REGIONAL MODELLING SYSTEM

RM Spec3 Public Transport Model Specification Report

Údarás Náisiúnta Iompair
National Transport Authority

DOCUMENT IDENTIFICATION TABLE

Client/Project owner	National Transport Authority
Title of Document	RM Spec3 Public Transport Model Specification Report
Task Order	07
Task	PT Model Development
Model Version	2.0.23
Document Status	Final

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Foreword

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

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

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

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

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

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

1 Introduction

1.1 Regional Modelling System

The NTA has developed a Regional Modelling System for the Republic of Ireland to assist in the appraisal of a wide range of potential future transport and land use options. The regional models 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 the NTA, SYSTRA and Jacobs Engineering Ireland.

An overview of the 5 regional models is presented below in both **Error! Reference source not found.** and Figure 1.1.

Table 1.1 Regional Models and their Population Centres

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

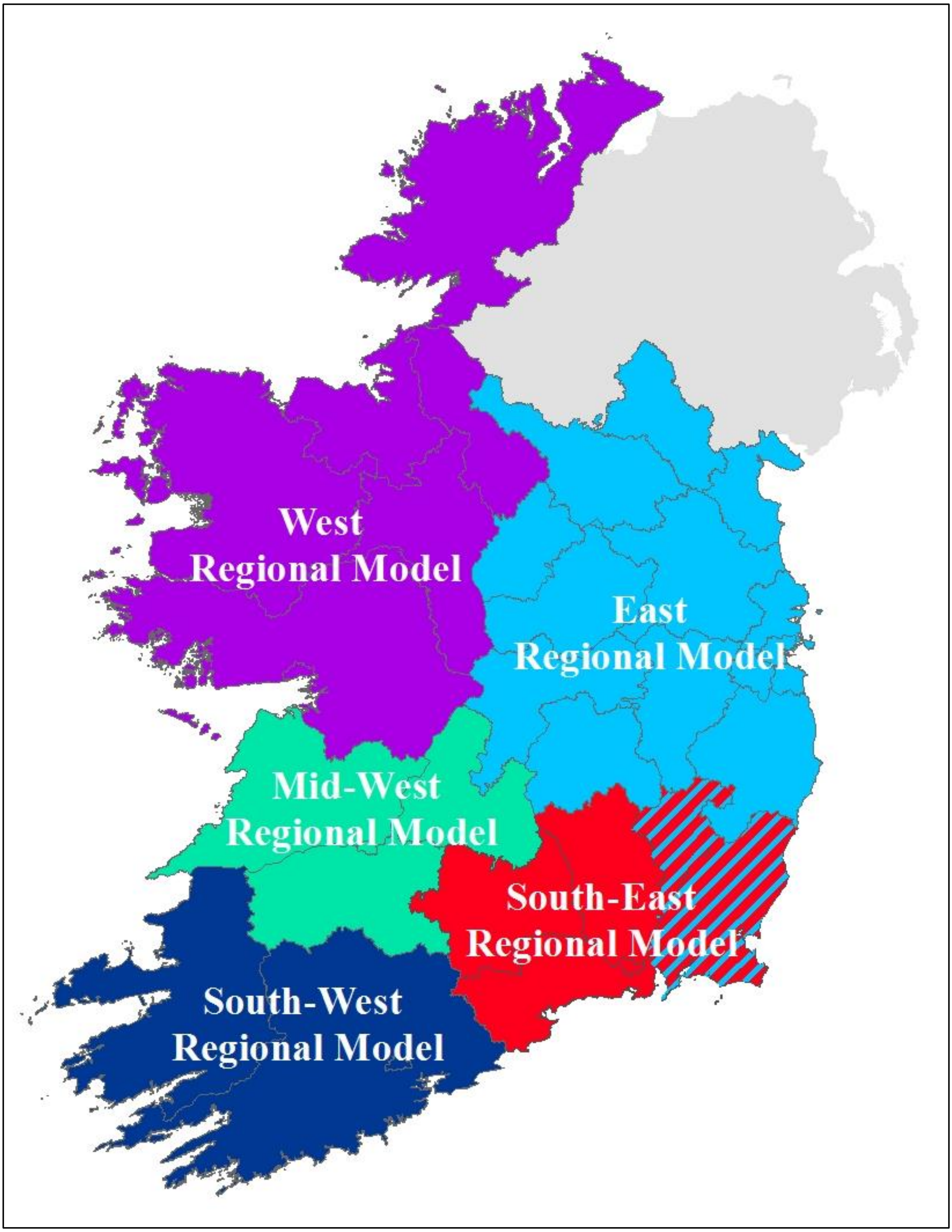

Figure 1.1 Regional Model Areas

1.2 Development of PT Model Specification

The 5 regional transport models comprising the NTA's Regional Modelling System (RMS) all use a consistent approach to the development of the Public Transport Model. An important objective of the RMS PT Model Specification is that its principles can be applied to any regional model area to act as an overarching public transport model development guide prior to calibrating to local data.

Four scoping reports were prepared that provide the basis for the specification of the regional modelling system, which are as follows:

- RMS Scope 1 NTA Modelling Needs Review;
- RMS Scope 2 Greater Dublin Area Model Review;
- RMS Scope 3 Transport Modelling Best Practice Review; and
- RMS Scope 4 Modelling Data Review

These documents form the foundations for the specification of the PT Model and its development, which is described throughout this Chapter.

TAG unit M3-2 provides guidance on PT assignment modelling in transport appraisals, which can be found via the following web link. With no specific Irish equivalent, this document was used as the primary point of guidance for the ERM PT Model specification and development in conjunction with the expertise and experience of NTA staff and the Consultants.

https://www.gov.uk/government/publications/webtag-tag-unit-m3-2-public-transport-assignment-modelling

The UK-based rail Passenger Demand Forecasting Handbook (PDFH, Version 5) also provided a valuable source of guidance and parameter values for PT assignment modelling where rail travel is a key feature. PDFH summarises over twenty years of research on rail demand forecasting, providing guidance on aspects such as the effects of service quality, fares and external factors on rail demand. It is recognised within the industry in the UK as the key source of evidence in this area. A range of other documents were reviewed for specific aspects of the PT Model development, e.g. validation criteria, and these are documented where relevant throughout this Chapter.

For the remainder of this report Public Transport is always abbreviated as PT.

1.3 RMS Model 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 regional models is shown below in Figure 1.2. The main stages of the regional modelling system are described below.

1.3.1 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.

1.3.2 Regional Models

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.

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.

Secondary Analysis

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

1.3.3 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

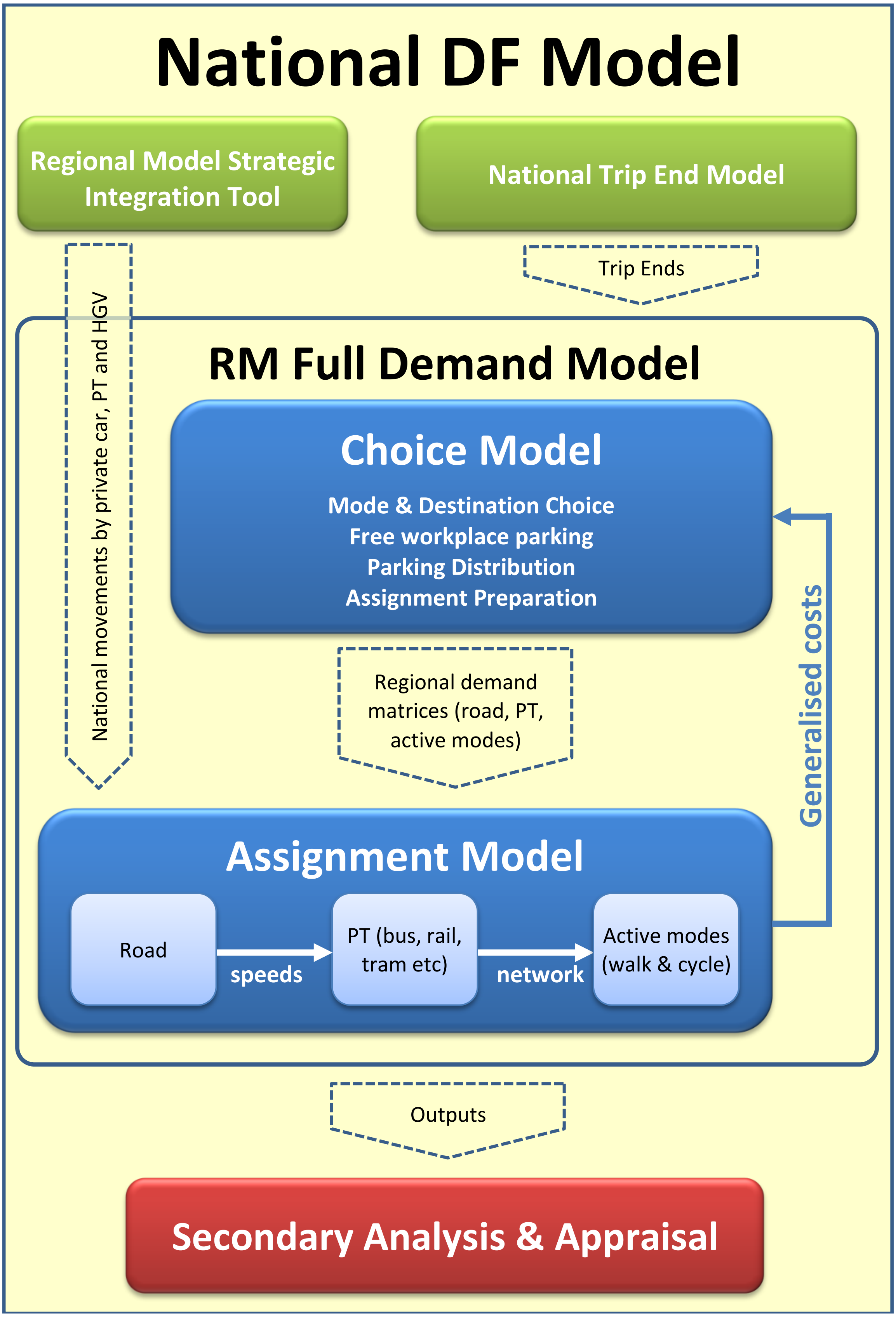

Figure 1.2 Model Structure

1.4 Structure of this Report

This report contains three chapters as follows:

- Chapter 2 RMS Public Transport Model Overview: provides an overview of the RMS Public Transport Model;
- Chapter 3 RMS Public Transport Model Specification: describes the specification of the RMS Public Transport Model; and
- Chapter 4 RMS Public Transport Calibration & Validation: provides an overview of the RMS Public Transport Calibration & Validation Process.

