REGIONAL MODELLING SYSTEM

**Modelling Services
Framework**

Regional Modelling System

Full Demand Model Specification Report

Údarás
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Foreword

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

The Regional Modelling System comprises the National Demand Forecasting Model (NDFM), 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 the 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 NTA, SYSTRA and Jacobs Engineering Ireland.

An overview of the 5 regional models is presented below in both Table **0.1** and Figure **0.1**.

Table 0.1 List of Regional Models and their area of coverage

Model Name	Code	Counties and population centres
Western 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
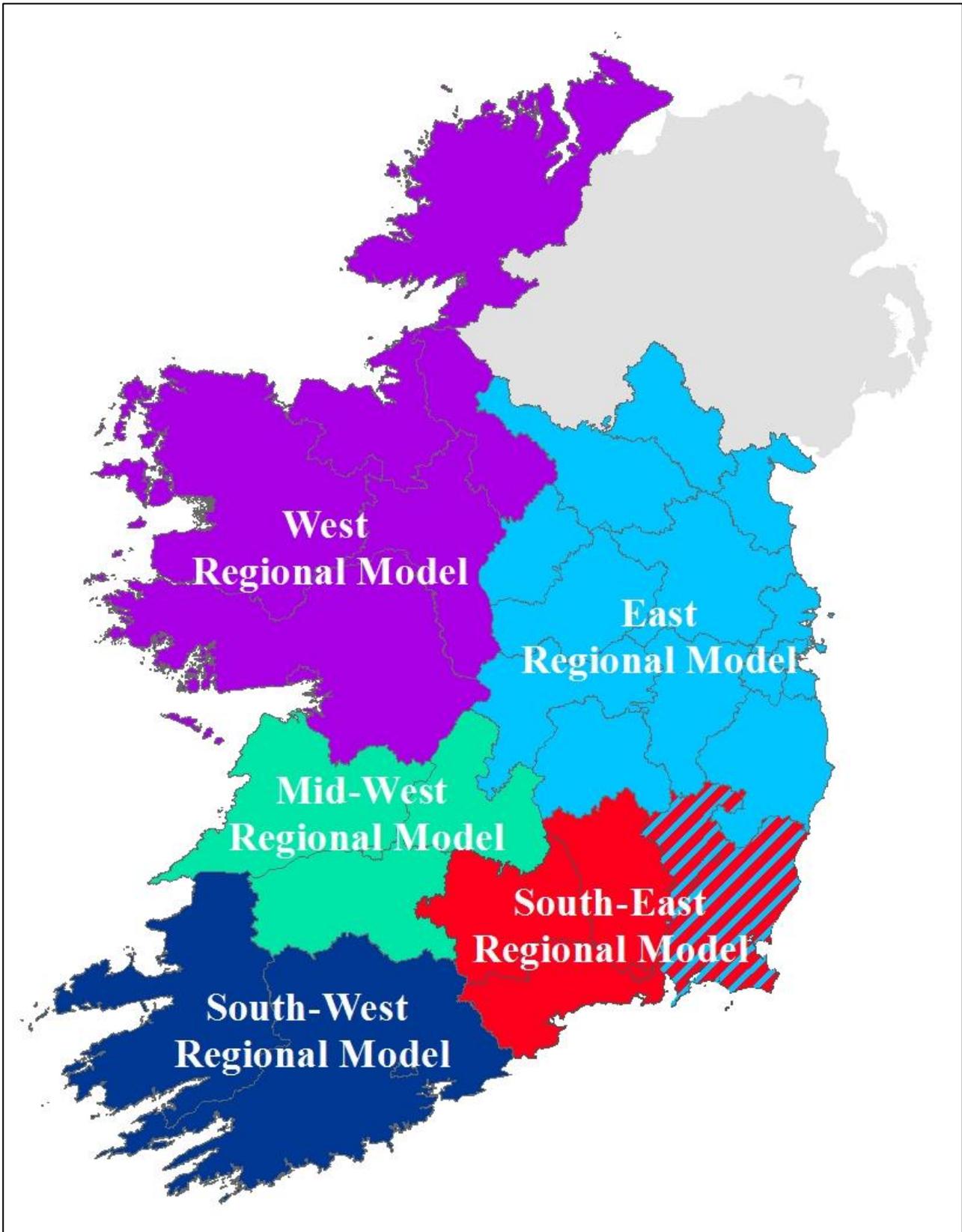
Figure 0.1 Regional Model Areas (the ERM and SERM overlap in the hashed area)

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 regional models is shown below in Figure **0.2**. 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

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.

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.

1.2.3   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
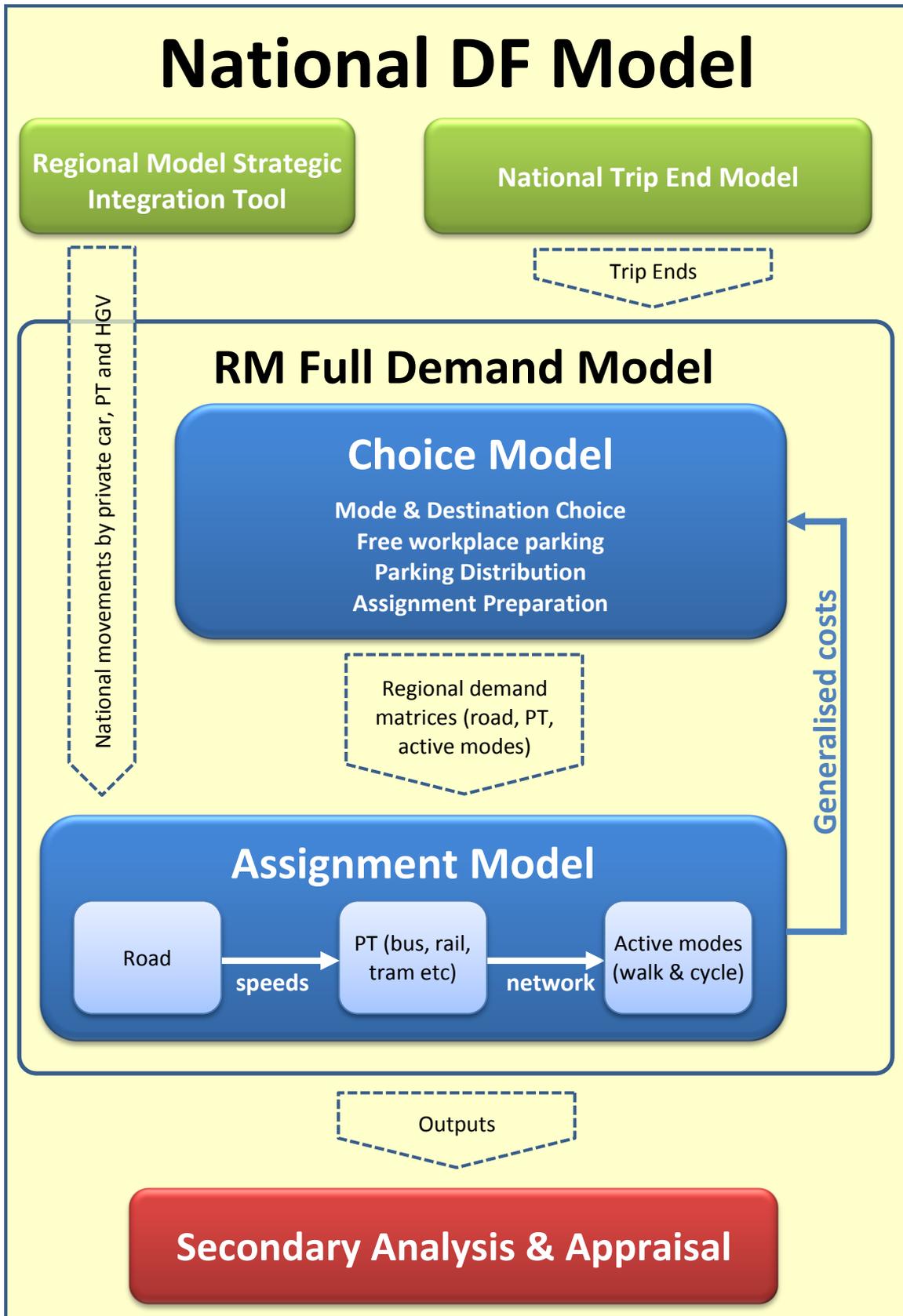
Figure 0.2 National and Regional Model Structure

1.3 Full Demand Model (FDM)

The full demand model is common across all five regions of the RMS. Its form is of the 'absolute' type, so trip matrices for each forecast year are calculated directly from input trip ends and costs. Figure **0.3** on Page 9 shows an overview of the different modules of the FDM, including those which have yet to be fully implemented (in green). The purpose of the FDM is to take input trip ends (at the 24-hour level) and costs (from the road, PT and active modes assignment models) and then to allocate trips to different time periods, modes and destinations for input to the peak-hour road, PT and active modes assignment models.

The FDM consists of the following modules:

- **Trip End Integration:** Converts the 24-hour trip ends output by the National Trip End Model (NTEM) into the appropriate zone system and time period disaggregation for the RMS;
- **Add-in Preparation:** Takes the output of the Regional Model Strategic Integration Tool (RMSIT), factors it if necessary, and converts it into the zone system and time period disaggregation required by the RMS. In addition, it also reads in internal goods movements, and can apply a growth factor to them, and subtracts the long distance movements from the trip ends passed on to the later stages of the model;
- **Initialisation:** Converts the trip ends into tours and the costs into the required formats;
- **Tour Mode & Destination Choice:** Calculates where each production trip end will match with an attraction trip end, and by what mode the trip will be made, given the time when the trip will take place;
- **Free Workplace Parking:** For the journey purposes which have free workplace parking the initial mode & destination choice does not include parking charges. This module takes the initial car demand and decides whether it can be accommodated in the available free workplace parking spaces. For the proportion of the car matrix which cannot be accommodated, and for the corresponding proportions of the other mode matrices, it undertakes a secondary mode split including parking charges;
- **One Way Mode & Destination Choice:** Similar to the main mode & destination choice stages except that it works on the one-way trip inputs;
- **Special Zone Mode Choice:** Models mode choice for zones such as ports and airports which are forecast differently than the regular population. Demand must be input for the peak hour in each time period;
- **User Class Aggregation:** Aggregates the initial 33 trip purposes into five user classes for further processing;
- **Park & Ride:** This module takes the trips assigned to Park & Ride by the mode & destination choice stage, works out which Park & Ride site each will use, and outputs the car and PT legs of each trip as well as information to be used in the calculation of the generalised costs;
- **Parking Distribution:** This allows car trips to park remotely from their destination, which is critical where parking capacity is limited or cheaper parking is available nearby. It only applies to certain areas in each of the regional models. The module gives car trips the choice to park in a number of alternative zones, based on the total trip cost and adds a

penalty to over-capacity zones. It outputs the car and walk legs of each trip, as well as information to be used in the calculation of the generalised costs;

- **Parking Constraint:** For models where the details of parking distribution are not of interest this module can be used to apply a basic limit on car demand.
- **Tour to Trip Conversion:** Takes the tour based information, including that using free workplace parking, and converts it into the outbound and return legs needed by the assignment;
- **Assignment Preparation:** Combines the tour based and one way trips, special zone movements and Add-ins and applies vehicle occupancy and period to peak hour factors as appropriate. It also applies incremental adjustments, calculates taxi matrices and allows for greenfield development input;
- **Road Assignment Model:** Uses SATURN to assign traffic to the road network and generate costs;
- **PT Assignment Model:** Assigns public transport demand and generates costs;
- **Active Modes Assignment Model:** Assigns walk and cycle demand and generates costs;
- **Generalised cost calculations:** Takes the road, PT and active modes costs and processes them to generalised costs. It also calculates costs and cost adjustments for Park & Ride and Parking Distribution affected trips;
- **Convergence Check:** Undertakes a comparison of costs and demand from each successive loop to identify if the model has converged within acceptable criteria.

The following module is not yet fully implemented or tested:

- **Macro Time of Day Choice:** This module has not yet been implemented due to a lack of data on time choice behaviour. If implemented, it will allow trips to shift between macro time periods (e.g. from 7-10am to 10am-1pm).
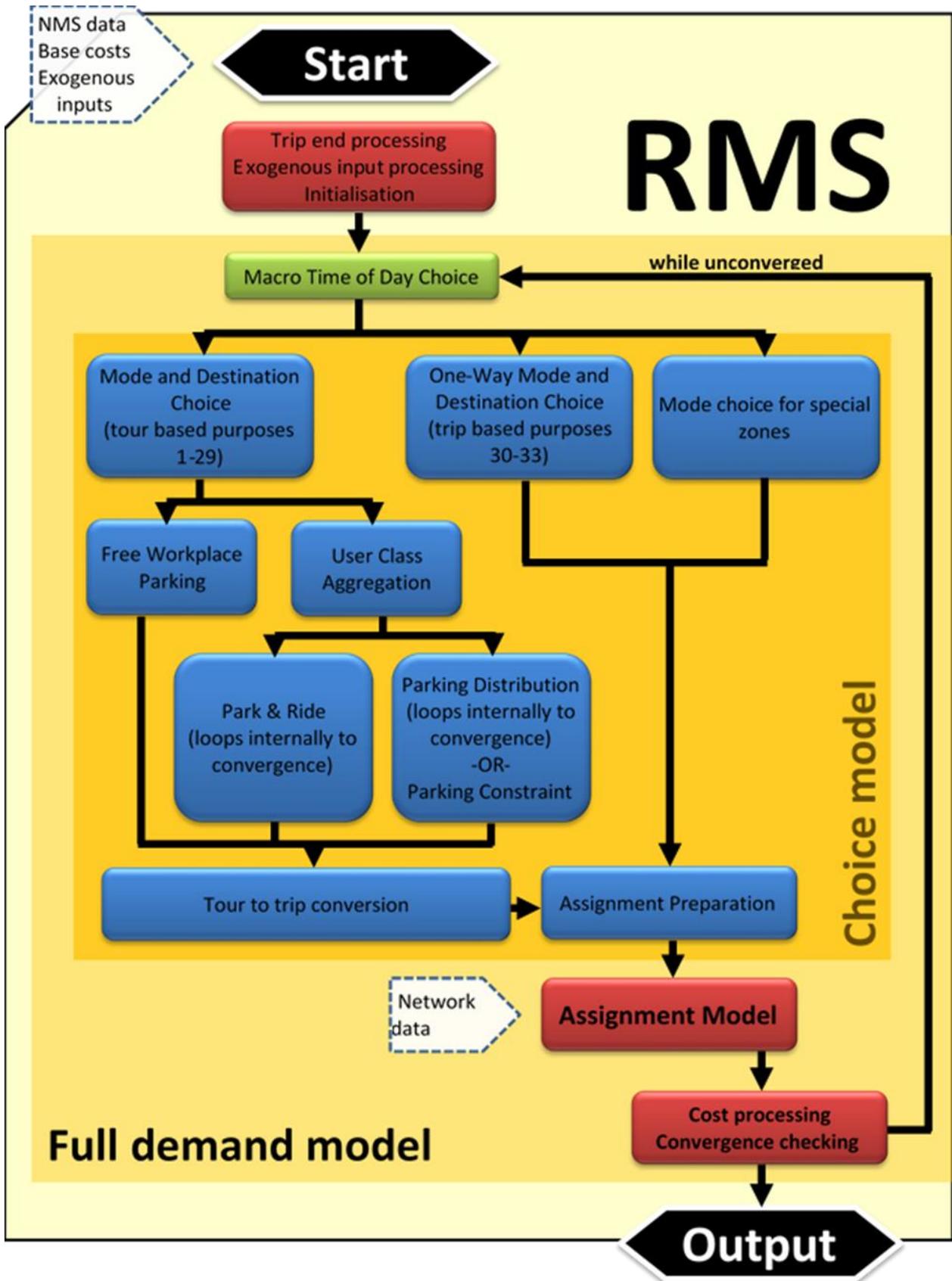
Figure 0.3 RMS Model Structure Overview

1.4   Report Library

This report is one document in a library of reports which describe various aspects of the scoping, building, development, calibration and validation of the NDFM and the five regional models.

