National Transport Model

Model Validation Report

August 2011

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Glossary of Terms

AADT	Annual Average Daily Traffic
BPR	Bureau of Public Roads
CA	Car Available
CN	Car Not Available
CO_2	Carbon Dioxide
CSO	Central Statistics Office
ED	Enumeration District
GIS	Geographical Information System
HBEB	Home Based Emplyers Business
HBED	Home based Education
HBO	Home Based Other
HBW	Home Based Work
HGV	Heavy Goods Vehicle
IP	Inter Peak
LOR	Leinster Orbital Route
ME	Matrix Estimation
MSA	Method of Successive Averages
NBM	National Bus Model
NHBEB	Non Home Based Employers Business
NHBO	Non Home Based Other
NRA	National Roads Authority
NRM	National Rail Model
NTM	National Traffic Model
NTpM	National Transport Model
NTS	National Travel Survey
PAG	Project Appraisal Guidelines
PCU	Passenger Car Unit
PJT	Perceived Journey Time
POWCAR	Place of Work Census of Anonymised Records
TAGM	Trip Attraction Generation Model
TMS	Traffic Management Study
VDM	Variable Demand Model

Introduction

1.0 Introduction

1.1 Background

The National Roads Authority (NRA) is the statutory body in Ireland with the responsibility for securing a safe and efficient network of national roads.

In 2007, the NRA commissioned the development of a National Traffic Model (NTM) to support strategic planning on the national road network over the period to 2040. The development of the NTM was intended to provide the starting point in the development of a more structured approach to project appraisal for all projects under the Authority's remit, ensuring that all projects were examined in a consistent manner.

The NTM comprises a series of modules which cover:

- Population and employment forecasts for 2025 and 2040 by zone (Trip Attraction Generation Model);
- GDP and Car Ownership forecasts for 2025 and 2040 (Car Ownership Model);
- A trip distribution model which adjusts the future demand matrix based on travel costs (Trip Distribution Model);
- A traffic assignment model for the AM Peak Period (07:00 – 09:00) and the Inter Peak Period (12:00 – 14:00);

The National Traffic Model was completed in 2008, and is currently maintained by the National Roads Authority Strategic Planning Unit. It continuously used as the basis for strategic planning, scheme appraisal and policy evaluation, and remains available for use by government bodies, local authorities and researchers.

1.2 The Role of a Multi Modal Variable Demand Model

In recent years, there has been an increased recognition of the importance of a more holistic assessment of how best to evaluate the impacts of transport infrastructure, policy and demand management initiatives – all of which can have significant impacts on the demand for road travel. This focus arises out of the realisation that environmental externalities are as significant a by-product of transport demand as traffic congestion and road safety, which for many years have been the focus of transport appraisal. In this regard, it is necessary to be able to forecast travel demand impacts of transport interventions, in addition to travel time and safety impacts.

The requirement for a National Transport Model (NTpM) which could assess such impacts was identified in 2009 by the National Roads Authority as part of the development of a national strategy for traffic management. The Traffic Management Study (TMS) set out a number of objectives (see Figure 1-1) which included reductions in Carbon Dioxide (CO_2), emissions and noise associated with travel demand.

Economic

- To improve the allocative efficiency of the national road network through the active allocation of demand for roadspace to those categories of user who maximise benefit and minimise adverse impact, particularly in congested areas;
- To reduce the economic impact of delay that results from incidents on the national road network through effective incident management
- To address excessive reliance on national roads as a means of supporting commuting traffic
- To maximise the capacity of congested areas of the road network through effective management solutions

Environmental

- To encourage the use of public transport on national roads through facilitating a reduction in travel times and an increase in reliability
- Contribute to reductions in CO_2 emissions, air pollution and noise

Accessibility and Social Inclusion

- To maintain and improve opportunities for access to business, employment, education, health and recreation where appropriate on national roads

Integration

- To promote an understanding of the requirements for integrated land use and transport planning policies in developing areas alongside or nearby national roads
- To encourage the use of public transport on national roads through supporting network integration

Safety

- To reduce knock-on safety risks that result from incidents on the national road network as a result of congestion and diversions to inappropriate routes
- To reduce the frequency and severity of accidents on National Roads

Figure 1-1 Objectives of the National Roads Traffic Management Study

Furthermore, the TMS recognised that the true economic impact on management measures could only be quantified when the demand responses of traffic management, demand management and fiscal policies where included in the assessment. This further supported the requirement for a National Transport Model which considered mode share, assignment and variable demand responses.

Road Pricing and tolling proposals form an important element of future traffic management strategies. Whist the National Traffic Model permitted an understanding of the potential rerouting impacts of road pricing and/or tolling proposals, the National Transport Model provides a more holistic view of the more positive impacts of tolling - namely demand reduction, emissions benefits, decongestion and mode share impacts.

1.3 Model Hierarchy

The National Transport Model is intended to support and complement the existing urban modes that are in use by authorities in Dublin, Cork and Limerick. The modelling of demand in those areas is best undertaken using specific urban models which can reflect the complexity of the network and transport provision in those areas. In the years since the completion of the National Traffic Model, it has been made available to a number of Local Authorities for undertaking strategic studies of transport demand and impact assessment. In addition, necessary information has been supplied to Cork City Council and Limerick City Council, to support the development of urban models by those authorities. It is intended that, as has been the case with the National Traffic Model, that the National Transport Model will continue to be used as a reference tool in the development and updating of the various urban transport models.

Outside the key urban areas, transport activity is strongly focused on road, with some 81% of motorised travel outside urban areas being undertaken with private vehicles[1], and 91% of all person kilometres using the road network (including bus and Heavy Goods Vehicles). This highlights the need for the National Roads Authority to maintain a strong understanding of rural and inter-urban transport demand at a strategic level, and the issues that will impact on such demand in the future. The Authority has progressed significant research into impacts of fuel price, electric vehicle usage and road pricing on travel demand – the National Transport Model now incorporates the findings of that research into a single analysis tool to support its strategic planning function.

In this way, the National Roads Authority can consider management and policy proposals as part of strategies to provide for future transport needs and to manage existing demands. The consideration of management options in this regard is central to the Common Appraisal Framework[2], which dictates a requirement to consider management solutions as an alternative to provision of major infrastructure.

1.4 Status of the National Transport Model

The National Transport Model was completed in 2011, and is now employed by the

[1] Source – National Transport Model Base Year Model outputs person km totals of 81% private car, 5% Heavy Goods Vehicles, 9% rail and 5% bus. Walking and cycling impacts are included in the change in vehicular travel demand prior to the assignment.

[2] Guidelines on a Common Appraisal Framework for Transport Projects and Programmes, Department of Transport, June 2009

National Roads Authority in strategic planning studies, transport policy impact assessments and appraisal of road tolling schemes.

In tandem with this development, the use of Variable Demand Models (including the National Transport Model) has been incorporated into the NRA Project Appraisal Guidelines (PAG). *PAG Unit 5.2: Construction of Transport Models* sets out criteria whereby the use of Variable Demand Models should be adopted for scheme appraisal, and is outlined overleaf in Table 1-1.

1.5 National Transport Model Functionality

The National Transport Model functionality was defined by the range of policies, measures and strategies that it would be required to assess, and the outputs that it would be required to generate.

At the model scoping stage, it was recognised that the end product should:

- Be based on a flexible, modular structure, allowing modules to be added/enhanced at a later date;
- Make maximum use of the National Traffic Model, which has been developed to a high level of accuracy and has been employed successfully since its completion in 2008; and
- Avoid over complication in modelling, to reduce the level of development risk.

The scoping exercise was progressed through a series of workshops within the project team. During these meetings, it was clear that the NRA would play an important role in the model development team, in addition to being the key final user. Discussions were also held with Irish Rail and Roads Service Northern Ireland, who both provided input to the model. The process led to the definition of a series of measures that would require assessment through the NTpM. These are outlined in Table 1-2.

As the model becomes more utilised, it is envisaged that its functionality would be complemented as needed by further refinement of these tools to provide a finer level of output. In essence, the model should begin with a robust working platform, and proceed towards improvements in various modules within its structure as additional data becomes available.

