

# Modelling Services Framework

## Mid-West Regional Model

### Public Transport Model Development Report

# CONTENTS

<b>Foreword .....</b>	<b>iv</b>
<b>1 Introduction.....</b>	<b>1</b>
1.1 Regional Modelling System.....	1
1.2 Regional Modelling System Structure .....	3
1.3 MWRM Public Transport Model Overview .....	6
1.4 This Report .....	10
<b>2 MWRM PTM Development.....</b>	<b>11</b>
2.1 Overview .....	11
2.2 Public Transport Services Definition .....	16
2.3 Fares Model Preparation.....	18
2.4 Wait Curve Preparation.....	26
2.5 Crowding Model Preparation.....	27
<b>3 MWRM Cube Voyager Implementation .....</b>	<b>29</b>
3.1 Overview .....	29
3.2 Inputs .....	29
3.3 Network Link Attributes .....	31
3.4 Key Parameters .....	32
3.5 Outputs .....	33
<b>4 MWRM PTM Calibration .....</b>	<b>36</b>
4.1 Introduction .....	36
4.2 Assignment Calibration Process .....	36
4.3 PT Model Network Progression.....	37
4.4 PT Model Parameters Progression .....	49
4.5 PT Model Matrix Progression .....	57
4.6 Summary.....	59
<b>5 MWRM PTM Validation .....</b>	<b>60</b>

5.1	Introduction .....	60
5.2	Assignment Validation Process.....	60
5.3	Observed Data .....	61
5.4	PT Network Validation.....	62
5.5	PT Assignment Validation – Boarding and Alighting .....	67
5.6	Interchange Validation .....	69
<b>6</b>	<b>Conclusions and Recommendations .....</b>	<b>70</b>
6.1	Summary.....	70
6.2	Model Development – Key points.....	70
6.3	Model Calibration and Validation.....	70
6.4	Recommendations for Improvement .....	70

## Tables

Table 1.1	Regional Models and their Population Centres .....	1
Table 1.2	MWRM Time Periods .....	9
Table 2.1	MWRM Irish Rail Intercity Fares Model.....	19
Table 2.2	Modelled vs Observed Average Fares .....	20
Table 2.3	MWRM BÉ Regional Fares Model .....	21
Table 2.4	Modelled vs Observed Average Fares .....	22
Table 2.5	Private Operator Fare Collection Log.....	23
Table 2.6	Private Operator Fares Model.....	24
Table 2.7	Private Operator Fares Model.....	25
Table 2.8	Wait Curve Definition .....	26
Table 3.1	Additional PTM Network Files .....	30
Table 3.2	PTM Parameters .....	33
Table 3.3	PTM Outputs.....	34
Table 4.1	Summary of Generalised Cost Tests carried out in SWRM .....	43
Table 4.2	Detailed Network Audit Recommendations.....	47
Table 4.3	Vehicle Capacities .....	48
Table 4.4	Summary of Parameter Options Retained for Revised PTAM .....	50
Table 4.5	Wait Curve Definition .....	52
Table 4.6	Detailed Parameter Audit Recommendations .....	54
Table 4.7	In-vehicle time factors – initial and calibrated values .....	54
Table 4.8	Bus speed factors by link characteristics and by time period .....	56
Table 4.9	Time factors by bus service characteristics and by time period .....	56
Table 5.1	PT Assignment Model Trip Matrix Validation Criteria.....	60

Table 5.2	PT Assignment Validation Criteria .....	61
Table 5.3	CERTU Guide 2003 – Transfer ratio range.....	61
Table 5.4	Service classification by journey time comparison to AVL data and by time-period.....	64
Table 5.5	Journey Time validation against AVL data – Summary table .....	64
Table 5.6	Service classification by journey time comparison to GTFS data and by time period.....	65
Table 5.7	Journey Time validation against GTFS data – Summary table .....	66
Table 5.8	Boarding and alighting validation by mode – AM time period .....	68
Table 5.9	Boarding and alighting validation by mode – LT time period.....	68
Table 5.10	Boarding and alighting validation by mode – SR time period .....	68
Table 5.11	Boarding and alighting validation by mode – PM time period .....	69
Table 5.12	Overall PT transfer ratio by time period .....	69

## Figures

Figure 1.1	Regional Model Areas .....	2
Figure 1.2	National and Regional Model structure .....	5
Figure 1.3	MWRM Zone System.....	8
Figure 2.1	MWRM CUBE Voyager PT Road Network .....	12
Figure 2.2	MWRM CUBE Voyager Rail Network .....	13
Figure 2.3	Additional Walk Links Included in the PTM.....	14
Figure 2.4	MWRM PTM PT Line Files .....	17
Figure 2.5	MWRM Irish Rail Intercity Fares Model .....	19
Figure 2.6	BÉ Limerick City Services.....	20
Figure 2.7	BÉ Regional Fares Model – Modelled vs Observed Results .....	22
Figure 2.8	Private Operator Fares Model – Modelled vs Observed Results .....	25
Figure 2.9	Wait Curves .....	27
Figure 2.10	Crowding Curves – Utilisation to Crowding Factors.....	28
Figure 3.1	General PTM Flow .....	29
Figure 4.1	Irish Rail MWRM PT Access Plot.....	39
Figure 4.2	Irish Rail Limerick City PT Access Plot .....	40
Figure 4.3	BÉ City MWRM PT Access Plot.....	41
Figure 4.4	BÉ Limerick City PT Access Plot .....	41
Figure 4.5	BÉ Regional and Private Bus Operator PT Access Plot .....	42
Figure 4.6	Example of zone disaggregation.....	44
Figure 4.7	Modelled wait curve .....	53
Figure 5.1	AVL data routes used in Journey Time validation.....	63
Figure 5.2	Bus Journey Times Scatter Plot – Model vs AVL.....	65
Figure 5.3	Scatter plot representing modelled and GTFS observed data .....	66

# Foreword

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

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

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

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

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

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

# 1 Introduction

## 1.1 Regional Modelling System

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

An overview of the 5 regional models is presented below in both Table 1.1 and Figure 1.1.

**Table 1.1 Regional Models and their Population Centres**

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

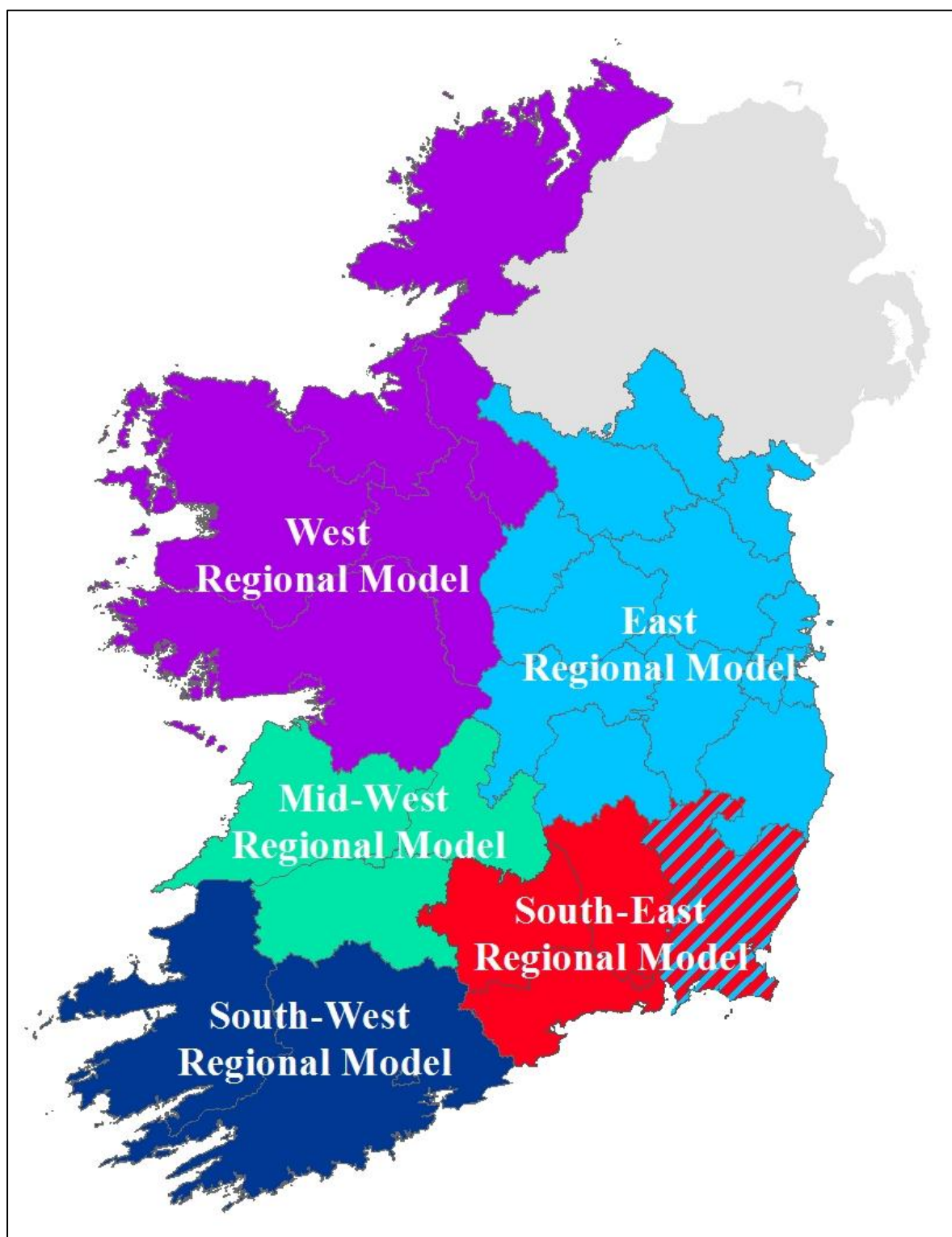


Figure 1.1 Regional Model Areas



## 1.2 Regional Modelling System Structure

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

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

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

### 1.2.1 National Demand Forecasting Model (NDFM).

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

### 1.2.2 Regional Models (RM)

A regional model is comprised *of the following key elements:*

#### ***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 Full Demand Model (FDM).

#### ***The Full Demand Model (FDM)***

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

See the RMS Spec 1 Full Demand Model Specification Report, RM Full Demand Model Development Report and MWRM Full Demand Model Calibration Report for further information.

#### ***Assignment Models***

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

The Road Model assigns FDM outputs (passenger cars) to the road network and includes capacity constraint, traffic signal delay and the impact of congestion. See the RM Spec 2 Road Model Specification Report for further information.



The Public Transport Model assigns FDM outputs (person trips) to the PT network and includes the impact of capacity restraint, such as crowding on PT vehicles, on people's perceived cost of travel. The model includes public transport networks and services for all PT sub-modes that operate within the modelled area. See the RM Spec 3 Public Transport Model Specification Report for further information (referred to as the PTM Specification Report for the remainder of this document).

### ***Secondary Analysis***

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

#### **1.2.3 Appraisal Modules**

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

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

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

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

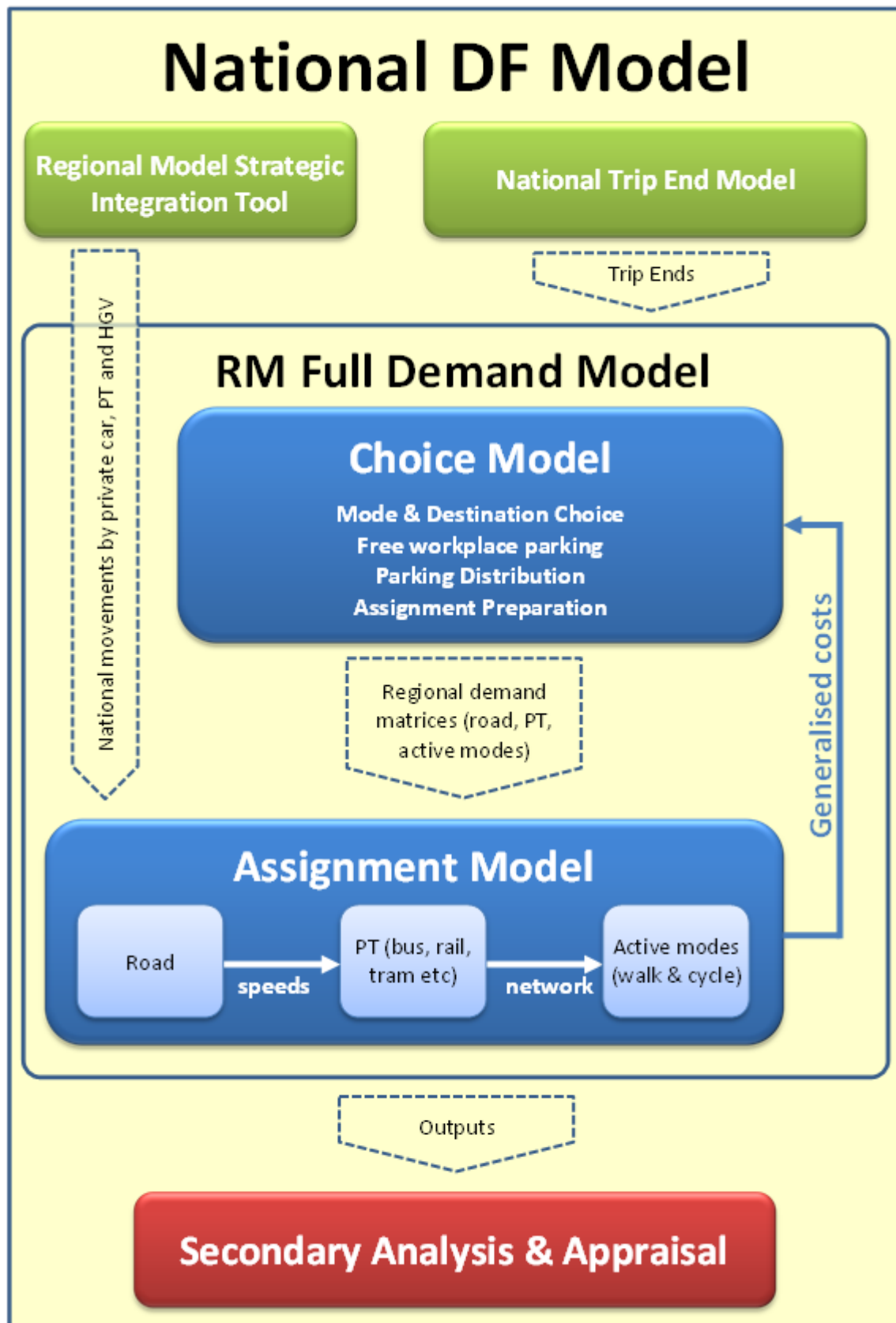


Figure 1.2 National and Regional Model structure

## 1.3 MWRM Public Transport Model Overview

### 1.3.1 MWRM Public Transport Model Development

Public Transport Model development and calibration is a task common to all NTA regional transport models. The PTM Specification Report, that provides a basis for consistency across all the models, was used as a guide for the development of the MWRM Public Transport Model.

The development of the MWRM has been broken down into a number of high-level tasks, of which the principal ones are shown below:

- Road model development and calibration;
- Public transport model development and calibration; and
- Demand model development and calibration.

The development of the MWRM followed a 'Repeatable Methods' approach (developed for the ERM), which provides the methodology, guidance and techniques to develop the Regional Modelling System. The methods used for public transport model development were based on earlier development work and emerging guidance undertaken for the ERM. The development of the MWRM Public Transport Model was based on the specification outlined in the PTM Specification Report.

### 1.3.2 PTM Demand Segmentation

The following user classes are defined in the PT assignment model:

- **Employers-Business (EMP):** trips on employers business;
- **Commute (COM):** commuting trips between home and work;
- **Other (OTH):** all other journey purposes including shopping, visiting friends, escort to education etc;
- **Non-Dedicated School (SCH):** primary and secondary school pupil trips on general PT services between home and place of education;
- **Concessionary-Travel:** passengers eligible for free travel passes on PT through the Free Travel Scheme; and

Further details are provided in Section 3.8.2 of the PTM Specification Report.

### 1.3.3 Network Development

The MWRM PT network comprises a number of input components, as follows:

- 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).

### 1.3.4 Linkages with Overall MWRM Transport Model

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

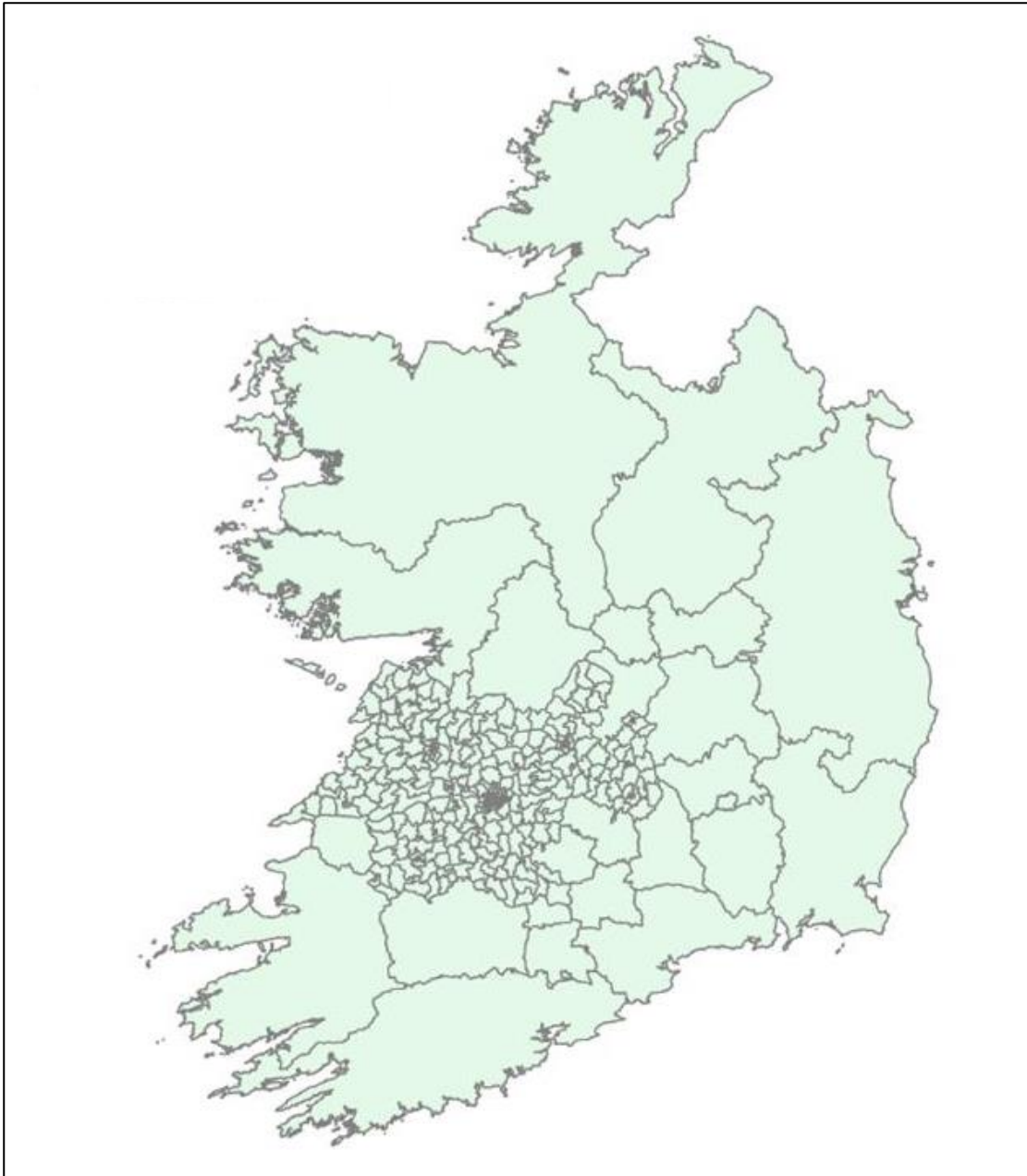
- Definition of Zone System
  - Definition of zonal boundaries for regional model.
- System Architecture
  - consideration of model procedures and their impact on run-times;
  - coordination with overall RMS;
  - standardisation with overall RMS (e.g. scripts, procedures, units); and,
  - Derivation and calculation of annualisation factors.