The NDFM is covered in detail in the report:

- NDFM Development Report

The scoping of the RMS FDM is covered in a number of reports:

- FDM Scope1 Demand Modelling Workshop Recommendations
- FDM Scope2 Demand Segmentation
- FDM Scope3 Modelling Time of Travel
- FDM Scope4 Trips, Tours and Triangles
- FDM Scope5 Car Ownership Scoping Report
- FDM Scope6 Active Modes
- FDM Scope7 Parking Model Specification
- FDM Scope8 Goods Vehicle Model Specification
- FDM Scope9 Taxi Model Specification
- FDM Scope10 Airport and Other Special Zones
- FDM Scope11 External Zones
- FDM Scope12 Base Year Matrix Building
- FDM Scope13 Incorporation of Road Assignment
- FDM Scope14 Public Transport Assignment
- FDM Scope15 Choice Model Specification
- FDM Scope16 Trip End Integration
- FDM Scope17 Modelling of Greenfield Developments
- FDM Scope18 Regional Transport Model Exogenous Variables

The full, and finalised FDM specification is reported in:

- RM Spec 1 Full Demand Model Specification Report

The following reports deal with FDM calibration and validation in the five RMS regions.

- ERM Full Demand Model Calibration Report
- SWRM Full Demand Model Calibration Report
- MWRM Full Demand Model Calibration Report
- WRM Full Demand Model Calibration Report
- SERM Full Demand Model Calibration Report

For each region, three additional reports give detailed information on the development, calibration and validation of the road, PT and active modes assignment models.

This report deals with the detailed development and testing of the FDM.

1.5   Structure of this Report

This report deals with the full, and finalised, FDM specification for Version 2 of the FDM.

- By its very nature this report is not intended to be comprehensible to the layperson. Chapter 2 outlines what is expected in terms of background knowledge and defines some technical terms which appear elsewhere;
- Chapter 3 deals with the overall structure, dimensioning and segmentation of the model;
- Chapters 4, 5 and 6 cover the set-up processes which lead into the main demand model loop;
- Chapter 7 describes the process of mode and destination choice for tours and Chapter 8 with the application of this process to one-way trips;
- Chapters 9-13 cover various detailed processing of the outputs from the mode and destination choice to cover all aspects of parking behaviour;
- Chapter 14 describes the process of mode choice in special zones, such as Ports and Airports which have demands which cannot be estimated by the main trip generation and destination choice modules;
- The conversion from tours to directed trips in each time period is described in Chapter 15;
- The preparation of assignment matrices can be found in Chapter 16;
- Chapters 17-19 cover the road, PT and active modes assignment processes; and,
- Chapters 20 and 21 gives details of the calculation of the generalised costs which are fed around to the next model loop and the process of recording convergence information.

Each FDM module described in this report is presented in terms of its general operation, inputs, outputs and mathematical operation along with any observations on its functionality.

2 Reader Requirements and Terminology

2.1 The Nature of this Report

This report is technical in nature. It is not intended for the layperson and it is assumed that the reader is familiar with the CUBE software platform and with the theory and standard practice of demand modelling. In addition, it is assumed that the reader will have access to the model to act as an aid to understanding, particularly when discussing file and directory structures.

2.2 Tours

The term 'tours' is used throughout this document and refers to either a From-Home / To-Home round trip (simple tour)[1], or to a more complex tour consisting of a From-Home / Non-Home / To-Home sequence of trips. This model considers simple tours as combined sets of two trips and complex tours as separate one way trips. Each simple tour ultimately consists of two separate trips. The term *outbound* refers to the From-Home leg of a simple tour, while *inbound* refers to the To-Home leg of a simple tour.

These two trip types are illustrated below in Figure 2.1. The simple tours are dealt with in the standard Mode and Destination Choice stage, while the collections of One-Way trips are modelled in the One Way Trips Module.
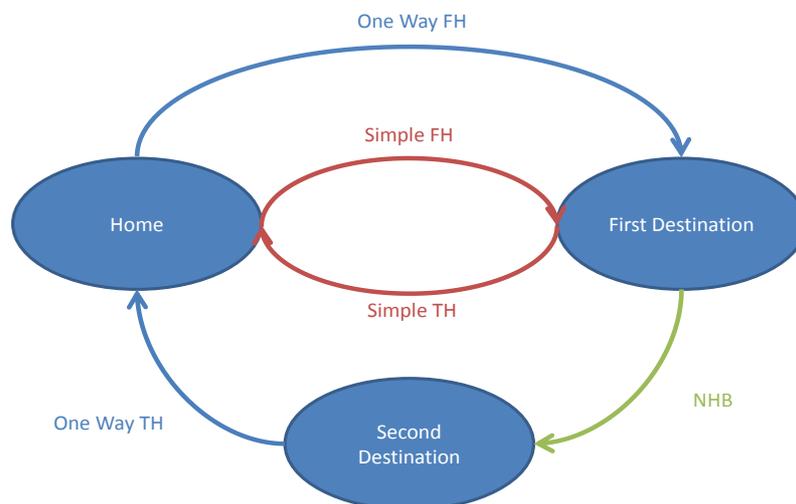
Figure 2.1 Tour Description

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[1] The classic example of a simple tour would be the pattern of travel shown by most employed persons most days: the person leaves home in the morning to go to work, spends the day at work and then returns home in the evening.

2.3   Costs

The term 'generalised cost' is also used throughout the report, and refers to the combined monetary and non-monetary costs of journeys. The term 'composite cost' refers to the combined cost of trips given the availability of alternative travel options and is used by the model to calculate trip distributions and such things as Park & Ride and Parking demand prior to splitting these across different Park & Ride sites / car parks. Composite costs are therefore also generalised costs though the term 'composite generalised cost' is generally not used.

2.4   Segmentations

Where segmentations of travel demand are described and / or referenced, they are broken down into components and discussed in order of precedence. For instance, if a table is broken down into five modes and five time periods then the tables will be in the following order:

- Mode 1, Time Period 1;
- Mode 1, Time Period 2;
- Mode 1, Time Period 3;
- Mode 1, Time Period 4;
- Mode 1, Time Period 5;
- Mode 2, Time Period 1; and so on.

3 FDM Structure and Dimensions

3.1 Model Structure

A simplified representation of the FDM structure is shown in Figure **0.3** and the place it occupies in the wider RMS suite is illustrated in Figure **0.2**. Although these illustrations give a reasonable overview of the model structure, in order to fully understand each element more detail is required. This additional detail for each element of the FDM, including model processes, inputs, and outputs, can be found in the remainder of this report.

3.2 Model Dimensions

3.2.1 Demand Segmentation

At the most disaggregate level travel demand in the FDM is segmented into 33 distinct classifications ('demand segments') as detailed in Table 3.1. The purpose, car availability and '3rd characteristic' columns give the features used to define the 33 separate demand segments while the 'user class' column gives the groupings used to assign the PT and active modes networks as well as for all processing stages from Park & Ride onwards which are carried out on these combined user classes to restrict runtimes which are otherwise prohibitive. The 'road class' column gives the user classes used for each demand segment in the road assignment which additionally includes four goods vehicle classes and a taxi class, described in more detail in Table 3.2.

Table 3.1 Demand Segmentation

No.	Purpose	Car Availability	3rd characteristic	User class	Road class
1	Commute	Available	Blue collar	COM	COM
2	Commute	Available	White collar	COM	COM
3	Commute	Not available	Blue collar	COM	COM
4	Commute	Not available	White collar	COM	COM
5	Education	Available	Primary	EDU	EDU
6	Education	Available	Secondary	EDU	EDU
7	Education	Available	Tertiary	EDU	EDU
8	Education	Not available	Primary	EDU	EDU
9	Education	Not available	Secondary	EDU	EDU
10	Education	Not available	Tertiary	EDU	EDU
11	Escort to education	Available	Primary	OTH	OTH
12	Escort to education	Available	Secondary	OTH	OTH
13	Escort to education	Available	Tertiary	OTH	OTH
14	Escort to education	Not available	Primary	OTH	OTH
15	Escort to education	Not available	Secondary	OTH	OTH
16	Escort to education	Not available	Tertiary	OTH	OTH
17	Other	Available	Employed	OTH	OTH
18	Other	Available	Non-working	OTH	OTH
19	Other	Not available	Employed	OTH	OTH

20	Other	Not available	Non-working	OTH	OTH
21	Shopping - food	Available	Employed	OTH	OTH
22	Shopping - food	Available	Non-working	OTH	OTH
23	Shopping - food	Not available	All	OTH	OTH
24	Visit friends / relatives	Available	Employed	OTH	OTH
25	Visit friends / relatives	Available	Non-working	OTH	OTH
26	Visit friends / relatives	Not available	All	OTH	OTH
27	Employers Business	All	All	EMP	EMP
28	All	Available	Retired	RET	OTH
29	All	Not Available	Retired	RET	OTH
30	One-way business	Available	All	EMP	EMP
31	One-way business	Not available	All	EMP	EMP
32	One-way other	Available	All	OTH	OTH
33	One-way other	Not available	All	OTH	OTH

Table 3.2 Road Model User Classes

Code	Description	Details
Taxi	Taxi	Defined as a proportion of User Class OTH
EMP	Employer's Business	Demand segments 27, 30, 31, User Class EMP
COM	Commute	Demand segments 1-4, User Class COM
EDU	Education	Demand segments 5-10, User Class EDU
OTH	Other	Demand segments 11-26, 32, 33, User Class OTH (less those transferred to Taxi)
LGV	LGV	Externally derived LGV matrices
OGV1	OGV1	Externally derived OGV1 matrices
OGV2_NP	OGV2	Externally derived OGV2 matrices lacking permits to enter any controlled areas
OGV2_P	OGV2	Externally derived OGV2 matrices with permits to enter controlled areas

The demand segments are aggregated to user classes on the basis of values of time which are considered to be common within each class allowing them to be assigned as a single block. This is also the case for the road classes where retired persons are additionally assumed to have values of time similar to those in the OTH user class and so can be further combined. The RET (retired) grouping is kept separate in the PT and active modes assignments due to the availability of concessionary fares (affecting PT choices) and due to the lower assumed walking and cycling speeds in this group (affecting costs).

3.2.2   Mode Segmentation

There are five modes used within the FDM to cover the full set of travel choices and these are always referred to by the same numeric identifier as shown in Table 3.3 below. Note that mode 6 (active) is a combination of walk and cycle and only appears within the mode choice model while the PT mode is further split into bus, rail, DART, Luas and any other available PT modes as part of the PT assignment.

Table 3.3 Modelled Modes

ID	Mode
1	Car
2	PT
3	Park & Ride
4	Walk
5	Cycle
6	Active

3.2.3   Time Period Segmentation

There are five time periods in the FDM, which are:

- AM: 07:00 to 10:00;
- Inter-peak 1 (IP1): 10:00 to 13:00;[2]
- Inter-peak 1 (IP2): 13:00 to 16:00;
- PM: 16:00 to 19:00; and
- Off-peak (OP): 19:00 to 07:00.

Although these are the time periods used in the demand model the assignment matrices represent single hour demands. For the AM and PM time periods these are the peak hours while for the inter-peak and off-peak time periods they represent an appropriate average hour.

3.2.4   Tour Segmentation

Simple tours are two-way trips that go outbound (From-Home) in a given time period and return (To-Home) in a second given time period. The standard naming conventions used for the simple tours are shown in Table 3.4.

The tours highlighted in green are considered invalid as they call for trips which return home before they leave. These tours are not included in any of the calculations. Those highlighted in red are valid only in commute demand segments and represent trips which arrive very early in the morning before the start of the AM time period. All other tours (in blue) are calculated for all of the demand segments in the FDM.

Table 3.4 Tour Grid Reference

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

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[2] Within the model IP1 and IP2 are referred to as LunchTime (LT) and School Run (SR) respectively as the use of two letter codes allowed programming to be checked more easily.

4 Trip End Integration

4.1 Overview

The National Trip End Model (NTEM) element of the National Demand Forecasting Model (NDFM)[3] produces trip ends, employed vs unemployed splits and blue collar / white collar worker proportions for each census small area[4] level and for each 24 hour period. These are input into the FDM. The Trip End Integration stage, which is shown diagrammatically in Figure 4.1, takes these inputs and converts them into 24 hour trip ends on the correct zone system and for the 33 demand segments.
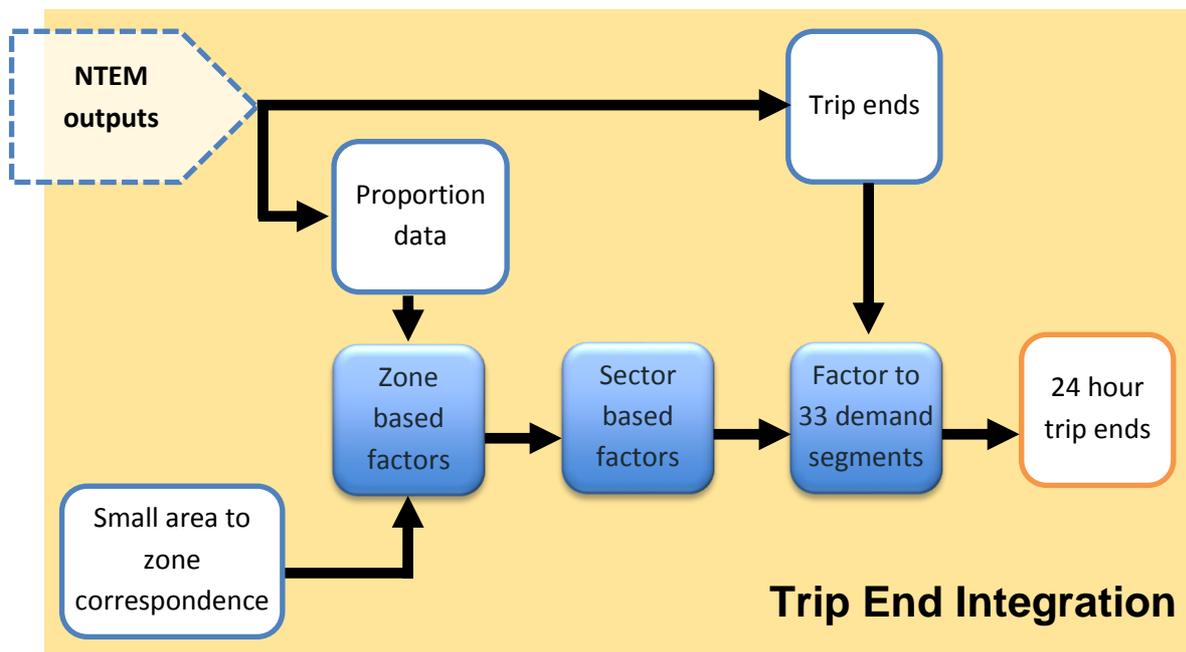
Figure 4.1 Trip End Integration

4.2 Inputs[5]

The inputs for this stage of the model are a number of database files (in CSV format) derived from the NTEM along with a number of files which define the model geography.

4.2.1 Trip Ends

The NTEM trip end inputs are:

- Non-retired productions (includes non-home-based origins);
- Non-retired attractions (includes non-home-based destinations);

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[3] The NDFM Development Report referred to in Section 1.4 (Report Library) describes the NDFM in full.

[4] Census small area refers to geographic units smaller than zones defined by the Irish census.

[5] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

- Non-retired one-way trips;
- Retired productions (includes non-home-based origins);
- Retired attractions (includes non-home-based destinations); and,
- Retired one-way trips.AM: 07:00 to 10:00;

4.2.2   Proportion Information

The NTEM proportion data inputs are:

- The ratio of employed to unemployed persons (of working age) for in each small area;
- The ratio of blue collar to white collar employees for each small area; and,
- Car availability proportions by higher level journey purpose for each small area.

4.2.3   Geographic Definition Files

The geographic definition files define the links between small areas and zones and between zones and sectors for the model region in use. There is also a simple list of all zones in the region which is used to ensure that information for all zones is output correctly.

4.3   Calculation Steps

For the trip end calculations, the proportions contained in the accompanying information files are applied to the input trip ends to give output trip ends appropriate to the model zone system and demand segment disaggregation.

The first stage of this process is to apply the small area to zone correspondence to the proportion information files to convert them to the zone level. Following this step this information is further aggregated to the sector level to allow the calculation of sector based factors to be used in zones which do not contain any housing. These zones have no production trip ends and so the proportions of car available / car-non-available, employed / unemployed and blue collar / white collar trip ends in them are not correct. Once these sector values have been obtained the factors at the zone level are calculated, overwriting with the sector values as appropriate.

These factors are then applied to the input trip ends to disaggregate them to the correct zone and demand segment groupings.

4.4   Outputs

The output from the Trip End Integration process is two matrix files; one for productions and one for attractions. Each row in these matrices represents an individual zone and columns 1-33 give the trip ends in each zone for the 33 demand segments. Columns 34-51 give disaggregate one-way and non-home-based trip end data for information purposes.

