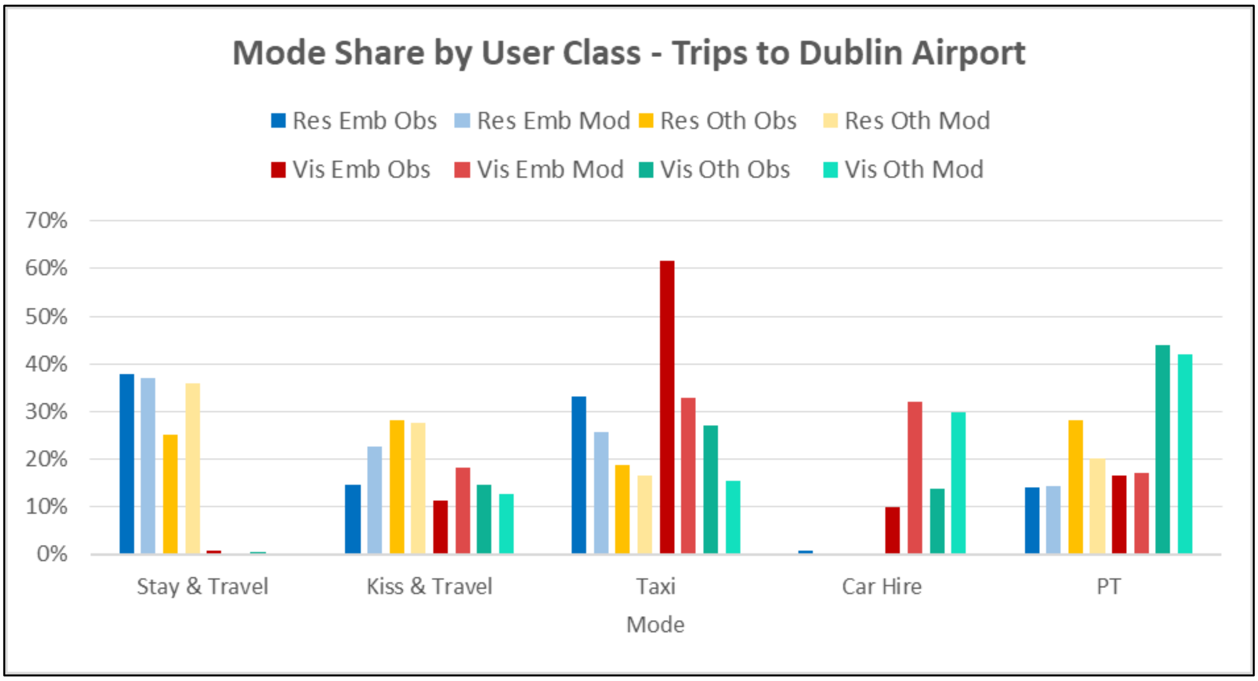


Figure 11.30 Calibration of Special Zones – Mode Share by User Class

With the present version of the ERM the calibrated trip distribution is a reasonable match to base year conditions in terms of trip distribution and mode share. Further analysis of the model sensitivity to future changes in the transport network is advised, particularly when considering changes to the public transport network or the parking supply serving Dublin Airport.

11.2.12 Incremental Adjustments

A final stage of the calibration of the Demand Model is to calculate incremental adjustments to capture the differences between the assignment matrices and the matrices produced by the Demand Model. In effect, these adjustments capture those trends that cannot be replicated or explained solely by costs within the model. It is important to recognise that these adjustments must be suitably small, as otherwise the Demand Model will lack a true response to travel costs and will be largely fixed.

In order to examine the performance of the model in terms of these incremental adjustment, the first test is to look at the overall differences between the demand and assignment matrices. In addition, these differences are also interrogated further at sector level to test the model's performance in each sector.

It is noted that no incremental adjustment is applied to active modes, as there is limited data to suggest that demand should be adjusted at the assignment stage. In contrast, adjustments are made at assignment level to the road and PT matrices based on count information, journey time data etc. that all combine to give a better picture of the level of travel demand for these modes at assignment stage.

There are two primary sources of differences in the demand matrices leading to incremental adjustments as follows:

- Those introduced by matrix adjustment and matrix estimation in the assignment calibration process; and
- Those changes which are introduced because of differences in travel costs between the "prior" and "final" matrices.

Because of the Demand Model calibration approach outlined in Chapter 10, the latter component should be relatively small as costs and demand are iterated numerous times before finalisation of the model. Thus, while comparisons could be made between the "prior" matrices of assignment and the Demand Model output, it is not considered a relevant investigation as the vast majority of changes to the demand matrices will be introduced by the first source – i.e. during assignment calibration.

A description of the actual derivation approach to incremental adjustments can be found in Section 10.4.2.

Table 11.25 below gives a summary of the overall incremental changes between the matrices following the Demand Model and Assignment stages of the model. The total differences and percentages differences are given for the Road, PT and Active Modes models for each time period.

Table 11.25 Assignment Incremental Summary

TP	Mode	Demand	Assign	Diff	% Diff
AM	Road	311,207	318,748	7,542	2.4%
LT	Road	192,493	205,199	12,705	6.6%
SR	Road	202,233	218,258	16,025	7.9%
PM	Road	267,276	283,304	16,028	6.0%
OP	Road	68,336	80,278	11,942	17.5%
24-hour	Road	1,041,546	1,105,787	64,242	6.2%
AM	PT	93,987	105,884	11,897	12.7%
LT	PT	33,799	31,697	-2,102	-6.2%
SR	PT	39,461	39,558	97	0.2%
PM	PT	75,860	86,545	10,685	14.1%
OP	PT	11,124	12,238	1,114	10.0%
24-hour	PT	254,231	275,923	21,692	8.5%
AM	Walk	145,432	145,415	-16	0.0%
LT	Walk	76,664	76,659	-5	0.0%
SR	Walk	108,909	108,895	-14	0.0%
PM	Walk	98,598	98,589	-8	0.0%
OP	Walk	10,460	10,457	-3	0.0%
24-hour	Walk	440,063	440,016	-47	0.0%
AM	Cycle	17,030	17,027	-3	0.0%
LT	Cycle	6,051	6,048	-3	-0.1%
SR	Cycle	7,325	7,321	-4	-0.1%
PM	Cycle	16,463	16,460	-3	0.0%
OP	Cycle	1,242	1,237	-5	-0.4%
24-hour	Cycle	48,112	48,093	-18	0.0%
24-hour	All	1,783,951	1,869,819	85,868	4.8%

Further discussion on the level of changes made to the matrix for the road model are included in Section 11.3 and for the PT model in Section 11.4.

Table 11.25 shows large changes overall in the road model, generally of the magnitude of 6-7% although the OP time period shows a much larger change (17.5%). The PT demand shows larger increases, generally of the order of 15% in the peaks and off-peak time periods, although inter-peaks (LT and SR) show much more modest levels of change.

Figure 11.31 to Figure 11.34 gives the comparison of the changes between the Demand and Assignment matrices for each sector for the Road and PT matrices in the AM and PM periods.

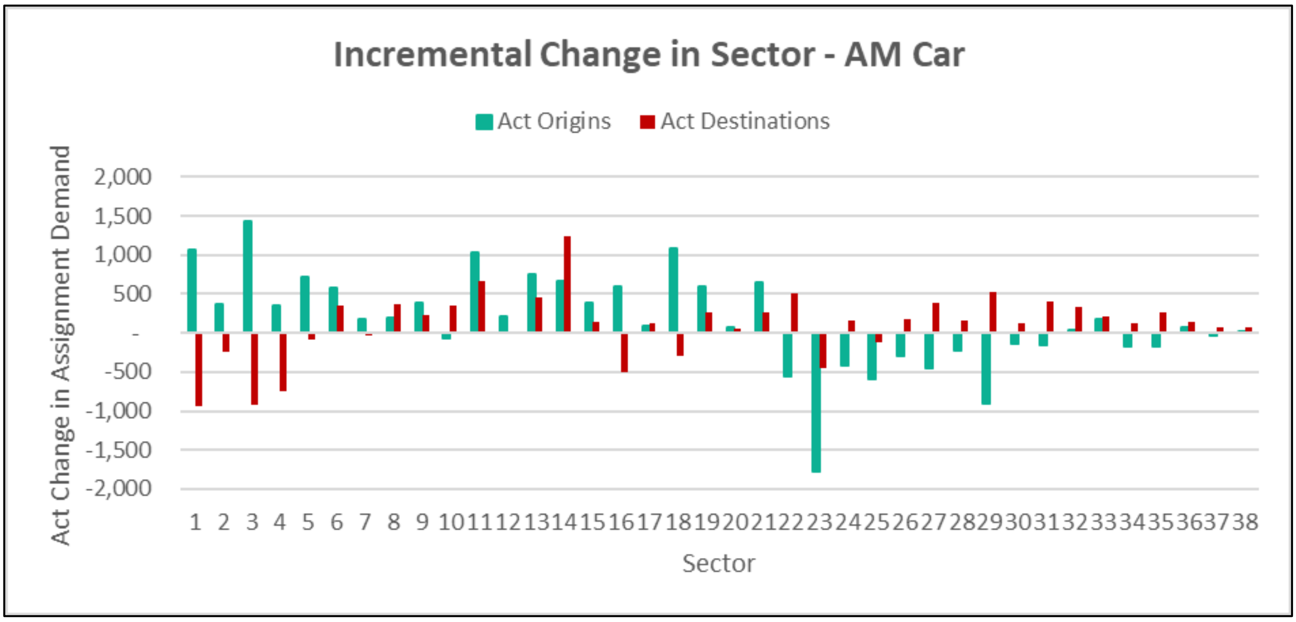


Figure 11.31 AM Car Summary of Changes in Incremental Adjustment by Sector

For the AM time period, there is a shifting of origins where the calibration of the road model matrices has increased the number of Dublin-based origins (sectors 1-10) and decreased the rural origins to the right of the chart.

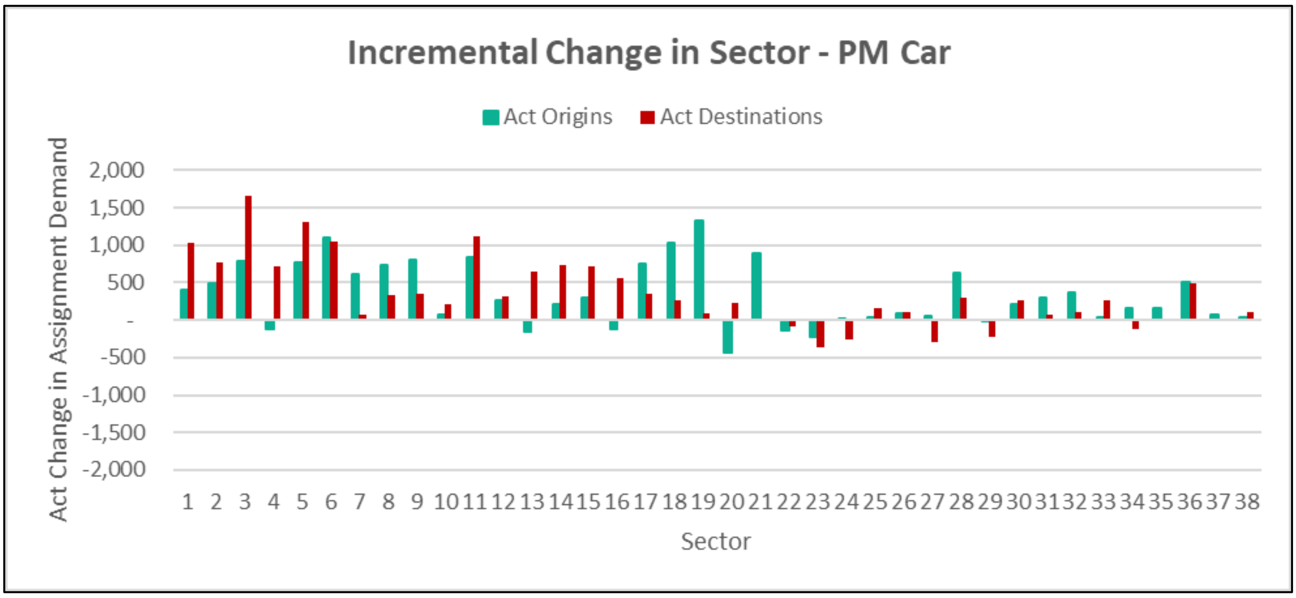


Figure 11.32 PM Car Summary of Changes in Incremental Adjustment by Sector

In the PM there is generally an icnrease in all sectors for both origins and destinations with the largest increase to destinations being in the lower numbered sectored which focus on urban Dublin.

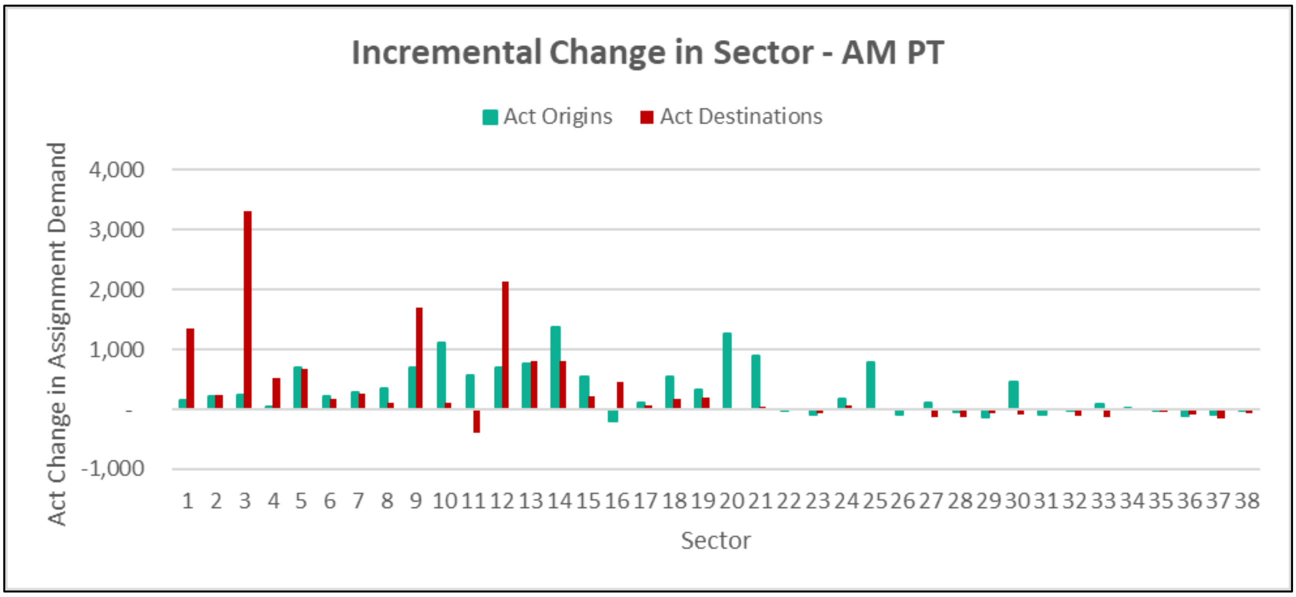


Figure 11.33 AM PT Changes in Incremental Adjustment by Sector

PT incrementals are almost universally increases suggesting the Demand Model cannot generate enough demand initially for PT and there is a clear focus for destinations to be increased towards sector 3 (the Central Business District). A similar trend exists in the reverse direction in the PM shown in Figure 11.34 where origins are increased from sector 3, but also everywhere else to a lesser extent.

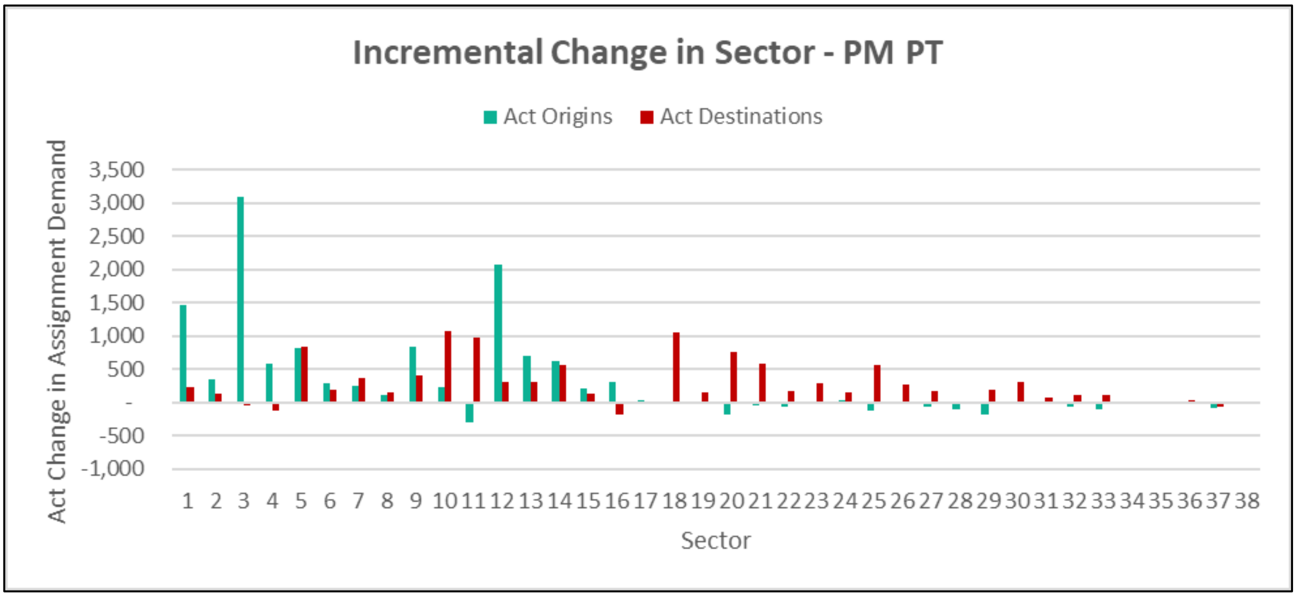
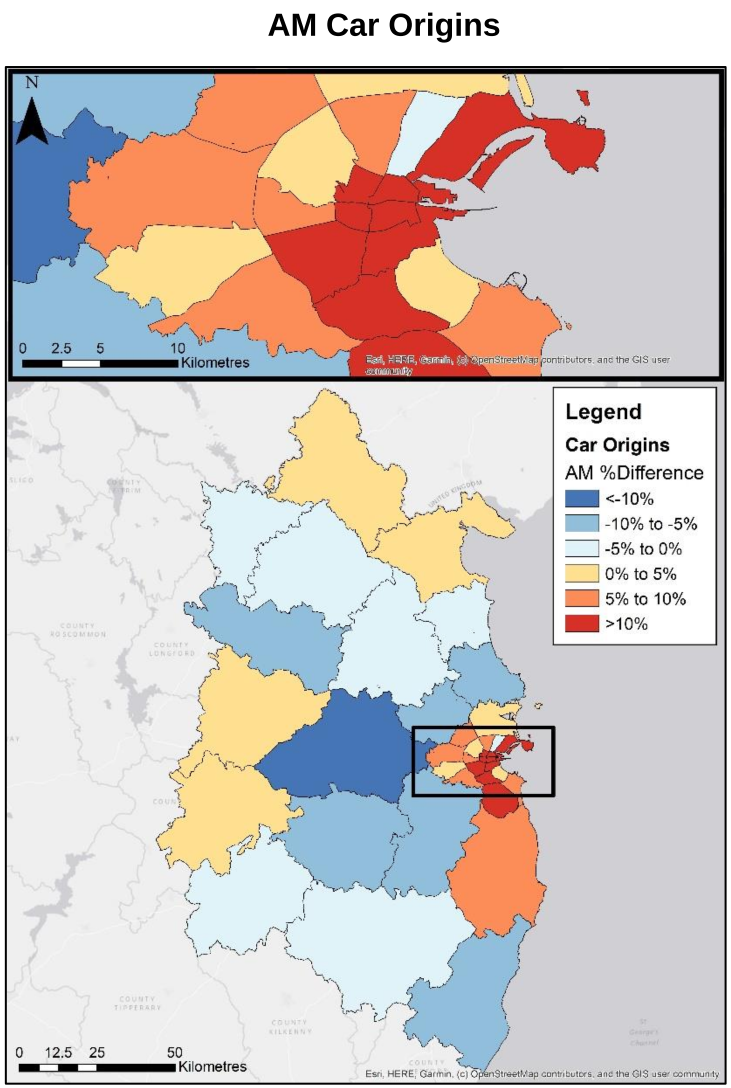


Figure 11.34 PM PT Changes in Incremental Adjustment by Sector

As a further summary of the changes that incrementals introduce, thematic maps presenting the percentage differences by sector for AM and PM time periods can be found in Figure 11.35 to Figure 11.38 for road and PT with green indicating a reduction and red/orange an increase due to incrementals.



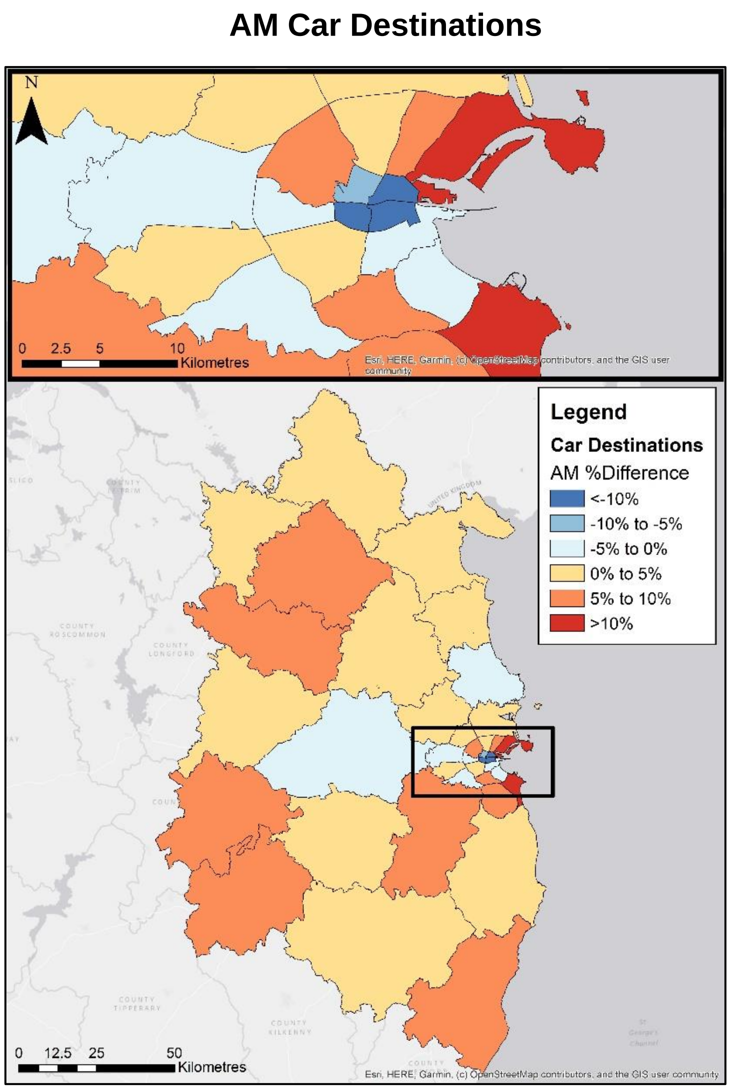
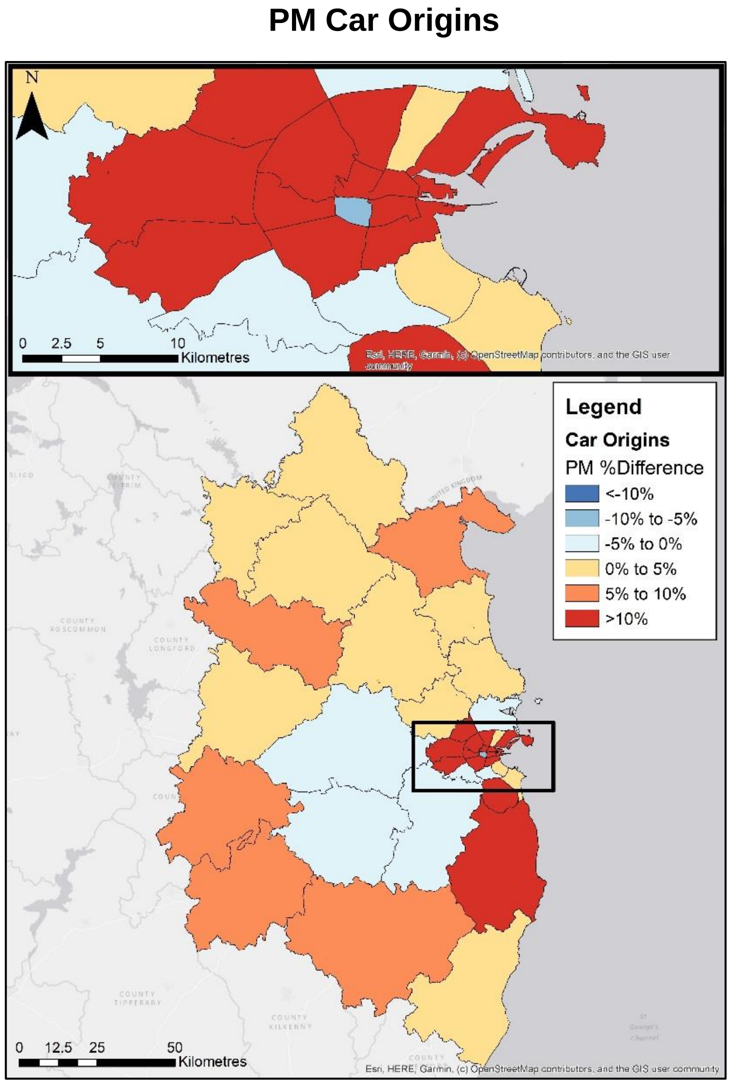


Figure 11.35 AM Car Incrementals % Difference by Sector



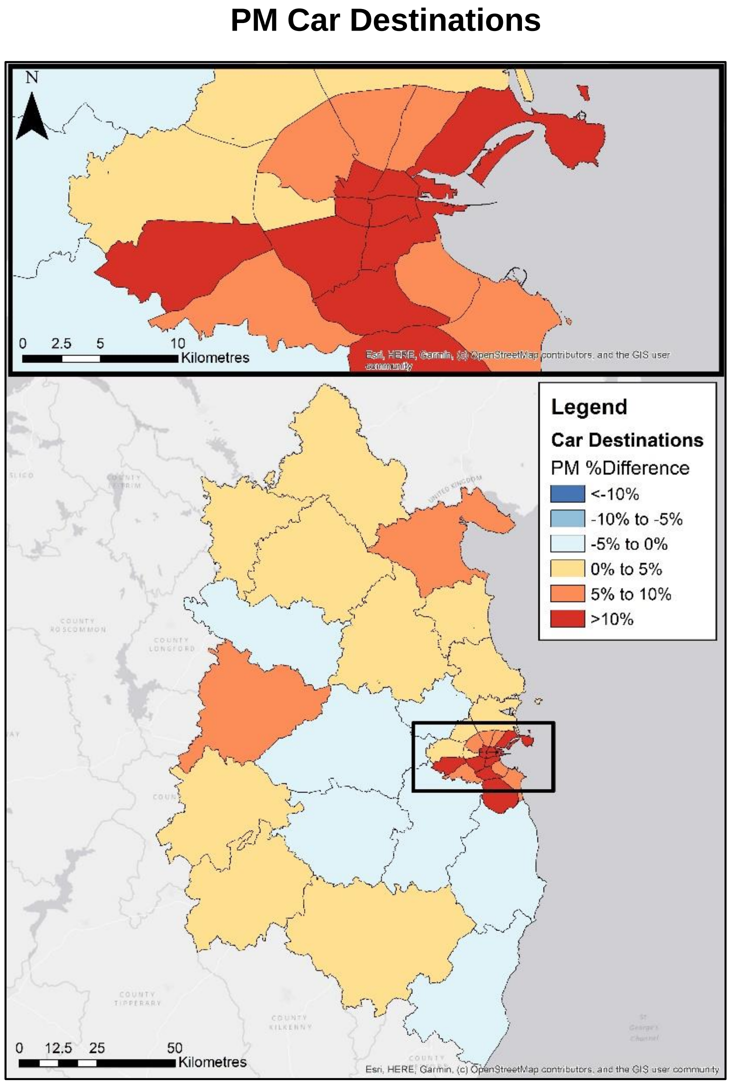


Figure 11.36 PM Car Incrementals % Difference by Sector

AM PT Origins **AM PT Destinations**

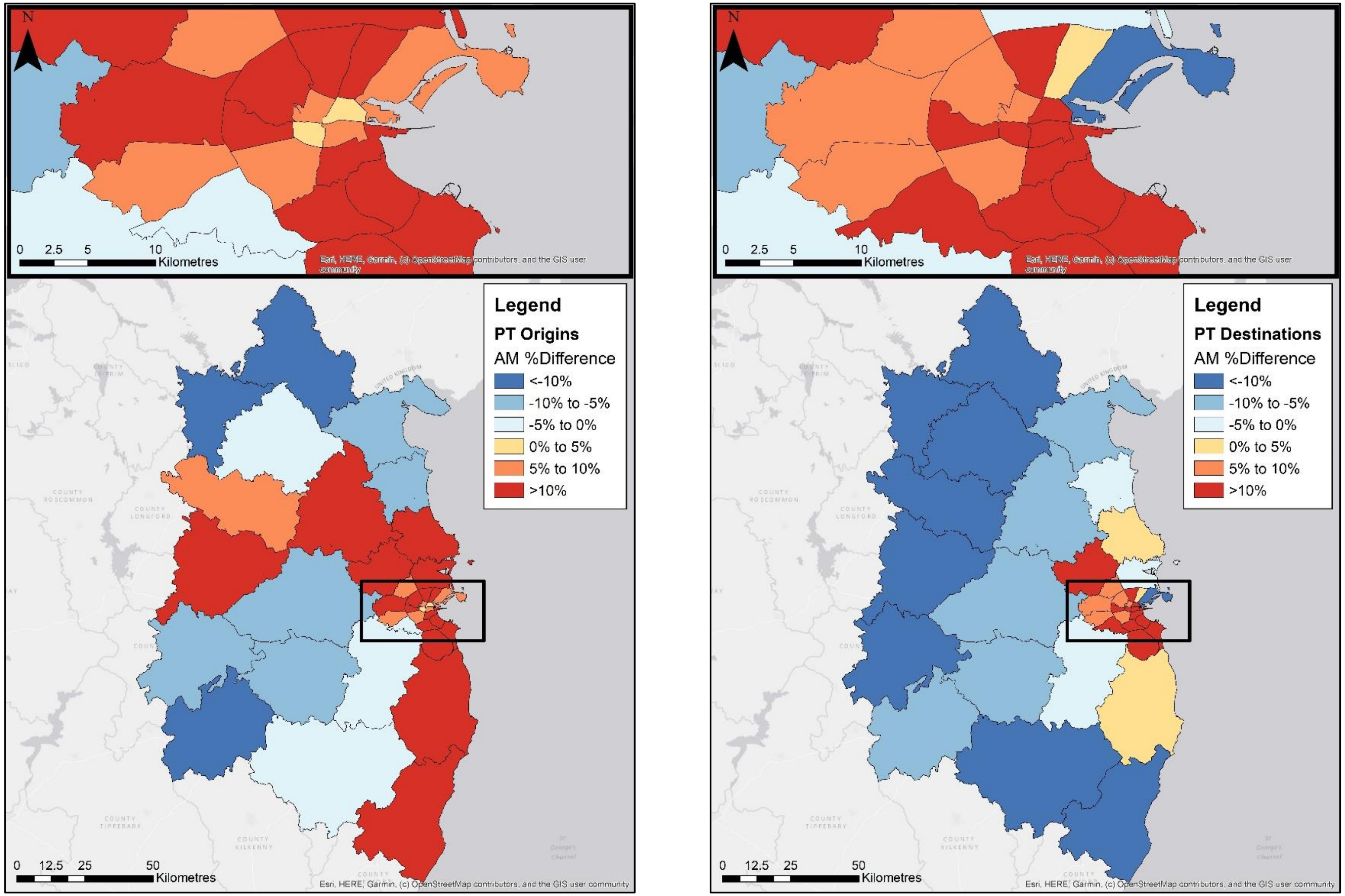
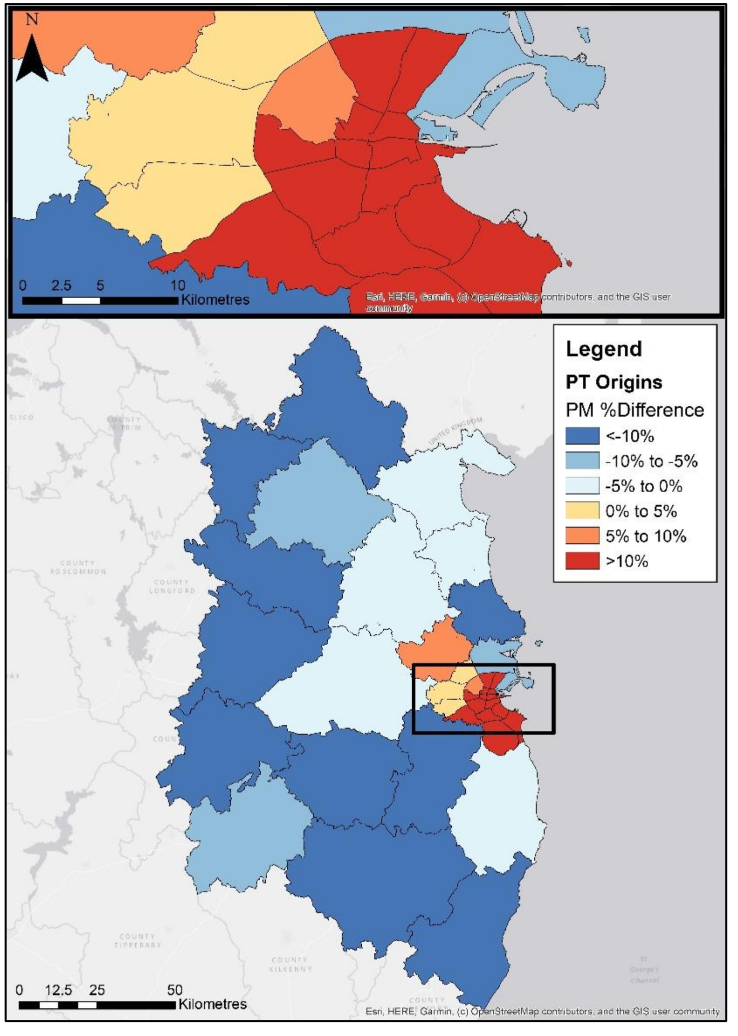


Figure 11.37 AM PT Incrementals % Difference by Sector

PM PT Origins



PM PT Destinations

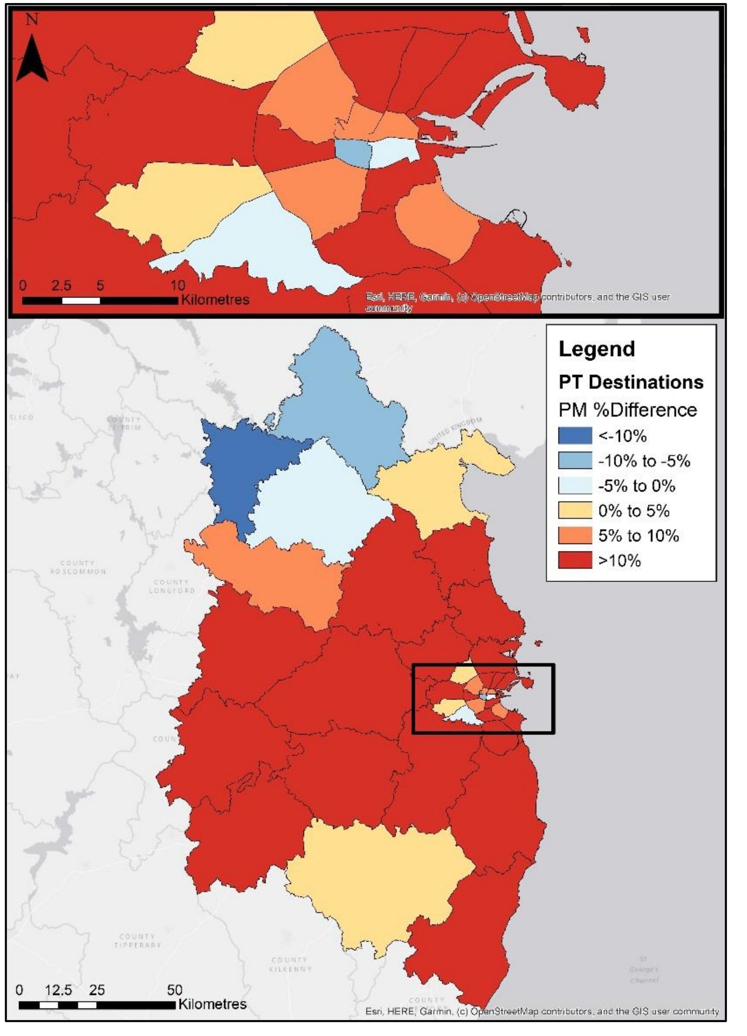


Figure 11.38 PM PT Incrementals % Difference by Sector

11.2.13 Demand Model Limitations and Recommendations

While the performance of the Demand Model is analysed and viewed as acceptable here, there are a number of items that could be improved upon in future versions of the model.

There are some notable differences between modelled and observed average generalised cost, mode share, and intrazonal movements, and the cause of these should be investigated and where possible addressed in future model versions. This is particularly pertinent for the employer's business and education user classes.

Park and Ride is noted to be based on limited data and has some large assumptions applied, particularly relating to the user classes which can choose it and how those trips will choose a site. Further investigation into alternative data sources and approaches should be considered as are discussed in Figure 11.22.

Both FWPP and Parking Distribution models have no observed occupancy data with which to validate against, so while the outputs of the model can be considered in terms of intuition and expectation, they cannot truly be validated against real-world usage and it is advised that this be addressed if possible.

While there is no recommendation for how large incremental adjustments should be within key guidance, steps should be taken to reduce the magnitude and impact of these parameters where possible to ensure the model is appropriately capturing trends rather than relying on final adjustments.

11.2.14 Demand Model Calibration – Summary

The above sections describe the performance of the Demand Model and how it replicates observed data (from the NHTS and POWSCAR) at critical stages of the model. Most of the focus is on replicating mode share and evaluating how the model responds to parking charges and availability of parking spaces. Overall, the model can be seen to represent a good fit of observed data and to respond intuitively in areas where no observed data exists. Where issues exist in terms of goodness of fit, these have been highlighted and recommendations made for later updates of the model.

11.3 Road Model Calibration and Validation

The road model is a key element of the model with extensive criteria that must be met to be considered compliant. The calibration and validation criteria set out in Chapter 7 included:

- Road traffic flow comparisons;
- Screenline comparisons;
- Journey time comparisons; and
- Convergence.

These indicators are considered for both the prior matrices and the final "post" matrix estimation matrices to provide information on the improvements that are introduced through matrix estimation and to provide confirmation that the process is therefore required.

In addition to these indicators of the performance of the final model, there is a significant focus within guidance such as UK TAG that any adjustment processes such as matrix estimation do not substantially alter the matrix. While any specific criteria can be relaxed in certain circumstances such as where the model is developed using synthetic matrices as this case, any changes will still have an influence away from the Demand Model derived matrices and thus could be detrimental to the overall model performance in application and should be monitored.

For these reasons, we consider the following comparisons of prior and post- estimation assignment matrices:

- Changes in trip ends;
- Changes in trip length; and
- Cellular and sector changes in the matrix.

11.3.1 Assignment Calibration

Individual Link Counts (All Vehicles)

Traffic flow comparisons have been undertaken and assessed against UK TAG recommended criteria, as set out in Chapter 7, for calibration.

A summary of the total traffic flow calibration comparisons is reported in Table 11.26.

Table 11.26 Road Model Calibration (All Vehicle Types)

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	83%	81%	87%	95%
LT	89%	87%	92%	96%
SR	85%	82%	89%	94%
PM	82%	80%	88%	93%
OP	97%	92%	97%	98%

All time periods have greater than 80% of links meeting the UK TAG link flow criteria, with LT, SR and OP periods exceeding the UK TAG recommended criteria of 85% of links meeting the criteria. All time periods have greater than 80% of links with a GEH value less than 5, with LT and OP periods exceeding the UK TAG recommended criteria of 85% of links meeting the criteria. All time periods have greater than 90% of links with a GEH value of less than 10.

With such a large number of counts in this model it can be difficult to evaluate model performance meaningfully across all locations. One measure is to plot the observed and modelled flows on a scatter chart to compare the following trends:

- Correlation, R^2, which should approach 1;
- Slope gradient, which should be close to 1; and

- Intercept, which should be nearly zero.

Scatter charts, presented in Figure 11.39 to Figure 11.43 present calibration count correlation separately for all time periods.