2 RMS Public Transport Model Overview

2.1 Introduction

The purpose of the PT Model is to allocate PT demand in a given time period (as output by the Full Demand Model) to PT services and routes operating between origin and destination zones. To do this, the PT Model must have a full representation of all PT lines, services and sub modes that operate throughout the modelled area. PT trips are the travel demand inputs to the PT Model, and the representation of PT lines and services are the supply inputs to the PT Model.

Figure 2.1 provides an overview of the PT Model structure. The principal function of the PT Model is to represent the relationship between supply and demand through an assignment procedure. Data is an essential input to all elements of the model, examples of which are outlined in Section 3.2 below.

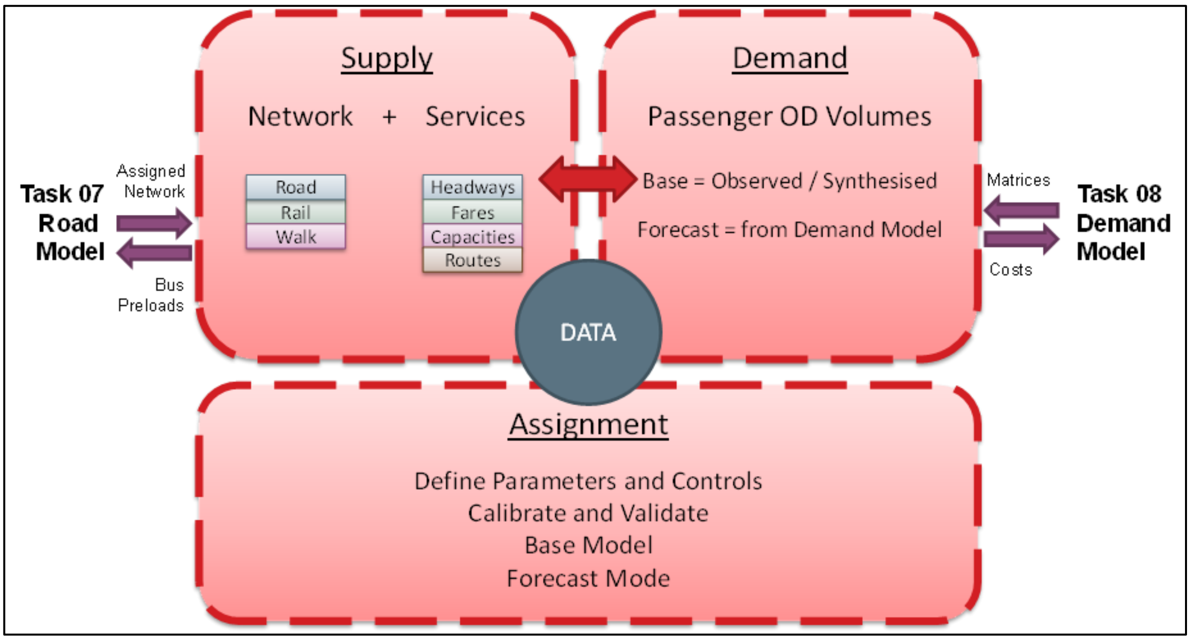

Figure 2.1 PT Model Structure Overview

Outputs of the PT Model which will be used directly in the Secondary Analysis component of the model include:

- Passenger flows on links and at stops and stations for operational analysis;
- Costs of travel (including walk, wait and transit times and fares) for economic appraisal; and
- Estimates of changes in fare revenue.

2.2 Linkages with Overall Transport Model

In developing a specification for the PT Model, it is essential to consider the inter-dependencies with the development of other components of the ERM. These linkages are highlighted in later sections where relevant and can be summarised as follows.

- Definition of Zone System (Task Order 3)
    - Definition of zonal boundaries for PT Model.
- System Architecture (Task Order 5)
    - Consideration of model procedures and their impact on run-times;
    - Coordination with overall ERM;
    - Standardisation with overall ERM (e.g. scripts, procedures, units); and
    - Derivation and calculation of annualisation factors.
- Road Model (Task Order 6)
    - Interchange of key data, notably network details including bus lanes, bus service volumes as pre-loads in the road model and assigned road journey times.
- Demand Model (Task Order 8)
    - The development of synthetic prior PT assignment matrices;
    - The park & ride methodology and, if relevant, the subsequent interchange of input generalised costs and output trip matrices;
    - Methodology for modelling peak periods – either as an average period hour or a peak hour; and
    - The definition of generalised cost parameters and specifically the value of time of PT users.

3 RMS Public Transport Model Specification

3.1 Overview

This Chapter provides a specification for the PT Assignment Model (PT Model) as part of the ERM. Aspects of the PT Model that require specification include:

- Which **time periods** to represent;
- If and how to **segment travel demand** (e.g. by journey purpose and/or fare);
- Approach to network coding;
- Representation of **fares**;
- Routines used to allocate travellers to PT services, including whether **assignment**s should be capacity-constrained;
- **Parameters** used within the assignment including coefficients of generalised cost and sensitivities; and
- **Calibration & validation** of the model to ensure that it accurately replicates observed PT travel patterns and conditions.

This Chapter describes the specification of the PT Model and considers all these aspects.

3.2 Input Data Sources

Data from a number of different sources forms an essential input into the building of the PT Model. Data is required to build the PT Model network and services, to prepare demand matrices and the fares model, to derive parameter values and to provide observed travel information used in model calibration & validation. Data sources used in the building of the PT Model include:

- NTA Journey Planner – this includes a range of network data on walk and cycle network characteristics; of particular interest was the "Introute" data, which is based on NavTEQ data, but with additions and modifications to line work and attributes. The additional information includes:
  - Footpath matrix
  - Cycle Lanes
  - Bus Lanes
  - Pedestrian Crossings

Note that the coverage and detail of Journey Planner / Introute data sources may vary by region.

- NTA Journey Planner - General Transit Feed Specification (GTFS);
- Bus Public Timetables (e.g. from Bus Éireann website) for relevant services that may not be included in the GTFS, e.g. rural town buses;
- Census POWSCAR data;
- National Household Travel Survey (NHTS);
- Airport Travel Survey;

- Automatic Vehicle Location and Control (AVLC) and Real Time Passenger Information (RTPI);
- Rail/Luas Census passenger counts from various years;
- Bus Cordon Counts – from 2011, 2012 and 2014;
- Rail, Luas and Bus ticket sales data; and
- Leap Card ticket sales data.

The application of the above data sources in model development is described throughout this document in the relevant sections.

3.3 Optional Time Period and User Class Reduction

PT assignment run times can be a significant proportion of overall model run times for the ERM. This is particularly the case where widespread PT crowding effects are being modelled. In addition, PT run times can be a constraint in terms of calibrating and validating the assignment model where it is necessary to test a series of model parameters. As a consequence, the requirement to operate within the timescales and programme for the overall model development means that the issue of model run times can restrict the overall specification for the PT Model.

Excessive run times can be mitigated by reducing the degree of segmentation necessary within the PT assignment models, or by reducing the number of time periods modelled.

The merits of these options are considered in the relevant sections below on PT Model Time Periods and PT Model User Classes.

3.4 PT Model Zone System

The PT Model zone system will be consistent with the overall ERM. The first version of the zone system to be used for PT Model development is as described in the ERM Zone System Development Report and shown in Figure 3.1 below.

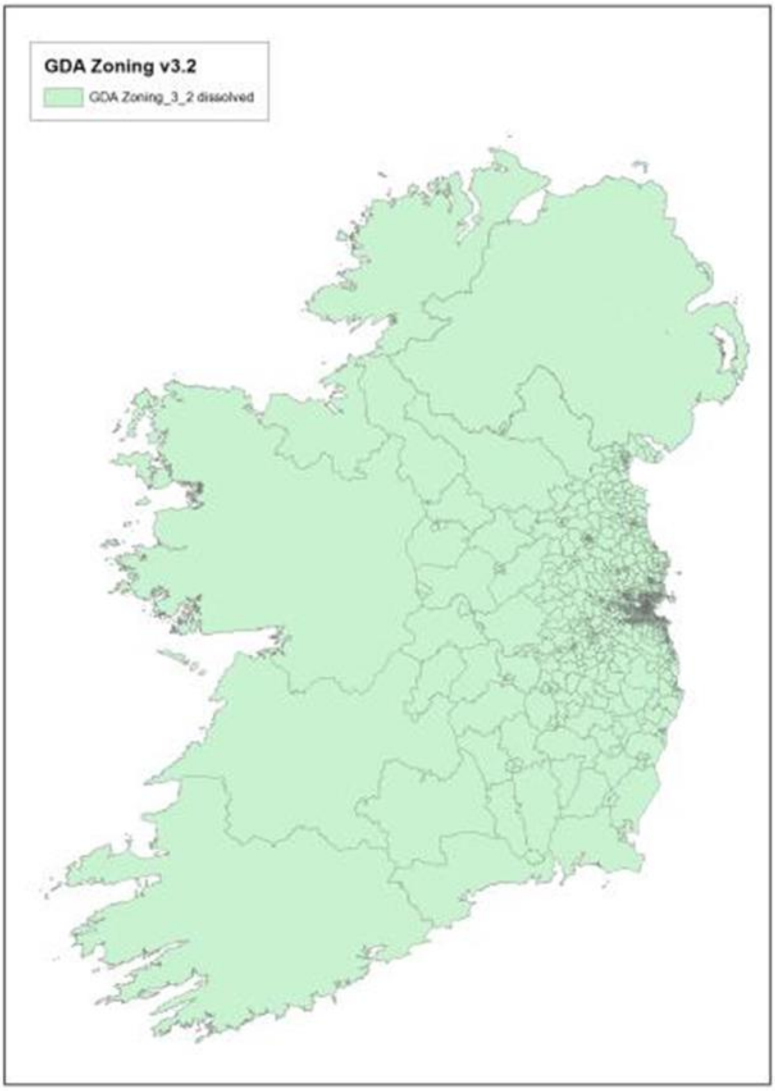

Figure 3.1 Zone System – v3.2

The zone system for the ERM, however, may evolve during the model development phase. This will be documented by the relevant development report of the model version concerned.