The final sum of the output trip ends in each zone is identical to sum of the initial trip end inputs.

5 Add-In Preparation

5.1 Overview

The Add-In Preparation stage (Figure 5.1) takes the exogenously derived inputs and processes them for later inclusion in the assignment matrices following their calculation by the FDM. Additionally, it adjusts the trip ends to take account of these exogenous inputs.
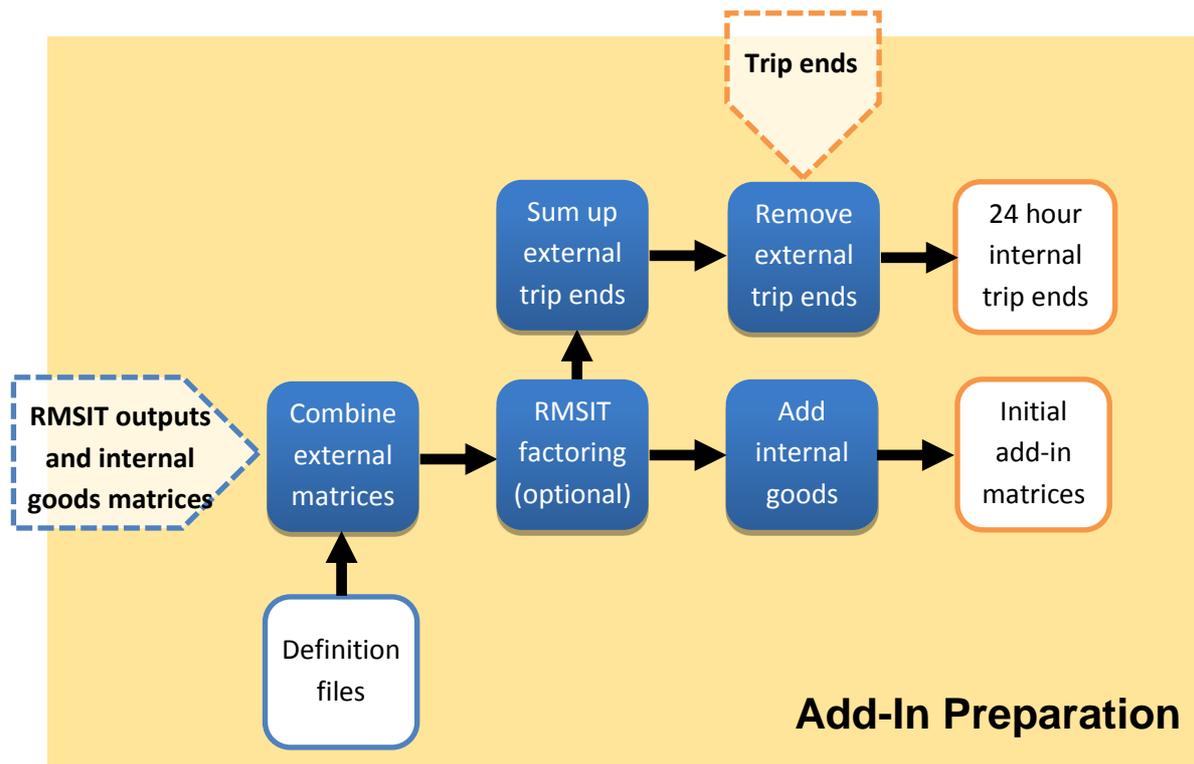
Figure 5.1 Add-In Preparation

5.2 Inputs[6]

5.2.1 Regional Model Strategic Integration Tool

The first set of inputs to the Add-In Preparation stage are 7 files derived from the Regional Model Strategic Integration Tool (RMSIT) element of the NDFM[7] and are pre-defined on the zone system of the appropriate region:

- EMP and OTH car trips by time period;
- EMP and OTH bus trips by time period;
- EMP and OTH rail trips by time period;

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[6] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

[7] The NDFM Development Report referred to in Section 1.4 (Report Library) describes the NDFM in full.

- COM car trips by time period;
- COM bus trips by time period;
- COM rail trips by time period; and,
- Goods vehicle trips by time period.

These trips represent inter-region movements which cross from one region of the RMS to another and so cannot be calculated internally in each region.

5.2.2 Internal Goods Movements

Internal goods movements are an additional input to the Add-In Preparation stage and are derived from the base calibrated models for each region.

5.2.3 Trip Ends

The trip end files output by the Trip End Integration stage are an input to the Add-In Preparation stage.

5.2.4 Definition Files

The final set of inputs at this stage are definition files giving factors to convert from time period to modelled hour and from car users to car drivers (persons to vehicles).

5.3 Calculation Steps

The first step in the Add-In Preparation stage is to combine the RMSIT matrices and to calculate appropriate 24 hour totals to use to adjust the trip ends. At this stage the matrices are also converted from time period to modelled hour, from persons to vehicles (for cars) and from vehicles to PCUs (for goods vehicles).

Following this stage there is an optional stage to limit the amount of external traffic relative to internal traffic according to the input key value {Factor_RMSIT}, which is set equal to 1 if this process is not required. Once this factor has been applied the internal goods matrix is added to the external trip matrix to give the output add-in matrices.

Finally, the 24 hour totals are taken and subtracted from the trip ends to ensure that external trips are not double counted.

5.4 Outputs

The outputs from the Add-In Preparation stage are initial add-in matrices for each time period (Addins_Initial_**XX**, where XX represents the time period) and revised trip ends which have been adjusted to remove the external trip ends ({Growth}_24H_Productions.MAT and {Growth}_24H_Attractions.MAT).

6 Initialisation

6.1 Overview

The initialisation stage (Figure 6.1) occurs at the start of the main FDM loop and performs two important functions:

- 24-hour trip end to tour trip end conversion
- Input cost processing
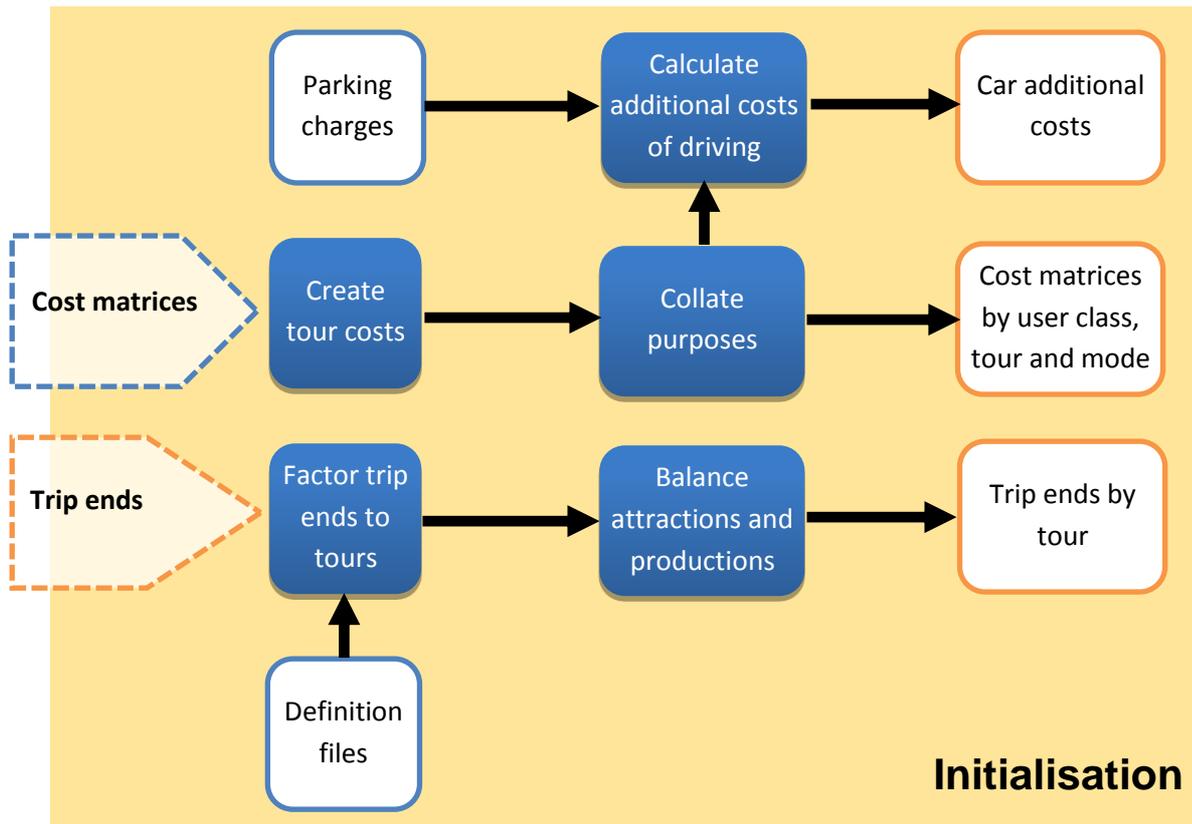
Figure 6.1 Initialisation

6.2 Inputs[8]

6.2.1 Trip End Processing

The trip end processing part of the Initialisation stage requires two sets of inputs, firstly the trip ends output by the Add-In Preparation Stage and secondly a set of factors to convert both production and attraction trip ends from 24 hour values to tours (Base_Prod_Tour_Proportions.MAT and Base_Attr_Tour_Proportions.MAT). These factors are derived from the National Household Travel Survey (2012) and differ by

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[8] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

regional area. Only trips which satisfied the following conditions were included in the analyses:

- Trip could be aligned correctly with car availability and purpose;
- Trip was on a weekday; and
- (for factors relating to the simple tours demand segments 1-29) a home-based pair could be confidently aligned by pairing a From-Home trip with a To-Home trip.

The proportion matrices consist of 25 layers, one for each tour and have values in every row (for every zone) and in the first 51 columns (for demand segments 1-33 and disaggregate NHB and One-Way segments 34-51). The sum of the values in each table for each zone and column should always be 1 as all trips are accounted for once all tours are considered.

6.2.2 Cost Processing

The cost processing stage takes generalised cost matrices for each time period disaggregated by mode and user class as well as tour based Park & Ride costs (these are also disaggregated by user class). Finally, parking charge information is input as a list of zones with associated hourly parking charges in euros.

6.3 Calculation Steps

6.3.1 Trip End Processing

The trip end processing stage is quite straightforward in that it simply applies the input tour proportion factors to the trip ends output by the Add-In Preparation Stage and then rebalances the productions and attractions.

6.3.2 Cost Processing

The first stage of the cost processing stage creates tour costs for car, PT, walk and cycle trips in each user class by taking the average of the cost of the From-Home and To-Home legs. These are then added on to the Park & Ride costs which are already calculated as averages and so do not need additional processing at this stage.

This process assumes that the outbound and return leg of a simple tour have the same purpose (which must be true) but also that they share a common mode (which may not always be true). Further discussion on these assumptions can be found in associated specification reports[9]

There is no real requirement for active modes costs to be calculated independently by tour given that there is no crowding and thus costs in each direction are the same, but in order to ensure consistency with other modes and to ensure that the model is suitable for any potential upgrades this step has been left in place.

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[9] See Section 1.4 (Report Library)

Finally, at this stage search, charge and walk costs associated with driving are calculated, as well as driving cost adjustment factors[10]. Driving cost adjustment factors are set to 1 while search times are set to 3 minutes and walk times at the intrazonal walk time (up to a maximum of 10 minutes). Hourly parking charges are set to the input parking charges in each zone (assuming that all users will park in their destination zone).

For the demand segments which have available free workplace parking (1-2 and 3-5) parking charges, search times and walk times are then reduced by 80% to reflect an assumed free parking availability of 80%.

6.4 Outputs

The initialisation process produces two trip end matrices ({Growth}_Tour_Productions.MAT and {Growth}_Tour_Attractions.MAT. Both of these have 25 layers, one for each of the 25 tours with data in each row relating to each zone and in columns 1-51 (for demand segments 1-33 and disaggregate NHB and One-Way segments 34-51).

Five average generalised cost files are output (.AGC files, one for each user class). Each of these contains 125 layers segmented by mode (5) and tour (25). COM_M1.AGC and COM_M4.AGC are also output here. The data contained in these last two files is a duplication of data contained in the main output files, but is stored in a format which makes it easier to input into the Parking Distribution stage[11].

This process also outputs three sets of cost files relating to the additional costs of driving:

- PDist_CostFacDrive**XX**.MAT: as factors (all 1 at this stage)
- PDist_CostPay**XX**.MAT: as hourly parking charges in euros
- PDist_CostRest**XX**.MAT: as summed search and walk times

XX may be "_WtAv_COM" for those costs relating to the COM demand segments, "_WtAv_EDU" for those costs relating to the EDU demand segments or left blank for costs relating to the remaining demand segments which do not have access to free workplace parking.

All of these matrices have 25 layers, one for each of the 25 tours. In the case of parking this means that the hourly cost of parking is set identically for each tour even though parking in the Off-peak period is considered to be free. This ensures compatibility with the outputs from the Parking Distribution module and is addressed by applying a charged-stay duration to the hourly parking cost when these are used in the calculations.

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[10] See Section **Error! Reference source not found.** for more information on these factors

[11] see Chapter **Error! Reference source not found.** for more information

7 Mode and Destination Choice

7.1 Overview

The Mode and Destination Choice module is the core component of the FDM. Its function is to replicate the choices (between modes and destinations) that a traveller will make when undertaking a journey for a particular purpose given that they will be travelling at a particular time of day (considering both outbound and inbound time periods). A simplified representation of the choice process applied in each of the 29 two-way demand segments is shown in Figure 7.1.
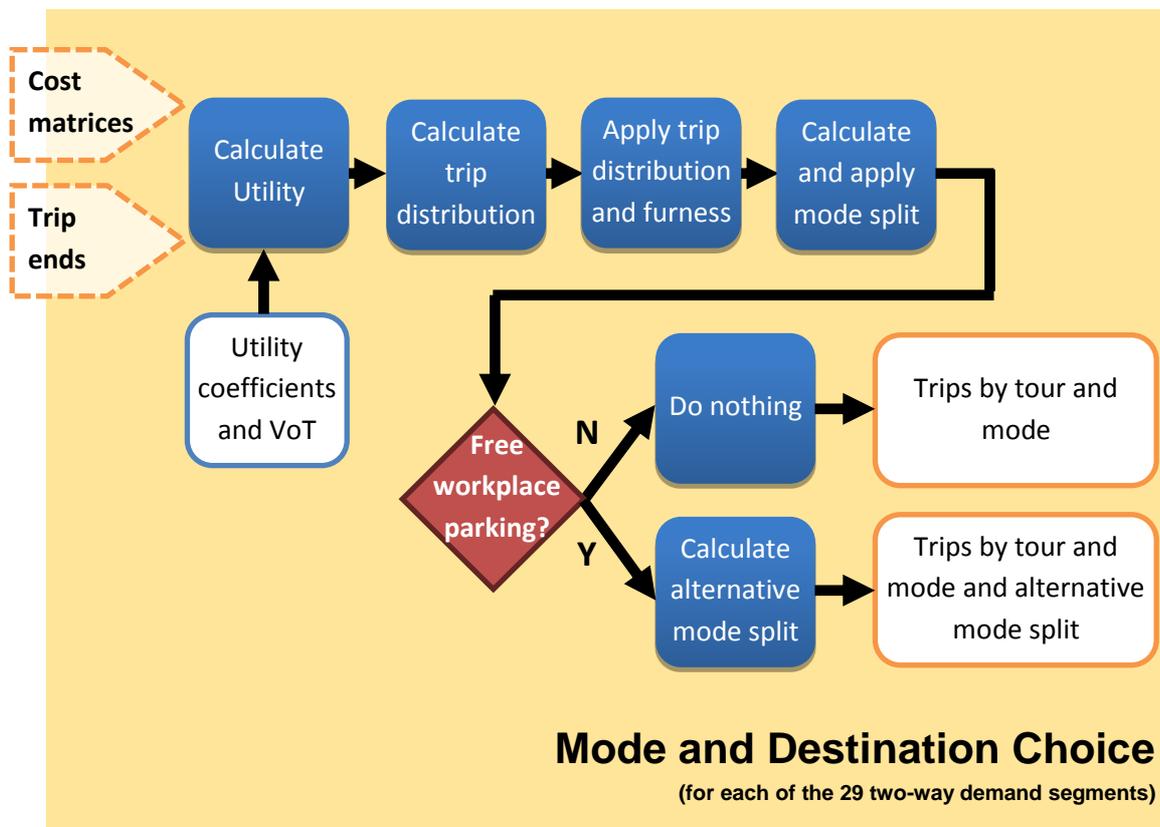
Figure 7.1 Mode and Destination Choice

7.2 Inputs[12]

The inputs to the Mode and Destination choice stage are shown in Figure 7.1. Purposes 1-4 use the COM costs while 5-10 use the EDU costs. The EMP costs are used by purpose 27 and the RET costs by 28 and 29. All other purposes use the OTH costs.