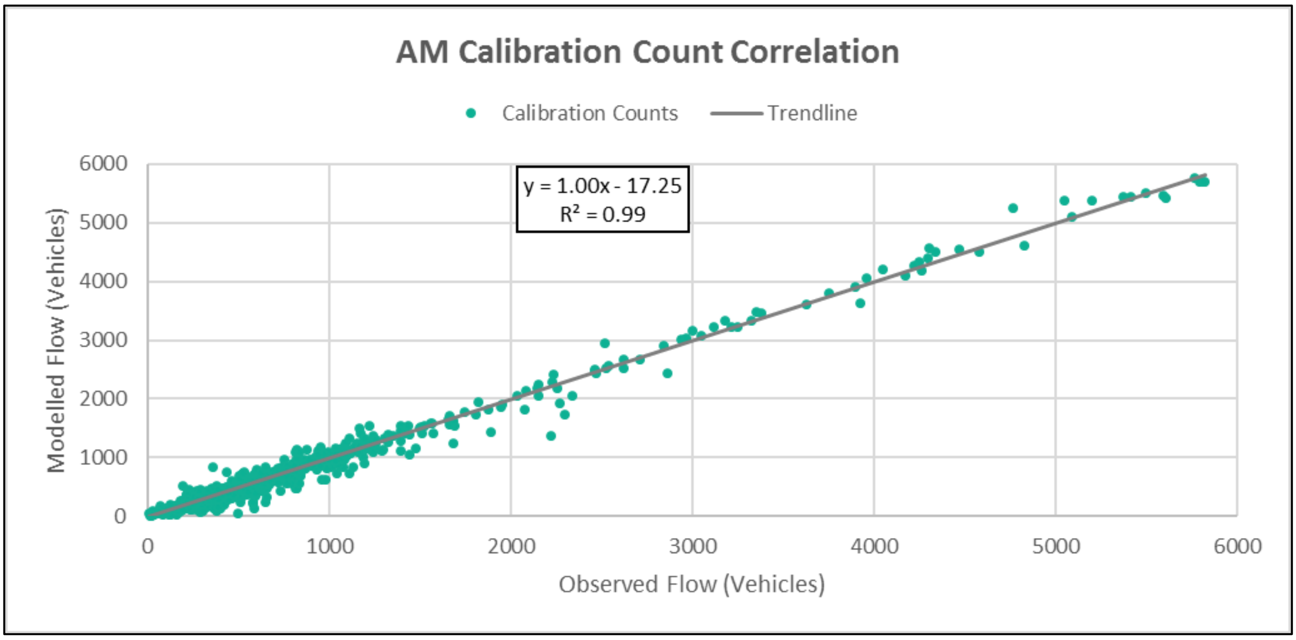


Figure 11.39 AM Individual Calibration Count Correlation

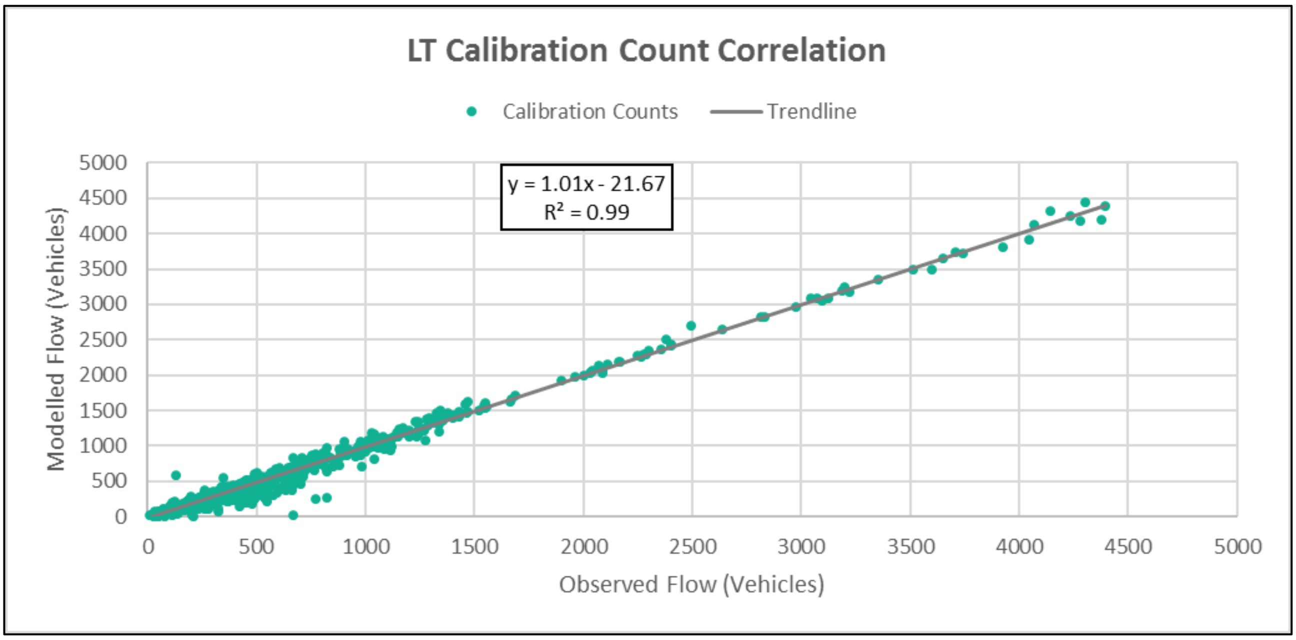


Figure 11.40 LT Individual Calibration Count Correlation

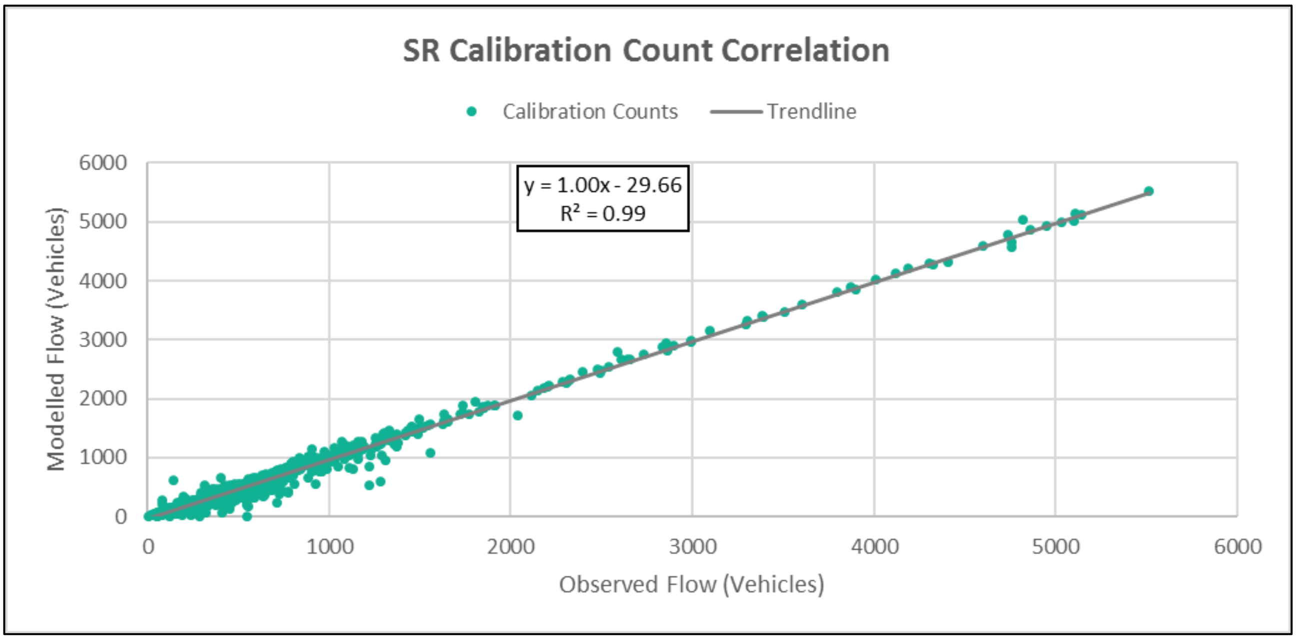


Figure 11.41 SR Individual Calibration Count Correlation

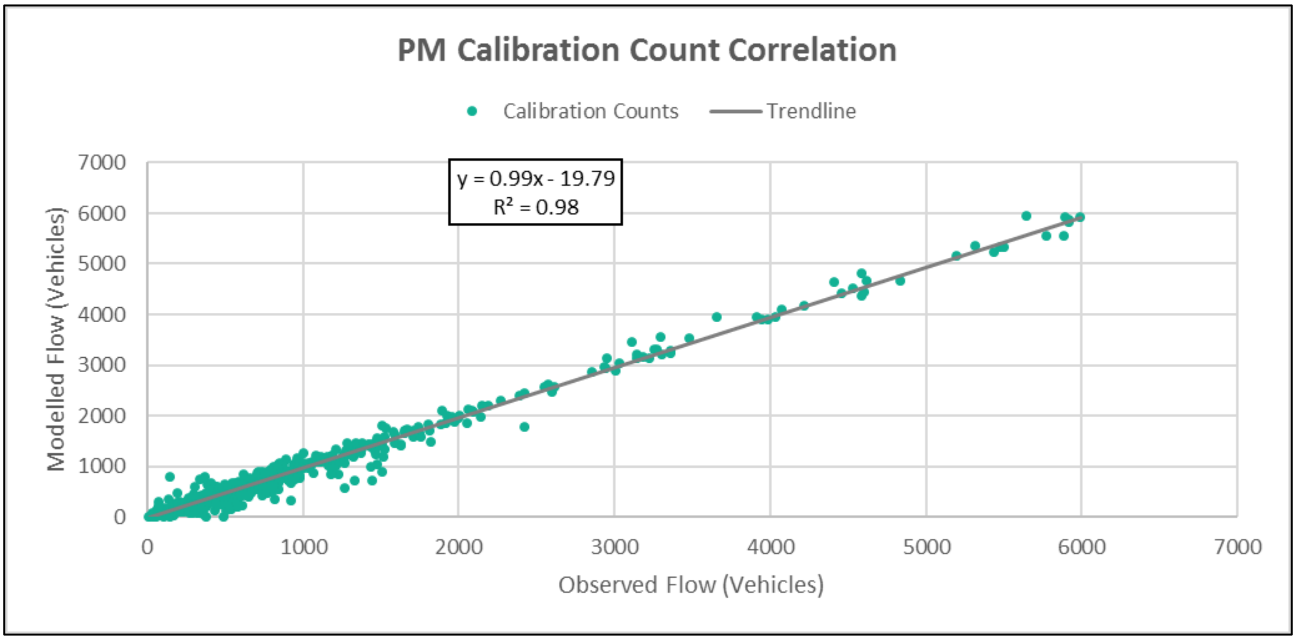


Figure 11.42 PM Individual Calibration Count Correlation

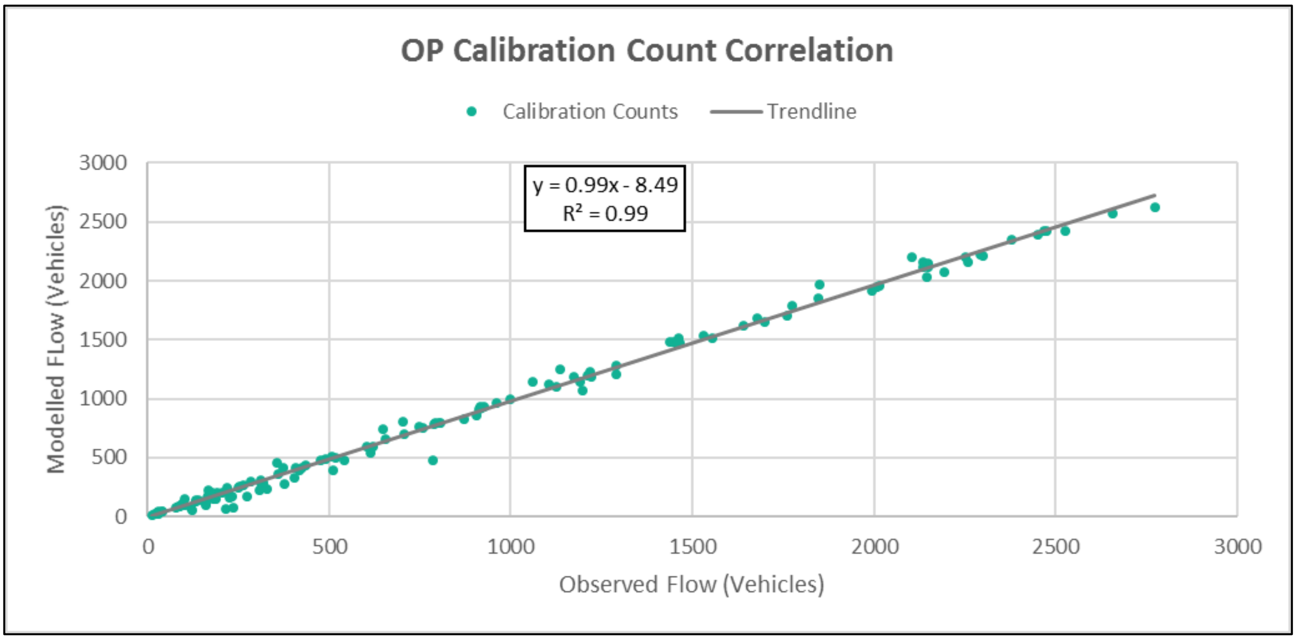


Figure 11.43 Individual Calibration Count Correlation

All time periods demonstrate an excellent level of calibration count correlation, with the best fit line displaying a gradient of near 1, and an R^2 greater than 0.98 in all cases.

A summary of these statistics for all time periods is presented in Table 11.27.

Table 11.27 Summary of Road Count Correlation by Time Period

TP	R^2	Slope	Intercept
AM	0.99	1.00	-17.25
LT	0.99	1.01	-21.67
SR	0.99	1.00	-29.66
PM	0.98	0.99	-19.79
OP	0.99	0.99	-8.49

While the statistics above provide useful information on overall levels of calibration and validation, further trends can be identified by considering the spatial layout of the performance of the counts.

The spatial GEH performance for the AM time period is displayed in Figure 11.44 and Figure 11.45, with those for the remaining time periods shown inthe Addendum.

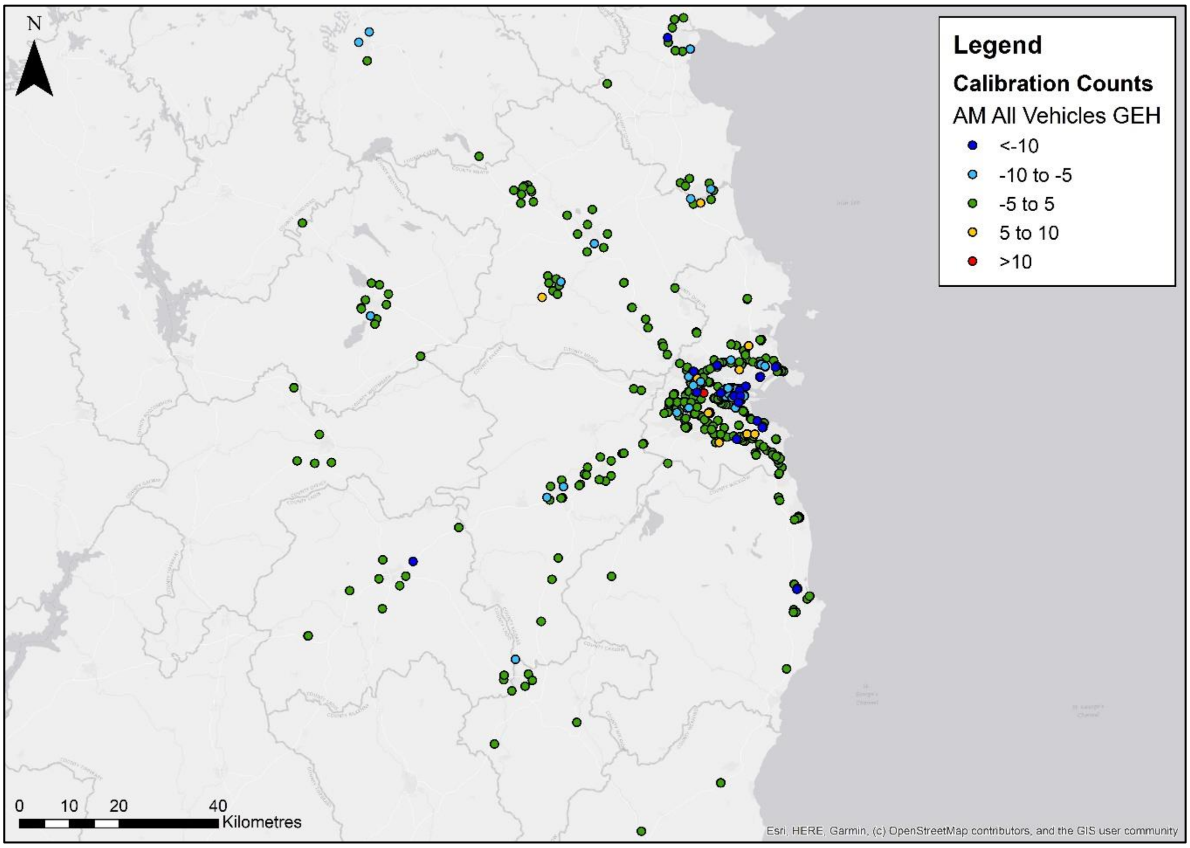


Figure 11.44 AM Spatial GEH Performance (All Vehicle Types, Model Area)

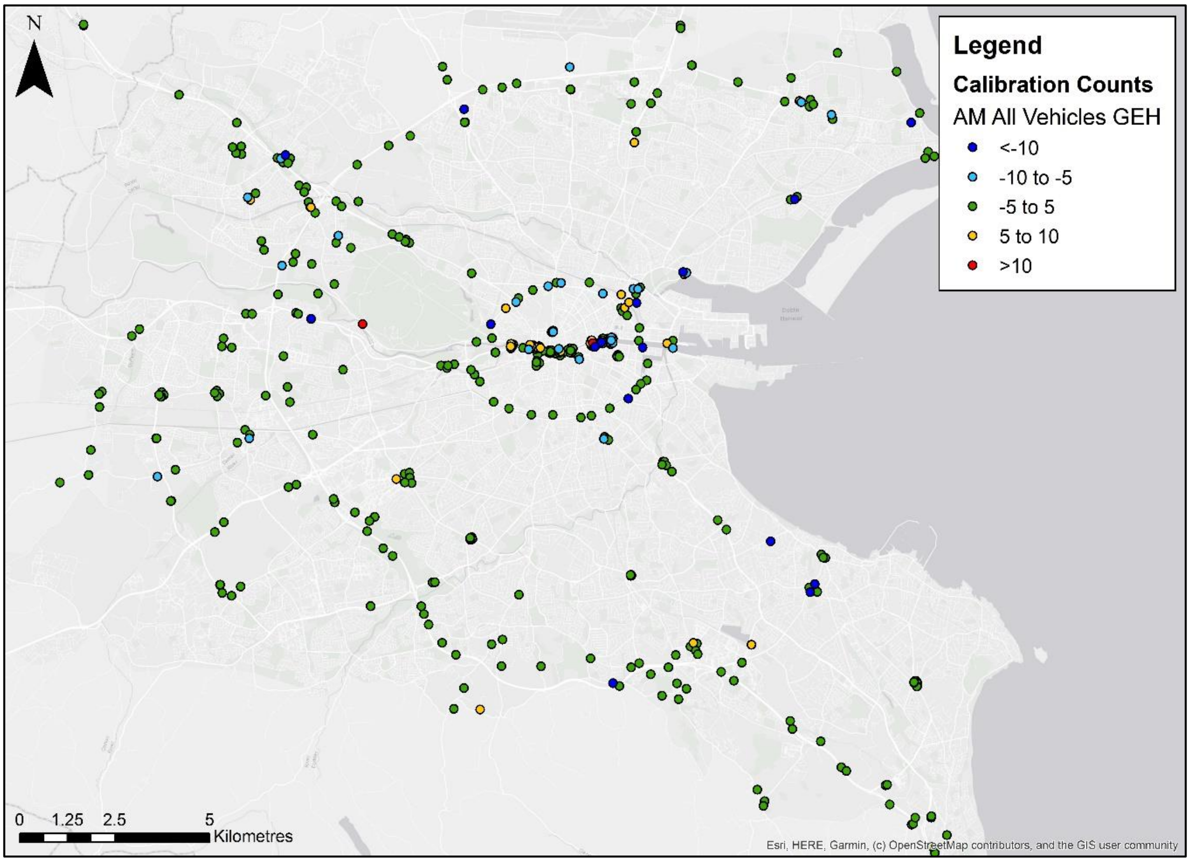


Figure 11.45 AM Spatial GEH Performance (All Vehicle Types, Dublin Area)

LGV

Considering LGVs separately, LGV individual flow performance, summarised in Table 11.28 indicates that at least 99% of flows in each time period meet the UK TAG criteria for flows. For LGVs, which typically have a lower observed volume, this is not a difficult criterion to meet, as all observed flows are less than 700 meaning modelled flows should be within 100 vehicles.

A better measure of the LGV performance is the GEH statistic. For LGVs at least 96% of links in each time period have a GEH of less than 5, with nearly all links having a GEH of less than 10.

Table 11.28 LGV Traffic Flow Comparisons

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	99%	97%	99%	99%
LT	99%	96%	97%	99%
SR	99%	96%	97%	99%
PM	99%	96%	98%	99%
OP	100%	96%	99%	100%

The spatial GEH performance for the AM time period is displayed in Figure 11.46 and Figure 11.47, with those for the remaining time periods shown in the Addendum.

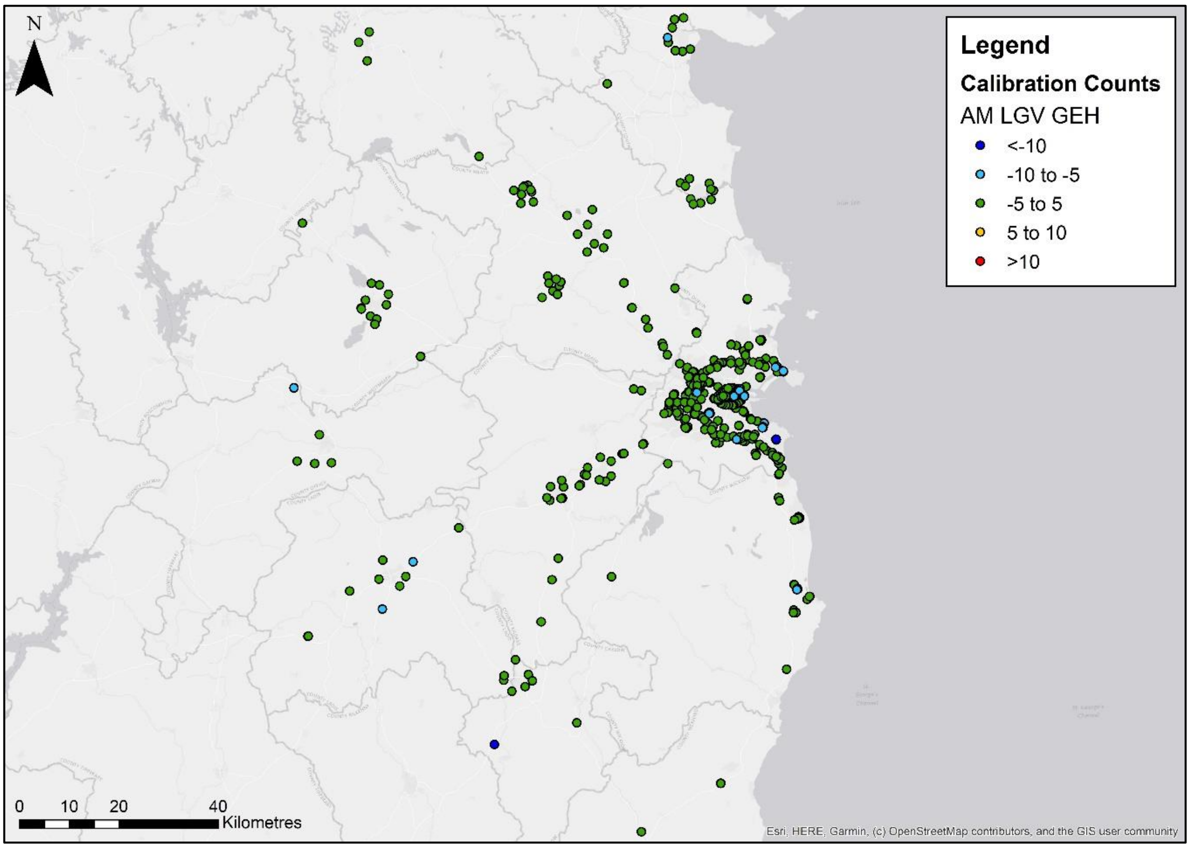


Figure 11.46 AM Spatial GEH Performance (LGVs Only, Model Area)

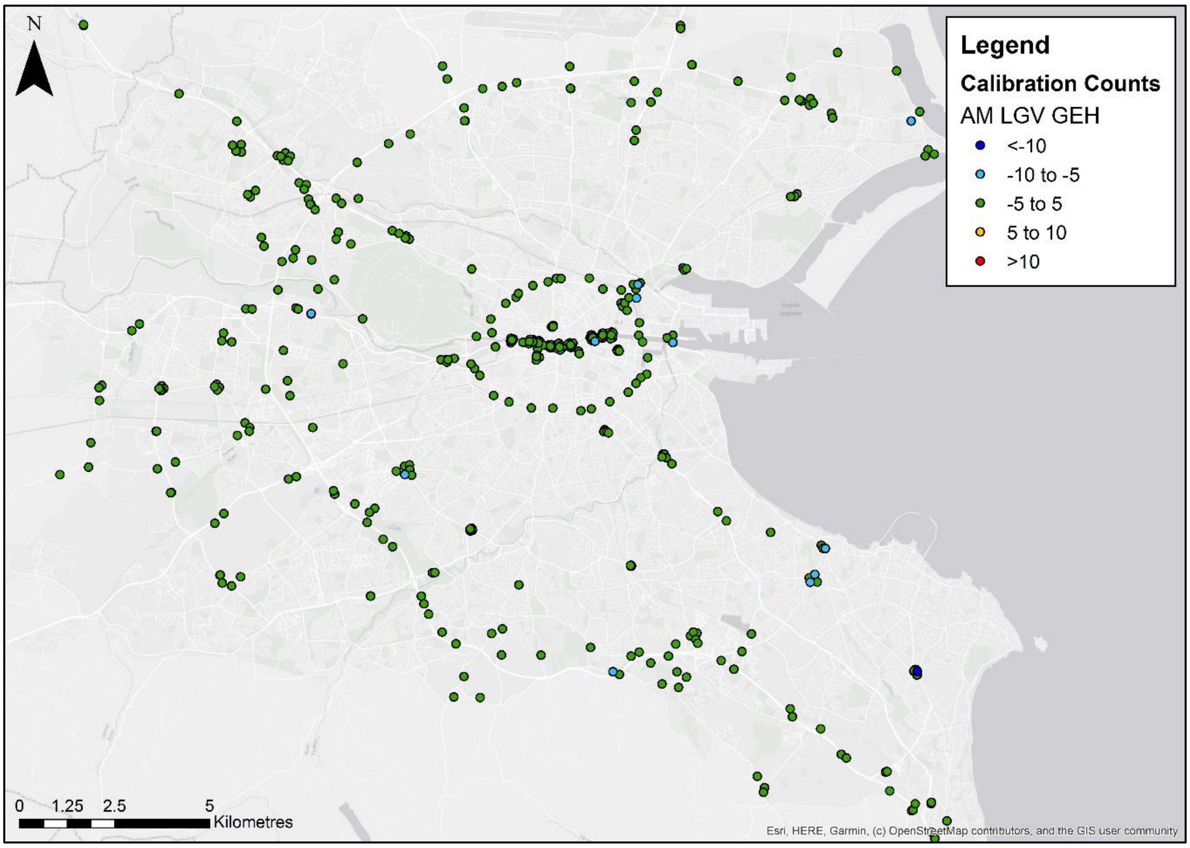


Figure 11.47 AM Spatial GEH Performance (LGVs Only, Dublin Area)

HGV

HGV individual flow performance, summarised in Table 11.29, indicates that 99% of flows in each time period meet the UK TAG criteria for flows. Much like LGVs, HGV observed volumes are typically below 700, meaning modelled flows should be within 100 vehicles to meet the UK TAG criteria. A better measure of the HGV performance is therefore the GEH statistic. For HGVs at least 96% of links in each time period have a GEH less than 5.

Table 11.29 HGV Traffic Flow Comparisons

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	100%	98%	99%	99%
LT	100%	97%	98%	99%
SR	100%	97%	98%	98%
PM	100%	96%	97%	97%
OP	100%	95%	99%	99%

The spatial GEH performance for the AM time period is displayed in Figure 11.48 and Figure 11.49, with those for the remaining time periods shown in the Addendum.

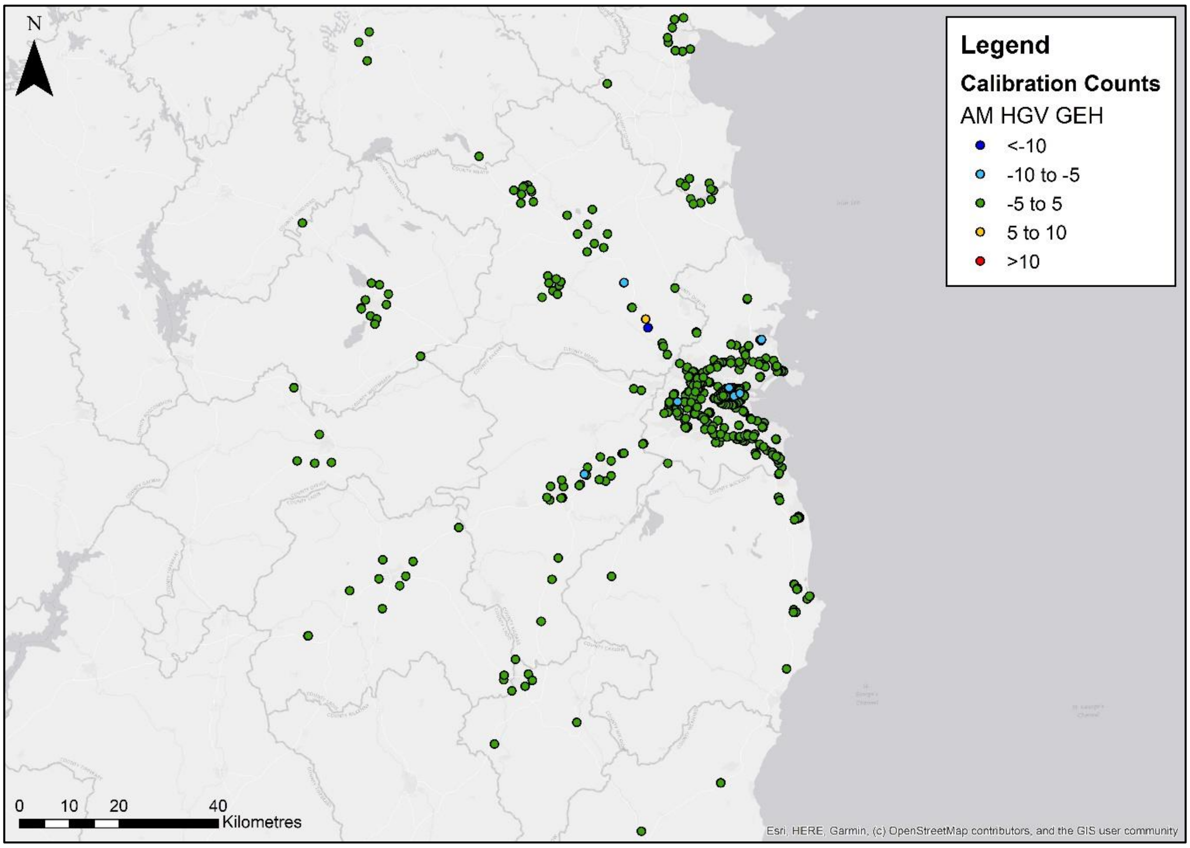


Figure 11.48 AM Spatial GEH Performance (HGVs Only, Model Area)

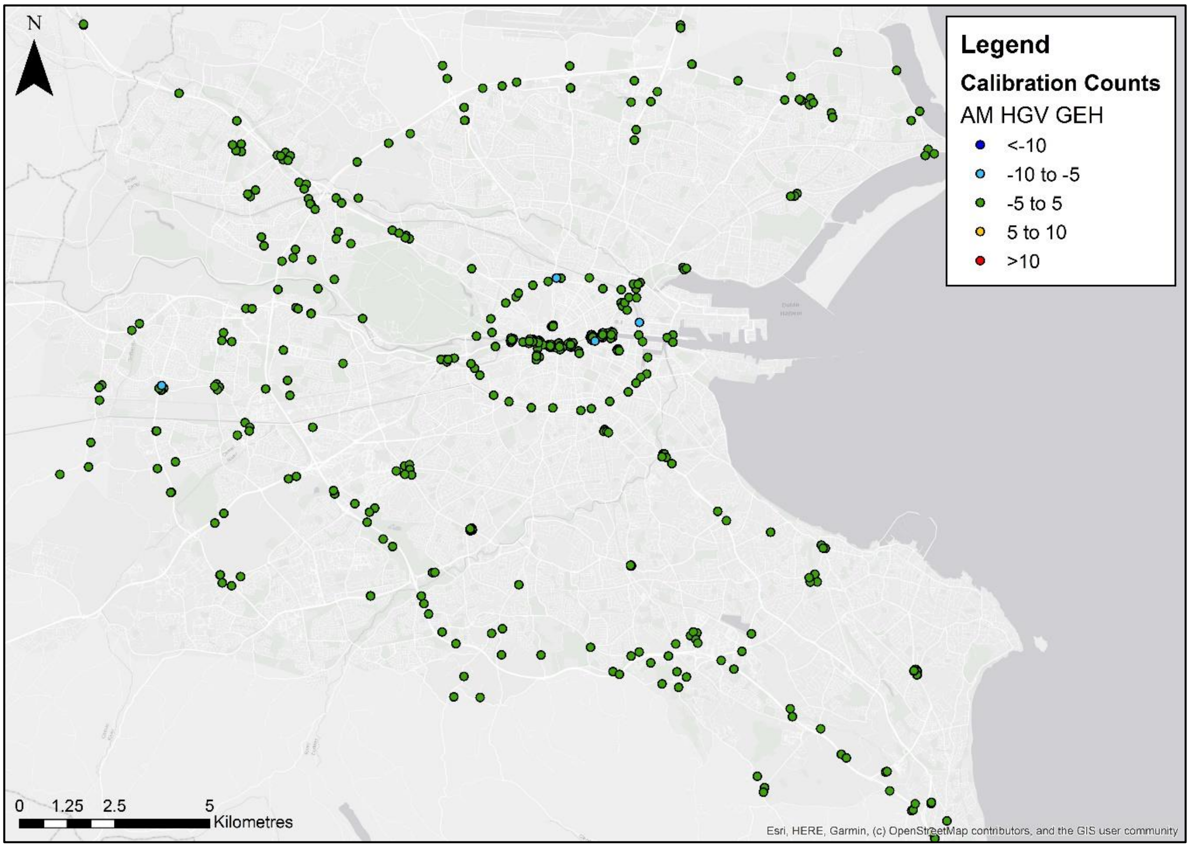


Figure 11.49 AM Spatial GEH Performance (HGVs Only, Dublin Area)

Taxis

A specific requirement of the ERM was to better represent taxis within the matrices and assignment model. Initial taxi matrices were derived on a sector-to-sector proportion of "Car Other" trips. These were then estimated to a limited set of taxi traffic counts. The scale of the change presented in Section 11.3.3 indicates that matrix estimation made significant changes to the original taxi matrix in order to match the observed data. Table 11.30 below compares Taxi Flows in various time periods.

Table 11.30 Taxi Flow Comparisons

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	98%	90%	97%	99%
LT	100%	97%	99%	99%
SR	100%	93%	98%	99%
PM	99%	93%	98%	99%

As all observed taxi link flow data is under 700 vehicles per hour, the applicable UK TAG criteria recommend modelled flows be within 100 vehicles. Therefore, while a reasonable number of links meet this criterion, the overall difference between the observed and modelled flows and the GEH performance indicate that the taxi matrix is larger than observed levels.

No taxi data was available for the OP period.

Screenlines (All Vehicles)

As noted in Chapter 7, screenlines have been used as a model calibration tool as opposed to a matrix validation tool. The matrix validation criteria set out in UK TAG Unit M3.1 and presented in Chapter 7 has been applied to the calibration of the screenlines.

UK TAG recommends presenting results both with and without high flow routes. As all or nearly all screenlines in the ERM contain high flow routes, such as motorways or national roads, this has not been undertaken.

In addition to individual link flow calibration, groupings of five or more individual link counts that form a geographic screenline are assessed against the UK TAG recommended criteria of modelled flows within 5% of observed flows. The overall screenline performance is presented in Table 11.31 by time period, with individual screenline performance presented in the Addendum.

Table 11.31 Road Model Screenline Calibration (All Vehicle Types)

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
AM	46%	75%	52%
LT	37%	62%	58%
SR	29%	62%	42%

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
PM	38%	58%	46%

The screenline performance summarised in in Table 11.31 and the Addendum, indicate that while no time period achieves TAG's recommended criterion of all or nearly all screenlines within 5% of observed levels, performance across the key screenlines of the River Liffey, Grand and Royal Canals and the M50 are reasonable.

The River Liffey screenline is within 5% of observed levels in both directions in the AM and PM time periods, and Northbound in the LT and SR time periods.

Aggregating the Grand and Royal Canal and M50 screenlines into inbound and outbound cordons results in both directions of each time period having modelled flows within 5% of observed levels indicating that cumulative travel demand to and from Dublin and Dublin city centre is accurately represented in the model.

Maps of screenlines are included in the Addendum, by time period, and an example of the AM is provided in Figure 11.50 to Figure 11.53.

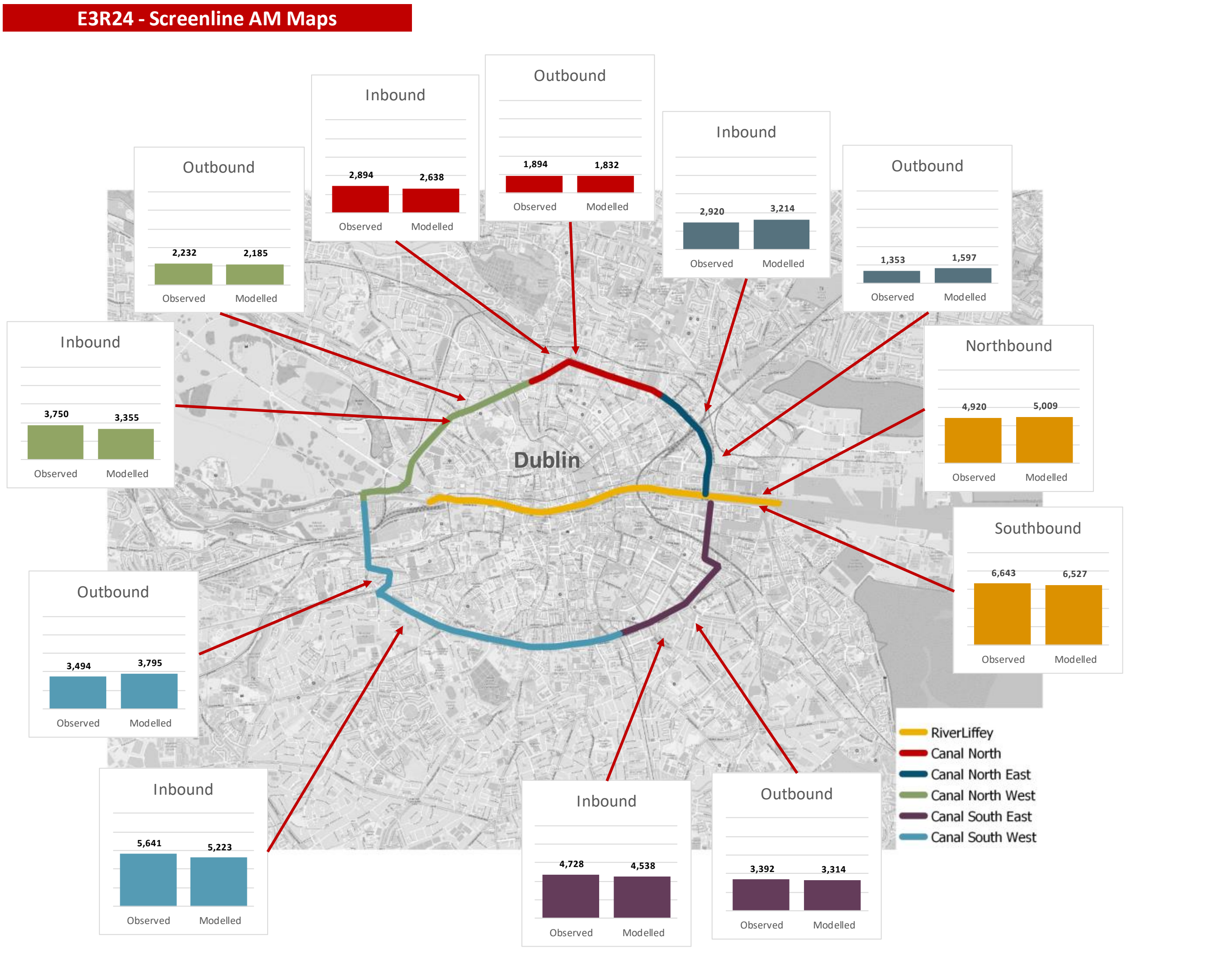


Figure 11.50 AM Road Screenline Comparison 1 – Canal Screenlines and River Liffey

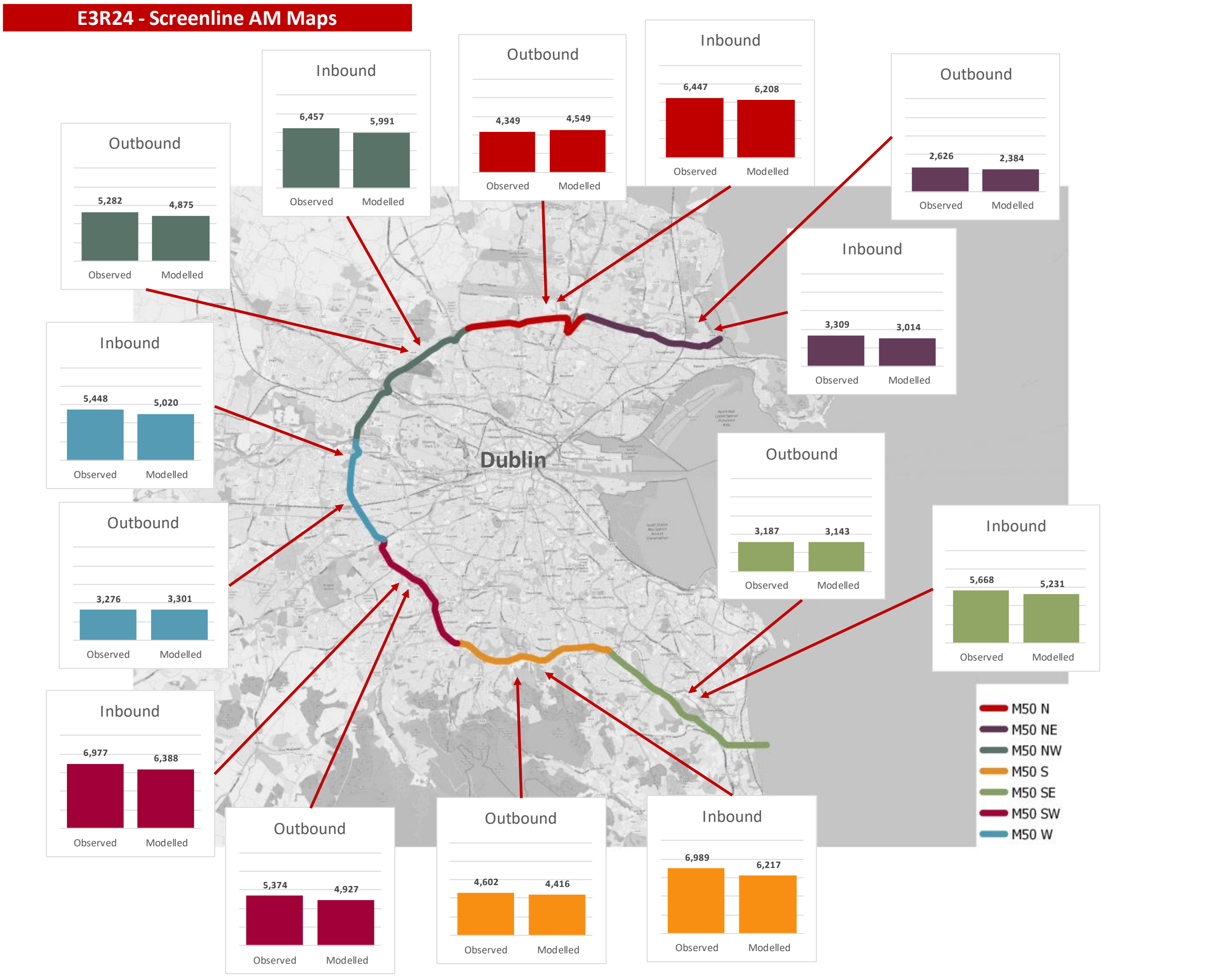


Figure 11.51 AM Road Screenline Comparison 2 – M50 Screenlines

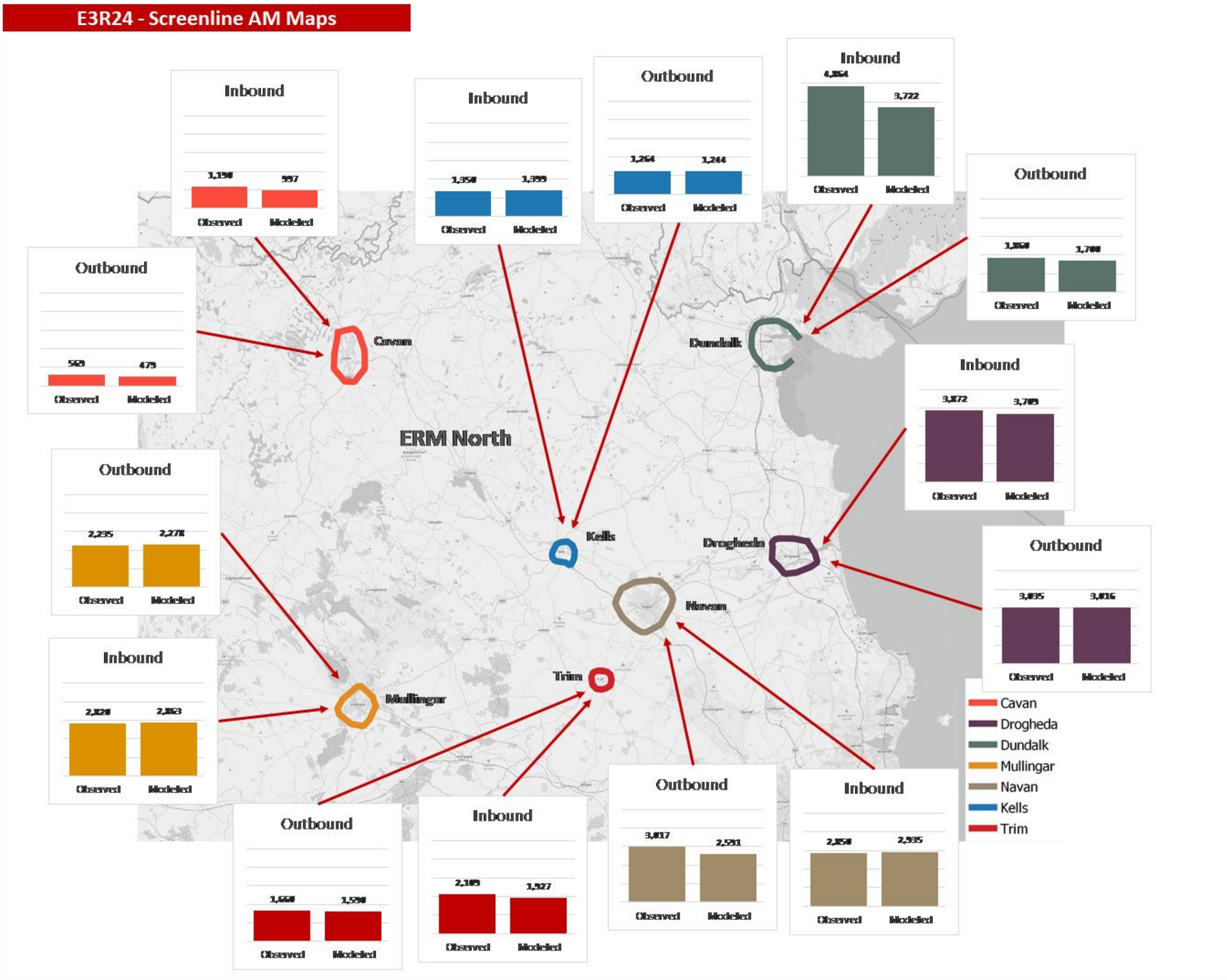


Figure 11.52 AM Road Screenline Comparison 3 – Northern Towns Screenlines

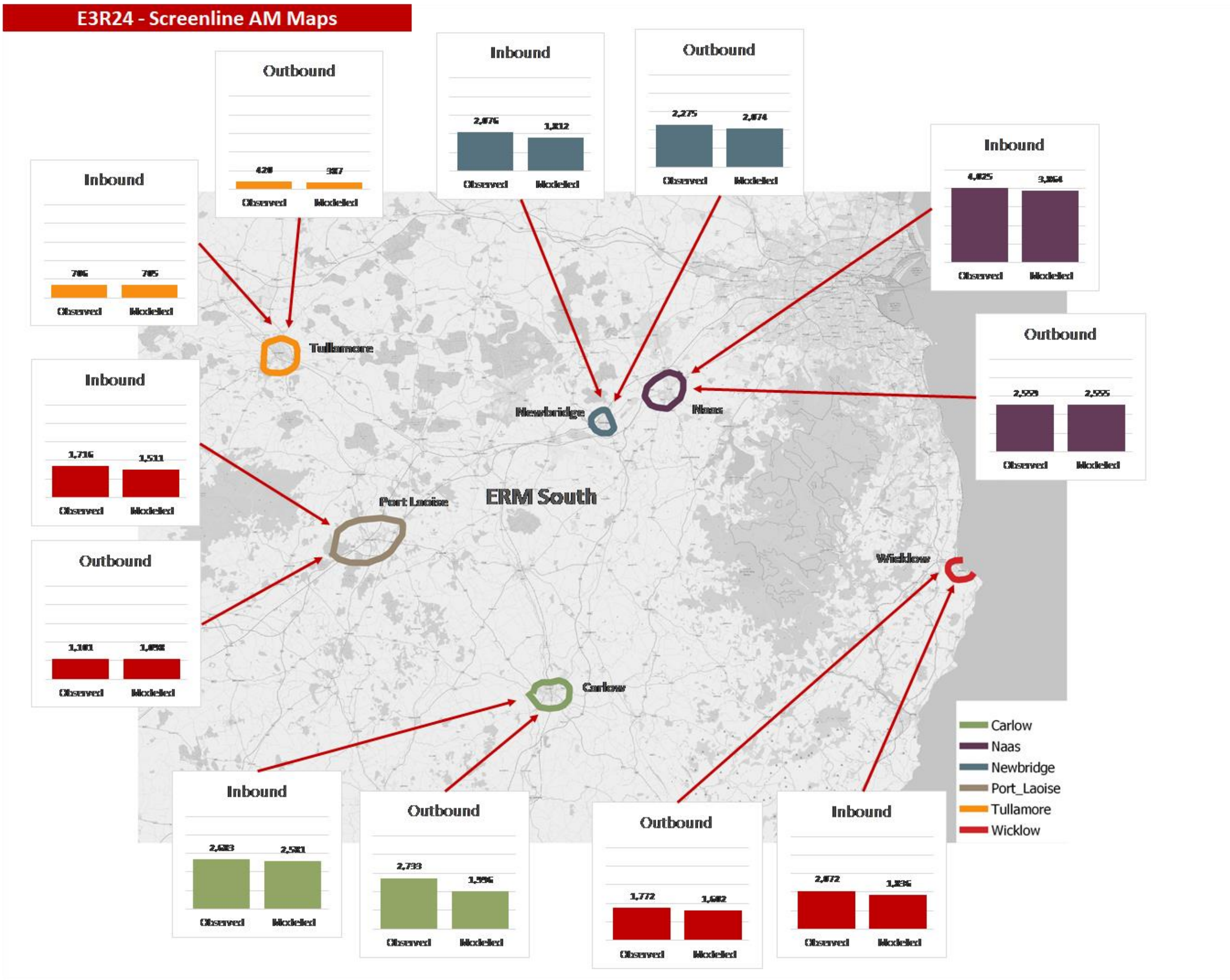


Figure 11.53 AM Road Screenline Comparison 4 – Southern Towns Screenlines

Car Screenlines

Car screenline performance, summarised in Table 11.32, indicates lower levels of performance when compared to the total traffic, LGV or HGV comparisons.