3.5 PT Model Base Year

The base year of the model will be 2012 with a nominal month of April. This is largely driven by the date of the POWSCAR and NHTS surveys, rather than the date of data for passenger flows in the PT Model. It should be noted that the POWSCAR dates to 2011 but the travel patterns are assumed to be broadly the same in 2012.

3.6 PT Model Time Periods

Table 3.1 details the four weekday periods that will be modelled in the PT Model. The periods will allow the relative differential in travel cost to be represented. The period to peak hour factors are defined in the Time Periods specification report (MSF 008_GDA 008.1.2 TimePeriods v3 8 20141210) and are also listed in the Table 3.1 below.

Table 3.1 PT Model Time Periods

PERIOD	DEMAND MODEL FULL PERIOD	ASSIGNMENT PERIOD	Period to Peak Hour Factors
AM Peak	07:00-10:00	Peak hour (factored from period)	0.47
Morning Interpeak (IP1)	10:00-13:00	Average hour from full period	Average (1/3)
Afternoon Interpeak (IP2)	13:00-16:00	Average hour from full period	Average (1/3)
PM Peak	16:00-19:00	Peak hour (factored from period)	0.40
Off Peak	19:00-07:00	not assigned	Average (1/12)

The PT Model will be based on demand levels for one-hour periods, using the broader (three hour) period distributions. The two Inter-peak periods (IP1 & IP2) will be represented by an average hour, whilst the AM and PM will be represented by peak hours.

Peak hour matrices can be obtained from the period matrices by applying the above peak hour factors

If lower initial runtimes are required during development and calibration, then the number of time periods can be reduced by choosing to not represent one of the inter-peak periods and adapting the demand model accordingly.

3.7 PT Model Sub-Modes

Travel movements by PT as a main mode will be produced by the demand model. The sub-mode choice will be modelled within the PT Model. This allows full application of the CUBE Voyager algorithms to allocate travellers between alternative routes and sub-modes. This is the most commonly adopted approach which avoids complication and excessive run times and offers a more realistic simulation of how travellers choose routes rather than a logit allocation between modes.

The CUBE Voyager PT module uses a two-step process to allocate trips between routes and sub-modes. The first step (enumeration) calculates all reasonable routes between zone pairs. The second step (evaluation) uses choice models to allocate trips to these routes (and sub-modes). This process is described in more detail in Section 3.12.1 below.

The model will include all existing sub-modes as well as proposed modes (BRT and Metro):

- Dart;
- Rail;
- Luas;
- Urban Bus;
- Inter-Urban Bus;
- BRT (new mode); and
- Metro (new mode).

3.8 Demand Segmentation

3.8.1 Overview

The PT Model demand segments (i.e. groups with differing values of time, fares or travel characteristics) need to be aligned with the ERM Demand Model segmentation. It is advantageous if the assignment segments are aggregations of the demand model segments so that forecast demand changes can be applied to the assignment matrices.

It is possible to split demand model segments for assignment if necessary, e.g. if further travel characteristics need to be represented, using a set of user calculated factors. The demand forecasts could not, however, capture differences between the behavioural traits of each “sub-segment”.

Further segmentation of the PT Model by ticket or fare category could in principle improve the accuracy of route choices. In particular, a significant volume of passenger movements makes use of the Leap Card and TaxSaver tickets, which offers a reduction in fare on a wide range of journeys including multi-modal season tickets. There is, however, limited available data to segment passenger demand for these fare groups by journey purpose, which is required as a minimum to define the relationship with the demand model and estimate remaining passenger numbers by purpose. Taking account of the limited data and the need to minimise run times, it is considered that the impact of Leap Card and TaxSaver tickets can be reasonably reflected in the modelling of average fares (see Section 3.13).

3.8.2 Definition of User Classes

Journey purpose does not directly affect PT service choice in the PT Model, but differences in value of time and PT fares between purposes are likely to have an impact.

On this basis, ***employers-business*** trips would typically be assigned separately to all other trips given the typically higher value of time and potential requirements for segmented economic analysis.

Although ***commute*** and ***other-non-employers-business*** *trips* may have a similar value of time and applicable fare, it would be preferable to retain them as separate journey purposes, particularly given the confidence in the commuter demand data from the

POWSCAR and the emphasis on *commute* as a separate purpose for operational and economic analysis.

Given the availability of free travel passes for persons aged 66 and over, it is proposed that these journeys are included in a **free-travel** demand segment in the PT Model. These journeys would have zero fare and, therefore, any variation in the value of time is irrelevant. The overall ERM demand model will include retired persons as a separate demand segment and this can be aligned to free travel scheme passenger demand with factors applied to account for eligibility and uptake as appropriate.

The overall demand model includes separate demand segments for primary and secondary **school travel**. School travel demand in the ERM will be separated further as follows:

- **Dedicated school transport** (e.g. specific bus for pupils only, taxis etc.) – largely outside the Dublin conurbation. This will not be assigned in the PT Model given the use of separate fixed route services and generalised costs can be assumed from distance; and
- **Non-dedicated school transport** (e.g. bus fare paid, use of travel pass) – largely within the Dublin conurbation. This would need to be assigned in the PT Model as a separate user class as the assigned demand will interact with other journey purposes, specifically relating to crowding.

The proportional split of school travel demand on dedicated and non-dedicated services will need to be estimated from available data. It is anticipated that this will be applied as a series of derived factors on sector or individual zone basis following the main demand model phase and prior to PT assignment.

A possible approach is to simply split by area with 100% dedicated school transport assumed outside the Dublin conurbation and 100% non-dedicated within the Dublin conurbation. Change over time could be applied using exogenous variables defined from available data and predicted trends.

Third-level students are included in the *other-non-employers-business trips* user class in the PT Model where it is assumed they typically have the same characteristics as other adult passengers.

Based on the above considerations, the following user classes would be defined in the PT assignment model, if model run time considerations were unconstrained:

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

3.8.3 User Class Specific Parameters

Each user class will have its own defined set of parameters such as values of time and allocation of fare. Table 3.2 provides an overview of these for the noted user classes.

Table 3.2 User Class Specific Parameters

User Class	Value of Time	Fare
Employers-Business	€25.15	modelled average adult fare based on annual revenue and ticket sales
Commute	€7.68	
Other	€6.93	
Non-Dedicated School	€6.93	special pupil fare for PSOs
Free-Travel	€6.93	zero fare

Notes: VOTs from Common Appraisal Framework: 2002 Values updated to 2012 using real growth in GNP per Employee (Euros per hour, 2012 values in 2002 prices)

3.8.4 Optional User Class Combination

PT assignment run times may be a significant component of overall ERM run-times, particularly if widespread PT crowding effects are being modelled. In addition, PT run times can be a constraint in terms of calibrating and validating the assignment model where it is necessary to test a series of model parameters. As a consequence, excessive model run times may be avoided by placing restrictions on some elements of the PT Model specification, in order to ensure that the overall model can be developed and run within a reasonable timeframe. A possible mitigation of excessive run times is to reduce the degree of segmentation within the PT assignment models.

There are a number of pros and cons associated with combining the user classes, which can be summarised as follows:

Pros

- Help minimise model run time in overall ERM, which benefits model application and forecasting.
- Help minimise model run times for PT assignment model calibration and validation allowing a greater number of model runs and the testing of a wider range of model parameters in the finite available timescale.

Cons

- *Employers-Business*, *Commute* and *Other* have different values of time (VOTs), which effects the value of perceived passenger fares. This has two potential impacts:
  - Assigned route choice where fare influences choice of service or mode. The c*ommute* and *other* VOTs are very similar and, therefore, this impact will be slight. For e*mployers-business* the impacts may be greater where more emphasis would be placed on modelled fare than in reality. However, given the small volume of trips (~200 in AM peak hour,

~300 trips in IP1 hour) then the overall impact on the assignment model will be minimal; and

    - Composite costs for the demand model where route choice and perceived fare values are both reflected. For *employers-business* this may mean the composite cost is slightly higher compared with using a separate VOT. The demand model, however, will be calibrated using the assigned composite costs from the PT Model and, therefore, the defined user classes and VOTs should not influence mode choice calibration as long as these don't change. It will mean that fare has a marginally higher influence, but as noted above the passenger volumes are very small.

- Loss of detail for economic appraisal etc. This, however, could be mitigated through manipulation of the model skims to calculate different perceived values.
- Loss of assigned flows split by *Employers-Business*, *Commute* and *Other* user-classes.

3.9 Model Network and Services

3.9.1 Network

The modelled network will be made up of the following components:

- Assigned **road network** with congested link times to estimate bus speeds;
- **Luas and rail infrastructure** taken from the Journey Planner GTFS data; and
- Walk links, which include
    - Zone centroid connectors, which are defined separately, as discussed below; and
    - Links between network nodes to allow walk routes to be created. Walk links between network nodes to allow walk routes across the network and interchange between services, e.g. rail-road connectors, off-road short cuts between modelled roads. Additional walk links have been defined based on analysis of the road network and Journey Planner database to identify where missing linkages need to be added to the PT Model. Rail-Road connectors have been prepared by defining links from each rail node to the nearest road node(s) based on actual access points and a distance based on GIS data.

The preparation of the zone centroid connectors is described in ***MSF 007_GDA IN01 PT Model Walk Connectors Note v1 5 20140311***. This provides an overview of the role of zone centroid connectors in the PT Model and their importance.