In addition, there are a number of inter-dependencies with other elements of MWRM:

- Road Model
  - Interchange of key data, notably network details and bus speeds.
- Demand Model
  - Inputs to PT Model**
    - PT Assignment Matrices; and
    - Generalised Cost parameters and specifically the value of time of public transport users.
  - Outputs from PT Model**
    - Cost skims for feedback into mode and destination choice (MDC)

### 1.3.5 MWRM Zone System

The PTM zone system is the same as the overall MWRM as described in the MWRM Zone System Development Report, and illustrated in Figure 1.3.



**Figure 1.3 MWRM Zone System**

The key zone system statistics include:

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

This high level of zonal detail allows access to Public Transport services to be modelled to a greater degree of accuracy. Increased zonal density in urban areas such as Limerick

City allows for the accurate representation of walk times for users wishing to access public transport. This allows the cost of travel by PT, and associated modal split, to be calculated with greater accuracy within the model.

### 1.3.6 Base Year

The base year of the model is 2012 with a nominal month of April. This is largely driven by the date of the Census (POWSCAR) and other travel surveys (e.g. the National Household Travel Survey). It should be noted that the POWSCAR dates to 2011 but the travel patterns are assumed to be broadly the same in 2012.

### 1.3.7 Time Periods

Table 1.2 below details the five weekday time periods that are modelled in the MWRM. The time periods allow the relative differential in travel cost to be represented. The PT assignment model requires a single hour to be assigned as representative of each period. Peak hour matrices were obtained from the period matrices by applying peak hour factors which were calculated from the NHTS based on the mid-point of the journey time, but without regard to journey purpose.

Table 1.2 MWRM Time Periods

PERIOD	DEMAND MODEL FULL PERIOD	ASSIGNMENT PERIOD	PERIOD TO PEAK HOUR FACTORS
<b>AM Peak</b>	07:00-10:00	Peak hour (factored from period)	0.61
<b>Morning Interpeak “Lunch Time” (LT)</b>	10:00-13:00	Average hour from full period	Average (1/3)
<b>Afternoon Interpeak “School Run” (SR)</b>	13:00-16:00	Average hour from full period	Average (1/3)
<b>PM Peak</b>	16:00-19:00	Peak hour (factored from period)	0.55
<b>Off Peak</b>	19:00-07:00	not assigned	Average (1/12)

### 1.1.1 Software

All demand and Public Transport model components are implemented in Cube Voyager version 6.4. SATURN version 11.2.05 is used for the Road Model Assignment. The main Cube application includes integration modules that execute the SATURN assignments and extract the necessary outputs that are required as inputs to the other components of the MWRM.

## 1.4 This Report

This report focuses on the development and calibration of the Public Transport Model (PTM) within the Mid-West Regional Model (MWRM) and includes the following chapters:

- **Chapter 2: MWRM PTM Development:** provides information on the specification of the PTM and an overview of its development;
- **Chapter 3: MWRM PTM Cube Voyager Implementation:** describes the implementation of the PTM within Cube Voyager;
- **Chapter 4: MWRM PTM Calibration:** details information on the PTM calibration, including tests and checks carried out on model route enumeration and assignment;
- **Chapter 5: MWRM PTM Validation:** sets out the specification and execution of the model validation process; and
- **Chapter 6: Conclusions and Recommendations:** summarises the calibration and validation of the MWRM PTM, and identifies recommendations for subsequent versions of the model.



## 2 MWRM PTM Development

### 2.1 Overview

The Public Transport Model (PTM) component of the MWRM comprises the following networks:

- Road Network;
- Rail Network; and
- Walk Network.

These are described below, in addition to other key elements required for the development of the WRM PTM including fares models, crowd curves and wait curves.

#### 2.1.1 MWRM Road Network

Within the overall MWRM the primary network is stored as a SATURN road model network. This is then converted into Cube Voyager format for each time period whenever the full model is run. The conversion process translates node coordinates, links distances, capacity indexes, bus lanes and congested speeds into Cube Voyager format for use in the PTM. The MWRM CUBE Voyager PT Road Network is shown in Figure 2.1.

Bus speeds in the PTM are calculated as part of this process depending on whether there is a bus lane coded on the link or not. Where a bus lane exists on a link, the bus speed is taken as the car speed for an uncongested assignment, to take account of signalised junction delays. Where no bus lane exists on the link, the bus speed is calculated as the assigned network congested speed. A link category based factor was calibrated to match journey time data during the calibration process. The final values are provided in Table 4.9 in Section 4.4.3 below.

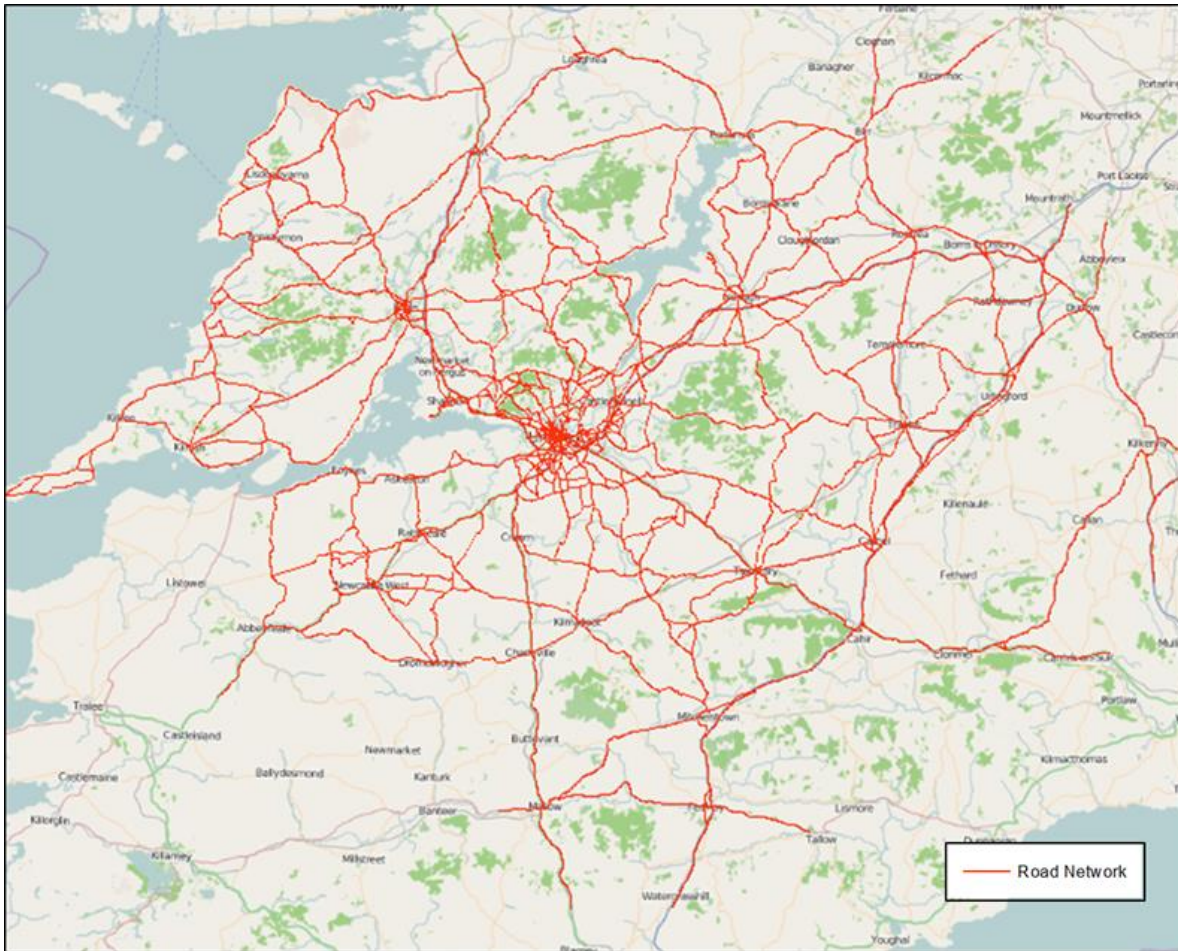


Figure 2.1 MWRM CUBE Voyager PT Road Network

### 2.1.2 MWRM Rail Network

Rail networks were built in ArcGIS, using General Transit Feed Specification (GTFS) shapefiles. This data is prepared by the NTA Journey Planner team, is publicly available, and provides a comprehensive representation of all PT services in the MWRM area covering all sub-modes. The key input files for the PTM include nodes and links files. Any modification to the rail networks is made to these input files. Section 3.2 details all the inputs to the Cube Voyager implementation of the PTM. The MWRM CUBE Voyager Rail Network is shown in Figure 2.2. In accordance with the ERM repeatable methods guidance, the network extends to one stop beyond the limit of the model area. All internal-external model services (and vice-versa) were coded to stop at this first station outside of the modelled area to ensure that external flows are loaded onto the correct services. For example, all services from Limerick to Dublin were coded to stop at Portlaoise, and a centroid connector from Dublin to Portlaoise is included, so that rail trips from Dublin to Limerick enter the model area on this rail corridor.

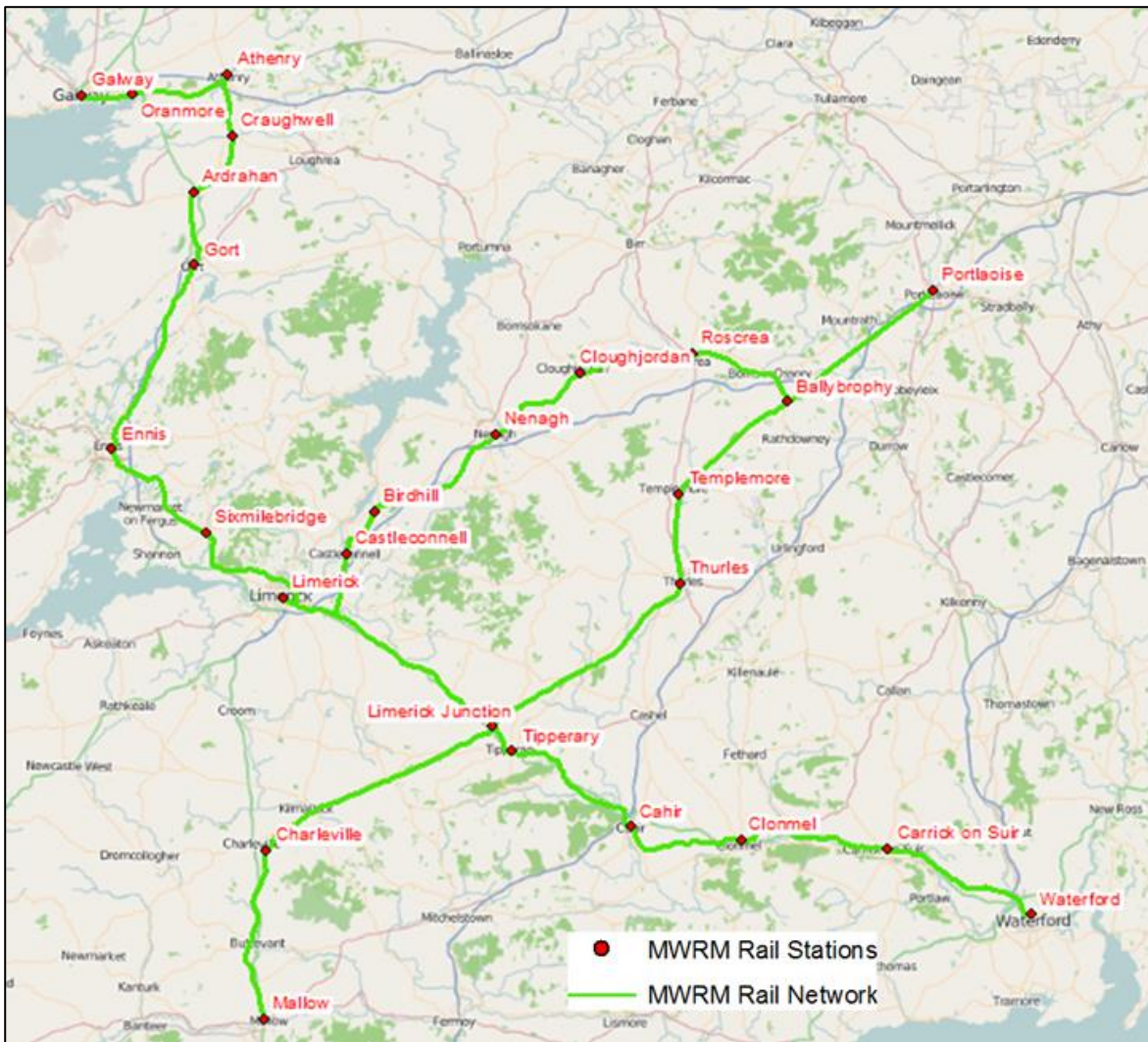


Figure 2.2 MWRM CUBE Voyager Rail Network

### 2.1.3 MWRM Walk Network

Additional links are sometimes necessary to accurately represent walk access to PT stops. Therefore, walk links were added to the network to represent pedestrian only streets and roads that were not coded in the road network. The parts of the network where additional walk details were required were identified by using a very detailed network GIS shape file (i.e., the 'Introute' geographical network data from the NTA journey planner network, detailed in the PTM Specification Report, Section 3.2).

The coded road network and Introute shape files were superimposed to manually define additional walk links in order to accurately represent short-cuts in and around Limerick city centre. Examples include pedestrian only links on Bedford Row between O'Connell Street and Henry Street. The additional walk links included in the PTM are illustrated in Figure 2.3, overleaf.



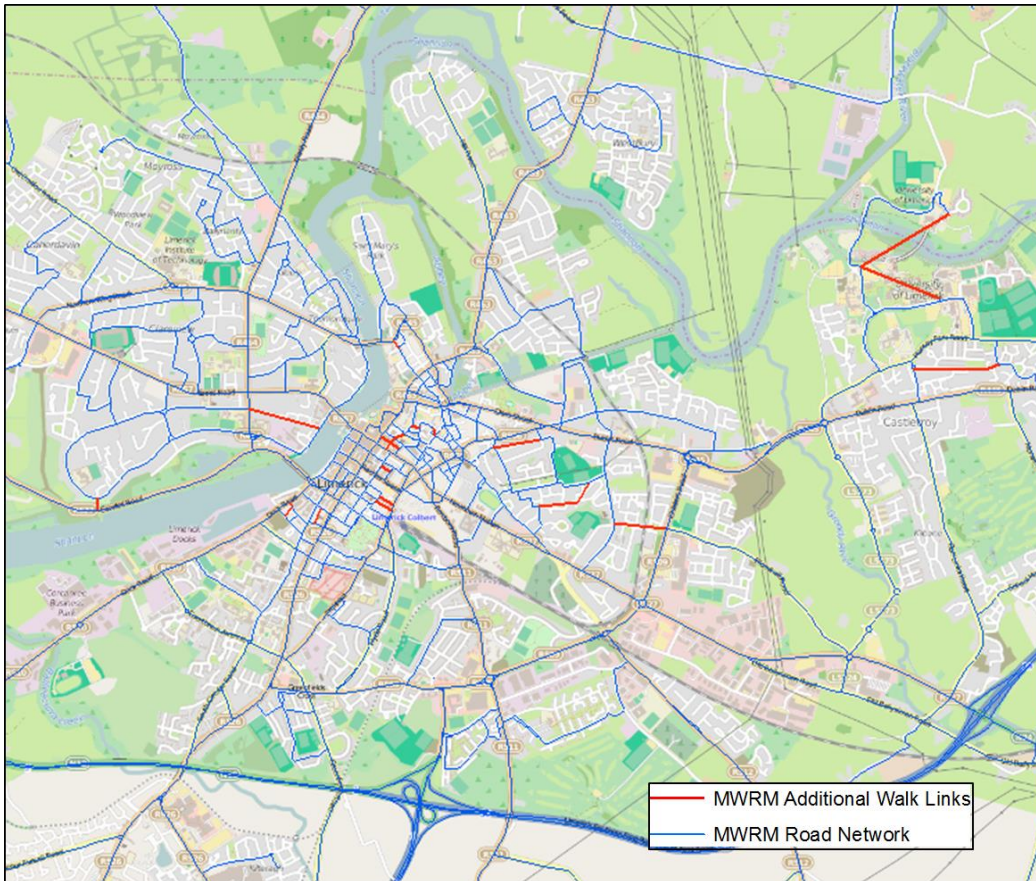


Figure 2.3 Additional Walk Links Included in the PTM

### 2.1.4 Node Convention

The node convention used within the PTM is hierarchical, i.e., each node is numbered based on the geographical area in which it is located. Details on the methodology for node numbering used can be found in the technical note *SA TN07 Regional Model Hierarchical Numbering System*. In line with convention in Cube Voyager, the start of the node numbering system is reserved for zone numbers (i.e. zone numbers are numbered sequentially, starting from 1). Following this, Road, Rail and Walk nodes have pre-defined ranges of node numbers, and headroom was left to add extra network in coding any future year transport schemes. The numbering of Road Network nodes provides a consistency between the Public Transport and Road Models. Note that although Light Rail is not included in the MWRM, the ranges of node numbers were kept the same to be consistent with the ERM.

The following node convention has been adopted for the MWRM PT network:

- 1 to 456: Zones;
- 61,600 to 72,499: Road network nodes;
- 99,000 to 99,499: Rail network nodes;
- 99,500 to 99,899: Light Rail nodes; and
- 99,900 to 99,999: Walk/Cycle nodes

### 2.1.5 Initial Zone Centroid Convention

As detailed in the PTM Specification Report (section 3.9.1), initially zone centroid positions and connector locations were inherited from the road model. This was later revised during calibration to provide an improved representation of PT travel costs, as detailed in Section 4.3.4 below.

### 2.1.6 Non-Transit Legs

Access to the PT network is provided by non-transit legs. Non-transit legs are minimum-cost segments, traversed by non-mechanised modes. They are generated by the Cube Voyager program to represent any leg of a route not undertaken on a PT service.

There are four types of zone centroid non-transit leg. In each case the initial values were taken from ERM; these were subsequently revised as part of the PT Model network and parameter calibration described in Section 4.4 below:

**1) Zone centroid to PT stop access by walk.**

Walking is the most frequently used mode of access and egress to PT services.

Walk legs are limited to an access time of 40 minutes with a maximum of 5 legs for each zone centroid for each PT sub- mode.

**2) Zone centroid to PT stop access by driving.**

This allows for access to a PT stop in areas where walk access would be too long or impractical – this applies especially in rural areas where zones are larger and PT supply is sparse. The access by drive links correspond to a “kiss and ride” for PT users – i.e. PT users being dropped off by car at PT stops. A 30 minutes penalty is applied to these legs to ensure that the walk access leg is preferred for all short distance access.

**3) Zone-to-zone access legs.**

The PT Model requires all PT trips to board at least one PT service. However, for zones located near to each other where there is limited network detail this can result in inconsistent routes and high generalised costs. This causes a problem for the demand model. Zone-to-zone direct access is therefore included as a non-transit leg. This allows walk trips between two zones if the cost is less than the cost of using PT between these zones. This ensures generalised costs increase consistently with distance. Initially this value was limited to a 10 minute walk, with the cost of this multiplied by a weight of 2 based on an initial review of short distance trips within the model. Zone-to-zone direct access was investigated further during model calibration as detailed in Section 4.4.2 later in this report.

**4) Stop-to-stop transfer legs.**

In addition to the three zone centroid non transit legs, there is a 4<sup>th</sup> type of leg: stop-to-stop transfer legs. They correspond to transfer walking legs between two transit legs. Initially, they were limited to a 20 minute walk.

## 2.2 Public Transport Services Definition

### 2.2.1 Overview

This section details the input data used and conventions adopted in the coding of PT Services in Cube Voyager software. As per Section 3.9.2 of the PTM Specification Report, service patterns were defined based on GTFS data.

### 2.2.2 System Data

Voyager requires additional 'system data' information for each service, such as mode, operator, and details of the fare system. The MWRM includes the following modes of transport:

- 1 – Commuter Rail (applies to the ERM and SWRM only at present)
- 2 – Other Rail
- 3 – Light Rail
- 4 – Urban Bus
- 5 – Inter Urban Bus
- 6 – BRT (not used in the base year)
- 7 – Metro (not used in the base year)

It also includes the following operators:

- 1 – Irish Rail
- 2 – Bus Éireann - City
- 3 – Bus Éireann - Regional
- 4 to 17 – Other Private Operators
- 150 – BRT operator (not used in the base year)
- 151 – Metro operator (not used in the base year)

To ensure consistency with ERM, the same modes have been used for MWRM even though some modes (for example Light Rail) are not included in the MWRM area. A detailed description of the fare systems utilised for each of the modes outlined above is provided in Section 2.3 below.