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[12] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

For purposes 1 and 2 the additional costs of driving are from the *WtAv_COM.MAT files while for 5-7 they are the *WtAv_EDU.MAT files. For all other car available purposes (11-13, 17, 18, 21, 22, 24, 25, 27 and 28) the straight additional costs of driving are used (PDist_CostFacDrive.MAT, PDist_CostPay.MAT and PDist_CostRest.MAT). For the non-car available demand segments (3, 4, 8-10, 14-16, 19, 20, 23, 26 and 29) neither these inputs, nor Parking_VoT.dbf, are required.

Table 7.1 Inputs to the Mode and Destination Choice Stage

File	Details
XXX_**Tours.AGC**	Costs from the Initialisation stage in the first loop and from the previous loop in later loops. Disaggregate by mode (5) and tour (25). (**XXX** refers to the user class (EMP, COM, OTH, EDU or RET)
P**XX_Alpha.MAT** P**XX _Beta.MAT** P**XX _ASC.MAT** P**XX _IZM.MAT** P**XX _LAMBDA.MAT**	Parameters which control the utility calculations (**XX** refers to the purpose number 01, 02 … 29)
PDist_CostFacDriveXXXX**.MAT** **PDist_CostPay**XXXX**.MAT** **PDist_CostRest**XXXX**.MAT**	The additional costs of driving from the Initialisation stage in the first loop and from the previous loop in later loops. Disaggregate by tour (25) (**XXXX** refers to the user class, either WtAv_COM, WtAv_EDU or nothing)
Parking_VoT.dbf	Values of time to convert parking charges to generalised costs (by year)

7.3 Mathematical Framework

The mathematical form of the Mode and Destination Choice state is a multinomial hierarchy as shown in Figure 7.2.
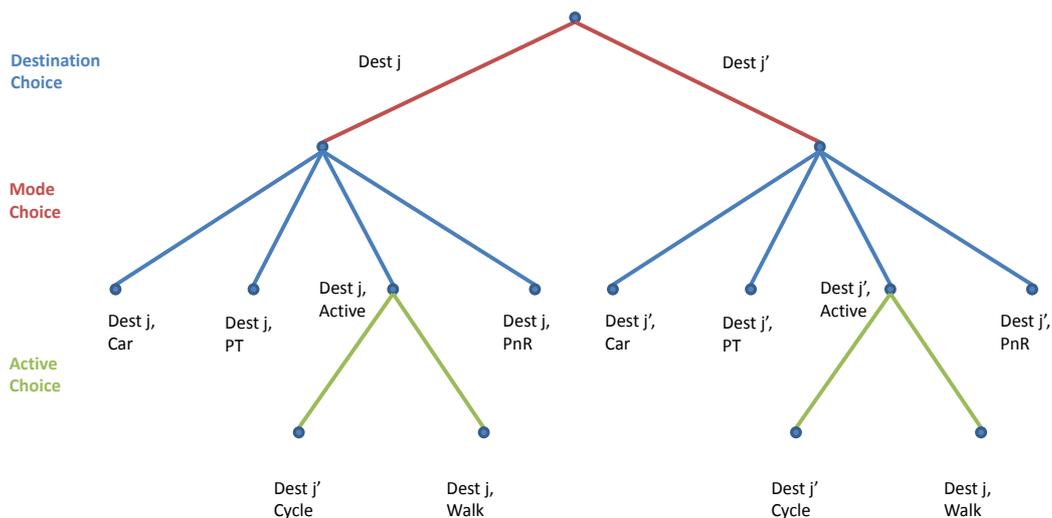
Figure 7.2 Mode and Destination Choice Model Hierarchy

The first choice level is that of destination and this is followed by the choice of main mode between PT, active modes, and, in the car-available demand segments, car and Park & Ride. Finally, there is a secondary mode split which divides the active modes into walking and cycling.

Mathematically the probability of making a choice is:

$$P_n = \frac{e^{\lambda V_n}}{\sum_{n \in N} e^{\lambda V_n}}$$

Where: $\lambda < 0$ is the relevant spread parameter;
V_n is the utility of choice n; and
N is the subset of choices considered.

The utility for the choices that have no dependents (i.e. are terminating branches of the tree) is defined as a function of the generalised cost.

$$V_{ij} = \alpha U_{ij} + \beta \ln(U_{ij}) + IZM + ASC_M$$

Where: V_{ij} is the utility to be used in the destination choice logit comparison;
$U_{ij} = \frac{1}{\lambda} \ln(\sum_{m \in M} e^{\lambda U_{mij}})$ is the generalised cost;
$IZM_m = 0$ if i ≠ j is an estimated intrazonal parameter;
ASC_M is the mode specific alternative specific constant and
α, β are estimated parameters.

For combinations of choices (such as destination choice decisions or the choice of the combined active mode pair) the utility is the composite cost of the utilities at the lower levels which is calculated as the logsum. For instance, the active mode utility is calculated as:

$$U_{active\ ij} = \frac{1}{\lambda_{act}} \ln \left(\sum_{m \in M} k e^{\lambda_{act} U_{mij}} \right)$$

Where: $U_{active\ ij}$ is the composite cost of active modes;
U_{mij} is the utility of walking or cycling respectively;
M is the set of mode choices (walking and cycling); and
$\lambda_{act} < 0$ is the active mode choice spread parameter.

Similarly, the destination choice utility is defined as:

$$V_{ij} = \frac{1}{\lambda_{mode}} \ln \left(\sum_{m \in M} e^{\lambda_{mode} U_{mij}} \right)$$

Where: V_{ij} is the composite cost of all modes to be used in destination choice;
U_{mij} is the utility (or indeed composite cost) of the lower level;
M is the set of mode choices (with walk and cycle combined as active modes); and

$\lambda_{mode} < 0$ is the mode choice spread parameter.

7.4 Calculation Steps

7.4.1 Utilities

The calculation steps undertaken in the model are undertaken separately for each demand segment. The first step is to calculate the utilities for each terminating branch of the choice hierarchy and then to carry out the logsum steps required to create the composite cost of travel using the active modes (walking and cycling), for use in the mode split stage, and the composite cost of travel by all available modes, for use in the trip distribution stage. As part of this process parking charges in Euros are adjusted to costs in minutes by applying an assumed charged parking duration and the VoT for the appropriate year. Section 12.3.5 gives more information on assumed parking charge durations.

7.4.2 Distribution

Having calculated these utilities, the composite cost of travel by all modes this cost is then used to calculate a distribution function and to distribute the trips between the possible destinations. Once the distribution has been calculated the matrices are furnessed using Cube Voyager's FRATAR module to ensure a match to both the production and attraction trip ends. For the demand segments which have access to free workplace parking the additional parking cost files are a weighted average of travel with and without free workplace parking and so the distribution takes account of the partial additional costs perceived by these groups.

7.4.3 Initial Mode Split

Mode split is applied to the distributed matrices. Initially the proportion of the trips in each cell by PT, active modes and, in the car-available demand segments, car and Park & Ride is found and then an additional calculation splits the active modes demand into walking and cycling. For the modes which have available free workplace parking the additional parking costs used at this stage are a weighted average of travel with and without free workplace parking.

7.4.4 Secondary Mode Split

Where free workplace parking exists (demand segments 1, 2 and 5-7) a sub-application calculates an alternative mode split for those travellers who cannot be accommodated in free workplace parking and are required to use alternative supplies which are either not free, or are further from their true destination.

7.5 Outputs

The primary outputs from this stage are matrix files for each purpose which are labelled P**XX**_MDCOut.MAT where **XX** is the purpose code. These matrix files consist of 125

tables corresponding to each tour (25) and mode (5) in that order, and give the number of person trips travelling between each I, J pair in each tour and by each mode.

In addition, the demand segments which can use free workplace parking (1, 2 and 5-7) output and additional matrix file with the same structure which gives the **proportions** of trips made by a particular mode between a zone pair having considered parking charges. These files are labelled P**XX**_ModalSplit_With_Parking_Charges.MAT.

8 One Way Trips Module

8.1 Overview

The One Way Trips Module is similar to the Mode and Destination Choice stage but calculates the distributions and mode splits for the one way trips rather than for the simple tours. There are there sets of one way trips; Non-Home-Based trips, From-Home single trips and To-Home single trips. In the context of the actual travel patterns of individuals these are best considered as the kinds of trips which leave home in the morning to go to a particular destination, such as a workplace, continue from there to a second destination, such as a supermarket and then return home from that second destination. This is illustrated in Figure 2.1 while Figure 8.1 shows the calculations undertaken by the One Way Trips Module in a diagrammatic form. The process is actually very similar to that used in the Mode and Destination Choice stage except that it applies to time periods rather than tours and there is no need for the additional mode split stage which applies to the free workplace parking.
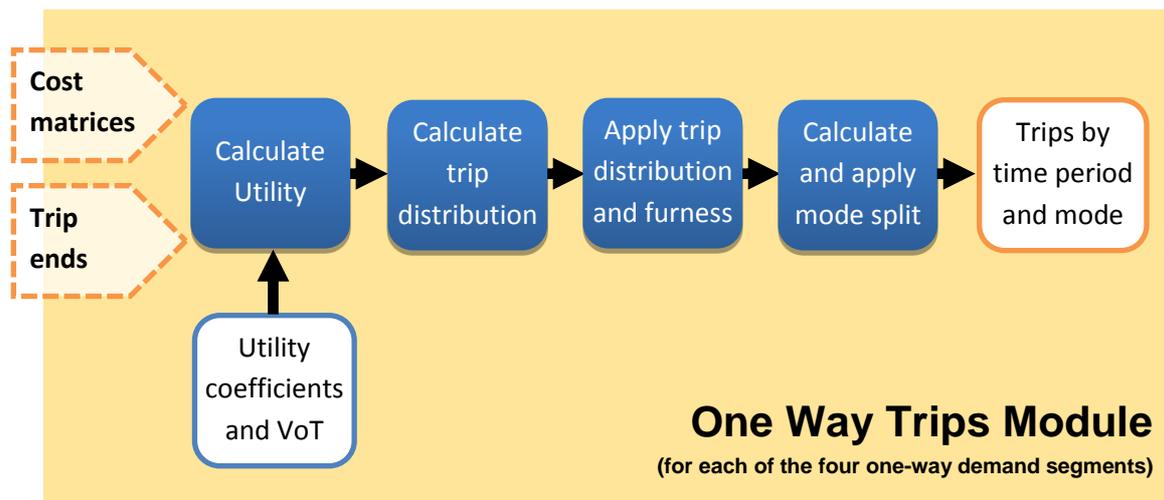
Figure 8.1 One Way Trips Module

8.2 Inputs[13]

The inputs to the One Way Trips Module are shown in Figure 8.1. Purposes 30 and 31 use the EMP costs while 32 and 33 use the OTH costs.

It is assumed that no trips have access to free parking and that it is appropriate to apply destination end additional parking costs and so the input additional costs of driving are from the straight calculations (PDist_CostFacDrive.MAT, PDist_CostPay.MAT and PDist_CostRest.MAT).

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[13] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

Table 8.1 Inputs to the One Way Trips Module

File	Details
XXX_**Tours.AGC**	Costs from the Initialisation stage in the first loop and from the previous loop in later loops. Disaggregate by mode (5) and tour (25). (**XXX** refers to the user class (EMP or OTH)
P**XX**_**Alpha.MAT** P**XX** _**Beta.MAT** P**XX** _**ASC.MAT** P**XX** _**IZM.MAT** P**XX** _**LAMBDA.MAT**	Parameters which control the utility calculations (**XX** refers to the purpose number 30, 31, 32 or 33)
PDist_CostFacDrive.MAT **PDist_CostPay.MAT** **PDist_CostRest.MAT**	The additional costs of driving from the Initialisation stage in the first loop and from the previous loop in later loops. Disaggregate by tour (25)
Parking_VoT.dbf	Values of time to convert parking charges to generalised costs (by year)

8.3 Mathematical Framework

Aside from the fact that the calculations are undertaken on the basis of time period rather than tour the mathematical basis underlying the One Way Trips Module is identical to that used in the Mode and Destination Choice Module and is described in Section 7.3.

8.4 Calculation Steps

The calculation steps in the One-Way Trips Module are very similar to those undertaken in the Mode and Destination Choice stage (see Section 7.4) except that calculations are undertaken on the basis of time periods rather than tours and there is no need for the secondary mode split stage. Parking charge durations are assumed to be 1.5 hours in all time periods except the Off-Peak where they are assumed to be zero.

The one-way trips require no further processing, as they are assumed not to be subject to the parking adjustment steps which follow the main Mode and Destination Choice module, and they are already in origin-destination format. This means that they can be aggregated directly at the end of the One-Way Trips Module into the correct format for input directly into the Assignment Preparation stage (Chapter 16).

8.5 Outputs

The outputs from the One-Way Trips Module are UC1_EMP.OWS and UC3_OTH.OWS. These files consist of 25 tables which cover each time period (5) and mode (5), and show the number of trips travelling between each I, J pair in each time period and by each mode.

9 Free Workplace Parking

9.1 Overview

In many locations there is significant free workplace parking but this is not unlimited, particularly in the more urban areas and so Free Workplace Parking (FWPP) module has been built to replicate the choices that a traveller may face if the demand for free workplace parking is larger than the available supply. This choice process is shown diagrammatically in Figure 9.1.
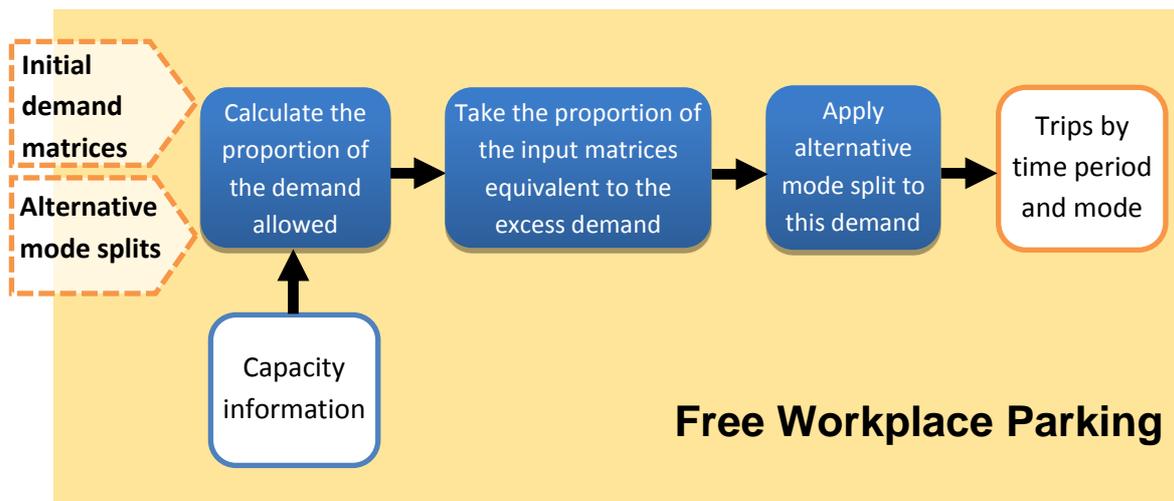
Figure 9.1 Free Work Place Parking Module

9.2 Inputs[14]

The inputs to the Free Workplace Parking Model are both sets of outputs from the Mode and Destination Choice Module for demand segments 1, 2 and 5-7. As well as the modelled inputs, a site file which contains a list of free spaces by zone is included in the input folder (FWPP_{Run ID}{Model Year}.CSV). This file must include a value for every zone but where there is ample free workplace parking and the restraint should not be applied then values of 99999 should be used for both the workplace and education related capacities. Finally, CarUserToCarDriver.PRM is used to convert between person trips and vehicles.

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[14] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

9.3   Mathematical Framework

The mathematical basis of the Free Workplace Parking Module is shown and described in Figure 9.2. Stage 1 of this process is undertaken by the Mode and Destination Choice Module while this module focusses on Stages 2 and 3.

Stage 1: Apply Mode split, assuming free parking for all

In the diagram to the left, the large square represents all of the "car-available" commuting trips to a particular destination zone.

The X axis represents the proportion of these trips which choose to travel by car, while the Y axis represents the proportion of trips with access to free parking.