Table 1-1 Criteria for Scoping of Transport Models

Category	Static Models	Assignment Models	Variable Demand Models
Description	Manual assignment calculations using fixed demand flows. Can comprise spreadsheet modelling, junction modelling or static microsimulation modelling.	Models which use a fixed traffic demand matrix, and assess impacts of reassignment only.	Models which include consideration of demand responses (Trip Generation, Distribution and Mode Share).
Nature of Scheme	• Non-major schemes (<€5m) • Road safety schemes • Localised improvement	• Major schemes (>€5m) • New roads • Significant upgrades to existing roads • Rural areas • Small urban areas	• Major schemes (>€5m) • New roads • Significant upgrades to existing roads • Major urban areas
Likely Impacts of Scheme	• Rural road networks with no route-switching • Single or multiple junctions in urban areas with no route-switching	• Schemes which will lead to changes in routing • Areas with limited public transport • Areas where induction or suppression of traffic is not anticipated • May use microsimulation models to model complex merging/shockwaves	• Schemes which will generate traffic impact • Major urban areas where congestion will exist • Schemes which lead to large reductions in journey time • Areas where induction or suppression of traffic is anticipated • Schemes which will increase competition with public transport

Source: PAG Unit 5.2: Construction of Transport Models

Table 1-2 Range of Policy/Infrastructural Measures that can be tested in the NTpM

Criteria	Measure
Network Management	Traffic Management
	Road Pricing/Tolling
	Public Transport Priority
	Demand Management
	Changes in Network Capacity
	New Infrastructure
	Parking Controls
Policy	Fuel Price
	Cordon Charging
	Freight Management Policies
Development	Development Impacts
	Spatial Planning Strategies
Other Modes	Public Transport Fares
	Public Transport Service Changes

1.6 NTpM Outputs

The outputs of the NTpM are currently structured to provide the basis for a range of indicators which form a consistent input to subsequent calculations. At present, the following outputs are generated:

Table 1-2 NTpM Outputs

Criteria	Measure
Travel Demand	Traffic flow on roads
	Passenger flow on rail links
	Bus demand by link/route
	Network passenger/traffic demand
	Mode share impacts
	Travel Time impacts
	Journey length impacts
	Changes in demand
	Speed on links
	Network Performance Indicators (km, hrs, trips, etc)
Financial	Traffic flow through toll points
	Toll revenue
	Public transport fare revenue
	Impact on exchequer
Environmental	Vehicle km travelled (by all modes)
	Emission (at inter-zonal level)
	Input to accessibility model (for consideration of Wider Economic Benefits)
	Input to air quality models

Model Structure

2.0 Model Structure

2.1 Overview

This chapter of the report outlines the structure of the NTpM and the approach taken in developing the key elements of the model. The structure of the NTpM can be broken down into 4 sub-models:

- Rail Model – National Rail Model (NRM);
- Bus Model – National Bus Model (NBM);
- Traffic Model – National Traffic Model (NTM); and
- The Variable Demand Model (VDM).

The NTM therefore represents one module of the NTpM. Separate public transport models for rail and bus were developed, with the variable demand model allocating demand between the modes.

The VDM is the central tool of the model suite which interfaces with the traffic and public transport elements of the NTpM. The VDM takes the outputs from the traffic and public transport assignments (cost skims), performs the relevant demand calculations and then feeds the updated demand matrices back into the assignment models. The basic structure of the NTpM is illustrated in Figure 2-1.

2.2 Walking and Cycling

In assessing the impacts of walking and cycling, it was firstly considered that representing the impact of changes in the level of walking and cycling is a key requirement in the model. Nevertheless, such trips are mainly short distance, and capturing actual patterns of activity (reporting origin and destination zones) would require substantial disaggregation of zones. For urban areas, disaggregation of zones to small geographical areas is possible, and can allow a high proportion of walking and cycling activity to be reflected in those models as trips between zones (inter-zonal trips). Even so, such an approach can still fail to reflect trips that take place wholly within individual zones (intra-zonal trips).

At national level, it is not practical to define zones at such a small scale due to the impact that it would have on run times. As such, a very large proportion of walking and cycling trips within a national model will be intra-zonal. Nevertheless, it was considered that the VDM element should capture the effects of measures on walking/cycling in the form of reduced aggregate vehicular travel demand. The health benefits of walking and cycling can then be appraised through employment of the methodology set out in the NRA *PAG Unit 13: Walking and Cycling Facilities*.

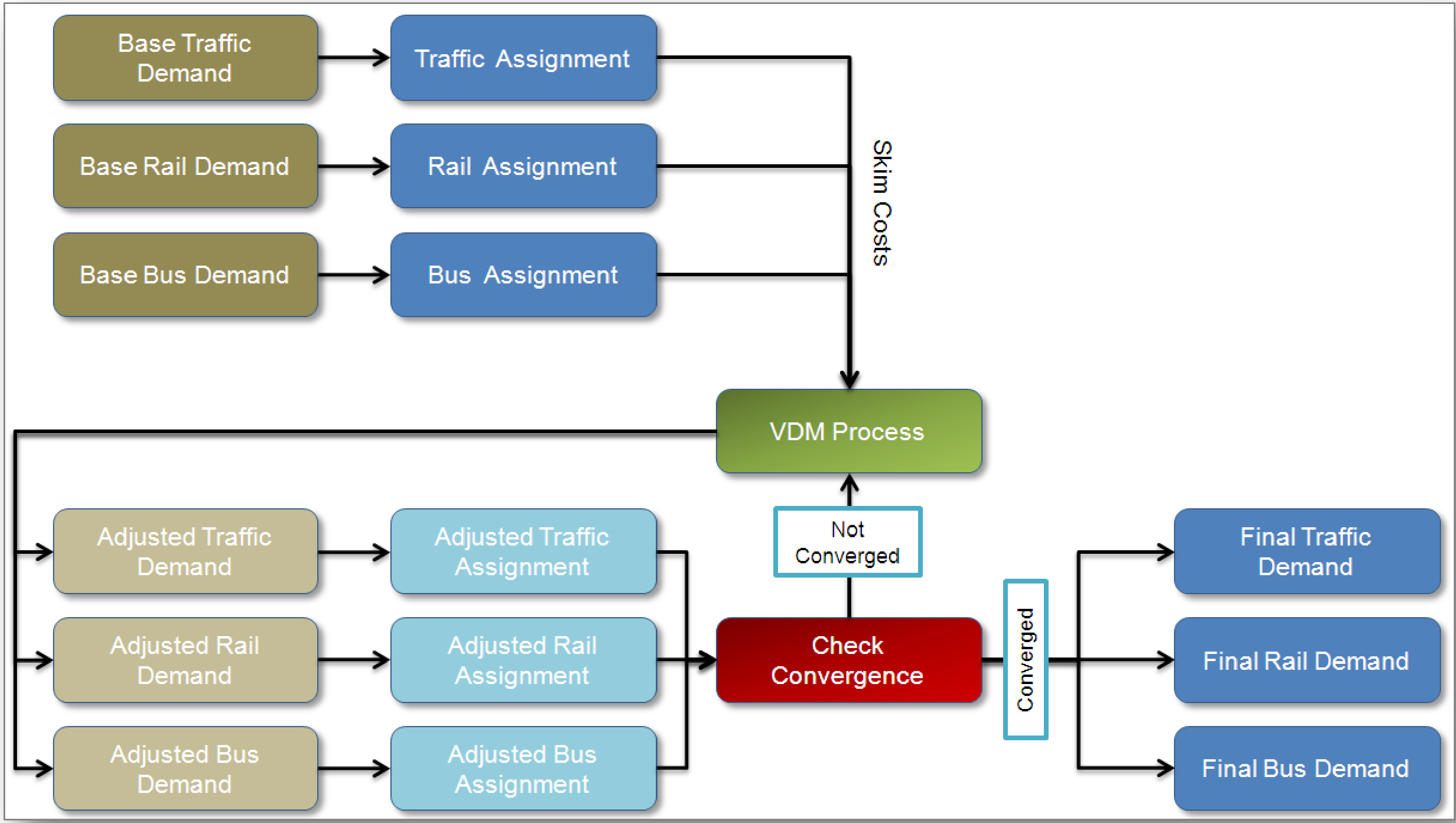

Figure 2-1 NTpM Basic Structure

2.3 Demand Segmentation

As with any transport model, demand is segregated into a number of individual matrices to represent travel mode, trip purpose, car availability and travel period. Details on segmentation are provided below.