### 2.2.3 Conversion from GTFS to Cube Voyager PT Service Code

The GTFS process outlined in Section 3.9.2 of the PTM Specification Report was used to convert GTFS data to Cube Voyager PT service coding – i.e. conversion to PT lines files. Although it is an automatic process, manual adjustments were required to modify some routes, e.g. to match road network structure or to fill gaps in the GTFS route definition.

The earliest 'complete' set of GTFS data that was available for this conversion was from February 2014. There was insufficient information available to identify which services in the 2014 dataset should be considered as invalid for inclusion in a 2012 base model. In the absence of this information, it was decided to use all of the February 2014 data, and to supplement it where necessary if some routes were identified which weren't included in GTFS. A review of a more recent GTFS data extract (July 2015) indicated that the 2014 dataset was detailed enough to represent all 2012 services, and therefore, no additional routes were added to the network.

On completion of the GTFS conversion process, a total of 248 lines were coded in the PTM, split across three lines files, one for bus services, one for rail services and one for services on new modes (empty in the base year).

The distribution of services across different operators is provided below:

- Rail: 33 services;
- Bus Éireann: 162 services; and
- Other buses: 53 services.

Modelled headways are based on the number of services that operate in each time period (i.e. 0700 – 1000, 1000 – 1300, 13:00 – 16:00 and 1600 – 1900) with the time period definition based on the timetable mid-point within the model network.

The PT Lines Files for the MWRM PTM represents the coded public transport services for rail, inter urban bus routes and urban bus routes as illustrated in Figure 2.4.

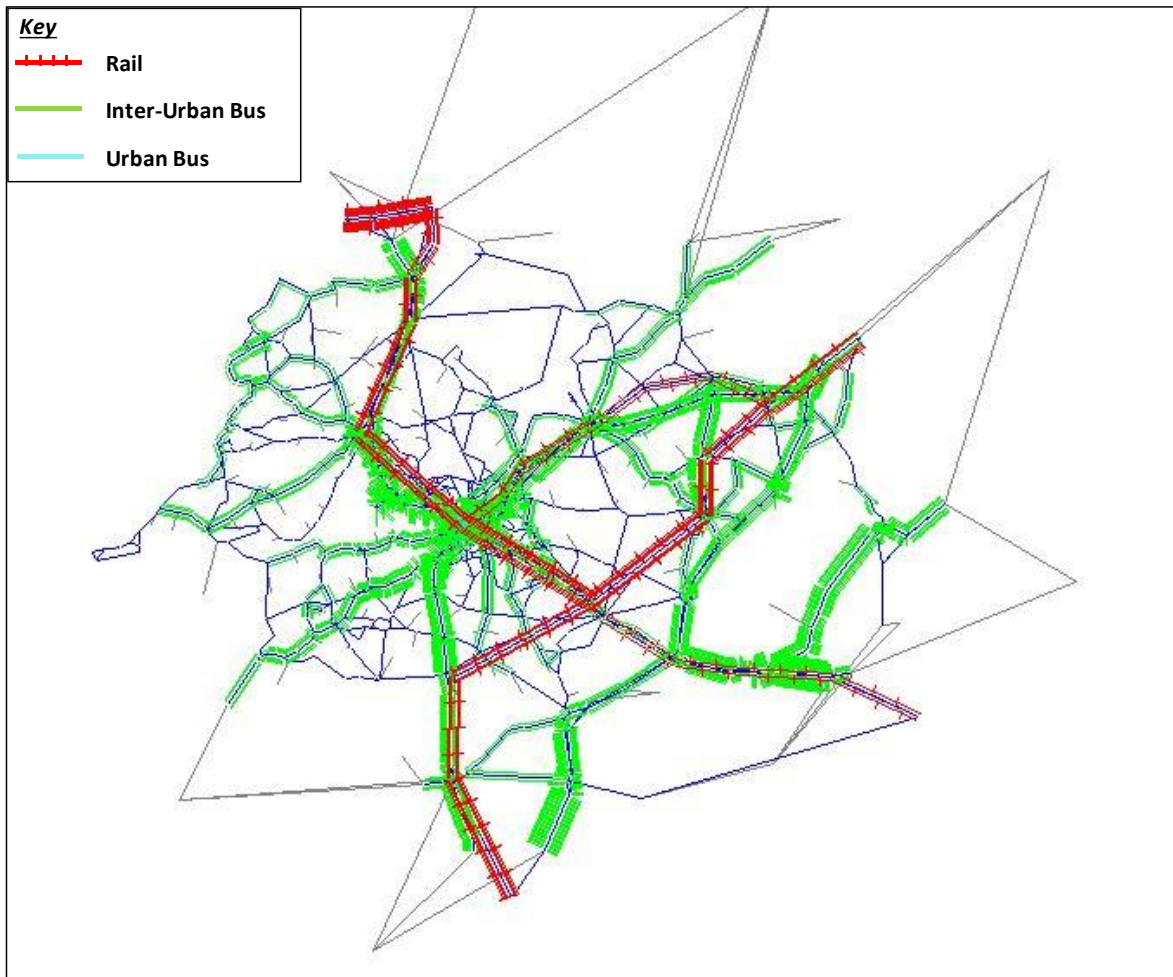


Figure 2.4 MWRM PTM PT Line Files



## 2.3 Fares Model Preparation

The methodology and source data used to define fares by operator in the MWRM PTM are detailed in Section 3.13 of the PTM Specification Report.

The following section of this report provides information on what was coded in the model. The fare system differs by user class; Free-travel users have a zero fare for all PT services, School-travel fares are flat fares defined by mode on Public Service Operator, and Commute, Employers' Business and 'Other' travel fares are defined by mode as detailed in the sections below.

### 2.3.1 Irish Rail Fares

Within the MWRM PTM, Irish Rail fares are modelled using a distance based fare system. This method is more flexible than a fixed fare matrix (between OD stations). It allows the model itself to calculate distances and is more flexible when implementing future schemes (i.e., a new railway station added to the network).

2012 fares and ticket sales information were obtained from the NTA, for the top 100 Irish Rail Intercity OD routes based on demand. The information included single, return, open return, weekly, monthly and annual ticket sales data. This data was then filtered for stations which are included in the MWRM area.

An average fare per trip was calculated for each OD route using the ticket sales information provided. The following assumptions on the number of journeys made on season tickets were applied to calculate the average fare per trip to be used in the Voyager fare model within the PTM<sup>1</sup>;

- 1 day ticket = 3 trips;
- 3 day ticket = 6 trips;
- 7 day ticket = 9 trips;
- Monthly ticket = 40 trips; and
- Annual ticket = 500 trips

The distances between stations were calculated using the accurate CUBE Voyager representation of the GTFS rail network. These distances were then used to plot the average fare per trip versus distance travelled for each of the Intercity ODs for which ticket sales data was available.

A 'best fit' analysis was carried out on this scatter plot to identify the appropriate Intercity Irish Rail fares model which could accurately represent observed data. The generated model fare structure is based on distance travelled, and the associated fares calculation is outlined in Table 2.1 below.

---

<sup>1</sup> Average trips per ticket type taken from consultant team's experience from other projects in Ireland & the UK. Rates were discussed with members of the NTA ticketing team and were deemed plausible.

Table 2.1 MWRM Irish Rail Intercity Fares Model

	Distance	<i>Fare = a*distance + b</i>	
		a	b
A	<50km	0.0210	€4.60
B	50-150km	0.1335	€5.65
C	150-250km	0.0800	€19.00
D	>250km	0.0353	€27.00

Figure 2.5, below, illustrates the observed average fares from the 2012 ticket sales data, plotted against the fares calculated using the model fare structure.

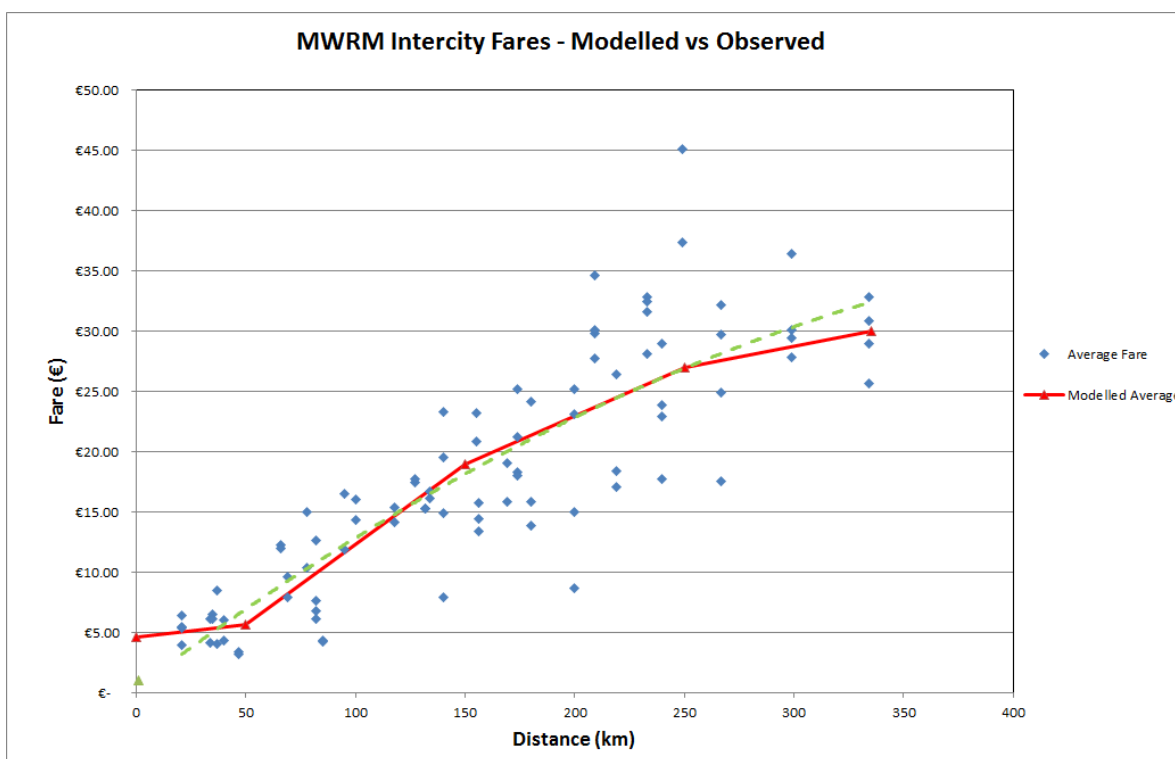


Figure 2.5 MWRM Irish Rail Intercity Fares Model

The average fares (from observed 2012 ticket sales data) for each of the four distance fare bands (outlined in Table 2.1) were compared against those calculated using the new fares model, and the results are presented in Table 2.2 below. The results indicate that the modelled fares provide a good representation of observed fare data.

Table 2.2 Modelled vs Observed Average Fares

Distance	Average Fare		
	Observed	Modelled	% Difference
<50km	€5.27	€5.31	1%
50-150km	€12.92	€12.78	-1%
150-250km	€23.32	€23.22	0%
>250km	€28.87	€28.76	0%
Overall	€17.96	€17.87	-1%

### 2.3.2 Bus Éireann City Fares

BÉ operates a number of city services within Limerick which charge an approximate flat fare for travel within the city. The BÉ Limerick City services, defined in the PTM, are illustrated in Figure 2.6 below.

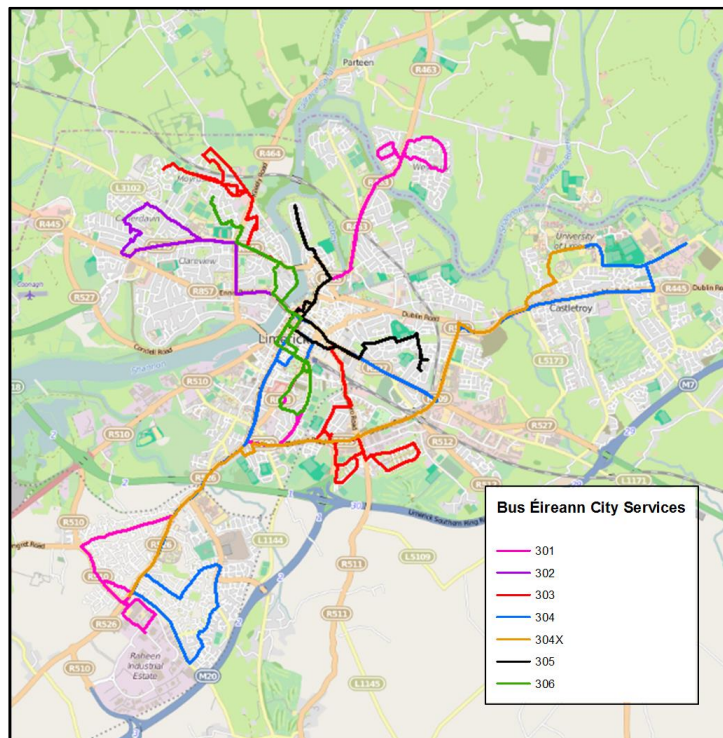


Figure 2.6 BÉ Limerick City Services

2013 ticket sales and revenue data for BÉ Limerick City services, was obtained from the NTA. This included information on all ticket types, including; singles, returns, day saver, 10 journey etc., and season products including TaxSaver tickets.

This data was used to calculate an approximate weighted average fare per trip for BÉ Limerick City Centre services. As outlined for Irish Rail above, a number of assumptions were made regarding the number of trips made on season tickets to calculate an approximate fare per trip.

This weighted average fare, equal to €1.55, was then applied as a flat fare structure in the CUBE Voyager fares model i.e. passengers travelling on defined BÉ city services are charged the calculated weighted average flat fare in the PTM, independent of distance travelled. This flat fare is discounted for schoolchild travel and is equal to €0.79.

### 2.3.3 Bus Éireann Regional Fares

BÉ regional services operates on a point to point basis i.e. a set fare charged based on the origin and destination of travel. Due to the significant amount of BÉ stops in the MWRM area, it was considered impractical to generate a Fare Matrix representing each OD route in the model. Therefore, the BÉ regional service fares were represented as a distance based structure in the PTM (as per the ERM model).

2013 revenue and ticket sales data were obtained from the NTA, for a number of BÉ regional routes. This included information on all ticket types, including; singles, returns, day saver, 10 journey etc., and season products including TaxSaver tickets. This data, along with the assumptions on the number of trips made on season tickets outlined previously, were used to calculate an average fare per trip for each OD route with data available.

The distances for each of the OD routes were taken from analysis of Google Maps. These distances were then used to plot the average fare per trip, versus distance travelled, for each of the BÉ regional ODs for which ticket sales data was available.

Similar to Irish Rail Intercity services described previously, a ‘best fit’ analysis was carried out to identify the appropriate BÉ Regional fares model which could accurately represent observed data. The generated model fare structure is based on distance travelled, and the associated fares calculation is outlined in Table 2.3 below.

**Table 2.3 MWRM BÉ Regional Fares Model**

<i>Fare = a*distance + b</i>			
	<b>Distance</b>	<b>a</b>	<b>b</b>
<b>A</b>	<35km	0.114	€2.20
<b>B</b>	35-60km	0.088	€6.20
<b>C</b>	60-85km	0.244	€8.40
<b>D</b>	85-120km	0.029	€14.50
<b>E</b>	>120km	0.129	€15.50

Figure 2.7 overleaf, illustrates the observed average fares from the 2013 ticket sales data, plotted against the fares calculated using the model fare structure.

The average fares (from observed 2013 ticket sales data) for a range of distances were compared against those calculated using the new fares model and the results are presented in Table 2.4, overleaf. The results indicate that the modelled fares provide a good representation of observed fare data.

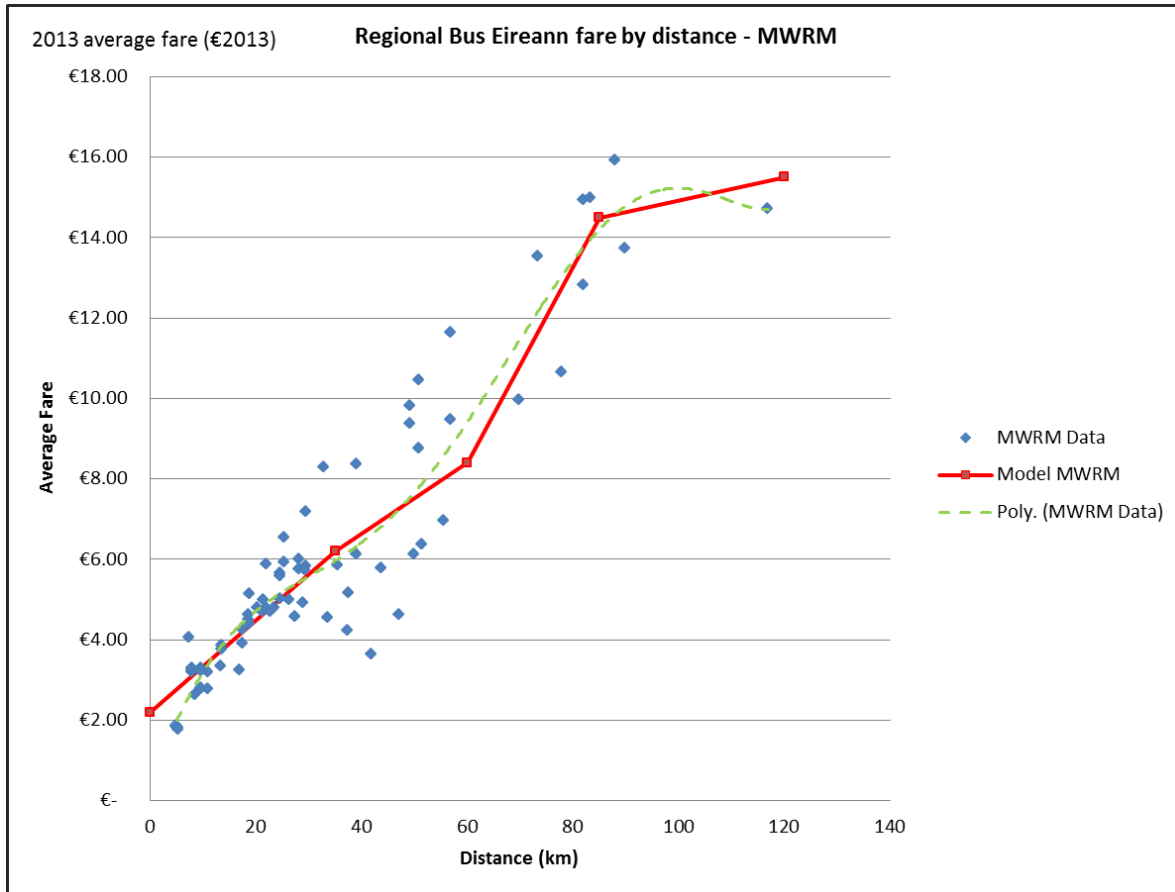


Figure 2.7 BÉ Regional Fares Model – Modelled vs Observed Results

Table 2.4 Modelled vs Observed Average Fares

Distance	Average Fare		
	Observed	Modelled	% Difference
<35km	€4.30	€4.28	0%
35-60	€7.20	€7.23	0%
60-85	€12.80	€12.83	0%
>85	€14.77	€14.88	1%
Overall	€6.08	€6.08	0%

### 2.3.4 Private Operator Fares

14 private bus operators were identified to operate in the MWRM model area following the GTFS data processing. Information on fares for these services were obtained from a web based search, and correspondence with the individual operators where possible.

The 14 private operators, and a log of data obtained, is outlined in Table 2.5 below. Each operator uses a different fare structure, and therefore, to model fares for all private operators, a distance based fare model was derived to match modelled to observed data.