In the first stage, the mode split is applied assuming everyone has access to free parking. Region A represents those trips which would be made by car in

Stage 2: Calculate proportion of trips offered free parking

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

Stage 3: Apply mode split to trips without access to free parking

The proportion of trips with no access to free parking (Region C in the diagram above) is subject to mode choice, but this time with parking charges included. In the diagram, the former Region C is now split into two – Region D which represents trips made by car which pay for parking; and Region E which represents trips made by other modes that would not have had access to free parking. Regions A and B are unchanged from the previous stage. Regions B and E can be combined at this stage.

Figure 9.2 Free Work Place Parking Mathematical Framework

The amount of free workplace parking available to those arriving in each time period depends on the number of vehicles still in position from previous time periods. Figure 9.3 shows the tours which are considered to impact on occupancy in each time period (reading across the rows).

Figure 9.3 Free Work Place Parking Tour Grid

9.4 Calculation Steps

The FWPP module begins by transposing the input matrices as CUBE works more quickly on row calculations than columns. The occupancy for each zone is then calculated in a separate step for each time period, including the impact of spaces taken by earlier arrivals.

Having established the proportion of each car matrix which exceeds the available demand the process then takes this proportion of the input matrices for all modes and applies the revised mode split proportions which include parking charges. For cars these new matrices overwrite the input matrices and for the other modes they are added to the unaltered proportions of the original matrices. The unaltered proportions of the car matrices are output as FWPP user matrices and From-Home and To-Home matrices by time period are created for output.

The adjusted matrices are transposed back to the correct I, J format for further processing.

9.5   Outputs

The outputs of this model component are identical in structure to those output by the Mode and Destination Choice stage so that they will be compatible with the next phase of the model. Thus they consist of 5 matrix files (one for each purpose) with 125 tables in each representing 25 tours by 5 modes. These are named P**XX**_FWPPOut.MAT, where **XX** represents the purpose.

The output FWPP user matrices are denominated COM_FWPP_Occupants_By_TP.MAT and EDU_FWPP_Occupants_By_TP.MAT.

10 User Class Aggregation

10.1 Overview

The parking adjustment processes which follow the Free Workplace Parking stage are extremely demanding in terms of memory and computational power and continuing to calculate for all 29 two-way demand segments would be prohibitive. In addition, similar demand segments are not considered to behave sufficiently differently at these stages for it to be considered worthwhile to calculate them separately. For these reasons the two-way tour matrices are aggregated from demand segments to user classes at this stage.

10.2 Inputs

The inputs to User Class Aggregation are the outputs from the Mode and Destination Choice and FWPP steps: P**XX**_MDCOut.MAT for all purposes except 1,2 and 5-7 and P**XX**_FWPPOut.MAT for 1, 2 and 5-7. **XX** represents the demand segment (01, 02, …, 29)

10.3 Calculation Steps

Due to limitations on the number of matrices which can be processed at any one time the aggregations are undertaken in several stages but the process is actually quite simple consisting of combining matrices for the same tours and modes according to the groupings shown in Table 10.1

Table 10.1 User Class Aggregation Groups

User class	Demand segments
EMP	27 – Employers Business
COM	1-4 – all Commute segments (car / no-car and blue / white collar)
OTH	11-26 – all Escort to Education, Food Shopping, Visiting and Other segments
EDU	5-10 – all Education segments (car / no-car and Primary / Secondary / Tertiary)
RET	28-29 – all Retired segments (car / no-car)

10.4   Outputs

Fifteen matrices are output from this stage (**XXX** refers to the user class):

- Five **XXX**_PnR_By_Tour.MAT used to deliver Park & Ride demand information to the Park & Ride module;
- Five **XXX**_Road_By_Tour.MAT used to deliver car demand information to the Parking Distribution / Parking Constraint modules; and,
- Five **XXX**_3Modes_By_Tour.MAT used to carry PT, walk and cycle demand information through to the Tour Aggregation stage.

11 Park & Ride

11.1 Overview

A Park & Ride trip is one which uses road and then PT for an outbound trip and returns using the same set of modes in reverse. Park & Ride is currently only allowed in specific zones which offer formal Park & Ride (either official car park sites or stations). It does not consider drivers who travel to a residential area to park and then get a bus on to their destination to avoid paying a parking charge. The Park & Ride demand is created by the Mode and Destination Choice module and the purpose of the Park & Ride module is to work out which Park & Ride site will be used by each Park & Ride trip and to calculate the associated car and PT trip legs.

11.2 Inputs

The inputs to this stage are the five Park & Ride matrices from the User Class Aggregation stage (**XXX**_PnR_By_Tour.MAT) and the average generalised costs from the COM class (COM_Tours.AGC). A decision was made not to use user class specific costs in this process as the difference between the cost of using different sites is more important than the absolute cost and the impact on runtimes of using exact costs was high. A PnR input site file, PNRSites_{Run ID}{Model Year}.csv, gives the necessary supply and parameter information for each site.

11.3 Mathematical Basis and Calculation Steps

The Park & Ride module uses a standard logit choice set up to assign the Park & Ride demand to individual Park & Ride sites. This process is complex and depends on multiple loops and the creation of dynamic scripts. The first stage is to create the total Park & Ride demand by adding together the demand from each user class. At this stage the proportion of the demand on each OD pair which comes from each user class is also calculated as it is needed split the output back to individual user classes towards the end of the module.

Having obtained the total demand, the process then loops over the outbound-from-site time periods so as to process all tours leaving at the same time together. This makes the calculation of demand versus capacity easier.

The process then enters a convergence loop. In this loop it carries out site choice for each inbound-to-site time period separately. Site choice is achieved by dynamically creating a script for each site in each time period. Within each script block the process creates a loop over the possible destinations for all allowed origins and creates a matrix to indicate the allowed trips. It sets the various parameter values and calculates a parking charge per person. Then, for each allowed trip it calculates the trip cost as follows:

$$Cost_{Site} = Cost_{Car,i,k} + Cost_{PT,k,j} + Cost_{Park} + Cost_{Attr} + Cost_{Extra}$$

Where: $Cost_{Car,i,k}$ is the car cost associated with travel between the origin and the site;

$Cost_{PT,k,j}$ is the PT cost associated with travel between the site and the destination;

$Cost_{Park}$ is the cost of parking (per person trip);

$Cost_{Attr}$ is an additional calibration cost; and

$Cost_{Extra}$ is a cost which increases as the site nears capacity.

The numerator of the logit choice function is then equal to $e^{\lambda Cost_{Site}}$ (where λ is the spread parameter). The denominator is equal to the sum of all of the numerators.

Having obtained the numerators and denominator the process then calculates the proportion of trips using each site and multiplies by the demand to get the number of trips.

Usages are summed up to get the total departures from each site in each time period and these values are compared to the available capacities. Where sites are overcapacity the Attr values are adjusted. Occupancy and Attr values are saved for convergence purposes and the process enters the next convergence loop. Convergence loops run until the changes in occupancy and Attr values fall below a pre-determined threshold or until a pre-set maximum number of loops is reached.

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

Once all five loops are completed the demand can be split back into user classes and individual trip legs can be created. Once car-to-site and PT-from-site legs are created for each tour the demand is converted to from-home and to-home trips in each time period and the resulting matrices are passed forward to the Tour Aggregation stage.

The cost of using Park & Ride which is passed forward is that given by the use of the lowest cost site.

11.4 Outputs

The outputs from this stage are five matrices labelled **XXX**_PnR_TP_Out.MAT, one for each user class. Each of these matrices has 20 layers for mode (2 – car and PT), direction (2 – From-Home and To-Home) and time period (5).

12 Parking Distribution

12.1 Overview

Town and city centres, particularly the historic centres of large cities are acknowledged to have less parking supply than there is parking demand, particularly in certain areas. For this reason, a model has been developed to shift people away from their first choice of parking location - in their destination zone - into other alternative zones based on a choice model offering an array of potential sites.

This replaces the input car demand matrices with a set of revised car demand matrices and **additional** walk legs which are added on to the walk matrices.

12.2 Inputs[15]

With the exception of parameters, parking charge and parking capacity information, the inputs to the parking distribution module are produced by previous modules, and consist of:

- the demand by grouped demand segment (EMP, COM, OTH, EDU, RET) and tour;
- the generalised cost of driving from the origin to a chosen parking zone by tour (only COM costs are used as these are considered sufficient to judge the relative cost of driving to each available zone); and,
- the generalised cost of walking from a chosen parking zone to the destination zone by tour (again, only COM costs are used as these are considered sufficient to judge the relative cost of walking from each available parking zone).

The parking distribution parameter file gives values for:

- Car_occupancy = 1.18
- Min_search_time = 54/60
- Max_search_time = 900/60
- Search_time_scaling_parameter = 1.46
- Value_of_Time = 11.57
- Lambda = -0.3
- Weight_on_walk_time = 2

Five Catalog key values provide additional controls:

- {Include_PDist}: set to omit or include parking distribution
- {Max_PDist_Loops}: controls the maximum number of parking distribution loops
- {PDist_ConvTest_Abs}: sets a maximum absolute value for the difference in demand for a specific zone between loops for it to be considered converged.

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[15] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

- {PDist_ConvTest_Percentage}: sets a maximum percentage value for the difference in demand for a specific zone between loops for it to be considered converged.
- {PDist_OutputInfo_Threshold}: sets a minimum value for the proportion of trips for a particular Production / Attraction combination using a particular parking zone for it to be printed to the output information file. Low values are useful for checking module operation, but higher values improve run times.

The parking charge file[16] gives the cost of parking for one hour (in Euros) in any zone which is considered to be covered by pay parking. The parking distribution input file[17] gives a capacity for each zone which will be subject to parking distribution (either as a result of capacity restraint or parking charges) or which might receive extra trips as a result. A third column holds a flag to show if the zone should be included in the parking distribution calculations or not (a 1 indicates that it should and a 0 that it shouldn't). This flag allows zones to be included in the information file, and to have their parking costs accurately calculated, but without redistributing trips with destinations in those zones or using them as overspill zones for other congested zones.

Table 12.1 Parking Charge Input File Description

Column	Variable	Description	Example Value
1	Zone	Model zone number (numeric)	1
2	Hourly_parking_charge	Hourly parking charge in euros (numeric)	2.9

Table 12.2 Parking Distribution Input File Description

Column	Variable	Description	Example Value
1	Zone	Model zone number (numeric)	1
2	Parking_charge	Number of parking spaces (numeric)	100
3	Include	Flag to indicate if this zones should be included in parking distribution (1=Yes, 0=No)	1

These files contain header rows which hold the column headings, and which must be in place on any future variations, but the actual names given to the columns are not used by the process and are purely cosmetic.

---

[16] {CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PCharge_{Run ID}{Model Year}.csv

[17] {CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PDist_{Run ID}{Model Year}.csv

12.3   Mathematical Framework and Calculation Steps

12.3.1   Set-Up

The main parking distribution module loop works on the basis of total demand (by tour) across all user classes before applying the costs calculated at the grouped demand segment level. Therefore, the first stage in the process is to take the input demand and sum it to a single total demand by time period. The second stage is to take in the input parking supply, charge and include-flag information and collate it into a format the process can use, including converting supply from vehicle spaces to person spaces. Finally, during the set-up process initialised convergence files and a blank blocking demand file are also produced. Once the first loop has been completed this latter file shows the number of spaces occupied at the start of each time period and is used to adjust the supply, but at this initial stage it is simply filled with zeros.

12.3.2   Parking Distribution Loop

The files from the set-up process are then passed into the main parking distribution process loop. For each tour this carries out the following series of calculations:

1. **Data set-up:** In the first loop this collates charge, supply, demand, type and search time[18] information for each zone. 'Type' is an internal definition which takes three possible values:

    1: *Demand[19] > Supply or Charge > 0:* Demand requires redistribution;

    2: *Demand[20] <= Supply and Charge = 0:* Zone is available for redistribution but trips with destinations in it need not be redistributed; or,

    3: *Include-flag=0 or zone not listed in input data or zone listed in input data with a capacity >= 99999 or zone has an area $>=3\pi^2$:* Zone does not require redistribution and is not available for redistributed trips[21].

    In subsequent loops supply is reduced to reflect blocking demand from vehicle remaining in spaces having arrived in previous time periods. Calculations are based on this revised figure and the supply and demand outputs are the ones appropriate to the current loop.

2. **Cost calculations:** For each zone which requires, or may be used for redistribution the process works out the cost of driving between the parking zone and the

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[18] See 12.3.4 for details of this calculation

[19] These demands are the actual Attraction based demands, not any revised demands following redistribution

[20] These demands are the actual Attraction based demands, not any revised demands following redistribution

[21] This allows zones to be excluded because they are too big to be walked in / out of (the area criterion), or if the user has excluded them, either by omitting them from the input list, including them with a very high capacity or flagging them to be ignored. This allows accurate charge, search and walk times to be calculated for all zones input. Zones which are omitted completely will not have these values calculated in detail. This can affect the distribution in the model, particularly for busy zones adjacent to areas where parking distribution is considered in full. Search times in these zones tend to be non-zero so omitting them completely tends to result in excessive car mode share for trips with Attractions in them. Including them, but omitting them from the formal parking distribution calculations, prevents high mode shares without having a detrimental effect on run times.

Production zone[22], the costs associated with searching and paying[23] in the parking zone and the cost of walking between the parking zone and the Attraction zone[24].

3. **Choice calculations:** The model applies a logit choice function to work out the likelihood of using each parking zone for each Production / Attraction combination (see Section 12.3.6).

4. **Supply calculations:** Once the choice steps are complete the model works out the number of trips to each parking zone in each tour and uses these to work out the number of filled spaces at the start of any time period and so adjust the supply available to that time period.

5. **Convergence calculation:** The parking demand in each zone is compared to that found in previous loops and the absolute and percentage convergence thresholds (input as Key values) in order to decide which zones have converged, and which zones have not. If any zones are unconverged the process will loop. Zones are considered converged if the pass on either the absolute or percentage convergence criteria and they are properly engaged with the process[25].

6. **Damping:** To speed up convergence by reducing the effect of flipping in the choice of parking zones the demand fed back to subsequent loops is damped such that it is the average of the current and all preceding loops. Additionally, as part of this process demand is capped at twice the supply to reduce the impact of extremely high demands in any one loop.

12.3.3 Leg Calculations

Once the main parking distribution loop has converged, the damped demand inputs to the last loop are carried forward to the leg calculation stage. This uses the damped demands to calculate the search times in each zone and then carries out the same parking zone choice process as in Step 3 of the main parking demand loop for each grouped demand segment and tour individually, as is required in the outputs.

Additionally, as part of this process the cost information is created and output.

12.3.4 Search Times

Search times are calculated on the basis of the conclusions from a study undertaken in Leeds which showed that the search time could be modelled as a function of the occupancy as follows:

$$STime = Min[S_{Max}, \alpha \times e^{\beta * 100 * OCC/CAP}]$$

Where: OCC is the occupancy of a site;
CAP is the number of spaces;

---

[22] The input driving costs are tour costs and so include both the output and return components.

[23] The costs of paying are converted to generalised costs by multiplying by the length of time parked in hours (see Section 12.3.5) multiplied by 60 and divided by the value of time.

[24] The costs of walking are tour costs and so include both the output and return components. They are converted to generalised costs by weighting with the input walk time weight.

[25] For more details relating to testing if zones are engaged with the parking distribution process see Section 12.3.8.

α is the minimum search time found to be 0.9 minutes;

β is a parameter found to be 0.0146; and

S_{Max} is a maximum value for search time currently set to 15 minutes.