Table 11.32 Car Screenline Comparison

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
AM	42%	62%	64%
LT	35%	58%	73%
SR	15%	50%	52%
PM	40%	58%	52%

Table 11.33 indicates that aggregating the screenlines into key strategic cordons indicates good model representation of car traffic traveling to and from Dublin and Dublin city centre.

The Addendum contains detail regarding the individual performance of each car screenline.

Table 11.33 Car Key Aggregated Screenline Differences

	AM	LT	SR	PM
Canal North Inbound	-4%	-2%	-4%	5%
Canal North Outbound	4%	-5%	-9%	0%
Canal South Inbound	-6%	-12%	-8%	0%
Canal South Outbound	4%	-12%	-13%	-8%
M50 North Inbound	-7%	-3%	-8%	-3%
M50 North Outbound	-4%	-6%	-6%	-3%
M50 South Inbound	-10%	-4%	-8%	-10%
M50 South Outbound	-5%	-5%	-7%	-9%
M50 West Inbound	-11%	-1%	-6%	0%
M50 West Outbound	1%	-11%	-4%	-8%

LGV Screenlines

LGV screenline performance, summarised in Table 11.34, indicates a reasonable level of performance in the LT time periods with 73% of screenlines having a modelled flow within 5% of observed levels. AM, SR, and PM performance is marginally poorer at 60%, 63% and 54% respectively.

Table 11.34 LGV Screenline Comparison

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
AM	60%	83%	100%
LT	73%	89%	100%
SR	63%	87%	98%
PM	54%	85%	96%

Table 11.35 indicates that aggregating the screenlines into key strategic cordons indicates good model representation of LGV traffic traveling to and from Dublin and Dublin city centre, with the exception of the M50 West (Inbound) screenline in the LT and SR time periods.

The Addendum contains detail regarding the individual performance of each LGV screenline. All modelled LGV screenline flows are within 100 vehicles of observed levels in each time period.

Table 11.35 LGV Key Aggregated Screenline Differences

	AM	LT	SR	PM
Canal North Inbound	-3%	-2%	-3%	-4%
Canal North Outbound	-2%	-2%	-2%	-5%
Canal South Inbound	-6%	-3%	-3%	-3%
Canal South Outbound	-3%	-1%	-3%	-2%
M50 North Inbound	-1%	-1%	2%	-2%
M50 North Outbound	-1%	-5%	-2%	-2%
M50 South Inbound	-3%	4%	6%	-2%
M50 South Outbound	-7%	-1%	-4%	-6%
M50 West Inbound	7%	14%	21%	-1%
M50 West Outbound	0%	0%	-3%	-5%

HGV Screenlines

Table 11.36 summarises the HGV screenline performance across the 52 ERM screenlines. While no time period meets the UK TAG recommended criteria of 85% of screenlines having a modelled flow within 5% of observed HGV levels, the AM, LT, and SR time periods demonstrate a reasonable level of calibration. The PM peak period is marginally worse, with 42% of screenlines meeting the UK TAG criteria.

Table 11.36 HGV Screenline Comparison

Time Period	Screenlines within 5%	Screenlines within 10%	GEH < 4
AM	58%	67%	100%
LT	52%	73%	98%
SR	60%	71%	98%
PM	42%	67%	98%

Table 11.37 indicates that aggregating the screenlines into key strategic cordons indicates good model representation of HGV traffic traveling to and from Dublin and Dublin city centre, with the exception of the M50 West (Inbound) screenline in the LT and SR time periods and the and the Canal North screenline.

The Addendum contains detail regarding the individual performance of each HGV screenline. All modelled flows are within 50 vehicles of observed levels in each time periods, with the exception of the M50 West Inbound screenline in the PM peak period (+58).

Table 11.37 HGV Key Aggregated Screenline Differences

	AM	LT	SR	PM
Canal North Inbound	-13%	-1%	-6%	-20%
Canal North Outbound	-30%	-28%	-34%	-36%
Canal South Inbound	-7%	1%	-3%	-8%
Canal South Outbound	1%	4%	3%	-8%
M50 North Inbound	-1%	-6%	-2%	-2%
M50 North Outbound	-2%	-6%	-3%	-6%
M50 South Inbound	-1%	-1%	-2%	-1%
M50 South Outbound	6%	-2%	-1%	-17%
M50 West Inbound	2%	17%	27%	69%
M50 West Outbound	1%	5%	-1%	-6%

11.3.2 Network Validation

The UK TAG guidance recommends that a number of origin-to-destination (OD) pairs are examined to ensure that the route choice between them is logical. The number that should be checked is dependent on the number of zones within the model (1,953) and the number of user classes represented by the assignment (10). The formula for calculating the recommended number of OD pairs is:

$$Number\ of\ OD\ Pairs = \ Number\ of\ Zones^{0.25}\ x\ User\ Classes$$

In the case of the ERM the recommended number of OD pairs is therefore 66. 33 OD pairs were selected, covering a variety of route types and land uses, and these were assessed in both directions. Three examples are given in this section, with the remainder being presented in the Addendum.

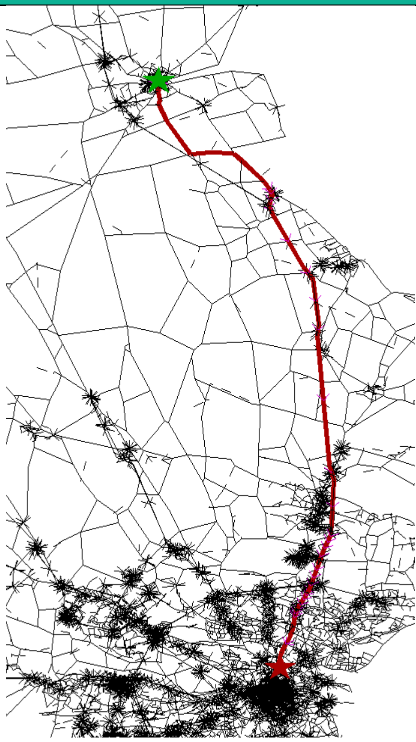
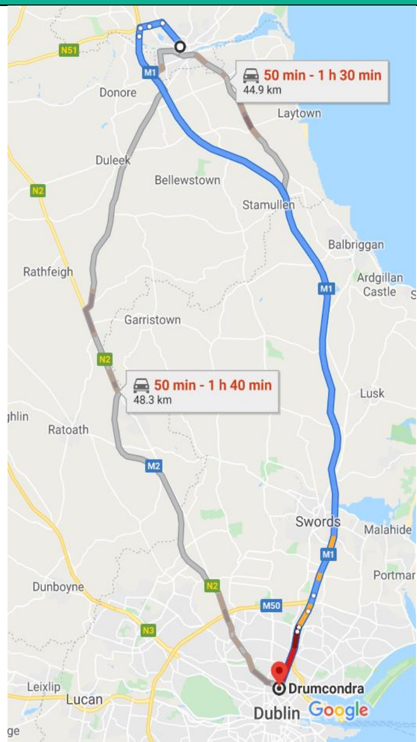
<table>
<tr><th>Drogheda to Drumcondra</th><th>Road Assignment Model</th><th>Google Maps</th></tr>
<tr><td>29145 to 2027</td><td rowspan="2"></td><td rowspan="2">
</td></tr>
<tr><td>Car Commute (UC2)</td></tr>
</table>

Figure 11.54 Route Choice Between Drogheda and Drumcondra

Figure 11.54 illustrates that traffic travelling from Drogheda to Drumcondra takes the correct route of the M1. Google Maps indicated three potential routes, and while the assignment model indicates that 100% of Car Commute traffic would take the displayed route, when plotting a “Forest” to display multiple path options in the model, all three routes are potential routes, along with the multitude of potential exits from Drogheda.

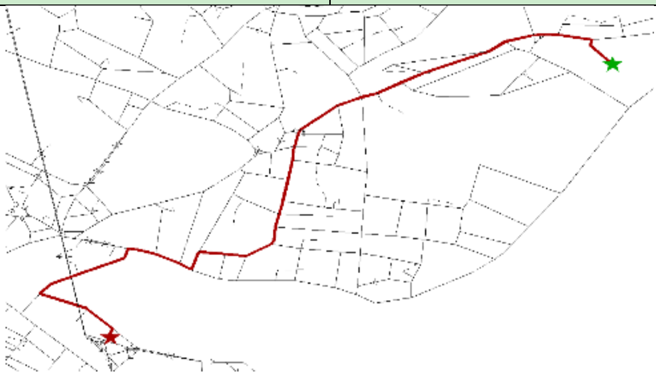
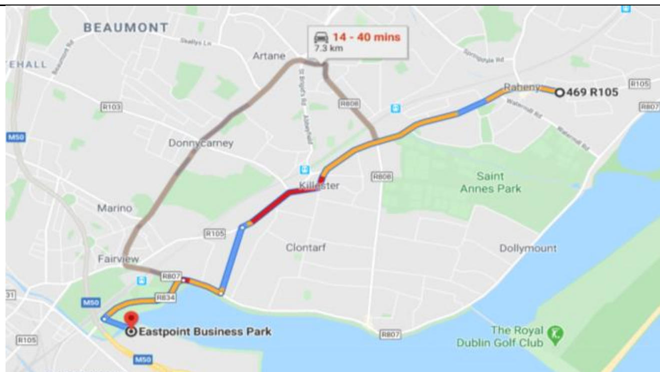
Raheny to Eastpoint	13037 to 4001	Car Commute (UC2)
Road Assignment Model		
Google Maps		

Figure 11.55 Route Choice Between Raheny and Eastpoint Business Park

Figure 11.55 shows that the model closely represents the correct route choice between Raheny and Eastpoint Business Park. In the road assignment model, traffic routes down Castle Avenue to avoid the delay visible in Google Maps around Collins Avenue East.

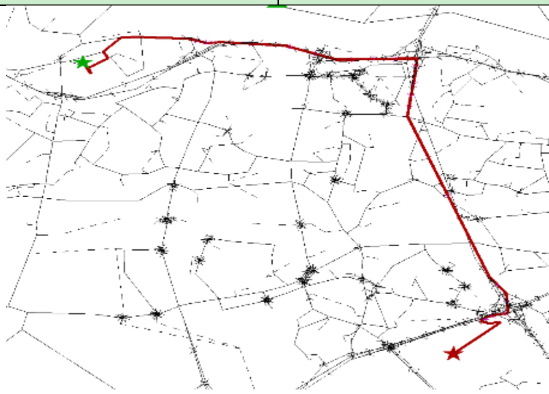
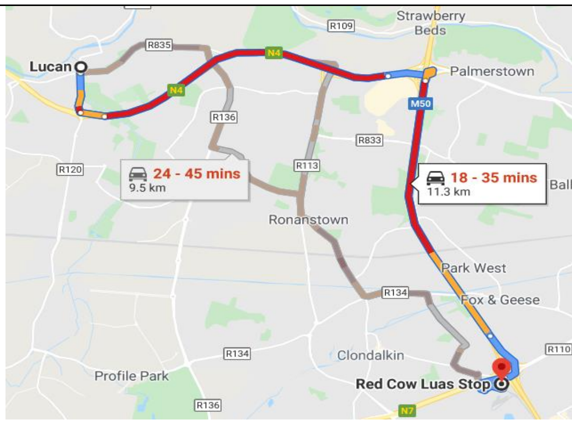
<table>
<tr><th>Lucan to Red Cow</th><th>25053 to 24048</th><th>Car Commute (UC2)</th></tr>
<tr><td>Road Assignment Model</td><td colspan="2"></td></tr>
<tr><td>Google Maps</td><td colspan="2">
</td></tr>
</table>

Figure 11.56 Route Choice Between Lucan and Red Cow Luas Park and Ride

The route choice in the model between Lucan and the Red Cow Park and Ride shows commuting traffic travelling via the N4 to the M50. Traffic joins the N4 at Junction 3 to avoid the high volume to capacity sections of the N4. Google Maps indicates that while this is one potential route, the preferred route would be to join the N4 at Junction 4.

Figure 11.54 to Figure 11.56 demonstrate that for these particular OD pairs route choice is sensible for the chosen user class.

11.3.3 Matrix Validation

Cells

Changes in the road assignment matrix at a cellular level by user class are also monitored throughout the matrix estimation process to ensure that they remain within acceptable levels, thus not distorting the matrix overly. The acceptance criteria adopted here is:

- An R^2 correlation statistic in excess of 0.95;
- A slope of the trendline within 0.98 and 1.02; and
- An intercept of the trendline near zero.

A summary of the cellular matrix correlation statistics is provided in Table 11.38 and shows larger than desired changes as a result of matrix estimation. Car Other and Car Education perform well across all time periods, while Car Commute is reasonable in the busier AM and PM peak periods.

Table 11.38 Prior and Post Estimation Comparison – Cellular Correlation (R^2)

User Class	AM	LT	SR	PM	OP
EMP	0.68	0.55	0.61	0.65	0.69
COM	0.87	0.81	0.79	0.84	0.92
OTH	0.95	0.87	0.93	0.92	0.96
EDU	0.96	0.87	0.96	0.92	0.84
RET	0.94	0.93	0.92	0.93	0.99
TAXI	0.25	0.14	0.14	0.27	0.82
LGV	0.62	0.50	0.75	0.57	0.85
OGV1	0.58	0.82	0.47	0.55	0.67
OGV2_P	0.14	0.39	0.31	0.09	0.53
OGV2_NP	0.30	0.44	0.40	0.26	0.68

The slope of the trendlines discussed above are provided in Table 11.39 and they show a good level of matrix integrity when considering the assigned Car user classes, excluding Taxi.

Less confidence was placed on the prior matrices for Taxi, LGV, OGV1 and OGV2 and subsequently less constraint was applied during the estimation of each of these user classes. This has resulted in poorer performance across both the R^2 and slope acceptance criteria.

Table 11.39 Prior and Post Estimation Comparison – Cellular Slope

User Class	AM	LT	SR	PM	OP
EMP	0.93	0.92	0.93	1.02	1.34
COM	0.99	1.03	1.01	0.98	1.03
OTH	1.01	1.00	0.97	0.98	1.02
EDU	1.01	0.97	0.96	0.99	1.15
RET	1.01	1.00	0.98	0.99	1.00
TAXI	0.70	0.41	0.43	0.80	1.16
LGV	0.69	0.38	0.88	0.82	0.80
OGV1	0.65	0.80	0.58	0.71	0.58
OGV2_P	0.24	0.20	0.17	0.15	0.54
OGV2_NP	0.26	0.27	0.24	0.27	1.57

Table 11.40 provides a summary of the intercept across each user class and time period, with all values recorded as 0.00. This is predominantly due to the number of records being assessed for each user class (up to 3,814,000), however it is a useful test to undertake.

Table 11.40 Prior and Post Estimation Comparison – Cellular Intercept

User Class	AM	LT	SR	PM	OP
EMP	0.00	0.00	0.00	0.00	0.00
COM	0.00	0.00	0.00	0.00	0.00
OTH	0.00	0.00	0.00	0.00	0.00
EDU	0.00	0.00	0.00	0.00	0.00
RET	0.00	0.00	0.00	0.00	0.00
TAXI	0.00	0.00	0.00	0.00	0.00
LGV	0.00	0.00	0.00	0.00	0.00
OGV1	0.00	0.00	0.00	0.00	0.00
OGV2_P	0.00	0.00	0.00	0.00	0.00
OGV2_NP	0.00	0.00	0.00	0.00	0.00

Trip Ends

To ensure that matrix estimation does not adjust the matrix too much, prior and post-estimation trip ends are plotted against each other and are monitored and compared against the following targets:

- An R2 correlation statistic in excess of 0.98;
- A slope of the trendline between 0.99 and 1.01; and
- Intercept of the trendline near zero.

The correlation statistics for origin and destinations are presented separately in Table 11.41 and Table 11.42.

Table 11.41 Prior and Post Estimation Comparison – Origin Correlation (R^2)

User Class	AM	LT	SR	PM	OP
EMP	0.84	0.93	0.93	0.91	0.82
COM	0.90	0.95	0.85	0.98	0.93
OTH	0.96	0.97	0.97	0.97	0.74
EDU	0.98	0.93	0.98	0.99	0.86
RET	0.97	0.96	0.92	0.94	0.92
TAXI	0.22	0.14	0.10	0.59	0.98
LGV	0.91	0.78	0.91	0.85	0.88
OGV1	0.86	0.91	0.83	0.86	0.80
OGV2_P	0.43	0.69	0.78	0.70	0.59
OGV2_NP	0.86	0.88	0.86	0.86	0.60

Table 11.42 Prior and Post Estimation Comparison – Destination Correlation (R^2)

User Class	AM	LT	SR	PM	OP
EMP	0.87	0.92	0.95	0.93	0.89
COM	0.99	0.96	0.92	0.94	0.89
OTH	0.98	0.98	0.98	0.96	0.85
EDU	0.98	0.97	0.97	0.96	0.92
RET	0.94	0.94	0.93	0.96	0.96
TAXI	0.37	0.51	0.68	0.86	0.97
LGV	0.90	0.80	0.94	0.84	0.84
OGV1	0.85	0.90	0.70	0.81	0.77
OGV2_P	0.46	0.65	0.52	0.53	0.74
OGV2_NP	0.83	0.86	0.83	0.82	0.82

The origin and destination correlation statistics indicate that generally the employers' business user class correlates significantly poorer than the other user classes in all time periods, predominantly due to the smaller size of the matrix. For origins, the commute user class also correlates to a lower level than the other user classes across the day for the origin trip ends, and in the LT, SR, and PM periods for destination trip ends.

The poor R^2 performance for the Taxi user class was anticipated due to the prior matrix derivation methodology, and lack of constraint applied during the taxi estimation process.

The slope of the trip ends when plotted as a scatter chart is provided in Table 11.43 and Table 11.44.

Table 11.43 Prior and Post Estimation Comparison – Origin Slope

User Class	AM	LT	SR	PM	OP
EMP	0.86	0.82	0.84	0.95	2.27
COM	0.82	0.95	1.09	0.99	1.16
OTH	1.03	1.08	1.07	1.01	1.54
EDU	1.02	0.99	0.98	1.02	1.45
RET	1.04	1.04	1.05	1.01	1.01
TAXI	0.34	0.12	0.12	0.56	2.12
LGV	0.90	0.61	0.90	0.86	0.69
OGV1	0.77	0.78	0.72	0.81	0.48
OGV2_P	0.34	0.28	0.24	0.27	0.74
OGV2_NP	0.52	0.50	0.51	0.60	1.16

Table 11.44 Prior and Post Estimation Comparison – Destination Slope

User Class	AM	LT	SR	PM	OP
EMP	0.83	0.75	0.86	1.09	1.83
COM	0.99	1.01	1.05	0.93	1.37
OTH	1.05	1.09	1.04	1.01	1.45
EDU	1.01	1.00	0.99	1.01	1.19
RET	1.03	1.06	1.07	1.05	1.07
TAXI	0.36	0.31	0.47	1.10	2.15
LGV	0.89	0.66	0.95	1.03	0.65
OGV1	0.76	0.78	0.77	0.80	0.54
OGV2_P	0.21	0.19	0.17	0.16	0.34
OGV2_NP	0.53	0.47	0.42	0.52	1.25

Few user classes satisfy the UK TAG criterion of a slope value between 0.99 and 1.01. However, slope values for the larger assignment user classes of Car Commute, Car Other and Car Education all lie in the range of 0.84 to 1.15, excluding the Off-peak period.

The intercept of the trendlines discussed above are provided in Table 11.45 and Table 11.46.

Table 11.45 Prior and Post Estimation Comparison – Origin Intercept

User Class	AM	LT	SR	PM	OP
EMP	1.96	1.38	2.34	1.70	-2.39
COM	13.17	0.68	0.52	1.32	-0.02
OTH	-2.20	-3.51	-3.19	-0.50	-5.02
EDU	-0.08	-0.01	-0.07	-0.09	-0.02
RET	0.03	0.33	0.26	0.16	0.07
TAXI	3.52	4.28	4.14	2.48	-0.84
LGV	0.75	3.36	0.96	1.22	0.37
OGV1	1.17	1.05	1.54	0.44	1.08
OGV2_P	0.00	0.00	0.00	0.00	0.00
OGV2_NP	0.08	0.09	0.07	0.05	0.00

Table 11.46 Prior and Post Estimation Comparison – Destination Intercept

User Class	AM	LT	SR	PM	OP
EMP	2.37	2.21	2.21	-0.05	-1.25
COM	0.83	0.31	1.06	5.02	-1.61
OTH	-3.35	-4.14	-1.49	-0.55	-3.84
EDU	-0.03	-0.01	-0.09	-0.05	0.00
RET	0.05	0.14	0.11	0.01	0.03
TAXI	3.45	3.58	2.97	0.99	-0.87
LGV	0.90	2.84	0.47	-0.35	0.80
OGV1	1.29	1.06	1.16	0.48	0.64
OGV2_P	0.01	0.01	0.01	0.00	0.00
OGV2_NP	0.08	0.12	0.12	0.09	0.00

All intercept values are close to 0 when considering the overall size of each user class.

Trip Length Distribution

The mean trip lengths (in kilometres) of the road model are also considered to check whether the changes introduced through matrix estimation have been within an acceptable level, with recommended criteria being:

- A change of mean average trip length within 5%; and
- A change in standard deviations of average trip length within 5%.

A summary of the percentage changes in each of these criteria are provided in Table 11.47 and Table 11.48, with trip length distribution graphs for each user class included in the Addendum.

Table 11.47 Percentage Change in Mean Trip Length Through Matrix Estimation

User Class	AM	LT	SR	PM	OP
EMP	-12%	-20%	-8%	-5%	10%
COM	-18%	-15%	-3%	-9%	12%
OTH	-11%	-16%	-5%	-5%	11%
EDU	1%	0%	10%	4%	31%
RET	0%	-2%	5%	3%	7%
TAXI	-6%	-18%	-11%	-6%	7%
LGV	-3%	2%	-3%	-3%	-21%
OGV1	-19%	-19%	-22%	-19%	-16%
OGV2_P	2%	2%	2%	1%	2%
OGV_NP	-18%	-18%	-19%	-19%	5%

Table 11.48 Percentage Change in Trip Length Standard Deviation Through Matrix Estimation

User Class	AM	LT	SR	PM	OP
EMP	-11%	-15%	-8%	-5%	4%
COM	-21%	-18%	-12%	-14%	7%
OTH	-16%	-20%	-13%	-14%	8%
EDU	-2%	-3%	11%	0%	23%
RET	-5%	-7%	-3%	-2%	5%
TAXI	-12%	-19%	-12%	-9%	1%
LGV	-1%	-1%	-3%	-3%	-13%
OGV1	-18%	-20%	-21%	-19%	4%
OGV2_P	-13%	5%	8%	17%	-2%
OGV2_NP	-7%	-7%	-7%	-12%	19%

For most user classes, the average trip length has been shortened by a figure greater than typically acceptable levels. Car Education, Car Retired and LGV perform well, and are within typically acceptable levels of change across most time periods.

The shortening of trip length is a common trait of matrix estimation as it seeks to meet observed counts by adjusting all traffic that passes through observation points. This is more pronounced if less constraint on trip end changes is applied as is the case with the ERM.

An additional measure of how closely the trip length distribution aligns before and after matrix estimation is the coincidence ratio. While available guidance does not set an acceptable level, values closer to 1 indicate a good correlation. The coincidence ratio for each time period is presented in Table 11.49.

Table 11.49 Coincidence Ratio of Trip Length

User Class	AM	LT	SR	PM	OP
EMP	0.89	0.79	0.85	0.90	0.73
COM	0.90	0.88	0.82	0.92	0.86
OTH	0.94	0.89	0.89	0.93	0.87
EDU	0.96	0.93	0.91	0.94	0.87
RET	0.93	0.90	0.86	0.91	0.91
TAXI	0.72	0.74	0.73	0.69	0.83
LGV	0.94	0.90	0.95	0.94	0.73
OGV1	0.85	0.83	0.83	0.84	0.63
OGV2_P	0.38	0.29	0.26	0.24	0.60
OGV2_NP	0.62	0.61	0.58	0.64	0.58

For user classes other than taxi and goods vehicles the coincidence ratio is sufficiently close to 1, which suggests that the overall trip making pattern has not been significantly distorted by matrix estimation when considered with the information presented in Table 11.47 and Table 11.48 that shows a general shortening of the overall trip length.

Trip length distribution graphs for each user class in each time period are presented in the Addendum.

Sector-to-sector Changes

UK TAG recommends that matrix estimation should not alter sector-to-sector movement totals by greater than 5%. The sector system applied to the ERM defines 38 sectors and was specified in Chapter 4. Two additional sectors were added to this system, with sector 39 including all route zones, and sector 40 including the rail route zones that carry no traffic in the road assignment model.

Considering only non-zero cells, as matrix estimation cannot increase a zero-value cell, Table 11.50 outlines the sector-to-sector changes.

Table 11.50 Prior and Post Estimation Comparison – Sector-to-Sector Changes

User Class	AM % < 5%	LT % < 5%	SR % < 5%	PM % < 5%	OP % < 5%
EMP	9%	7%	9%	11%	21%
COM	10%	8%	11%	11%	23%
OTH	9%	8%	10%	12%	24%
EDU	18%	16%	18%	15%	44%
RET	12%	10%	12%	13%	28%
TAXI	6%	6%	7%	6%	24%
LGV	11%	14%	14%	10%	18%
OGV1	10%	10%	8%	8%	19%
OGV2_P	40%	40%	38%	38%	52%
OGV2_NP	39%	38%	39%	38%	35%
Car Total	9%	8%	10%	12%	23%
LGV Total	11%	14%	14%	10%	18%
HGV Total	10%	10%	8%	9%	19%
Total	11%	8%	12%	13%	23%

Table 11.50 indicates that sector-to-sector changes are larger than recommended, confirming that matrix estimation is making larger than desirable changes to match the prior matrix to the observed count data coverage.

11.3.4 Assignment Validation

Flows

Traffic flow comparisons have been undertaken and assessed against UK TAG recommended criteria, as set out in Chapter 7, for validation. The assessment of validation has been undertaken at a total vehicle level, as the dataset used to validate the ERM (SCATS) is only provided at a total vehicle level and cannot be accurately disaggregated. This dataset may also include vehicle types not modelled within the ERM, such as motorbikes or private hire buses. Despite this, and owing to a lack of alternative data, the validation dataset was retained for the assessment of the ERM.

A summary of the traffic flow validation comparisons is reported in Table 11.51. It is highlighted that there is no available validation data for traffic flow in the off-peak time period.

Table 11.51 Road Model Validation (All Vehicle Types)

Time Period	Links Meeting TAG	GEH < 5	GEH < 7	GEH < 10
AM	42%	35%	46%	61%
LT	41%	32%	43%	59%
SR	37%	30%	41%	57%
PM	37%	30%	43%	58%

No time period meets the UK TAG flow or GEH criteria across the validation dataset. As noted above, the dataset is provided as an "all vehicle" count which may include vehicle types not modelled within the ERM, such as motorbikes or private hire buses. Summing the observed flows across all validation counts and comparing them to the summed modelled flows indicates that in each time period the modelled flows are lower than the observed flows. This difference ranges from -10% in the AM period to -27% in the SR period.

The spatial GEH performance for the AM time period is displayed in Figure 11.57, with those for the remaining time periods shown in the Addendum.

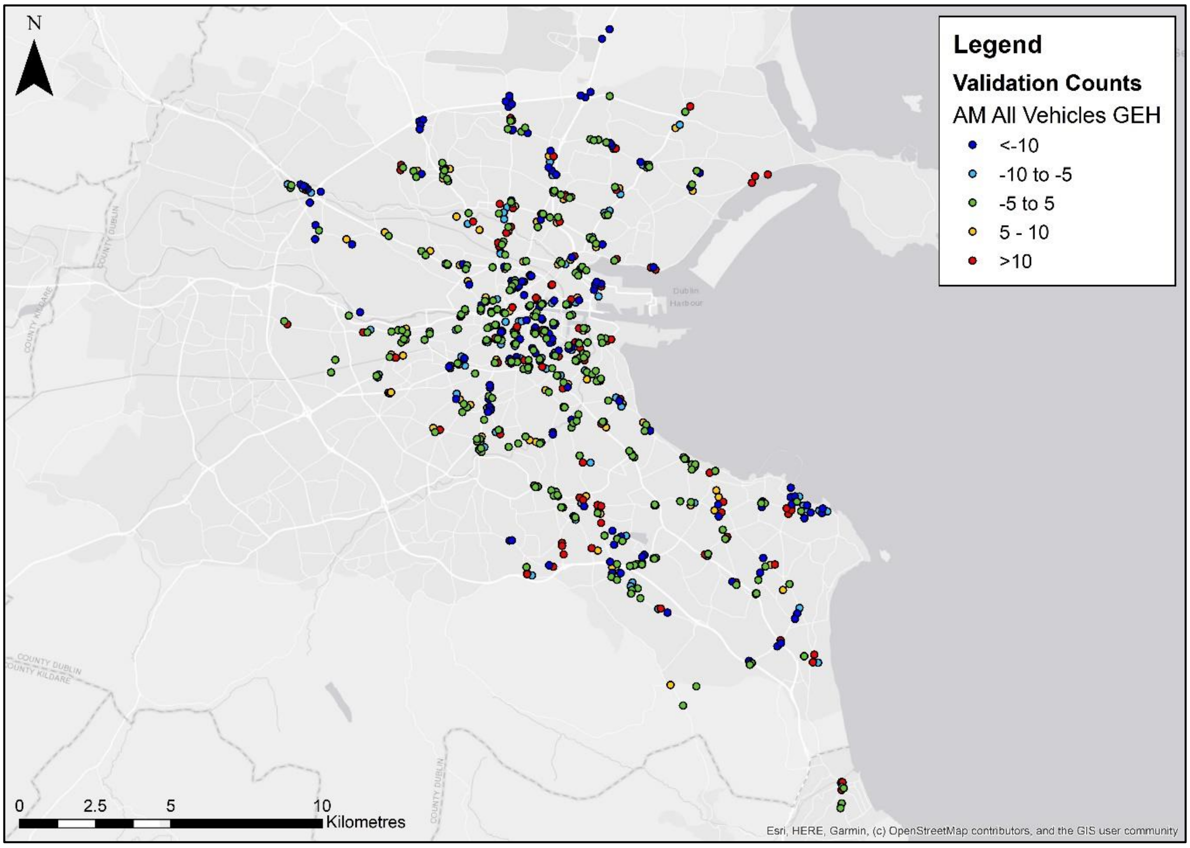


Figure 11.57 AM Spatial GEH Performance (All Vehicle Types)

Journey Times

A series of journey time routes have been derived which set out to capture key travel movements across the modelled area. These can be broken down into the following four strategic categories:

- Northern radial route;
- Southern radial routes;
- Orbital routes; and
- Non-central routes.

A description of each route along with their labelling convention for reference in later tables is shown in Figure 11.58 to Figure 11.61.

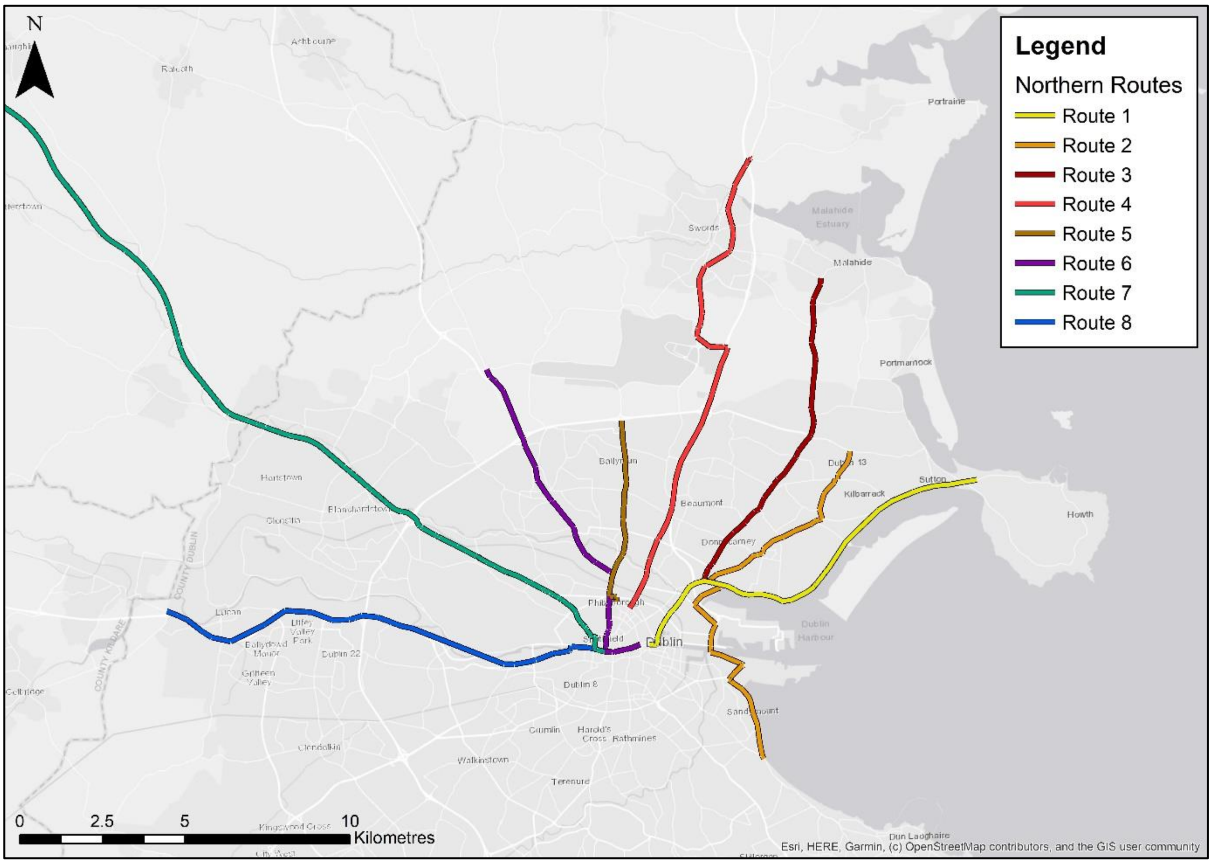


Figure 11.58 Northern Journey Time Route Definition

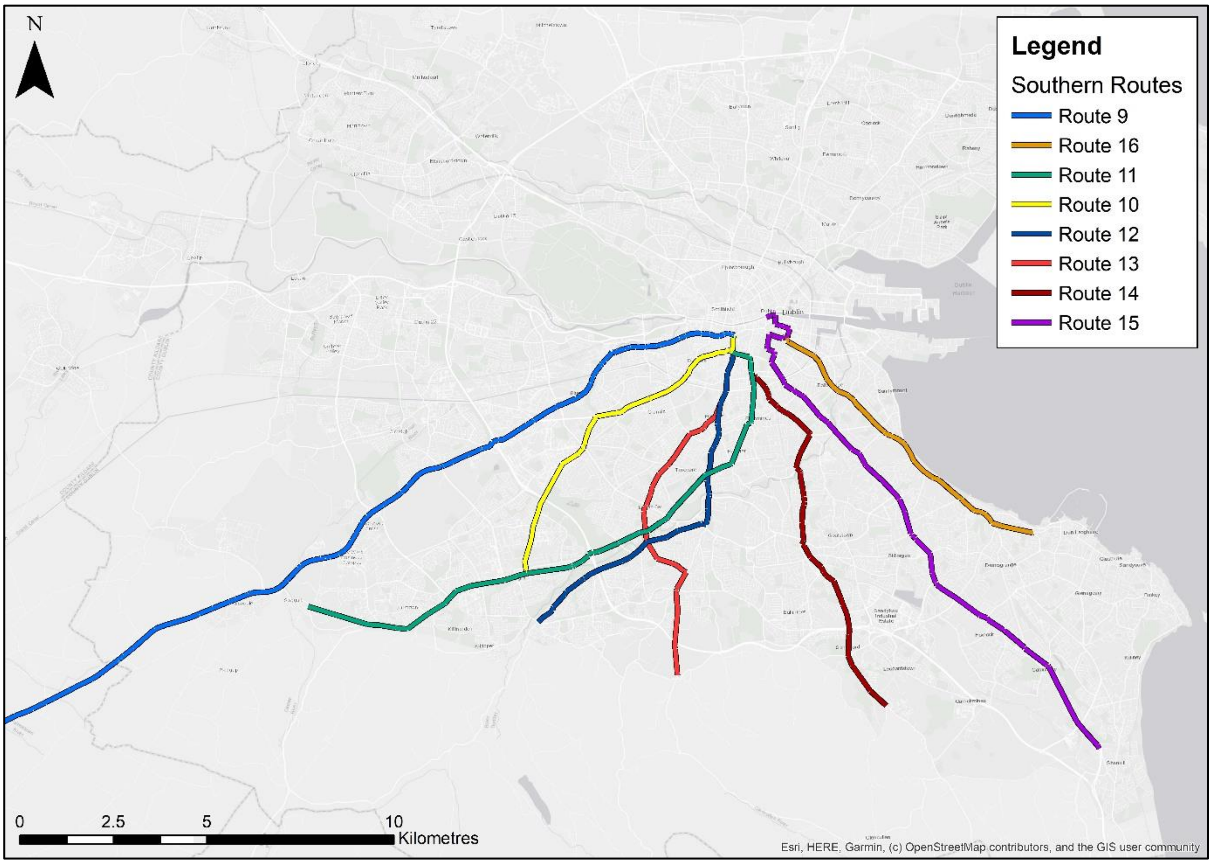


Figure 11.59 Southern Journey Time Route Definition

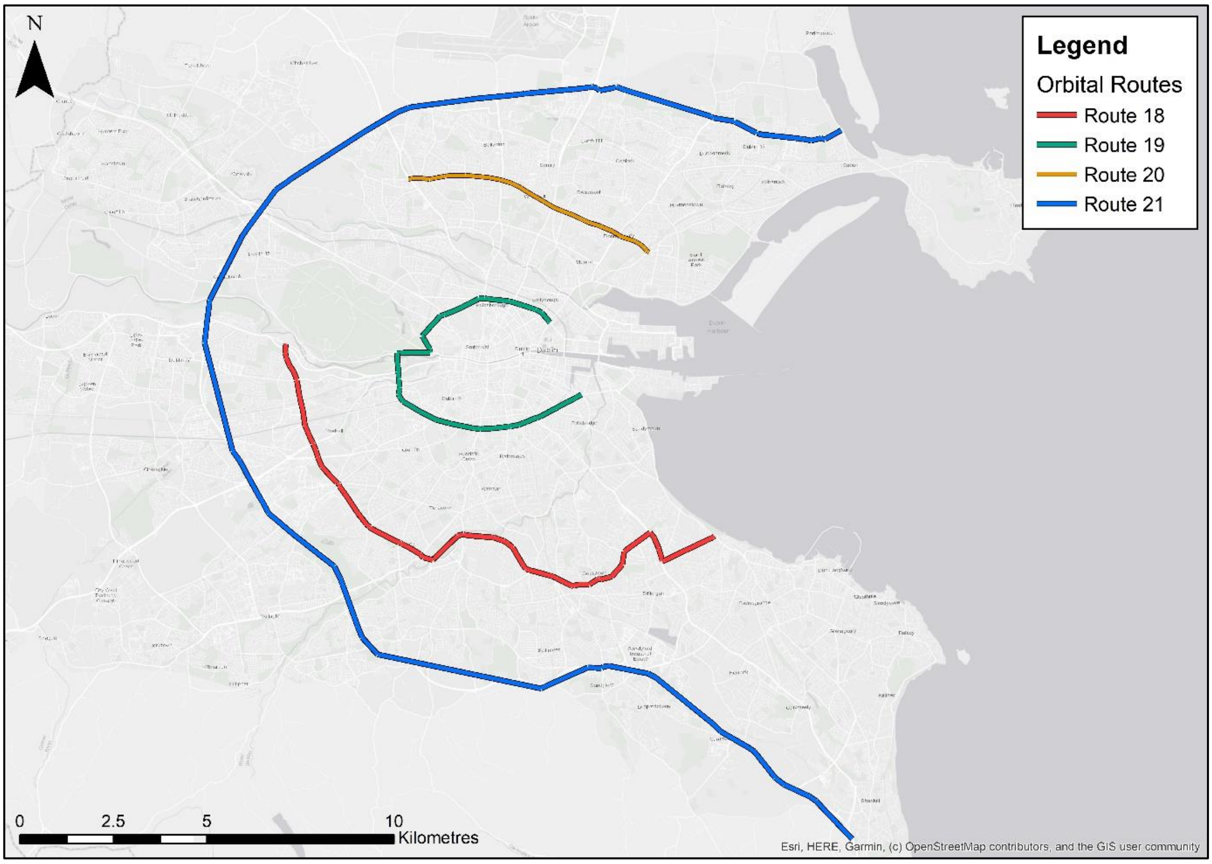


Figure 11.60 Orbital Journey Time Route Definition

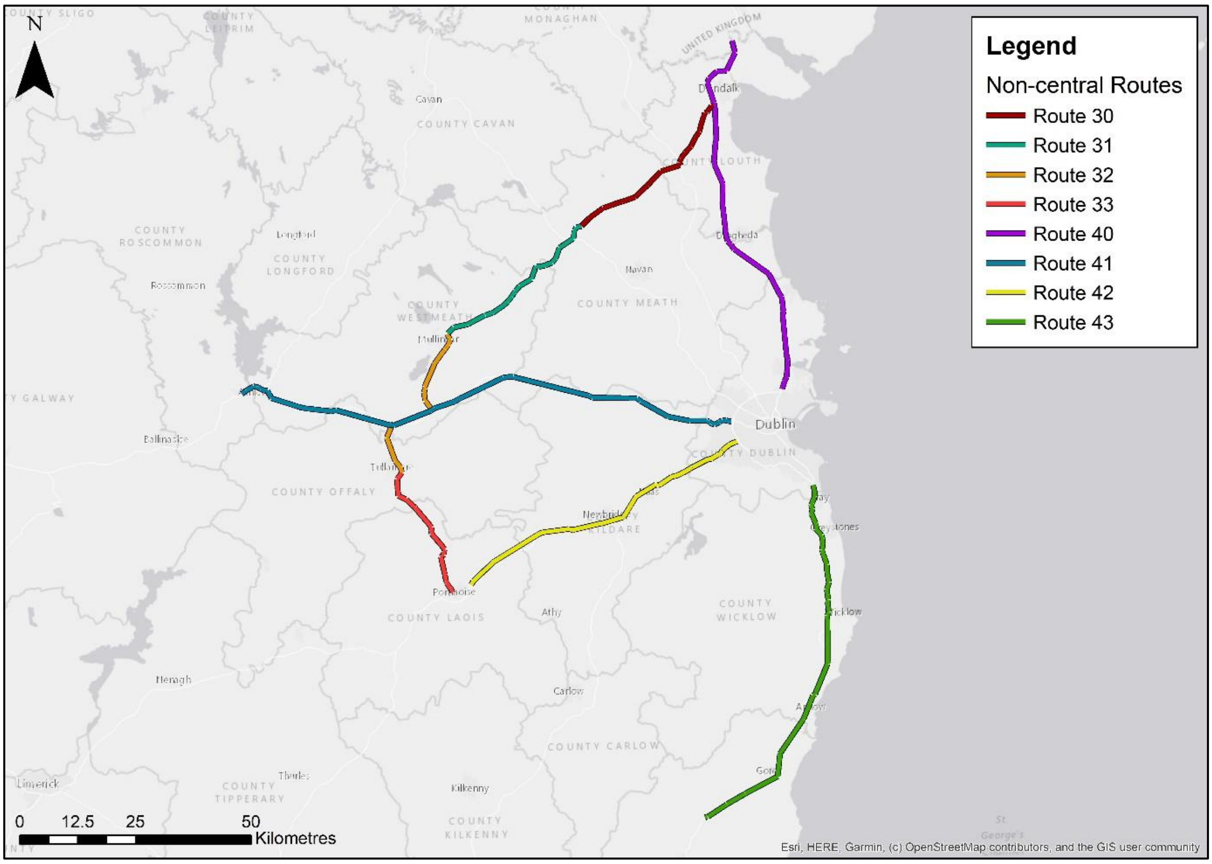


Figure 11.61 Non-central Journey Time Route Definition

Journey time comparisons are made for each route within the network and can be summarised as pass or fail based on the overall journey time across the entire route, with a route considered to pass where the modelled times falls within 15% of the observed survey times (or 1 minute, if higher than 15%). Across the model, this should be achieved for 85% of routes for the model to be considered "compliant".