2.3.1 Travel Modes

The NTpM was developed in order to assess the impact of network and policy changes upon the following modes:

- Road;
- Rail;
- Bus; and
- Heavy Goods Vehicle (HGV)

The VDM process accounts for the impact of increased walking and cycling on the level of transport demand. At this stage, the demand model does not assign walking and cycling demand – to do so would require significant disaggregation of zones which would make model runtime unsustainably high. It is considered that walking and cycling assignment should continue to be addressed in existing or future models for urban areas.

It was considered that domestic air travel was not a significant part of national travel and, for reasons of minimising technical risk need not be included in the NTpM.

International travel was not considered other than the modelling of access to major international ports (air and sea). The development of an international demand matrix could be undertaken as part of a subsequent enhancement of the freight demand matrix, and would likely incorporate some of the information from Eurostat and the TRANSTOOLS[3] models.

2.3.2 Trip Purposes

The NTpM requires demand data for all 3 modes (road, rail and bus) to be segmented into 3 trip purposes, as follows:

- Commuting;
- Business; and
- Other

These trip purposes reflect the range of parameter values currently available form the Department of Transport, Tourism and Sport and which are used in project appraisal. Within the NTM, a higher level of trip purpose disaggregation was retained through the model development, using the following definitions:

- Home Based Work (HBW);
- Home Based Employers Business (HBEB);

[3] **TRANS-TOOLS** is a European transport network model covering both passengers and freight, as well as intermodal transport. It combines advanced modelling techniques in transport generation and assignment, economic activity, trade, logistics, regional development and environmental impacts. See http://energy.jrc.ec.europa.eu/transtools/TT_model.html

- Home Based Education (HBED);
- Home Based Other (HBO);
- Non Home Based Employers Business (NHBEB);
- Non Home Based Other (NHBO); and
- Freight (HGV).

These classifications were subsequently combined in the final model. Further information on the development of the road and HGV matrices is set out in the NTM Model Validation Report.

2.3.3 Car Availability

Each public transport passenger demand matrix is split into Car Available (CA) and Car Non-Available (CN) matrices. This removes the possibility of Car Non-Available public transport demand moving to road in the 'Do-Something' scenario.

Figure 2-2 NTpM Demand Segmentation

2.4 Model Period

In the variable demand model demand data is needed for a consistent time frame between modes. The NTpM therefore represents the 15 hour weekday period between 7am and 10pm. This period was chosen as the majority of public transport services occur between these hours.

2.4.1 Public Transport Modes

The rail and bus models were constructed as models for a single 15-hour period using the available data. In fact, the development of rail and bus matrices for shorter periods would be significantly more complex due to the long duration of many such trips (up to 4 hours). This would require some interpretation of what travel would be considered to occur during that short period, and would likely lead to subsequent complications with annualisation.

2.4.2 Road Mode

The traffic model has been developed for an AM Peak and Inter Peak, with the 15-hour total calculated as a multiple of the assignment for each period based on regression using national traffic count information. This generates a consistent time period across all three travel modes.

2.5 Model Software

A technical review of software packages was undertaken during the development of the NTM. That review focused on the following elements:

- Road network modelling capability
- Public transport network modelling capability
- Integration of road/PT modules
- GIS linkages
- Demand modelling
- Integration with other packages

A detailed comparative assessment was undertaken to understand the relative merits of the different software packages. At that time, it was recommended that VISUM be adopted for the development of the National Traffic Model. VISUM has been shown to be technically appropriate for the type of work being proposed, with a strong GIS interface, allowing high quality presentation of results. VISUM has also been shown to have a substantial user base.

In order to maintain some compatibility with the NTM, and to avoid the need for additional expenditure on modelling software licenses, it has been considered that the NTpM would be best developed using the existing VISUM platform. This conclusion was also reached on the basis of available experience in developing Python[4] scripting for interaction with VISUM outputs, and the lower risk in product development that such experience brings.

[4] Python is an open source programming language used to integrate systems within Windows (*www.python.org*)

Data Sources

3.0 Data Sources

3.1 Overview

The NTpM draws from a number of data sources which have facilitated the development of the demand matrices, the transport network, transport services and the validation of the Variable Demand Modelling processes. Key data sources are outlined here.

3.2 Transport Network and Services

3.2.1 Road Network

The road network is drawn from the NTM, which is, in turn, based on NAVTEQ data, suitably refined to accurately represent the road network in the base year. The road network includes all national primary, secondary and regional roads, plus local roads of any strategic importance. The road network is at a relatively refined level of detail – it is considered that additional level of detail on the road network would only be of value with further subdivision of zones beyond the current 874 zones. The Project Appraisal Guidelines dictate an increase in the level of detail in the road network, and associated model zoning, as part of the development of detailed Local Area Models. Further detail on the development of the road network is included in the NTM Model Validation Report.

The NTM is currently being enhanced to include a significantly higher detail in Northern Ireland, following ongoing dialogue with Roads Service, and the transfer of necessary data to the NRA in 2011.

3.2.2 Rail Network and Services

The main source of network information for the NTM was also NAVTEQ data. NAVTEQ provides the rail network in Geographical Information System (GIS) format which facilitated coding directly into the NTpM VISUM file.

All rail stations have been included through the network. For urban areas (Dublin and Cork), where multiple stations exist within an individual zone, all stations have been included for the model, but with stations connected to the same zones using multiple connectors. This approach ensures that the model is consistent with a full station to station matrix developed for rail travel. At mainline stations, separate connectors are provided for mainline, outer commuter and DART services – this ensures that aggregate station demand can be more easily allocated to different service types, hence simplifying the validation exercise.

Services and frequencies have been referenced from timetables in autumn 2010, and have been coded based on consistent routes at defined headways, which reflects many of the current Irish Rail timetables for intercity travel.

3.2.3 Bus Network and Services

Bus services have been coded onto the road network - this was achievable without the inclusion of any additional road links (reflecting the high level of detail that exists within the road network). Bus timetables from the following major operators were used to define service routes and main service stops.

- Bus Éireann;
- Aircoach;
- JJ Kavanagh & Sons;
- Citylink;
- Matthews;
- GoBus; and
- John McGinley.

3.3 Base Year Transport Demand

3.3.1 The Base Year

Data for the NTpM has been drawn from a number of sources. Although the traffic model had been constructed to a 2006 Base Year, it was considered necessary to project that forward to a new base year. Significant data on rail trips was available in 2009, with some additional data provided for March 2010. It was considered that data made available for rail demand was representative of 2009 – as such a 2009 Base year was defined for the NTpM.

3.3.2 Traffic Demand

The NTM contains basic demand information for the road network. Although constructed for a base year of 2006, the 2006 demand matrices were adjusted to represent a 2009 base year. This conversion to a 2009 demand matrix was undertaken by applying an aggregate factor to the 2006 demand matrix (described further below). The 15-hour weekday demand was calculated as a function of AM Peak and Inter Peak demand[5].

3.3.3 Rail Demand

The development of the rail demand matrix required access to a number of data sources, and the elimination of double counting to enable the construction of a demand matrix segregated by trip purpose. The following information was utilised:

- Census Journey to Work data (POWCAR);
- Aggregate Rail Demand indicators;
- Rail Ticketing Data;
- Behaviour and Attitude survey;
- Further manual boarding and alighting counts on mainline services at Connolly, Heuston, Limerick Junction, Mallow and Cork Train Stations;
- Train occupancy surveys at key points throughout the network: This information for March 2010 was made available from on-board counting equipment on the new InterCity railcars for the Sligo, Westport, Galway, Tralee, Rosslare Europort and Waterford routes. Manual counts were undertaken on the Waterford branch lines and the Western Rail corridor; and
- Counts of interchange passenger movements at Limerick Junction

[5] The Base Year for the NTM remains as 2006 – the 2009 model is a forecast model. Nevertheless, in running the model, a 2010 road network is used, which incorporates completion of the MIU's.

Aggregate Rail Demand

Rail demand is recorded at an aggregate level by Irish Rail on an annual basis. Aggregate totals (million passengers per annum) are outlined below in Table 3-1 from 2005 to 2009, and highlight a general increase in passenger numbers up to 2007, with a slight decline in 2008 and a substantial decline in 2009, with passenger levels reverting back to those seen during 2005.