Figure 12.1 shows the variation in this time with percentage occupancy, indicating that it is minimally affected below around 85% demand, rises beyond 100% and reaches a maximum at 200%.
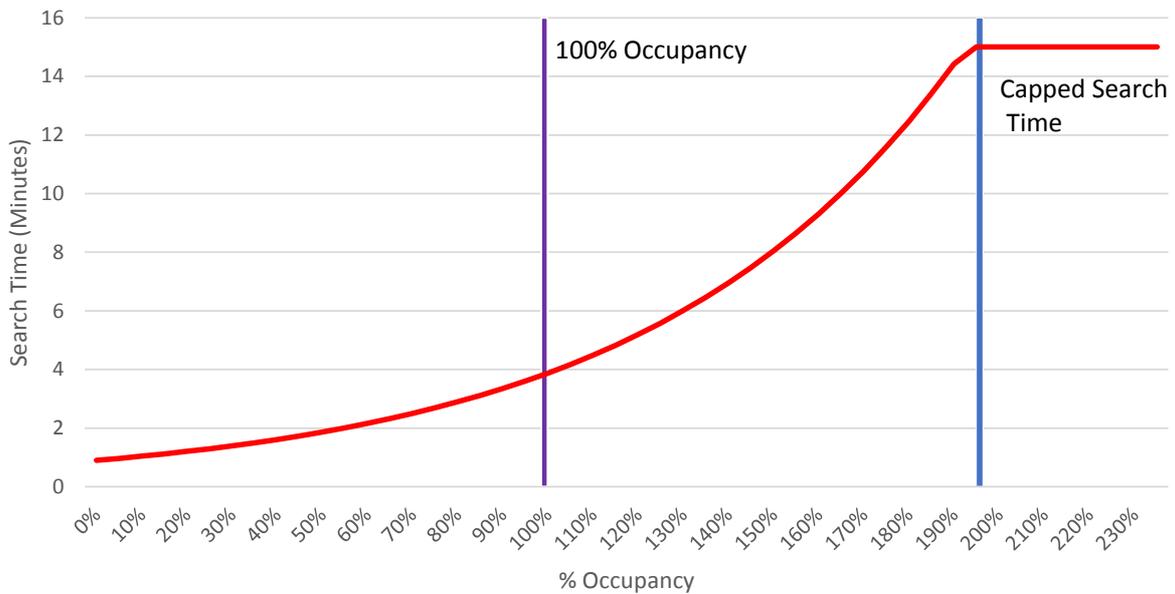
Figure 12.1 Capacity Constraint Curve

12.3.5 Length of Time Spent Parked

Table 12.3, below gives the amount of time spent parked for each tour.

Table 12.3 Parking Duration Matrix (Hours)

		Inbound Time Period				
		AM	LT	SR	PM	OP
Outbound Time Period	AM	1.5	3	6	9	10.5
	LT	0	1.5	3	6	7.5
	SR	0	0	1.5	3	4.5
	PM	0	0	0	1.5	1.5
	OP	1.5	4.5	7.5	10.5	0

12.3.6 Parking Zone Choice

The choice of parking zone for each Production / Attraction combination is governed by a logit choice function. The logit choice is calculated as:

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

<u>Where</u>: P_s is the probability of choosing site s;

$\lambda < 0$ is the spread parameter for Parking Distribution site choice;
S represents the choice set of available sites (as defined by catchments); and
U_{ijs} is the utility of travelling from zone i to zone j via site s.

The utility here can be further expanded into its relevant components:

$$U_s = \frac{(GCar_{ikT1} + GWK_{kjT1} + GWK_{jkT2} + GCar_{kiT2})}{2} + P + S + W$$

<u>Where</u>: $GCar_{ikT1}$ is the generalised cost of travelling by car from zone i to zone k during time period 1;

GWK_{kjT1} is the generalised cost of travelling by walking from zone k to zone j during time period 1;

GWK_{jkT2} is the generalised cost of travelling by walking from zone j to zone k during time period 2;

$GCar_{kiT2}$ is the generalised cost of travelling by car from zone k to zone i during time period 2;
P is the parking charge per person for a site;
S is the "search" cost at the site introduced by the Parking Distribution constraint function.

12.3.7 Supply Calculations

Tours which are considered to block spaces and so affect supply at the start of each time period are shown in Figure 12.2. The OP period is considered to start at a point overnight when all modelled vehicles are at the Production end of their trip and so it has no blocked demand and can access the full supply. At the start of the AM time period trips on tours 22, 23 and 24 (COM trips only) are already in position and blocking spaces, reducing the available supply but trips on tour 21 will not block AM spaces as they leave during the AM time period. By the start of the PM time period only trips on tours 5, 10 and 15 are blocking spaces: all other trips have either left, or are in the process of leaving.

Figure 12.2 Tours Blocking Spaces by Time Period

12.3.8 Zone Engagement

To improve the convergence of the parking distribution, loop the process additionally checks for zones which are not engaging with the process properly. Broadly this takes account of zones which, particularly in early loops of the process, tend to return unrealistically small or unrealistically large capacities. There are other examples but the commonest example of zones which do not engage with the process in the early stages relates to zones with parking charges. These frequently return zero occupancies through a number of early iterations of the process until the damped demand in the zones around them has built up sufficiently for the search times to become comparable with the charge.

Up to the tenth loop the engagement test looks for zones which have non-zero capacities but where demand is either less than 85% of capacity or more than 200%. Beyond Loop 10 only zones with non-zero capacities, zero charges and demand less than 85% of capacity are flagged as, depending on the overall demand, some charged zones may always have low demands and some zones may always be overcapacity.

12.4 Outputs

The outputs of the Parking Distribution module are the car and walk demand by grouped demand segment and tour and three cost files to use in adjusting the costs of using a car to reach specific destination zones:

1) PDist_CostFacDrive: This contains adjustment factors by tour to use to adjust the direct cost of driving based on the distribution of parking zones. For example, a trip from origin O to destination D might become O>P>D. If P is nearer to O than D then the cost factor will be less than 1, while if P is on the far side of D relative to O then the cost factor will be greater than 1. The overall factors are based on weighted averages of all of the production / attraction / parking zone combinations.

2) PDist_CostPay: This contains the weighted average of the hourly cost of parking of all of the production / attraction / parking zone combinations by tour.

3) PDist_CostRest: This contains the weighted average of the search and weighted walk times of all of the production / attraction / parking zone combinations by tour.

These cost files are later processed to provide appropriate values for COM and EDU trips, based on the usage of free workplace parking in these groups.

In addition, the process produces some files which can be used to check its operation. The first of these is a set of O>P>D probabilities for each tour. These list production zones, attraction zones and parking zones along with usage probabilities for all combinations where the probability exceeds the value set in {PDist_OutputInfo_Threshold}. Secondly some simple totals are collected (by grouped demand segment and tour) giving the total number of walk trips; a measure of the number of individual users who have been redistributed.

Finally, the process produces convergence information. For each time period print files are produced which give the parking zone, the supply, the occupancy in the last loop, the occupancy in the current loop, the absolute difference, the maximum absolute difference observed on any zone, the percentage difference, the maximum percentage difference observed on any zone and an indication of whether the zone is engaging with the distribution process. Additionally, a summary convergence file is created giving collated convergence information for each loop.

13   Parking Constraint

13.1   Overview

The Parking Constraint Module is intended to provide some basic capability to limit the use of cars where parking demand exceeds parking supply but in a rapid basic way only suitable for use when the area of interest is at a distance from areas where there is competition for parking and runtime is an issue. It should not be used in combination with the Parking Distribution Module as there is no functionality available to work out the true Attraction end of trips once they have passed through Parking Distribution.

13.2   Inputs[26]

The inputs to the Parking Constraint are the full set of outputs from the Parking Distribution Module (if Parking Distribution is not run these are copies of the corresponding input matrices) and the parking capacity information file, PDist_{Run ID}{Model Year}.csv which is converted to person spaces using the occupancy input with the Parking Distribution parameter values.

13.3   Calculations

If Parking Constraint is not run the input matrices are padded to mimic the extra layers the process would have created and passed through this step unaltered. If Parking Constraint is run, then the calculations take place in three stages:

1) The proportion of demand which can be accommodated is calculated. This takes into account spaces taken by earlier arrivals using the same methodology as that used by the Parking Distribution Module.
2) Allowed car trips are passed through
3) Disallowed car trips are shared between the other modes on the basis of the proportions in the User Class Aggregation Outputs

Once this process is complete the matrices are aggregated back to the correct format for processing in the next module.

At present the code includes functionality to process the walk trips input from the Parking Distribution Module, but this functionality is redundant as the two modules should not be used in combination.

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[26] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

13.4   Outputs

The outputs from this process are five matrices named **XXX**_PCon_TP_Out.MAT, where XXX denotes the user class (EMP, COM, OTH, EDU and RET). These consist of 100 layers each and are disaggregate by mode (4) and tour (25).

14 Special Zones

14.1 Overview

The Special Zones module takes the predicted total demand for travel to special zones, such as airports and ports, whose demand depends on factors not included in the model, such as the range of flights and destinations available and splits it to the modes available.

14.2 Inputs

The inputs to the Special Zones stage are a special zone data file (SZ_data.csv) which gives:

- Zone
- User Class (1 or 3)
- Average total parking charge / taxi fare for whole stay
- Lambda
- Alpha_Car
- Beta_Car
- ASC_Car
- Alpha_PT
- Beta_PT
- ASC_PT
- Proportion of car to make taxi
- Proportion of car to make Kiss & Fly / Ride / Sail

Each special zone in the model will usually require a record for both user classes 1 and 3 (EMP and OTH). The average total parking charge / taxi fare is estimated by considering the cost of parking and local taxi travel. It is assumed that these can be taken to be similar as a minimal proportion of travellers will pay more to park than a taxi would have cost and most will use public transport where taxi fares are much higher than parking charges.

The proportions to assign to taxi and Kiss & Fly / Ride / Sail are derived from data, if it is available, or by taking figures from other similar sites if not. The lambda, alpha and ASC values are set during calibration. Beta values are currently set to 0.

In addition to these five demand matrices are input, one for each time period, each with two layers, for EMP and OTH demand. Generalised cost (.GCM) matrices are used to provide the generalised costs of travel and Parking_VoT.dbf gives the values of time needed to convert the parking charges / taxi fares.

The five AddIns_Initial_**XX**.MAT (**XX** denotes the time period) created by the Add-In Preparation stage are also an input here, so that they can be combined with the special zone demand.

14.3   Calculation Steps

The calculation steps here are similar to those in the standard Mode Choice calculations (in the Mode and Destination Choice or One Way Trips modules) and depend on the same mathematical framework.

Having added in the cost of parking / taxi fares to the driving cost the utility of travelling by car or public transport is calculated and the proportion of trips choosing to use each mode is obtained. The trips by car are then split into straight (parking), taxi and Kiss & Fly / Ride / Sail trips using the input proportions. Trips in the latter two groups are additionally transposed and added to the un-transposed trips to reflect the return leg of such trips.

Finally trips are grouped to the user classes used in the road assignments and added on to the initial Add-In matrices.

14.4   Outputs

The outputs from this stage are five Addins_Final_**XX**.MAT matrices each with 24 layers (one for each assignment class – 9 road classes, 5 PT, 5 walk and 5 cycle).

15 Tour Aggregation

15.1 Overview

While the FDM carries out its calculations at a tour level, the assignment models work strictly in time periods and so a conversion process is required.

15.2 Inputs[27]

The inputs to this element of the model are the outputs from the FWPP Module, User Class Aggregation, Park & Ride and Parking Constraint (if Parking Distribution is in use rather than Parking Constraint these are merely padded versions of the Parking Distribution outputs). In each case there are five matrices, one for each user class.

Those from the FWPP Module contain 10 layers (modes (1, car) and direction (2, From-Home and To-Home) and time period (5)). Those from the User Class Aggregation Stage contain 75 layers (modes (3, PT, walk, cycle) and tours (25)). Those from the Park & Ride Stage contain 20 layers (modes (2, car and PT), direction (2, From-Home and To-Home) and time period (5)) and those from the Parking Constraint Stage contain 100 layers (modes (4) and tours (25)).

15.3 Calculation Steps

For each user class the matrices are combined into From-Home and To-Home groupings. For the User Class Aggregation and Parking Constraint outputs, matrices must initially be converted from tours to From-Home and To-Home trips by time period. Table 15.1 illustrates the outbound and inbound time periods for each tour. For matrices of tours each unit of demand represents two trips and so a trip must be added to the appropriate From-Home matrix and a transposed trip added to the appropriate To-Home matrix.

Table 15.1 Tour Grid

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

Once tour to trip conversion has been undertaken the From-Home and To-Home trips can then be summed across all modes.

15.4   Outputs

The outputs of the Tour Aggregation stage are ten matrix files which contain trips by direction, with From-Home and To-Home trips in the .FHS and .THS files respectively. There are five files for each direction each denoting a different user class and containing 20 tables (modes (4) and time periods (5)).

16 Assignment Preparation

16.1 Overview

The Assignment Preparation converts the output FDM matrices into the format required by the assignment model, in particular converting from persons to vehicles, from time periods to representative peak hours and including greenfield demand, incremental adjustment and Add-In matrices. Figure 16.1 shows this process in a simplified format.
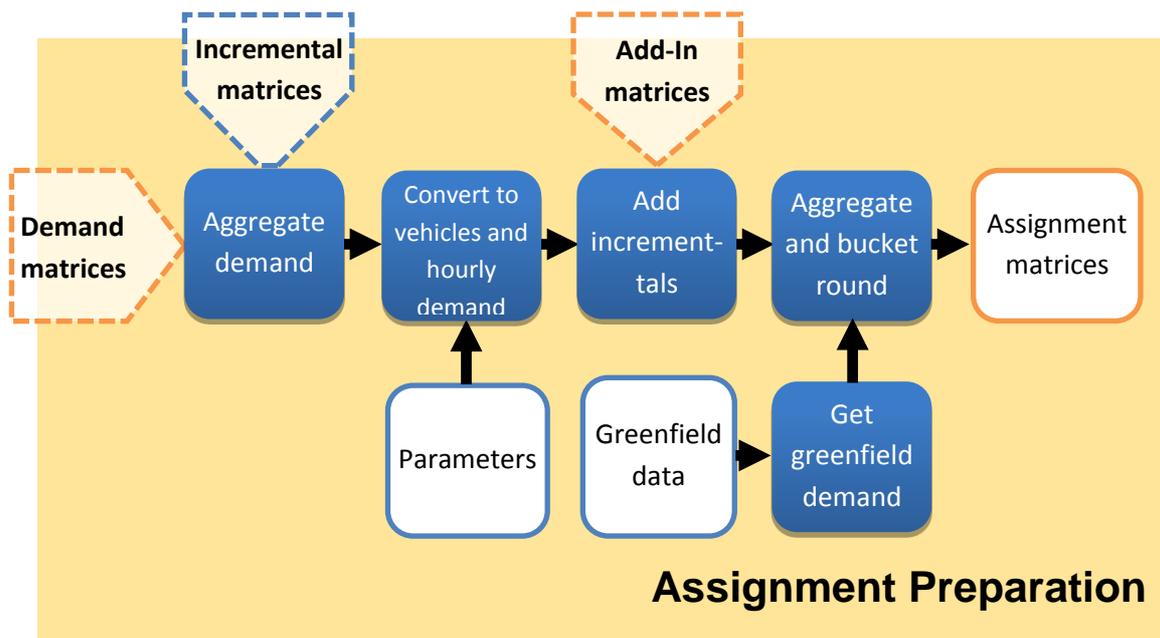
Figure 16.1 Assignment Preparation

16.2 Inputs[28]

The inputs to this component are the From-Home and To-Home matrices from the Tour Aggregation Stage and the output one way matrices (OWS) from the One Way Trips Module. All of these are disaggregated by time period and user class. The Add-In matrices are also inputs into this step. There are five of these, one for each time period and at the stage they are input they are required to be disaggregated by assignment class.

There are a number of additional inputs which are not calculated by the FDM.

- Greenfield Development information;
- Period to Hour factors;
- Car User to Car Driver (CUCD) factors; and

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[28] A full list of primary model inputs and catalogue keys can be found in Appendix A and B.

■ Incremental adjustments.

Information on the derivation of period to hour and car user to car driver factors can be found in the appropriate scoping notes[29]. The incremental adjustments are calculated outside the FDM by comparing calibrated base matrices to matrices produced by the base demand model. These calculations are undertaken on a cell by cell basis separately for each mode, user class, and time period so that in the base year the assignment matrices produced by the FDM match the calibrated assignment matrices **exactly**. In forecast mode this effectively passes across travel demand choices which cannot be captured effectively within the demand model choice mechanisms. At present additive adjustments are used for cars and public transport and multiplicative adjustments for walking and cycling.

16.3 Calculation Steps

The first calculation step in this module takes the From-Home and To-Home outputs from the Tour Aggregation Stage and combines them with the one way matrices to give one matrix for each user class. Each of these matrices has 20 layers and they are disaggregated by mode (4) and time period (5). Following this Period to Hour factors are applied to convert from time periods to representative peak hours and Car User to Car Driver factors to convert the car matrices from persons to cars. Five matrices are then output, one for each time period, disaggregated by mode (4) and user class (5).

Incremental adjustment is carried out which produces five matrices which are passed to the Greenfield process and a taxi matrix.