**Table 2.5 Private Operator Fare Collection Log**

<b>Company</b>	<b>Operator #</b>	<b>Fare Data Available ?</b>	<b>Comment</b>
<b>Bernard Kavanagh &amp; Sons</b>	4	Yes	Runs in and out of Thurles
<b>Catherine Madigan</b>	5	No	No Website information available - Runs near Newcastle West
<b>Citylink</b>	6	Yes	Galway to Cork/Limerick fares
<b>Dublin Coach</b>	7	Yes	Runs through Limerick and Ennis
<b>Eurobus</b>	8	Yes	Information available on Limerick fares
<b>J.J.Kavanagh &amp; Sons</b>	9	Yes	Runs through Limerick
<b>JJ. Kavanagh</b>	10	Yes	Runs on the outskirts of simulation area, down the M8 to Cork
<b>John Kearns</b>	11	Yes	data on fares from Galway to Birr
<b>John O'Donoghue &amp; Sons</b>	12	No	runs locally near Kilmallock
<b>K Buggy Coaches</b>	13	No	No Website information available
<b>Kelly Travel</b>	14	Yes	Runs in and out of Limerick
<b>M&amp;A Coaches</b>	15	Yes	Runs on edge of model network
<b>Robert Ryan</b>	16	No	No Website information available
<b>Slieve Bloom Coach Tours</b>	17	No	Fare information unavailable online

Limited information was available on various private operator ticket types, and as such, the majority of publicly available fares information was based on single or return tickets. The distances for each of the private operator OD routes (for which fare information was available) were taken from analysis of Google Maps. These distances were then used to plot the average single fare per trip, versus distance travelled, for each of the Private Operator ODs for which fare information data was available.

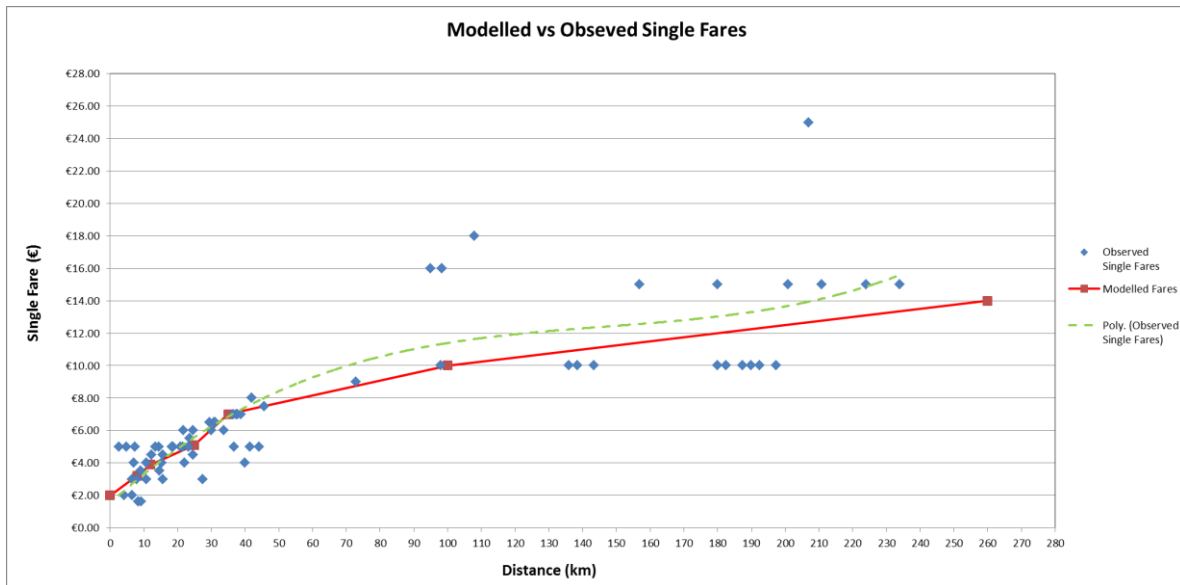
Similar to Irish Rail Intercity, and BÉ Regional services described previously, a 'best fit' analysis was carried out to identify the appropriate Private Operator fares model which could accurately represent observed data. The generated model fare structure is based on distance travelled, and the associated fares calculation is outlined in Table 2.6.

**Table 2.6 Private Operator Fares Model**

		<i>Fare = a*distance + b</i>	
	<b>Distance</b>	<b>a</b>	<b>b</b>
<b>A</b>	0 to 8 km	0.13	€1.75
<b>B</b>	8 to 12 km	0.15	€2.79
<b>C</b>	12 to 25 km	0.08	€3.40
<b>D</b>	25 to 35 km	0.16	€4.45
<b>E</b>	35 to 100 km	0.04	€6.11
<b>F</b>	100 to 260 km	0.02	€8.73
<b>G</b>	>260 km		€11.91

Figure 2.8, overleaf, illustrates the observed average fares from publicly available information, plotted against the fares calculated using the model fare structure.





**Figure 2.8 Private Operator Fares Model – Modelled vs Observed Results**

The results of this comparison are outlined in Table 2.7 below. The results indicate that the modelled fares provide a good representation of observed fare data.

Where appropriate, calculated fares were weighted appropriately based on BÉ data to account for the use of season tickets and other reduced fare products. As outlined previously, all fares represented in the CUBE voyager model must be 2012 fares in 2011 (€) prices. The private operator fares obtained from the web based search are in 2014 (€) prices. In order to discount these fares to 2012 prices, it was assumed that these services experienced comparable fare increases to those experienced by BÉ in recent years (approx. 12% increase between 2012 and 2014).

**Table 2.7 Private Operator Fares Model**

<b>% Difference (modelled vs observed fare)</b>	<b>No. of Services</b>	<b>% of Total</b>
<b>&lt;-50%</b>	2	1%
<b>btw -50% &amp; -25%</b>	13	10%
<b>btw -25% &amp; +25%</b>	101	74%
<b>btw 25% &amp; 50%</b>	12	9%
<b>&gt;50%</b>	8	6%

## 2.4 Wait Curve Preparation

A wait curve was implemented for all PT lines in the PTM. This defines the relationship between services headways and perceived wait times. The wait curve initially implemented for the MWRM PT Model is the Passenger Demand Forecasting Handbook (PDFH) Non-London Inter Urban curve as per Section 3.12.3 of the Specification Report. The curve data points are shown in Table 2.8, and illustrated in

Figure 2.9, overleaf. A single wait curve is used for all modes in the model. This curve was updated during model calibration to provide an improved estimation of generalised costs (please refer to section 4.4.2 below for further details).

**Table 2.8 Wait Curve Definition**

HEADWAY	PERCEIVED WAIT TIME (MINUTES) INTER-URBAN
5	5
10	10
15	14
20	18
30	23
40	26
60	31
90	39
120	47
180	63

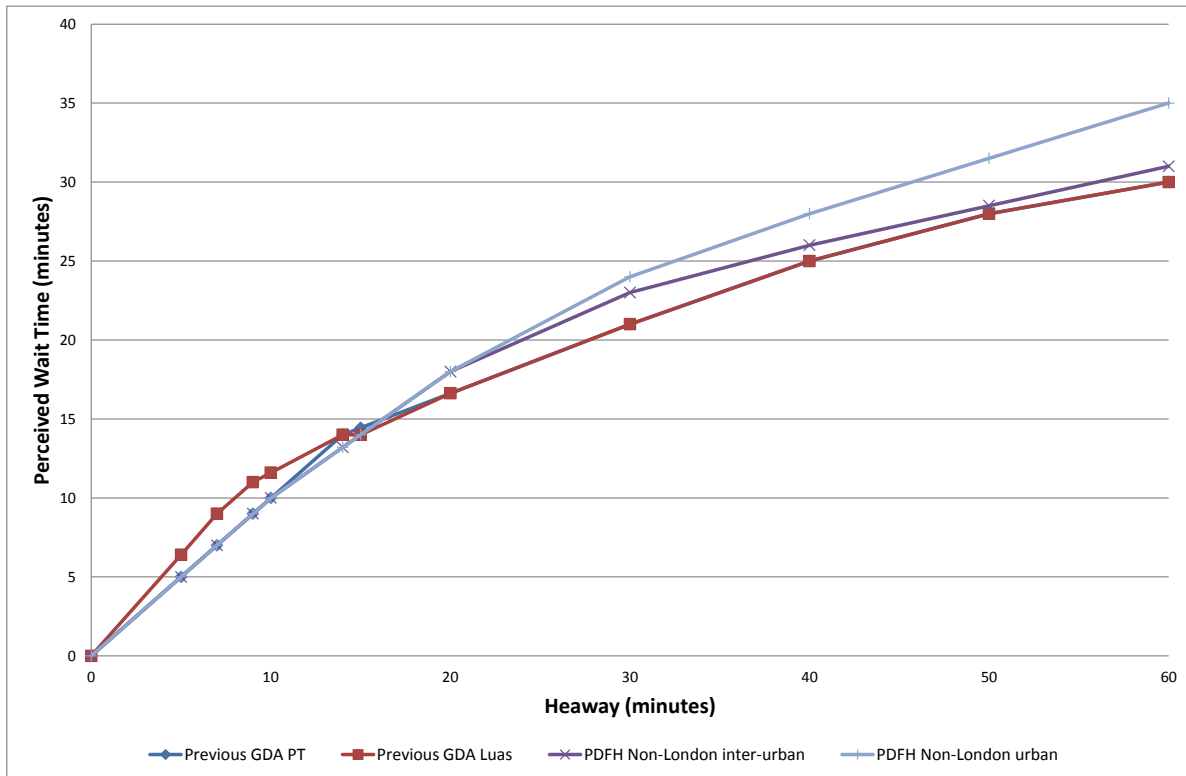


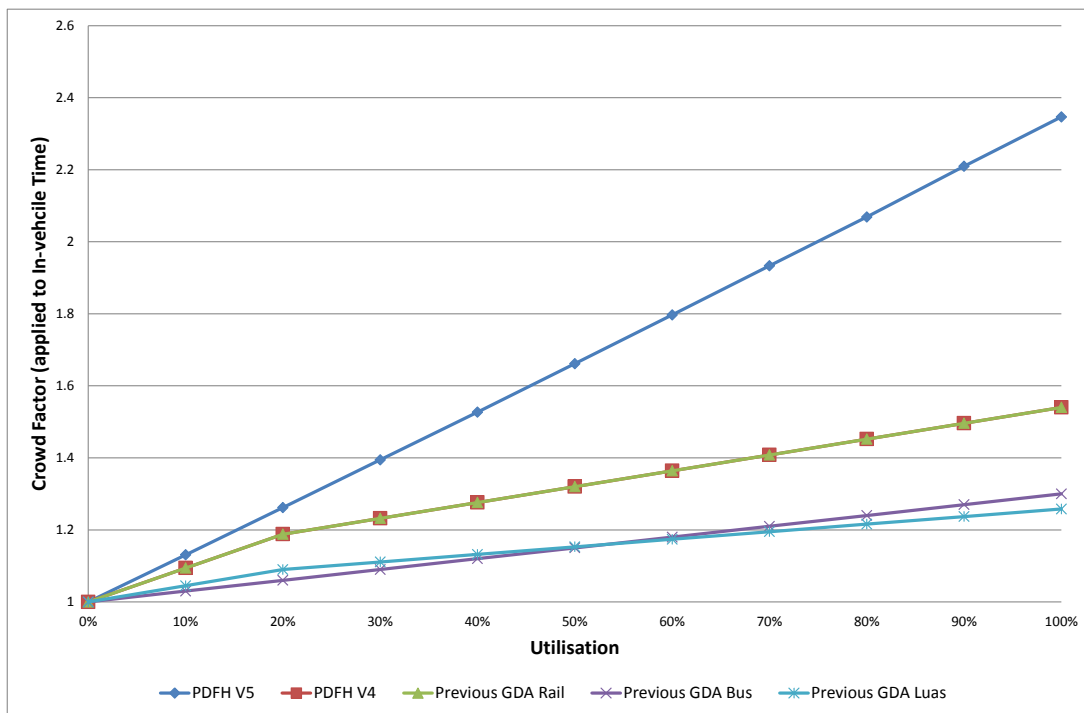
Figure 2.9 Wait Curves

## 2.5 Crowding Model Preparation

As discussed in Section 3.12.4 of the PTM Specification Report, crowding is modelled for all time periods. Modelling PT crowding is an iterative process. The model calculates an initial set of crowding factors and passenger loadings, feeds these back into the model and produces a revised set of passenger loadings and corresponding perceived crowding costs.

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 previous GDA model (see Figure 2.10 overleaf). Crowding curves are implemented as multiplicative curves in the CUBE Voyager 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.



**Figure 2.10 Crowding Curves – Utilisation to Crowding Factors**

Based on vehicle capacity data and surveys, seating and crush capacities by mode were initially coded as:

- Irish Rail: differ by service
- Bus: Seating capacity: 50 / Crush capacity: 52

These capacities were reviewed as part of the calibration process (see Section 4.3.4).

In accordance with Section 3.12.4 of the PT Model Specification Report the model is set up to run 5 crowding iterations to ensure a sufficient redistribution of the demand on crowded services.

## 3 MWRM Cube Voyager Implementation

### 3.1 Overview

Figure 3.1 illustrates the general implementation of the PTM within Cube Voyager. The PTM takes user specified inputs, and outputs from the Full Demand Model (FDM), to generate outputs for reporting purposes and cost skims which are fed back into the demand model. The inputs, outputs and calculation steps (the latter being identical for each time period) for the PTM are described in more detail in the following sections of this report.

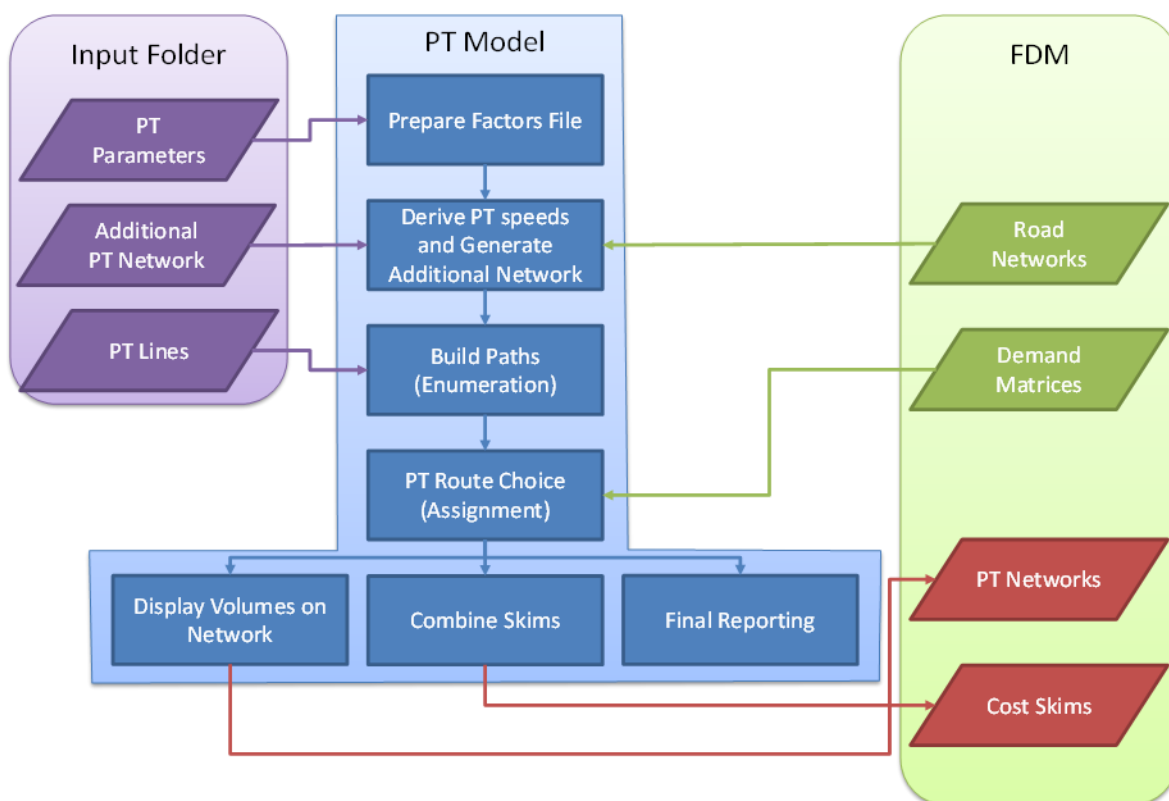


Figure 3.1 General PTM Flow

### 3.2 Inputs

The PTM takes two categories of inputs: outputs from the FDM and inputs supplied by the user describing the scenario to be modelled. Each of these categories can then be further divided as follows:

## User Supplied Inputs

- network files (which describe the “supply” of public transport, comprising public transport infrastructure and services, including associated infrastructure such as walk connectors, bus lanes and roads along which buses run);
- parameters (which control how the model operates); and
- analysis files (which specify the reports to be created as the PT model runs).

## FDM Outputs

- matrices (which contain the demand for public transport services)

### 3.2.1 Network Files

The basic PT network structure is generated as an output from the road model assignment, and this is then supplemented with additional network detail such as non-transit (walk) links supplied by the user. In total seven additional network files required by the PTM, detailed in Table 3.1, have to be supplied by the user as inputs to the model.

Table 3.1 Additional PTM Network Files

FILE	DESCRIPTION
<b>DBus_FareZones.DBF;</b>	Dublin Bus Fare Zones – not used in MWRM but included for consistency with the other Regional Models
<b>Luas_Links.DBF;</b>	Luas Links – not used in MWRM but included for consistency with the other Regional Models
<b>Luas_Nodes.DBF;</b>	Luas Stops – not used in MWRM but included for consistency with the other Regional Models
<b>Rail_Links.DBF;</b>	Rail Links
<b>Rail_Nodes.DBF;</b>	Rail Stations
<b>Walk_Links.DBF; and</b>	Walk Links
<b>Walk_Nodes.DBF.</b>	Walk Nodes

Nodes files contain node numbers and their X and Y coordinates. Link files contain an A and B node, distance (in kilometres), link type (used in assignment definition), and reverse flag (indicating whether it is a two-way link).

### 3.2.2 Matrices

The FDM outputs demand matrices by user class for input to the PTM. The five user classes are detailed previously in Chapter 1. As noted also in that section, these demand matrices are calculated within the FDM individually by time period reflecting persons travelling in a representative peak hour.

### 3.2.3 Parameters

The PTM relies on a large number of parameter definitions, and they are contained within a number of files in the *Factor\_Files* and *Additional\_PT* folders in the input directory.

#### **Factor Files**

Factor files contain a range of parameters used for routes enumeration and assignment, including In-vehicle time weights, boarding and transfer penalties, wait curves and fare systems etc. More details on how these parameters operate can be found in the Cube Voyager Help manual. Separate factor files are defined for each combination of user class and time period. In addition, a set of additional factor files (one for each time period) is defined with the suffix ZOD (for Zero Demand). This is used to reduce PT assignment run times by reducing the level of calculation in the model for OD pairs between which there is no PT demand.

#### **Fares**

The *Additional\_PT* folder contains Fares files which set out the various fare systems to be utilised within the PTAM for each mode and time period. In addition, PT operators and modes are defined using a system text file, **SYSTEM\_FILE.PTS**.

#### **Non-Transit Legs**

Finally, an external script file, **NTL\_GENERATE\_SCRIPT.txt**, is contained in the Additional PT folder and is read in during a model run. This file is generally not altered. This script defines various parameters used to build the Non-Transit Legs, such as maximum number of PT stops a zone can reach by mode or specific PT access for external zones.

### 3.2.4 Analysis Files

Select links are undertaken during PTM assignment and are defined using a script file (not a core part of the model but referenced by the true scripts), **SELECT\_LINK\_SPEC.txt**. The select link input file provides a way for the user to input links / lines to be skimmed, with output matrices added at the end of the cost matrices.

## 3.3 Network Link Attributes

The PT network shares attributes with the road network, but also includes additional attributes. Below is a list of PT network attributes and their definitions:

- **Distance:** Link distance in kilometres;
- **CI:** Capacity Index - dumped from the road network;
- **Bus\_Lanes:** Indicator whether a bus lane is coded on the link (=1) or not (=0) - dumped from the road network;
- **Link\_Type:** Attribute to identify the main role of the link as follows:
  - 1 – Road link
  - 25 – Walk only link and zone connectors
  - 27 – Rail link



(Note that Link\_Type 0 is also included in the PT and Active Modes Models. This is used to represent the reverse direction of one-way streets that are included to allow pedestrians to walk along them to access public transport services or to make a walking trip).