Table 3-1 Irish Rail Aggregate Demand (passengers/year) - 2005-2009

	2005	2006	2007	2008	2009
Inter City/Commuter	21.399	23.662	25.261	24.781	21.278
DART	16.256	19.689	20.254	19.865	17.520
Total	**37.655**	**43.351**	**45.515**	**44.646**	**38.798**

This aggregate passenger data is used as a control total for the rail demand matrix during the model development.

Ticketing Data

Ticket sales information was made available by Irish Rail for a sample of weekdays, and allowed the generation of a partial origin-destination matrix for weekday ticket sales. This data allowed the definition of a number of categories for both single and return tickets such as: Standard Adult; First Class; Children; OAP; Student; and Work (Included in POWCAR dataset).

It is noted that the ticketing database included many trips which would also be included in the POWCAR dataset and excluded many trips where users had possession of pre-purchased travel passes. The process for eliminating this double counting is outlined in section 4 of this report.

Behaviour & Attitude Survey Data (2009)

AECOM received the raw data from a Behaviour & Attitudes survey carried out on Irish Rail Inter City services. The surveys were undertaken between June 2009 and November 2009 during which over 9,000 surveys were collected. The surveys provide a profile of existing Irish Rail passengers including age and trip purpose; a comparison of opinion of rail travel with alternative modes; ticketing information such as the method of purchase and ticket type, level of satisfaction with quality of service, reliability, catering facilities and staff; and recommendations on scope for general improvements of Irish Rail services.

The survey data provided good information on the split of trip purposes for existing rail passengers by intercity route, allowing the segmentation of the rail demand matrix by purpose.

Irish Rail Census

Irish Rail conduct a comprehensive series of passenger counts at railway stations throughout the Greater Dublin Area in October/November each year. The data for 2009 provided control totals for station demand as part of the development of the rail demand matrix.

Passenger Boarding & Alighting Surveys

Additional passenger boarding and alighting surveys were carried out at Connolly, Heuston, Limerick Junction, Mallow and Cork Train Stations. These surveys were undertaken on the 29th of June 2010 for the period 07:00 – 21:00. The surveys undertaken at Heuston, Limerick Junction, Mallow and Cork train stations dealt primarily with the Dublin to Cork route but also took into account trains to and from Tralee at Mallow, trains to and from Limerick at Limerick junction and trains to and from both Midleton and Cobh at Cork.

Route Loading Data

Route loading data were received from Irish Rail for a number of intercity routes for the month of March 2010. The route loading data provide links flows between train stations on each route. Route loading data were provided in each direction on the following rail corridors:

- Dublin – Galway;
- Dublin – Limerick;
- Dublin – Rosslare;
- Dublin – Sligo;
- Cork – Tralee;
- Dublin – Waterford; and
- Dublin – Westport

3.3.4 Bus Passenger Demand

The collection of inter-urban bus passenger demand presented particular difficulties given the current competitive scenario within which the bus market operates. It was not considered that it would be feasible to collate bus demand data for representation in a transport model that would be available for use by third parties, without potentially sensitive data becoming capable of being interpolated from the model, pending the development of rigid protocols for access to and use of such information. As such, it was necessary to develop a 'representative' picture of bus demand which would enable the model to function, but would not divulge sensitive information. Demand on bus services within cities is not included within the scope of the National Transport Model – this is reflected within the relevant urban models.

Aggregate annual patronage information was available for Bus Éireann and represents a high proportion of total bus travel outside urban areas. Aggregate data for other main inter-urban bus operators was not readily available and assumptions have been made of aggregate patronage based on the number of services operated (number of services factored by an assumed occupancy level and catchment population). The total annual bus patronage for 2009 was assumed to be 26.38m trips, based on the following breakdown of operators:

- Bus Éireann – 23.93m
- Aircoach – 0.90m;

- JJ Kavanagh & Sons – 0.45m;
- Matthew's – 0.10m;
- CityLink – 0.90m; and
- McGinley – 0.10m.

Table 3-2 Bus Éireann Aggregate Demand (2005-2009)

Customer Journeys	2005	2006	2007	2008	2009
Provincial Services	21.574	21.940	22.085	21.217	18.323
School Transport	43.596	42.367	45.507	45.709	42.388
Other	27.467	27.783	28.136	26.948	23.929
Total	**92.637m**	**92.090m**	**95.728m**	**93.874m**	**84.640m**

No bus passenger survey data, either route loading or boarding and alighting data was collected for use in the NTpM. This was not seen as a significant shortcoming, as bus represents a relatively low proportion of travel outside urban areas. As information becomes available in the future, the model can be updated as appropriate.

National Traffic Model

4.0 National Traffic Model

4.1 Overview

The National Traffic Model was completed in 2008, and comprises a strategic assignment model for the Republic of Ireland (with a coarser level of detail for Northern Ireland), built on a National Trip Attraction Generation Model (TAGM). Since 2008, it has been used as the basis for appraisal of road schemes, and has been made available to transport related public bodies for local area modelling. This section of the report provides an overview of the development of the National Traffic Model which now forms part of the National Transport Model.

4.2 Data Collection

4.2.1 Census (2006)

The Census database of journey to work trips was released in late 2007, and reports all journeys to work by ED for 2006. This information was extracted for input to the traffic model, thereby giving good Origin-Destination information without the necessity for widespread Roadside Interview Surveys. The POWCAR information also provides travel mode and time of departure, thereby allowing journeys by car during the AM Peak to be isolated.

The data was imported into database format. A total of 1,834,472 records were imported. According to CSO, the workforce comprises 1,930,042 persons. It was therefore necessary to factor the available dataset to account for missing records those who did not successfully code a place of work, or those with a variable place of work.,

The AM Peak traffic model is a Peak Period Model, modelling the average hour within the period 07:00 – 09:00. The POWCAR data identifies the time of departure for work trips in half hour intervals throughout the morning. In identifying the relevant commuting trips on the network, the following assumptions are made:

- Trips departing between 07:00 and 09:00 are valid trips and are included;
- Trips departing before 07:00 may be on the network during the 07:00 to 09:00 period. Conversely it is noted that trips departing just before 09:00 may not be on the network for much of the 07:00 to 09:00 period. It is assumed that both these overlaps cancel each other, and that only trips departing between 07:00 and 09:00 should be included; and
- Trips during the modelled period (1 hour) are achieved by dividing the 07:00 – 09:00 period by 2.

It is noted that the POWCAR dataset provides data only for the AM Peak Period. It is of limited use in the development of the Inter Peak Matrix, when Roadside Interview Data represents the main input into the development of the trip matrices.

Even with the reduction of the POWCAR data to the Average Peak Hour, it was evident that the number of work trips in the POWCAR data exceeded that which was observed in the Origin Destination surveys. A net reduction factor of 23.5% (10% to reflect the number of people who travel to work on a typical weekday as not all employees work a 5-

day week, and then by a further 15% to reflect typical attendance rates) was identified as appropriate to factor down the overall POWCAR matrix. Examining the resulting assignment, this reduces the proportion of Journey to Work trips during the AM Peak to 70% of total trips, which is consistent with the findings of the Roadside Interview surveys.

4.2.2 Origin Destination Surveys

Following initial exploration of a number of alternative forms of data collection, it was considered that road-side interviews would be the chosen method of data collection. This decision was made due to the high response rate that is achievable and the reduced likelihood for error due to the interviewer being present to deal immediately with any queries. Nevertheless, it was recognised that the extent of the road side interviews would need to be comprehensive to produce an accurate model and would therefore require the inclusion of all national primary, secondary and regional roads and all major links and distributor roads to significant towns and cities throughout the country.

Survey locations were selected on their strategic position to capture the potential maximum number of trips within the vicinity. The data collection would exclude the Leinster region due to data been available from previous work and other sections of the road network where RSIs were undertaken as part of NRA/Local Authority road schemes. The sites have been selected based on:

- Proximity to populated urban areas;
- Connectivity to significant urbanised populated areas; and
- Hierarchy of road network.

In order to identify survey locations, the population of towns and rural areas were taken from the Preliminary Census results (CSO, 2006). Surveys locations were then chosen on roads connecting to towns where the population is greater than 7,000 and from rural areas to significant towns/rural area where the population of the rural areas was greater than 8,000.

Origin and destination addresses were converted to the equivalent Enumeration District (ED) number defined within the model. MapInfo GIS software was used to undertake a logic check, whereby origins and destinations for each site were plotted on background base mapping to visually check that origins and destinations were on opposite sides of the interview site; and investigated if otherwise. The information was stored in an Excel spreadsheet for each individual RSI site for the AM, Midday and PM peak hours. The ED numbering system uses the 2006 CSO Enumeration Districts such that information could be easily compiled with CSO data to complete the matrix development process.