The Greenfield process allows for three types of Greenfield site definition:

1) Greenfield Option 1 merely modifies the incremental adjustment to be multiplicative rather than additive such that Greenfield demand can be mimicked by placing appropriate factors in the incremental matrices.
2) Greenfield Option 2 supplies trip ends and the existing zones on which demand should be based and uses these to produce greenfield demand.
3) Greenfield Option 3 reads bespoke demand from separate input files.

These allow Greenfield demand to be calculated and added to the pre-existing demand. However, it should be noted that although the Greenfield process is fully implemented it has only been tested on sample input data and has not been fully validated.

The Add-In matrices are combined with the outputs from the Greenfield process and divided into five road matrices (one for each time period and each with nine layers, representing each road user class), five PT and five active modes matrices (each disaggregate by user class (5)).

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[29] See Section 1.4 (Report Library)

Finally, in order to improve assignment model runtimes by reducing the number of cells in a matrix which need to be considered, a 'bucket rounding' procedure is used to remove small numbers of trips while retaining the trip demand. This process is applied individually to each user class, mode, and time period.

By considering any cell with a value below 0.001 as a small trip (0.1 for PT trips), these trips are then collected as a residue and summed until they aggregate to a value greater than or equal to the cut-off value at which point they are added directly to the cell which 'fills the bucket'. There is no significant adjustment (more than the cut-off value) to any particular cell in the matrix and no adjustment to the matrix total.

In order to avoid a tendency to fill particular columns which can occur, for example, if the process always starts from Zone 1, the bucket rounding procedure always starts from the intrazonal cell.

16.4   Outputs

The outputs from the Assignment Preparation stage are the 16 matrices required by the assignment models:

- Road_AM_{Run ID}{Growth}{Model Year}.HWM;
- Road_LT_{Run ID}{Growth}{ Model Year}.HWM;
- Road_SR_{Run ID}{Growth}{ Model Year}.HWM;
- Road_PM_{Run ID}{Growth}{ Model Year}.HWM;
- Road_OP_{Run ID}{Growth}{ Model Year}.HWM;
- PT_AM_{Run ID}{Growth}{ Model Year}.PTM;
- PT_LT_{Run ID}{Growth}{ Model Year}.PTM;
- PT_SR_{Run ID}{Growth}{ Model Year}.PTM;
- PT_PM_{Run ID}{Growth}{ Model Year}.PTM;
- PT_OP_{Run ID}{Growth}{Model Year}.PTM;
- Active_AM_{Run ID}{Growth}{Model Year}.AAM;
- Active_LT_{Run ID}{Growth}{Model Year}.AAM;
- Active_SR_{Run ID}{Growth}{Model Year}.AAM;
- Active_PM_{Run ID}{Growth}{Model Year}.AAM; and
- Active_OP_{Run ID}{Growth}{Model Year}.AAM.

Additionally, a printfile containing matrix totals is output (MatrixTotals.PRN).

17 Road Assignment Model

17.1 Overview

The road assignment model is carried out externally in SATURN with SATURN being called directly from the FDM itself, receiving inputs from it and returning outputs to it.

17.2 Inputs[30]

The inputs to the Road Assignment are the taxi, car and goods vehicle assignment matrices prepared by the Assignment Preparation Stage as well as a series of SATURN input files which define all the necessary network parameters, including VOC and VoT, as well as PT bus lines files which are used to generate preloads for the road model.

17.3 Calculation Steps

The first step in the calculation process derives bus preload files based on the actual PT bus lines. Following this first step, the assignment matrices are then converted into CSV files and subsequently stacked to .UFM files for use in SATURN. These .UFM files are then assigned to the network. These procedures are undertaken via PILOT scripts which write key files for use by the SATURN assignments and then use a command line interface to call the assignment proper. This creates a consistent procedure which does not rely on user intervention and is automated within the demand model.

The use of a hierarchical zone system in the road assignment model has to be accounted for in CUBE (which can only consider a sequential zone system), and this is undertaken through a region specific Visual Basic program called Seq_2_Hier.exe. This command line executable is contained in the Params folder[31].

Having assigned the network, it is then converted into CUBE Voyager format with a series of link and node attributes transferred across as listed in Table 17.1 and Table 17.2.

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[30] A full list of primary model inputs and catalog keys can be found in Appendix A and B.

[31] Further information on Seq_2_Hier.exe, including the source code, is available on request but it is a simple program which merely compares sequential zone numbers to corresponding hierarchical zone 'names' and replaces the former with the latter before running the SATURN assignment. This process is reversed on returning SATURN outputs to the main model.

Table 17.1 CUBE Output Network Link Attributes

Attribute	Unit	DA Code	Notes
Distance	Km	1893	
Free flow speed	Kph	1803	
Link capacity	PCU	1833	
Lanes		N/A	This is not readily available form DA codes and must be extracted alternately
Congested time	Minute	4013	
Congested speed	Minute	N/A	This is not readily available form DA codes and must be calculated
Average queue	PCU	1433	
Demand flows by user class	PCU	3803-3903	Dependent on the final number of user classes
Bus flows	PCU	2003	
Actual flow	PCU	4513	
Demand flow	PCU	4503	
Link delay	Minute	1513	
Total PCU hours in time period	PCU hours	1543	Used as a gauge of the total delay and people affected

Table 17.2 CUBE Output Network Node Attributes

Attribute	Notes
Coordinates	Used for spatial reference
Junction type	As defined in SATURN
Delay	Total delay at a junction
Flow	Total flow through a junction
Capacity	Total junction capacity
V/C	Volume over capacity

17.4   Outputs

The outputs from the Road Assignment model for the FDM processes are generalised cost skims by time period (5) in CUBE Voyager matrix format and assigned road networks in CUBE Voyager network format which are passed on to the PT model.

The cost skims are derived during the SATURN procedures using the standard generalised cost formulation:

$$GC = A * Distance + B * Time + C * Toll$$

This cost formulation is defined uniquely for each user class and more detail on this process can be found in the road model reports[32] for each regional model.

In addition, there are a series of standard SATURN outputs which are produced which can aid interrogation of a road assignment including:

- .LPT – an output print file detailing the assignment stages;
- .UFS – an assigned network in SATURN format;
- .UFC – a file of link costs from each loop of assignment;
- .LPN – an output print file detailing the network build stages;
- .ERL – an error list by turning movement created during the network build stages;
- .UFN – an unassigned network in SATURN format;
- Cost skims; and
- Individual skims.

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[32] See Section 1.4 (Report Library)

18   PT Assignment Model

18.1   Overview

The Public Transport Assignment takes the public transport matrices generated by the Assignment Preparation stage and assigns these to the public transport network in order to generate patterns of flows and the costs required to update the choice model processes.

18.2   Inputs

The inputs of the PT model are supplied from two locations: the FDM and the input folder. The FDM generates the basic network structure as an output from the Road Assignment Model and this is then supplemented with additional network detail such as non-transit (walk) links from the input directory. There are ten additional network files available in the Input folder, which are required by the PT model:

- LUAS_Links.DBF;
- Rail_Links.DBF;
- Walk_Links.DBF;
- Metro_Links.DBF;
- LUAS_Nodes.DBF;
- Rail_Nodes.DBF;
- Walk_Nodes.DBF;
- DBus_FareZones.DBF;
- BRT_FareZones.DBF; and
- Metro_Nodes.DBF.

The names of these files in general should be sufficient to describe their purpose. The node files contain node numbers, X and Y coordinates and, where required, station names and fare zone information. The link files typically contain an A and B node, the link length (in kms), the link type (used in assignment definition), a reverse flag (indicating whether two way) and any other necessary information.

In addition to network definition, the FDM provides demand matrices by user class of which five are considered in the PT model: EMP, COM, OTH, EDU and RET. These demand matrices are provided individually by time period reflecting persons travelling in an average or peak hour.

The PT assignment model 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 stored in the Input directory. The input factor files are shown in

Table 18.1.

Table 18.1 PT Assignment Model: Input Factor Files

Files	
EMP_NO_VOT_AM.FAC	EMP_NO_VOT_LT.FAC
EMP_NO_VOT_SR.FAC	EMP_NO_VOT_PM.FAC
COM_NO_VOT_AM.FAC	COM_NO_VOT_LT.FAC
COM_NO_VOT_SR.FAC	COM_NO_VOT_PM.FAC
OTH_NO_VOT_AM.FAC	OTH_NO_VOT_LT.FAC
OTH_NO_VOT_SR.FAC	OTH_NO_VOT_PM.FAC
EDU_NO_VOT_AM.FAC	EDU_NO_VOT_LT.FAC
EDU_NO_VOT_SR.FAC	EDU_NO_VOT_PM.FAC
RET_NO_VOT_AM.FAC	RET_NO_VOT_LT.FAC
RET_NO_VOT_SR.FAC	RET_NO_VOT_PM.FAC
ZOD_NO_VOT_AM.FAC	ZOD_NO_VOT_LT.FAC
ZOD_NO_VOT_SR.FAC	ZOD_NO_VOT_PM.FAC

For each of these input factor files the name identifies the user class and time period to which they apply. A 'ZOD' prefix indicates a reference to zero demand, used to reduce PT assignment run times. The *Additional_PT* folder contains information on fares in four files, one for each assigned time period. In addition, PT operators and modes are defined using a system file, GDA_SYSTEM_FILE.PTS.

Select links are undertaken during the PT 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.

Finally, an external script file, NTL_GENERATE_SCRIPT.txt, is used by the model to govern the creation of non-transit legs.

18.3   Calculation Steps

The calculation steps of the PT model are identical by time period and are shown diagrammatically in

Table 18.1. Having received the inputs from the previous model stages and from the Input folder the model prepares the factor files and network information before running through the process of enumerating all of the possible route options for each I, J pair, taking into account the modes available and the times, distances and number of interchanges that each option will require. Following this stage, the model divides the trips between the various route options on the basis or the cost (including the fare) of each combination. Having calculated the trip pattern, the model skims the costs and returns both the costs and network information to the main FDM process.

18.4   Outputs

The outputs of the PT Assignment Model fall into two categories, those required by the FDM, and those produced purely for reporting purposes.

18.4.1   FDM Outputs

The FDM outputs are the assigned networks, which are passed on to Active Mode Assignment as the starting point for the network build procedure at that stage, and generalised cost matrices by user class for each of the four assigned time periods. To give the skims for the unassigned time period (Off-Peak), an additional ten-minute penalty is added to the skims from the first interpeak period (IP1 or LT). This reflects the lower service frequencies in the Off-Peak while assuming that those who choose to travel are aware of the timetables.

18.4.2   Reporting Outputs

The reporting outputs produced by the PT Assignment model include those shown in Table 18.2:

Table 18.2 PT Assignment Model: Input Factor Files[33]

Files	
TP_MATRIX_TOTALS.CSV	TP_LINK_RECS.DBF
TP_LINK_RECS_PREP.DBF	TP_ON_OFFS.DBF
TP_ON_OFFS_NT.DBF	TP_ON_OFFS_PREP.DBF
TP_RAIL_B&A.DBF	TP_RAIL_B&A_SPLIT.DBF
TP_ALL_LOADINGS.DBF	TP_PT_ASSIGNED.LIN
TP_PT_COMPCST.MAT	TP_PT_EMP.MAT
TP_PT_COM.MAT	TP_PT_OTH.MAT
TP_PT_EDU.MAT	TP_PT_RET.MAT
TP_PT_WKONLYTRIPS.MAT	TP_SELECTLINK.MAT
SKIM_TP_PT_EMP.MAT	SKIM_TP_PT_COM.MAT
SKIM_TP_PT_OTH.MAT	SKIM_TP_PT_EDU.MAT
SKIM_TP_PT_RET.MAT	SKIM_TP_PT_ZOD.MAT
TP_PT_ASSIGNED.NET	TP_PT_ENUM.NET
TP_PT_LOADED.NET	PRIOR.NET
PT_PREP.NET	PT_SPEEDS.NET
PT_PREP.NTL	TP_PT_ASSIGNED.REP
TP_PT_ENUM.REP	

These outputs are discussed in significantly more detail in the *PT Development Reports*[34] for each regional model.

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[33] The emboldened **TP** indicates a time period variable and can take the values AM, LT, SR and PM.

[34] See Section 1.4 (Report Library)
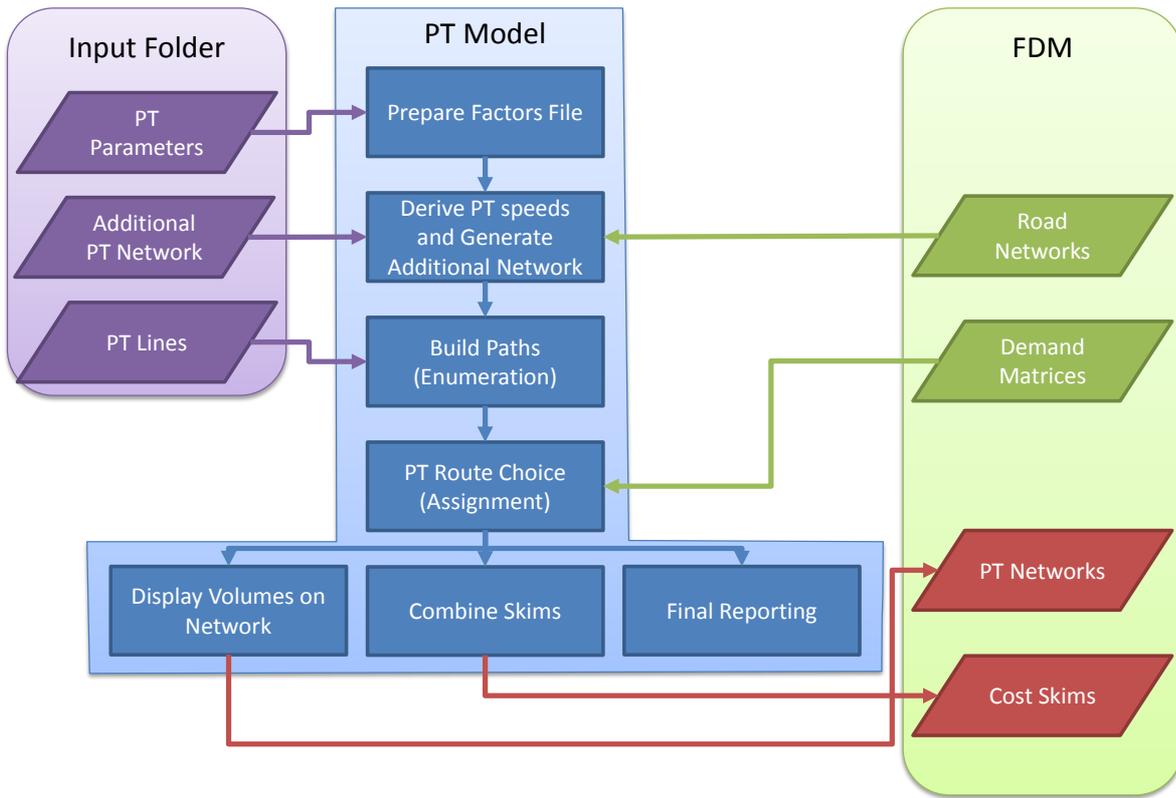
Figure 18.1 General PT Model Flow

19   Active Modes Assignment Model

19.1   Overview

The Active Modes Assignment Model takes the active modes matrices generated by the Assignment Preparation stage and assigns these to the active modes network in order to generate patterns of flows and the costs required to update the choice model processes. This Active Modes Assignment assumes no crowding or delays.

19.2   Inputs

The inputs for the Active Modes Assignment Model are the output CUBE format PT networks, the demand model produced assignment matrices (by time period and consisting of 5 user classes and two modes), and two additional network files contained in the Input folder: PED_ONLY.DBF, and CYCLE_DATA.DBF. These indicate pedestrian only links and cycle lanes.

19.3   Calculation Steps

The active assignment is a CUBE Voyager lowest cost path road assignment with no junction modelling and an assignment based purely on distance and a constant speed by mode.

Average walk and cycle speeds differ by age based on NHTS 2012 data. This is taken into account in the Active Modes Assignment Model for an accurate representation of costs by User Class. Maximum cycle speeds defined on the network vary from 12 to 20kph with 12kph being the default speed. Cycle speeds on specific facilities such as cycle lanes or greenways are higher than 12kph, depending on the cycle friendly qualities of these facilities such as the lack of traffic, surface, width, spacing of interchanges and so on. More detail on the definition of the active modes networks is available in the Active Modes Model Development Reports for each region[35].