An overall post-Matrix Estimation Journey Time summary by direction is reported in Table 11.52.

Table 11.52 Journey Time Summary

Criteria	AM	LT	SR	PM	OP	Total
Pass	28	51	48	35	47	209
Fail	28	5	8	21	9	71
Total	56	56	56	56	56	280
% Pass	50%	91%	86%	63%	84%	75%
% Fail	50%	9%	14%	37%	16%	25%
Within 20%	64%	95%	93%	73%	96%	84%

Journey time validation performance for the uncongested time periods (LT, SR, and OP) is good, with only the OP not meeting the UK TAG recommended criteria by 1%. The performances of the AM and PM models are not as robust at 50% and 63% of routes within the 15% criterion, respectively.

Further context of how each type of route performs is provided in Table 11.53.

Table 11.53 Journey Time Summary by Route Type

Route Set	Summary	Count	AM	LT	SR	PM	OP	Total
Northern Radial - Inbound	Count	8	3	7	8	5	7	30
	% Pass		38%	88%	100%	63%	88%	75%
Northern Radial - Outbound	Count	8	5	6	7	5	6	29
	% Pass		63%	75%	88%	63%	75%	73%
Southern Radial - Inbound	Count	8	1	8	8	4	6	27
	% Pass		13%	100%	100%	50%	75%	68%
Southern Radial - Outbound	Count	8	6	6	5	5	6	28
	% Pass		75%	75%	63%	63%	75%	70%
Orbital	Count	8	1	8	4	1	8	22
	% Pass		13%	100%	50%	13%	100%	55%
Non-Central	Count	16	12	16	16	15	14	73
	% Pass		75%	100%	100%	94%	88%	91%

Inbound routes in the AM perform poorly, as do orbital routes in both the AM and PM periods. PM routes perform similarly regardless of directionality or whether they are located North or South of Dublin. Non-central routes perform very well across all time periods.

Further information on individual routes and directions are summarised for each time period in the Addendum. An example of the AM time period routes is provided in Table 11.54.

Table 11.54 AM Journey Time Comparisons

ID	Direction	Model	Observed	Difference	% Difference	Pass/Fail
1	Inbound	2,806	2,307	499	22%	Fail
2	Inbound	3,086	2,960	126	4%	Pass
3	Inbound	2,050	1,578	472	30%	Fail
4	Inbound	2,395	2,485	-90	-4%	Pass
5	Inbound	1,394	1,654	-260	-16%	Fail
6	Inbound	2,085	2,702	-617	-23%	Fail
7	Inbound	2,152	2,821	-669	-24%	Fail
8	Inbound	1,728	1,788	-60	-3%	Pass
9	Inbound	2,337	3,116	-779	-25%	Fail
10	Inbound	1,977	2,259	-282	-12%	Pass
11	Inbound	2,616	3,647	-1,031	-28%	Fail
12	Inbound	1,914	2,482	-568	-23%	Fail
13	Inbound	1,386	1,997	-611	-31%	Fail
14	Inbound	1,943	2,617	-674	-26%	Fail
15	Inbound	2,353	3,388	-1,035	-31%	Fail
16	Inbound	1,850	2,500	-650	-26%	Fail
18	Westbound	2,602	3,404	-802	-24%	Fail
18	Eastbound	2,554	3,774	-1,220	-32%	Fail
19	Eastbound	2,601	3,506	-905	-26%	Fail
19	Westbound	2,637	3,770	-1,133	-30%	Fail
20	Westbound	1,201	1,566	-365	-23%	Fail
20	Eastbound	1,117	1,580	-463	-29%	Fail
21	Westbound	3,205	3,759	-554	-15%	Pass
21	Eastbound	2,588	3,237	-649	-20%	Fail
1	Outbound	1,558	1,867	-309	-17%	Fail
2	Outbound	1,917	2,256	-339	-15%	Fail
3	Outbound	1,213	1,378	-165	-12%	Pass
4	Outbound	2,628	1,983	645	33%	Fail
5	Outbound	1,234	1,114	120	11%	Pass
6	Outbound	1,710	1,597	113	7%	Pass
7	Outbound	1,947	1,892	55	3%	Pass

ID	Direction	Model	Observed	Difference	% Difference	Pass/Fail
8	Outbound	1,131	1,051	80	8%	Pass
9	Outbound	1,994	1,864	130	7%	Pass
10	Outbound	1,766	1,804	-38	-2%	Pass
11	Outbound	2,296	2,705	-409	-15%	Fail
12	Outbound	1,732	2,002	-270	-13%	Pass
13	Outbound	1,254	1,505	-251	-17%	Fail
14	Outbound	1,740	1,755	-15	-1%	Pass
15	Outbound	2,050	2,352	-302	-13%	Pass
16	Outbound	1,394	1,635	-241	-15%	Pass
30	Westbound	2,501	2,359	142	6%	Pass
30	Eastbound	2,552	2,405	147	6%	Pass
31	Westbound	2,435	2,153	282	13%	Pass
31	Eastbound	2,436	2,112	324	15%	Fail
32	Westbound	2,064	1,778	286	16%	Fail
32	Eastbound	2,067	1,763	304	17%	Fail
33	Eastbound	2,370	2,267	103	5%	Pass
33	Westbound	2,262	2,098	164	8%	Pass
40	Outbound	2,878	2,886	-8	0%	Pass
40	Inbound	3,129	2,967	162	5%	Pass
41	Inbound	3,723	3,850	-127	-3%	Pass
41	Outbound	3,640	3,584	56	2%	Pass
42	Inbound	2,654	3,365	-711	-21%	Fail
42	Outbound	2,688	2,421	267	11%	Pass
43	Inbound	4,179	3,851	328	9%	Pass
43	Outbound	3,409	3,423	-14	0%	Pass

The performance of routes can also be considered graphically in two ways. The first is the standard traditional approach of reporting journey times as a distance time chart, and all routes and time periods are provided in the Addendum for the reader to consider. An example of Route 1 Inbound is provided in Figure 11.62.

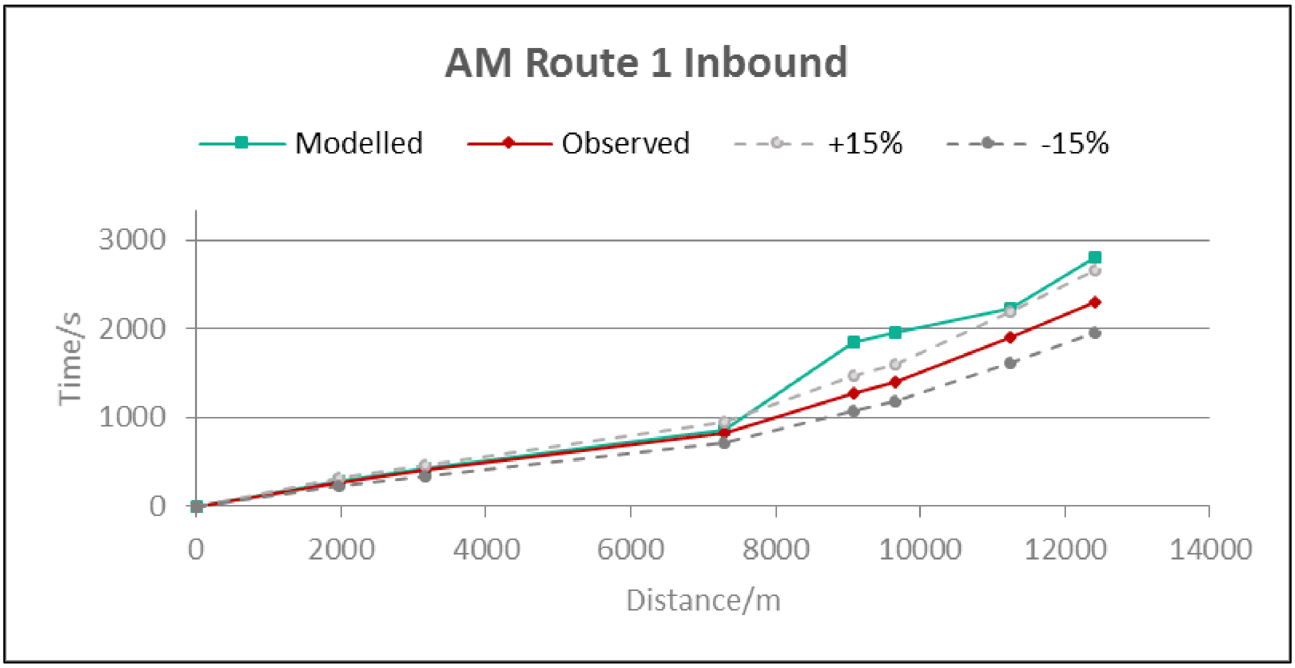


Figure 11.62 Route 1 Inbound AM Journey Time versus Distance Chart

In addition to the time versus distance chart a GIS shapefile has been prepared that can provide further information on each route by segment, identifying whether it passes or fails to meet UK TAG recommended criteria.

A comparison of each of the overall journey time routes is shown by time period in Figure 11.63 to Figure 11.67.

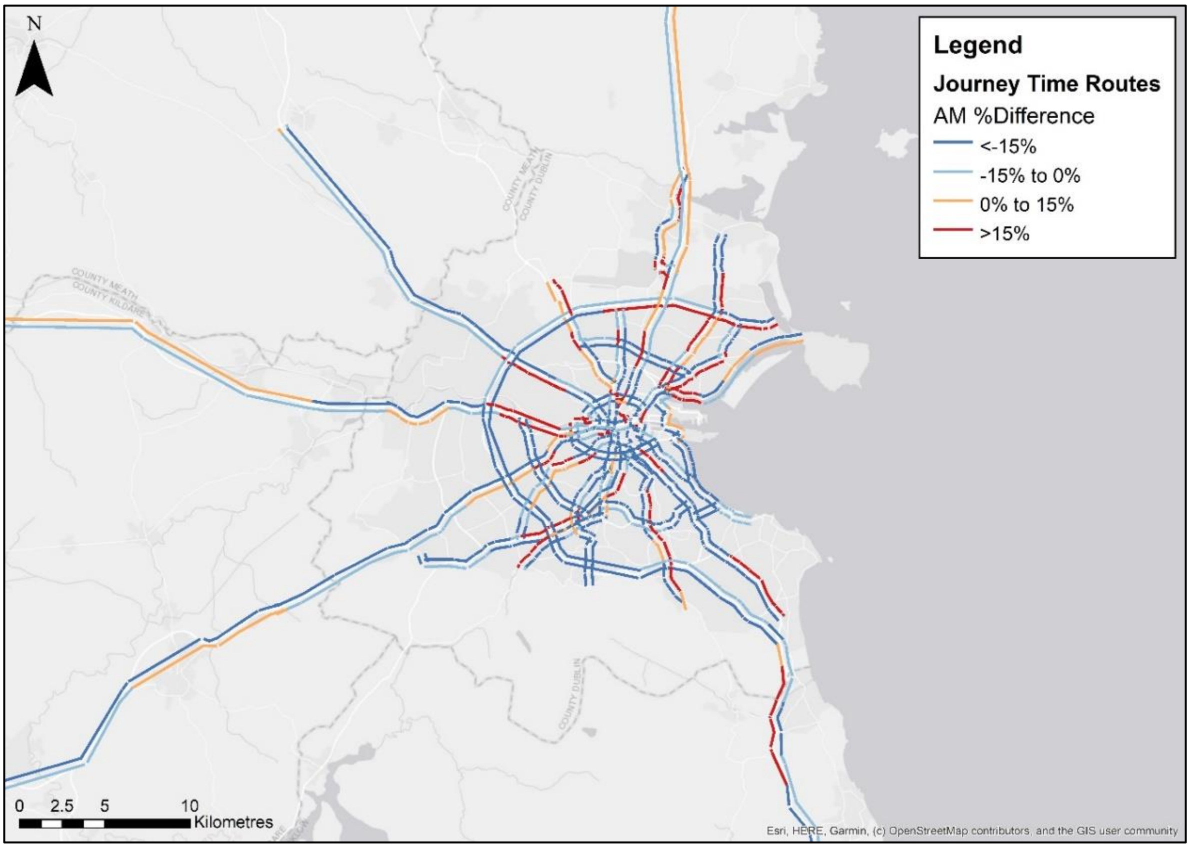


Figure 11.63 AM Journey Time Routes – Overall Performance

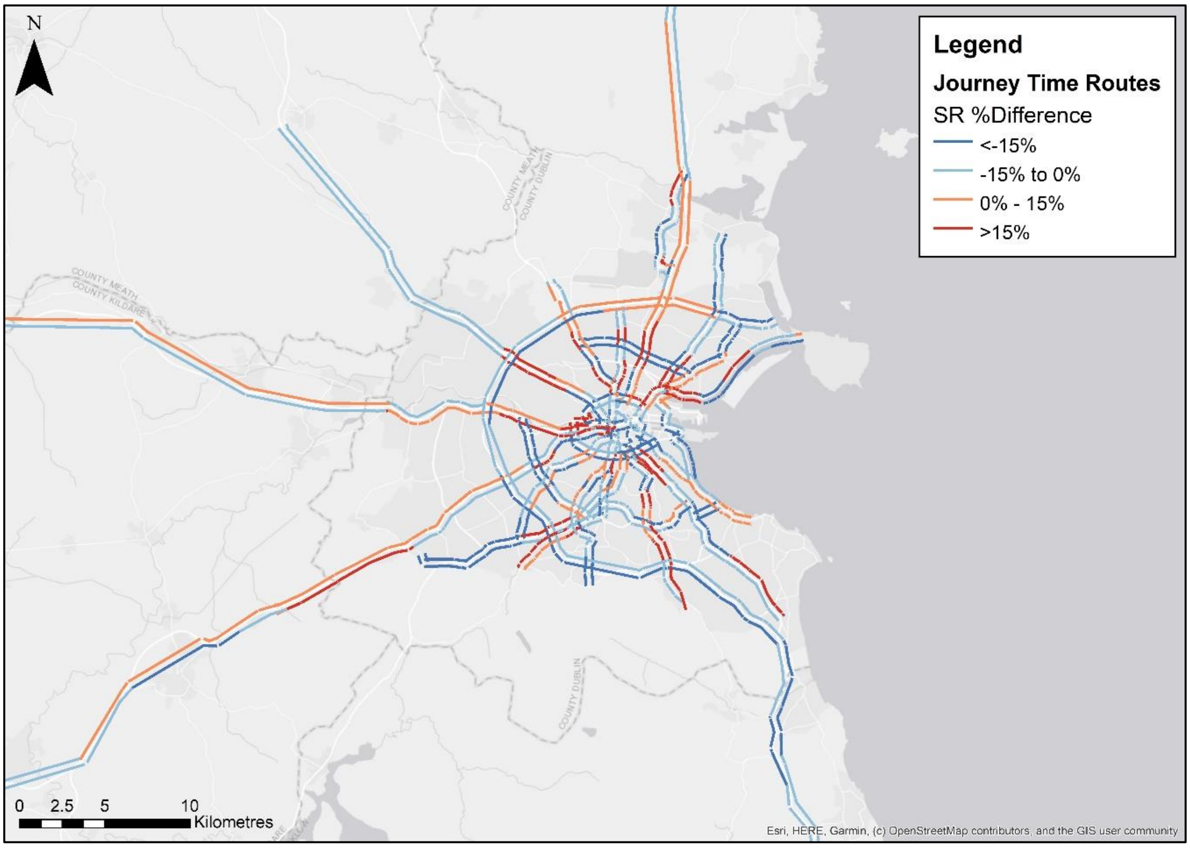


Figure 11.64 LT Journey Time Routes – Overall Performance

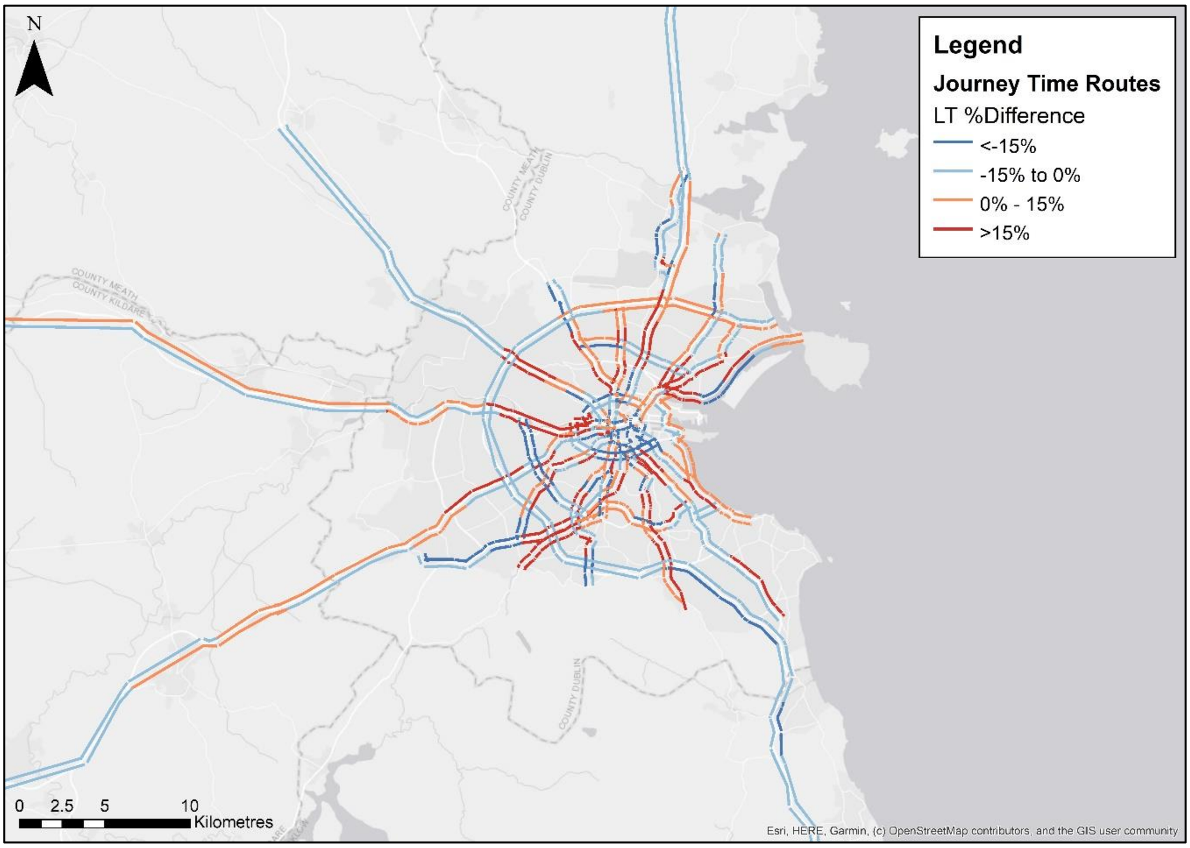


Figure 11.65 SR Journey Time Routes – Overall Performance

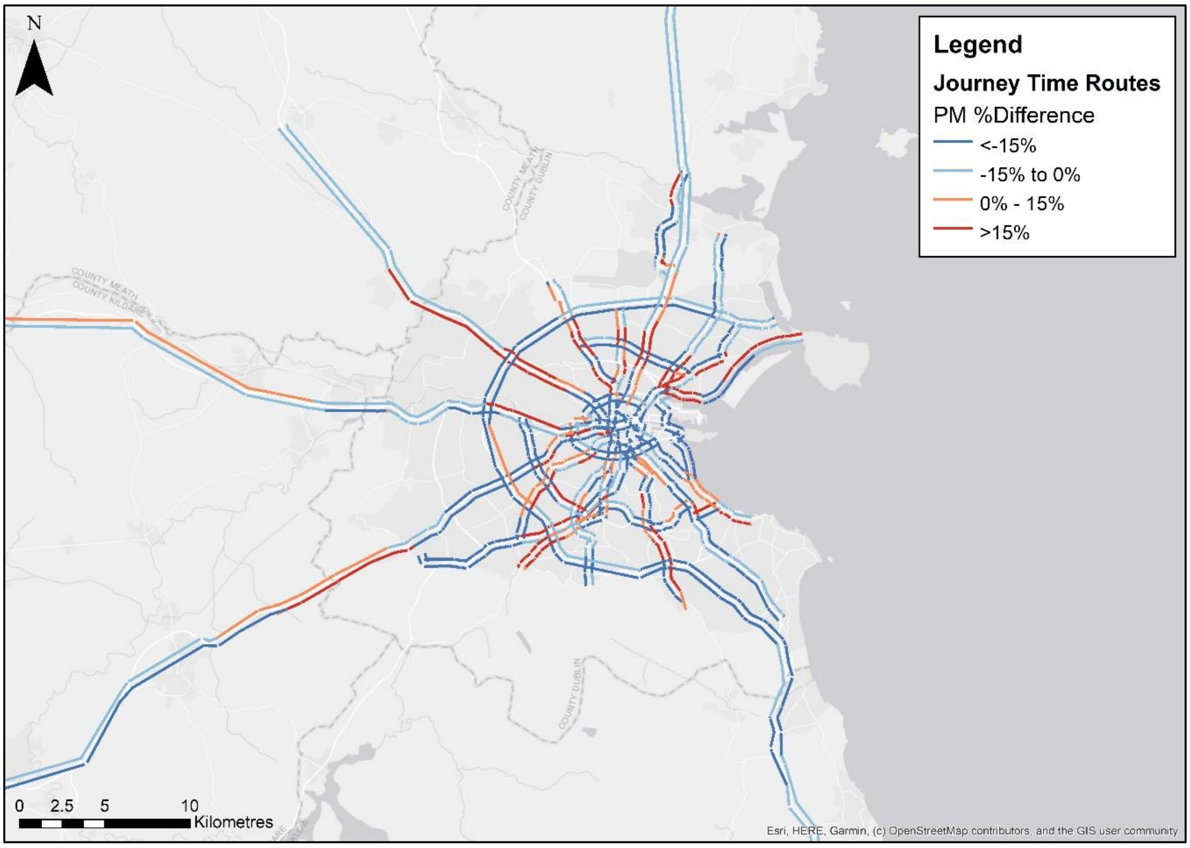


Figure 11.66 PM Journey Time Routes – Overall Performance

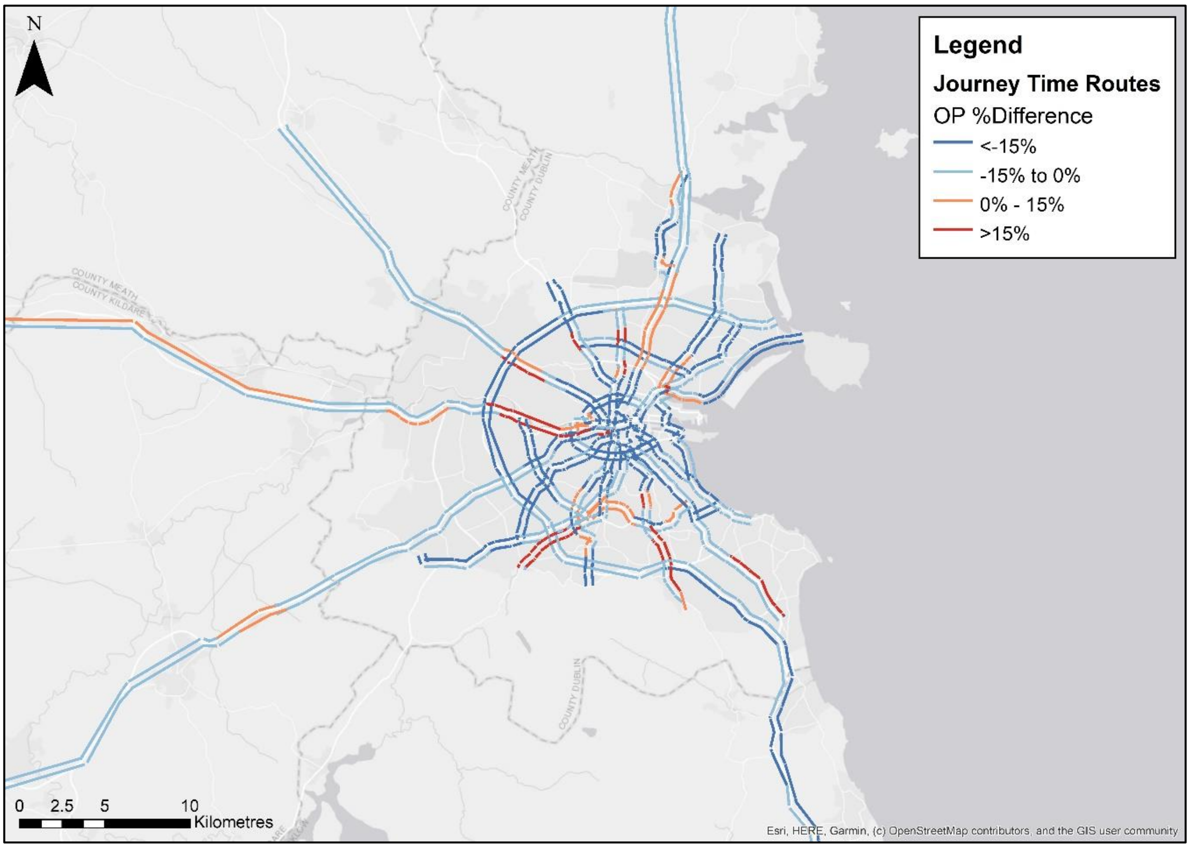


Figure 11.67 OP Journey Time Routes – Overall Performance

These figures show that the model performs well in the LT time period but is generally too fast within the city limits in all other time periods, more than the 15% in those areas highlighted in dark blue.

In summary journey times are replicated well in outlying areas of the model for all time periods but for urban areas of Dublin there is a distinct lack of delay despite the road traffic counts showing reasonable or increased levels of congestion when matched against observed data.

11.3.5 Assignment Convergence

The recommended base year model convergence criteria are set out in Chapter 7, and summarised in Table 11.55.

Table 11.55 Summary of Convergence Measures and Base Model Acceptable Values

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

The final convergence reported by SATURN is expressed in terms of Delta and %GAP, with the model terminating once user-defined values of %GAP, P and P2 from Table 11.55 have been met for four successive iterations. The final convergence of each model is presented in Table 11.56.

Table 11.56 Final Model Convergence Summary

Convergence Indicator	AM	LT	SR	PM	OP
Assignment / Simulation Loops	62	64	51	117	13
Delta	0.017	0.023	0.009	0.018	0.001
% GAP	0.020	0.041	0.023	0.032	0.001
P (%)	98.9	98.1	98.5	98.1	100
P2 (%)	99.7	99.8	99.8	99.6	100

All time periods converge well to a more stringent model termination criterion of a %GAP value less than 0.05%. While the PM peak does take longer to reach a converges state the number of assignment / simulation loops are still within the upper specified limit of 150 assignment / simulation loops. The reasons for the higher number of assignment / simulation loops are less clear, however the PM peak does carry more traffic than any other time period as is evidenced by the sum of the observed traffic counts presented in Section 11.3.1 and Section 11.3.4 and is generally the most congested modelled hour in Dublin.

11.3.6 Road Model Summary

The model performance in relation to link flow as set out in Section 11.3.1 indicates that the model is close to meeting the UK TAG link flow criteria for all modelled time periods. Screenline performance, set out in Section 11.3.1 shows that while the model does not calibrate across all screenlines, aggregating key screenlines into strategic cordons indicates a good representation of traffic travelling to and from Dublin and Dublin city centre.

The model does not perform to a satisfactory level when compared against the SCATS validation dataset, however consideration must be given to the non-modelled vehicles that will be present in the SCATS count dataset. Owing to a lack of alternative datasets, the SCATS dataset was retained as a validation dataset.

Model journey times perform well in the uncongested LT, SR, and OP peak periods and in the uncongested AM outbound travel direction, however there is an underestimation of travel delay in the AM inbound travel direction. Orbital routes do not perform as well in the AM and PM time periods as the radial routes while non-central routes perform well across all time periods.

The high level statistics for the road assignment model are summarised in Table 11.57.

Table 11.57 Final Road Model Performance Summary

Measure	AM	LT	SR	PM	OP
%GAP	0.020	0.041	0.023	0.032	0.001
Assignment / Simulation Loops	62	64	51	117	13
% Links within UK TAG Flow Criteria (Calibration)	83%	89%	85%	82%	97%
% Links GEH < 5	81%	87%	82%	80%	92%
Screenlines Passing UK TAG Flow Criteria	46%	37%	29%	38%	n/a
% Links within UK TAG Flow Criteria (Validation)	42%	41%	37%	37%	n/a
Journey Times Passing UK TAG Validation	50%	89%	86%	63%	84%

In order to match observed traffic counts matrix estimation is having to make larger changes to the prior matrices. This is demonstrated through the statistical analysis of the prior and estimated matrices in terms of R^2 and slope, through mean and standard deviation of trip length distribution changes and through sector-to-sector differences. The effects of matrix estimation are summarised in Section 11.3.3.

11.3.7 Recommendations and Limitations

The performance of most corridors when considered across the assigned time periods is of reasonable standard, however consideration must be given to the performance of the inbound direction of the radial journey time routes in the AM peak. It is recommended that additional comparisons against median TomTom journey times and Google Maps indicative times is undertaken to provide the model user with numerous points of comparison, particularly given the model's improved performance against these datasets.

Introducing greater constraints during the matrix estimation procedure, either by reducing the XAMAX balancing factor to a value below 3, introducing additional constraints at a trip end level or freezing blocks of zones would have the impact of improving the model performance when comparing against TAG's matrix estimation criteria. However, it is likely that introducing additional constraints would worsen the traffic flow calibration and validation, and the journey time validation of the ERM.

The derivation of the OGV1 and OGV2 matrices results in little OGV2 traffic originating from within the model area, excluding the special zones of the Airport, Dublin Port and Dun Laoghaire Port. Improving the representation and true origin-destination of the OGV1 and OGV2 matrices would allow for tighter control of the matrix estimation of goods vehicles.

Similarly, the taxi matrix is derived as a sector-based factor of "Car Other" and is adjusted significantly by matrix estimation to match known taxi count data across the canal cordon. Revising the derivation process would also for the taxi user class to simply be estimated as part of the larger “Car” vehicle class, resulting in better correlation between the prior and estimated taxi matrix.

Matrix estimation in general could be improved by estimating to total screenline targets, where available. This would have the effect of reducing the “lumpiness” of the incremental matrix, however in order to implement this the prior matrix needs to be closer to observed levels so that both flows and journey times are improved by the estimation process.

11.4 Public Transport Calibration

The PT model is a key component of the model with extensive criteria that must be met in order to be considered compliant. This section will discuss the results from PT Model including:

- Public transport flows across screenlines;
- Journey time comparisons;
- Boarding and alighting comparisons;
- Crowding analysis;
- Fares Model; and
- Time Penalties.

11.4.1 Matrix Calibration

Similar to the road model, as discussed in Chapter 10, the Demand Model Public Transport prior matrices require further adjustment to improve the level of fit between assignment performance and observed data. As set out in TAG guidelines, the level of changes should not be significant which is measured by a set of criteria.

Trip Ends

The level of changes on the trip ends applied to the PT matrix estimation is assessed based on the following TAG criteria:

- slope to be within 0.99 and 1.01;
- near zero intercept; and
- and R^2 above 0.95.

The table below shows the level of change caused by matrix estimation on the Trip Ends. This shows that the post-estimation matrices compare reasonably well to the priors, with correlations indicated by R^2 values near to 1.00. There are exceptions on a few cases where this criterion has not been met. However, the slope values indicate that in general the estimated origins are generally lower than the equivalent priors whereas destinations tend to be higher. The regression analysis of prior and post trip ends are summarised in Table 11.58 below.

Table 11.58 Trip Ends correlation parameters

Time Period	Origins			Destinations			Origins				Destinations			
	R^2	Slope	Intercept	R^2	Slope	Intercept								
AM	0.96	0.92	0.02	1.00	0.96	-2.27	Fail	Fail	Pass	Pass	Fail	Pass	Fail	Fail
PM	1.00	0.94	-0.30	0.97	1.06	0.39	Pass	Fail	Pass	Fail	Fail	Pass	Pass	Fail
LT	1.00	1.03	0.24	1.00	1.01	0.48	Pass	Fail	Pass	Pass	Fail	Pass	Pass	Fail
SR	1.00	1.00	0.32	1.00	1.00	0.20	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
OP	0.99	0.94	-0.02	0.91	0.87	0.41	Pass	Fail	Pass	Fail	Fail	Pass	Pass	Fail

Trip Length Distribution

There are two criteria set out by TAG guidelines for Trip Length Distributions. These are:

- Means within 5%; and
- Standard Deviations within 5%.

The estimated trip length distribution is generally lower than the prior distributions, especially for Education and Retired trips with an exception in AM where the estimated trip length are longer than the priors for all user classes. The Education trips have a large difference in time periods other than AM and SR as there are very low number of trips made outside these periods whereas Retired trips are generally low in all time periods. The mean and standard deviation comparisons are summarised in Table 11.59 and Table 11.60 respectively.

Table 11.59 Trip Length Distribution Mean comparison

Mean	%Diff (Post – Prior)					Criteria Met				
	EMP	COM	OTH	EDU	RET	EMP	COM	OTH	EDU	RET
AM	9%	6%	7%	5%	3%	Fail	Fail	Fail	Pass	Pass
LT	3%	-5%	6%	-43%	-26%	Pass	Pass	Fail	Fail	Fail
SR	-3%	1%	0%	7%	-24%	Pass	Pass	Pass	Fail	Fail
PM	-3%	-6%	0%	-39%	-29%	Pass	Fail	Pass	Fail	Fail
OP	2%	-2%	6%	-52%	-32%	Pass	Pass	Fail	Fail	Fail

Table 11.60 Trip Length Distribution Standard Deviation comparison

Std Dev	%Diff (Post – Prior)					Criteria Met				
	EMP	COM	OTH	EDU	RET	EMP	COM	OTH	EDU	RET
AM	1%	5%	0%	3%	4%	Pass	Fail	Pass	Pass	Pass
LT	1%	10%	-1%	139%	-50%	Pass	Fail	Pass	Fail	Fail
SR	1%	0%	0%	0%	-30%	Pass	Pass	Pass	Pass	Fail
PM	0%	2%	-1%	96%	-56%	Pass	Pass	Pass	Fail	Fail
OP	1%	10%	2%	140%	-97%	Pass	Fail	Pass	Fail	Fail

Sector to sector level matrices

The criterion for changes in matrices at sectors level is to ensure the changes are within 5%. The analysis summarised in Table 11.61 is based on coincidence ratio between the prior and post matrices for each user class. The analysis shows that the estimated matrices are generally higher than 5% except LT and SR where the level of changes are well within the required criteria.

Table 11.61 Sector to Sector Matrices Coincidence Ratio

Time Period	AM	PM	LT	SR	OP
EMP	1.09	1.04	0.99	0.98	1.05
COM	1.12	1.09	1.00	0.99	1.12
OTH	1.05	1.03	0.99	0.99	1.08
EDU	1.07	1.17	1.02	1.00	1.08
RET	1.06	0.39	0.35	0.57	0.02
All Purposes	1.08	1.07	0.99	0.96	1.07

11.4.2 Flows (across screenline)

Figure 11.68 and Figure 11.69 show the screenline performance along the Canal Cordon in AM and PM time periods respectively. These are based on the GEH values in comparison to the observed data. The northern part of the cordon has a relatively low correlation with the observed flows in both peak periods.

Figure 11.68 AM Flow Screenline GEH Values vs Observed

Figure 11.69 PM Flow Screenline GEH Values vs Observed

Table 11.62 below summarises Bus passenger flows passing the Canal Cordon screenline. This shows that 8 sites (36%) in AM Peak and 11 sites (48%) in PM peak have a GEH of under 5 with total modelled bus flows being 10% lower in the AM peak and 2% higher in the PM peak compared to the observed data.

Table 11.62 Bus Flows Across Screenline

TP	Cordon	Direction	Location	Mode	Observed	Modelled	GEH	GEH Pass/Fail
AM	Canal	Inbound	Mount Street Bridge	BUS	390	279.5	6.0	Fail
AM	Canal	Inbound	Baggot Street Bridge	BUS	262	52.6	16.7	Fail
AM	Canal	Inbound	Leeson Street Bridge	BUS	1794	967.6	22.2	Fail
AM	Canal	Inbound	Charlemont Street Bridge	BUS	75	1.6	11.9	Fail
AM	Canal	Inbound	Herberton Road	BUS	132	53.6	8.1	Fail
AM	Canal	Inbound	Portobello Bridge	BUS	1923	1652.4	6.4	Fail
AM	Canal	Inbound	Harold's Cross Bridge	BUS	1040	1222.3	5.4	Fail
AM	Canal	Inbound	Clougher Road	BUS	123	79.3	4.3	Pass
AM	Canal	Inbound	Dolphins Barn	BUS	818	898	2.7	Pass
AM	Canal	Inbound	South Circular Road	BUS	285	35	19.8	Fail
AM	Canal	Inbound	Old Kilmainham	BUS	472	555.1	3.7	Pass
AM	Canal	Inbound	St. Johns Road West	BUS	3156	3185.8	0.5	Pass
AM	Canal	Inbound	Old Cabra Road	BUS	1360	1885.5	13.0	Fail

TP	Cordon	Direction	Location	Mode	Observed	Modelled	GEH	GEH Pass/Fail
AM	Canal	Inbound	Cabra Road (St. Peter's Church)	BUS	1621	1319.1	7.9	Fail
AM	Canal	Inbound	Blackhorse Avenue	BUS	429	449.6	1.0	Pass
AM	Canal	Inbound	North Circular Road (Charleville)	BUS	336	56.3	20.0	Fail
AM	Canal	Inbound	Phibsborough Road North	BUS	1458	1141.9	8.8	Fail
AM	Canal	Inbound	Newcomen Road Bridge	BUS	3422	3286.7	2.3	Pass
AM	Canal	Inbound	Binns Bridge	BUS	2541	1990.3	11.6	Fail
AM	Canal	Inbound	Ballybough (Clarke's) Bridge	BUS	353	100.8	16.7	Fail
AM	Canal	Inbound	Port Tunnel	BUS	2790	2929.5	2.6	Pass
AM	Canal	Inbound	Conyngham Road	BUS	620	482.1	5.9	Fail
PM	Canal	Outbound	Barrow Street	BUS	172	176.1	0.3	Pass
PM	Canal	Outbound	Mount Street Bridge	BUS	408	168.2	14.1	Fail
PM	Canal	Outbound	Baggot Street Bridge	BUS	189	157.7	2.4	Pass
PM	Canal	Outbound	Leeson Street Bridge	BUS	1985	1642.5	8.0	Fail
PM	Canal	Outbound	Charlemont Street Bridge	BUS	96	3.7	13.1	Fail
PM	Canal	Outbound	Herberton Road	BUS	74	64.4	1.2	Pass
PM	Canal	Outbound	Portobello Bridge	BUS	1662	1561.4	2.5	Pass
PM	Canal	Outbound	Harold's Cross Bridge	BUS	852	905.4	1.8	Pass
PM	Canal	Outbound	Clougher Road	BUS	142	86	5.2	Fail
PM	Canal	Outbound	Dolphins Barn	BUS	818	768.7	1.8	Pass
PM	Canal	Outbound	South Circular Road	BUS	105	26.9	9.6	Fail
PM	Canal	Outbound	Old Kilmainham	BUS	554	603.3	2.0	Pass
PM	Canal	Outbound	St. Johns Road West	BUS	2767	3538.4	13.7	Fail
PM	Canal	Outbound	Old Cabra Road	BUS	846	1241.7	12.2	Fail
PM	Canal	Outbound	Cabra Road (St. Peter's Church)	BUS	955	997.6	1.4	Pass
PM	Canal	Outbound	Blackhorse Avenue	BUS	368	216.7	8.8	Fail
PM	Canal	Outbound	North Circular Road (Charleville)	BUS	130	55.5	7.7	Fail
PM	Canal	Outbound	Phibsborough Road North	BUS	1065	1013.4	1.6	Pass
PM	Canal	Outbound	Newcomen Road Bridge	BUS	2541	2806.2	5.1	Fail
PM	Canal	Outbound	Binns Bridge	BUS	1916	1791.1	2.9	Pass
PM	Canal	Outbound	Ballybough (Clarke's) Bridge	BUS	175	94.1	7.0	Fail
PM	Canal	Outbound	Port Tunnel	BUS	1286	1662.5	9.8	Fail
PM	Canal	Outbound	Conyngham Road	BUS	451	474.5	1.1	Pass

The Rail screenline performance shown in

Table 11.63 below shows a generally good performance with modelled flows being well within the GEH criteria of being below 5. There are instances in the SR and PM periods where modelled flows are higher than observed. Competing services and time/cost parameters including wait time and boarding time penalties will be reviewed to further improve this position.

Table 11.63 Rail Flows across Screenline

TP	Cordon	Direction	Location	Mode	Observed	Modelled	GEH	GEH Pass/Fail
AM	Canal	Inbound	Heuston	RAIL	2204	2070.6	2.9	Pass
AM	Canal	Inbound	Connolly	RAIL	10112	9624.5	4.9	Pass
AM	Canal	Inbound	Grand Canal Dock to Pearse	RAIL	3138	3391.7	4.4	Pass
AM	Canal	Outbound	Heuston	RAIL	252	223.4	1.9	Pass
AM	Canal	Outbound	Connolly	RAIL	698	800.5	3.7	Pass
AM	Canal	Outbound	Pearse to Grand Canal Dock	RAIL	3982	3869	1.8	Pass
LT	Canal	Inbound	Heuston	RAIL	512	484.9	1.2	Pass
LT	Canal	Inbound	Connolly	RAIL	751	822	2.5	Pass
LT	Canal	Inbound	Pearse to Grand Canal Dock	RAIL	416	388.9	1.4	Pass
LT	Canal	Outbound	Heuston	RAIL	308	282.7	1.5	Pass
LT	Canal	Outbound	Connolly	RAIL	884	778	3.7	Pass
LT	Canal	Outbound	Grand Canal Dock to Pearse	RAIL	572	586.7	0.6	Pass
SR	Canal	Inbound	Heuston	RAIL	307	278.6	1.7	Pass
SR	Canal	Inbound	Connolly	RAIL	617	658.9	1.7	Pass
SR	Canal	Inbound	Pearse to Grand Canal Dock	RAIL	590	779.8	7.3	Fail
SR	Canal	Outbound	Heuston	RAIL	205	414.9	11.9	Fail
SR	Canal	Outbound	Connolly	RAIL	1383	1799.1	10.4	Fail
SR	Canal	Outbound	Grand Canal Dock to Pearse	RAIL	710	821.6	4.0	Pass
PM	Canal	Inbound	Heuston	RAIL	161	190.6	2.2	Pass
PM	Canal	Inbound	Connolly	RAIL	1007	1071.8	2.0	Pass
PM	Canal	Inbound	Pearse to Grand Canal Dock	RAIL	2131	2231.2	2.1	Pass
PM	Canal	Outbound	Heuston	RAIL	1585	2476.9	19.8	Fail
PM	Canal	Outbound	Connolly	RAIL	8639	9461.3	8.6	Fail
PM	Canal	Outbound	Grand Canal Dock to Pearse	RAIL	3549	3912.3	5.9	Fail
OP	Canal	Inbound	Heuston	RAIL	55	101.2	5.2	Fail
OP	Canal	Inbound	Connolly	RAIL	104	401.8	18.7	Fail
OP	Canal	Inbound	Pearse to Grand Canal Dock	RAIL	503	315.3	9.3	Fail
OP	Canal	Outbound	Heuston	RAIL	116	97.1	1.8	Pass
OP	Canal	Outbound	Connolly	RAIL	763	516	9.8	Fail
OP	Canal	Outbound	Grand Canal Dock to Pearse	RAIL	287	336.7	2.8	Pass

Similar to Rail flows, Luas screenline performance shown in Table 11.64 below shows a good performance across time periods and in both directions.