Zone centroids provide access/egress from zones to the network and services. The centroid positions should be consistent between the road model and the PT Model. Direct zone-to-stop zone centroid connectors can be added from the centroid. The best configuration of zone centroid connectors can really only be determined from analysing a network assignment, and is therefore to be determined during calibration.

3.9.2 PT Lines Files

The development of the PT lines file is dependent on the input of PT system and service data. This includes the definition of System Information and the coding of PT services.

System Information contains PT Model definition data for:

- Modes;
- Operator definition;
- Wait curves; and
- Crowding curves.

The PT lines file contains the data for the modelled PT services including the route the service will take across the modelled transport network. Individual PT lines data contains the following information:

- Mode;
- Operating Company;
- Route Type (circular/linear);
- Service Type (stopping/express);
- Headway for Modelled Time Periods;
- Short and long text descriptions; and
- Sequence of Nodes along the route.

The following broad approach will be taken when preparing the PT lines files:

- All services will initially be taken from the General Transit Feed Specification (GTFS) for February 2014. This data is prepared by the NTA Journey Planner team, is publicly available and provides a comprehensive representation of all PT services in the ERM area covering all sub-modes. Initial checks suggest this should provide a robust and accurate representation of nearly all PT services;
- Procedures have been prepared to process the GTFS data and prepare Voyager line coding. This includes the identification of stopping nodes and run times between stops, which is particularly relevant for rail and Luas services;
- The GTFS service specification will be compared with a nominal month of April 2012 to identify if any edits should be made to represent a 2012 base year. This will be based on any significant changes in PT routes and timetables between these periods;
- A review of the private bus operators included in GTFS versus those included the previous version of the ERM PT Model will be undertaken. Identified missing operator services will be manually added to the PT lines file based on the previous ERM coding which will be cross-checked against publicly available timetable data;
- Modelled headways will be based on the number of services that operate in each time period (i.e. 0700 – 1000, 1000 – 1300, 1300 – 1600 and 1600 – 1900) with the time period definition based on the timetable mid-point within the model network;
- If necessary, long distance services will be included in more than one time period, particularly those with an infrequent service pattern, to ensure connectivity throughout the model network;
- Where the strategic modelled network does not include the actual road (e.g. diversions to local settlements), the modelled service will be routed using the nearest equivalent road; and

- External (or 'route') zones will be connected to 'dummy' nodes around the edge of the ERM network to allow connectivity to the internal modelled area. External zones will be split by rail/bus sub-mode to determine the appropriate assignment mode.

3.9.3 Bus Speeds

Bus speeds in the PT Model network (where no bus lanes are present) will initially set to equal the congested road speeds (based on a completed road model assignment). Where bus lanes are coded they will be initialised to the free flow speed (from a special low-flow road model assignment).

Factors can then be applied to the initial bus speeds to account for differences between buses and cars on various link types (motorway, urban area, bus lanes, etc.).

A principle source of data for the calibration of the bus speed factors and validation of the bus journey times will be the NTA Journey Planner real time data for Dublin Bus & Bus Éireann. Validation of the modelled bus journey times to observed and/or timetable data will be presented in the PT Model Development Report. All other PT modes will be coded with run-times taken from GTFS or public timetables.

3.9.4 Bus Speed Factors Based on Link Characteristics

A low flow assignment, which will include delays related to traffic signals but not congestion, can be used to approximate normal bus running speeds in bus lanes. The table below shows the set of initial factors that should be used in the PT Model. Separate factors may be applied by time period. The factors presented for BRT may need to be reconsidered if BRT services are actually coded.

Table 3.3 Bus Speed Factors – Links Characteristics

Link characteristics	Factor
Motorway	0.95
Rural Single	0.90
Rural Dual	0.95
Urban Single/Dual	0.85
Simulation Area	0.85
Bus Lane	0.95
BRT factor on Bus Lane	0.95
BRT factor on normal road	0.90

3.9.5 Bus Speed Factors Based on Service Type

This step allows for a second factoring of the bus speeds, because it is sometimes necessary to differentiate speeds between urban services (which stop frequently, e.g. every 400m), inter urban services, and express services. Separate factors may be applied by time period. The initial values to be applied across all time periods are outlined in the table below. Note that these are expressed as time factors rather than speed factors and are applied during the line coding stage of the GTFS process outlined above in Section 3.9.2.

Table 3.4 Bus Time Factors – Service Type

Type	AM	LT	SR	PM	Description
Urban	1.39	1.36	1.41	1.39	Urban Bus services
Normal	1.15	1.15	1.20	1.23	Non-Urban services, non-express
Express	1.10	1.10	1.10	1.10	Non-Urban, express services

3.10 Matrix Preparation

The PT Model demand matrices will be based on the prior matrices prepared in ***FDM Scope12 Base Year Matrix Building***. These matrices are prepared using POWSCAR data where applicable with remaining journey purposes synthesised using the Trip End Model trip ends and a preliminary estimate of PT Model generalised costs for distribution.

As part of the PT Model development these matrices will be adjusted using available observed PT data to ensure a better representation of PT travel movements. Available data includes ticket sales data for rail, Luas and bus as well as complimentary passenger census data.

Figure 3.2 provides a summary of the data sources that will be used to prepare the PT Model demand matrices.

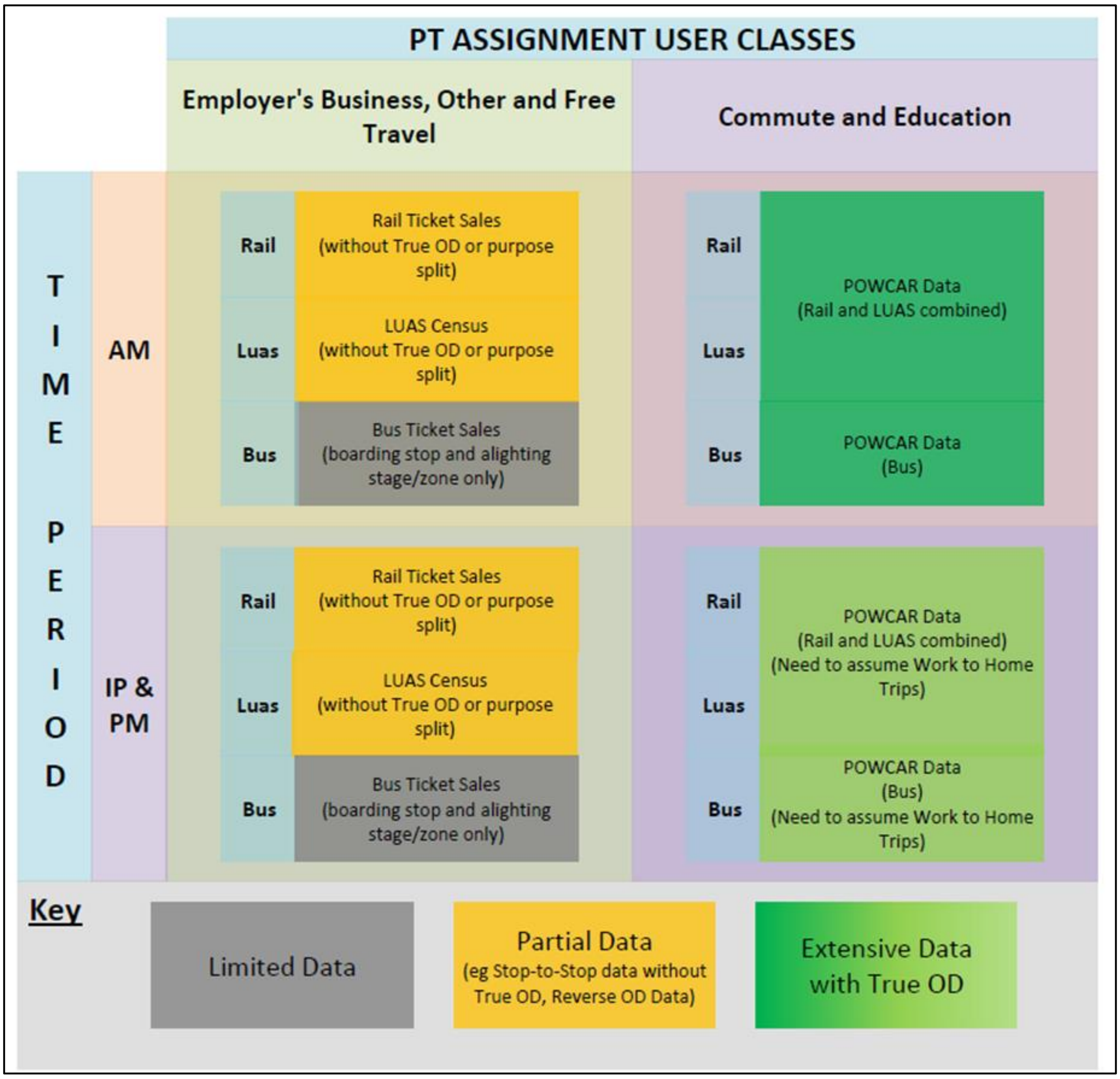

Figure 3.2 PT Model Matrix Data Sources

The following steps will be undertaken to prepare the demand matrices:

- Annual sector matrices by mode will be prepared based on available rail, Luas, Dublin Bus, and Bus Éireann ticket sales and census data:
- These matrices will be combined to produce a sectored annual demand matrix for nearly all passenger movements in the modelled area;
- Annualisation factors (prepared in Task 05 System Architecture using household survey travel diary data) will be applied to derive weekday demand matrices;
- The prior matrices from Task 08 Demand Model will be aggregated by all demand segments and time periods and sectored to prepare weekday matrices equivalent to the combined ticket based matrices;
- A flag matrix will be prepared to identify sector movements where there is missing data for Bus Éireann or private operator services (, e.g. serving Swords), and where no factors will be applied to the prior matrices;

- **Expansion factors** will be derived and applied at a weekday sector level to match the prior matrices (minus non-observed data) to the combined ticket based matrices. This will retain the underlying zone origin/destination, journey purpose and time period segmentation from the prior matrices; and
- **Further factors** will be applied as necessary to the time period matrices during the model calibration to achieve a better match against observed passenger flow data. This additional factoring process will be based on analysis of the assigned demand and the variance in modelled and observed flows.