Within the assignment itself active modes speeds are adjusted downwards for the EDU and RET user classes such that EDU walk speeds are equal to 96% of the standard speeds while EDU cycle speeds are 83% of the standard speeds. RET walk speeds are 86% of the standard speeds and RET cycle speeds are 79% of the standard speeds.

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[35] See Section 1.4 (Report Library)

19.4   Outputs

The outputs of this process include an assigned network, with walk and cycle flows by user class, and a set of generalised cost skims (in generalised minutes). Active modes travel costs are equivalent to journey time due to the lack of fares, tolls, parking charges or operating costs in the model.

20 Generalised Cost Calculations

20.1 Overview

The Assignment models generate new cost skims which need to be processed so that they can be returned to the main FDM loop, primarily by the creation of tour-based costs.

20.2 Inputs[36]

The inputs to this process are the generalised cost skims from each of the three assignment models (road, PT, and active) which are disaggregate by mode and time period. In addition, the driving cost adjustment matrices (PDist_CostFacDrive, PDist_CostPay and PDist_CostRest) generated by the Parking Distribution Module are also input for further processing here.

20.3 Calculation Steps

20.3.1 Create tour costs

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

20.3.2 Park & Ride

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

20.3.3 Aggregation by Purpose

Tour costs for all five modes are then aggregated by purpose to produce five matrices with 125 layers disaggregate by mode (5) and tour (25).

20.3.4 Aggregation by Time Period

The cost skims from the assignments and an approximate generalised cost for Park & Ride are also aggregated for use in the Convergence stage. This produces one matrix for each time period with 25 layers (modes (5) and user classes (5)).

20.3.5 Parking distribution

Cost feedback from the parking distribution process is an important aspect of the demand model. The parking distribution process outputs three cost files:

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[36] A full list of primary model inputs and catalog keys can be found in Appendix A and B.

- PDist_CostFacDrive: adjustment factors by tour to use to adjust the direct cost of driving based on the distribution of parking zones.
- PDist_CostPay: the weighted average of the hourly cost of parking of all of the production / attraction / parking zone combinations by tour.
- PDist_CostRest: the weighted average of the search and weighted walk times of all of the production / attraction / parking zone combinations by tour.

These require further processing at the generalised cost stage to take account of the impacts of FWPP in the COM and EDU demand segments. At its most basic level this looks for the proportion of trips in each time period and zone using FWPP and produces a weighted average of the costs on the basis of the levels of FWPP usage in the EMP and COM groups. However, it also calculates proportions at higher, aggregate levels to use for zone and time period combinations where car trips may be lacking in any particular demand model loop.

Additionally, the step carries out averaging of the costs relating to parking to prevent instability from one loop to the next. This process differs from loop to loop:

1) At the end of the first loop the costs passed to the next loop are an average of the initially estimated input costs and those output by the first loop.
2) At the end of the second loop the costs passed to the next loop are an average of those output at the end of the first loop and those output at the end of the second loop.
3) At the end of all further loops the costs passed to the next loop are an average of those output at the end of the current loop and the previously averaged costs from the penultimate loop.

20.4   Outputs

The outputs from this stage are:

- five purpose specific sets of average generalised cost matrices (.AGC's) each with 125 tables segmented by tours (25) and modes (5);
- five time period specific sets of generalised cost matrices (.GCMs) each with 25 layers (modes (5) and user classes (5)); and,
- nine driving cost adjustment matrices (three each for COM, EDU and all other user classes)

21 Convergence

21.1 Overview

The convergence stage compares the output from each FDM loop with the output from the previous loop in order to establish the degree of convergence. At present the model will not automatically stop once convergence is reached but the convergence file does allow a user to manually adjust the number of loops required based on experience with modelling in each region and to check that any individual run has converged satisfactorily and to run further loops if it has not.

21.2 Inputs[37]

The inputs to this stage are the generalised cost (.GCM) matrices and the demand matrices from the Assignment Preparation stage from both the current and previous demand model loop.

21.3 Calculation Steps

Convergence of the demand model is evaluated using GAP analysis, which is a standard measure of convergence for supply and demand systems. This is defined as:

$$GAP = 100 \times \frac{\sum_{ij} C_{ij} |T_{ij} - T_{ij}'|}{\sum_{ij} C_{ij} T_{ij}'}$$

<u>Where</u>: GAP is the GAP statistic;

C_{ij} is the generalised cost on the previous demand model loop;

T_{ij} are the trips on the previous demand model loop; and

T_{ij}' are the trips on the current demand model loop.

Convergence is considered to be acceptable when GAP<0.2 but dependent on runtimes it may be worth pursuing a value below 0.1.

21.4 Outputs

The output of this module is a single print file which details GAP convergence calculated across all modes on every successive loop.

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[37] A full list of primary model inputs and catalog keys can be found in Appendix A and B.

Appendix A   Full list of input files

Group	Input file
NDFM outputs and tour proportions	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Dem_Zone_Zone_HGV.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Dem_Zone_Zone_M1.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Dem_Zone_Zone_M2.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Dem_Zone_Zone_M3.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Work_Zone_Zone_M1.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Work_Zone_Zone_M2.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Work_Zone_Zone_M3.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Prods_CA.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Blue_White_Collar.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Emp_Split.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\One_Way_NonRetired.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\One_Way_Retired.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Two_Way_Attractions_NonRetired.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Two_Way_Attractions_Retired.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Two_Way_Productions_NonRetired.CSV
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Two_Way_Productions_Retired.CSV
	{CATALOG_DIR}\Params\Trip_End_Parameters\Base_Prod_Tour_Proportions.MAT
	{CATALOG_DIR}\Params\Trip_End_Parameters\Base_Attr_Tour_Proportions.MAT
Special demands	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Internal_Goods.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\AM_SpecialZones.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\LT_SpecialZones.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\OP_SpecialZones.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\PM_SpecialZones.MAT
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\SR_SpecialZones.MAT
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\Special_Zones\SZ_data.csv
Base cost matrices	{CATALOG_DIR}\Params\BaseGenCosts\AM_ALL_D0.GCM
	{CATALOG_DIR}\Params\BaseGenCosts\LT_ALL_D0.GCM
	{CATALOG_DIR}\Params\BaseGenCosts\SR_ALL_D0.GCM
	{CATALOG_DIR}\Params\BaseGenCosts\PM_ALL_D0.GCM
	{CATALOG_DIR}\Params\BaseGenCosts\OP_ALL_D0.GCM
	{CATALOG_DIR}\Params\BaseGenCosts\EMP_M3.AGC
	{CATALOG_DIR}\Params\BaseGenCosts\COM_M3.AGC
	{CATALOG_DIR}\Params\BaseGenCosts\OTH_M3.AGC
	{CATALOG_DIR}\Params\BaseGenCosts\EDU_M3.AGC
	{CATALOG_DIR}\Params\BaseGenCosts\RET_M3.AGC
Zone information files	{CATALOG_DIR}\Params\Zone_Conversion\Seq_2_Hier.exe
	{CATALOG_DIR}\PARAMS\SYNTHESIS_SECTOR_V1_1.TXT
	{CATALOG_DIR}\Params\Trip_End_Parameters\SECTOR_LIST.DBF
	{CATALOG_DIR}\Params\Trip_End_Parameters\ZONE_LIST.DBF
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\Zone_Areas.DBF
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\Zone_Lookup.csv
	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\SA_Zones_Sector.DBF

Group	Input file
Mode and destination choice parameters MDC for 01-29 One Way for 30-33	{CATALOG_DIR}\Params\MDC_Params\P??_ALPHA.MAT
	{CATALOG_DIR}\Params\MDC_Params\P??_BETA.MAT
	{CATALOG_DIR}\Params\MDC_Params\P??_LAMBDA.MAT
	{CATALOG_DIR}\Params\MDC_Params\P??_ASC.MAT
	{CATALOG_DIR}\Params\MDC_Params\P??_IZM.MAT
	{CATALOG_DIR}\Params\OneWay_Params\P??_ALPHA.MAT"
	{CATALOG_DIR}\Params\OneWay_Params\P??_BETA.MAT"
	{CATALOG_DIR}\Params\OneWay_Params\P??_LAMBDA.MAT"
	{CATALOG_DIR}\Params\OneWay_Params\P??_ASC.MAT"
	{CATALOG_DIR}\Params\OneWay_Params\P??_IZM.MAT"
Parking information	{CATALOG_DIR}\Params\GenCost_Params\Parking_VoT.dbf
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\FWPP_{Run ID}{Model Year}.CSV
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PCharge_{Run ID}{Model Year}.CSV
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PDist_{Run ID}{Model Year}.CSV
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PDistParams_{Run ID}{Model Year}.DAT
	{CATALOG_DIR}\Runs\{Model Year}\{Run ID}\Input\PnRSites_{Run ID}{Model Year}.CSV
Greenfield inputs	{CATALOG_DIR}\Runs\{Model Year}\2 Demand\{Growth}\Greenfield_Allocation.txt
	{CATALOG_DIR}\Params\Greenfield\Generic_Greenfield_Zone_File.MAT
	{CATALOG_DIR}\Runs\{Year}\2 Demand\{Growth}\GField\GField_Zone_?.csv
Road networks (AM, LT/IP1, SR/IP2, PM or OP)	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\Saturn.dat
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\DefaultOptions.dat
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\DefaultParams.dat
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\SATURN.BUS
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\saturn.111
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_Signals.111
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\saturn.222
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\saturn.333
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\saturn_??.444
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_9UC_Tolls_2011.444
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\saturn.555
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_NRA_JT_2014.666 *(except OP)*
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\JT20{Model Year}_??.666
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_additional.777
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_Bridges.777
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_Inner.777
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_M50.777
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_M50_ATC.777
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_Outer.777 *(AM only)*
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\3 Road\??\??_PreLd.PLD *(except OP)*

PT network files **(factor files for EMP, COM, OTH, EDU, RET and ZOD)**	**{CATALOG_DIR}\Params\4 PT \4 PT_VOT_Table.dbf**	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\FARES.MAT	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\FARES_AM.FAR	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\FARES_LT.FAR	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\FARES_PM.FAR	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\FARES_SR.FAR	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\NTL_GENERATE_SCRIPT.txt	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\4 PT_Dump_Links.csv	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\SELECT_LINK_SPEC.TXT	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Additional_PT\SYSTEM_FILE.PTS	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Factor_Files\???_NO_VOT_AM.FAC	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Factor_Files\???_NO_VOT_LT.FAC	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Factor_Files\???_NO_VOT_PM.FAC	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Factor_Files\???_NO_VOT_SR.FAC	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Lines\Bus_{RunID}_{Model Year}.LIN	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Lines\New_Mode_{RunID}_{Model Year}.LIN	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Lines\Rail_{RunID}_{Model Year}.LIN	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\BRT_FareZones.DBF	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\DBus_FareZones.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Luas_Links.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Luas_Nodes.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Metro_Links.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Metro_Nodes.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Rail_Links.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Rail_Nodes.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Walk_Links.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\4 PT\Walk_Nodes.dbf	
Active modes	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\AMM\CYCLE_DATA.dbf	
	{CATALOG_DIR}\Runs\{Model Year}\{RunID}\Input\Networks\AMM\PED_ONLY.DBF	
Finalisation files	{CATALOG_DIR}\Params\AssPrep\CarUserToCarDriver.PRM	
	{CATALOG_DIR}\Params\AssPrep\PeriodToHour.PRM	
	{CATALOG_DIR}\Params\AssPrep\AM_Incrementals.INC	
	{CATALOG_DIR}\Params\AssPrep\LT_Incrementals.INC	
	{CATALOG_DIR}\Params\AssPrep\SR_Incrementals.INC	
	{CATALOG_DIR}\Params\AssPrep\PM_Incrementals.INC	
	{CATALOG_DIR}\Params\AssPrep\OP_Incrementals.INC	
	{CATALOG_DIR}\Params\AssPrep\TaxiProps.MAT	
	{CATALOG_DIR}\Params\AssPrep\Taxi_Incrementals.INC	
Preliminary test / dummy files	{CATALOG_DIR}\Params\Active_Assignment \Dummy_Active_Assign.AAM	
	{CATALOG_DIR}\Params\Empty.prn	
	{CATALOG_DIR}\Params\FWPP\Dummy_FWPP.MAT	
	{CATALOG_DIR}\Params\PnR\PnR_Blank_Costs.AGC	
	{CATALOG_DIR}\Params\PnR\PnR_Start_File.CSV	
	{CATALOG_DIR}\Params\4 PT \4 PT_Assignment_Test.PTM	
	{CATALOG_DIR}\Params\3 Road\Dummy_Demand.UFM	
	{CATALOG_DIR}\Params\3 Road\Matrix_LowFlow.UFM	
	{CATALOG_DIR}\Params\3 Road\SATALL_KR_1ITER.DAT	

Appendix B   Full List of Catalogue Keys

Key	Description
{Scen. Name}	The name of the scenario
{Run ID}	The ID for this run
{Growth}	The growth scenario
{Model Year}	The model test year (12 for the base)
{Zones}	The total number of zones in the model
{Internal_Zones}	The number of the last internal zone in the model
{Int_Zones}	The internal zones for the PT assignment
{Externals}	The external zones, as ranges (1754-1843 or 7,23,45-73,123-126)
{Ext_Zones}	The external zones for the PT assignment
{OGV_Permit}	The zones where OGVs need permits (central Dublin)
{Max Dem Loops}	The maximum number of demand loops to run (1 for the base, 5 for the future)
{Dloop}	For Warm Start models needing to start after the first loop, the demand loop to pick up the process from
{Model Choice}	Tells the model whether to run right through or whether to run only parts of the the process
{Model Run Options}	A switch to tell the model to start from scratch or to pick up from an intermediate point (Warm Start)
{Jump To}	The point in the model to pick up from when Warm Start is in use
{Highway Period}	Set this to run individual highway assignments
{Public Transport Period}	Set this to run individual PT assignments
{Program_Directory}	The folder containing the SATURN executable files (.../XEXES)
{User Program Folder}	The local folder to use to store SATURN working files
{Include FWPP}	Turn this on to include Free Workplace Parking
{Include PnR}	Turn this on to include Park & Ride
{Include PDIST}	Turn this on to include Parking Distribution
{Include Pcon}	Turn this on to include Parking Constraint. This should only be used if {Include_PDist} is turned off
{PT Loops}	The demand model loops in which the PT assignment will be run
{Crowding}	Turn this on to use Crowding in the public transport models
{Crowding Iterations}	The number of loops to run in the Crowding model in order to try and achieve convergence
{PT_SL}	Public Transport_Select Link. Set this to 1 to extract select link information from the PT assignment using the select link script defined in the input folder
{Keep_Files_Setting}	Defines the range of intermediate output files to keep at the end of the model run
{Delete Route File}	Turn this on to delete the PT route files. This will save a lot of disk space
{PnR_Alpha}	The Alpha value for Park & Ride (scalar on the road cost)
{PnR_Gamma}	The Gamma value for Park & Ride (scalar on the PT cost)
{PnR_LParam}	The likelihood of finding a space in Park & Ride (related to the search time)
{PnR_Lambda}	The Lambda value (spread parameter) for Park & Ride site choice
{PnR_Occupancy}	The Park & Ride occupancy derived from the NHTS
{PnR_Penalty}	The penalty to be applied to Park & Ride sites which exceed the far capacity
{PnR_Grad}	The gradient of the Park & Ride capacity constraint
{PnR_Succ}	The number of successive loops on which Park & Ride must meet convergence criteria before exiting
{PnR Loops}	The demand model loops in which the Park & Ride process will be run
{Max_PnR_Loop}	The maximum number of Park & Ride loops to run
{PnR_Attr_Threshold}	The maximum change in the Park & Ride Attr values which can be classed as converged
{PnR_Occ_Threshold}	The maximum change in the Park & Ride occupancy which can be classed as converged

{PnR_VOT}	The Value of Time for Park & Ride
{Max_PDist_Loop}	The number of loops to run in the Parking Distribution process in order to try and achieve convergence
{PDist_ConvTest_Abs}	The absolute convergence threshold for the Parking Distribution process
{PDist_ConvTest_Percentage}	The percentage convergence threshold for the Parking Distribution process
{PDist_OutputInfo_Threshold}	The cut off for Parking Distribution output information - lower values increase runtime
{Limit_Max_Memory_Usage}	A switch to tell the model whether to run all four PT assignments simultaneously (high memory requirements) or to run them in two pairs.
{Int_Goods_Growth_Factor}	A factor to apply to the input internal goods matrices
{Spec_Zns_Growth_Factor}	A factor to apply to the input special zone demand
{Factor_RMSIT}	A factor to apply to RMSIT if required