4.2.3 Volumetric Counts

A series of volumetric counts were also undertaken to assist in the matrix development. ATC's were generally undertaken from late April to late May 2007. Data was recorded continuously for a 4 week period.

4.3 Network Development

4.3.1 NAVTEQ

The main source of network information for the National Traffic Model was sourced from NAVTEQ data.NAVTEQ data provides detailed information on all existing roads throughout the country at all levels of complexity, with information on road type, speed and distances. The NAVTEQ information also provides geographical data for all roads which allows the data to be input directly to a VISUM network file.

Nevertheless, the NAVTEQ information leads to a 'Raw' network dataset, which requires significant processing to ensure that it is suitable for use in the current application. This section describes the extent of the network that has been imported to the National Traffic Model, the work undertaken to refine this network, and the relevant checking of the final network.

The first phase in developing the network was to import the NAVTEQ data into VISUM and define the network parameters that would be used throughout the model development.

4.3.2 Network Coding

Detailed coding of the network consists of several key elements as follows:

Links
Each link in the modelled network has been classified based on the NRA classification of link types. The model network can be grouped into five key link types:

- Motorways;
- National Primary Roads;
- National Secondary Roads;
- Regional Roads; and
- Local Roads.

Link Capacity
All links in the modelled network have been coded to include their link capacity which is based on a 1 hour capacity derived from the Highway Capacity Manual[6]. Also the number of lanes on each link type has been included in the network. In total there are 40 different types of link included in the network.

Nodes
Due to the strategic nature and size of the model, it was necessary to make several assumptions which globally affect all nodes in the model network. These are as follows:

- Control Type - The control type at all nodes is set to unknown;
- Turning Movements - All turning movements are possible at each node;
- Priority – Priority is given to the major flow at each node;
- Transport Systems – All turning movements are open to all transport systems.

[6] Highway Capacity Manual. US Transportation Research Board, 2000

Connectors

Once the network has been coded it needs to be connected with the zoning system so the trips can be assigned onto the network. This involves a process of connecting the zones to the network at one or more locations via zone connectors. The connectors act as both the origin and destination point for each zone. Zone connectors were added automatically by VISUM, and subsequent manual adjustments were made to ensure accurate allocation of connectors, particularly for urban areas.

4.3.3 Speed Flow Curves

The VISUM software has a variety of approaches that can be used for defining speed flow curves. The most commonly used is the BPR (Bureau of Public Roads) approach.

The BPR function was used as the staring point for assessing the speed flow relationship in the model. The BPR function works well once the link capacity does not reach its saturation point. Initial reviews of the model showed that although several links where over capacity the speed on the link was not reducing. As such, it was decided to use another function to define the speed flow curves. The BPR3 function was used which is derived from the original BPR function but takes into account the reduction in speed on an over capacity link. The function is defined as follows:

$$t_{cur} = t_0 * (1 + (a * sat^b)) + (q - q\max) * d$$

$$sat = \frac{q}{q_{\max} * c}$$

Where q = flow and a, b, c and d are user defined parameters.

The BPR3 function was used to develop volume-delay functions for the following road types:

- Motorway;
- Dual Carriageways;
- National Primary Roads;
- National Secondary Roads; and
- Urban Roads

4.3.4 Network Checking

A process of reviewing the network was undertaken to check for any errors which may have occurred during the initial network coding. The following key checks were undertaken as part of the review:

- Zone Connectors and Closed Links;
- Link Capacity; and
- Routing of Traffic.

4.4 Trip Matrix Development

4.4.1 Modelled Time Period

The following time periods are modelled within the National Traffic Model:

- Average hour in the morning peak between 07:00 and 09:00;
- Average hour in the inter peak period between 12:00 and 14:00.

The approach of modelling an 'average' hour is considered the most suitable for a strategic model such as the National Traffic Model. Modelling a discreet hour in such cases can lead to problems relating to the actual timing of a trip. Also, the factoring of average hour assignments to an Annual Average Daily Traffic (AADT) figure is more robust using this technique.

4.4.2 Matrix Data Processing

The RSI data collected in the 2007 surveys and for the NRA's 2006 Leinster Model was subject to a thorough review. Prior to using the data, all records were checked to ensure that they had correctly been coded to a known Enumeration District and expansion factors calculated, based on observed traffic volumes to enable the creation of RSI site matrices for an average AM Peak hour and Inter Peak hour disaggregated into one of seven journey purposes as follows:

- Home Based Work (HBW);
- Home Based Employers Business (HBEB);
- Home Based Education (HBED);
- Home Based Other (HBO);
- Non Home Based Employers Business (NHBEB);
- Non Home Based Other (NHBO); and
- Freight (HGV).

The number of records available for use before and after the ED coding process had been completed is summarised in Table 4-1.

Table 4-1 Summary of RSI records coded to ED level

Data Source	No. of Records	Initial Status		Final Status	
		No. Usable	Proportion	No. Usable	Proportion
2006 Leinster Model	4,588	3,061	66.72%	4,573	99.67%
2007 National Model	19,800	17,300	87.37%	19,797	99.98%
Total	24,388	20,361	82.50%	24,370	99.93%

4.4.3 Zone System

The matrix was based on a system of 874 zones (6 of which represent Northern Ireland). This is shown in Figure 4-1.