Table 11.64 Luas Flows across Screenline

TP	Cordon	Direction	Location	Mode	Observed	Modelled	GEH	GEH Pass/Fail
AM	Canal	Inbound	Charlemont	LUAS	3794	4201.1	6.4	Fail
AM	Canal	Inbound	Suir Road	LUAS	2247	2361.3	2.4	Pass
AM	Canal	Outbound	Hatch Street	LUAS	1422	1529.5	2.8	Pass
AM	Canal	Outbound	Rialto	LUAS	786	896.4	3.8	Pass
LT	Canal	Inbound	Charlemont	LUAS	684	708.2	0.9	Pass
LT	Canal	Inbound	Suir Road	LUAS	606	642	1.4	Pass
LT	Canal	Outbound	Hatch Street	LUAS	456	437.8	0.9	Pass
LT	Canal	Outbound	Rialto	LUAS	545	542.6	0.1	Pass
SR	Canal	Inbound	Charlemont	LUAS	567	639	2.9	Pass
SR	Canal	Inbound	Suir Road	LUAS	688	745.5	2.1	Pass
SR	Canal	Outbound	Hatch Street	LUAS	809	979.6	5.7	Fail
SR	Canal	Outbound	Rialto	LUAS	695	1028	11.3	Fail
PM	Canal	Inbound	Charlemont	LUAS	1536	1726.6	4.7	Pass
PM	Canal	Inbound	Suir Road	LUAS	1110	1255.1	4.2	Pass
PM	Canal	Outbound	Hatch Street	LUAS	1886	2236.7	7.7	Fail
PM	Canal	Outbound	Rialto	LUAS	1346	1828.8	12.1	Fail
OP	Canal	Inbound	Charlemont	LUAS	428	182.3	14.1	Fail
OP	Canal	Inbound	Suir Road	LUAS	201	288.6	5.6	Fail
OP	Canal	Outbound	Hatch Street	LUAS	926	246.3	28.1	Fail
OP	Canal	Outbound	Rialto	LUAS	551	358.3	9.0	Fail

11.4.3 Public Transport Flow Summary

Table 11.65 and Table 11.66 summarise the modelled and observed total flow for each main public transport model across the Dublin Canal Cordon, for AM and PM respectively.

Table 11.65 Public Transport Totals across Screenline (AM)

	Flow Inbound			
	Rail	Luas	Bus	**Total**
Observed	15,454	10,093	25,400	**50,947**
Modelled	15,087	11,095	22,625	**48,806**
Difference	-367	1,002	-2,775	**-2,141**
% Difference	-2%	10%	-11%	**-4%**

Table 11.66 Public Transport Totals across Screenline (PM)

	Flow Outbound			
	Rail	Luas	Bus	**Total**
Observed	16,911	5,447	18,977	**41,335**
Modelled	19,154	6,847	19,712	**45,712**
Difference	2,243	1,400	735	**4,377**
% Difference	13%	26%	4%	**11%**

11.4.4 Journey Time Comparisons

The journey times in the PT model have been calibrated against the observed timetable (GTFS) and Automatic Vehicle Location (AVL) datasets.

Journey times are evaluated based on a comparison of modelled and observed journey times on complete routes, where the percentage difference is used as the key comparator. In a perfect model these would all equal zero across every route, and a percentage value higher than zero indicates the modelled journey time is slower than the observed value.

A set of journey time factors have been calculated and applied based on the type of service and the sectoral corridors (as shown in Figure 11.70 and below in Table 11.67) on which bus services are operating. These calibration processes have resulted in an overall increase of bus journey times to better meet the criteria.

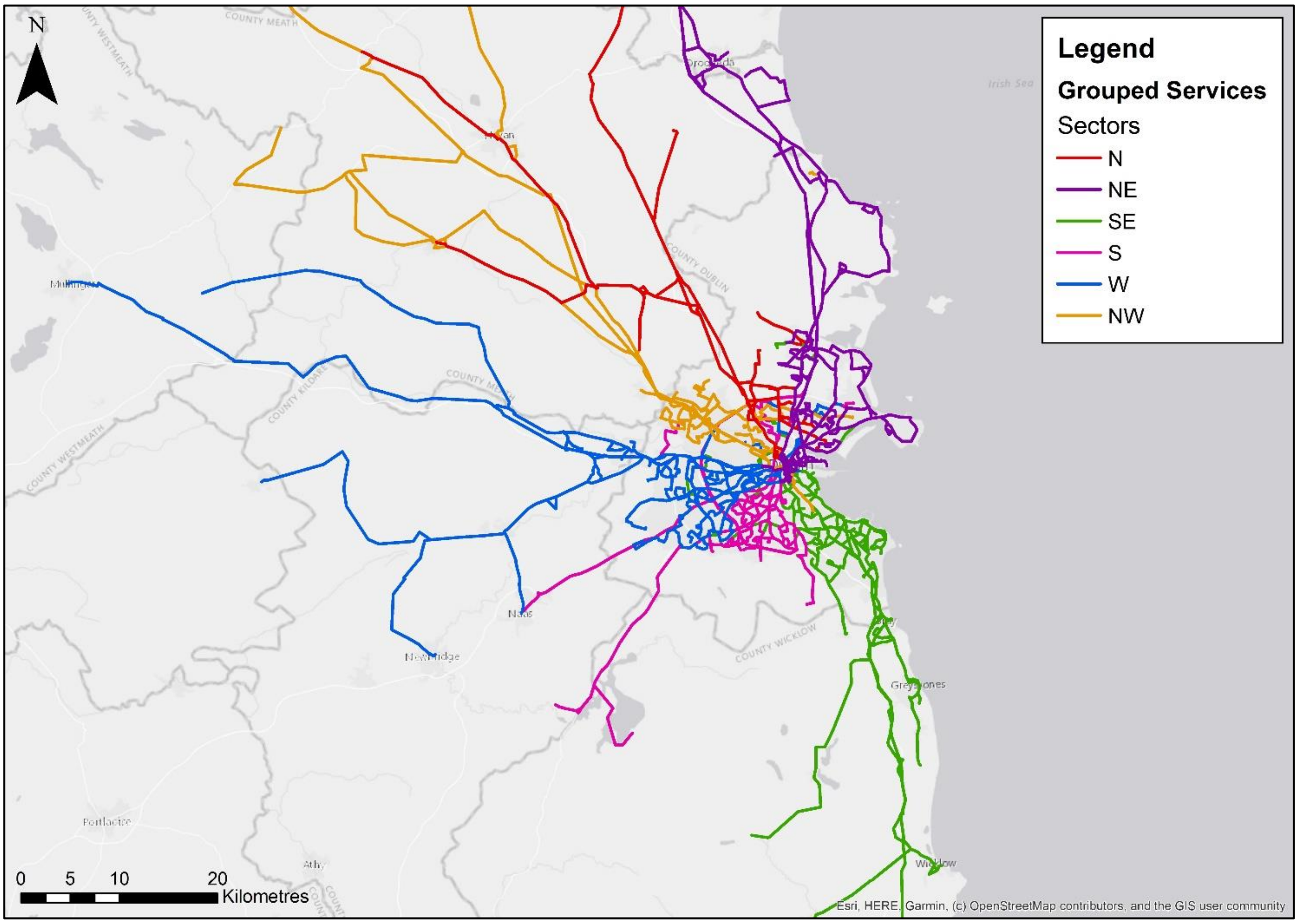


Figure 11.70 Grouped Bus Services by Sectors

With this process applied, the model has 725 services (42%) across all time periods passing the GEH criteria.

Table 11.67 Journey Time Pass Fail Criteria Summary

Time Period	No. Pass	% Pass	No. Fail	% Fail
AM	181	52.90%	161	48.00%
LT	148	53.43%	129	46.57%
SR	141	48.45%	150	51.55%
PM	163	48.66%	172	51.34%
OP	106	46.09%	124	53.91%
Total	739	50.10%	736	49.90%

As a further test, a set of bands are used to define how close the percentage comparison of journey times is across routes and to indicate how large the outliers are. Figure 11.71 shows that the majority of modelled journey times are within 10% of the observed, however a large number of services are modelled with longer than observed journey times.

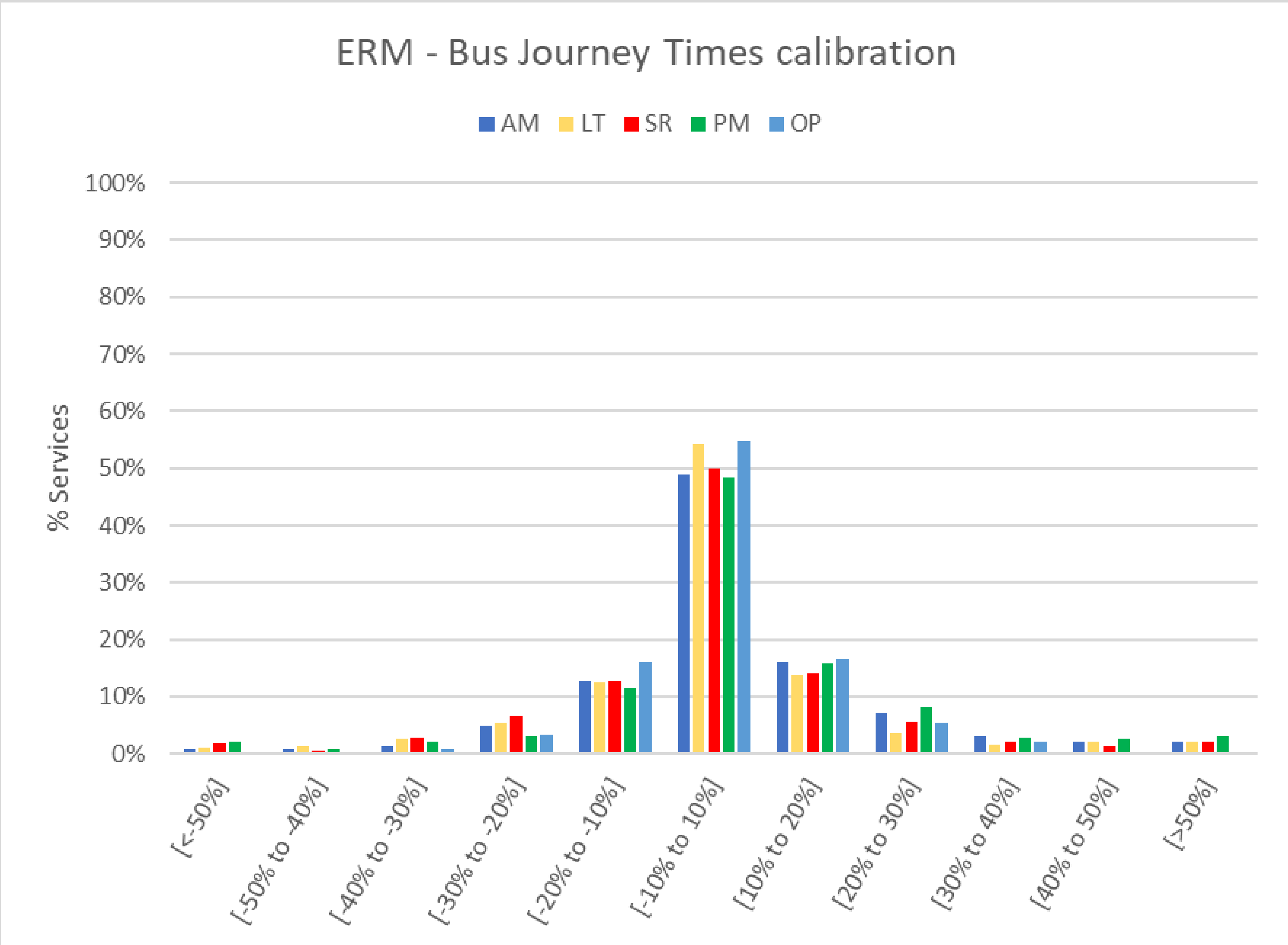
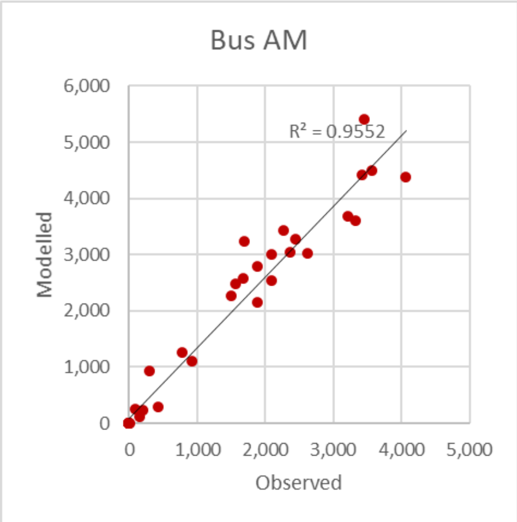
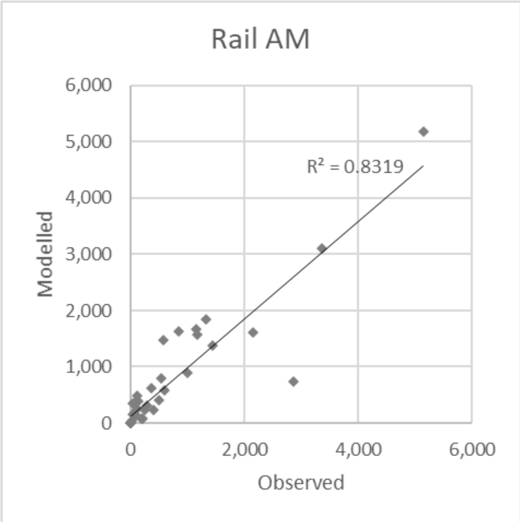


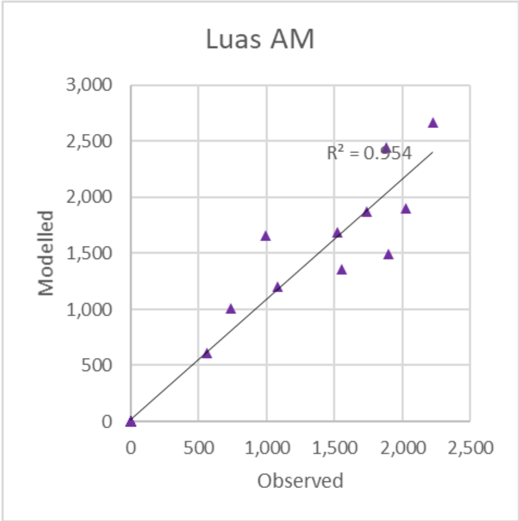
Figure 11.71 Proportion of Journey Times within % Comparison Bands by Time Period

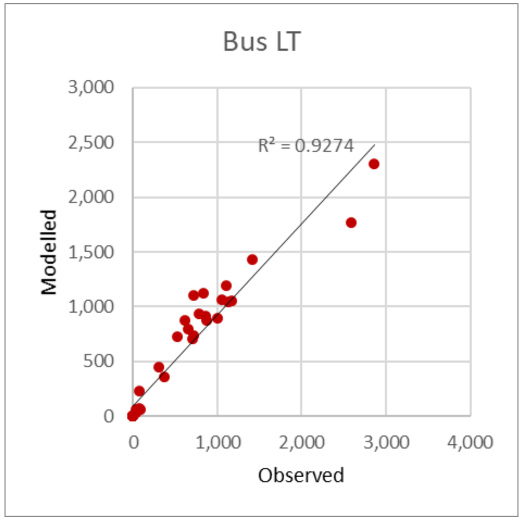
11.4.5 Boarding / Alighting Comparisons

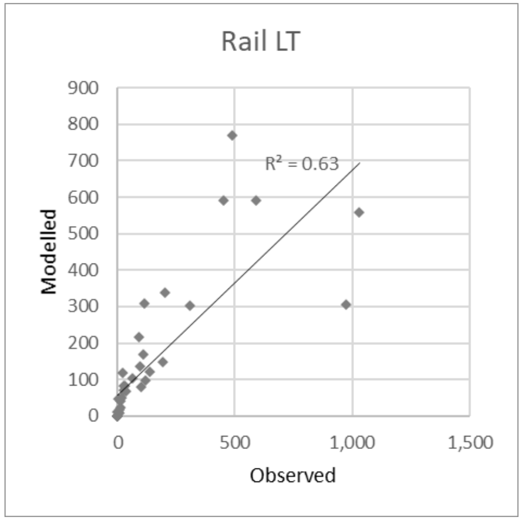
Figure 11.72 below show the correlation between observed and modelled PT boardings across all model sectors. These show generally good correlations across different time periods and sub modes especially in peak periods.

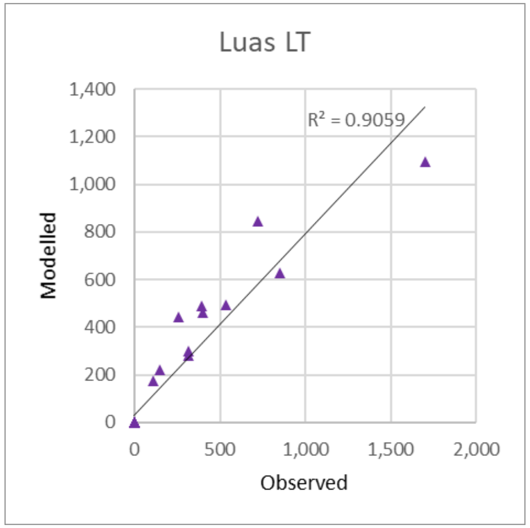

Bus AM
Modelled
Observed
R² = 0.9552
0
1,000
2,000
3,000
4,000
5,000
6,000

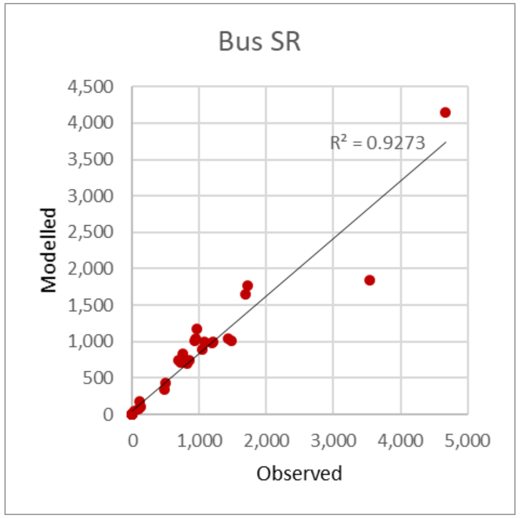

Rail AM
Modelled
Observed
R² = 0.8319
0
2,000
4,000
6,000

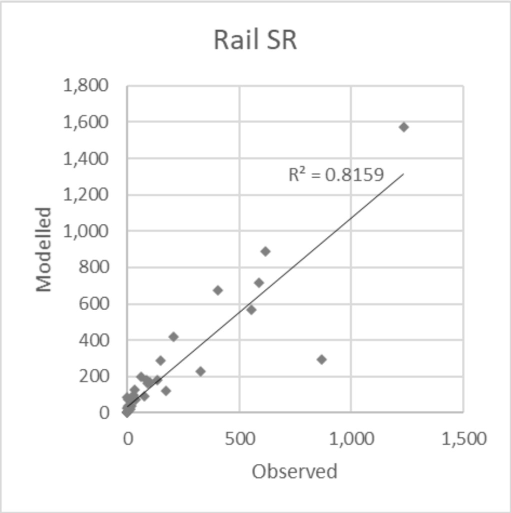

Luas AM
Modelled
Observed
R² = 0.954
0
500
1,000
1,500
2,000
2,500
3,000

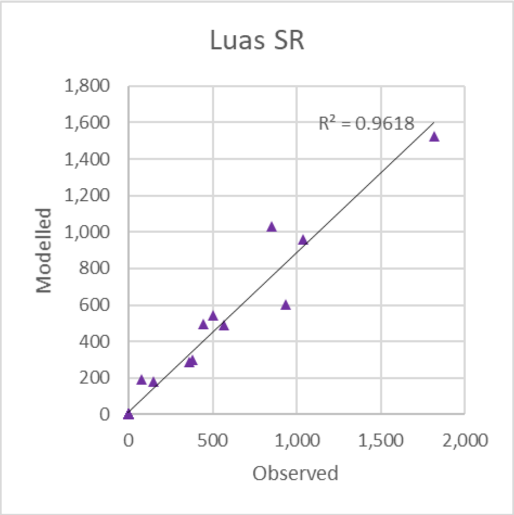

Bus LT
Modelled
Observed
R² = 0.9274
0
1,000
2,000
3,000
4,000
500
1,500
2,500

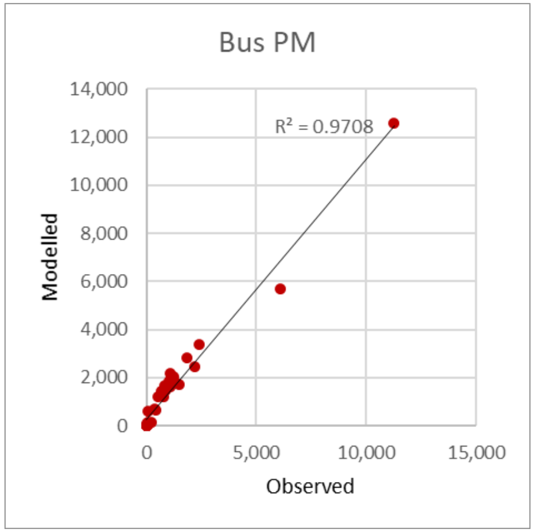

Rail LT
Modelled
Observed
R² = 0.63
0
100
200
300
400
500
600
700
800
900
1,000
1,500

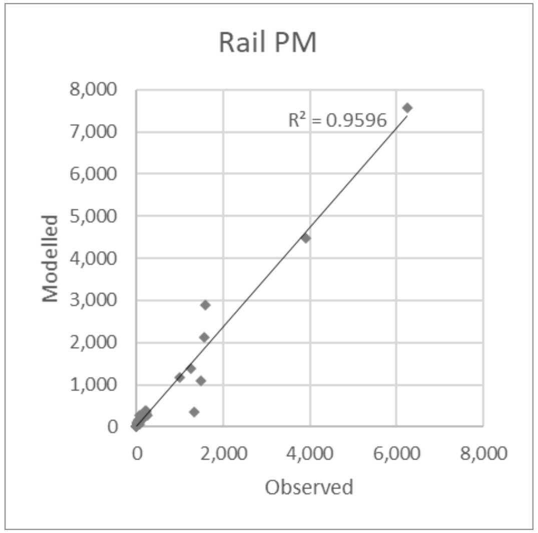

Luas LT
Modelled
Observed
R² = 0.9059
0
200
400
600
800
1,000
1,200
1,400
500
1,500
2,000

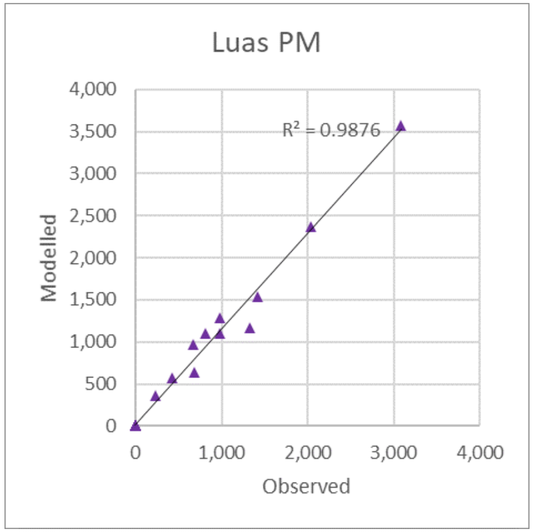

Bus SR
Modelled
Observed
R² = 0.9273
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
1,000
2,000
3,000
4,000
5,000


Rail SR
Modelled
Observed
R² = 0.8159
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
500
1,000
1,500


Luas SR
Modelled
Observed
R² = 0.9618
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
500
1,000
1,500
2,000


Bus PM
Modelled
Observed
R² = 0.9708
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
5,000
10,000
15,000


Rail PM
Modelled
Observed
R² = 0.9596
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
2,000
4,000
6,000
8,000


Luas PM
Modelled
Observed
R² = 0.9876
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
1,000
2,000
3,000
4,000

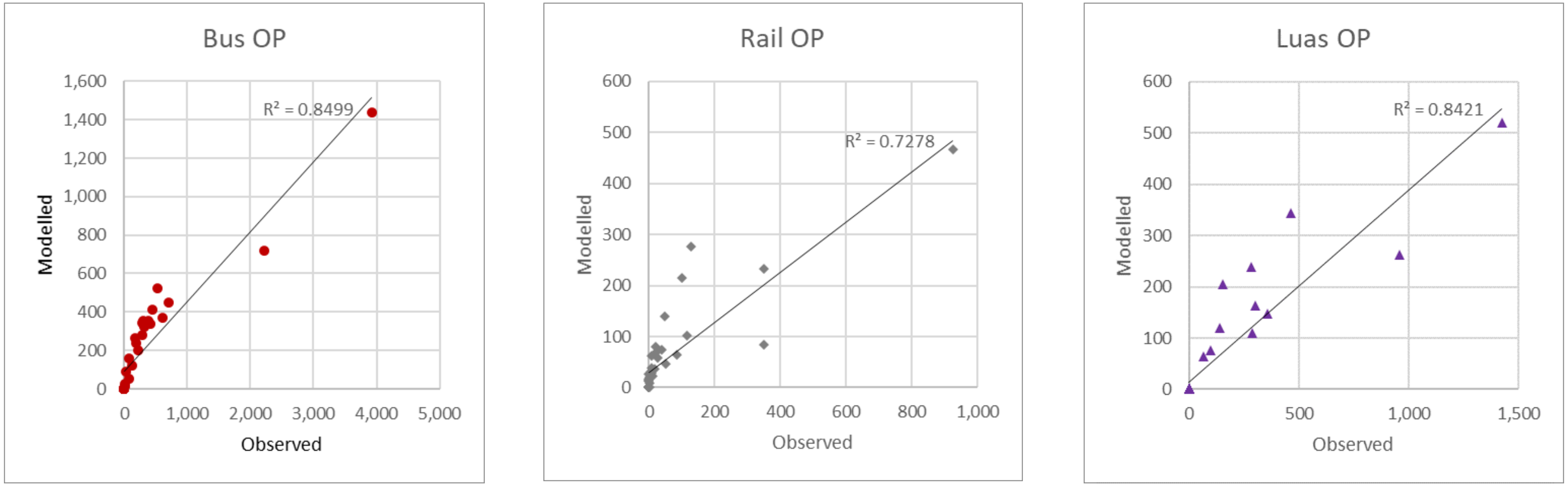


Figure 11.72 PT Boarding and Alighting Comparison

However, there are outliers identified for bus boardings which are found to occur in Dublin City Centre sectors (Sectors 1 and 3). Figure 11.73 to Figure 11.75 below show the bus boardings GEH in Dublin City Centre in AM and PM peak respectively. This shows that the boardings on the corridor on the northern embankment of River Liffey are significantly high in AM Peak. Similarly, the boardings on Amiens Street also appear to be significantly higher in the same time period. On the other hand, the boardings on Westmoreland Street to O'Connell Street are low. The boardings during PM peak are generally low on these corridors.

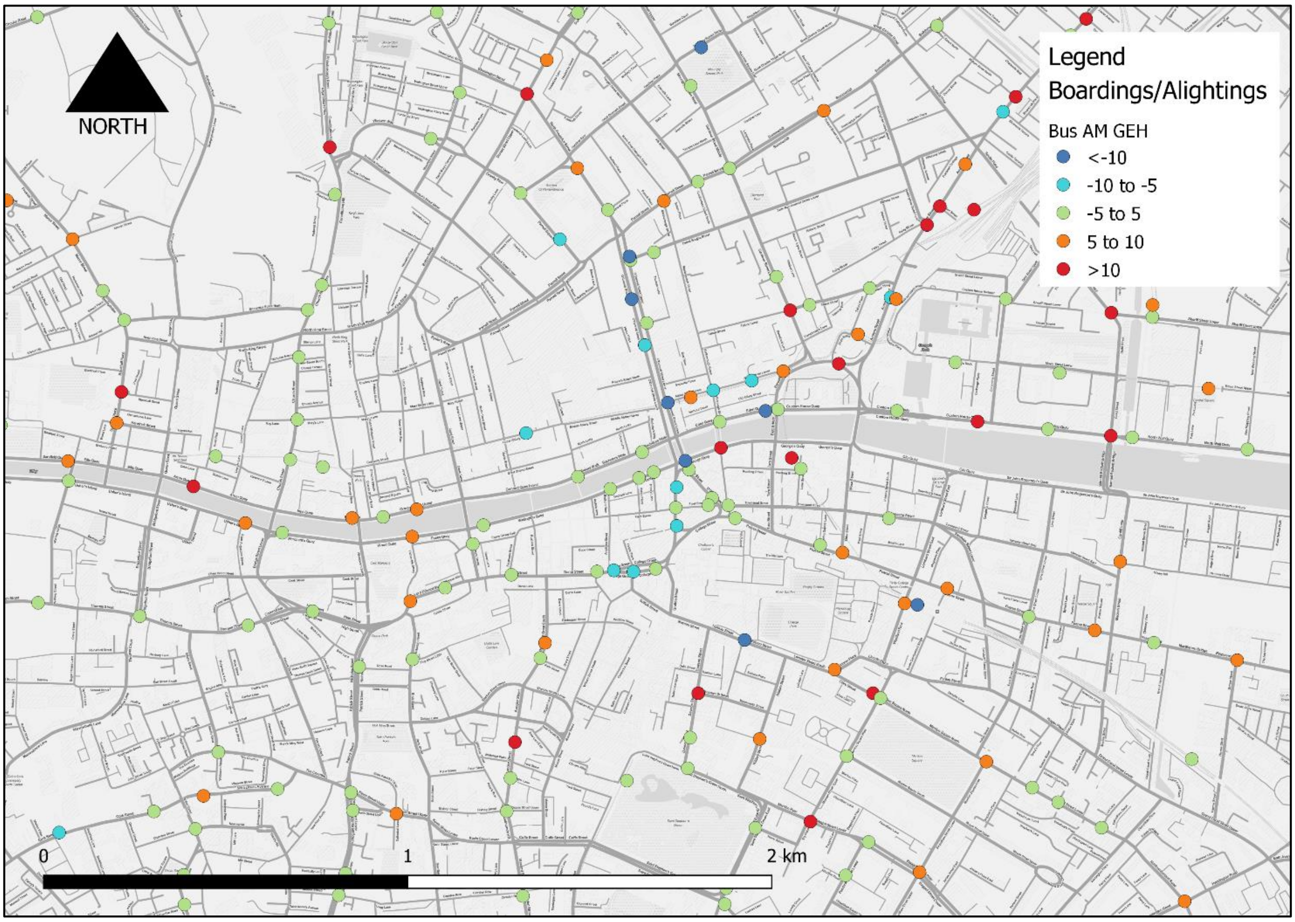


Figure 11.73 Bus Boarders/Alighters GEH AM Peak

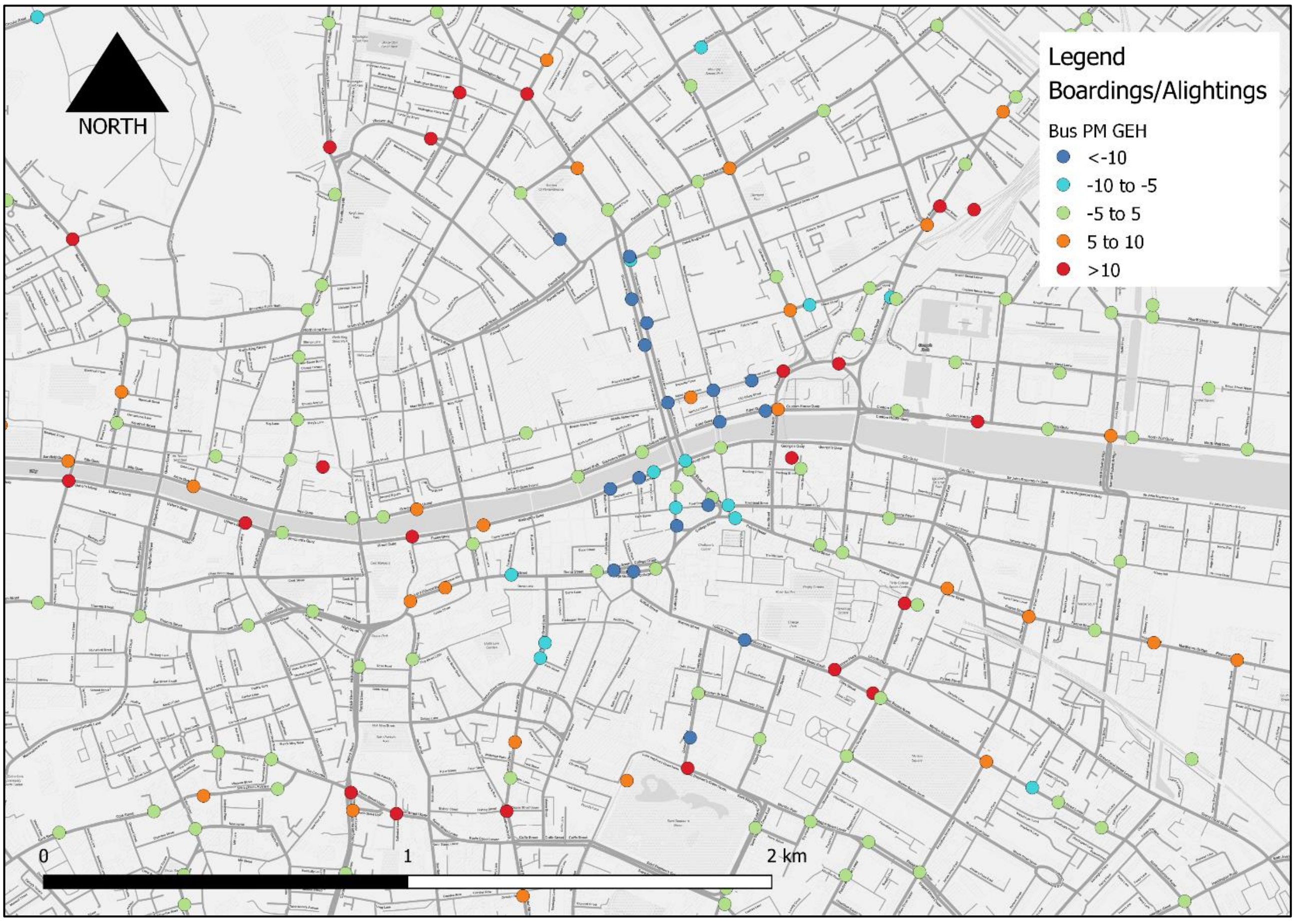


Figure 11.74 Bus Boarders/Alighters GEH PM Peak

The large number of bus boardings in the city centre can partly be attributed to the high transfers to bus from other modes and from other buses. There is a substantial amount of transfers to bus from the Luas Red Line particularly at Museum, Smithfield, and Abbey Street Luas stops which is consistent with the high boardings on the bus corridor on the north of the river. High transfers to bus are also observed at Tara Street, Busáras, and Connolly stations.

There is no available observed data to compare against which solely considers transfers, so this analysis is provided for the modelled flows only.

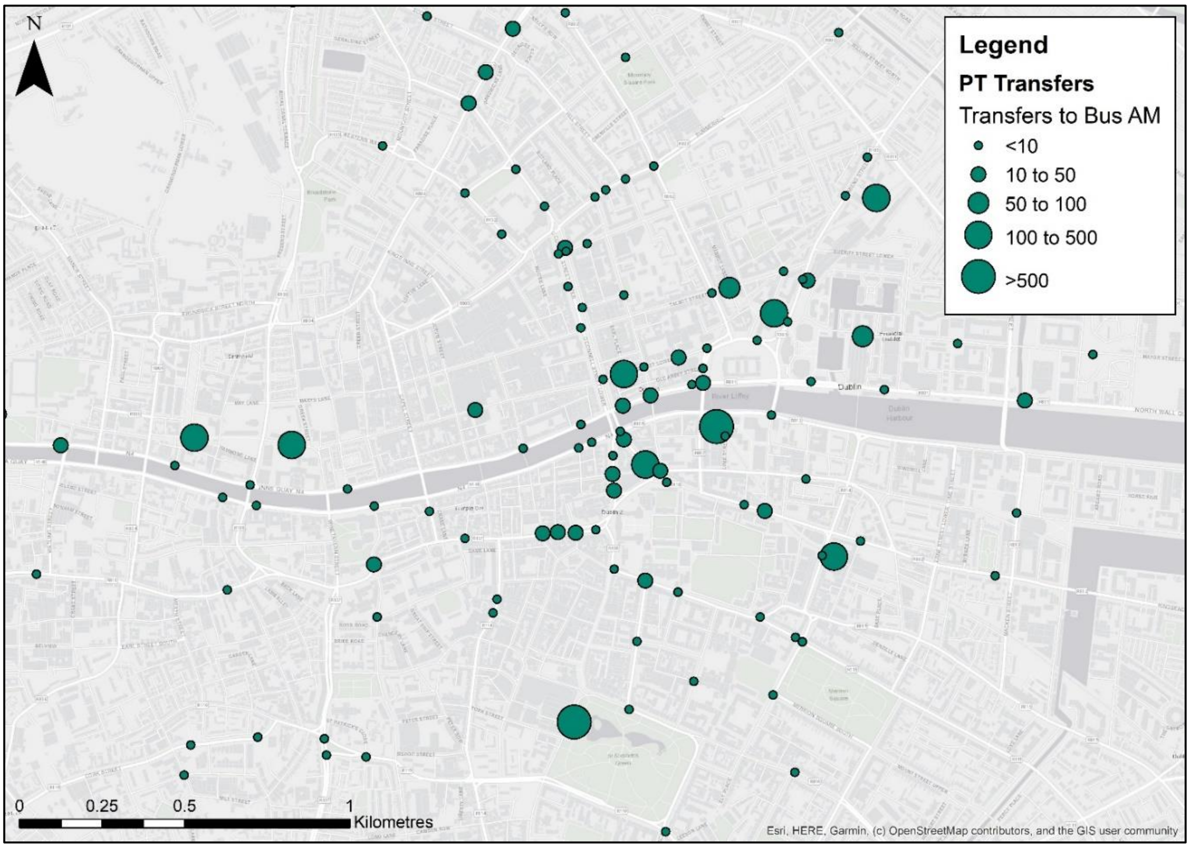


Figure 11.75 PT Transfers to Bus AM Peak

The Rail and Luas boardings in the AM and PM peak are shown in Figure 11.76 and Figure 11.77 below. These figures show generally high boardings in both modes across different corridors. The number of modelled boardings with significantly high and low numbers compared to the observed are mainly seen in areas outside Dublin, whilst there is a relatively good validation within the city centre.

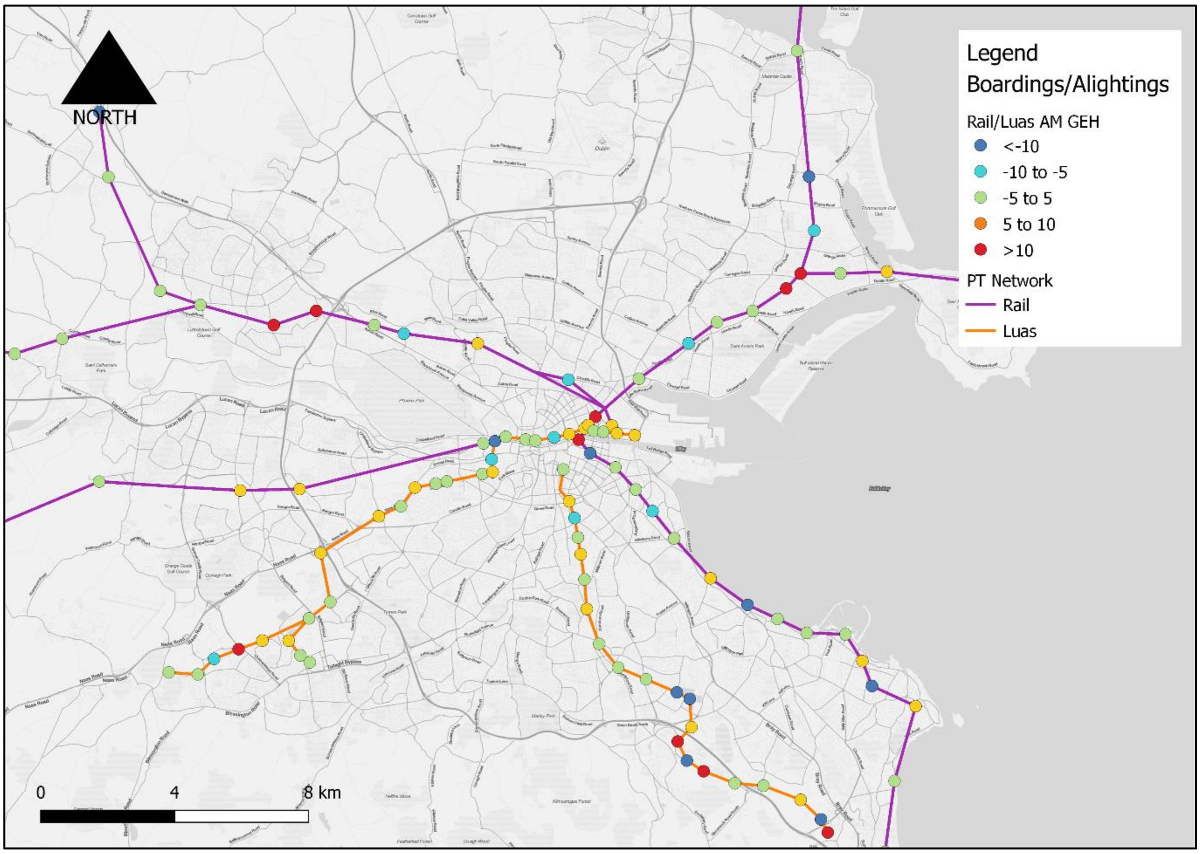


Figure 11.76 Rail and Luas Boarders/Alighters GEH AM Peak

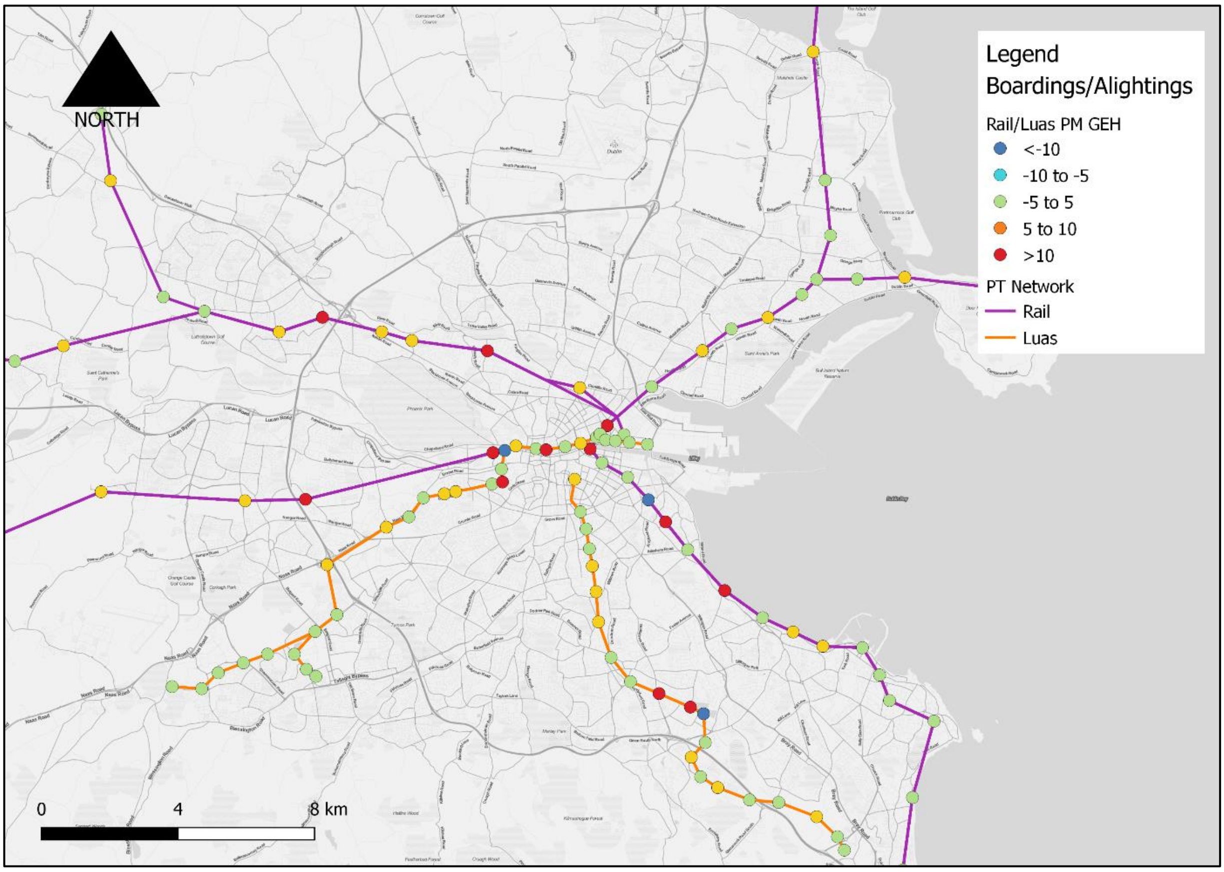


Figure 11.77 Rail and Luas Boarders/Alighters GEH PM Peak

11.4.6 Public Transport Crowding

Checks have been undertaken on PT outputs to identify services with high crowding levels, particularly the ones with flows higher than their capacities. There are 82 lines (4%) across all time periods with occupancy higher than 100%. These services have been checked in more detail and it was found that the some of these overcrowded services have insufficient vehicle capacity or service frequency due to incorrect coding. Following this analysis illustrated in Table 11.68 below, these lines have been corrected in the PT model.

Table 11.68 PT Service Crowding Analysis

Time Period	No. of Routes	%OCC					
		0-50%	50-80%	80-100%	100-125%	125-150%	>150%
AM	571	336	121	58	35	10	11
LT	439	398	33	3	4	1	0
SR	449	391	38	9	6	0	5
PM	543	489	35	9	6	0	4
Total	2002	1614	227	79	51	11	20
% Total		81%	11%	4%	3%	1%	1%

11.4.7 Public Transport Crowding Convergence

The PT assignment was run for a varying number of iterations to assess the impacts the number of crowding loops has on the assigned demand. The number of crowd model iterations tested are presented in Table 11.69.