The above process is summarised in Figure 3.3.

Figure 3.3 PT Model Matrix Preparation

The following steps will be undertaken to prepare sector matrices by mode from the ticket sales and census data.

- **Rail** station to station demand will be derived from annual ticket sales data. This is not a comprehensive record of all rail station pairs but review of the data indicates that the majority of key movements are included. There is a shortfall in annual passenger numbers compared with the Irish Rail Annual Report figures and this is likely to be due at least in part to the omission of free travel passenger journeys as well as fare evasion. Estimated annualisation of weekday passenger census figures correspond well with the Irish Rail Annual Report figures. Therefore, in the absence of any other data sources the rail passenger demand at a station to station level will be estimated from the tickets sales data furnessed to match the weekday passenger census. This will be aligned to the ERM zones sector system to prepare sectored annual rail demand matrices.

- **Luas** station to station demand will be derived from a combination of passenger census OD (single day) and annual ticket sales data to determine average weekday demand. This provides a comprehensive record of all Luas station pairs for all ticket types. This will be aligned to the ERM zones sector system to prepare sectored annual Luas demand matrices by time period.
- **Dublin Bus** stage based ticket data, disaggregated by route and number of stages, will be aligned to the ERM zones sector system to prepare sectored annual Dublin Bus demand matrices. This includes all passengers but some assumptions will need to be made regarding the number of stages travelled for Leap Card, TaxSaver and free travel scheme passengers, which will be estimated from cash fare data.
- **Bus Éireann** 2013 ticket sales journeys data for available journeys will be aligned to the ERM zones sector system to prepare sectored annual demand matrices. This is not a comprehensive record of all Bus Éireann passenger volumes or routes. However, data is available for a significant number of key routes, and where data cannot be obtained the equivalent sector movements will need to be classed as unobserved and demand entirely synthesised.

3.11 Park & Ride Integration

Park & Ride will be fully integrated within the ERM Full Demand Model. This will provide estimates of Park & Ride demand, which will be calibrated in the base year and forecast in future years. This will include separation of the road and PT legs of Park & Ride trips that will then be incorporated in the road and PT assignment matrices for the appropriate demand segments.

The PT leg generalised costs will form a significant component of park & ride generalised costs which are input to the demand model and specifically mode choice. Therefore, there is a process of iteration between the calibration & validation of the PT Model, road assignment model, the Park & Ride model and the overall ERM demand model. This ultimately requires the ‘lock-down’ of each individual model in a pre-determined order and this will be coordinated within Task 05 - System Architecture. The current proposed hierarchy for ‘locking down’ the final ERM base year model is as follows:

- calibrate & validate the Road Assignment Model and fix the demand matrices and, hence, generalised costs and assigned speeds for the PT Model;
- calibrate & validate the PT Model and fix the demand matrices and, hence, generalised costs;
- calibrate & validate the Park & Ride Model and fix the input true-OD demand matrices and reproduce the output assignment model demand legs to match the assignment models; and
- Calibrate the overall Demand Model to reproduce the true-OD Park & Ride demand matrices and the assignment model demand matrices.

3.12 Assignment Methodology

3.12.1 Assignment Procedure

The Voyager frequency and cost-based strategic PT assignment method will be used. The choice of routes (and sub-modes) will be based on a generalised cost based formulation of travel costs that includes fares, in-vehicle travel times, waiting times, boarding penalties and interchange penalties.

The path building and loading procedures will be developed using the CUBE Voyager PT assignment model software.

The model assignment is split into two stages as follows.

- Route Enumeration:
  - This identifies a set of discrete routes between each zone pair, along with the probabilities that passengers will use each route. Routes that fail to meet certain criteria are discarded. The criteria are specified using the Spread Factor and Spread Constant parameters that define the range of routes that will be retained for each zone pair based on their generalised time relative to the minimum generalised time. Fares are not included explicitly at this stage but a mode specific run-time factor, exclusively used in route enumeration, is used to make a proxy of the impact of fare on generalised costs. Passenger crowding is not considered within this Route Enumeration stage.
- Route Evaluation:
  - This calculates the "probability of use" for each of the enumerated routes between zone pairs, including the impacts of crowding and fares. This includes the following sub-models:
    - → Walk Choice Model – applied when passengers have alternative walk choices available, i.e. access/egress to services, transfer between services;
    - → Service Frequency and Cost Model - allocates passengers to the transit choices available at a stop taking account of headway/frequency and cost to destination; and
    - → Alternative Alighting Model – applied when a line has two or more valid alighting points.

Further details on the PT assignment processes can be found in the Cube Voyager software help documentation.

3.12.2 Assignment Parameters

Values of time were determined as part of the demand model development to ensure consistent values are used throughout the model, and ensure compliance with the relevant guidance, e.g. TAG. These are detailed in the Exogenous Variables Note (titled MSF 008_GDA 8.3.05 Exogenous Variables v2 3 20150120). Other components of generalised cost will be treated as calibration parameters and adjusted within reasonable bounds during the calibration process.

The appropriate definition of assignment parameters will ensure the PT Model provides robust estimates of sub-mode choice, assignment and generalised cost before integrating it into the full model. A number of assignment control parameters will be adjusted to ensure that the model represents the base year situation and can respond to proposed changes in future tests. Key parameters 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 even different vehicle types; and
- **Wait Curves and Factors** - these relate service frequencies to the actual perceived wait time experiences by passengers. This is especially important when journeys involve interchange and services of differing frequencies which is common, for example rail links to onward bus travel.

Table 3.5 shows the indicative PT Model parameters which will be determined as part of the model calibration. This includes lower and upper values for each parameter as well as the initial value for testing. Each demand segment and time period can have its own defined set of parameters though this will only be applied where necessary.

The enumeration parameters will be defined based on achieving a reasonable range of enumerated routes for assignment, while maintaining practical model run-times. All other parameters will be based on standard ranges – either from the previous version of the GDA model or from other models or studies. They will be adjusted within these standard ranges during the iterative calibration of the model to ensure the overall ERM gives a good match of observed modal split and passenger loadings.

The Consultants have recently completed a stated preference exercise relating to BRT in the Dublin area[1]. This study provides a range of parameters that will also be referenced and used to provide initial parameter values where appropriate, e.g. in-vehicle weights.

[1] From BRT Stated Preference, see ***20140122 30009226 NTA BRT Stated Preference Research - Final Report v1.5***

Table 3.5 Indicative PT Model Parameters Ranges for Calibration

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	0	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 Section 3.12.3		
Crowd Model Parameters	see Section 3.12.4		

3.12.3 Wait Time

A wait curve will be implemented for all PT lines in the PT Model. This defines the relationship between services headways and perceived wait times. PDFH is the best available U.K. source for defining wait curves and Table 3.6 shows the wait curve values for Non-London inter-urban and urban, which are considered most appropriate for the Dublin area.

Table 3.6 Wait Curve Definition

HEADWAY	PERCEIVED WAIT TIME (MINUTES) INTER-URBAN	PERCEIVED WAIT TIME (MINUTES) URBAN
5	5	5
10	10	10
15	14	14
20	18	18
30	23	24
40	26	28
60	31	35
90	39	45
120	47	55
180	63	74

Figure 3.4 shows the PDFH wait curves and compares these with the wait curves included in the previous version of the ERM PT Model and indicates that they are very similar. This also highlights the higher perceived wait times associated with headways above 30 minutes for the PDFH Urban curve, which is considered intuitive where typically urban services have lower headways than inter-urban services with associated passenger expectations.

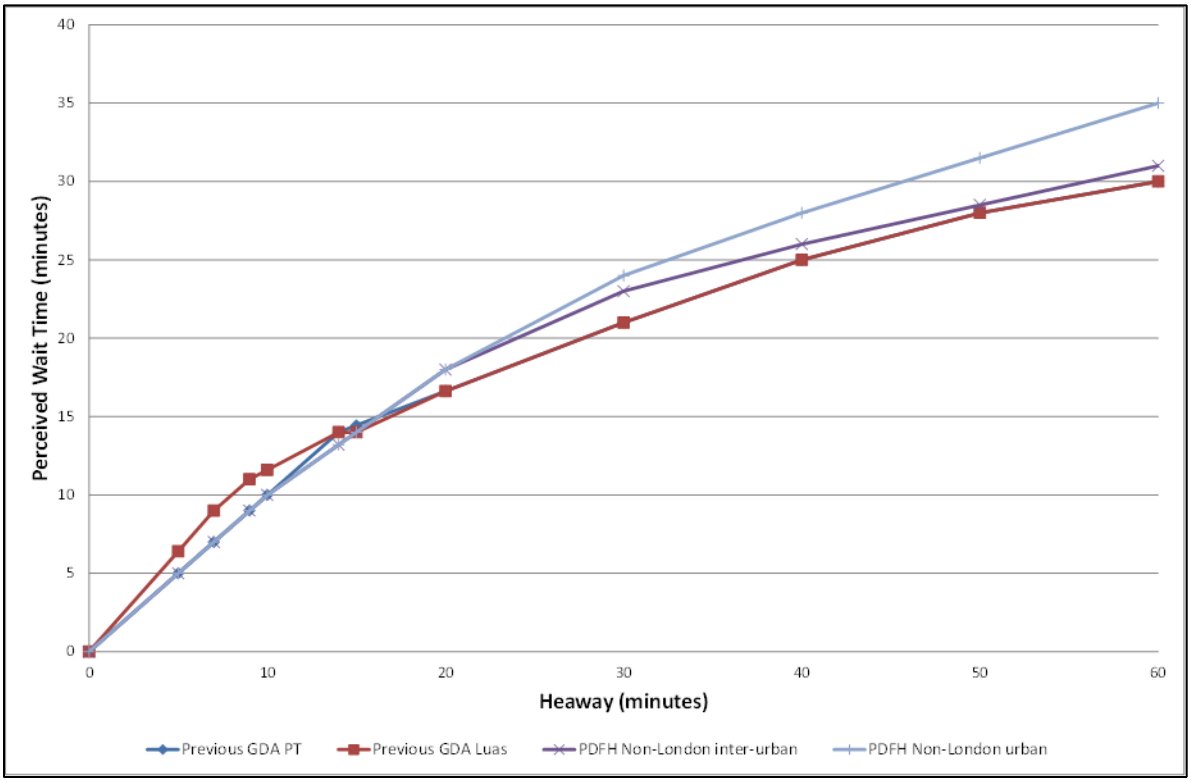

Figure 3.4 Wait Curves

It is proposed that the PDFH Non-London Inter Urban curve is applied to DART, Luas, Dublin Bus and other Bus services in the PT Model. This can be reviewed during the PT Model calibration, if necessary, with adjustments made to reflect ERM characteristics, e.g. if Luas services would be better represented with a different wait curve as per the previous ERM.