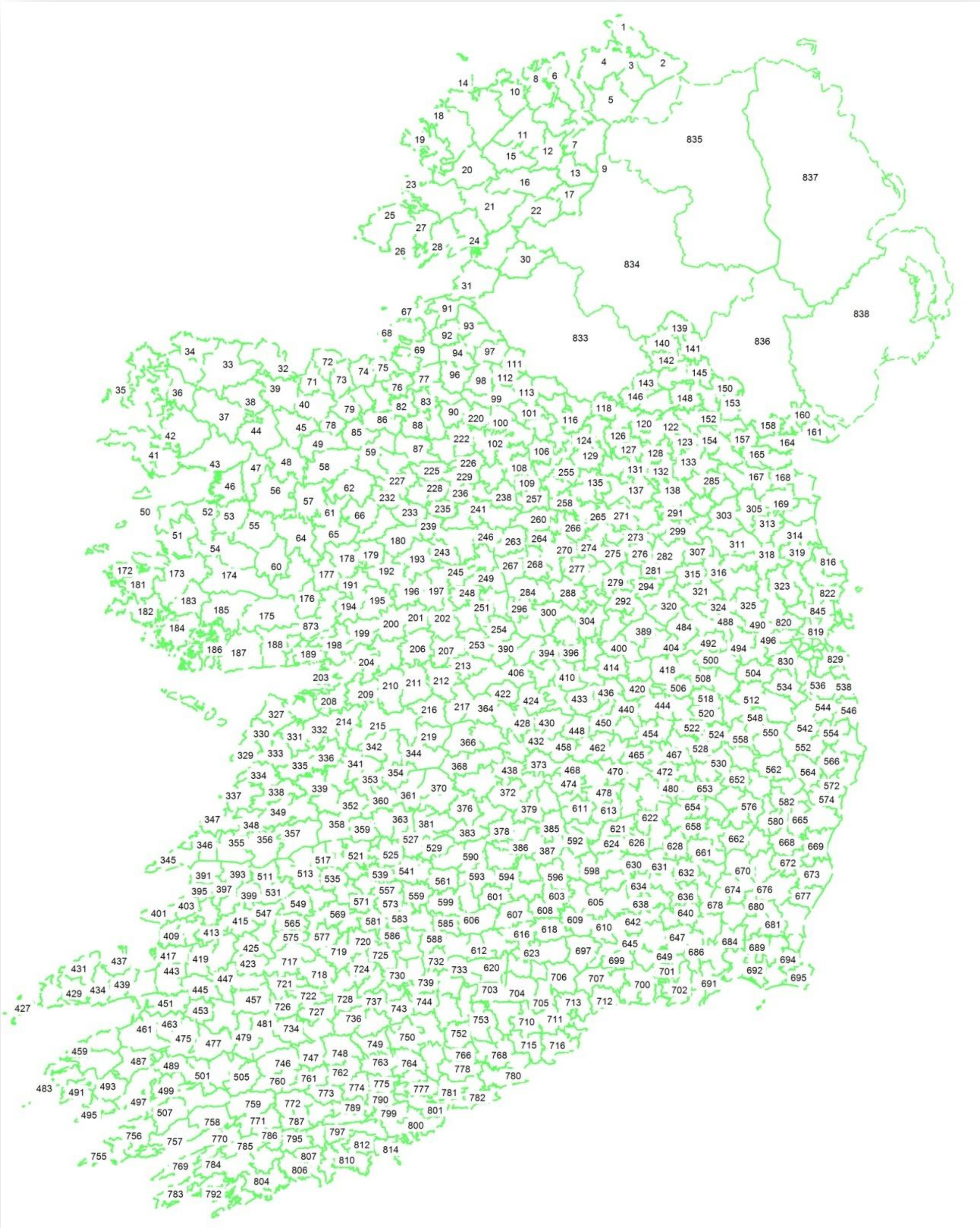

Figure 4-1 Zone Plan for National Traffic Model

4.4.4 Construction of Matrices

The expanded site RSI matrices were combined to form a series of screenlines, designed to capture the major strategic movements between (inter) different areas (sectors) of the country. An exercise was then carried out to qualify the degree of confidence that could be placed in the ability of the screenlines to capture traffic movements between the different sectors. This was done by considering sector to sector movements and noting the position of the RSI sites in relation to the strategic road network.

Individual screenline matrices were created by combining all the applicable expanded RSI site matrices. An overall observed inter-sector matrix, for each time period and split by journey purpose was then derived by adding together the individual screenline matrices.

For trips wholly within the Leinster screenline (defined as Leinster intra-sector) use was made of the matrices previously developed for the Leinster Orbital Route (LOR) traffic model.

- LOR AM (08:00-09:00) and IP (average hour between 10:00 and 16:00) light and heavy vehicle matrices converted from passenger car units (PCU) to vehicle equivalent (Light vehicle = 1PCU, Heavy vehicle = 2PCU);
- Trip end in LOR matrix attributed to an equivalent ED. Where a single LOR zone equated to more than one ED zone, a random process was used to allocate the zone weighted in favour of those zones with the largest population;
- Trips with a trip end external to the Leinster area discarded;
- AM Peak Hour matrix factored by 0.92 to represent average 07:00-09:00 value; and
- IP matrix factored by 0.93 to covert to average 12:00-14:00 value; and
- Light vehicle matrix disaggregated into six journey purposes based on proportions observed in the Leinster RSI data,

The production of the observed trip matrices from the RSI surveys, detailed above, does not provide trip matrices that can be assigned immediately by the model. This is due to two limitations inherent in all RSI surveys:

- Only trips travelling between sectors are surveyed and sampled, so there is little or no information available on trips which start and end in the same sector. These trips need to be estimated and infilled; and

- RSI surveys only sample a limited number of the trips. The characteristics of these surveyed trips, including the origin and destination zones, are then expanded to represent all of the vehicles which passed that site. This expansion results in a "lumpy" matrix, with multiple trips between the observed origin-destination pairs, but no trips to or from the zones around them. Smoothing the observed trip matrix redistributes these expanded observed trips across zones near the origin and destination of the trips.

For both these reasons, the expanded observed trip matrices only provide the basis for the final trip matrices, with further processing required. A summary of the steps in this multi-stage process is given below:

- Calculate trips (by trip purpose and time period) between 168 sub-sectors (created by zonal aggregation);
- Spread estimated trips between sub-sectors across the zones in the origin and destination sub-sectors;
- Calculate trips between zones in each sub-sector;
- Spread estimated trips between zones within each sub-sector;
- Replace estimated trips within LOR internal model area with LOR trips; and

- Combine trips into assignment classes (HBW, Light vehicles and Heavy Goods Vehicles in AM, Light vehicles and Heavy Goods Vehicles in IP).

As part of this process, regression analysis was then undertaken to derive the direct demand equations that would be used to estimate trips between sub-sectors for each of the trip purposes. The analysis used the combined trips from both the AM and IP periods. This analysis related the expanded number of observed trips between sub-sectors to the following demographic data for the origin and destination zones:

- Population – school age, working age or adult, depending on trip purpose;
- Car available population – working age or adult, depending on trip purpose;
- Households; and
- Employment – either total or broken down into eight industry categories.

Following generation of the estimated number of trips between sub-sectors, these were split between the AM and IP time periods. This split was based on the proportion of the total expanded observed vehicles in each of the time periods for each of the seven trip purposes.

After estimating the trips between sub-sectors and smoothing them across the zones in the origin and destination sub-sectors, the next stage was to estimate the number and pattern of trips between zones in the same sub-sector. As the sub-sectors had been defined so that they were all within only one of the cordoned sectors, there was no observed data from the RSI surveys that could be used to estimate their internal trips. It was therefore necessary to estimate the total number of trips starting and ending in each zone and, using the number of trips already estimated between sub-sectors, calculate the remaining number of within-sub-sector trips.

To calculate the number of trips starting and ending in each zone (the origin and destination trip ends for each zone), a regression analysis was undertaken using the LOR trip matrices and the underlying demographic data for the NTM zones covered by the LOR model area. In order to provide as robust an estimate as possible, the trip end models calculated light vehicles and HGVs only, and combined the trips from the AM and IP periods.

Prior to the completion of the final matrices, two further steps were undertaken:

- Replace all trips internal to the LOR model area with the trips from the LOR matrices; and
- Replace the AM HBW trip matrix with commuting trips recorded by the 2006 Census (Place of Work – Census of Anonymous Records (POWCAR) dataset).

The first of these steps, replacing the estimated trips entirely internal to LOR model area, is intended to better represent the trips in and around Dublin. As this area is entirely internal to the Leinster sector, the RSI surveys provided no information on these trips. Consequently, the trips from the LOR model, which utilised RSI surveys within this area, will provide a better estimate of trips entirely within this important area.

The second step, replacing the AM HBW trip matrix entirely with a matrix of the commuting trips (departing between 07:00 and 09:00) recorded by POWCAR, is intended to better represent the important morning commuting trips. As the POWCAR dataset was collected as part of the 2006 Census, it includes the commuting patterns of every person present in Ireland on Census night (rather than estimating these based on a limited sample collected at the RSI survey sites).

Prior to being used, the POWCAR trips were reduced by 10% to reflect the number of people who travel to work on a typical weekday (to account for those not working a 5-day week), and then reduce the residual total by a further 15% to reflect typical attendance rates (to account for people being on leave, sick, working at home, etc). The cumulative result of this was to reduce the number of trips in the POWCAR dataset by 23.5%.

Finally, as POWCAR only recorded the number of trips from Home to Work, it was necessary to estimate and add in the trips in the reverse direction (Work to Home) in the morning. Analysis of the Leinster RSI data showed that Home Based Work trips in the AM period were 96.0% Home to Work and 4.0% Work to Home. Using this, 4.2% of the transposed POWCAR matrix was added to itself, with the resulting matrix representing all Home Based Work trips made by car in the AM period.

Table 4-2 shows the total number of vehicle trips for each of the eight trip purposes in the two time periods.

Table 4-2 AM and IP Trip Totals

	Total Vehicle Trips	
Trip Purpose	**AM Period**	**IP Period**
Home Based Work	331,871	86,653
Home Based Employer's Business	30,179	18,240
Home Based Education	21,337	16,912
Home Based Other	48,818	167,536
Non-Home Based Employer's Business	34,060	65,507
Non-Home Based Other	51,232	92,350
HGV	25,372	25,532
Total	**542,868**	**467,731**

4.5 Model Calibration

4.5.1 Overview

The purpose of model calibration is to ensure that the model assignments reflect the existing travel situation. Calibration is an iterative process, whereby the model is continually revised to ensure that the most accurate replications of the base year conditions are represented. The main emphasis of the calibration process is to ensure that in the AM and Inter Peak periods:

- Network coding reflects the observed base year road network conditions therefore generating accurate traffic patterns and consequently influencing route choice;
- Traffic patterns throughout the model are accurately reflected, including the route choices selected; and
- Traffic volumes on both main roads and alternative routes are modelled accurately.

4.5.2 Traffic Data Used in the Calibration Process

The traffic data for the calibration was derived from a number of sources, including;

- NRA ATC's 2005 and 2006 counts;
- Leinster Study ATC's 2005; and
- RSI ATCs 2007 (AM Peak only).