Table 11.69 Crowding Convergence Tests

Test No.	Number of Crowding Iterations
1	2
2	3
3	4
4	5*
5	6
6	7
7	20
8	21

*(current number of iterations in the model)

11.4.8 Convergence criteria

The magnitude of changes from one crowd model loop to another was measured on two levels:

- at the stop level (boarding); and
- at the line level (total boardings).

The indicator that was used to assess differences between two successive iterations is the composite cost Root-Mean-Square Error (RMSE). It is calculated for iteration n as

$$RMSE_n = \sqrt{\frac{\sum_{i,j}(C^n_{i,j} - C^{n-1}_{i,j})^2}{nb\ of\ i,j\ pairs\ with C_{i,j} > 0}}$$

Where $C^n_{i,j}$ is the PT composite cost from zone i to zone j at the end of iteration n.

11.4.9 Crowding Convergence Results – Boardings

Table 11.70 below classifies the PT stops by relative difference in number of boardings between two successive iterations of the crowd model. The number of stops with the exact same number of boardings as in previous iteration increases the more crowding loops are run, which was expected as the assignment gets more stTable 11.70able, pointing to a converging model.

The number of stops with 0 change between loop 20 & 21 (3,139) is significantly higher than between loop 6 & 7 (2,554). This suggests that more iterations might bring the proportions of stops with exact same number of boardings closer to 100%.

Table 11.70 PT Stop Distribution by Relative Difference Between Successive Loops

	loop 2-3	loop 3-4	loop 4-5	loop 5-6	loop 6-7	loop 20-21
No Change	2,018	2,064	2,192	2,382	2,554	3,139
<1%	1,210	1,242	1,221	1,104	959	386
1-2%	150	121	79	39	25	19
2-3%	55	43	28	11	10	6
3-4%	38	30	8	7	5	4
4-5%	16	16	11	7	4	4
5-10%	53	30	12	4	3	3
10-15%	11	9	2	0	0	0
15-20%	4	0	3	3	1	1
20-25%	4	2	0	1	0	0
25-50%	5	5	4	4	4	3
>50%	2	4	6	4	1	1
Total	**3,566**	**3,566**	**3,566**	**3,566**	**3,566**	**3,566**

11.4.10 Crowding Convergence Results – Services/Lines

Table 11.71 classifies the set of PT lines by the relative difference in number of boardings between two successive iterations. Similar to what was observed at the stop level, the number of PT lines with exactly the same number of boardings increases as more crowd model loops are run.

Table 11.71 PT Lines Distribution by Relative Difference Between Successive Loops

	loop 2-3	loop 3-4	loop 4-5	loop 5-6	loop 6-7	loop 20-21
No Change	89	100	117	139	157	268
<1%	358	364	382	387	385	272
1-2%	53	47	39	21	10	14
2-3%	18	21	16	10	1	1
3-4%	7	6	6	0	2	1
4-5%	6	11	1	2	2	2
5-10%	17	10	2	3	2	4
10-15%	9	2	0	2	3	1
15-20%	3	0	0	0	0	1
20-25%	3	2	1	1	0	0
25-50%	2	1	0	2	3	2
>50%	6	7	7	4	6	5
Total	571	571	571	571	571	571

Although the PT assignment progresses to a solution that replicates identically from one loop to another, it is evident that some lines are oscillating without any sign of reaching an equilibrium.

Further investigation revealed that the routes which do not converge have most of their route in common, i.e. nearly the same service expect a branch at the start/end of the route. Lines 4105 and 4107 for example are very similar routes, with a significant level of demand, and exhibit continuous demand flipping from one iteration to another[64]. Line coding may be amended to avoid such oscillations by changing the frequencies to have the same cost on both lines without crowding or by consolidating the 2 routes in a single coded route.

11.4.11 Recommendations

The current number of crowd model iterations (5) shows a reasonable stability: boardings at 95.7% of the stops changed by less than 1% between loop 4 and 5 and demand on 87.4% of the lines changed by less than 1% between loop 4 and 5. However the tests showed that running the assignment for 20 crowding iterations can increase the stability, as 98.9% of the stops change by less than 1% and 94.6% of the lines between loop 20 and 21. These results don't mean the flows are more correct after 20 loops or 5 but it tells us that the assignment is closer to an equilibrium that can be replicated. Furthermore, the analysis of the evolution of RMSE with the number of iterations indicates that there is little benefit in running the ERM PT assignment for more than 8 crowding iterations.

11.4.12 Fares Model

The fares model has been updated based on various information including updated ticket sales and revenue data and estimations based on the NTA Fares Determination document. Figure 11.78 below compares the fares models for each sub-mode in the 2012 and 2016 versions of the model.

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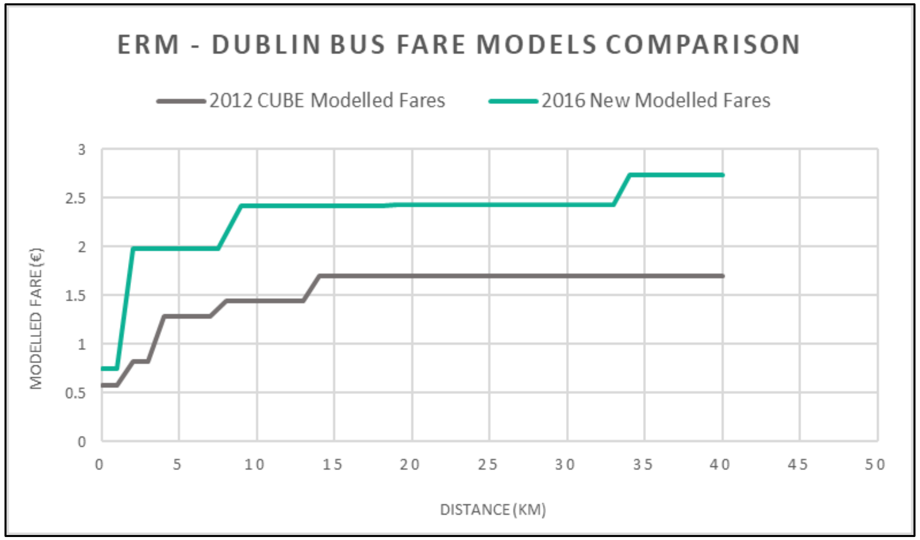
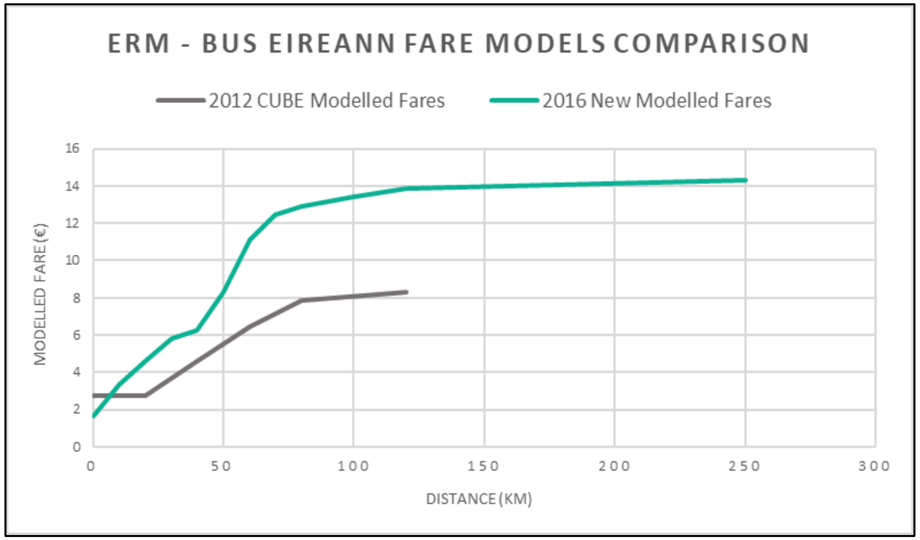
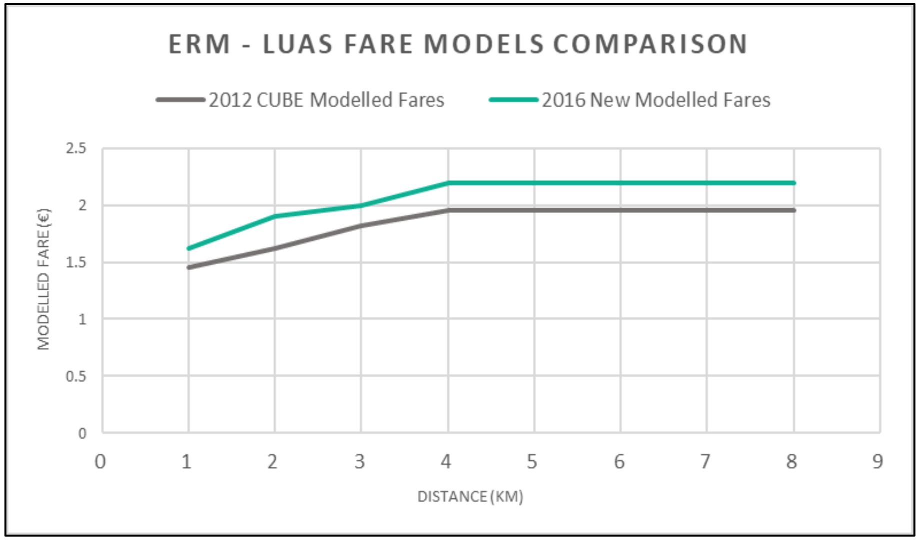
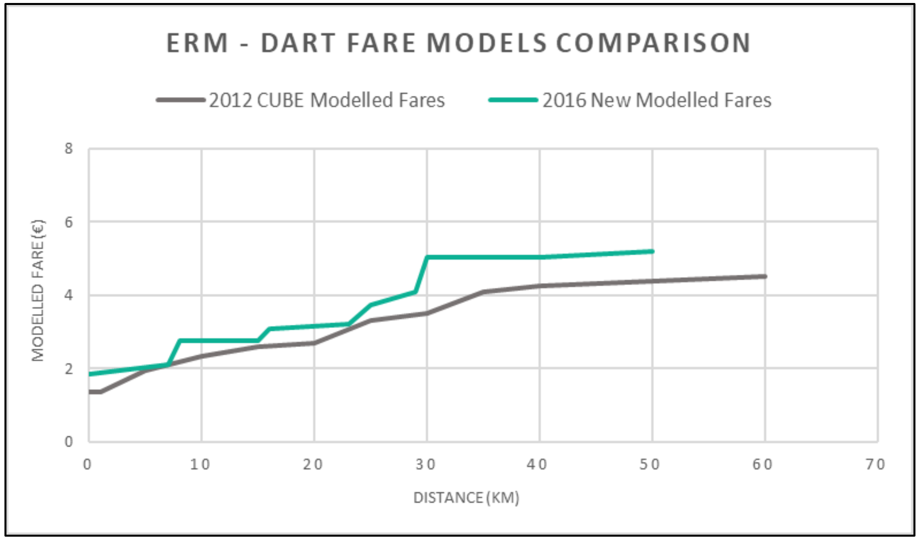
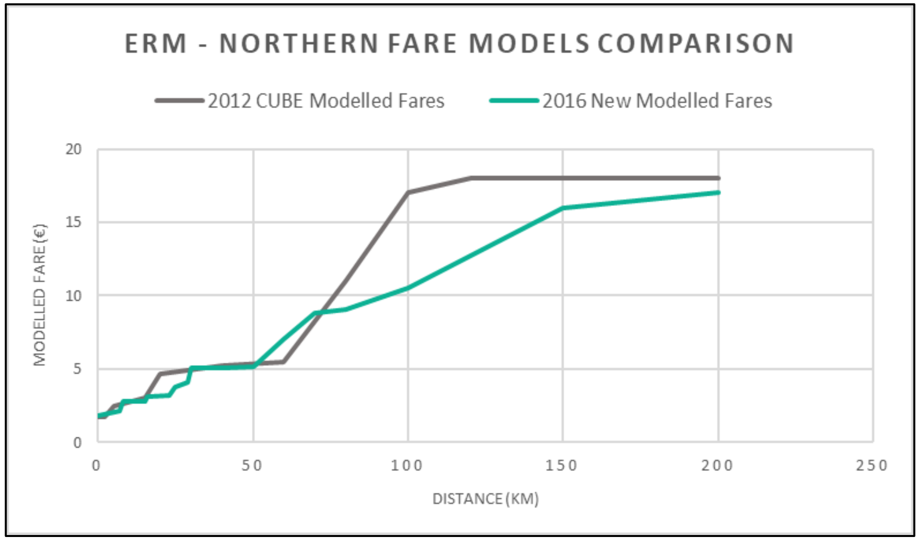
[64] This phenomenon is explained in the Cube user's manual: "Crowded networks might cause instabilities in the loadings between iterations, as demand switches toward less congested routes. In turn, those routes might become more heavily loaded, and thus less attractive at the next iteration. These changes might converge toward a solution, or might continue oscillating; oscillation is more likely in highly overloaded networks."


ERM - DUBLIN BUS FARE MODELS COMPARISON
2012 CUBE Modelled Fares
2016 New Modelled Fares
MODELLED FARE (€)
DISTANCE (KM)


ERM - BUS EIREANN FARE MODELS COMPARISON
2012 CUBE Modelled Fares
2016 New Modelled Fares
MODELLED FARE (€)
DISTANCE (KM)


ERM - LUAS FARE MODELS COMPARISON
2012 CUBE Modelled Fares
2016 New Modelled Fares
MODELLED FARE (€)
DISTANCE (KM)


ERM - DART FARE MODELS COMPARISON
2012 CUBE Modelled Fares
2016 New Modelled Fares
MODELLED FARE (€)
DISTANCE (KM)



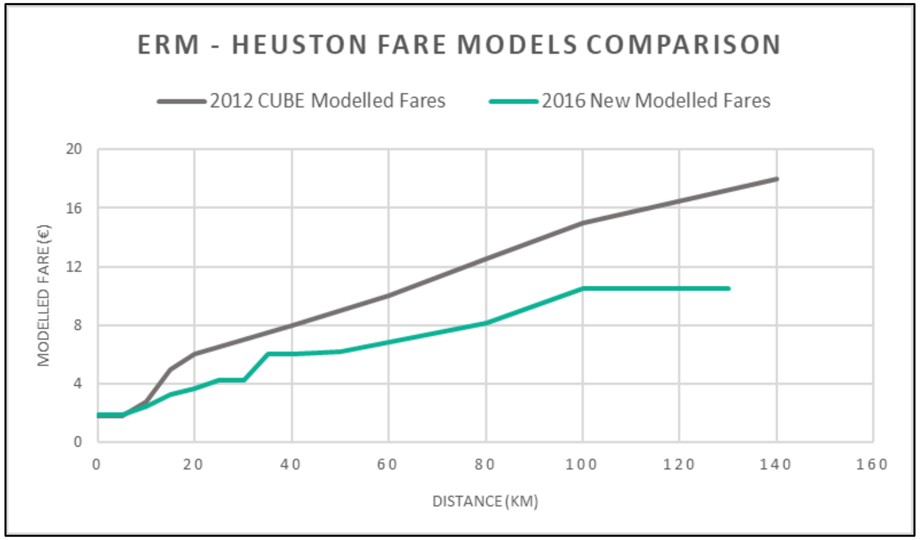


Figure 11.78 Fare Models 2012 vs 2016 Comparison

The updated Dublin Bus Fares Model has been built based on the demand weighted average of various Dublin Bus ticket sales revenue. This shows that fares in the 2016 model are generally higher than in the previous version of the model especially for trips longer than 2 kilometres where the difference is more substantial.

Similar to Dublin Bus, the fares model for Bus Eireann has been updated based on the revenue data across different ticket types. These have then been averaged by the number of trips made on each ticket type. The updated modelled fares are higher when compared to the 2012 modelled fares particularly on longer distance trips.

The Luas fare model has been updated based on the 2016 ticket sales data. The dataset covers both Red and Green lines of Luas and all ticket types. Overall, the updated fares are around 13% higher compared to the 2012 model.

The analysis on the Rail fares has been divided into several service groups. The fare models have then been updated based on the updated ticket sales data by origin and destination stations. This covers all ticket types including single, return, Flex and any multi-days and season tickets.

Figure 11.78 shows the updated DART fares model which resulted in higher fares for this service especially on trips longer than 30 kilometres.

The updated fares model for Northern services resulted in similar fares to the 2012 model for trips with distances of up to 70 kilometres. However, the model has estimated a more moderate increase of fares on longer trips, resulting in lower fares for these trips.

The fares model for Heuston services has also been updated with a smaller rate of increase by distances. In general, the modelled fares for these services are lower than the 2012 model.

11.4.13 PT Model Recommendations

Consideration of the following points is recommended for the next major update of the ERM PT Model and its input data.

Leap data provides a continuous source of observed PT journeys across all modes, including transfers. More use should be made of this dataset in future. More extensive bus patronage data should be obtained and used to validate the model.

The way Cube assigns demand to different routes with similar costs can be controlled through parameters from Cube v6.4.5 that are not available in the version used to calibrate the model (v6.45). To prevent convergence issues in the current version, aggregation of similar routes (that differ by a few nodes) can be considered (in forecasting) to improve convergence and prevent the crowding model oscillating service choice from one loop to another.

The low flow assignment can be locally congested (due to the 0.0001 unitary matrix concentrating trips in certain area) leading to slower bus speeds on bus lanes than without bus lanes. Care should be taken to avoid this in forecasting.

11.5 Active Modes Validation

11.5.1 Overview

The development of the active modes model is detailed in Chapter 9. Further to the various sense outlined in that chapter, the following sections present the flow validation based on the set of counts available for both walk and cycle. No calibration of these has been undertaken. The flows presented here are direct assignment of the respective walk and cycle demand matrices.

11.5.2 Walk and Cycle Count Comparison

Observed data is comprised mainly of walk and cycle data obtained through the Canal Cordon survey in 2016. Where available, other sites with walk and/or cycle counts have been included in the observed data set also. The comparisons between walk and/or cycle counts are outlined in Table 11.72 and Figure 11.79 below.

Table 11.72 Walk and Cycle Count Comparison (Canal Cordon)

	AM		LT		SR		PM	
	Walk	Cycle	Walk	Cycle	Walk	Cycle	Walk	Cycle
Observed	27,084	19,499	11,188	4,837	13,542	5,715	26,610	15,709
Modelled	26,716	7,766	10,085	1,792	9,638	2,127	18,476	5,760
Total Counts	127	287	127	287	127	287	127	287
GEH <5	27	114	30	45	30	62	37	95
% GEH <5	21%	40%	24%	16%	24%	22%	29%	33%
GEH <7	39	79	38	27	43	27	46	69
% GEH <7	31%	28%	30%	9%	34%	9%	36%	24%
GEH <10	60	51	58	10	54	12	62	42
% GEH <10	47%	18%	46%	3%	43%	4%	49%	15%

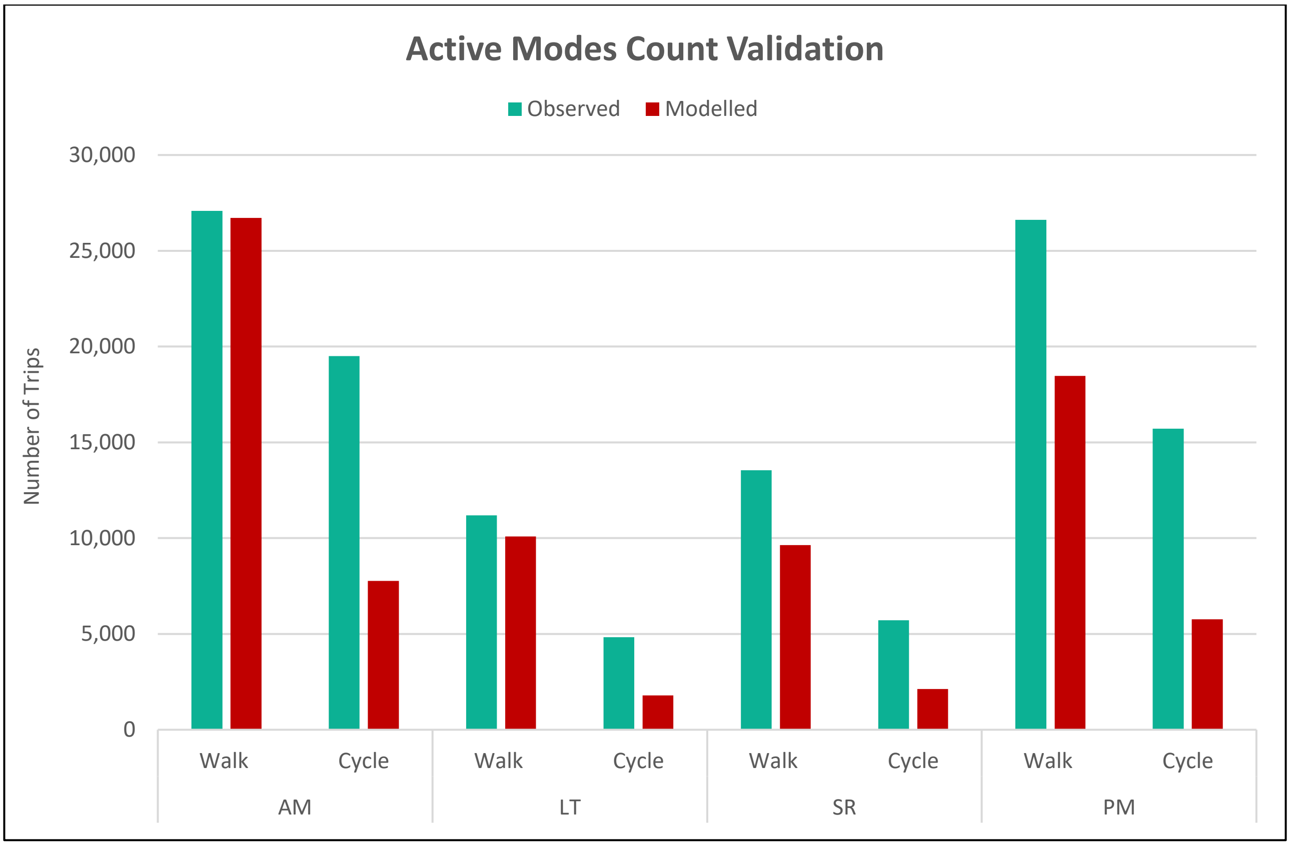


Figure 11.79 Walk and Cycle Count Comparison

11.5.3 Assessment

The demand matrices for walking and cycling when assigned to the respective active modes networks provide the above flows. The assignment flows are, a total level (i.e. the sum of all data points), below the observed. The walking and cycling assignment models do not include a robust route choice mechanism as compared with the road and PT models so will present much more variable results. This is not a weakness of the Demand Model in terms of generating travel costs by walking and cycling—route choice by active modes is much less a function of congestion and therefore demand and costs are relatively independent of each other. However, it should be noted that assignment of walking and cycling flows is done relatively simplistically on a quickest path basis and does not at present include other factors that do influence route choice such as traffic congestion, pinch points, air quality, or gradient. For these reasons the above presentation of the comparisons at a total level is a good validation of the overall demand level generated by the Demand Model and broad travel patterns; however, the comparisons are not an indication of how well the route choice aspect of the Active Modes model validates.

12 Realism Testing

12.1 Introduction

Realism tests are a standard industry practice undertaken as part of overall Demand Model validation to evaluate a Demand Model response to set changes in inputs, specifically:

- 10% increase in car fuel cost;
- 10% increase in PT fare; and
- 10% increase in car journey time.

All tests should be run with a base year model with no changes other than those specified in the test itself.

These tests are used as there are a range of responses which are considered appropriate and acceptable as standard and therefore the model can be evaluated in a meaningful manner.

It is noted that in some guidance, such as UK TAG, there is a suggestion that the results of realism tests may influence a decision to revise model parameters to better align with recommended responses. For the ERM, the outputs of the realism tests have not been used in such a manner.

12.2 Car Fuel Cost

12.2.1 Test Description

For the first test, car fuel cost was increased within the road assignment by adjusting the fuel cost values used in the road assignment model as presented in Table 12.1.

Table 12.1 Comparison of Car Fuel Costs

Test	Petrol Price (Euro / Litre)	Diesel Price (Euro / Litre)
Base Year	€1.3639	€1.2499
Fuel Increase Test	€1.5003	€1.3749

For clarity, overall generalised cost used within the road model is derived as a linear combination:

$$GC = PPM \times T + PPK \times D + M$$

Where:

- GC is the generalised cost in units of Pence;
- T is time in units of minutes (including any time penalties);

- D is distance in kilometres;
- M is monetary charge in Pence;
- PPM is a user-defined parameter specifying “Pence Per Minute”; and
- PPK specifies “Pence Per Kilometre”.

The PPK values are dependent on the fuel cost and are calculated separately for all road user classes within the model as:

$$PPK = \frac{PPL\left(\frac{Fcomp_a}{v} + Fcomp_b v + Fcomp_c v + Fcomp_d v^2\right) + \left(NFOC_a + \frac{NFOC_b}{v}\right)}{TaxRate}$$

Where:

- v is the average network speed in km/h, differentiated by time period and recalculated dynamically on each demand loop;
- PPL is the price per litre of fuel (euros) which varies by fuel type (petrol or diesel);
- $Fcomp_a$, $Fcomp_b$, $Fcomp_c$, and $Fcomp_d$ parameters are used to derive a fuel consumption rate which vary by vehicle type[65] and fuel type;
- $NFOC_a$ and $NFOC_b$ are parameters to derive non-fuel operating costs varying by purpose and vehicle type; and
- $TaxRate$ is the tax applied which here is considered as a rebate for business purposes (23%).

With these fuel prices changed the Demand Model was then run to convergence in a 2016 scenario with no other changes to the model, until GAP convergence was achieved. A summary of the overall GAP convergence is provided in Table 12.2.

Table 12.2 Convergence Summary for Car Fuel Cost Realism Test

Demand Loop	%GAP
1	-
2	1.69
3	0.44
4	0.41
5	0.40
6	0.36

[65] Vehicle type here is considered as car, LGV, OGV1, or OGV2

The model achieved an overall GAP convergence of 0.396 after 5 loops which is not compliant with UK TAG standards (below 0.2 in large models) but shows a similar level of %GAP convergence with a multi-loop base year model (0.27 after 8 loops).

12.2.2 Measuring and Evaluating the Response

To evaluate model response, comparisons are made between the final Demand Model loop results of the test scenario discussed in 12.2.1 against the single Demand Model loop base year model.

All model responses are considered as elasticities rather than absolute values, so that a 10% increase in fuel cost might be expected to produce a 2% decrease in car trips, for example.

These responses are evaluated based on:

$$e = \frac{\log(\mathrm{VehKm}_{\mathrm{Test}}) - \log(\mathrm{VehKm}_{\mathrm{Base}})}{\log(\mathrm{FuelCost}_{\mathrm{Test}}) - \log(\mathrm{FuelCost}_{\mathrm{Base}})} = \frac{\log(\mathrm{VehKm}_{\mathrm{Test}}) - \log(\mathrm{VehKm}_{\mathrm{Base}})}{\log(1.1)}$$

Where:

- e is the elasticity being measured;
- $\mathrm{VehKm}_{\mathrm{Test}}$ is the sum of test car vehicle-kms (from the realism test);
- $\mathrm{VehKm}_{\mathrm{Base}}$ is the sum of original car vehicle-kms (base year);
- $\mathrm{FuelCost}_{\mathrm{Test}}$ is the test fuel cost (from the realism test); and
- $\mathrm{FuelCost}_{\mathrm{Base}}$ is the original fuel cost (base year).

Elasticities would typically be expected to be negative, and for ease of discussion an elasticity closer to zero will be considered less elastic and referred to as lower (while strictly speaking being greater numerically).

It is noted that realism testing is generally only considered for the fully responsive and validated element of the Demand Model, and therefore excludes specific sections of demand including:

- Travel to, from, and between external zones;
- Special zones[66] (which have an alternative mode choice and are generally considered very different in response to cost changes);
- Centroid connectors which are subject to additional assumptions and relaxed constraints and
- Goods vehicles which can be considered within this context as fixed assignment matrices.

The off-peak time period within the road assignment model is not explicitly validated in the same level of detail as the other time periods and therefore falls outside the definitions for

[66] Special zones are those zones which represent ports and airports and is considered a standard term within this model

inclusion above but is still reported here given the reliance on costs within the Demand Model which influence all time periods based on the tour structure of the calculations.

The elasticities are measured on both a matrix and network basis. For matrix calculations, this is taken by multiplying the skimmed distances[67] of the road assignments with the assigned demand. To emphasise the point regarding what is included in a matrix context, only trips which do not have an origin or destination in either a special zone or external area are considered, i.e. only fully internal trips which do not relate to special zones.

For network elasticities a subset of the full network is used, shown in Figure 12.1, identified based on the following attributes:

- Fully simulated network;
- Not excessively influenced by fixed or non-standard demand;
- Excludes centroid connectors which are subject to additional assumptions and relaxed constraints; and
- Appropriately validated within the road assignment (excluding the off-peak time period).

It is noted that network elasticities would be expected to be different from the matrix-based elasticities as they will include some elements of fixed demand such as external trips and goods vehicles.

[67] Taken directly from the road assignment using Saturn software by skimming average distance along the (forest of) multiple paths used within the assignment.

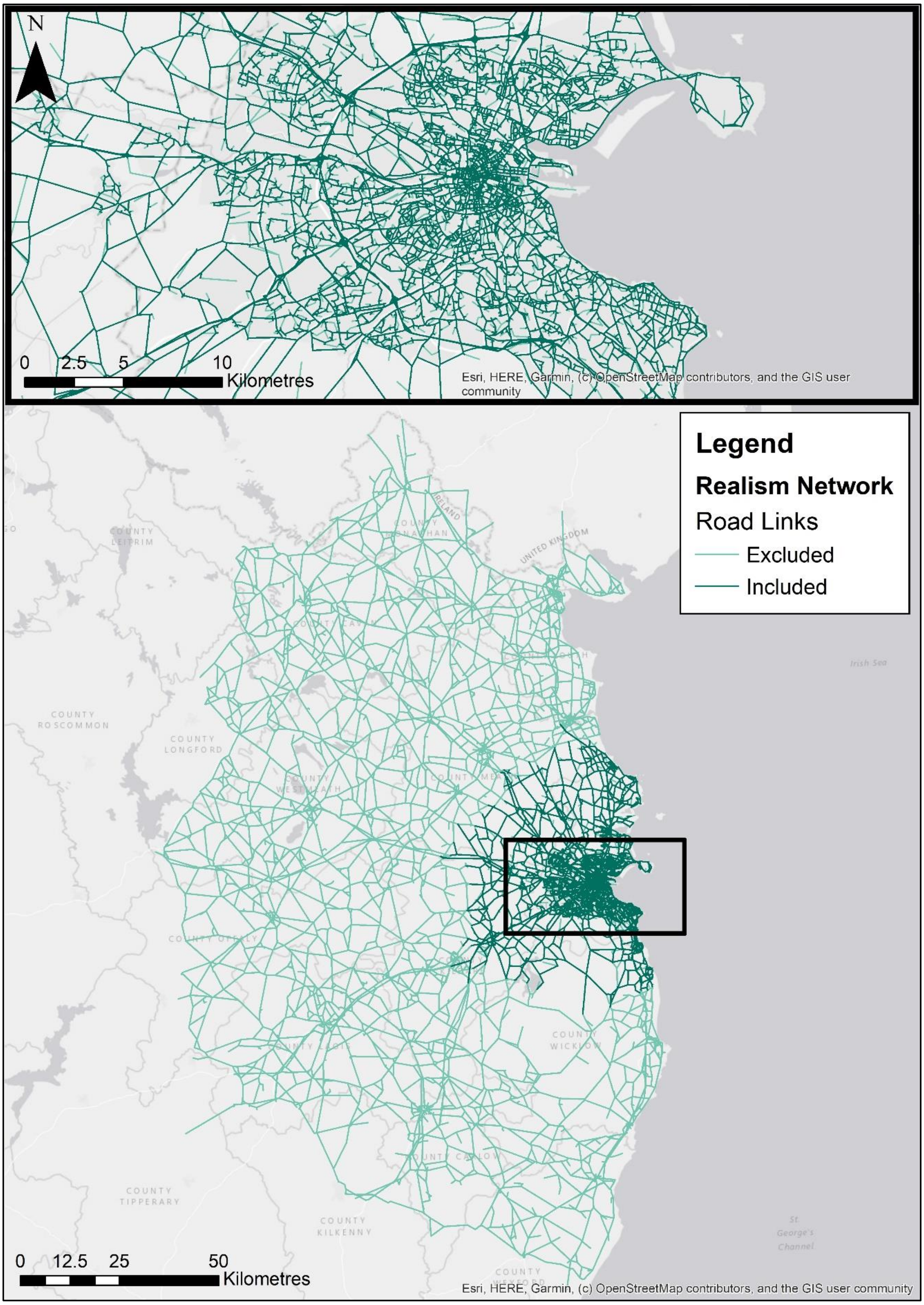


Figure 12.1 Relevant Network for Road Realism Tests

12.2.3 Target Elasticities

The target elasticities are initially taken from UK TAG Unit M2, Section 6.4 which states an expected elasticity of -0.3 would be reasonable, where:

- 'The annual average fuel cost elasticity should lie within the range -0.25 to -0.35 (overall, across all purposes); and
- The annual average fuel cost elasticity should lie on the "right" side of -0.3, taking account of the levels of income and average trip lengths prevailing in the modelled area.

Fuel cost elasticities would be expected to be weaker than -0.3 (i.e. closer to zero) where trip lengths are shorter than average, car driver mode shares are higher than average, and where proportions of low elasticity demand segments, such as employers' business, are higher than average, and stronger (i.e. further from zero) where the opposite applies. Higher than average income levels may also be consistent with a weaker elasticity. However, it is generally difficult to estimate the magnitude of the effects of these factors and therefore the extent to which the true elasticity for the area being modelled may vary from the figure of -0.3.' [68]

UK TAG continues that:

'Elasticities may also be regarded as more plausible if:

- The pattern of annual average elasticities shows values for employers' business trips near to -0.1, for discretionary trips near to -0.4, and for commuting and education somewhere near the average; and
- The pattern of all-purpose elasticities shows peak period elasticities which are lower than interpeak elasticities which are lower than off-peak elasticities.

Fuel cost elasticities would be expected to be weaker than -0.3 (i.e. closer to zero) where trip lengths are shorter than average, car driver mode shares are higher than average, and where proportions of low elasticity demand segments, such as employers' business, are higher than average, and stronger (i.e. further from zero) where the opposite applies. Higher than average income levels may also be consistent with a weaker elasticity. However, it is generally difficult to estimate the magnitude of the effects of these factors and therefore the extent to which the true elasticity for the area being modelled may vary from the figure of -0.3. It is for this reason that an acceptable range, from -0.25 to -0.35, is specified and analysts should not use models for scheme appraisal which have elasticities outside this range without providing a reasoned case for doing so and without the Department's approval.

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[68] UK TAG Unit M2: Variable Demand Modelling, 6.4.14
https://webarchive.nationalarchives.gov.uk/20191102080310/https://www.gov.uk/government/publications/tag-unit-m2-variable-demand-modelling

Note that, if local variations in values of time are used to argue for a particular target fuel cost elasticity, local values of time should be used in the model. In this case, evidence for the local values of time will be required.

Elasticities may also be regarded as more plausible if:

- the pattern of annual average elasticities shows values for employers' business trips near to -0.1, for discretionary trips near to -0.4, and for commuting and education somewhere near the average; and
- the pattern of all-purpose elasticities shows peak period elasticities which are lower than interpeak elasticities which are lower than off-peak elasticities.

While there is little or no empirical evidence to support the variation in elasticities by purpose and time period, most models show the pattern suggested above, although a few models which are otherwise acceptable have been created which show morning peak elasticities which are higher than inter-peak elasticities which are higher than evening peak elasticities. In the case of models which show different variations in elasticities by purpose and time period, an explanation for the differences will need to be provided.'[69]

With these conditions in mind a colour coding system has been adopted to highlight the NTA's recommended ranges for elasticities when presented as outlined in Table 12.3 and Table 12.4.

Table 12.3 Car Fuel Cost Recommended Elasticity Range by Trip Purpose

Trip Purpose	Recommended Range	Bound 1	Bound 2
EMP	-0.1 ± 25%	-0.075	-0.125
COM	-0.3 ± 20%	-0.24	-0.36
EDU	-0.3 ± 20%	-0.24	-0.36
OTH	-0.4 ± 20%	-0.32	-0.48
RET	-0.4 ± 20%	-0.32	-0.48
Overall	-0.25 to -0.35	-0.25	-0.35

[69] UK TAG Unit M2: Variable Demand Modelling, 6.4.17
https://webarchive.nationalarchives.gov.uk/20191102080310/https://www.gov.uk/government/publications/tag-unit-m2-variable-demand-modelling

Table 12.4 Car Fuel Cost Recommended Elasticity Range by Time Period

Trip Purpose	Recommended Range	Bound 1	Bound 2
AM	-0.25 to -0.30	-0.25	-0.30
LT	-0.30 to -0.35	-0.30	-0.35
SR	-0.30 to -0.35	-0.30	-0.35
PM	-0.25 to -0.30	-0.25	-0.30
OP	-0.40 to -0.501	-0.40	-0.50
Overall	-0.25 to -0.35	-0.25	-0.35

12.2.4 Matrix Based Test Results

The results of the realism test are as shown in Table 12.5 with green values being within the ranges indicated above in Table 12.3 and Table 12.4 and red values being outside.

Table 12.5 Matrix-Based Car Vehicle-km Response to +10% in Car Fuel Cost Elasticity

TP	EMP	COM	OTH	EDU	RET	TAX	Total
AM	0.107	-0.270	-0.349	-0.202	-0.289	-0.271	-0.195
LT	0.060	-0.298	-0.269	-0.203	-0.286	-0.248	-0.181
SR	0.056	-0.275	-0.187	-0.181	-0.227	-0.159	-0.148
PM	0.106	-0.262	-0.305	-0.148	-0.225	-0.236	-0.180
OP	-0.014	-0.300	-0.220	-0.106	-0.135	-0.210	-0.182
24-Hour[70]	0.069	-0.272	-0.258	-0.171	-0.247	-0.224	-0.178

The modelled response is low in the majority of cases in comparison with the NTA guidelines and overall the final elasticity values of -0.178 is outside the recommended range of UK TAG.

EMP in the majority of cases shows a positive response which is contrary to expectations and suggests that care should be taken when considering road schemes predominately focussed on that purpose, and may indicate there are significant levels of crowding which get removed during this test which ultimately improve journey times for that purpose making their overall costs less.

EDU and RET are below the NTA guidelines but follow the general trends that UK TAG advises could be considered reasonable.

[70] 24-hour here is calculated based on summing the vehicle-kms from the assignment model across the day and scaling up to period level using the model CUCD factors

Examining time period variations, the AM has the highest elasticity which is intuitive and expected while SR has the lowest. The LT and OP time periods are of a magnitude with the PM peak suggesting that either they are high, or the PM is too weak in its response but given the value of AM overall (-0.195) the PM may be seen to be too light in its response, possibly because of the make-up of travel purposes.

It is worth noting that the inclusion of Parking Distribution within the model means that because of the measure being considered (vehicle-kms) and the allowance of journeys to split into legs within that model (a road and a walk leg), it is entirely possible that trips to these areas would become more likely to park in a different area given different levels of occupancy through relaxed congestion, and this predominately would be expected to target EMP and COM purposes which may explain the low or positive responses.

Expansion to consider the full end to end distance rather than just the vehicle distance could lead to a different comparison but is outside what the guidance relates to.

It is also worth considering how elasticities vary over geography to identify whether they behave intuitively over longer distances and so a sector based comparison for all trips is provided in Table 12.6. It is noted that this will include sector pairs which have low demand which could lead to odd elasticities, but there is a clear trend for elasticity to increase in magnitude for longer journeys and for some shorter journeys within Dublin. Furthermore, within a sector there is actually a modelled reduction in trips forecast due to reduced congestion (as shown in the red cells which indicate a positive elasticity).

A colour scale has been applied based on percentiles with blue for negative values and red for positive values.