## 3.4 Key Parameters

Key parameters are outlined in Section 3.12 of the PTM Specification Report, and include:

- **route enumeration controls** – these determine the spread of routes that are taken forward to evaluation and the more detailed assignment stage;
- **boarding & interchange penalties** – these relate not only to service reliability but also to the provision of facilities at boarding points, such as waiting facilities, information and security. These may relate to future proposed network enhancements;
- **in-vehicle weights** by modal preference factors – associated with the relative comfort and perception of travel time in different modes, or different vehicle types; and
- **wait curves and factors** - these relate actual service frequencies to the perceived wait time experienced by passengers. This is especially important when journeys involve interchange and services of differing frequencies, for example interchange between rail and bus services.

Table 3.2, below, outlines the range of initial values for parameters used to set up the PTM.

Table 3.2 PTM Parameters

MODEL PARAMETER	VALUE/FACTOR		
	LOWER	INITIAL	UPPER
Spread Factor	1.2	1.25	1.75
Spread Constant (minutes)	0	15	15
Route Enumeration Fare In-vehicle Time Factors (vary by sub-mode)	0.75	1.00	1.25
Boarding Penalty (minutes, may vary by sub-mode)	0	5	10
Transfer Penalty (minutes, may vary by sub-mode)	0	5	20
In-vehicle Time Factors (initial from BRT study; calibrated may vary by time period):			
- DART rail	1.00	1.39	2.00
- Rail	1.00	1.39	2.00
- Luas	1.00	1.00	2.00
- Urban bus	1.00	1.90	2.00
- Inter-urban bus	1.00	1.90	2.00
- BRT and Metro	determined from BRT study relative to other calibrated sub-mode IVTs		
Walk Time Factor	1.60	1.60	2.00
Minimum Wait Time	0 mins		
Maximum Wait Time	60 mins		
Wait Curves	see previous section		
Crowd Model Parameters	see previous section		

## 3.5 Outputs

The outputs of the PTM fall into two categories, namely:

- Those required by the FDM; and
- Those produced purely for reporting.

### 3.5.1 FDM Outputs

The outputs required by the FDM include:

- **Assigned networks** which are passed on to the active mode assignment as the starting point for their network build procedure; and
- **Generalised cost matrices** by user class for each of the four assigned time periods to be fed back into mode and destination choice. For the unassigned time periods, assumptions are applied to derive approximations of generalised costs as detailed in Chapter 21 of the FDM Specification Report.

### 3.5.2 Reporting Outputs

The PTM produces a number of reporting outputs specifically by time period (in individual folders). Table 3.3 summarises these outputs.<sup>2</sup>

Table 3.3 PTM Outputs

REPORT	DESCRIPTION
<b>TP_MATRIX_TOTALS.CSV;</b>	Summary of matrix totals
<b>TP_LINK_RECS.DBF;</b>	Network links with PT lines data (Count of lines, services/hour) and assigned trips.
<b>TP_LINK_RECS_PREP.DBF;</b>	Network links with PT lines data (Count of lines, services/hour).
<b>TP_ON_OFFS.DBF;</b>	Network links with Boarding and Alighting data by line.
<b>TP_ON_OFFS_NT.DBF;</b>	Network links with Boarding and Alighting (Non Transit legs only).
<b>TP_ON_OFFS_PREP.DBF;</b>	File to prepare the ON_OFFS file
<b>TP_RAIL_B&amp;A.DBF;</b>	Total boarding and alighting by node.
<b>TP_RAIL_B&amp;A_SPLIT.DBF;</b>	Total boarding and alighting by node and by mode.
<b>TP_RAIL_LOADINGS.DBF;</b>	Rail network links flows by line.
<b>TP_PT_ASSIGNED.LIN;</b>	Line file with volume information.
<b>TP_PT_COMPCST.MAT;</b>	PT Composite Costs matrices for all user classes.
<b>TP_PT_EMP.MAT;</b>	Detailed components of PT costs for UC Employers Business.
<b>TP_PT_COM.MAT;</b>	Detailed components of PT costs for UC Commute.
<b>TP_PT_RET.MAT;</b>	Detailed components of PT costs for UC Free Travel.
<b>TP_PT_OTH.MAT;</b>	Detailed components of PT costs for UC Other.
<b>TP_PT_EDU.MAT;</b>	Detailed components of PT costs for UC Education.
<b>TP_PT_WKONLYTRIPS.MAT;</b>	PT Walk Only trips – Matrices of trips that do not board a service.
<b>TP_SELECTLINK.MAT;</b>	Select Link Matrices defined by input file “SELECT_LINK_SPEC.TXT”, i.e., PT trips which

<sup>2</sup> The **TP** indicates a time period variable and can take the values AM, LT, SR, and PM.

	pass through the select link.
<b>SKIM_TP_PT_EMP.MAT</b>	PT skims extracted from the assignment for UC Employers' Business, including composite cost, distance, time, boardings, wait and transfer costs.
<b>SKIM_TP_PT_COM.MAT;</b>	PT skims extracted from the assignment for UC Commute, including composite cost, distance, time, boardings, wait and transfer costs.
<b>SKIM_TP_PT_RET.MAT</b>	PT skims extracted from the assignment for UC Free-Travel, including composite cost, distance, time, boardings, wait and transfer costs.
<b>SKIM_TP_PT_OTH.MAT;</b>	PT skims extracted from the assignment for UC Other, including composite cost, distance, time, boardings, wait and transfer costs.
<b>SKIM_TP_PT_EDU.MAT;</b>	PT skims extracted from the assignment for UC Education, including composite cost, distance, time, boardings, wait and transfer costs.
<b>SKIM_TP_PT_ZD.MAT;</b>	PT skims extracted from the assignment for zone pairs with zero demand, including composite cost, distance, time, boardings, wait and transfer costs.
<b>TP_PT_ASSIGNED.NET;</b>	Assigned PT network.
<b>TP_PT_ENUM.NET;</b>	PT network with enumerated routes.
<b>TP_PT_LOADED.NET;</b>	PT network with PT flows loaded on links.
<b>PRIOR.NET;</b>	PT network (Road network + PT specific links).
<b>PT_PREP.NET;</b>	PT network post Non-Transit legs generation.
<b>PT_SPEEDS.NET;</b>	Road network with PT speeds defined.
<b>PT_PREP.NTL;</b>	Non Transit Leg file – Zone access to PT stops.
<b>TP_PT_ASSIGNED.REP; and</b>	Data on assignment parameters.
<b>TP_PT_ENUM.REP.</b>	Data on Route enumeration parameters.

## 4 MWRM PTM Calibration

### 4.1 Introduction

This chapter describes the process of calibration of the PTM, while Chapter 5 outlines the results of the PTM validation. In conventional modelling theory, these are two separate processes. Model calibration is the process of adjusting model parameters and inputs to ensure the model outputs match observed data as closely as possible. Model validation is the process of comparing the outputs of the calibrated model against a separate set of observed data not used in the calibration process. In practice, however, the two processes are interlinked in that issues identified during validation stage can be addressed by modifying calibration parameters.

PT Model calibration followed an iterative process, where improvements to the PT model led to better costs, which fed into the Demand Model, which in turn was improved to produce better estimates of PT demand. The Demand Model calibration process is described in MWRM Demand Model Calibration Report.

### 4.2 Assignment Calibration Process

#### 4.2.1 Overview

Calibration is the process of adjusting the PT Model to ensure it provides robust estimates of sub-mode choice, assignment and generalised cost before integrating it into the full MWRM. This is typically achieved in iteration with the validation of the model to independent data. For the MWRM, assignment calibration was undertaken through comparisons of model outputs and observed data for the following:

- Passenger Flows;
- Boardings and Alightings;
- Bus Journey Times; and
- Interchanges.

The UK's Department for Transport's Transport Analysis Guidance (TAG) unit M3-2 PT assignment modelling, January 2014, indicates that the assignment model may be recalibrated by one or more of the following means:

- 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.

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

Calibration is broadly split into three components discussed in the following sections of this chapter, namely, adjustments to:

- PT Network;
- PT Parameters; and
- PT Matrices.

## 4.3 PT Model Network Progression

### 4.3.1 Overview

The development of the initial PT network, services and fares model has already been described in Chapter 2. Following this, two types of checks were carried out:

- **Non Transit Leg PT Access Testing:** To ensure levels of access to PT services were represented correctly for all zones in the PTM; and
- **PT Generalised Cost Checks:** To ensure the costs generated by the PT model would not cause problems during the calibration of the demand model. For example, large PT costs could lead to insensitive generalised cost parameters estimated during calibration. This may impact on the model's sensitivity to future PT scheme changes.

### 4.3.2 Non Transit Leg PT Access Testing

Every model zone is assigned to a 'zone centroid' network node. PT trips to/from a zone begin and end at the centroid to access the main PT and/or road network via a centroid connector by walking.

The actual distances walked from locations within a zone boundary and the actual network within that zone can vary substantially (and this variance is in proportion to the zone size). Ideally the centroid connector length is chosen so as to minimise this variance for all trips, but since not all trips are observed, a general rule for connector length is usually applied. This can result in long connectors (and hence long walks) between the locations of trip origins/destinations, (abstractly represented by centroids), and the nearest PT services.

The tests below investigate the walk time from each zone centroid to access the nearest PT stop for each of the following sub-modes:

- **Rail:** representing Irish Rail services in the MWRM modelled area;
- **Urban Bus:** representing Limerick City bus services; and
- **Inter-Urban Bus:** representing BÉ regional services along with private bus operators in the MWRM modelled area.

The analysis involved identifying the minimum walk or driving time from each zone to access the nearest PT stop, for each sub-mode, using the modelled lines derived from GTFS and the network taken directly from the road model.

No account was taken of the other journey characteristics that would be considered in a full PT assignment, including headways, transit times and fares.

Internal zones had walk or drive access to all PT modes except for urban bus services, which were only accessible by walk. Access by car was capped to 30 minutes drive. The perceived cost for motorised access included a 30 minutes penalty, and this was multiplied by a factor of 2. For walk access, the assumed walk speed was 4.8kph and no walk access routes greater than 40 minutes were included. It should be noted that these values represent initial assignment parameters prior to model calibration. These parameters were updated during calibration as detailed in Section 4.3.3 below. External zones had motorised access only, limited to 200 minutes, and this directly connected to only the rail and inter urban bus modes.

The general finding expected was that zones on PT services would have low access time, with zones more distant from such services having correspondingly higher access times. Any zone (or set of zones) which contradicted this expectation was investigated for connectivity issues (e.g. missing centroid connectors or lack of PT network/service coding) and then corrected.

The results of the PT access test for each sub-mode are outlined in the following sections of this chapter.

### ***Rail Access Tests***

The identified minimum walk time from each zone in the MWRM to access the nearest Irish Rail station was represented in ArcGIS, and the results are illustrated in Figure 4.1. The results indicate that access costs are reduced at zones which are in proximity to available rail stations, which intuitively makes sense. As expected, zones which are significant distances from any rail station have quite high rail access costs and are represented in red and grey.

Figure 4.2, overleaf, provides a more detailed map of Irish Rail access for zones in Limerick City. The results indicate that access to Irish Rail stops are being represented appropriately in the PTM, with increasing walk times associated with zones at further distances from Limerick Colbert rail station.



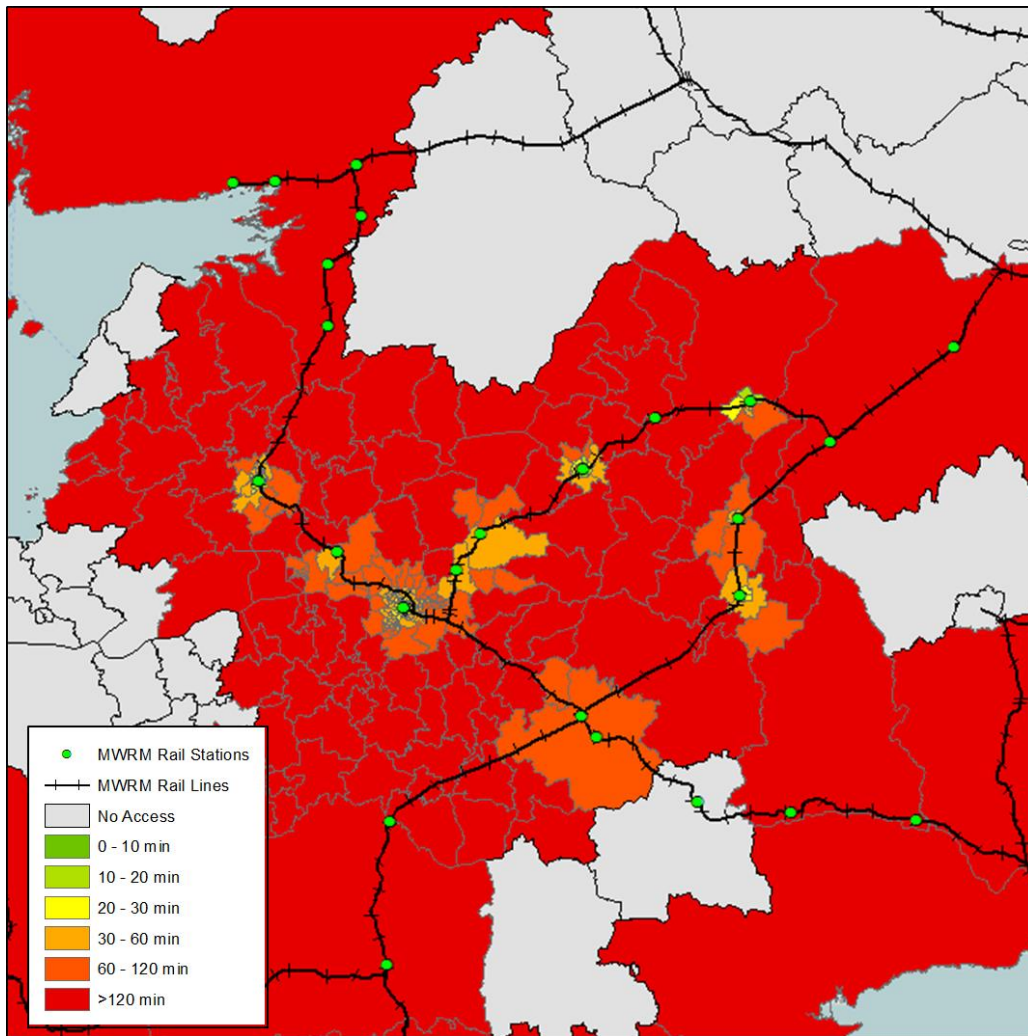


Figure 4.1 Irish Rail MWRM PT Access Plot

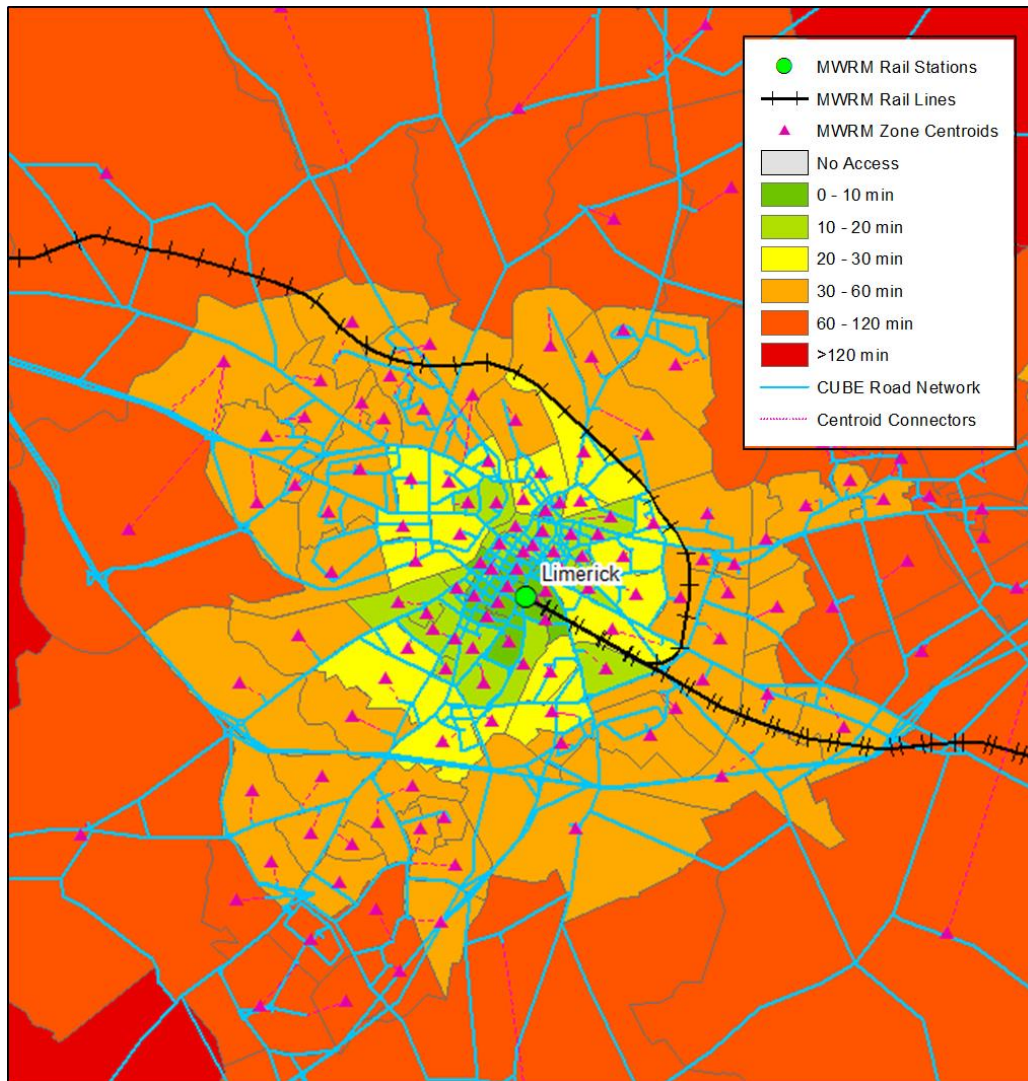


Figure 4.2 Irish Rail Limerick City PT Access Plot

### ***Urban Bus Access Tests***

Within the MWRM, 'Urban Bus' refers to BÉ Limerick City services and, similar to rail above, a non-transit leg assignment was carried out to analyse the minimum walk time from zones to the nearest BÉ city stop. The results of this analysis are illustrated in Figure 4.3 and Figure 4.4 below.