An investigation showed that no consistent traffic growth statistics could be derived to convert these sources to a single year (i.e. 2006). Therefore the decision was made that the traffic data would not to be manipulated to reflect one universal base year. The base year of the National Traffic Model is 2006 (the 2009 model is a forecast model which is developed post calibration) and the counts in the calibration process were considered reflective of this base year. In order to facilitate the future year trip forecast process, and to allow the model matrices to be estimated, the traffic count data was divided in three categories:

- Light vehicles;
- Heavy vehicles; and
- Total traffic.

This subdivision of the total traffic volume into two classes provides an added level of realism to the model. It also provides greater flexibility and accuracy during the calibration process to ensure the final vehicle composition of a link flow is representative in the base year.

4.5.3 Scope of Calibration

The following calibration checks were undertaken for each model period, using the previously identified elements of the survey database:

- Network coding checks - Assignment of the fully-observed matrix to the base models provided a comprehensive check of the network. This enabled the coding of the junctions to be verified and also highlighted any program error files which needed to be addressed. Any errors identified during this process were corrected;

- Route Choice calibration – In order to demonstrate the model accurately reflected realistic route choice throughout the model, a significant number of investigations were made of routing for zone to zone movements. This also included reviewing the count data to ensure that observed link flows were being accurately modelled.

- Traffic Flow Calibration – Two important measures of calibration are described in the UK DRMB Volume 12a ***Section 4.4.42***, namely calibration of Link Flows, and Calibration of Screenlines.

4.5.4 Matrix Estimation

The model calibration involved several stages of targeted matrix estimation. This process is designed to automatically manipulate the origin and destination matrices to match a counted volume along a particular link or multiple links. The National Traffic Model contains two user class matrices; therefore it was necessary to disaggregate the total traffic count volumes to reflect this i.e. light and heavy vehicles. The matrix estimation process was undertaken on the AM and Inter Peak separately.

4.5.5 Calibration Results

Calibration has been done across screenlines, and against traffic flows for both the AM and Inter Peak. A summary of traffic flow calibration is shown below.

Table 4-3 Summary of Traffic Flow Calibration Results

Time Periods	% of Calibration Sites with GEH < 5		
	Total Traffic	Lights	Heavies
AM peak	85%	86%	92%
Inter Peak	90%	88%	92%

The calibration results suggest that the AM Peak and Inter Peak models have been calibrated to a standard compliant with DRMB criteria. Although the Inter-peak has failed to completely match certain criteria the distribution of the matched counts throughout the model are sufficient to consider the model fit for purpose

4.6 Model Validation

4.6.1 Overview

To demonstrate that the models provide a robust platform for further option development and testing, it is necessary to show that the base models accurately and realistically represent observed conditions in the base year. Following the network and matrix calibration process the calibrated model was compared against actual 2006 observed NRA ATC counts. These counts are representative of the observed model base year and have remained independent of the calibration process. The outputs from the assignments were independently compared with observed data in order to ensure that base year conditions were replicated in the modelling process. Validation checks included:

- Network validation checks (previously discussed);
- Matrix validation checks (previously discussed);
- Link flow validation and statistical criteria; and
- Overall model validation (e.g. journey time surveys).

The base year networks were independently checked to ensure that the correct characteristics had been coded for the junctions and links in the model. Particular attention was paid to the location of zone connectors to ensure that assigned trips entered and left the network at realistic locations. The model was checked to ensure that locations that were experiencing stress in the base year, due to link capacity constraints, were realistic. If these issues are not resolved in the base year the error would be factored up in future years which could influence the model forecasting and future year performance.

The validation traffic count data was subdivided into the three categories similar to the data calibration. This enabled the validation of the traffic flow vehicle composition, namely the split between the light and heavy goods vehicles.

4.6.2 Validation of Traffic Flows

The observed and modelled flows were compared at each of the validation sites in accordance with the criteria above. The permissible difference was calculated for each value (based on the observed figure) and compared with that which had been modelled.

Table 4-4 Summary of Traffic Flow Validation

Time Periods	% of Calibration Sites Meeting the criteria that: Individual Flows within 15% for flows 700 – 2700 vph Individual flows within 100 vph for flows < 700 vph Individual flows within 400 vph for flows > 2700 vph		
	Total Traffic	**Lights**	**Heavies**
AM Peak	88%	88%	98%
Inter Peak	97%	98%	98%

The comparison against the validation counts shows that the AM peak and Inter-peak clearly match the DRMB requirement for traffic flow at the specific count locations. The AM peak and Inter Peak match beyond the 85% guideline for all three categories. DRMB recommends that the total traffic match is above 85%, the additional matching category provides an extra level of detail to the model.

The calculated GEH statistics for the observed and modelled flows were considered at each of the validation sites in accordance with the above criteria. A summary of results are presented in Table 6-5 below.

Table 4-5 Summary of GEH Validation

Time Periods	% of Validation Sites with GEH < 5		
	Total Traffic	**Lights**	**Heavies**
AM Peak	85%	85%	92%
Inter Peak	93%	98%	92%

Similar to the flow criteria the AM Peak and Inter Peak models match the validation count GEH criteria. Both models have matched the GEH criteria at more than 85% of the count locations. The model results have clearly shown that at the validation count locations the model represents a "good fit". This indicates that the model should be 'fit for purpose' to assess the effect of road schemes, when considered alongside the forecasting methodology. The validation count locations used for the traffic flow and GEH comparisons are consistent throughout the AM Peak and Inter Peak periods.

DMRB recommends a correlation coefficient analysis of the modelled count data in order to give some measure of the goodness of model fit against observed data. The slope of the best-fit regression line indicates the extent to which modelled values are over or under estimated. The guidance suggests that in the main area of influence of the scheme, acceptable values of the former are above 0.95 and of the latter between 0.9 and 1.10. A value of 1.0 for both statistics represents a perfect fit. However, the model is at a national scale and there are no specific schemes identified at this stage, so this level of regression is going to be very difficult to achieve across the model area. Therefore the regression analysis has been carried out across all validation counts but this might generate a misleading result due to the wide range of flows.

Table 4-6 outlines the results for the model regression analysis for the validation of total traffic counts. The table shows that both the AM and Inter Peak models represent an appropriate level of correlation between the modelled and observed data.

Table 4-6 Summary of Regression Analysis

Time Period	Y Value	R^2 Value
AM Peak	1.143	0.981
Inter Peak	1.076	0.992

4.6.3 Validation of Journey Times

The journey time comparison is required to show that the model is reflecting the actual base year network conditions, in terms of network speed, distance and delay. The model is a time based assignment only; therefore the delay is generated by the speed flow relationships assumed in the model. The model does not contain any detailed junction modelling; therefore the speed flow curves have been manipulated to reflect a level of delay given the constraints of the network. The journey time comparison is an important part of the validation process, as this indicates if the speed flow curves are performing as required and producing realistic travel times. This will in turn dictate whether the traffic routing patterns are modelled correctly.

DMRB states that the modelled journey time is required to be within 1 minute or 15% of the observed time. Tables 6-7 and 6-8 summarise the journey time results for the AM and Inter Peak models respectively. The AM Peak model matches the DMRB criteria for all 11 routes and is clearly shown to reflect realistic journey times and speeds. This indicates that the network coding is accurate and that the speed flow relationships are producing a realistic level of delay in relation to the traffic demand.

The Inter Peak model also matches well against the 11 routes, although only 10 routes match the DMRB criteria. The one route that is outside the criteria is still within an acceptable tolerance. In general, the Inter Peak model appears to be slightly faster than the observed times. In the AM Peak the level of traffic demand is higher than for the Inter Peak, and will therefore produce a higher level of delay as the average speed reduces.

The models have therefore matched the available observed journey times suitably; however the influence of AM Peak period congestion has not necessarily been accurately reflected in specific locations. Therefore, additional journey time comparisons would be required in order to validate the model at a local level dependent on the model application.