It should be noted that the maximum perceived wait time will initially be capped at 60 minutes for all modes, which is in line with common practice and considered appropriate for the ERM. The curves in the ERM model will be based on half the headway at first and decline with increasing headway.

3.12.4 Crowd Model

Ideally crowding should be modelled for all bus and rail services where available service capacity is an issue; however, crowd modelling significantly increases model runtimes and could therefore be applied selectively to reduce this effect. As a minimum, crowding will be included in the PT Model for the morning and evening peak for rail and Luas services. The model structure allows the user to model crowding effects on tram /metro services in forecast years, if required.

Crowding is not typically considered to be a significant issue outside the peak periods and therefore it is proposed that it is not applied in the Inter Peak period assignment. This also assists in reducing model run times.

Typically, no crowding modelling calculations are performed for bus services, as it is assumed that operators will be likely to increase the vehicle capacity and/or service frequency on routes where demand regularly exceeds vehicle capacity, and thus the average load factors are likely to remain broadly constant over time. For the ERM, however, anecdotal evidence suggests Dublin Bus services are capacity constrained and therefore crowding should be modelled on bus services as per the previous versions of the Greater Dublin Area Model.

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. Convergence of the model is achieved when the PTs loadings (and hence the crowding costs) do not change significantly between iterations.

The number of iterations is specified by the user. A review of the convergence of the Base Year model will be undertaken. Typically, five iterations of the PT crowding loop will generally be sufficient for a model of this nature. Model users should consider reviewing the number of iterations depending on the interventions being tested in forecast mode.

The PT crowding assignment requires the specification of the following data:

- PT line capacities;
- PT crowding curves; and
- Passenger and vehicle arrival profiles.

Line capacities will be required for all services in the base year where the crowd model is applied.

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 capacity is reached. Utilisation is 100% when the vehicle is at crush capacity, i.e. all standing room is taken. Crush capacity data will also be required for all services in the base year where the crowd model is applied.

Figure 3.5 shows the Passenger Demand Forecasting Handbook (PDFH versions 4 and 5) crowd curves and compares these with the crowd curves included in the previous (2006 base) version of GDA Model. This indicates that the previous version of PDFH (version 4) that has been used as the basis of the previous ERM rail crowd curve with slightly lower crowd penalties for Luas and bus. The more recent PDFH (version 5) guidance recommends that the measure of crowding '*is taken to be the load factor up to 100% of seats being taken, and the standing passengers per m^2 of standing space beyond that*'. This approach is based on rail passenger surveys conducted in 2008, and is a change from PDFH version 4, with a notable increase in the crowding penalty.

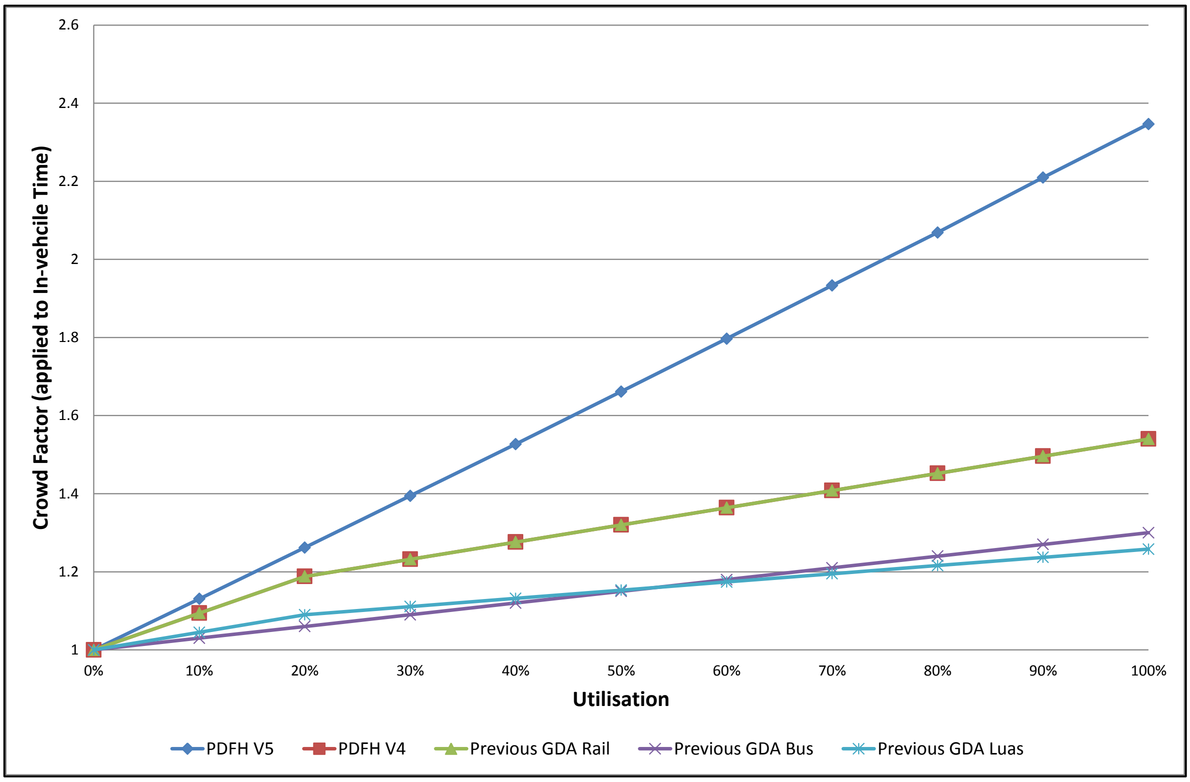

Figure 3.5 Crowd Curves

The best approach for applying crowd penalties and associated curves will require to be reviewed in respect of PT service vehicle specifications and characteristics in the model area. For example, Luas vehicles are designed to accommodate a significant number of standing passengers and the PDFH measurement may not be appropriate where a penalty is applied for any level of standing. It is initially proposed that the old ERM crowd curves are used initially and this can be reviewed during the PT Model calibration, if necessary.

3.13 Fares Model

Fares typically form a significant component of a PT journey generalised cost and, therefore, should be represented as accurately as the available data allows.

Voyager provides for the following fare systems in the Evaluation stage:

- Free fares;
- Flat fares;
- Distance based, typically specified as a curve which can be stepped or interpolated between specified fare-distance points;
- Concentric / annular zones based on the boarding and alighting stops; and
- Non-concentric zones, either based on the number of zones traversed (e.g. if 3 zones are crossed then the fare would be €X) or on the sum of fares associated with each zone traversed (e.g. if zones ***x, y*** and ***z*** were crossed the fare would be fare***x***+ fare***y*** + fare***z***).

Voyager does allow for a number of different fare structures to be used in a single assignment. Typically, a fare structure will be set for each operator or mode. Voyager also allows for an approximation of through ticketing by use of a fare reduction where a transfer between lines or fare systems occurs.

The Fares Model for the ERM PT Model will be based on a set of free, distance-based and station to station fare tables. Fare tables will be allocated to modelled operators by user class. The following steps will be undertaken to prepare the fare tables:

- All fare tables will be prepared in terms of a 2010 price index;
- It is initially suggested that the same fare tables will be used in all time periods and across all demand segments. This could be considered further if their available data or evidence to suggest any segmentation of fares. E.g. commuters may use a greater proportion of season tickets; however, there is limited evidence to inform how a specific average commuter fare could be determined;
- Free travel fares will be coded with zero fare;
- Rail and Luas fares will be defined by station pair and prepared using the same ticket data sources as the demand matrix preparation as follows:
    - Revenue and journeys data used to derive average fares with indices applied to represent all available years equivalent to 2012 fares in 2010 prices; and
    - For station pairs without tickets sales data or with very low annual passenger volumes, distance based fares will be based on rail distances and average fare per kilometres. This will be estimated from the aggregated ticket sales data on an area basis to reflect any regional variations. Free travel passenger volumes will be removed before calculating the average fares.
- Stage based Dublin Bus fares will be defined based on ticket data as follows:
    - Ticket sales data will be used to determine a weighted average fare based on the number of journeys for each fare value. 2012 data is available disaggregated by route, number of stages and fare value. This excludes free travel passengers;
    - The data includes Leap Card and TaxSaver fares and therefore should provide a good representation of the average fare paid by all passengers.
- Distance based Bus Éireann fares will be defined based on average distances as follows:
    - 2013 ticket sales revenue and journeys data for available journeys will be processed to derive average fares. This will be correlated with the equivalent distances to define a distance based fares table;
    - Indices will be applied to represent 2013 data equivalent to 2012 fares in 2010 prices;
- For private bus operators NTA licensing data or publicly available fares information will be used. Where appropriate, these fares will be factored based on Dublin Bus and/or Bus Éireann data to account for the use of season tickets and other reduce fare products. Where no fares information is available the Dublin Bus and/or Bus Éireann fares tables will be used as appropriate or an assumed fare. This is not considered to be a significant issue as there will be few operators who will fall into

this category and these be will relatively minor in scale with limited impact on the assignment and generalised costs; and

- Transfer fares between fare systems will be determined based on the available Leap Card and TaxSaver ticket data. This can be a negative value that is applied to reflect the benefit of through fares. An average value will be derived for each fare table to represent the average for all passengers based on the uptake of Leap Card and TaxSaver tickets for valid passenger movements.