Table 12.6 Matrix-Based Car Vehicle-km Response to +10% in Car Fuel Cost Elasticity

(Sectored AM Total Demand)

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	0.361	-0.19	-0	0.098	0.036	-0.03	-0.06	-0.03	-0.01	-0.06	-0.01	0.01	0.009	0.002	-0.02	-0.15	2.451	0.304	-0.13	-0.14	0.021	-0.11	-0.49	-0.1	-0.08	-0.11	-0.15	-1.11	-2.28	-0.17	0	0	-14.5	-0.62	-0.49	-0.19	-0.84	0.488
2	0.419	0.148	-0.02	0.243	0.003	-0.05	-0.02	-0.02	0.011	-0.01	-0.05	0.005	-0	-0.04	-0.05	-0.16	-0.41	-0.51	-0.04	-0.05	0	-0.15	-0.28	-0.06	-0.04	-0.06	0	-2.13	-0.65	-0.15	-1	0.636	-7.27	-0.45	-0.1	-0.06	0	-0.47
3	0.002	-0.01	-0.01	-0.01	-0.01	-0.01	-0	-0.01	-0.02	-0.04	-0.02	-0	-0.02	-0.02	-0.03	-0.02	-0.05	0.001	-0.01	0.081	-0.18	-0.07	-0.04	-0.07	-0.07	-0.11	-0.65	-0.57	-0.03	-0.04	-0.23	-1.91	8.508	-4.25	-11.5	-0.2	0	-0.2
4	3.018	0	-0.42	0	-1.53	-1.66	-1.88	-1.93	-1.29	-1.3	-0.28	-1.06	-1.67	-0.97	-1.35	-1.22	-1.73	-2.12	-2.52	-1.51	0	-1.94	-2	-1.97	-1.56	-2.99	-7.27	-1.66	-1.71	-1.37	-2.41	0	-2.06	-9.26	0.219	-3.96	0	0
5	0.095	0	0.222	-0.22	0.404	-0.01	0.01	-0.12	0	0.019	-0.01	-0.15	-0.11	-0.13	-0.22	-0.38	0	0	-0.11	-0.11	0	-1.07	0	-0.11	0	0.058	0	0	0	-0.43	-2.34	0	0	0	-0	-0.3	-7.27	0
6	-0.01	-0	-0.01	-0.02	0.008	0.059	-0.03	-0.05	-0.1	-0.1	-0.13	-0.14	-0.03	-0.99	-0.41	-0.02	-0.02	-0.17	-0.19	-1.36	-1.54	-0.52	-0.56	-0.45	-0.86	-0.77	-3.17	-2.24	-0.95	-0.97	-2.09	-1.07	-1.25	-1.57	-0.72	-2.77	-7.91	0
7	-0.03	-0.03	-0.03	0	-0.02	-0.07	0.123	-0.08	-0.07	-0.04	-0.07	-0.31	-0.32	-1.29	-1.21	-0.29	-0.11	-0.05	-0.08	-0.63	-3.77	-0.65	-0.35	-0.26	-0.6	-1.32	-5.07	-2.48	-1.41	-0.59	-2.66	-0.98	-0.86	-0.85	-1.01	-2.08	0	0.913
8	-0.02	0.02	-0.01	0.016	-0.02	-0.06	-0.02	0.072	0.006	-0.16	-0.12	-0.1	-0.28	-0.27	-1.06	-0.33	-0.16	-0.24	-0.04	-1.24	-1.2	-0.66	-0.66	-0.42	-1.39	-2.67	-1.04	-2.46	-1.38	-0.87	-1.71	-0.35	-1.24	-1.46	-1.49	-4.9	-0.71	-0.84
9	0.362	-1.27	-0.08	0.203	0	0	0	-0.05	-0.04	-0.14	-0.02	-0.12	-0.09	0.112	0	0.029	-1.47	-0.15	-0.21	-0.69	0	-0.66	0.273	-0.32	-0.89	0	0	0	-0.34	-1.71	0	0.882	-1.91	0	0	0	0	-9.61
10	0.001	-0.01	-0.01	-0.01	0.067	-0.1	-0.11	-0.14	-0	0.066	-0.01	-0.09	-0.52	-0.05	-0.27	-0.54	-0.38	-0.61	-0.35	-0.22	-3.84	-0.51	-1.65	-0.67	-0.37	-0.77	-3.63	-2.15	-0.63	-3.41	-3.48	-0.68	-1.26	-3.59	-3.9	-1.51	2.341	-1.07
11	0	0	0.006	0	0.014	-0.19	0.636	0	-0.02	0	-0.01	0.005	-0	-0	0	-0.51	0	-2.04	-0.14	-0.31	-0.2	-1.54	-5.36	-0.55	-0.07	-0.39	-0.47	0	0.287	-0.98	0	0	0	0	0	-1.19	0	0
12	-0.01	-0.01	-0.01	-0.02	0.008	-0.13	-0.27	-0.07	-0.07	-0.44	-0.63	0.084	-0.02	-0.04	-0.03	-0.37	-0.79	-1.03	-0.95	-1.34	-0.49	-1.68	-2.8	-1.14	-2.19	-1.47	-1.54	-5.89	-3.26	-4.36	-6.13	-3.81	-5.93	0.488	-1.4	-4.37	-4.93	0
13	-0.01	-0.06	0.006	0.002	0.013	-0.02	-0.31	-0.47	-0.24	-0.3	-0.42	-0.01	0.044	-0.35	-0.07	-0.08	-0.19	-0.52	-0.48	-3.63	-1.05	-0.89	-1.88	-1.38	-2.7	-5.56	-3.4	-4.62	-2.13	-2.56	-3.99	-5.6	-3.02	-2.53	-0.88	-8.07	-3.02	-7.27
14	-0.01	-0.01	-0.01	-0.02	-0.04	-0.97	-1.38	-0.37	-0.06	-0.23	-0.01	-0.02	-0.25	0.032	-0.02	-0.75	-1.11	-2.05	-1.19	-3.29	-0.31	-1.85	-4.96	-4.99	-3.85	-2.74	-1.72	-3.75	-3.88	-4.99	-9.23	-0.64	-7.16	-3.86	-4.52	-4.37	3.018	-9.61
15	-0.11	-0.34	-0.17	0	-0.06	-0.57	-0.79	-2.06	-0.98	-1.39	-0.48	-0.05	-0.02	-0.02	0.05	-0.25	-0.71	-1.04	-0.65	-5.38	-0.27	-1.1	-3.6	-2	-3.65	-2.71	-1.21	-2.92	-2.03	-3.53	-3.74	1.401	-5.46	-13.1	-8.51	-7.27	0	0
16	-0.18	-0.6	-0.16	-0.02	-0.08	-0.02	-0.17	-0.46	-0.36	-0.57	-0.8	-0.24	-0.08	-0.99	-0.36	0.05	0.007	-0.15	-0.19	-1.98	-1.06	-0.35	-0.65	-0.63	-1.06	-2.07	-2.63	-2.63	-0.82	-0.75	-2.25	-1.36	-1.64	-1.65	-0.96	-1.57	0.6	0
17	-0.11	-0.13	-0.02	-0.01	-0.1	0.035	-0.08	-0.05	-0.08	-0.45	-0.46	-0.59	-0.2	-1.55	-0.59	-0.05	0.034	-0.04	-0.02	-1.39	-2.16	-0.34	-0.42	-0.34	-0.9	-1.3	-4.37	-2.37	-0.89	-0.52	-2.17	-0.92	-1.14	-0.68	-1.15	-2.32	0.488	0
18	-0.21	-0.45	-0.14	-0.14	-0.13	-0.17	-0.08	-0.15	-0.23	-0.44	-0.68	-0.85	-0.56	-2.18	-0.78	-0.22	-0.02	0.037	-0.04	-1.24	-2.86	-0.32	-0.23	-0.17	-0.69	-1.11	-5.23	-1.63	-0.63	-0.64	-1.51	-2.08	-0.83	-0.53	-1.62	-1.56	-0.82	-0.64
19	-0.04	0.004	-0.08	-0.04	-0.13	-0.23	-0.14	-0.03	-0.09	-0.25	-0.28	-0.85	-0.72	-1.87	-1.01	-0.26	-0.2	-0.04	0.053	-0.54	-2.04	-0.57	-0.46	-0.13	-0.49	-1.06	-2.59	-1.23	-0.66	-0.97	-0.89	-1.75	-1.05	-0.91	-1.67	-1.68	0.778	-2.34
20	1.051	0.53	0.22	0.25	0.761	0.061	-0.34	-0.54	0.234	0.75	0.869	0.237	-0.25	-0.03	-0.57	-0.1	-0.16	-0.38	-0.99	0.282	-1.95	-0.07	-0.96	-0.8	-0.1	-0.35	-4.67	-1.98	-0.45	-1.8	-1.44	-2.08	-0.8	-2.49	-2.25	-0.53	-5.99	-1.76
21	0	-6.6	0	-0.75	0	-1.18	-1.47	-3.87	-2.4	-3.39	-3.13	-0.52	-0.32	-0.39	-0.16	-0.48	-0.99	-1.41	-1.04	-3.04	0.004	-0.55	-1.33	-2.65	-2.89	-5.08	-0.42	-0.26	-0.73	-3.56	-1.56	-0.32	-5.07	-1	0	-4.25	0	0
22	-0.91	-2.66	-0.12	-0.04	-0.57	-0.36	-0.47	-1.12	-0.77	-1.24	-1.88	-1.02	-0.57	-1.87	-0.9	-0.24	-0.26	-0.29	-0.29	-1.53	-0.62	0.028	-0.15	-0.32	-1	-1.42	-0.65	-0.48	-0.22	-0.51	-1.18	-0.52	-0.6	0.03	0.273	-1.96	-3.65	-4.93
23	-0.83	-1.27	-0.54	-0.44	-0.4	-0.55	-0.75	-0.86	-0.65	-1.12	-1.57	-1.59	-1.28	-3.18	-2.05	-0.42	-0.35	-0.16	-0.31	-1.5	-2.43	-0.14	-0.02	-0.17	-0.58	-0.51	-1.87	-1.1	-0.26	-0.22	-0.44	-0.33	-0.28	-0.31	-0.52	-0.8	-0.85	-0.57
24	-0.07	-0.09	-0.05	-0.09	-0.24	-0.42	-0.44	-0.19	-0.26	-0.54	-0.55	-0.94	-1.34	-3.3	-2.51	-0.57	-0.3	-0.12	-0.08	-0.68	-3.67	-0.42	-0.24	0.066	-0.29	-0.42	-8.11	-3.3	-0.79	-0.34	-0.22	-1.2	-0.67	-0.6	-0.83	-0.79	-0.68	-0.1
25	-0.05	-0.09	-0.04	-0.03	-0.35	-0.79	-0.61	-0.38	-0.22	-0.35	-0.31	-0.33	-1.73	-1.63	-2.21	-0.53	-0.48	-0.46	-0.35	-0.49	-3.75	-1.02	-0.63	-0.23	0.011	-0.16	-5.99	-3.68	-0.95	-0.39	-1.05	-1.62	-1.34	-0.6	-0.93	-0.79	-3.19	-1.92
26	-0.36	-0.38	-0.13	-0.13	-1.13	-2.75	-1.89	-1.16	-0.63	-0.75	-0.75	-0.77	-3.21	-1.94	-4.95	-1.51	-1.72	-1.17	-1.42	-0.95	-6.17	-1.07	-0.43	-0.28	-0.17	0.031	0	-8.27	-1.11	-0.19	-2.34	-0.68	-0.36	-0.4	-0.43	-0.37	-1.08	-1.01
27	0	-16.4	-6.5	-4.39	0	-4.9	-4.4	-7.81	-7.81	-9.98	-14.5	-2.53	-1.51	-2.66	-0.69	-1.95	-2.99	-3.8	-3.27	-8.93	-0.45	-0.87	-1.57	-8.16	-10.8	-28.1	-0.15	-0.32	-0.59	-7.02	-0.46	-0.91	-1.11	-5.87	0	0	0	0
28	-2.99	-7.72	-1.11	-1.39	-8.18	-4.3	-2.77	-5.33	-5.51	-6.68	-9.27	-6.81	-4.82	-6.62	-2.53	-2.46	-2.84	-1.67	-1.83	-5.6	-0.39	-0.47	-0.79	-2.99	-6.77	-5.17	-0.3	-0.12	-0.33	-1.51	-0.25	-0.61	-0.23	-0.5	4.742	-10.9	-7.27	0
29	-1.09	-3.7	-0.18	-0.19	-1.66	-0.85	-0.67	-1.56	-1.06	-1.33	-2.14	-1.77	-1.66	-3.63	-2.29	-0.58	-0.7	-0.53	-0.52	-1.2	-0.88	-0.19	-0.27	-0.44	-1.25	-1.14	-0.39	-0.31	-0.06	-0.63	-0.41	-0.3	-0.37	-0.46	0.814	-1.52	-1.4	-3.34
30	-0.87	-0.34	-0.33	-1.48	-2.52	-1.72	-1.08	-1.01	-1.45	-2.27	-2.8	-2.76	-2.37	-5.95	-3.35	-1.24	-1	-0.68	-0.72	-1.04	-4.41	-0.65	-0.28	-0.23	-0.33	-0.19	-5.57	-4.76	-0.89	-0.03	-0.63	-0.58	-0.41	-0.27	-0.32	-0.4	-0.71	-0.62
31	-2.55	-6.83	-0.78	-0.99	-8.48	-3.22	-2.16	-4	-3.88	-3.9	-6.14	-5.87	-6.07	-11.1	-6.14	-1.97	-2.14	-1.17	-1.32	-4.55	-3.39	-0.68	-0.57	-1.3	-4.45	-5.13	-0.49	-0.23	-0.33	-1.71	-0.05	-0.19	-0.38	-0.4	0.929	-1.3	-2.53	-7.27
32	-3.12	-5.54	-1.89	-1.82	-2.05	-4.07	-3.93	-4.71	-4.13	-6.07	-6.91	-7.86	-8.31	-13.7	-6.08	-2.22	-2.28	-1.6	-2.27	-3.56	-4.95	-0.62	-0.46	-1.27	-2.71	-1.83	-0.66	-0.57	-0.33	-1.03	-0.19	-0.06	-0.26	-0.57	-0.63	-1.71	-2.01	0.42
33	-1.86	-3.56	-1.27	-1.09	-0.9	-1.54	-1.86	-2.56	-1.38	-1.99	-2.91	-3.74	-2.57	-6.32	-3.42	-1.35	-1.21	-0.68	-0.86	-1.54	-4.19	-0.52	-0.3	-0.51	-0.8	-0.44	-1.27	-1.09	-0.38	-0.35	-0.28	-0.21	-0.06	-0.25	-0.38	-0.62	-0.77	-0.91
34	-2.41	-1.65	-2.22	-2.62	-1.97	-2.39	-2.1	-1.51	-2.18	-1.62	-3.03	-4.78	-3.38	-7.01	-3.41	-1.78	-1.58	-0.98	-1.21	-1.06	-5.36	-0.61	-0.47	-0.53	-0.8	-0.48	-4.25	-1.78	-0.74	-0.24	-0.3	-0.39	-0.29	-0.01	-0.23	-0.41	-0.35	-0.54
35	-1.66	-1.02	-1.4	0	-4.5	-2.56	-1.35	-1.45	-1.46	-1.97	-2.6	-3.15	-3.22	-6.01	-3.65	-1.67	-1.67	-1.04	-0.84	-1.29	-4.74	-1.06	-0.75	-0.78	-0.93	-0.51	-3.02	-5.36	-0.88	-0.32	-0.22	-0.41	-0.48	-0.27	-0.08	-0.31	-0.31	-0.33
36	-1.23	-1.54	-0.24	-0.84	-2.5	-12.9	-7.27	-3.79	-1.41	-1.38	-1.65	-1.79	-12.3	-2.84	-12	-5.32	-3.29	-2.8	-3.46	-1.08	-30.3	-1.66	-0.72	-0.59	-0.78	-0.31	0	-13.1	-0.48	-0.44	-4.74	-0.79	-0.36	-0.59	-0.35	-0.08	-0.29	-0.35
37	-2.04	-1.79	-14.2	0	-11.8	-6.59	-2.95	-2.66	-3.58	-4.7	-5.34	-12.1	-7.82	-16	-6.36	-3.42	-2.31	-2.42	-1.95	-2.64	-12.3	-1.38	-1.24	-1.47	-2.87	-1.33	0	-5.36	-1.48	-0.82	-1.4	-0.72	-0.68	-0.39	-0.3	-0.51	-0.08	-0.35
38	-4.25	-4.74	-0.49	-0.65	-7.27	-24.5	-10.1	-7.19	-5.43	-5.48	-5.26	-8.43	-8.61	-4.25	-4.25	-11.4	-7.81	-7	-6.85	-3.04	-11.5	-7.51	-2.22	-1.73	-1.83	-0.73	0	-9.61	-1.96	-0.75	0	0.778	-0.26	-0.74	-0.36	-0.4	-0.37	-0.15

12.2.5 Network Based Test Results

An overall summary for the network-based analysis is provided in Table 12.7 and shows broadly similar trends to the matrix-based analyses above, although with all elasticities being slightly lower or more positive. This relates to the inclusion of fixed demand which cannot be excluded from this test (goods vehicles, externals etc.) which overall will dampen the effect of the elasticity when measured in this manner.

Table 12.7 Car Vehicle-km Response to +10% in Car Fuel Cost Elasticity (Network-Based)

TP	EMP	COM	OTH	EDU	RET	TAX	Total
AM	0.134	-0.204	-0.284	-0.284	-0.265	-0.218	-0.142
LT	0.080	-0.216	-0.222	-0.237	-0.239	-0.216	-0.142
SR	0.066	-0.204	-0.140	-0.264	-0.184	-0.109	-0.109
PM	0.135	-0.189	-0.216	-0.138	-0.162	-0.167	-0.118
OP	-0.013	-0.219	-0.172	-0.110	-0.019	-0.179	-0.145
24-Hour[71]	0.087	-0.201	-0.199	-0.200	-0.192	-0.177	-0.131

12.2.6 Car Fuel Cost Summary

The overall elasticities presented for the road fuel test are considered low in line with expected results although further analysis of results shows intuitive and reasonable trends which reflect different travel purposes and times of day with the exception of PM peak travel which is of a similar elasticity to the inter-peak periods.

12.3 Public Transport Fare

12.3.1 Test Description

For the PT fare test, adjustments are made directly to the fare files in the model where the monetary value of each fare is uplifted by 10%. An example of a before and after fare table is provided below in Table 12.8.

[71] 24-hour here is calculated based on summing the vehicle-kms from the assignment model across the day and scaling up to period level using the model CUCD factors

Table 12.8 Fare Table Adjustment Example

Original Fare Table	Uplifted Fare Table
FARESYSTEM NUMBER=1,	FARESYSTEM NUMBER=1,
NAME="DART",	NAME="DART",
LONGNAME="DART - Distance Based",	LONGNAME="DART - Distance Based",
STRUCTURE=DISTANCE,	STRUCTURE=DISTANCE,
SAME=CUMULATIVE,	SAME=CUMULATIVE,
IBOARDFARE=0,	IBOARDFARE=0,
FARETABLE=0-1.84,7-1.84,	FARETABLE=0-2.024,7-2.321,
8-2.11, 15-2.11,	8-3.388, 15-3.553,
16-3.08, 23-3.23,	16-4.114, 23-3.553,
25-3.74, 29-4.09,	25-4.114, 29-4.449,
30-5.03, 40-5.03,	30-5.533, 40-5.533,
50-5.19, 60-5.19	50-5.709, 60-5.709
INTERPOLATE=T	INTERPOLATE=T=T

Following these adjustments, the Demand Model was then run to convergence in a 2016 scenario with no other changes to the model for 8 demand loops until a GAP convergence of 0.385915 was achieved. This is above the UK TAG guidance of 0.2 in large models and therefore is not compliant with UK TAG standards but shows only a slight increase of 0.11 above a multi-loop base year model (0.27 after 8 loops).

A summary of convergence is provided in Table 12.9.

Table 12.9 Public Transport Fare Realism Test

Demand Loop	%GAP
1	-
2	1.714
3	0.436
4	0.413
5	0.404
6	0.409
7	0.400
8	0.386

12.3.2 Measuring and Evaluating the Response

To evaluate model response, comparisons are made between the final Demand Model loop results of the test scenario discussed in 12.3.1 against the single Demand Model loop base year model.

All model responses are considered as elasticities rather than absolute values, so that a 10% increase in PT fare might be expected to produce a 2% decrease in PT trips, for example.

These responses are evaluated based on

$$e = \frac{\log(\mathrm{PTTrips}_{\mathrm{Test}}) - \log(\mathrm{PTTrips}_{\mathrm{Base}})}{\log(\mathrm{PTTrips}_{\mathrm{Test}}) - \log(\mathrm{PTTrips}_{\mathrm{Base}})} = \frac{\log(\mathrm{PTTrips}_{\mathrm{Test}}) - \log(\mathrm{PTTrips}_{\mathrm{Base}})}{\log(1.1)}$$

Where:

- e is the elasticity being measured;
- $\mathrm{PTTrips}_{\mathrm{Test}}$ is the sum of test PT person trips (from the realism test);
- $\mathrm{PTTrips}_{\mathrm{Base}}$ is the sum of original PT person trips (base year);
- $\mathrm{FuelCost}_{\mathrm{Test}}$ is the test PT fare (from the realism test); and
- $\mathrm{FuelCost}_{\mathrm{Base}}$ is the original PT fare (base year).

Elasticities would typically be expected to be negative, and for ease of discussion an elasticity closer to zero will be considered less elastic and referred to as lower (while strictly speaking being greater numerically).

The elasticities here are measured solely on an assignment matrix basis, based on overall trip numbers and restricted to internal zones. Special zones are not subject to the same responses as the rest of the modelled area and have also been excluded from calculations. For complete clarity this means that the matrix comparisons are limited to fully internal trips (i.e. trips which have both an internal origin and destination, but which do not start or end in a special zone).

The off-peak time period within the PT assignment model is not explicitly validated in the same level of detail as the other time periods and therefore falls outside the definitions for inclusion above but is still reported here given the reliance on costs within the Demand Model which influence all time periods based on the tour structure of the calculations.

12.3.3 Target Elasticities

The target elasticities are taken from UK TAG Unit M2, Section 6.4, which advises an expected elasticity between -0.2 and -0.9 would be reasonable, where:

- 'The pattern of annual average public transport fare elasticities shows values for non-discretionary purposes which are lower than those for discretionary trips; and
- The pattern of all-purpose public transport fare elasticities shows peak period elasticities which are lower than inter-peak elasticities which are lower than off-peak elasticities.

However, there is little or no empirical evidence available to support these patterns and other patterns may be acceptable.'[72]

12.3.4 Test Results

The results of the realism test are as shown in Table 12.10and show that results largely tend towards the lower end of the recommended values.

Table 12.10 PT Trip Response to 10% Increase in PT Fare Elasticity Results

TP	EMP	COM	OTH	EDU	RET	Total
AM	0.060	-0.273	-0.313	-0.145	0.015	-0.215
LT	-0.484	-0.647	-0.616	-0.200	0.135	-0.501
SR	-0.307	-0.251	-0.420	-0.162	0.447	-0.283
PM	0.010	-0.261	-0.326	-0.119	0.293	-0.223
OP	-0.218	-0.089	-0.406	-0.182	0.180	-0.292
24-Hour	-0.136	-0.265	-0.413	-0.145	0.166	-0.265

The overall elasticity is -0.265 which is within the recommended range although towards the less elastic end of the scale and by time period the peaks are shown to be less elastic than the inter- and off-peak time periods as would be expected.

Purposes show some different trends which are worth considering further:

- COM is within range and is less than OTH so follows the expected trends;
- EDU is lower than COM but must be noted will be non-discretionary and will also pay lower fares which appears intuitive with the results; and
- EMP generally shows a low response overall but more importantly highlights a positive increase in the AM.

This last point in particular does not seem initially intuitive but should be considered alongside the notably high value of time, 21.93 euros per hour for EMP in comparison to 12.24 euros per hour for COM and EDU and 8.78 euros per hour for OTH and RET.

This difference in the values of time alongside the relatively low importance of fare in overall PT generalised cost particularly when considering crowded PT networks means that the generalised cost can improve overall for that specific journey purpose despite the fact that fares increased in the test. The fact this positive elasticity response only happens in the congested peaks leads to this being potentially acceptable as a trend, but care should be taken when evaluating EMP as part of PT fare tests.

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[72] UK TAG Unit M2: Variable Demand Modelling, 6.4.22
https://webarchive.nationalarchives.gov.uk/20191102080310/https://www.gov.uk/government/publications/tag-unit-m2-variable-demand-modelling

RET trips show a very muted response and in some cases the elasticity is positive. It must be stated that within this PT assignment model RET trips do not pay a fare and therefore their generalised cost does not see a *direct* change based on the test. However, the reduction of PT trips from other user classes which have moved away from PT based on the increased cost means there will be a reduction in crowding which in turn could lead to an overall reduction in generalised cost for some RET trips as an *indirect* response to the test. It is therefore considered entirely reasonable that the RET response can be positive so long as overall the magnitude of the elasticity is low.

A sector-based comparison for all trips is provided in Table 12.11 to demonstrate how elasticities vary over geography and identify whether they behave intuitively over longer distances. A colour scale has been applied based on percentiles with blue for negative values and red for positive values.

Shorter distance trips (typically clustered around the leading diagonal) tend to be shorter while longer distance trips (generally more numerically distant in the row and column) show higher elasticities likely due to longer journeys.

Table 12.11 PT Trip Response to 10% Increase in PT Fare Elasticity Results

(Sectored AM Total Demand)

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	-0.24	-0.23	-0.18	-0.22	-0.21	-0.28	-0.38	-0.27	-0.32	-0.33	-0.29	-0.2	-0.3	-0.19	-0.14	-0.37	-0.48	-0.48	-0.68	-0.41	-0.24	-0.48	-0.56	-0.35	-0.15	-0.3	0	0	0	-0.14	0	0	0	0	0	0	0	0
2	-0.25	-0.26	-0.18	-0.27	-0.3	-0.33	-0.35	-0.21	-0.26	-0.32	-0.36	-0.26	-0.29	-0.21	-0.08	-0.4	-0.37	-0.41	-0.48	-0.45	-0.1	-1.62	-0.18	-0.19	-0.19	-0.25	0	0	-1.24	-0.81	0	0	0	0	0	-1.11	0	0
3	-0.14	-0.14	-0.21	-0.25	-0.22	-0.34	-0.29	-0.2	-0.14	-0.42	-0.24	-0.2	-0.28	-0.24	-0.13	-0.7	-0.88	-0.65	-1.06	-0.19	-0.66	-1.31	-0.96	-0.28	-0.89	0	0	0	0	-4.25	0	0	0	0	0	0	0	0
4	-0.18	-0.2	-0.25	-0.26	-0.28	-0.25	-0.25	-0.22	-0.2	-0.41	-0.43	-0.24	-0.32	-0.29	-0.07	-0.25	-0.43	-0.46	-0.74	-0.27	-0.38	-0.89	-0.41	-0.42	-1.75	0	0	0	-0.91	-2.34	0	-4.25	0	0	0	0	0	0
5	-0.17	-0.18	-0.18	-0.27	-0.27	-0.29	-0.38	-0.13	-0.09	-0.39	-0.25	-0.27	-0.26	-0.25	-0.08	-0.34	-0.21	-0.18	-0.18	-0.2	-0.3	-0.44	-0.39	-0.12	-0.13	-0.17	0	0	0	-0.43	0	0	0	0	0	0	0	0
6	-0.2	-0.22	-0.22	-0.29	-0.33	-0.23	-0.3	-0.28	-0.19	-0.54	-0.42	-0.4	-0.32	-0.34	-0.21	-0.24	-0.27	-0.45	-0.89	-0.18	-0.38	-0.62	-0.57	-0.33	0	0	0	-1.62	-5.36	0	0	0	0	0	0	0	0	0
7	-0.2	-0.25	-0.13	-0.21	-0.42	-0.22	-0.21	-0.18	-0.16	-0.43	-0.45	-0.3	-0.43	-0.34	-0.07	-0.2	-0.26	-0.2	-0.28	-0.41	-0.07	-0.41	-0.36	-0.19	-0.28	-0.49	0	0	-1.17	0	0	0	0	0	0	0	0	0
8	-0.18	-0.23	-0.09	-0.25	-0.37	-0.47	-0.35	-0.17	-0.2	-0.32	-0.26	-0.27	-0.32	-0.19	-0.15	-0.79	-0.44	-0.23	-0.31	-0.53	-0.26	-0.9	-0.29	-0.29	-0.17	-0.16	0	0	0	-0.59	0	0	0	0	0	-0.13	0	0
9	-0.24	-0.22	-0.3	-0.4	-0.36	-0.42	-0.26	-0.22	-0.27	-0.21	-0.38	-0.25	-0.24	-0.13	-0.12	-0.61	-0.14	-0.25	-0.56	-0.28	-0.11	0	-0.23	-0.28	-0.59	-0.96	0	0	0	-0.62	0	0	0	0	0	0	0	0
10	-0.27	-0.24	-0.25	-0.27	-0.22	-0.18	-0.16	-0.31	-0.22	-0.2	-0.18	-0.23	-0.13	-0.27	-0.13	-0.14	-0.15	-0.17	-0.66	-0.3	-0.31	-0.12	-0.23	-0.24	-0.44	-0.3	0	0	-0.28	-0.2	0	-7.27	0	0	0	-0.14	0	0
11	-0.12	-0.23	-0.02	-0.29	-0.13	-0.29	-0.38	-0.35	-0.36	-0.22	-0.2	-0.16	-0.2	-0.34	-0.08	-0.17	-0.19	-0.29	-0.37	-0.29	-0.39	-0.06	-0.26	-0.31	-0.19	-0.15	0	-0.72	-0.11	-0.08	0	-0.28	-0.18	0	0	-0.09	0	0
12	-0.06	-0.16	-0.12	-0.14	-0.17	-0.3	-0.24	-0.12	-0.12	-0.27	-0.2	-0.28	-0.28	-0.25	-0.22	-0.44	-0.4	-0.26	-0.19	-0.25	-0.61	-0.18	0	-0.21	-0.26	0	-4.25	0	0	-0.17	0	0	0	0	0	0	0	0
13	-0.34	-0.17	-0.2	-0.26	-0.19	-0.23	-0.25	-0.08	-0.08	-0.26	-0.33	-0.3	-0.22	-0.25	-0.13	-0.42	-0.58	-0.12	-0.16	-0.2	-0.16	-0.43	-0.87	-0.17	-0.09	0	0	0	0	0	0	0	0	0	0	0	0	0
14	-0.06	-0.15	-0.09	-0.19	-0.2	-0.21	-0.17	-0.16	-0.08	-0.21	-0.26	-0.12	-0.24	-0.2	-0.16	-0.38	-0.19	-0.16	-0.13	-0.15	-0.33	-0.17	-0.13	-0.05	-0.17	-0.3	-0.6	0	0	-0.3	0	0	0	0	0	-1.8	0	0
15	-0.04	-0.05	-0.02	-0.07	-0.08	-0.15	-0.1	-0.05	-0.06	-0.13	-0.17	-0.17	-0.17	-0.17	-0.19	-0.18	-0.17	-0.07	-0.08	-0.08	-0.23	-0.09	-0.11	-0.07	0	0	0	0	0	-0.23	0	0	0	0	0	0	0	0
16	-0.07	-0.18	-0.15	-0.13	-0.32	-0.2	-0.21	-0.52	-0.29	-0.82	-0.53	-0.45	-0.3	-0.47	-0.21	-0.2	-0.24	-0.47	-3.02	-0.44	0	-0.28	-2.18	0	0	0	0	-1.47	-0.28	0	0	0	0	0	0	0	0	0
17	-0.09	-0.18	-0.04	-0.22	-0.46	-0.22	-0.26	-0.27	-0.18	-1.16	-0.43	-0.5	-0.71	-0.67	-0.44	-0.28	-0.23	-0.22	-7.27	-0.62	0	-0.41	-0.3	0	0	0	0	0	-0.35	0	0	0	0	0	0	0	0	0
18	-0.14	-0.33	-0.09	-0.21	-0.34	-0.38	-0.21	-0.24	-0.16	-0.42	-0.28	-0.26	-0.39	-0.32	-0.05	-0.34	-0.18	-0.19	-0.33	-0.54	-0.07	-0.29	-0.33	-0.33	0	0	0	0	-0.53	-0.2	-3.02	0	-0.72	0	0	0	0	0
19	-0.14	-0.47	-0.17	-0.57	-0.48	-0.61	-0.43	-0.18	-0.3	-0.39	-0.21	-0.2	-0.39	-0.19	-0.45	-1.18	-0.96	-0.2	-0.19	-1.39	-0.08	-0.84	-0.37	-0.19	-0.21	0	0	0	0	-0.37	0	0	-0.28	0	0	0	0	0
20	-0.11	-0.24	-0.07	-0.16	-0.14	-0.31	-0.26	-0.27	-0.18	-0.26	-0.21	-0.17	-0.22	-0.23	-0.26	-0.38	-0.54	-0.41	-0.59	-0.18	-0.54	-0.73	-1	-0.28	-0.38	-0.52	-1.59	-1.43	-0.99	-1.47	-0.88	-0.87	-0.98	-2.34	-2.06	-0.94	-1.17	-1.04
21	-0.15	-0.18	-0.09	-0.2	-0.24	-0.13	-0.16	-0.13	-0.04	-0.42	-0.44	-0.1	-0.5	-0.26	-0.25	0	0	-0.03	-0.64	-0.2	-0.23	0	0	0	0	0	-1.24	0	0	0	7.273	0	0	0	0	0	0	0
22	-0.4	-0.55	-0.18	-0.37	-0.48	-0.39	-0.48	-0.53	-0.14	-1.62	-0.25	-0.29	-0.36	-0.42	-0.08	-0.15	-0.32	-0.35	0	-0.55	0	-0.15	-0.35	0	0	0	0	-0.56	-0.28	0	-0.63	-1.11	0	0	0	0	0	0
23	-0.24	-0.46	-0.17	-0.4	-0.3	-0.49	-0.49	-0.26	-0.22	-0.29	-0.34	-0.14	-0.11	-0.22	-0.16	-0.81	-0.7	-0.32	-0.3	-0.85	-0.09	-0.35	-0.17	-0.29	-0.27	0	0	-2.34	-0.42	0	-0.41	-0.03	-0.75	0	0	0	0	0
24	-0.15	-0.37	-0.22	-0.59	-0.25	-0.34	-0.39	-0.33	-0.17	-0.34	-0.19	-0.14	-0.29	-0.1	-0.07	0	0	-0.3	-0.38	-0.39	-0.3	0	-0.14	-0.18	-0.11	-0.49	0	0	0	-0.35	0	0	0	0	-0.51	0	0	0
25	-0.11	-0.23	-0.08	-0.24	-0.22	-0.21	-0.15	-0.47	-0.18	-0.33	-0.22	-0.18	-0.19	-0.26	-0.17	-0.16	-0.11	-0.29	-0.28	-0.35	-0.11	0	0	-0.16	-0.21	-0.3	0	0	0	-0.44	0	0	0	0	0	-0.76	0	-1.91
26	-0.24	-0.59	-0.12	-0.59	-0.51	-0.3	-0.54	-0.17	-0.53	-0.89	-0.59	-0.49	-0.52	-0.75	0	-0.84	0	0	-0.36	-0.46	0	0	0	-0.4	-0.28	-0.15	0	0	0	-0.34	0	0	0	0	0	-0.29	0	-0.28
27	-0.18	-0.25	-0.14	-0.55	-0.77	-0.86	0	0	-0.06	0	-0.21	-0.38	-1.61	-0.3	-4.93	-1.82	0	0	0	-0.37	-0.58	-0.91	0	0	0	0	-0.31	-0.47	-0.66	0	0	0	0	0	0	0	0	0
28	-0.77	-0.87	-0.72	-0.54	-1.54	-1.2	-2.27	-1.66	-0.17	-1.35	-0.24	-0.78	-0.25	-0.13	-3.53	-0.71	-0.64	-0.27	0	-0.59	0	-0.43	-1.4	0	0	0	-0.71	-0.2	-0.29	0	0	0	0	0	0	0	0	0
29	-0.28	-0.73	-0.18	-0.37	-0.88	-0.81	-1.06	-0.39	-0.17	-6.17	-0.48	-0.55	-0.35	-0.66	0	-0.78	-0.68	-0.45	0	-0.6	0	-0.44	-0.36	0	0	0	0	-0.46	-0.23	0	-0.26	-0.43	-1.11	0	0	0	0	0
30	-0.17	-0.28	-0.2	-0.29	-0.2	-0.36	-0.45	-0.49	-0.06	-0.24	-0.24	-0.16	-0.13	-0.18	0	-1.75	-2.11	-0.43	-0.59	-0.79	-0.26	0	-0.03	-0.32	0.824	-0.41	0	0	0	-0.16	0	0	0	-0.64	-0.48	-0.48	-0.39	-3.02
31	-0.43	-0.71	-0.29	-0.39	-1.9	-1.88	-1.59	-0.88	-0.6	0	-0.64	-0.26	-1.99	-1.11	0	-2.67	-1.02	-0.73	0	-0.59	0	-0.73	-0.79	0	0	0	0	-0.37	-0.45	0	-0.15	-0.64	-0.74	0	0	0	0	0
32	-0.29	-0.38	-0.23	-0.2	-2.19	-2.67	-1.79	-1.45	-0.85	-3.02	-0.58	-0.09	0	-3.02	0	-13.6	-1.5	-1.07	0	-0.34	0	-0.92	-0.06	0	0	0	0	-0.6	-0.26	0	-0.49	-0.08	-0.57	0	0	0	0	0
33	-0.34	-0.61	-0.23	-0.63	-0.32	-0.77	-0.59	-0.08	-0.16	-0.57	-0.36	-0.3	-0.21	-0.3	0	0	-0.66	-0.47	-0.45	-0.42	0	-4.25	-0.11	-0.2	-0.78	0	0	0	-1.05	0	-1.11	-0.18	-0.22	0	0	0	0	0
34	-0.15	-0.33	-0.09	-0.42	-0.1	0	-1.31	-0.49	-0.05	-0.4	0	-0.03	0	0	0	0	0	-0.38	-0.59	-1.84	0	0	0	-0.57	0	-7.27	0	0	0	-0.45	0	0	0	-0.22	-0.36	0	-0.58	0
35	-0.17	-0.41	-0.15	-0.43	-0.24	-0.4	-0.83	-0.95	-0.06	-0.12	-0.21	-0.06	-0.04	-0.15	0	0	0	-0.31	-1	-1.31	0	0	-0.21	-0.45	0	-0.71	0	0	0	-0.27	0	0	0	-0.35	-0.25	0	-0.29	-0.72
36	-0.71	-0.58	-0.58	-0.21	-0.44	-0.16	-0.25	-0.41	-0.86	-1.24	-0.85	-0.49	-0.2	-0.11	0	-0.08	0	0	-0.35	-0.84	0	0	0	-0.95	-0.77	-0.37	0	0	0	-0.62	0	0	0	0	0	-0.17	0	-0.45
37	-0.31	-0.8	-0.15	-1.62	0.089	0	0	-2.57	0	0.94	-0.11	0.161	0	0.28	0	0	0	0	-11.5	-0.77	0	0	0	-0.78	0	0	0	0	0	-0.86	0	0	0	-0.39	-0.35	0	-0.25	-0.67
38	-0.25	-0.41	-0.28	-0.36	-0.26	0	0	0	0	-0.69	-0.15	0.084	0	-0.54	0	0	0	0	-1.5	-1.29	0	0	0	-0.91	0	-1.35	0	0	0	-1.24	0	0	0	0	-0.39	-0.29	-0.13	-0.32

12.3.5 PT Fare Summary

The PT fare response overall is within recommended ranges based on UK TAG guidance although is acknowledged to be at the low end of the scale. Time period variances follow expected patterns and the same applies to the majority of purposes, but it is noted that the EMP response is mildly positive within the AM and PM peaks.

Further consideration of geographic patterns shows generally increasing elasticity for longer distance trips.

12.4 Car Journey Time Test

12.4.1 Test Description

Car journey time is a component of the overall generalised cost but in order to simplify the adjustments and implementation of the test within the model a simplification has been undertaken where the scaling has been applied to the overall generalised cost of car travel within the model (assignment skim element only, and not changing parking). This is considered a reasonable approximation as the generalised cost is predominately made up of the time element for the road model, but it is noted that the response would be expected to be higher than if testing only the journey time changes by an equivalent uplift.

12.4.2 Measuring and Evaluating the Response

To evaluate model response, comparisons are made between the **single** demand loop results of the test scenario discussed in 12.3.1 against the single Demand Model loop base year model.

All model responses are considered as elasticities rather than absolute values, so that a 10% increase in generalised cost might be expected to produce a 2% decrease in car trips, for example.

These responses are evaluated based on

$$\mathrm{e} = \frac{\log(\mathrm{CarTrips_{Test}}) - \log(\mathrm{CarTrips_{Base}})}{\log(\mathrm{CarTrips_{Test}}) - \log(\mathrm{CarTrips_{Base}})} = \frac{\log(\mathrm{CarTrips_{Test}}) - \log(\mathrm{CarTrips_{Base}})}{\log(1.1)}$$

Where:

- e is the elasticity being measured;
- $\mathrm{CarTrips_{Test}}$ is the sum of test car vehicle[73] trips (from the realism test);
- $\mathrm{CarTrips_{Base}}$ is the sum of original car vehicle trips (base year);
- $\mathrm{FuelCost_{Test}}$ is the test PT fare (from the realism test); and
- $\mathrm{FuelCost_{Base}}$ is the original PT fare (base year).

[73] For clarity the model reports PCU but these are equivalent to vehicles for the car trips being considered here

Elasticities would typically be expected to be negative, and for ease of discussion an elasticity closer to zero will be considered less elastic and referred to as lower (while strictly speaking being greater numerically).

It is noted that realism testing is generally only considered for the fully responsive and validated element of the Demand Model, and therefore excludes specific sections of demand including:

- Travel to, from, and between external zones;
- Special zones (which have an alternative mode choice and are generally considered very different in response to cost changes);
- Centroid connectors which are subject to additional assumptions and relaxed constraints; and
- Goods vehicles which can be considered within this context as fixed assignment matrices.

The off-peak time period within the road assignment model is not explicitly validated in the same level of detail as the other time periods and therefore falls outside the definitions for inclusion above but is still reported here given the reliance on costs within the Demand Model which influence all time periods based on the tour structure of the calculations.

The elasticities here are measured solely on a matrix basis, based on overall car trip numbers and therefore excluded goods trips, and restricted to internal zones. Special zones are not subject to the same responses as the rest of the modelled area and have also been excluded from calculations.

The off-peak time period within the road assignment model is not explicitly validated in the same level of detail as the other time periods and therefore falls outside the definitions for inclusion above but is still reported here given the reliance on costs within the Demand Model which influence all time periods based on the tour structure of the calculations.

12.4.3 Target Elasticities

The target elasticities are taken from UK TAG Unit M2, Section 6.4, which advises a lower response (more positive) than -2.0.

12.4.4 Test Results

The results of the realism test are as shown in Table 12.12 and show that results all come within the recommended UK TAGtargets with the exception of COM which show a positive response in later time periods. This is due to the Parking Distribution (PD) model which is at capacity in the LT of the base year, and thus reductions in demand in the AM due to the test actually mean more people can park and therefore travel by car in the LT and later time periods, thus influencing a positive response. This predominately affects the COM user class as the PD area is restricted to an area similar to the canal cordon (but not identical) and therefore sees more demand by car from the COM user class than others.

Table 12.12 Matrix-Based Car Trip Response to +10% in Car Generalised Time Elasticity

TP	EMP	COM	OTH	EDU	RET	Total
AM	-0.078	-0.032	-0.245	-0.468	-0.204	-0.236
LT	-0.050	0.395	-0.169	-0.714	-0.171	-0.239
SR	-0.035	0.078	-0.192	-0.378	-0.193	-0.247
PM	-0.074	0.012	-0.208	-0.694	-0.204	-0.256
OP	-0.067	-0.162	-0.209	-0.427	-0.235	-0.271
24-Hour	-0.063	-0.006	-0.203	-0.541	-0.190	-0.247

A sector-based comparison for all trips in the AM time period is provided in Table 12.13 to demonstrate how elasticities vary over geography and identify whether they behave intuitively over longer distances. A colour scale has been applied based on percentiles with blue for negative values and red for positive values.

Shorter distance trips (typically clustered around the leading diagonal) tend to be shorter while longer distance trips (generally more numerically distant in the row and column) show higher elasticities likely due to longer journeys.

As with the car fuel test this shows a positive response in the city centre which will be due to the reduced congestion in the areas subject to Parking Distribution which ultimately feeds through to an increased access potentially for car trips overall.

Table 12.13 Car Trip Response to +10% in Car Generalised Cost Elasticity

(Sectored AM Total Demand)

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	16.33	14.1	15.01	9.574	2.179	-4.7	-6.95	-2.95	-1.58	1.482	-1.84	-9.19	-11.9	-21.9	-17.4	-19.9	-18.8	-11.3	-12	-20.6	-35.2	-24.1	-16.1	-10.7	-22.9	-31.5	0	0	-35.3	-16.2	0	0	-29	-30.5	0	0	0	0
2	19.14	15.12	14.67	13.73	-5.38	-6.66	-3.28	-0.95	-5.88	-8.33	-8.86	-19	-31.7	-37	-34.3	-22.4	-17.6	-14.9	-11.4	-25	0	-34	-23.7	-14.4	-29	-33.3	0	0	-50.7	-31.5	0.724	13.14	-48.5	-40.5	-50.3	0	-23.6	0
3	9.334	9.324	18.52	14.83	11.6	0.591	-6.05	-5.84	-2.51	-1.8	-3.45	-1.47	-6.53	-13.7	-11.1	-15.1	-16	-11.4	-12.8	-26.9	-19.7	-31.8	-20.5	-8.9	-14.2	-20.4	-43.6	0	-56.8	-13.7	0	0	-35.6	-35.7	0	-58.9	0	0
4	3.632	17.09	9.41	22.25	0.922	0.558	-1.91	-3.56	-12.6	-14.6	-14.1	-12	-19.7	-33.2	-28.4	-15	-15.8	-13.4	-18.1	-40.5	0	-35.8	-23	-35.9	0	0	0	0	-45.9	0	0	12.63	-54.3	13.4	0	0	0	0
5	0.185	-0.16	12.81	3.37	7.959	-6.94	-18.5	-19.9	-20.3	-23.6	-20.6	-0.9	-8.63	-16.1	-16.8	-22.1	-32.5	-31.5	-28.7	-45.2	-29	-41.4	-47.2	0	0	0	-43.3	0	0	0	-29.4	0	0	0	0	0	0	0
6	-5.56	-10.5	3.656	3.339	-2.07	2.69	-4.85	-26.6	-29.1	-29.3	-17.5	-11.7	-8.06	-23.7	-20.2	-5.77	-5.97	-10.2	-35.2	0	-41.5	-17.5	-14.8	-29.3	0	-4.28	19.19	11.93	-31.6	-53.3	1.955	2.244	-7.65	-10.1	-13.1	0	0	0
7	-6.03	-5.96	-3.76	-0.02	-14.6	-2.05	3.094	-13.4	-20.3	-21.8	-13.9	-19.5	-17.1	-26.2	-49	-10.9	-2	-6.31	-19.7	-56.1	0	-23.5	-24.5	-32.4	0	-9.34	9.614	8.882	-41.4	0	-6.53	-8.38	-2.92	-7.63	-19	0	0	0
8	-6.46	0.963	-5.52	-3.74	-16.1	-17.6	-13.5	-0.05	-5.03	-16.7	-13.8	-22.2	-47	-55.5	0	-35.3	-35.3	-18.6	-6.08	-18.3	0	0	-55.9	-14.8	-41.3	4.13	0	0	0	-55.4	0	0	-14.5	-2.41	-5.22	-22.8	0	0
9	-0.06	-4.42	-2.31	-8.01	-18.6	-23.2	-29.6	-6.17	1.415	-3.69	-12.5	-25.9	-51.9	-53.6	0	-43.9	-44.5	-32.1	-11.7	-10.6	0	0	-65	-14.2	-22.2	-45.5	0	0	0	-43.7	0	0	-17.2	-6.8	-9.36	-12.4	0	-30.5
10	2.74	-8.8	-2.25	-10.8	-19.3	-33.5	-27.6	-18	-3.16	2.034	-3.69	-22.8	-42.6	-51.2	-11.5	-50.7	-56.5	-50.8	-22.3	-10	0	-15.9	0	-22.9	-28	-45.6	0	0	0	7.944	0	0	-32.8	-9.91	-13.6	-11.9	0	-31.9
11	1.559	-7.09	-1.26	-8.39	-17.7	-31.5	-16.6	-18.7	-8.44	-0.2	2.206	-22.9	-39.4	-43.6	-46	-65.9	-51.4	-39.4	-22.2	-8.25	-59.4	-26.1	-40	-44	-34.7	-52.5	-6.94	0	0	-8.29	0	0	-28.2	-41.6	-50.2	-27.4	0	-45.8
12	-15.2	-23.8	-4.02	-20.4	-2.09	-19.3	-30.5	-36	-36.7	-52.7	-35	3.949	-4.06	-5.35	-10.5	-29.1	-39.2	-47.5	-64.7	-76.4	-23.7	-44.1	0	0	-29.3	-43.3	-5.79	-0.45	0	-21.3	-32	-24	-27.2	0	0	0	0	0
13	-13.4	-17.2	-0.61	-15.6	-2.44	-5.32	-15	-55.5	-62.4	0	-24.5	-0.37	2.448	-5.62	-2.41	-7.83	-14.4	-33.3	-72.7	0	-15.4	-22.9	-69.9	0	0	0	-1.41	3.622	0	-11	-16.7	-15.1	-15.4	0	0	0	0	0
14	-21.8	-33.6	-10.5	-34.5	-9.04	-23.4	-38.8	-47.4	-53.5	-65.4	-39.1	0.999	-2.98	3.593	-4.69	-25.6	-30.7	-63.4	0	0	-9.29	-42.4	0	0	-24.7	-34.6	-45.3	-19.1	0	-18.8	-22.7	-23.7	-22	-32.2	0	0	0	0
15	-17.6	-30.5	-5.21	-24.2	-8.98	-15.2	-25.1	0	-61.1	0	-31.8	-2.54	2.793	-2.45	-1.03	-18.6	-21.9	-46.4	0	0	-9.85	-27.9	0	0	0	0	0	-1.55	0	0	0	0	0	0	0	0	0	0
16	-17	-21.2	-13.4	-16.4	-17.2	-3.48	-9.24	-59.1	-55.3	-52.2	-35.9	-16.7	-8.41	-19.2	-21.6	3.409	1.311	-13.2	-42.4	-84.5	-49.3	-5.98	-30.7	-73	0	-15.8	9.614	1.958	-28.8	-7.07	-1.73	-3.51	-13.8	-18.2	-29	0	0	0
17	-16.2	-17.3	-11.2	-16.2	-32.1	-0.17	-2.07	-40	-39.8	-30.4	-25.8	-28.6	-19.1	-28	-38	-0.36	3.884	-5.94	-28.6	-66.1	0	-9.17	-20.8	-25.9	0	-16.3	2.965	11.74	-29.6	-53.3	-0.19	-5.29	-2.36	-6.16	0	0	0	0
18	-15	-6.69	-10.8	-10.5	-18.1	-4.12	-1.4	-10.9	-21.7	-29.2	-35.3	-25.6	-26.1	-31.8	-68.8	-7.53	2.288	2.129	-5.72	-30.5	0	-11.3	-5.51	-11.2	-52.9	0	-32.9	-4.87	-39.5	-43	-18.4	-23.6	-48.8	-47.9	-14.1	-41.8	0	0
19	-16	-8.18	-8.58	-11.9	-21	-17.1	-15.6	-4.28	-8.83	-20.5	-31.6	-43.2	0	0	0	-33.5	-22.9	-8.67	4.312	-16.2	0	-51.3	-23.5	-3.03	-29.1	0	0	-37.7	0	-32.2	0	0	-23.6	-8.76	1.749	-9.36	0	0
20	-19.8	-22.6	-28.5	-34.7	-37.2	-52.5	-72.2	-17.1	-9.32	-5.98	-8.46	-46.5	0	0	0	-70.3	-66.8	-45.3	-14	0.061	-42.1	0	0	-12.8	-10.1	-33.7	0	-66	-28.8	-52.5	0	0	-28.6	-12.9	-16.6	-28.3	0	-36
21	-35.5	0	-31.8	0	-14.6	-21.6	-33	0	0	0	-47.2	-5.8	-2.8	-0.14	-1.12	-28.5	-28.4	0	0	0	8.312	-33	0	0	0	0	-10.1	-20.9	-41.5	0	0	0	0	0	0	0	0	0
22	-30.2	-28.4	-25.6	-28.7	-21.9	-9.21	-14.7	0	0	0	-52.2	-26.6	-18.4	-27.4	-30.6	-2.74	-2.81	-11.2	-49.1	0	-44.7	8.974	-7.84	-36.2	0	0	0	-22.5	-1.47	-69	-57.8	-15.2	-12	-31.5	0	0	0	0
23	-30	-16.8	-33.4	-22.3	-30.8	-9.49	-12.3	-32.9	-45.2	0	0	0	-43.1	-36.6	0	-17.6	-4.92	-0.68	-16	-54.8	0	-1.49	6.745	-7.18	-63.2	0	0	-71.1	-8.12	-11.7	-39.7	-11.6	-11.9	-31	0	0	0	0
24	-15.7	-9.08	-20.2	-23.3	-32.1	-16.2	-17.5	-7.73	-7.82	-15.1	-42.3	0	0	-44.3	0	-31.2	-18.1	-7.5	3.204	-6.38	0	-34.3	-8.71	9.117	-12.9	-27.1	0	0	0	-12.8	0	0	-68.2	-54.3	-12.2	-64.1	0	-33.1
25	-18.2	-16.7	-26.5	-47.6	-51.8	0	0	-21.1	-11.3	-12.7	-28.7	0	0	0	0	0	0	-52.1	-14.6	-0.96	0	0	-53.9	-8.24	7.204	-4.47	0	0	0	-16	0	0	0	0	-47.8	-42.3	0	-34.1
26	-23.9	-23.6	-28.4	0	0	0	0	-33	-21.4	-20.9	-40	0	0	0	0	0	0	-52.7	-21.7	-13.7	0	0	0	-13.2	0.547	9.032	0	0	0	-13.2	0	0	0	0	-50.5	-9.14	0	-23.5
27	0	0	0	0	-21.1	0	0	0	0	0	0	-19.7	-5.24	-17.6	-23.5	0	0	0	0	0	-1.84	0	0	0	0	0	3.351	-9.44	-43.6	0	0	0	0	0	0	0	0	0
28	0	0	-7.84	0	0	-19.2	0	0	0	0	0	-30.3	-18.4	-27.1	-43	-7.93	-12.9	-45.1	0	0	-14.9	-9.63	-47	0	0	0	-15.3	0.603	-9.4	0	-18.6	0	0	0	0	0	0	0
29	0	0	22.3	-34.1	0	-17.4	-27	0	0	0	0	0	0	-53.4	0	-18.8	-13.8	-27.7	-69	0	0	3.933	-12	0	0	0	-56.2	-17.7	9.797	0	-7.32	-16	0	0	0	0	0	0
30	-38.5	-22.6	-32.7	-32.4	0	-38.5	-43.1	-26.6	-25.5	-36	0	0	0	0	0	-67.5	-32.3	-21.8	-9.75	-25.6	0	-55.7	-11.4	-1.44	-17.7	-11.4	0	0	0	7.495	0	0	-35	-13.3	-13.3	-20.5	-73.9	-50.8
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39.09	51.43	0	0	0	-26	-55.7	0	0	0	0	-28.5	-7.27	0	8.756	-15.6	-67.3	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-48.8	-45.3	-63	0	0	0	-30.6	-24.1	0	0	0	0	0	-14.5	0	-10.8	6.912	-12.8	0	0	0	0	0
33	0	0	0	-53.8	-39.9	-41.5	-43.8	0	0	0	0	0	0	0	0	-53.9	-40.2	-34.6	-52	0	0	-63.5	-12.6	-37.4	0	0	0	0	-67.1	-30.3	-51.9	-2.9	8.788	-8.6	-58.7	0	-35.3	0
34	0	-48.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-44.5	-40.6	0	0	0	-23.2	-28.2	0	-55.7	0	0	0	-3.98	0	0	0.49	10.8	-5.9	-50.5	-10.4	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-42.9	0	0	0	0	-31.7	-38.3	-30.5	0	0	0	-2.64	0	0	-44.4	-2.36	8.319	-11.8	0.602	-12.7
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-84.2	0	0	0	-42.9	-46	-9.07	0	0	0	-24.3	0	0	0	0	-15.9	4.919	0	-15.7
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-26.5	-14.5	-7.52	-68.5	7.611	-23.7
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-18.3	0	0	0	-46.7	0	0	0	0	-10.4	-11.4	-19.1	6.023

12.5 Conclusion

The realism tests undertaken and subsequent results compared with known responses, indicate that the model produces intuitive responses to changes in travel costs. The fuel cost test identifies a low response overall and notably a positive response for EMP which suggests that care should be taken should schemes targeting that subset of demand (road travellers within EMP) and also that overall any changes to fuel cost could be lower than expected for all purposes.