The results indicate that access costs to BÉ City services increase for zones at further distances from Limerick City centre. Within Limerick City centre, all zones which are in close proximity to BÉ City services experience reduced access times, in the order of 0 – 10 minutes. This access time is increased at zones on the edge of the city due to reduced zonal disaggregation and increased distances from zone centroids to the nearest bus stop. The results also indicate that access to BÉ Limerick City services is being represented appropriately in the PTM

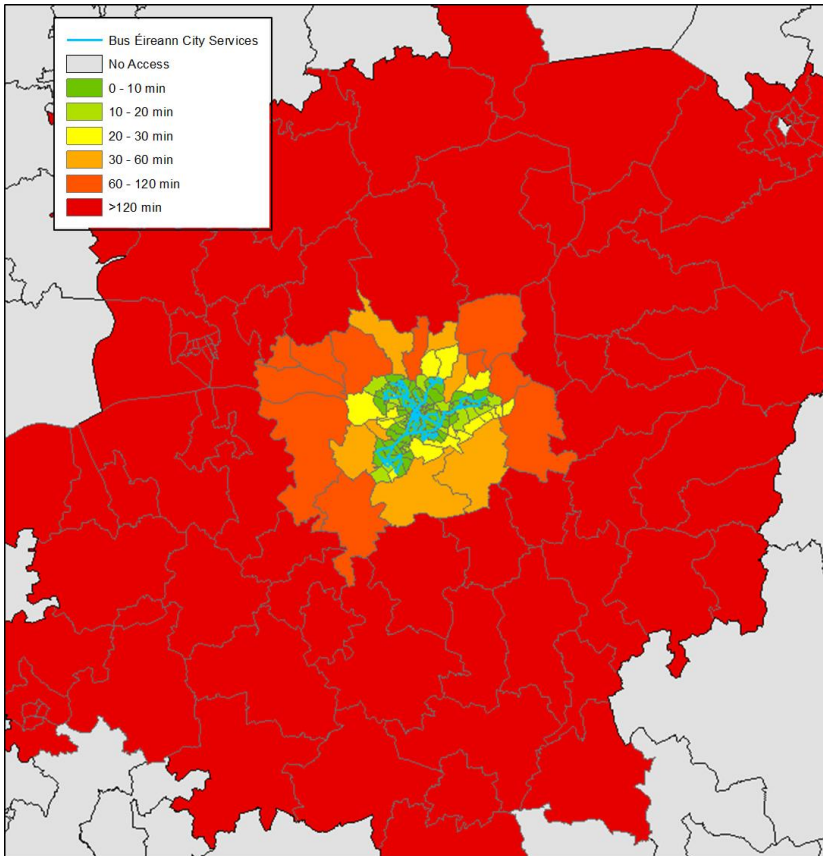


Figure 4.3 BÉ City MWRM PT Access Plot

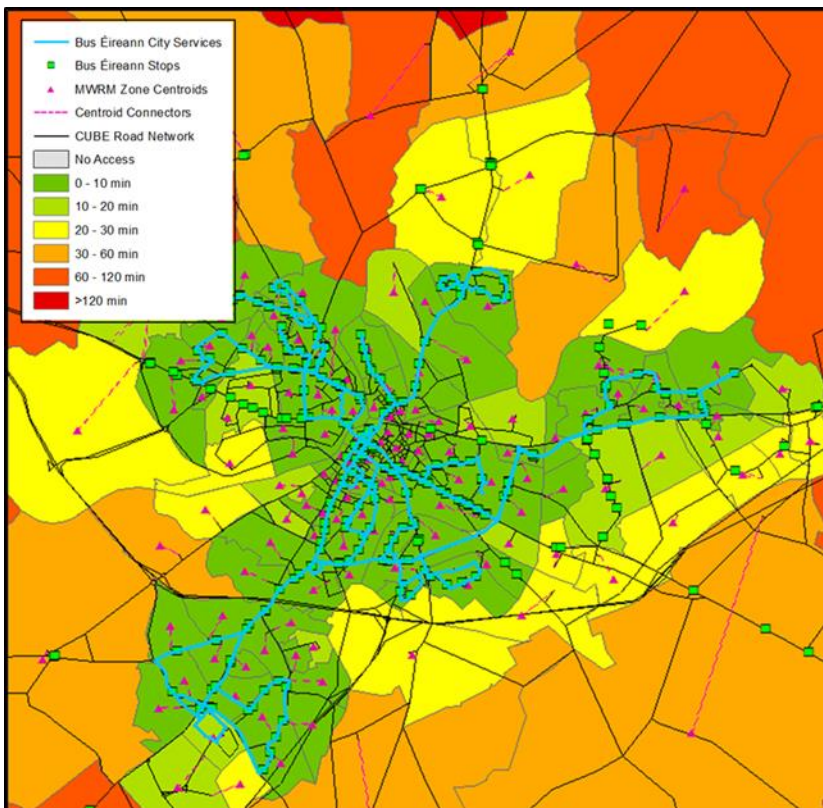
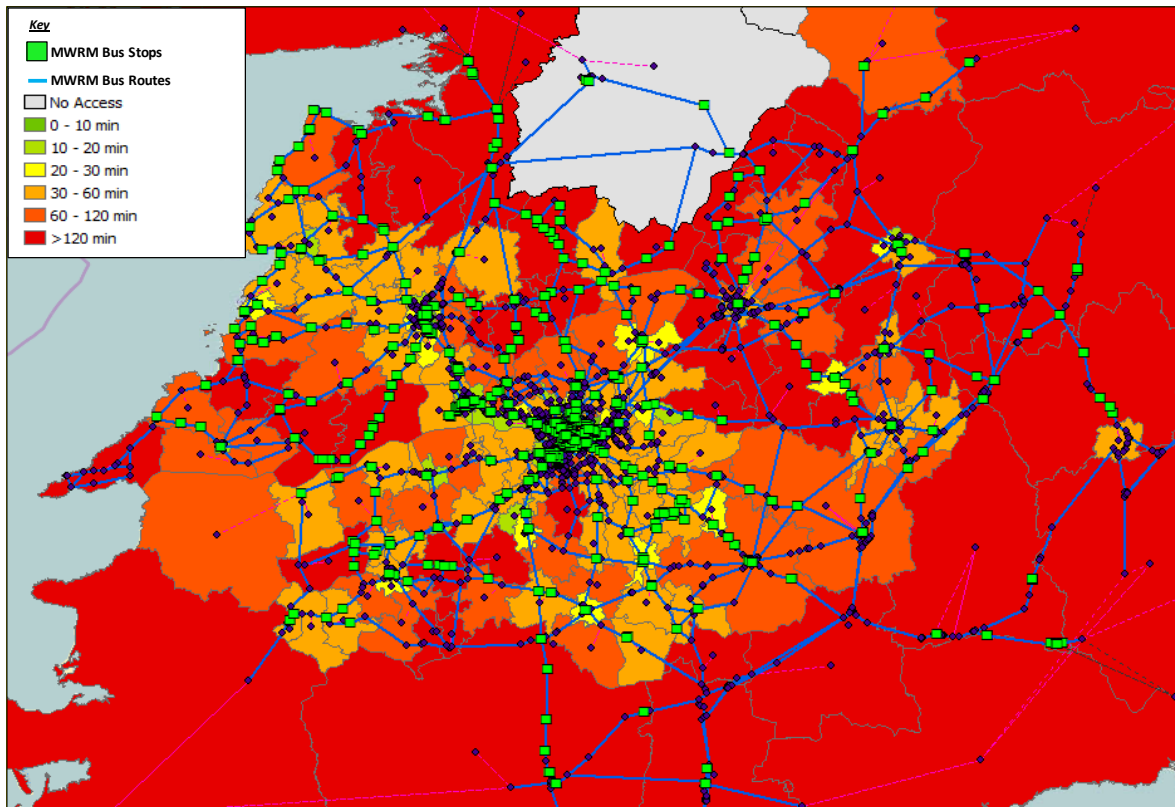


Figure 4.4 BÉ Limerick City PT Access Plot



## Inter-Urban Bus Access Tests

Within the MWRM, 'Inter-Urban Bus' represents BÉ regional services, as well as private bus services operating within the region. The results of the PT access analysis for these services are illustrated in Figure 4.5 below.



**Figure 4.5 BÉ Regional and Private Bus Operator PT Access Plot**

Due to the dispersed nature of the regional bus services, it is more difficult to accurately analyse PT access. However, the results in Figure 4.5, illustrate a reduced walk time and access costs for passengers in regional cities and towns such as Ennis, Roscrea, Thurles, Nenagh and Abbeyfeale etc. Analysis of results of the PT access tests at key locations throughout the MWRM indicates that access to regional bus services is being represented appropriately within the PTM.

It should be noted that the access cost for external zones is fixed and depends only on their distance from the nearest bus stop or rail station in the model. In other words, the length and position of external connectors is critical in determining these costs.

### 4.3.3 PT Generalised Cost Checks – Network Checks

The initial access tests, detailed above, provided a check on the developed PT Network in terms of access and connectivity to public transport services. It was noted through an initial assignment of the SWRM, that the developed PT model was generating significantly high generalised costs which would cause difficulties during calibration of the FDM.

A series of tests were carried out in the SWRM to identify measures which could assist in producing more realistic PT generalised costs. The full set of tests are described in further

detail in Section 4.3 of the SWRM Public Transport Model Development Report. For completeness, all tests were described in the SWRM report, even though not all changes were retained in the revised version of the PT Model. Table 4.1 below, provides an overview of all network tests undertaken on the SWRM including an indicator stating whether the change was retained or not.

**Table 4.1 Summary of Generalised Cost Tests carried out in SWRM**

Test	Retained?
Zone Disaggregation	Retain
Cap PT Cost Connectors	Do Not Retain
All Services Make All Stops	Do Not Retain
Direct Zone to Stop Connectors	Retain
PT Services Reviewed	Retain
Cap Centroid Connectors	Retain

It was envisaged that all of the regional models (outside the ERM) would experience similar problems in terms of high levels of PT generalised cost. Therefore, alterations from the SWRM which were found to be beneficial in terms of better representing generalised costs were adopted for all regions, including the MWRM. The following sections provide a brief description of the changes which were adopted for the MWRM on foot of testing carried out in the SWRM PTM.

### ***Zone Disaggregation***

In the initial PT assignment, the length of the PT walk connector was taken to be proportional to the area of the zone (it was taken to be  $\frac{2}{3}$  of the radius of the zone, with the approximation that each zone was a perfect circle). This resulted in long walk connectors, and hence a high PT access cost, for some zones.

Where a zone had a walk connector longer than 3km it was flagged for review. For each of these zones the population density of each of the CSAs making up the zone was displayed on a map. If there was an area that was more densely populated (usually a small town or village) this was separated into a new zone, and the surrounding more rural area left as a separate zone. Further information on the zone disaggregation process is provided in Chapter 4 of the MWRM Zone System Development Report.

For example,

Figure 4.6 overleaf, shows the original zone boundaries in black. The blue shading shows the population density in each of the CSAs making up the zone; the darker the blue the higher the population density. The area to the north east of the zone is more densely

populated than the rest of the zone, so this was separated into a new zone (highlighted by the red line) keeping the boundaries of the CSAs intact.

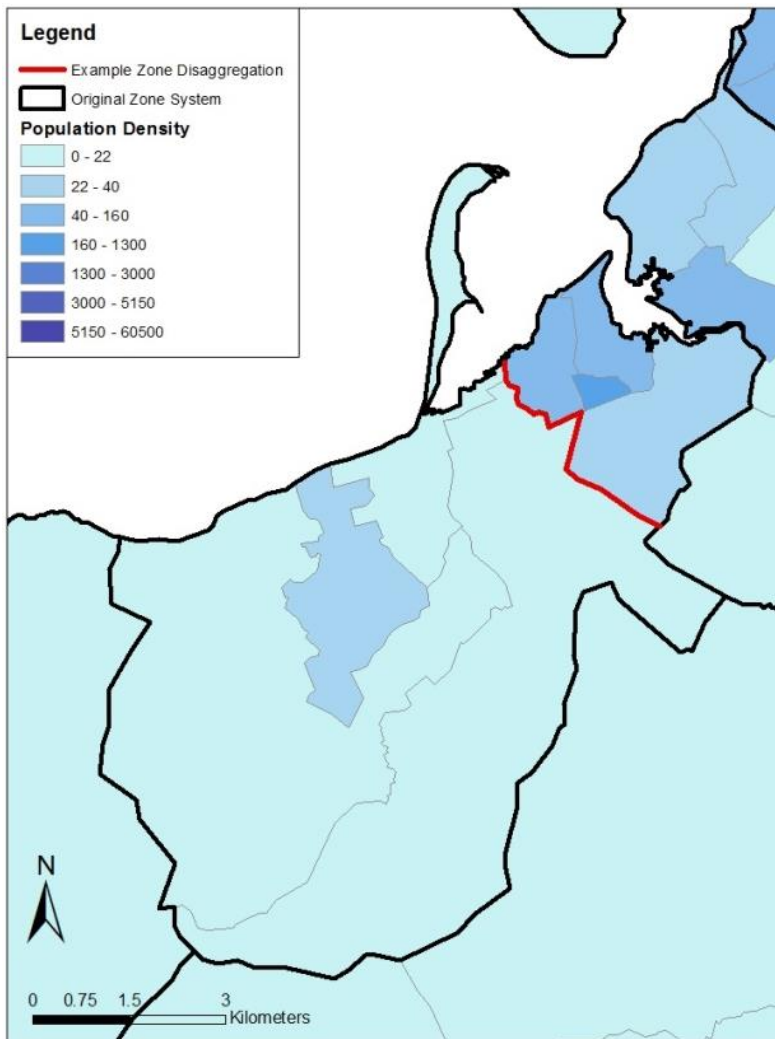


Figure 4.6 Example of zone disaggregation

### ***Direct Zone to Stop Connectors***

The repeatable methods developed for the ERM include a process for revising walk connectors in areas where the road network is not detailed enough to represent the routes used by passengers when accessing PT services (see *PT TN01 PT Model Walk Connections* technical note for further information). This is mainly an issue in rural areas. This approach was adapted to the MWRM, and adjusted to fit better to local characteristics before being applied:

- 1) All centroids were relocated based on a weighted location of Geo-Directory population and employment.



- 2) In dense areas where zones are relatively small and there is a detailed representation of the road network, a single connector to the nearest node was coded to replace the connectors inherited from the SATURN model. These are connected to spigots which are often not connected to the nearest node to the centroid. The connector distances were estimated based on crow-fly distance from relocated centroids to the closest node. Crow-fly distances were multiplied by a factor of 1.2. This is a commonly applied factor in Accession<sup>3</sup> used to estimate the actual distance walked along a road, taking into account the geometry of the road network which is represented by straight lines in the SATURN model.
- 3) In other areas where zones are bigger and the modelled network is coarser, possible walk routes are not fully represented, and this can lead to a bus/ rail bias. For example, if a network link was coded from the centroid directly to a train station, whereas there is no direct link from the centroid to the nearest bus stop. In this instance passengers have to walk along modelled links in the highway network to access bus and this may result in more passengers being modelled as using the train due to the lower access time when there is actually a bus stop closer than the train station. To avoid this, the centroids were connected:
  - a) Directly to all of the GTFS PT stops if they are located less than 2.4km from the zone centroid (crow-fly distance). (This is based on the maximum walk time of 30 minutes and a walk speed of 4.8km/h.)
  - b) To the nearest node if there is no stop less than 2.4km from the zone centroid (crow-fly distance).

To incorporate these changes within the PTM, all zone centroids connectors inherited from the highway assignment are automatically deleted. Instead all of the PT connectors are included in the Walk\_links.dbf input file at the network building stage. The approach described above required the categorisation of zones based on size, location and network density to select the appropriate zone connectivity method.

A manual check of the connectors produced was undertaken to ensure they are sensible. This included consideration of the PT services at each stop to ensure that valid services are connected, and to retain a single stop on each valid bus corridor by selecting the minimum distance corridor. Effort was made to remove or amend connections that may not be possible in reality due to physical barriers, for example rivers or motorways.

## ***PT Services Reviewed***

Investigation of the GTFS extraction process for the SWRM revealed that only services which operated on a Tuesday were included in the model. In rural areas, where some services do not operate every day, these services were not included in the model, even though they may be used by people who recorded their trip in the NHTS. Therefore, in line

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<sup>3</sup> An accessibility analysis software package

with the SWRM, the GTFS processing method was revised to include services which operate on any weekday.

In addition to this, a detailed review was carried out on outputs from the GTFS extraction process. Stopping sequences for certain lines were updated as some routes weren't properly coded. In particular, issues arose where services extended outside the model area (e.g. Dublin-Limerick) and were not coded as stopping at the edge of the network.

All modelled headways were checked against timetables available online from Bus Éireann and other service provider websites. Where necessary, headways were updated to represent as accurately as possible all bus services in the modelled area.

### ***Cap Centroid Connectors***

Checks on the SWRM FDM identified an overestimation of the percentage of walk trips which were intrazonal, and that this error was strongly correlated with the length of zone centroid connector. Further information on this error is provided in the SWRM PT Model Development Final Report. To resolve this, a cap of 500m was applied to zone centroid connectors in all the regional models including the MWRM.

#### **4.3.4 Detailed Network Audit**

A detailed network audit was completed after all major changes outlined above had been applied to the model. This identified a number of recommendations that were applied, and are summarised in the Table 4.2 below:

Table 4.2 Detailed Network Audit Recommendations

Type	Description
<b>Network Services</b>	Rail and bus services leaving and entering the model updated to have their last stopping node at the last node of the network
<b>Fares</b>	Education fares applied to urban buses only
<b>Headways</b>	All headways capped at 61 minutes to avoid capacity issues
<b>Capacities</b>	Bus capacities updated based on fleet information provided by BE
<b>External Connectors</b>	New methodology for calculating lengths of external connectors

### ***Crowding Headways***

The calculation of coded headways is based on the frequency of services from GTFS data at the period level (i.e. 7-10 in the AM) whereas only the peak hour (60min) is being assigned.

For a service going only once in the AM period (say at 8.30 AM), a headway of 180min was initially coded. This resulted in an hourly capacity being divided by three (180/60). In order to avoid underestimation of supply and inconsistent crowding, the headways were capped at 61 minutes. The impact of that is a correct hourly capacity for the assigned peak hour. Nevertheless, the wait time will tend to be underestimated. This is arguable as a service running only once in the AM period would most likely run within the peak hour, and therefore, the wait time would probably correspond to that of an hourly service.

The capping of headways can have another drawback if there is a requirement to convert services into fleet requirement or 24h operating costs. The model inputs are now not able to differentiate between 60 min or 180 min headway services.

### ***Capacities***

During the detailed network audit, and analysis of the PT crowding model, a review of bus capacities in operation in the MWRM was undertaken. Available Bus Éireann fleet information was utilised to calculate an average capacity by type of service and area.

No similar information was available for private operators, and as such, the same capacities as for Bus Éireann Regional Services were coded, assuming that they use similar type of vehicles (i.e. single coaches). Revised vehicle capacities are summarised in Table 4.3 below, and were included in the PT model superseding the standard values initially outlined in Section 2.5 previously.

Table 4.3 Vehicle Capacities

Operator	Type of service	Seating capacity	Crush capacity
<b>Bus Éireann</b>	Limerick City services	46	78
<b>Bus Éireann</b>	Regional services	53	55
<b>Private Operators</b>	Regional services	53	55

### ***Updated External Connector Distances***

Initially, a dummy length of 50 km was applied to all external zone connectors within the MWRM PTM. External demand is generated by the Regional Model Strategic Integration Tool (RMSIT), and not the FDM. Therefore, the costs generated by external access were not required by the FDM and so the length of connector was deemed to be of little importance.

Through further investigation of PT assignment during the detailed network audit, it was noted that this generic connector distance was causing issues between PT sub-mode choice for external zone demand. Therefore, a new methodology was introduced whereby the connector distances were calculated based on the cost of travelling by sub-mode (i.e. bus and rail) from the centroid connector to a defined settlement on the edge of the model network.

The cost of travelling by sub-mode was calculated based on:

- Distance from the defined zone centroid location to the settlement on the edge of the model network e.g. Dublin – Portlaoise;
- Time of travel based on sub-mode; and
- Approximate fare calculated utilising the MWRM distance based fare structures for bus and rail.

The approximate cost of travel was calculated for each connector and PT mode available, and this was utilised to generate updated connector distances for input into the MWRM PTM.

## 4.4 PT Model Parameters Progression

### 4.4.1 Initial Parameters

Initial PT model parameters were taken from the PTM Specification Report and an early version of the ERM, and are outlined in Table 3.2 previously, along with an acceptable range of values.

### 4.4.2 PT Generalised Cost Checks

As part of the PT Generalised Cost checks outlined previously in Section 4.3.3 and detailed in the SWRM Public Transport Model Development Report, a number of PT assignment parameters were reviewed and updated. The main changes were made in the following PT input files:

- **NTL\_GENERATE\_SCRIPT.txt:** defines the non-transit legs generation process;
- **SYSTEM\_FILE.pts:** defines the mode, operators, wait curves and crowding curves within the PTM; and
- **AM\_PT\_ASS\_8.s:** Script controlling the PT assignment within CUBE.

As a starting point, assignment parameters were inherited from the ERM. The principal ones were:

- Mode 96: Drive to PT Stop (see Section 2.1.6 for further details)
  - 30 min penalty on connector
  - Maximum 90 minutes
  - Slack of 10 minutes
  - 5 legs by sub-mode
  - Weight factor: 2
- Mode 97: Walk to PT Stop (see Section 2.1.6 for further details)
  - Maximum 30 minutes
  - Slack of 30 min
  - 5 legs by sub-mode
  - Weight factor: 2
- Mode 98: Zone-to-zone walk (see Section 2.1.6 for further details)
  - Maximum 20 minutes
  - Pure walk cost
  - Weight factor: 2

Similar to the network checks outlined previously, a series of tests were carried out in the SWRM on alterations to PT parameters and their impact on producing improved generalised costs for calibration. Table 4.4 below provides an overview of all tests undertaken including an indicator to state whether the proposed change is to be retained in all regional models, including the MWRM. Detailed descriptions of all tests are described in the SWRM Public Transport Model Development Report.