4 RMS Public Transport Calibration & Validation

4.1 Overview

The calibration & validation process will be undertaken for the PT assignment component and the PT matrices within the ERM, by comparison of model outputs with the following observed data (assuming this data is available):

- Passenger loadings (link counts);
- Boarding and alighting volumes;
- Passenger flows on key movements;
- Passenger loadings versus service capacities;
- Bus journey times; and
- Revenue.

4.2 Calibration Approach

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 ERM. This is typically achieved in iteration with the validation of the model to independent data.

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. Table 3.5 above shows the indicative PT Model parameters which will be determined as part of the model calibration.

4.3 Validation Approach

The validation of the ERM PT Model will compare the modelled passenger flows with equivalent observed data across screenlines/cordons, boarding/alighting volumes at rail and Luas stations and on specific cross-network movements. Comparisons of annual ticket sales revenue and analysis of modelled loadings versus capacities will also be undertaken. Bus journey times will also be validated against observed data.

The following sections describe each of these validation elements. All validation data will be tabulated and provided in full in the PT Model Development Reports for each Regional Model.

As noted above, the UK DfT TAG guidance is considered the most relevant for the ERM and this includes validation criterion for PT assignment models. An exploration of non-UK guidance has been undertaken to determine if any other international calibration & validation standards would be appropriate for the ERM. Table 4.1 provides a summary of the available guidance for PT assignment model validation.

Table 4.1 PT Assignment Model Validation Guidance Sources

Organisation	Location	Guidance	Description
UK Department of Transport	UK	WebTAG Unit M3.2 PT Assignment	UK guidance for transport appraisal Validation criterion for passenger flow comparisons
Florida Department of Transportation Systems Planning Office	Florida (US)	FSUTMS Principles of Model Calibration Validation	Guidelines on transport modelling calibration Guidelines for PT service times using root-mean-square error (RMSE)
ARUP - Hong Kong planning department	Hong Kong (China)	HK Transport Modelling Approach and Validation	Report on a multi modal transport model calibration Validation criterion for passenger flow comparisons though less onerous than UK TAG
CERTU	France	Modélisation des déplacements urbains de voyageurs - Guide des pratiques	Guidelines on Transport modelling in urban areas Validation criterion for passenger flow comparisons slightly more onerous than UK TAG but on a more limited sample

Inspection of Table 4.1 shows that there is limited guidance relating to the calibration & validation of PT assignment models beyond the UK DfT Transport Appraisal Guidance (TAG). Where alternative international guidance is available this is not dissimilar to TAG with only the French CERTU providing a slightly more onerous validation criterion. Therefore, it is considered that application of TAG is the most appropriate approach for the ERM PT Model validation.

4.3.1 Passenger Flow Comparisons

Two passenger count cordons will be defined as follows based on the available data:

- Inner Dublin Canal cordon (see Figure 4.1); and
- Outer Dublin cordon (see Figure 4.2).

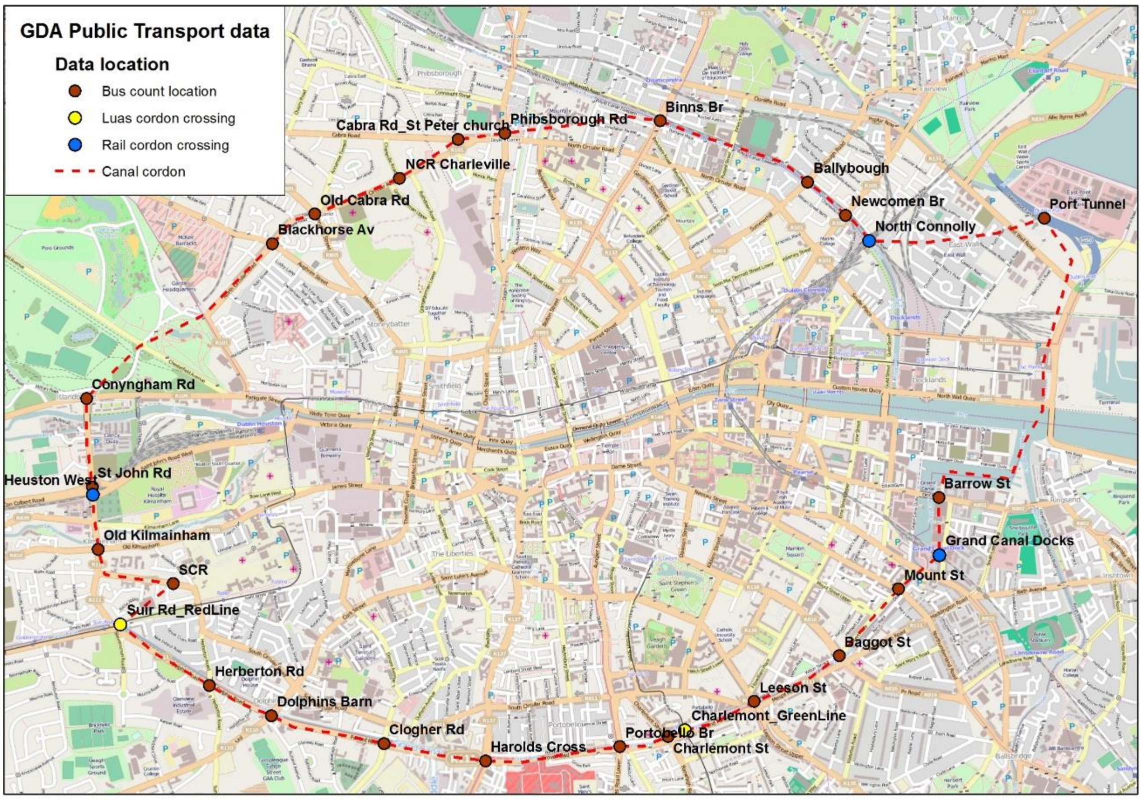

Figure 4.1 Inner Dublin Canal Cordon

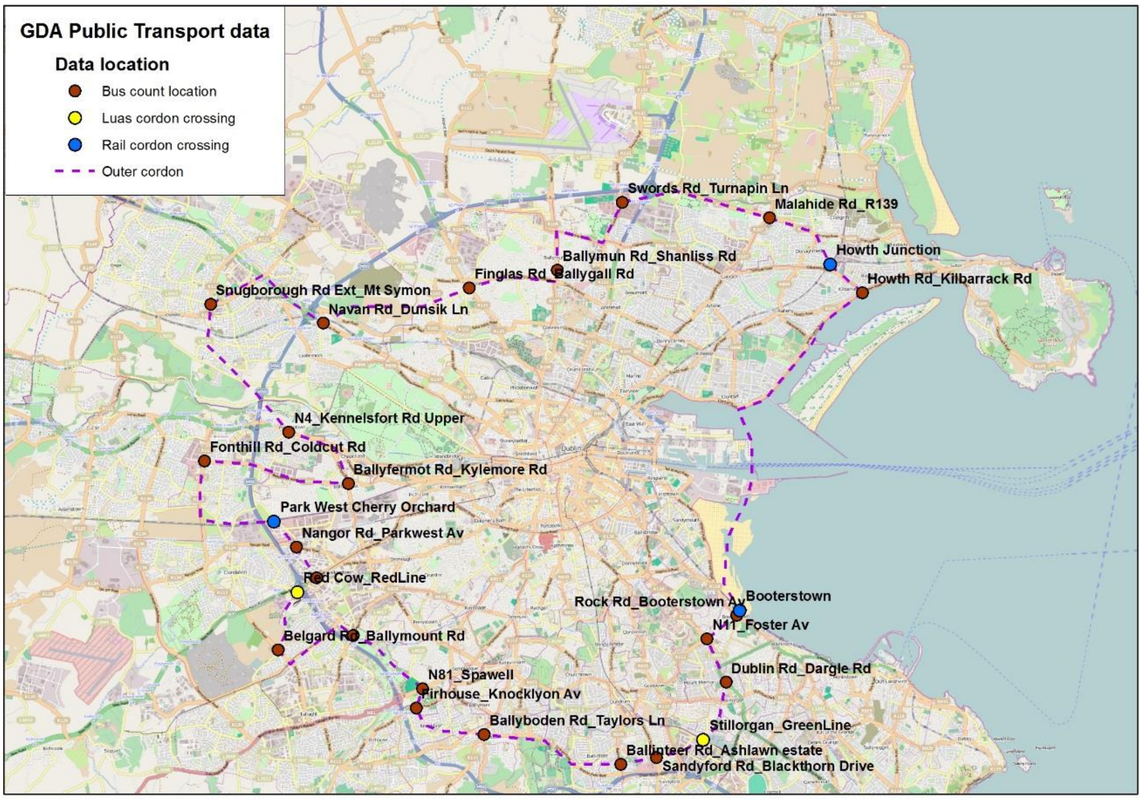

Figure 4.2 Outer Dublin Cordon

The following data sources are available for the passenger loading comparisons:

- 2011 bus census of passenger flows for the above cordons. It should be noted that data is only available for the PT Model modelled morning peak period. Data is also available for the afternoon Inter Peak (1300-1600). 2012 data is also available for the canal inbound cordon only;
- 2012 Luas census of passenger flows between stations, which can be aligned to the above cordons. This is available for all PT Model modelled time periods; and
- 2012 and 2013 rail (including Dart) census of passenger flows between stations, which can be aligned to the above cordons. This is available for all PT Model modelled time periods.

The limited bus passenger flow data means that a full multi-modal comparison of passenger flows can only be undertaken for the PT Model morning peak. Further data collection would be required for the remaining two PT Model time periods (Inter Peak and PM Peak).

TAG unit M3-2 indicates that the following passenger flow validation criterion should be considered:

- Modelled PT flow should ideally fall within 15% of observed flow across appropriate screenlines; and
- Modelled PT flow should ideally fall within 25% of observed flow on individual links, except where observed flows are particularly low (less than 150), on individual links.