It is noted that the PT response is at the lower end of the scale, and therefore might be considered an optimistic forecast in response to PT fare changes. e.g. less responsive to increases in fare. It is also highlighted that the comparison data is not local to the region and so should be considered a reasonable response at this time unless further data becomes available.

13 Conclusions and Recommendations

13.1 Overview

The Regional Modelling System (RMS) has been developed by the National Transport Authority (NTA) to assist in the detailed appraisal of transport schemes and strategies across Ireland, and particularly in its main five cities. The calibration of East Regional Model (ERM) has been undertaken as part of the overall update of the NTA's Regional Modelling System.

The RMS was first developed for a 2012 base year and released in 2015. The present update to RMS was started in 2017 and involved a range of improvements to the main model components including:

- Upgrading the National Demand Forecasting Model into single integrated application;
- Implementation of a comprehensive version and quality control system to help manage base year and model code maintenance and updates;
- Development of a National Zoning System to serve as the primary source of zone boundaries within the area covered by each of the regional models;
- Redefinition of the model boundaries based on the commuter catchments of each main regional city;
- Development of the Long-Distance Model, a Cube based Ireland-wide demand and assignment model within NDFM that links inter-regional travel demand across all five regional models;
- Estimation of initial mode and destination logit parameters estimation using ALOGIT based on the NHTS and POWSCAR datasets;
- Development of systematic integrated processes for deriving mode share, trip length and generalised cost distributions to calibrate the estimated parameters and support model validation;
- Improved convergence and parking constraint mechanisms in the Parking Distribution model;
- Enhanced representation of trip tours including better linkages between the home-based attraction and non-home-based production trip end totals;
- More disaggregate population segments and trip rate derivation;
- Development of an integrated model analysis toolkit that executes as part of a standard run and links to a flexible macro-enabled spreadsheet to assess model performance across a range of indicators;
- Developing significant runtime improvements throughout the system and maximising efficiency on NTA servers as well as standard development hardware setups;
- Improved convergence in the road model and the Demand Model; and
- Development of a range of tools and procedures to provide consistent model input generation across the regional models (in terms of parameters and network/service

data), manipulate and manage the NHTS and POWSCAR data sources, and enable extraction of additional model data for development and calibration purposes.

13.2 Model Dimensions

The dimensions of the 2016 Regional Modelling System (summarised below) are very similar to the preceding system.

13.2.1 Modelled Year

- A base year of 2016 (to coincide with Census/POWSCAR and National Household data sets); and
- For forecasting, the RMS can represent any year for which land use and infrastructure provision assumptions can be provided. These should be prepared for key future years around critical infrastructure opening years and/or national planning targets to support short, medium and long term horizon planning and appraisal.

13.2.2 Modes of Travel

The following are the available modes of travel in the each of the regional Demand Models:

- Private vehicles – cars (distinguishing between car driver and car passenger) within the Demand Model;
- Public transport sub-modes (bus, rail, Luas, Metro);
- Park and Ride to/from designated locations;
- Active modes (walking and cycling); and
- Taxis.

Additional mode choice functionality is provided in the Special Zones module to distinguish passengers who travel by car and park at airports, those who are dropped off at airports, and those who arrive/depart by taxi.

The road model assigns vehicular demand matrices for additional goods vehicle classes and taxi trips. It should be noted that taxi as a mode is not an available travel choice in the Demand Model. Taxi trips are simply derived from the Demand Model car matrices using a proportion and subsequently estimated to taxi counts, however their inclusion in the model is important particularly in Dublin City centre.

13.2.3 Time Periods

The ERM and other regional models represent a full day broken down into 5 time periods as follows:

- AM Peak period covering the period between 0700-1000;
- Morning Inter-Peak covering the period between 1000-1300;
- Afternoon Inter-Peak covering the period between 1300-1600;
- PM Peak period covering the period between 1600-1900; and
- Off-Peak covering the period between 1900-0700.

In the assignment of trips to the transport networks, each of the 3-hour periods is factored down to represent the peak one-hour demand within the period. The 12-hour Off-Peak period is factored to represent evening demand at 8-9pm. Unlike the 2012 RMS, this time period is assigned to the relevant networks in each of the latest regional models, however, less confidence can be placed in its outputs and level of calibration than the four daytime periods.

13.2.4 Demand Segmentation:

Groups of people with similar travel behaviours (for example, commuters who own a car) are represented by distinct demand segments in the regional models. This allows those groups to be treated differently in the model according to their behaviour, for example, people travelling to do shopping may have a choice of retail locations, whereas those travelling to work have less flexibility. Demand for travel can be adjusted more accurately to change in populations, jobs, etc. when it is segmented.

Demand is segmented by the following attributes, based on an analysis of the National Household Travel Survey, so that the final segments represent differing travel behaviours:

- Home base journey purposes, e.g.
  - Commute;
  - Education,
  - Escort to Education;
  - Shopping;
  - Visiting friends/relatives;
  - Employers business; and
  - Other (which combines all trip types not part of the above categories).
- Non-home-based trips, derived from the destinations of home-based trips;
- All home based trips are segmented by car availability, which is a function of household car ownership and competition levels; and
- Access to free car parking – while not a primary demand segment in terms of the models' standard trip ends, this segmentation is created within the initial stages of the Demand Model based on workplace parking capacities.

Segments that represent very small proportions of overall travel demand have been combined into the "Other" journey purpose. Demand segmentation has not changed between the 2012 and 2016 versions of the RMS, however improvements have been made to the treatment of car availability and tours within NTEM.

13.2.5 Zoning System

Zone System development is detailed in Chapter 4 which sets out the data sources used to derive the zone system for a, the four categories of zones contained within the zone system (geographic, route, special and sector).

The basic element of the RMS zoning system is the Census SAPS boundary system the associated data from the 2016 Census (supplied by the CSO). Small Area Population

Statistics (SAPS) is provided by the CSO based on Census data at enumeration areas called Census Small Areas (CSAs). CSAs are combined or sub-divided systematically to make model zones that contain consistent levels of population, employment, and trip making within the resulting areas. This was done for the entire Rep. of Ireland to make a single combined zone system. This was necessary given each model area was redefined relative to the 2012 models to be based on the commute catchment of its main regional city without regard to the boundaries of other regional models.

The 2012 models instead had exclusive model areas, except for an area of overlap between the ERM and SERM. The 2016 approach necessitated the development of a one-to-many zone to regional model allocation system from a single national zone system in order to derive overlapping model areas.

The full national and regional model zone system, including all numbering and sector systems, is now defined within single consistent database to enable national data such as the NHTS and POWSCAR to be consistently mapped to all models independent of any boundary. It also reduces the risk of any errors in inconsistencies being introduced when updating model zone systems in future.

Route zones in the 2016 RMS have received significant additional attention compared to the preceding system. Route zones are the links through which road traffic and rail service flows enter and leave the edge of a regional model. In the 2016 RMS route zone matrices are provided directly from the NDFM through its Long Distance Model and Regional Model System Integration Tool. These systems, along with the National Trip End Model, respond to the same planning data forecasting inputs to ensure that all regional models receive consistent route zone flows for a given RMS forecast scenario.

For further information, see Chapter 4 of this document and the *RMS Zone System Development Report.*

Special Zones are non-geographic zones of transport demand whose trip patterns are not related to the standard demand segments (e.g. work, education, etc.) that comprise the Demand Model component of the regional models. Although Special Zones could in principal include a range of hard-to-model locations at present they include only airports and ferry ports. More information is provided on Special Zones below.

13.3 Model Development Summary

The model was developed, calibrated and validated in line with current transport modelling guidance, primarily from United Kingdom Department for Transport's Transport Analysis Guidance, building on the work undertaken to deliver the previous version of the RMS in 2016/2017. Each component was developed using the best available data, such as the 2016 Census, National Household Travel Survey, recent traffic and passenger volume data, standard PT timetable data formats such as Google Transit Feed Specification and GPS-based journey time data.

The development of the three assignment models is detailed in Chapters 7, 8 and 9 for the Road Assignment Mode, PT Assignment Model and Active Modes Assignment Model respectively. Each chapter sets out the development and calibration methodologies that underpinned the assignment models.

The ERM was calibrated and validated against the recommended criteria set out in the UK TAG. The level of calibration and validation achieved across each of the model components is of a high standard when considering the model scale and type.

13.3.1 Demand Model

The Demand Model is made up many components and considerable effort has been undertaken to develop and understand the performance of each of these models.

Observed data for the calibration of the mode and destination choice models was obtained from two sources: Census 2016 Place of Work, School or College - Census of Anonymised Records (POWSCAR), and the 2017 National Household Travel Survey (NHTS).

Comparisons of mode share, average generalised cost, trips length, and intrazonal movement proportions have been summarised between the modelled results and summaries of the key datasets, the NHTS and POWSCAR. These comparisons generally show close correspondence for individual demand segments with some notable deviations, particularly among the education and home-based employer's business segments. Discussion has been made as to the possible reasons behind these deviations and these limitations should be borne in mind for specific schemes which may target them.

The Demand Model also considers three different parking models: Parking Distribution, Free Workplace Parking, and Park and Ride. With limited data available to develop these models the supporting assumptions for the algorithms have been laid out so that users can understand the source of the results. Where possible validations have been undertaken against observed or synthesised data as in the Park and Ride model and where not possible the model results have been discussed in additional detail so that the trends and responses can be seen to be intuitive.

As the Demand Model is an absolute model[74] with an incremental adjustment it contains a key linkage with the assignment models which is fundamentally underpinned by a set of factors to convert Demand Model outputs to the best estimate of assignment demand. These factors have been discussed and quantified to establish their relative performance.

The response of the Demand Model has also been established through realism testing as defined in UK TAG guidance using the standard three measures: change in car fuel,

[74] There are two predominant forms of transport model development, absolute and incremental, and both have key strengths and weaknesses. Absolute models tend to have a better response to large changes without needing additional measures put in place to account for large swings in cost and demand, or pivoting from an empty area

change in PT fare, and change in car journey time. While the PT test comes within the recommendations outlined in UK TAG, both the car journey time and car fuel test showed muted responses, but this is largely due to the impact of Parking Distribution within the urban area and in some ways highlights and justifies the benefits of such modelling of constraint which is far beyond an industry standard approach, particularly in a predominately urban context.

13.3.2 Road Assignment Model

The Road Assignment Model calibrates to a good standard when considering individual link counts. Disaggregated screenlines (i.e. M50 Northeast, M50 North, M50 Northwest) do not perform as well as their aggregated counterpart (i.e. M50) indicating that travel demand to and from Dublin is accurate, however, sector-to-sector movements within these areas are less well calibrated.

For the road model, the target flow calibration and validation criteria are in line with UK TAG Unit M3-1 Section 3 Table 2, shown in Table 13.1.

Table 13.1 Flow and Turning Movement Validation

Link Flow and Turning Movement Validation Criteria and Acceptability Guidelines			AM	LT	SR	PM
Criteria	Description of Criteria	Guideline	Model Result			
1	Individual flows within 100 veh/h of counts for flows less than 700 veh/h Individual flows within 15% of counts for flows from 700 to 2,700 veh/h > 85% of cases Individual flows within 400 veh/h of counts for flows more than 2,700 veh/h	> 85% of cases	83%	89%	85%	82%
2	GEH < 5 for individual flows	> 85% of cases	81%	87%	83%	80%

Journey time validation is strong in the less congested time periods and less congested direction of the busy AM and PM periods, as shown in Table 13.2. The model may tend to underestimate congestion related delay in the inbound direction in the AM peak and outbound direction in the PM peak. The observed journey time data used to validate the model, however, may overstate delays and have been found to be generally slower than Google Maps estimates for the same routes. The route choice algorithm works by minimising travel times across the network (i.e. all paths between A and B take an equal amount of time), which can tend to smooth out local traffic peaks.

Table 13.2 Journey Time Summary by Route Type

Route Set	Summary	Count	AM	LT	SR	PM	OP	Total
Northern Radial - Inbound	Count	8	3	7	8	5	7	30
	% Pass		38%	88%	100%	63%	88%	75%
Northern Radial - Outbound	Count	8	5	6	7	5	6	29
	% Pass		63%	75%	88%	63%	75%	73%
Southern Radial - Inbound	Count	8	1	8	8	4	6	27
	% Pass		13%	100%	100%	50%	75%	68%
Southern Radial - Outbound	Count	8	6	6	5	5	6	28
	% Pass		75%	75%	63%	63%	75%	70%
Orbital	Count	8	1	8	4	1	8	22
	% Pass		13%	100%	50%	13%	100%	55%
Non-Central	Count	16	12	16	16	15	14	73
	% Pass		75%	100%	100%	94%	88%	91%

13.3.3 Public Transport Assignment Model

The ERM Public Transport assignment model includes all the services that are coded in GTFS (General Transit Feed System) with the time period being modelled. Assignment parameters are set based on initial values provided by UK TAG Unit 3.2 and the Passenger Demand Forecasting Handbook v6[75].

The calibration and validation process for assignment component and matrices of the PT model is achieved by comparison of model outputs with the following observed data:

- Passenger loadings (link counts);
- Boarding and alighting volumes;
- Passenger flows on key movements;
- Passenger loadings versus service capacities;
- Bus journey times; and
- Ticket sales revenue.

Calibration is the process of adjusting the PT Model to ensure it provides robust estimates of sub-mode choice, assignment and generalised cost. This is typically achieved in iteration with the validation of the model to independent data.

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[75] The Passenger Demand Forecasting Handbook (PDFH) is an industry-recognised source of evidence, summarising over twenty years of research on rail demand forecasting. The PDFH is only available to members of the Passenger Demand Forecasting Council. For more information, see https://www.raildeliverygroup.com/pdfc.html

UK TAG unit M3-2[76] (PT assignment modelling), sets out the following means of PT model calibration:

- Adjustments may be made to the zone centroid connector times, costs and loading points;
- Adjustments may be made to the network detail, and any service amalgamations in the interests of simplicity may be reconsidered;
- The in-vehicle time factors may be varied;
- The values of walking and waiting time coefficients or weights may be varied;
- The interchange penalties may be varied;
- The parameters used in the trip loading algorithms may be modified;
- The path building and trip loading algorithms may be changed; and
- The demand may be segmented by person (ticket) type.

UK 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.

UK TAG unit M3-2 indicates that the following passenger flow validation criterion should be considered:

- Modelled PT flow should ideally fall within 15% of observed flow across appropriate screenlines; and
- Modelled PT flow should ideally fall within 25% of observed flow on individual links, except where observed flows are particularly low (less than 150), on individual links.

Passenger flow validation for the Dublin canal cordon are summarised in Table 13.3 below. Themajority of the screenlines are meeting the modelled flows within +/- 15% of observed criterion, except for outbound flows in SR (overestimated +30%) and OP inbound flows (underestimated -44%). The balance between the PT sub modes (Bus, Rail and Luas) is matching well the observed data.

76 https://webarchive.nationalarchives.gov.uk/20191103110735/https://www.gov.uk/government/publications/webtag-tag-unit-m3-2-public-transport-assignment-modelling

Table 13.3 Public Transport Flow Validation (Canal Cordon)

		Rail	Luas	Bus	Total	Rail	Luas	Bus	Total
AM	Observed	15,454	10,093	25,400	**50,947**	4,932	4,614		**9,546**
	Modelled	15,087	11,095	22,625	**48,806**	4,893	4,650		**9,543**
	Difference	*-367*	*1,002*	*-2,775*	***-2,141***	*-39*	*36*		***-3***
	% Difference	*-2%*	*10%*	*-11%*	***-4%***	*-1%*	*1%*		***0%***
LT	Observed	1,679	2,053		**3,732**	1,764	1,606		**3,370**
	Modelled	1,696	2,314		**4,010**	1,647	1,618		**3,265**
	Difference	*17*	*261*		***278***	*-117*	*12*		***-105***
	% Difference	*1%*	*13%*		***7%***	*-7%*	*1%*		***-3%***
SR	Observed	1,514	2,123		**3,637**	2,298	2,676		**4,974**
	Modelled	1,717	2,449		**4,166**	3,036	3,447		**6,483**
	Difference	*203*	*326*		***529***	*738*	*771*		***1,509***
	% Difference	*13%*	*15%*		***15%***	*32%*	*29%*		***30%***
PM	Observed	3,299	5,021		**8,320**	13,773	5,447	19,557	**38,777**
	Modelled	3,494	5,548		**9,042**	15,851	6,847	20,056	**42,753**
	Difference	*195*	*527*		***722***	*2,078*	*1,400*	*499*	***3,976***
	% Difference	*6%*	*10%*		***9%***	*15%*	*26%*	*3%*	***10%***
OP	Observed	662	1,032		**1,694**	1,166	2,299		**3,465**
	Modelled	818	864		**1,682**	950	1,000		**1,949**
	Difference	*156*	*-168*		***-12***	*-216*	*-1,300*		***-1,516***
	% Difference	*24%*	*-16%*		***-1%***	*-19%*	*-57%*		***-44%***

13.3.4 Active Modes Assignment Model

The Active Modes Assignment Model network is the aggregation of different networks (road and walking), with equivalent node, link, zone connectors, and numbering convention. Assignment is based on a minimum time path.

Walk speeds are fixed independent of link type. A slightly slower speed, based on NHTS data observations, is set for Education and Retired User Classes.

Cycling speeds are based on link type, where information on Quality of Service, and/or or descriptions of other characteristics (road type, presence of marked cycle lanes, etc.) were used to assign speeds of between 12km/h and 20km/h. For both walk and cycle, no account of congestion is taken account of in determining route choice.

The Active Modes model has been validated at count total level. There is no guidance on the level of validation that should be achieved. It should be noted that no calibration of the active modes demand matrices or assignment models has been undertaken.

Active Modes flow validation is summarised in Table 13.4 below. Modelled walk flows are matching observed flows at the global scale, even though slightly underestimated in SR and PM. Modelled cycle flows are constantly underestimated across all time periods. The total modelled cycle demand is calibrated at the user class level. Discrepancies at the assignment stage between modelled and observed.

Table 13.4 Active Modes Flow Validation (All Counts)

		Walk	Cycle
AM	Observed	27,084	19,499
	Modelled	26,716	7,766
	Difference	*-368*	*-11,733*
	% Difference	*-1%*	*-60%*
LT	Observed	11,188	4,837
	Modelled	10,085	1,792
	Difference	*-1103*	*-3045*
	% Difference	*-10%*	*-63%*
SR	Observed	13,542	5,715
	Modelled	9,638	2,127
	Difference	*-3904*	*-3588*
	% Difference	*-29%*	*-63%*
PM	Observed	26,610	15,709
	Modelled	18,476	5,760
	Difference	*-8134*	*-9949*
	% Difference	*-31%*	*-63%*

13.4 Model Realism

Chapter 12 provides detail on the three standard realism tests: Car Fuel, Public Transport Fare, and Car Journey Times. The realism tests undertaken and subsequent results compared with known responses, indicate that the model produces intuitive responses to changes in travel costs. The fuel cost test identifies a low response overall and notably a positive response for EMP which suggests that care should be taken should schemes targeting that subset of demand (road travellers within EMP) and also that overall any changes to fuel cost could be lower than expected for all purposes.

It is noted that the PT response is at the lower end of the scale, and therefore might be considered an optimistic forecast in response to PT fare changes. e.g. less responsive to increases in fare. It is also highlighted that the comparison data is not local to the region and so should be considered a reasonable response at this time unless further data becomes available.

13.5 Additional Information

This report is intended to include all aspects of the model development and calibration, without the more detailed levels technical descriptions found in the library of reference documents. As far as possible the relevant sections of the reference documents have been clearly sign posted throughout the report. The NTA's existing model report library contains over 300 documents from the original and more recent model development and at the time of writing, many of these are being reviewed and combined to make the reference library simpler and easier to follow. Where relevant below, the key recent reference documents are mentioned to provide the reader with additional sources of information if needed.

The Regional Modelling System includes the following key components, each of which is generally covered in more detail than this report in its own development report:

- National Demand Forecasting Model (NDFM):
  - The NDFM consists of five sub-components each of which have been summarised in this report in Chapter 6 but are more fully described in the below reference documents; these are:
    - Planning Data Adjustment Tool (*PDAT Report*);
    - National Trip End Model (*NTEM Report*);
    - Car Ownership and Competitions Models (*Car Ownership Report*);
    - Regional Modelling System Integration Tool (*RMSIT Report*); and
    - Long Distance Model (*LDM Report*).
- Demand Model:
  - The Demand Model is a set of interlinked travel choice and assignment models that apply trip ends (from the NDFM) to input travel costs (from calibrated assignments) to produce assignment matrices though the choice modes and hence multi-modal network flows for base and forecast years;
  - Each of the regional models including the ERM is based on the same underlying demand (or choice) model system;
  - This report provides the most complete description of the Demand Model, in Chapter 6;
  - Chapter 6 details the development of each component that makes up the regional Demand Model, the purpose of each component, the data requirements for each component and the outputs produced by each component; and
  - Additional information can be found in various reference reports, the most important of which include:
    - *Goods Vehicles Note*;
    - *Parking Distribution Note*; and
    - *Special Zones Modelling Note*.
- Assignment Models:
  - The Road, Public Transport, and Active Modes assignment models receive the trip matrices produced by the Demand Model and assign them in their respective

transport networks to determine route choice and the generalised cost for origin and destination pair;
    - The Road Assignment Model assigns Demand Model outputs to the road network and includes capacity constraint, traffic signal delay and the impact of congestion to estimate route-choice through the network. See the *Road Model Networks Development Report* for further information;
    - The Public Transport Assignment Model assigns Demand Model 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 and choice of public transport service. The model includes public transport networks and services for all PT sub-modes that operate within the ERM modelled area. See *Public Transport Networks Development Note*; and
    - The Active Modes Assignment Model assigns walk and cycle demand to the road network and includes additional walk and cycle only links to enable full paths to be calculated for these modes. See *Active Modes Networks Development Note*.

13.6 Recommendations

This section briefly summarises some of the high level improvements which could be made the ERM given lessons learned during its calibration.

13.6.1 Road Model

- Data:
    - The calibration dataset should be expanded to incorporate recent counts undertaken for Metro and BusConnects projects; and
    - Alternatives to the TomTom dataset should be investigated to obtain more certainty on the end-to-end journey time estimates for comparison to model times.
- Matrix Estimation:
    - Matrix estimation to screenline totals should be considered a first step in adjusting Demand Model road matrices, before the adjustment to calibration counts. This could result in more predictable and evenly applied adjustments to the matrix cells generally;
    - Trip end constraint should be based on zone type, with tighter constraints applied in areas where there is higher confidence in count data; and
    - A process to adjust LDM matrices outside the matrix estimation approach should be considered, possibly using factors as a model parameter to account for the different modelling capabilities of the LDM and the regional model.
- Coding Standards:
    - Standard capacities by area type (urban, suburban, rural) should be reviewed and added to the *Road Model Coding Guide*; and
    - Cycle time coding should be reviewed throughout the road model to allow offsets to function.

13.6.2 Public Transport Model

- Data: Include geographical Leap data:
  - Leap data provides a continuous source of observed PT journeys across all modes, including transfers; but
  - Only high level analysis was done as part of the 2016 ERM update and using a geographic tag (by station, bus route and stop number etc) could provide a larger dataset to supplement the 1-day survey data used in the calibration.
- Crowding model:
  - The way Cube assigns demand to different routes with similar costs can be controlled through parameters from Cube v6.4.5; and
  - An aggregation of similar routes (that differ by a few nodes) can be considered to improve convergence and prevent the crowding model oscillating service choice from one loop to another.
- School Buses:
  - The introduction of Non-Transit Legs to represent school buses has not been done for the ERM; and
  - This should be applied outside the metropolitan Dublin area where the ERM covers rural areas with significant school transport operation.

13.6.3 Active Modes

Following the development and the calibration/validation of the overall ERM, some areas have been identified where potential improvements could be made, as follows:

- Active: Cycle sensitivity:
  - The cycle mode constants in the Mode and Destination Choice are likely to make the demand response to cycle scheme low; hence
  - Further sensitivity tests are recommended, e.g. increasing speed on cycle facilities by 10% or overall cycle speed by 10%.
- More data on walking and cycling speeds and routing across a range of road users should be obtained, which would allow development of more refined assignment;
- Data to differentiate visitors from the standard modelled journey purpose, particularly to better enable predication of pedestrian volumes in the city centre, should be obtained;
- Consider how cyclists in particular are affected by congestion effects and/or particular characteristics of junctions; and
- Classify links using pedestrian oriented characteristics (pedestrianized area, number of shops, large sidewalks) to reflect their attractiveness for walking in the assignment.

Appendices

Annex 1 Complete list of Reference Documents

Active Modes Model Development Report

Calibration Guide

Car Ownership Report

Coding Guide

Data Management Report

Demand Data Processing Report

Demand Segmentation Report

Demand Specification Report

Fares Modelling Report

Goods Scoping Report

Forecasting Note

LDM Report

Model Estimation Report

Network Development Process Report

Network Link Specification Report

NHTS Data Processing Note

NTEM Report

Parking Specification Report

PDAT Report

POWSCAR Data Processing Note

PT and Active Modes Data Processing Report

PT Model Development Report

RMSIT Report

Road Model Data Processing Report

Road Model Development Note

Special Zones Report

Taxi Scoping Report

Peak Hour Specification Report

Trips and Tours Data Review Report

Zones Report

Glossary

Automatic Vehicle Location – A system used to automatically determine and transmit the location of each vehicle in a fleet. In the Public Transport industry, this is used to update the real-time position of buses, trams and trains. This can be used to measure journey times, compare route performance against timetable and update real-time passenger information screens.

Car Availability – A type of demand segmentation which indicates if transport users have access to a car for a particular trip. Note that this is related to, but is not the same as car ownership and car competition. People in households with cars will not necessarily have a car available for an individual; conversely, people in households without cars may still have a car available to them (as a passenger). The probability of having a car available will increase as the ratio of cars to adults in the household increases.

Car Competition Model – A component of the National Demand Forecasting Model. This model takes the average number of cars per household and average number of adults per household and calculates the proportion of household which have zero cars; the proportion which have few cars than adults (“competition”), and the proportion of households which have as many cars as adults. The level of car competition influences Car Availability for individual trips.

Car Ownership Model – A component of the National Demand Forecasting Model which calculates the total number of cars owned in the state based on changing demographics, observed trends in ownership and economic growth. The outputs from this model provide an input to the Car Competition Model.

Census Small Area – The smallest geographical area used to present census data. CSAs are compiled by the National Institute of Regional and Spatial Analysis on behalf of the Ordnance Survey Ireland and in consultation with the Central Statistics Office. They typically contain between 50 and 200 dwellings and the CSA system used for the 2016 census consisted of 18,641 CSAs covering the whole of the Republic of Ireland.

Common Appraisal Framework – Guidance produced by the Department of Transport, Tourism and Sport providing a common framework for the appraisal of transport investments which is consistent with the Public Spending Code. The document aims to assist scheme promoters in constructing robust and comparable business cases for submission to Government, and sets out the key stages in the approval process and the analysis that is required at each stage. The CAF also provides guidance on specific parameters and processes that are to be used in the analysis and appraisal.

Datastore – A online database created by the NTA to store traffic count data from a variety of sources.

Demand Model – A core component of each regional model, the Demand Model is formed of several sub-models and processes. In combination, these models and processes take all-day travel demand from the National Demand Forecasting Model in the form of trip ends, and output origin-destination travel matrices by mode and time period to be used by each of the assignment models.

Demand Segment – Demand is split into a number of segments, based on the features of individual trips such as the trip purpose, car availability, employment type, etc. The main processes of the Demand Model are undertaken separately for each demand segment using parameters and assumptions appropriate to that demand segment.

Electoral Divisions - The smallest legally defined administrative areas in Ireland. There are a total of 3,440 electoral divisions in Ireland and they are used to define local electoral areas for elections to county and city councils and to define constituencies in elections to the Dáil. Many statistics generated by the Central Statistics Office are published at an Electoral Division level.

Free Workplace Parking – Describes the practice of providing employees access to free parking spaces at or near their place of work. This also applies to colleges and universities providing free parking for students. As the cost of parking is a big factor in travel behaviour, the model contains a process which can segment travellers based on their access to free workplace parking and apply differential parking charges to each segment.

Furness – A process used to calculate balancing factors in trip distribution / destination choice. Following the initial calculation of trips using trip distribution or destination choice, the total number of trips travelling from each origin and to each destination zone are unlikely to match the trip ends for the respective zones. Balancing factors for each origin and destination zone (designated A_i and B_j) must be calculated. In a singly-constrained furness process one of the factors (usually B) is assumed to be zero, and the remaining factor (A) can be calculated for each zone by simply dividing the origin trip end for each zone by the sum of all trips travelling from that zone (replace “origin” for “destination”, and “from” with “to” in the rare case that the demand matrix is destination constrained). For a doubly-constrained, the process is not as simple as changes in any of the A factors will influence all of the B factors and vice versa. To solve this issue the A factors are calculated as for a singly-constrained furness process and then the B factors are calculated in the same way, taking into account the A factors. The A factors then need to be recalculated, taking into account the B factors and this process is repeated iteratively until the total number of trips both from and to each zone “matches” the respective origin or destination trip ends.

General Transit Feed Specification - defines a common format for public transportation schedules and associated geographic information. The format consists of between 6 and 13 plain text tables, which together describe a transit system’s scheduled operation as visible to riders. This includes (as a minimum): operators, routes, trips, stops and timetables.

Generalised Cost - The sum of the monetary and non-monetary costs of a journey. Monetary costs include public transport fares, fuel costs, parking charges and tolls, whereas non-monetary costs refer to the time spent undertaking the journey. As the two types of cost are in different units, one has to be converted to the other using a value of time figure, which may vary by demand segment / journey purpose.

The generalised cost is equivalent to the price of the good in supply and demand theory, and so demand for journeys can be related to the generalised cost of those journeys using the price elasticity of demand. Supply is equivalent to capacity (and, for roads, road quality) on the network.

Geodirectory - Geodirectory was jointly established by An Post and Ordnance Survey Ireland and manages a definitive reference dictionary for all 1.9 million buildings that receive post in the Republic of Ireland

Gravity Model – A model which estimates demand between two locations, based on the theory that the number of trips is proportional to the size of the two locations but inversely proportional to the distance between the two locations. The name of the model is analogous to physics as early models posited that trips were inversely proportional to the square of distance, however in more recent models the distance parameter is often replaced by a more comprehensive function based on generalised cost.

Greater Dublin Area - The city of Dublin and its hinterland. The area is defined by the Dublin Transport Authority Act 2008 as the counties of Dublin (Dublin City, South Dublin, Dún Laoghaire–Rathdown and Fingal) along with Meath, Kildare, and Wicklow.

Incremental Adjustment Matrices – Matrices of very small adjustments which are applied to the assignment matrices at a cellular level and account for small discrepancies in observed behaviour which can’t be explained at an aggregate level by the Demand Model.

Intrazonal – Trips which start and end in the same zone. Although these are not assigned to the networks, they still need to be calculated as they can form a significant proportion of total zonal demand.

Journey Purpose – The main reason for making a muti-leg trip (e.g. work, education).

Long Distance Model – A component of the National Demand Forecasting Model. Calculates a demand matrix described the number of trips travelling between each pair of major settlements. This matrix is then used by the RMSIT module to determine the number of trips travelling between different regional models.

Matrices – Matrices can be defined in either Origin-Destination format (OD) or Production-Attraction format (PA)

> OD format is used in the RMS to store one-way and non-homebased trips. The matrix stores each trip based on its origin zone (start point) to define the matrix row and its destination zone (end point) to define the column.
>
> PA format is used in the RMS to store homebased tours. As tours consist of two-way return trips then the zones at both ends of the trip are both an origin and a destination. Trips are therefore stored in the matrix using their production zone (home end of both trips) to defined the matrix row and their attraction zone (non-

home end of both trips) to define the column. Prior to assignment, tours will need to be split into individual trips and converted from PA to OD format. This involves the “transposition” (diagonal flipping) of the return trip so that the attraction end of the trip becomes the origin.

MyPlan - Myplan.ie is a web map portal providing spatial information relevant to the statutory planning system in Ireland. It is an initiative of the Department of Housing, Planning, Community and Local Government in conjunction with Irish Local Authorities. The data is available through web map viewers, web map services and open data.

National Demand Forecasting Model – an integrated suite of components that provide national level forecasts of daily travel demand produced by and attracted to each of the 18,641 Census Small Areas, and of inter-urban travel between most settlements with a population greater than 5,000.

National Household Travel Survey – An extensive survey of nearly 6,000 households undertaken by the NTA between January and December 2017. The main purpose of the survey was to obtain essential information on all day travel patterns and travel behaviour across the country as a whole. In addition to questions about the household, such as employment status and car ownership, the survey included a three-day travel diary recording details of all trips undertaken by household members.

National Trip End Model – A component of the National Demand Forecasting Model, this process calculates the number of trips generated in each Census Small Area based on land-use and population variables, and segmented by journey purpose.

NUTS3 - Nomenclature of Territorial Units for Statistics (NUTS) is a European geocode standard for providing statistical data and divide countries into similar sized areas to allow for direct comparison between different areas. NUTS3 is the smallest area defined by this system (although there are smaller zones, Local Administrative Units)

Parking Distribution – A component of the regional Demand Models, this module is used to model areas where parking demand outstrips parking supply. The module simulates the behaviour of drivers who choose to park in another nearby location, with less constraint, and to walk to their final destination. The model also provides travellers with an option to park remotely when there are other factors which may discourage parking in the destination zone. For example, parking in a neighbouring zone with cheap off-street parking to avoid expensive on-street parking at the destination, or parking outside the city centre to avoid delays crossing the canals. The Parking Distribution model works similarly to Park and Ride by splitting road trips into two legs, which in this case are a road leg and a walk leg.

Passenger Car Units - a measure used primarily to assess highway capacity. Different vehicles are assigned different values, according to a variety of factors which indicate how much capacity they use up (e.g. space on the road, or time taken to pass through a junction). By definition, a car has a value of 1; smaller vehicles will generally have lower values, and larger vehicles will have higher values.

Planning Data Adjustment Tool – A component of the National Demand Forecasting Model which enables the user to define the changes (growth or reduction) in any set of planning data variables that impact on travel demand, between the base and any forecast year. It does this in a flexible manner while ensuring that individual fields in the planning data remain consistent.

POWSCAR – Place of Work, School or College – Census of Anonymised Records. As part of the Census 2016, all workers were coded to their place of work and all students (aged 5 and up) were coded to their place of school or college. By combining with the home location of the individual, this dataset provides an almost 100% sample of journeys to work, school and college along with an indication of journey time and usual mode.

Project Appraisal Guidelines – A guidance document from TII which sets out the parameters and tools to be employed in the appraisal of national roads.

Public Service Obligation – In the context of transport, this describes routes which are not commercially viable and so are supported by the local authority.

Public Transport Assignment Model – A key component of the Regional Modelling System, this takes the demand by Public Transport and assigns it to the PT network to determine which route and services each trip takes.

Public Transport Capacity – Within PT assignment, the cost of travel is assumed to increase as services become busier. This represents both the discomfort of the passengers as well as the possibility that an individual service cannot be accessed because it is over-capacity. The “crowding” algorithm within the PT Assignment Model uses two parameter to define the cost.

> Seating Capacity – This represents the point at which the costs start to increase capacity. It is referred to as seating capacity as perceived costs usually increase when people are forced to stand, but on some vehicles where people expect to stand (e.g. tram) the seating capacity may be greater than the actual number of seats.
>
> Crush Capacity – This represents that absolute capacity of the vehicle and it is physically impossible to increase the number of passengers above this number.

Regional Model – Describes one of the five models covering the various regions: East Regional Model, Mid West Regional Model, South East Regional Model and South West Regional Model. The regional models contain the Demand Model and the Road, PT and Active Modes Assignments. The regional models take trip ends from the National Demand Forecasting Model, calculate destination and mode choice and assign the resulting demand matrices to the appropriate networks.

Regional Modelling System – Describes the entire NTA modelling system for the Republic of Ireland. Consists of the National Demand Forecasting Model and the five regional models.

Regional Modelling System Integration Tool – Part of the National Demand Forecasting Model. This component takes the inter-settlement matrices from the LDM and calculates which trips would enter, leave or travel through each region. Passes on trip ends and inter-regional matrices to the regional models.

Road Assignment Model – A key component of the Regional Modelling System, this takes the demand by car and assigns it to the road network to determine which route each vehicle takes.

SAPMAP – A mapping application developed by the Central Statistics Office to allow users to access Small Area Population Statistics through an interactive map.

Secondary Analysis & Appraisal – A component of the Regional Modelling System which automatically produces key output from the model to be used in appraisal.

Sectors – An aggregation of zones used for analysis purposes.

Settlements – In the model, describes an urban conurbation of over 5,000 population. Settlements are used as the basis for calculating long-distance travel using the LDM component. This ultimately allows the model to calculate the number of trips travelling into, out of, and through regions.

Small Area Population Statistics – a range of common statistics produced by the Central Statistics Office using data from the 2016 census.

Tours – For most demand segments, demand is stored as tours. Each tour can represent multiple trips, although the RMS only deals with simple tours and more complex tours with multiple destinations are broken down into component trips

> Simple Tours – describes a simple two-way return journey from home to another location (e.g. work). In the model, most travel purposes are stored as simple tours, with each tour later being split into two, one-way trips for the purposes of assignment.
>
> Complex Tours – describe tours which involve more than two legs (e.g. triangular tours and other tours which involve more than one destination). In the RMS, these are split into individual one-way trips (both home-based and non-home-based)

Traffic Zones Most demand is represented in the model by taking all trips starting or ending within a particular geographic area (known as a zone) and dealing with them as a single unit. Some demand is associated with a particular point (e.g. a port or airport), which is also referred to as a “zone” for simplicity even though it may not have a geographically defined area.

> Geographic Zones –These zones have boundaries and associated population, employment, and trip generation data. The main Demand Model performs its calculations at the geographic zone level.
>
> Special Zones – describes zones which represent unique locations which generates and attracts trips which do not behave in the same way as other locations. This includes, for example, ports and airports. Although these locations will be contained within a geographic zone (which is used to represent regular trips to the zone, such

as commuting), a special zone is used to represent other trips such as international passengers who require additional or differential treatment.
Route Zones - despite the name, “route zones” do not represent a geographic area. Instead they are connected to road and rail links at the edges of each regional model and are used to represent trips that are entering or leaving the model area.

Trip End Integration – A component of the regional models, which converts National Trip End Model (NTEM) trip ends from the CSA level to the zoning system of the regional model.

Trip Purpose – The reason for making a particular one-way trip, usually defined by the destination (e.g. work, shopping).

UK Transport Analysis Guidance – A comprehensive guide to the conduct of transport studies provided by the UK Department for Transport. The document provides advice on how to conduct appraisal and includes detailed guidance on how to create a transport model.

User Class – Associated with the assignment models, the user class defines a mixture of vehicle types and journey purposes and differentiates between trips which may have different values of time or other costs.

Value of Time – in economic terms is the opportunity cost of the time that a traveller spends on his/her journey. Is used throughout the RMS in appraisal to quantify the economic benefits of savings, but also to allow costs in different units (monetary/non-monetary) to be combined.

Zone Centroids - Represents a geographical point within a zone, positioned in relation to the population and jobs within the zone. Within the model, all trips associated with the zone are assumed to start or end their journey at the centroid, as this represents the average location of all travellers starting or ending their journey in the zone.

Zone Centroid Connectors - Zone centroid connectors provide the link between each zone’s centroid and the transport network. These connectors differ for each mode to reflect the different routes used by trips to access each mode’s transport network.

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