Table 4.4 Summary of Parameter Options Retained for Revised PTAM

Test Description	Retained
Include Drive Time on Connectors	Retain
Remove 30 minute Penalty for Driving	Do Not Retain
Increase Non-Transit Legs and Slack Value	Retain
Remove Drive Time Weight	Do Not Retain
Remove Drive Access and Increase Walk Cap	Do Not Retain
Rural Drive Access and No Penalty	Do Not Retain
Decrease Driving Cap to 30 Minutes	Retain
Revised Maximum Waiting Time	Retain
Zone-to-Zone Walk Penalty	Retain

The following sections provide a brief description of the parameter changes which were adopted for the MWRM on foot of testing carried out in the SWRM PTM.

### ***Include Drive Time on Connectors***

As noted earlier in Section 4.4.2, initially drive time along the zone connector was not taken into account in the access cost calculation. Instead, a fixed penalty of 30 minutes was added regardless of the length of the connector. Therefore, for more consistency, including the actual drive time on the connector in addition to the fixed 30 minute penalty was tested in the SWRM. The results indicated that the change had little impact on average costs and cost distribution. It was decided that this alteration should be adopted across all regional models as it provides a more accurate representation of drive access costs.

### ***Increase Non-Transit Legs and Slack Values***

As noted previously in Section 2.1.6, Non-Transit Legs represent the link between a zone and nearby PT stops. Increasing the number of Non-Transit Legs generated within the PT model increases the number of PT stops which passengers from a particular zone can access. The Slack Value controls how many route options are considered in the PT assignment. The PT Model finds the best (i.e., lowest cost) leg for a mode, and then also retains all legs that do not exceed this lowest cost plus the slack value. Increasing the slack value increases the number of route options in the PT assignment.

The initial parameter taken from ERM had a value of 1 for motorised Non-Transit Legs for rail. After reviewing this, it was increased to 2 based on the assumption that people might get a lift to a rail station that was not the closest to where they live.



The initial slack parameter from the ERM was 10 minutes. In an area with frequent PT services this value is reasonable. However, in the more rural areas in the MWRM, this causes an issue because the PT services are coded for all four time periods in the same lines file. If a service does not operate in certain time periods it is coded with a headway of 0. However, the Non-Transit Leg Generation step ignores this, and generates a non-Transit leg to this stop even if there is no actual service in that time period, resulting in a high cost. Increasing the slack gives a greater choice for passengers, so they can choose a PT stop that is further away but has a service during that time period.

### ***Decrease Driving Cap to 30 Minutes***

Initially, drive access to PT Stops (Mode 96) was capped at 60 minutes (30 minute drive + 30 minute penalty). This high value was introduced to ensure that all zones have PT access. However, through analysis in the SWRM, it was noted that allowing a drive of 60 minutes was excessive leading to unrealistically long drive access legs for PT journeys. Through iterative testing in the SWRM, a drive access cap of 30 minutes was considered sensible based on a balance between the number of zones with available PT access and the drive distance allowed. This 30 minute cap was adopted across all Regional Models including the MWRM.

### ***Revised Maximum Waiting time***

In order to further reduce PT generalised costs, a test was carried out in the SWRM to reduce the maximum waiting time for a PT service from 30 minutes to 15 minutes (i.e. a perceived wait time of 30 minutes based on a wait factor of 2). This is a standard value for maximum waiting time and resulted in a small reduction in average PT costs. Thus, this revised maximum wait time value was adopted in the MWRM.

### ***Zone to Zone Walk Penalty***

As noted in Section 2.1.6 above, zone-to-zone direct access was included in the model to ensure that costs are increasing consistently with distance. Initially, the direct non-transit leg access from zone to zone was allocated a perceived cost of twice the walk access cost. However, it was noted during initial testing in the SWRM that using this approach was creating quite low PT access costs for short distance zone to zone trips, and thus, overestimating short distance PT demand.

The zone to zone non-transit leg was developed to re-create short distance PT journeys between zones which could not be represented within the model due to lack of network detail. Therefore, the cost of access for these journeys should reflect boarding costs, fares, wait times etc. and it was decided that it would not be fair to represent their costs as just walk costs as originally planned.

Analysis was carried out on short distance zone to zone trips within the model where PT services were coded. For these services an average penalty of 15 minutes (multiplied by two to convert it into a perceived value) was identified which represented boarding penalty, fare and waiting time. This 15 minute penalty was then applied to the direct zone-zone

access costs and, in addition, the zone-to-zone walk time was capped at 10 minutes. As a result, the overall demand calibration was noted to have improved with the cost distributions more accurately matching observed data. Therefore, this zone to zone penalty was adopted for all Regional Models.

### ***Updated Wait Curve***

As noted in Section 2.4 previously, the PDFH Non-London inter-urban wait curve was initially adopted for the MWRM. However, due to the generalised costs problems noted within the SWRM, it was decided, through consultation with the NTA, that the wait curve would be altered to assist in providing more realistic cost estimates. Table 4.5 and Figure 4.7 below illustrate the wait curve applied to all modes within the MWRM.

**Table 4.5 Wait Curve Definition**

<b>Headway</b>	<b>Wait Curve Value (Mins)</b>	<b>Perceived Wait Time (mins)</b>
5	2.5	5
10	5	10
15	7	14
20	9	18
30	11.5	23
40	13	26
60	15	30
90	17	34
120	18	36
180	20	40

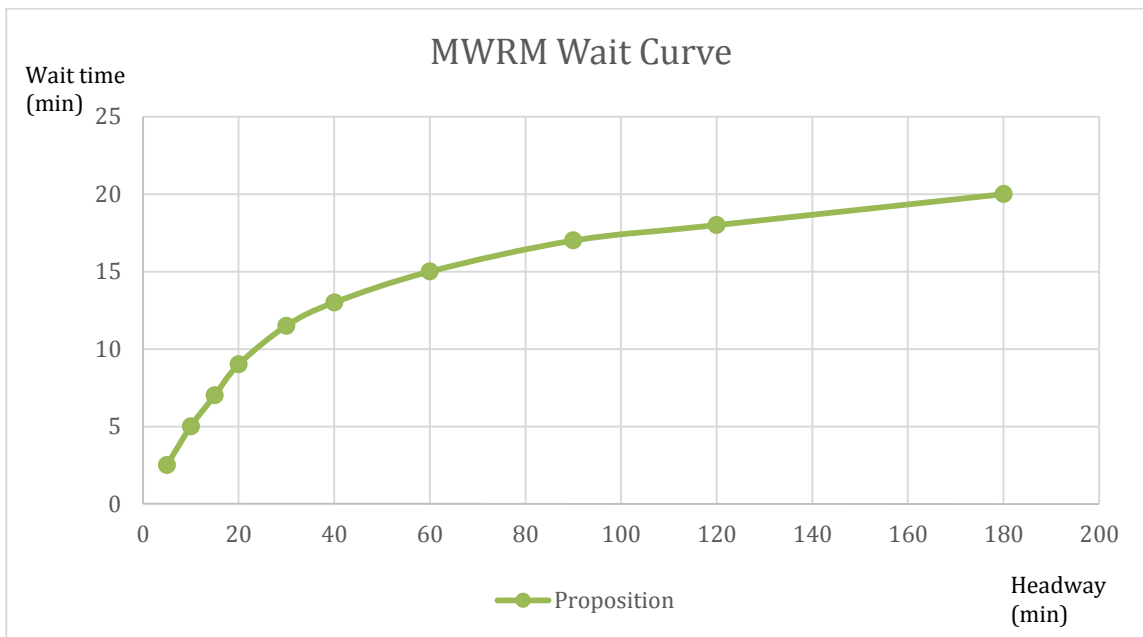


Figure 4.7 Modelled wait curve

#### 4.4.3 Detailed Parameter Audit

At the same time as the Detailed Network Audit described in Section 4.3.4, a detailed audit of parameter values was also conducted. This identified a number of recommendations that were applied, and are summarised in the Table 4.6 below. More details on the In-Vehicle Time factors, Walk and Wait Time Factors, Boarding and Interchange penalties and Load Distribution Factors are given in the following sections.

Table 4.6 Detailed Parameter Audit Recommendations

Type	Description
Non-Transit Legs	Revised mode 98 (zone-to-zone) cost: now estimated with 30min + 2x walk time and capped at 10 min walk (i.e. a maximum cost of 50 min)
Non-Transit Legs	Number of walk legs increased from 5 to 10
Crowding Curves	Rail crowding curve was used for all other modes – this was corrected for all buses
In-Vehicle Time	Rail IVT set to 1.3 Bus IVT set to 1.5
Walk Time Factor	Set to 1.6
Wait Time Factor	Set to 2.0
Boarding Penalty	Set to 5
Interchange Penalty	Set to 5 for all modes
Load Distribution Factor	Set to 50% for coaches in the PTM

### ***In Vehicle Time Factors***

In-vehicle time factors are defined for the 5 modes (Commuter Rail, Other Rail, Light Rail, City Bus and Other Bus) to represent relative comfort and perception of travel time. Calibration started with initial values from BRT stated preference research, which were refined to improve model calibration. Table 4.7 summarises the in-vehicle time factors utilised in the MWRM PTAM which were adopted from the ERM calibration.

Table 4.7 In-vehicle time factors – initial and calibrated values

MODE	ERM CALIBRATED V1	WRM CALIBRATED
DART	1.30	1.30
OTHER RAIL	1.30	1.30
LUAS	1.00	1.00
CITY BUS	1.50	1.50
OTHER BUS	1.50	1.50

### ***Walk and wait time factors***

Walk time factors represent the discomfort of walking to/ from a transit stop. This value is applied to the total walk time to/ from a transit stop, including walk time on the zone centroid connector and on the PT network. WebTAG suggests values between 1.5 and 2.0. A walk time factor of 1.6 was calibrated in the ERM model, following stated preference study recommendations. This value was retained for MWRM as tests with higher values didn't improve the validation.

Drive time to PT has a higher time factor of 2.0. While driving may be expected to have a lower factor than walking (because of the relative comfort of driving compared to walking and the greater speed at which distances can be covered), the impact of reducing this factor was to increase the number of trips which drive to PT. As aspects such as car availability, and availability of parking at public transport stops, are not taken into account in the drive access to PT, this led to an over-estimation of drive trips to public transport. Therefore, the higher time factor for drive access to PT was retained within the MWRM.

Wait time factor represents the discomfort of waiting for a PT service. WebTAG suggests values between 1.5 and 2.5. A mid-range value of 2.0 was used for the ERM. This value was retained for MWRM.

### ***Boarding and Interchange penalties***

A time penalty was applied at each initial boarding to reflect the time taken to board on a particular service. Calibration has resulted in a single value of 5 minutes for all modes.

An interchange penalty was also applied to any journey with a transfer between sub-modes. This reflects the transfer cost from one mode to another including the quality of the waiting facilities (information, security, etc.), and a single value of 5 minutes for all sub-modes has been adopted in the MWRM.

### **Bus Speed Factors**

As detailed in Section 2.1.1 previously, bus speeds are derived from the assigned road networks. Speed on bus lanes is first equated to uncongested assignment speeds on the road network. Bus speeds where bus lanes do not operate are calculated using the congested speed. During calibration, the congested speed is factored by a link characteristic based factor. Table 4.8 below shows these factors that are applied for all time periods. The initial factors were inherited from the calibrated ERM.

Table 4.8 Bus speed factors by link characteristics and by time period

Name	Link Characteristics	All Time Period Factor
<b>FAC1</b>	Motorways	0.95
<b>FAC2</b>	Rural Single	0.90
<b>FAC3</b>	Rural Dual	0.95
<b>FAC4</b>	Urban Dual/Single	0.85
<b>FAC5</b>	Simulation area	0.85
<b>FAC6</b>	Bus Lane	0.95

A minimum bus speed of 5km/h was defined to prevent journey times from increasing excessively where the road network is locally saturated.

To take into account the varying running time of bus services, a TIME FACTOR has also been applied which is dependent on the quality and type of the service. In summary, time factors were calculated for the following category of services:

- **Urban:** Urban Bus services
- **Normal:** Non Urban services, non express
- **Express:** Non Urban, express services

These factors were altered in an iterative process to match AVL and GTFS journey time data during validation (see Section 5.4 below for further details). The finalised time factors for the MWRM are outlined in Table 4.9 below.

Table 4.9 Time factors by bus service characteristics and by time period

Name	AM	IP1	IP2	PM
<b>Urban</b>	1.20	1.20	1.25	1.23
<b>Normal</b>	1.30	1.30	1.30	1.30
<b>Express</b>	1.15	1.15	1.15	1.15

### Load Distribution Factor

Through testing it was noted that a significant number of buses in the ERM network were experiencing crowding and this was impacting on the level of convergence which could be achieved. An issue was identified with our current regional and private operator bus capacities (outlined in Section 2.5 previously) and the way in which CUBE models crowding.

Within CUBE, the identified crowd curve increases the perceived cost of travel when occupancy on the service is between seated and crush capacity. Within the PT Model, the



seated and crush capacity for single decker coaches are very similar (i.e. Seated Capacity = 52, Crush Capacity = 54). Therefore, no crowding occurs on these services up to a load of 52 passengers and then, with a relatively small increase in demand (i.e. 2 passengers), the full crowding impact is introduced with a 30% increase in perceived travel time. This significant cost increase due a small alteration in demand was impacting on the ability of the crowding model to achieve convergence.

In order to address this issue, it was decided to alter the Load Distribution factor (LOADDISTFAC) in CUBE. This factor essentially controls the point of seat occupancy at which passengers begin to experience an increase in perceived travel time due to crowding. Initially, this value was set to 100% i.e. crowding does not occur until occupancy is above the defined seated capacity. However, in light of testing carried out in the ERM, it was decided that, for single decker coaches, crowding should begin at 50% of the seated capacity. It is assumed that at a 50% occupancy, passengers must start to share seats thus impacting on the level of space available to them for their legs, luggage etc. Therefore, this was deemed a logical value for the Load Distribution Factor for these services. Tests within the ERM suggested that this updated factor improved the level of convergence achieved within the PT Crowding Model and, as such, was adopted in the MWRM PT Model.

## 4.5 PT Model Matrix Progression

### 4.5.1 FDM Matrices

The PT assignment matrices are generated by the final calibrated Full Demand Model (FDM) as illustrated in Figure 1.2 previously. The FDM has been through numerous iterations and further details on the development of the MWRM FDM, and the process of calibration, are provided in the MWRM Demand Model Calibration Report and the RM Full Demand Model Development Report.

The development of the MWRM PT Model has impacted on the development and calibration of the FDM through the following:

- **Decrease in PT Generalised Costs:** At an early stage of development of the FDM, it was noted that the PT Model was generating significantly high generalised costs which were causing difficulties during calibration of the FDM. To alleviate this issue, a number of tests were carried out in the SWRM to assist in reducing generalised costs leading to a series of network and parameter updates which were adopted across all regional models. Section 4.3.3 and 4.4.2 above, provide details on the various network and parameter changes incorporated in the MWRM PT Model to feed more realistic costs into the FDM during calibration;
- **Detailed Model Audit:** As noted in Section 2.3 of the RM Full Demand Model Development Report, version SAVE 14 of the FDM was the first full release version of the model believed to be suitable for use across all the regions without significant error. At this stage, a detailed audit of all elements

of the FDM was undertaken including the PT Model. On foot of this audit, a number of network and parameter updates, outlined in Sections 4.3.4 and 4.4.3, were incorporated into the MWRM PT Model. These updates assisted in improving the PT assignment model, and therefore allowed better costs to be fed into the FDM.

- **Iterative Feedback of costs:** As noted previously in Section 1.2, the FDM works on an iterative loop whereby generated matrices are assigned to road, PT and Active networks and associated costs are fed back into mode and destination choice to generate new demand until convergence is reached. At various stages throughout the development and calibration of the MWRM FDM, costs were extracted from the PT assignment model. In some cases small network and coding issues were noted and fixed, however, these are not described in detail in this report. For a number of iterations, a matrix factoring process (described later in this chapter) was undertaken to ensure modelled PT flows matched observed count data, and therefore provide more realistic PT costs for the FDM calibration.

The final PT assignment matrices (known as 'prior' matrices) were generated from Version 2.0.23 of the MWRM FDM. As noted previously, for further information on this version of the model, including calibration statistics, the reader is referred to the MWRM Demand Model Calibration Report.

## 4.5.2 PT Factoring

As noted for all the ERM, SWRM and WRM PT models, a factoring process was undertaken to ensure that modelled flows provide a more accurate representation of observed counts. This factoring process is reliant on the availability of PT flow counts on key strategic links entering the main urban centre of the regional model.

For the MWRM, limited count data was available for rail and bus boardings at stations within the model area from the following sources:

- the 2013 Rail Census; and
- A boarding and Alighting survey carried out by Count On Us in 2009.

However, the Count On Us survey data had a number of drawbacks, including:

- Surveys were taken in 2009 and may not be reflective of conditions in the model base year of 2012;
- Surveys do not cover all bus services entering the city centre; and
- Surveys were undertaken in June, and are therefore likely to underestimate the level of PT demand during a normal representative month in the year due to:
  - Lack of school and college travel due to summer holidays; and
  - Reduced general demand due to summer holiday period.

Therefore, due to the limitations outlined above, it was decided that there was insufficient data available to carry out a satisfactory matrix factoring process.

Initially, it was suggested that annual ticket sales data, available for certain routes within the model area, could be utilised to factor PT demand. However, a number of issues were noted with using annual ticket sales as the only source of data to calibrate PT demand. The main concern is with the level of assumptions which have to be applied to ensure that the annual ticket sales are in a comparable format to peak hour flows from the model. There is also an issue with confidence in the ticketing data received e.g. are trips on period tickets such as weeklies, monthlies and annuals accurately represented in the data. Initial tests using the annual ticket sales data suggested that calculated factors would be too extreme, and hence, overly distort the PT matrix generated by the FDM. Therefore, it was decided that for the MWRM, matrix factoring would not be undertaken until further count data sources became available.

## 4.6 Summary

The calibration process has involved three different but interlinked processes which have been adjusted in accordance with the hierarchy outlined in WebTAG:

- The PT Network has been reviewed and adjustments made to zone centroid connectors, costs, loading points, as well as to the coding of PT services;
- PT model parameters (in-vehicle time factors, walk and wait time coefficients, interchange penalties) have been adjusted to obtain better costs and achieve a better match between modelled flows with observed data; and
- PT demand was generated by the MWRM FDM with no additional factoring of demand undertaken.

## 5 MWRM PTM Validation

### 5.1 Introduction

PT Model validation is a key step to ensure confidence that the calibrated model gives an accurate representation of observed Public Transport trips. This section outlines the observed data sources used in the PTM validation and shows the comparisons with model outputs as a measure of how well the calibrated PT Model validates.

### 5.2 Assignment Validation Process

#### 5.2.1 Overview

The assignment validation process was undertaken by comparing the outputs of the MWRM PT assignment and observed data for the following:

- Passenger Flows;
- Bus Journey Times;
- Boardings and Alightings;
- Line Profiles; and
- Interchanges.

#### 5.2.2 Validation Criteria

TAG unit M3-2 identifies four kinds of check that should be undertaken as part of the process of validation of a PT assignment model:

- Validation of the trip matrix;
- Network validation;
- Service validation; and
- Assignment validation.

Table 5.1 outlines the trip matrix validation criteria, as set out in TAG Unit M3-2, Section 7.1.2:

**Table 5.1 PT Assignment Model Trip Matrix Validation Criteria**

<b>Criteria</b>	<b>Acceptability Guideline</b>
<b>Differences between modelled flows and counts across screenlines should be less than 15% of the counts</b>	95% of cases

TAG Unit M3-2, Section 7.1.3 sets out that validation of the network should include checks on:

- The geometry of the network (including the location of PT stops, access points); and
- Times/ speeds in the model (including, in-vehicle time, access and interchange times).

TAG Unit M3-2, Section 7.1.4 sets out that validation of the services should include checks on:

- Modelled versus observed number of PT vehicles; and
- Other service features, including stopping patterns for rail.