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

The GEH Statistic is defined as:

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

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

The GEH statistic is typically used for the validation of road assignment models. It is, however, also a useful indicator for PT assignment model though a greater level of tolerance would be expected due to the higher level of variation of PT data. In the absence of official guidance it is considered that, for a model of this complexity and size, a GEH of five or less is considered to be excellent. Values between five and 10 are considered to be acceptable. Values outside this range will require explanation to understand the differences (e.g. there may be questions regarding the integrity of specific counts in comparison to other proximity data).

4.3.2 Boarding and Alighting Volumes

Rail and Luas boarding/alighting data will also be taken from the relevant census data and compared with equivalent modelled flows. This will be undertaken for all Luas and Rail stations in the internal modelled area. Stations will also be grouped by location to validate the modelled boarding/alighting volumes by area, e.g. Dublin city centre, north suburban Dublin etc.

Dublin Bus boardings from ticketing data are available for a single day in May 2014. These will be compared with equivalent modelled flows on an area basis, e.g. bus stops assigned to the standard ERM sector system.

TAG M3.2 states that '*wherever possible, a check should be made between the annual patronage derived from the model and annual patronage derived by the operator*'. This will be achieved through annualisation of the specific time period boarding/alighting data to estimate annual figures for the observed and modelled flows. This will provide a useful indicator of the overall PT Model performance across all four time periods. Annual tickets sales data will also be referenced, noting that this is an independent dataset and that there may be some differences in how the data is structured, e.g. boarding/alighting volumes at interchange points may not be included in through ticket volumes.

The validation criteria for the boarding/alighting comparison will follow that for the passenger flow comparisons, i.e. modelled flow within 15% across all stations and within

25% of observed for individual stations. Where flows at individual stations are low (less than 150) then the GEH statistic will provide a useful alternative indicator.

4.3.3 Revenue

Annual ticket sales data is available for Irish Rail (including Dart), Luas, Dublin Bus and Bus Éireann. Equivalent model revenues can be skimmed in the PT Model and annualised using the same annualisation factors used in the matrix development.

This revenue data can be used to inform matrix calibration, which will be restricted to journeys within the ERM internal model area to obtain directly equivalent data. Comparisons will include annual revenue by sub-mode, i.e. rail, Luas, bus. Although there is no specific criterion for the validation of annual revenue, the passenger flow criteria of modelled flow within 15% of observed for aggregate cordons/screenlines will be used as a proxy.

4.3.4 Loadings versus Capacity

Another useful indicator for the validation of the PT Model is the comparison of modelled passenger flows versus modelled capacities, assuming that the PT Model will include crowding on the PT lines. This analysis will provide the ratio of passenger flow to seated capacity on modelled rail links and individual services. This will highlight where the most crowded services within the modelled network are and this can be compared with the previous ERM, anecdotal evidence and anticipated behaviour. For example, crowding levels in the AM Peak can be compared with the PM Peak.

This analysis will combine the modelled passenger flows and boarding/alighting volumes to prepare a series of graphs showing the service loadings by line and direction, e.g. LUAS Green Line Northbound, by time period. Figure 4.3 shows an example graph with ‘dummy’ data.

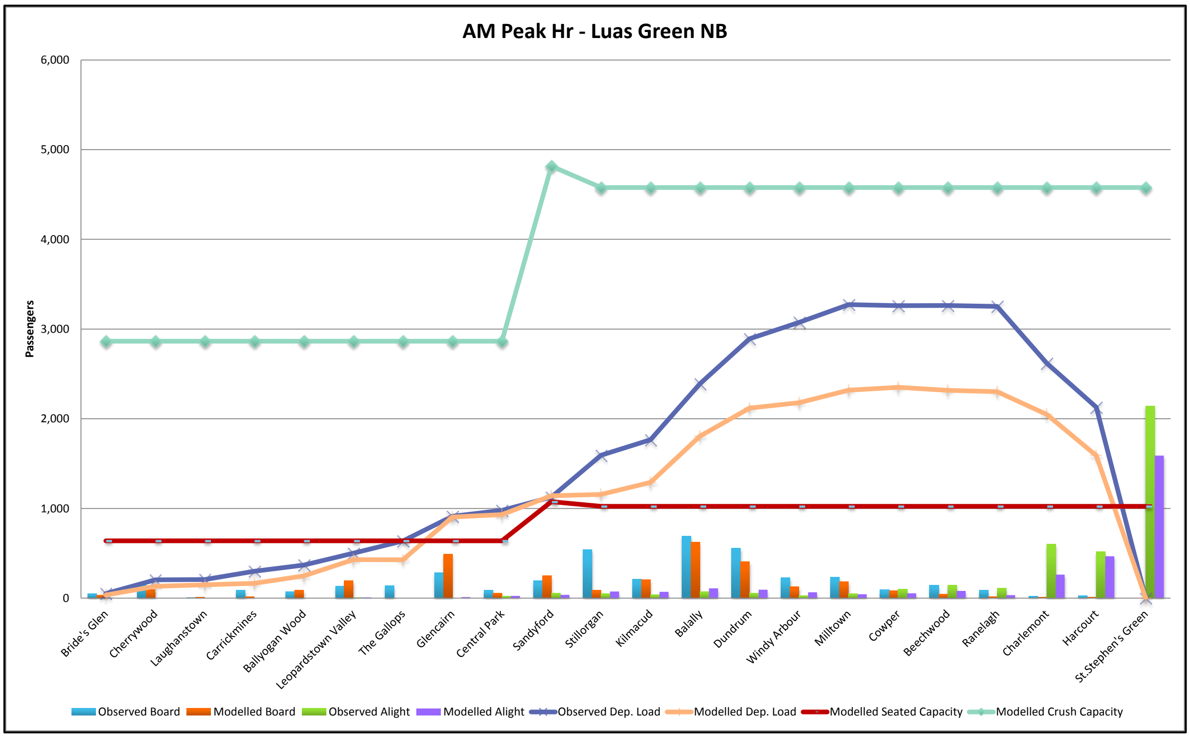

Figure 4.3 Example Service Loading Graph

4.3.5 Bus Journey Times

As noted in Section 3.9.3, modelled bus journey times will be compared with observed data and this will be undertaken in tandem with the calibration of the bus speed factors. The principle source of data will be real time data for Dublin Bus & Bus Éireann (through the Automatic Vehicle Location system). Where data is not available, (e.g. for private operators) timetable route times could be taken from GTFS. Timetable route times will also be compared with observed times to check for any anomalies.

Bus journey times will be compared for all routes in each time period. There is no specific guidance in TAG regarding the validation of modelled PT journey times. The validation criteria for highway assignment journey times (TAG M3.1) will be used as a proxy where modelled times along routes should be within 15% of surveyed times. This criterion is considered very exacting for a PT assignment model and may not be achievable for all routes. Where data is available the confidence intervals of observed times will be presented alongside the modelled times.

A scatter plot of observed versus modelled bus times will be also prepared (see example in Figure 4.4), which will highlight any outlying routes and assist with the calibration of the bus speed factors.

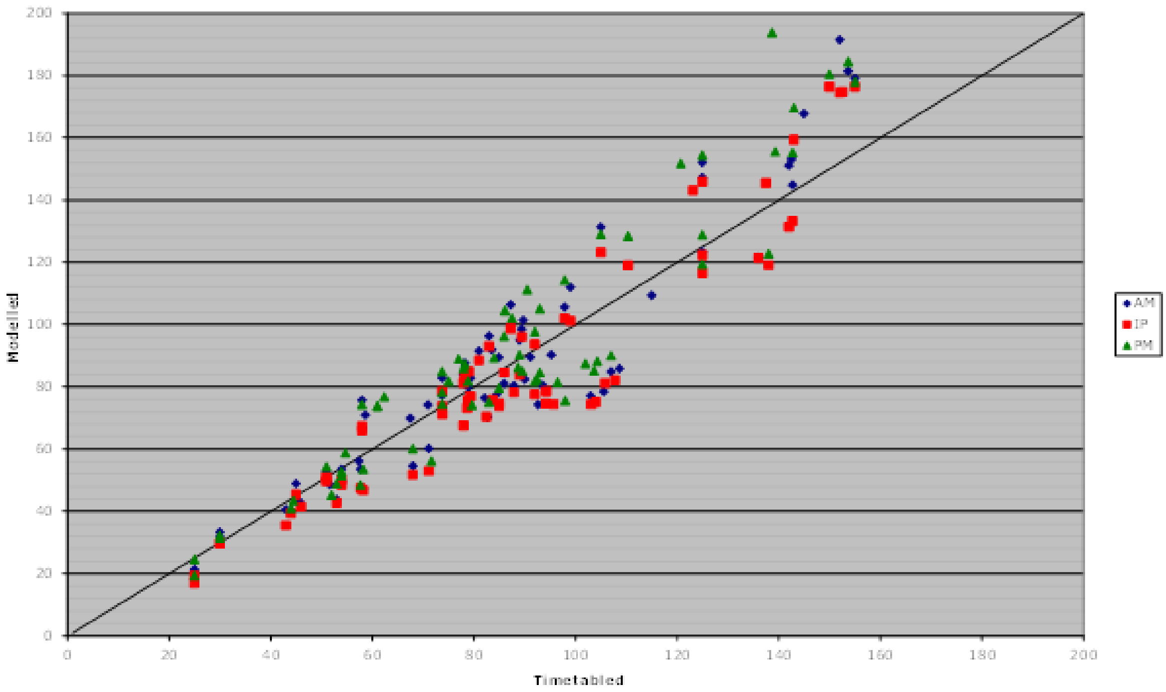

Figure 4.4 Example of Bus Times Scatter Plot

National Transport Authority
Dún Scéine
Harcourt Lane
Dublin 2

Údarás Náisúnta Iompair
Dún Scéine
Lána Fhearchair
Baile Átha Cliath 2

Tel: +353 1 879 8300
Fax: +353 1 879 8333

www.nationaltransport.ie