Table 5.2 outlines the PT assignment validation criteria as set out in TAG Unit M3-2, Section 7.1.5 and 7.1.6:

**Table 5.2 PT Assignment Validation Criteria**

<b>Criteria</b>	<b>Acceptability Guideline</b>
<b>Differences between modelled flows and counts by PT sub-mode across all screenlines (in total)</b>	Difference less than 15%
<b>Differences between modelled flows and counts on individual links should be less than 25% of the counts (unless observed flows are less than 150 passengers per hour)</b>	All links

In addition, checks should be made on passengers boarding and alighting in urban centres.

Guidance from the 2003 Modélisation des Déplacements Urbains de Voyageurs, published by CERTU, provides transfer ratio (total boardings over total trips) ranges based on the population of the modelled city (Table 5.3 below):

**Table 5.3 CERTU Guide 2003 – Transfer ratio range**

<b>City Population</b>	<b>Transfer Ratio 2000</b>	<b>Transfer Ratio 1995</b>
<b>&gt;300,000</b>	1.05 to 1.65	1.05 to 1.55
<b>100,000 to 300,000</b>	1.02 to 1.33	1.1 to 1.34
<b>&lt;100,000</b>	1.0 to 1.33	1.0 to 1.44

## 5.3 Observed Data

### 5.3.1 Overview

Observed data has been collected from a number of different surveys undertaken on different dates, and was processed to build a single database to define observed flows to use in the model validation. The following data sources have been used:

- Rail: Irish Rail 2013 survey; and
- Bus: Count On Us (2009 Survey)

### 5.3.2 *Rail Data*

Data from the National Rail Census of 2013 was processed to obtain boarding and alighting figures for all the rail lines within the MWRM. Only boardings and alightings at rail stations located within the internal area of the model were considered in the overall summaries.

### 5.3.3 *Bus Data*

In June 2009, Count On Us carried out the following surveys on PT services in Limerick City:

1. Boarding and alighting (B&A) surveys for BÉ City services at stops within Limerick City; and
2. Boarding and alighting surveys for regional bus services at Limerick Colbert Bus Station, Shannon Airport and Ennis Bus Station.

It should be noted that whilst the Count On Us surveys provided a good database of count information for PT services operating in Limerick City, the data also had the following drawbacks:

- Surveys were taken in 2009 and may not be reflective of conditions in the model base year of 2012; and
- Surveys were undertaken in June, and are therefore likely to underestimate the level of PT demand during a normal representative month in the year due to:
  - Lack of school and college travel due to summer holidays; and
  - Reduced general demand due to summer holiday period.

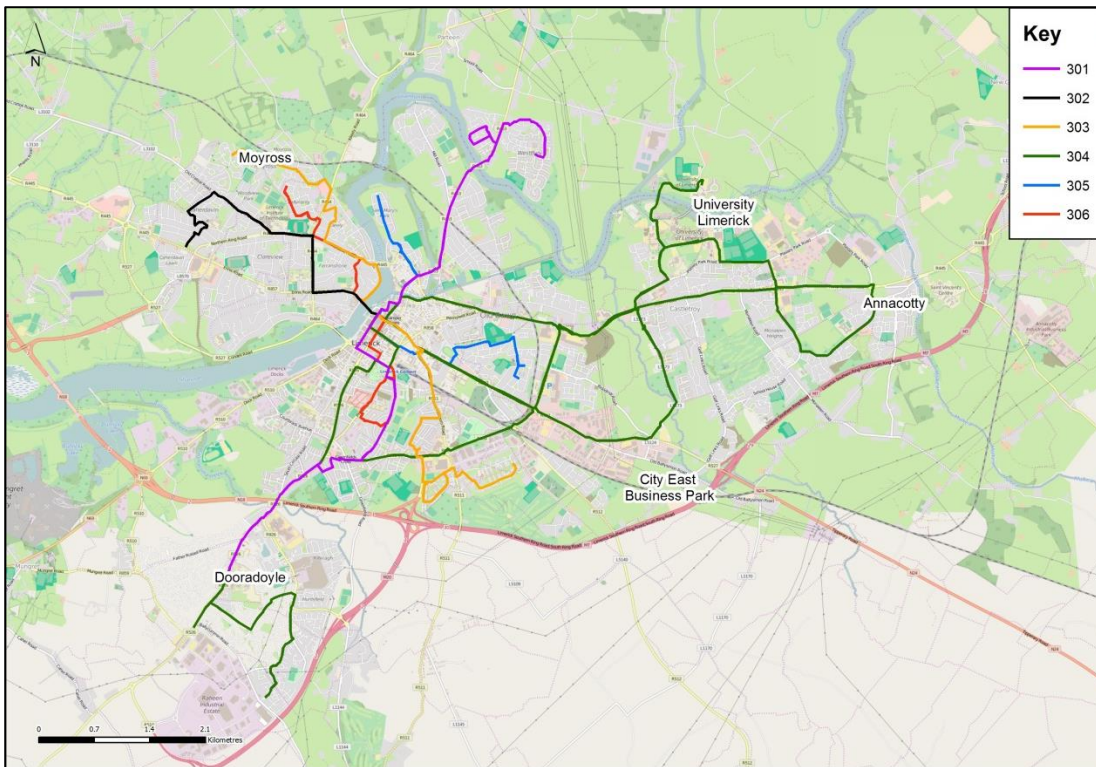
## 5.4 PT Network Validation

### 5.4.1 Observed Data

Data to validate bus journey times produced by the PTM came from two different sources: Automatic Vehicle Location (AVL) data and General Transit Feed Specification (GTFS) data.

AVL data, dated from November 2012, contains average journey time between stops for each hour of the day on 6 different routes, distributed across the network (see Figure 5.1 below).





**Figure 5.1 AVL data routes used in Journey Time validation**

As the AVL data has only been processed for a limited number of bus lines, GTFS timetables have also been used to check other bus lines' journey times. GTFS timetables are not observed data but planned journey times for each service.

#### 5.4.2 Model Validation – AVL Data

Modelled journey times for a total of 11 services have been compared against AVL data. Two indicators have been extracted: the proportion of services faster/ slower than the AVL data, and the proportion of services 15% and 25% of the observed journey times.

The first indicator, summarised in Table 5.4 overleaf, measures the balance between services where the modelled journey time is too fast and those where the modelled journey time is too slow. If the model is adequately reflecting journey times, then it would be expected that equal numbers of services that are too fast and services that are too slow when compared to observed journey times would be expected. However, if it is found that the majority of services are too fast (or too slow), this may be indicative of issues with either the road network speeds or with the factors applied to the bus journey times. Results for the MWRM show that modelled services are slightly faster than observed data in all time periods.



Table 5.4 Service classification by journey time comparison to AVL data and by time-period

	AM	IP1	IP2	PM
<b>Model faster than observed AVL data</b>	10 (91%)	10 (91%)	9 (82%)	9 (82%)
<b>Model within +/-10min of the observed AVL data</b>	10 (91%)	11 (100%)	11 (100%)	11 (100%)
<b>Model slower than observed AVL data</b>	1 (9%)	1 (9%)	2 (18%)	2 (18%)
<b>Average Journey Time difference</b>	-10%	-9%	-7%	-7%

The second indicator contains two levels of validation, based on the percentage difference between modelled and observed journey times: less than 15% and less than 25%. Table 5.5 provides a summary of these figures. More than 73% of the modelled journey times are within +/- 25% of the observed journey times across the four time periods. Detailed validation tables for AVL journey times are given in Appendix A.

Table 5.5 Journey Time validation against AVL data – Summary table

Criteria		AM	IP1	IP2	PM
<b>&lt;15%</b>	Bus services	6	6	7	7
	%	55%	55%	64%	64%
<b>&lt;25%</b>	Bus services	8	9	9	9
	%	73%	82%	82%	82%
	Total	11	11	11	11

Figure 5.2 overleaf, presents a scatter plot illustrating modelled and AVL observed data for the 11 services across the four time periods. It shows that slightly more of the services have been modelled quicker than observed as more points are just below the line  $y=x$ . However overall, there is a good level of correlation between the modelled and AVL data.

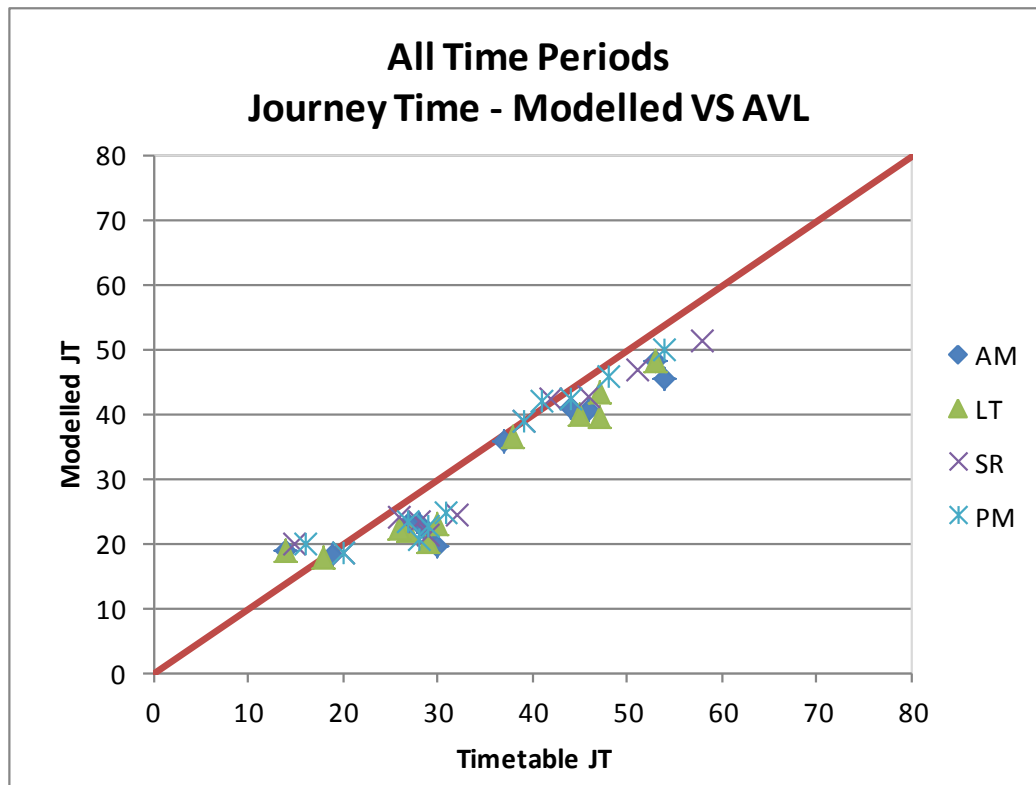


Figure 5.2 Bus Journey Times Scatter Plot – Model vs AVL

#### 5.4.3 Model Validation – GTFS Data

The same indicators as for AVL data are produced with GTFS data in the tables below. The Journey Time validation process has focussed more on matching the observed AVL data rather than the GTFS data, as GTFS data does not take into account network delays, etc., and therefore, the tables and charts below are provided for sense check purposes only.

Table 5.6 Service classification by journey time comparison to GTFS data and by time period

	AM	IP1	IP2	PM
<b>Model faster than observed AVL data</b>	30 (56%)	22 (69%)	16 (57%)	31 (49%)
<b>Model within +/-10min of the observed AVL data</b>	34 (62%)	24 (44%)	21 (39%)	42 (78%)
<b>Model slower than observed AVL data</b>	24 (44%)	10 (31%)	12 (43%)	32 (51%)
<b>Average Journey Time difference</b>	+16%	+2%	+11%	+11%

Table 5.7 Journey Time validation against GTFS data – Summary table

Criteria		AM	IP1	IP2	PM
<15%	Bus services	23	15	13	23
	%	43%	47%	46%	37%
<25%	Bus services	34	22	19	38
	%	63%	69%	68%	60%
	Total	54	32	28	63

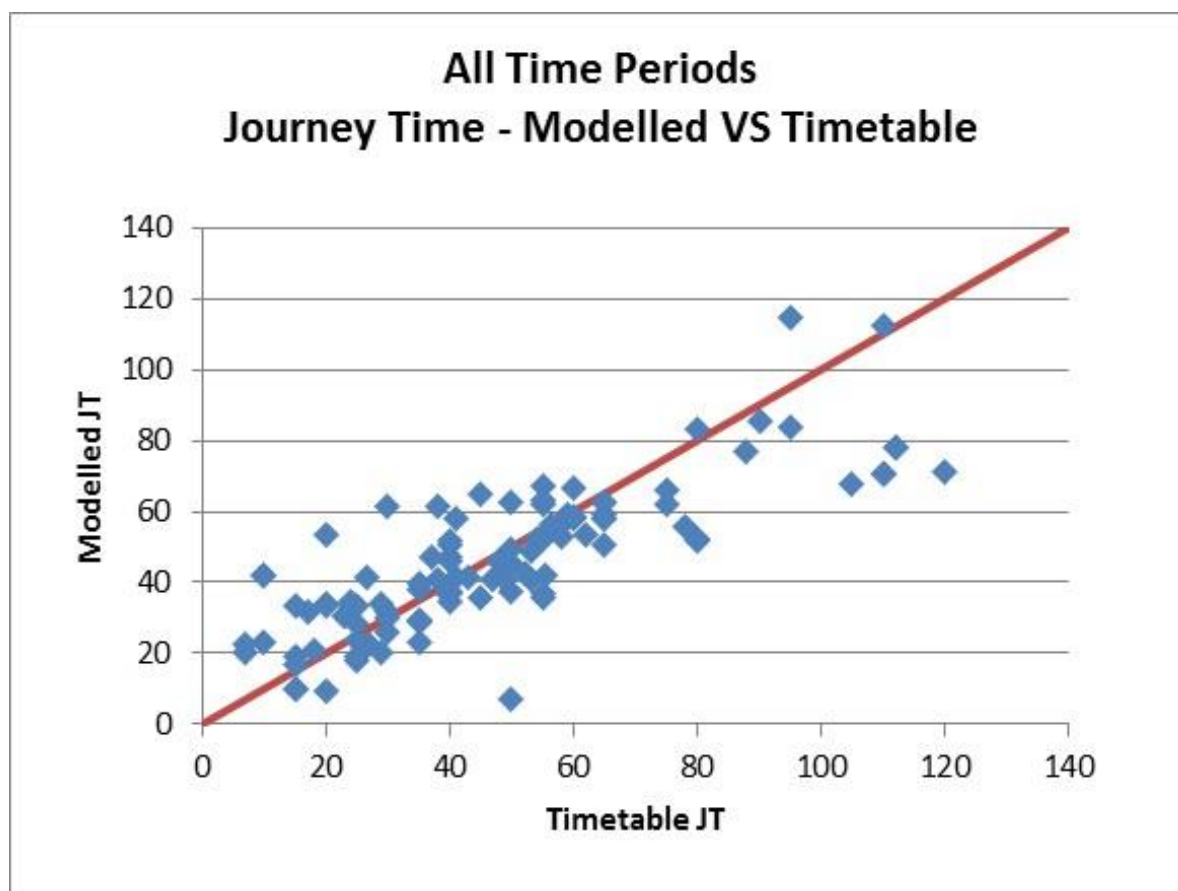


Figure 5.3 Scatter plot representing modelled and GTFS observed data

## 5.5 PT Assignment Validation – Boarding and Alighting

### 5.5.1 Model Validation

As discussed previously in Section 5.3, boarding and alighting data was available for rail services from the 2013 Rail Census, and for regional bus services from surveys undertaken in 2009.

Observed and modelled data for boarding and alighting volumes are summarised by time period in Table 5.8, Table 5.9, Table 5.10 and Table 5.11 below. In general, the model appears to be underestimating boardings and alightings. However, there are a number of shortcomings associated with the observed count data including:

- B&A data only available for certain regional bus services at Limerick Bus Station, Shannon Airport and Ennis Bus Station. This limited range of data is unlikely to provide an accurate representation of B&A in the MWRM area; and
- Count data is from 2009, however, a number of bus services operating in Limerick (particularly city services) were noted to have changed in the period from when the counts were taken to the model base year of 2012. Therefore, the bus count data is not a true representation of the base model bus network.

Based on the shortcomings noted above, it is recommended that the observed B&A data should be treated with caution, and that further counts would be required to provide a better indication of how well the model is representing PT boarding and alighting in the area.

More details on boarding and alighting by location, sector and time period are provided in Appendix B.

Table 5.8 Boarding and alighting validation by mode – AM time period

		Observed	Modelled	Diff.	% Diff.
<b>Rail</b>	Board	303	474	170	56%
	Alight	92	477	385	418%
<b>Bus</b>	Board	193	405	212	110%
	Alight	91	884	793	873%
<b>All modes</b>	Board	496	879	383	77%
	Alight	183	1361	1178	643%

Table 5.9 Boarding and alighting validation by mode – LT time period

		Observed	Modelled	Diff.	% Diff.
<b>Rail</b>	Board	77	133	56	73%
	Alight	54	118	63	117%
<b>Bus</b>	Board	145	182	36	25%
	Alight	138	159	22	16%
<b>All modes</b>	Board	223	315	92	41%
	Alight	192	277	85	44%

Table 5.10 Boarding and alighting validation by mode – SR time period

		Observed	Modelled	Diff.	% Diff.
<b>Rail</b>	Board	64	166	102	161%
	Alight	69	156	87	127%
<b>Bus</b>	Board	188	273	85	45%
	Alight	192	195	3	1%
<b>All modes</b>	Board	252	439	187	74%
	Alight	261	351	90	34%

Table 5.11 Boarding and alighting validation by mode – PM time period

		Observed	Modelled	Diff.	% Diff.
Rail	Board	162	273	110	68%
	Alight	321	317	-4	-1%
Bus	Board	269	649	380	141%
	Alight	201	437	236	118%
All modes	Board	431	922	491	114%
	Alight	521	754	233	45%

## 5.6 Interchange Validation

Table 5.12 below illustrates the transfer ratio by time-period for the MWRM PT Model which are within guideline ranges provided in Table 5.3 above for a city of Limerick's size (1.02 to 1.33).

Table 5.12 Overall PT transfer ratio by time period

	AM	LT	SR	PM
<b>Total Trips</b>	8,628	2,690	3,834	5,342
<b>Intrazonal</b>	1,252	204	588	386
<b>Trips Assigned</b>	7,376	2,486	3,246	4,956
<b>Total Boarding</b>	8,564	2,729	3,616	5,855
<b>Transfer Ratio</b>	1.16	1.10	1.11	1.18



## 6 Conclusions and Recommendations

### 6.1 Summary

This report has described the development, calibration and validation of the Public Transport Assignment Model component of the Mid-West Regional Model. This section summarises the key points of the model development, the strength and weakness of the model revealed by the validation process and a set of recommendations for further enhancements.

### 6.2 Model Development – Key points

As the PT network is the aggregation of different networks (road, rail, Luas, walking), a node convention and a link convention was defined to facilitate output analysis and provide a framework for any additional network coding.

Bus network speeds are derived from road network congested speed. Factors based on link characteristics were calibrated to represent relative bus speed to car speed on different road types. Bus speeds on bus lanes are defined as car speed on an uncongested network (or low flow assignment), to take account of traffic light delays.

All PT lines files are automatically derived from General Transit Feed Specification data, using a bespoke process developed for this model.

Fares are included in the PT assignment model. Separate fare models were built by operator, based on ticketing data, to calculate average fare by user class.

### 6.3 Model Calibration and Validation

More than 73% of the modelled journey times are within +/- 25% of the observed AVL journey times across each of the four time periods.

In general, the model appears to be overestimating boardings and alightings. However, based on shortcomings noted with available count data, it is recommended that the observed B&A data should be treated with caution, and that further counts would be required to provide a better indication of how well the model is representing PT boardings and alightings in the area.

The interchange ratio is within the recommended thresholds for a city of Limerick's size.

### 6.4 Recommendations for Improvement

#### 6.4.1 Additional Surveys

Further actions to improve both the calibration and validation processes should be considered. This could include a more extensive PT survey process to collect more information on bus flows across the entire day and revenue information to calibrate the fares models.

### 6.4.2 Accessibility for Rural Areas

The motorised access mode for PT (mode 96) tends to create long drive access legs, and can also have an impact on sub-mode choice. Re-analysing the motorised access parameters may allow this to be improved.



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