Table 4-7 AM Peak Highway Model Journey Time Validation

Route Number	Route Description	Observed Distance (km)	Observed Speed (kph)	Observed Time (secs)	Modelled Distance (km)	Modelled Speed (kph)	Modelled Time (secs)	Does modelled route match DMRB Criteria of 15% Observed?
1	Cork to Mallow	31.3	75.1	1500	30.8	74.3	1492	YES
2	Swords to Dundalk	69.5	94.8	2640	68.9	103.1	2409	YES
3	Bray to Gorey	68.3	77.3	3180	68.7	81.9	3022	YES
4	Letterkenny to Donegal	48.7	66.4	2640	46.2	66.6	2498	YES
5	Waterford to Cahir	64.3	60.3	3840	60.2	64.1	3380	YES
6	Kells to Blanchardstown	55	63.5	3120	53.9	54.9	3539	YES
7	Westport to Ballina	52.5	57.3	3300	54.5	69.5	2848	YES
8	Athlone to Elphin	58.8	63	3360	57.4	67.9	3044	YES
9	Portlaosie to Toomyvara	61.4	67	3300	59.5	65.9	3253	YES
10	Killarney to Mallow	66.3	65.2	3660	62.2	71.8	3121	YES
11	Carlow to Thomastown	40.7	61.1	2400	40.4	68.5	2122	YES
					Percentage of routes matching DMRB Criteria			100%

Note: DMRB Target > 85% of Routes

Table 4-8 Inter Peak Highway Model Journey Time Validation

Route Number	Route Description	Observed Distance (km)	Observed Speed (kph)	Observed Time (secs)	Modelled Distance (km)	Modelled Speed (kph)	Modelled Time (secs)	Does modelled route match DMRB Criteria of 15% Observed?
1	Cork to Mallow	31.3	75.1	1500	30.8	76.6	1447	YES
2	Swords to Dundalk	69.5	94.8	2640	68.9	102.7	2418	YES
3	Bray to Gorey	68.3	77.3	3180	68.7	79.2	3127	YES
4	Letterkenny to Donegal	48.7	66.4	2640	46.2	66.1	2517	YES
5	Waterford to Cahir	64.3	60.3	3840	60.2	64.2	3376	YES
6	Kells to Blanchardstown	55	63.5	3120	53.9	64.4	3014	YES
7	Westport to Ballina	52.5	57.3	3300	54.5	70.0	2827	YES
8	Athlone to Elphin	58.8	63	3360	57.4	67.0	3089	YES
9	Portlaosie to Toomyvara	61.4	67	3300	59.5	66.6	3219	YES
10	Killarney to Mallow	66.3	65.2	3660	62.2	72.3	3097	NO
11	Carlow to Thomastown	40.7	61.1	2400	40.4	69.1	2102	YES
					Percentage of routes matching DMRB Criteria			100%

Note: DMRB Target > 85% of Routes

4.6.4 Network Checking

The model network was reviewed throughout the calibration and validation process in order to ensure that the base case depicted the actual current situation. The modelling methodology, including calibration, has focused on simulating current traffic patterns and traffic volumes on an accurate base year network structure. Traffic behaviour can be classed as validated as the model has matched the criteria given in current guidance for both traffic count and journey time validation/calibration.

4.6.5 Model Convergence

The model assignment procedure involves the model reaching a point of equilibrium through an iterative process. The model must therefore achieve a satisfactory point of convergence in order to produce results that are both reflective of the network over a number of iterations of assigning demand to the network. The convergence indicators vary by different transport modelling packages; therefore multiple criteria are outlined in the DMRB. The DMRB criteria that is used to show that the VISUM software reaches a level of convergence is the percentage of links with a flow change <5% across 4 consecutive iterations greater than 90%. The model software produces the convergence information by user class, defining the percentage difference in link volume per vehicle class.

Table 4-9 below indicates that the AM Peak and Inter Peak models both reached a satisfactory level of convergence.

Table 4-9 Model Convergence

Time Period	Number of Iterations	Measure of Convergence (Percentage of links with flow change (P) <5%			
		Final Convergence Lights (POWCAR)	Final Convergence Lights (Cars)	Final Convergence Heavies	Number of Iterations > 90%
AM Peak	8	98.5%	98.4%	97.4%	7
Inter Peak	13	N/A	99.5%	99.4%	12

4.6.6 Conclusions

The National Traffic Model validates well in all modelled periods. The models therefore provide a sound platform from which to develop future year option testing scenarios for the National road network. However, the model has been calibrated and validated at a strategic level only and therefore the model may not reflect accurately the situation at local level. Therefore, the model would require re-calibrating and re-validating in order to simulate traffic responses at a local scale if a cordon of the model was extracted. Guidance on the cordoning of the NTM is provided in *PAG Unit 5.2: Construction of Transport Models.*

National Rail Model

5.0 National Rail Model

5.1 Overview

The development of the rail module of the NTpM was prepared as a stand alone assignment model which would reflect all (commuter and InterCity) base year rail transport demand on the network. It has already been employed by Irish Rail in the examination of rail investment strategies, and has become known as the National Rail Model (NRM), due to its usefulness as a stand alone tool. The development of the NRM is outlined here.

5.2 Zone System

The definition of the zone system reflects that used in the NTM. In the rail model, each zone is associated with a specific rail station (or cluster of stations in the case of urban areas). Figure 5-1 provides an example of how rail stations are connected to the NTpM zones.

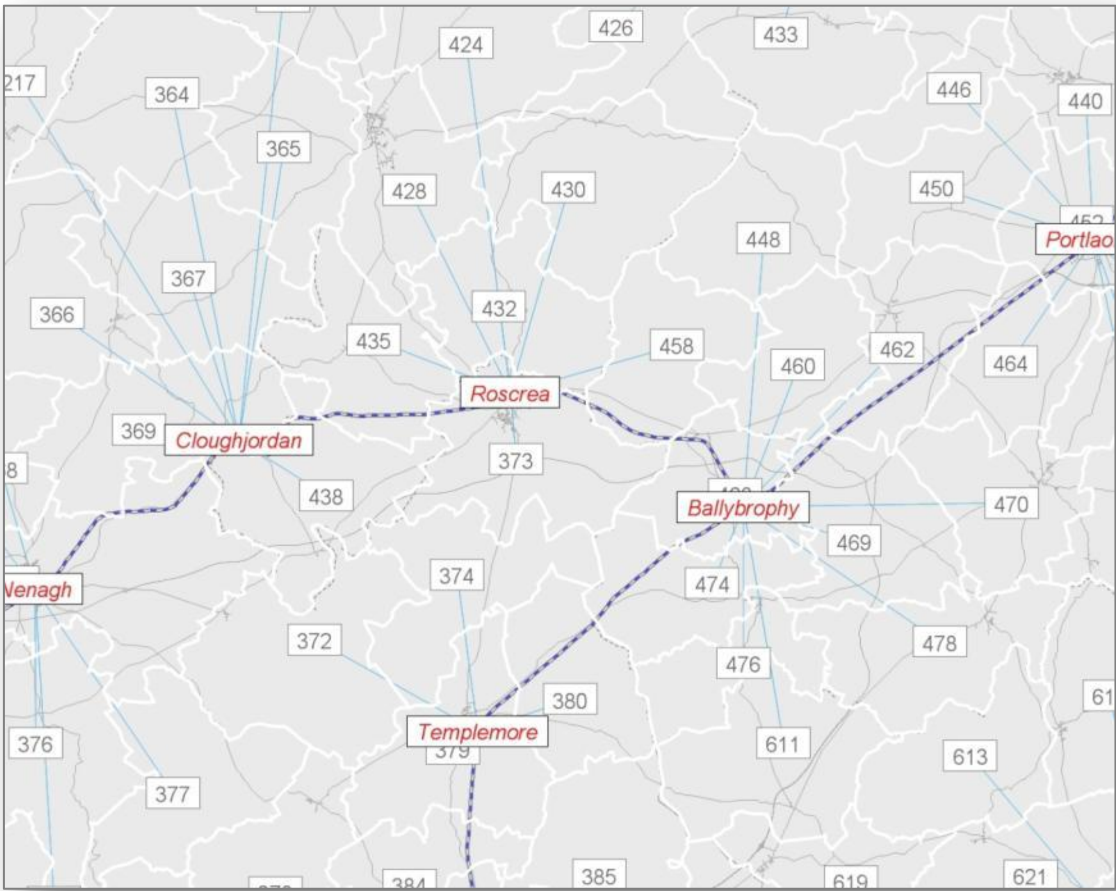

Figure 5-1 NTpM Station Connectors

5.3 Rail Passenger Demand

Although the ticket sales data received from Irish Rail provided a useful indication of rail demand, they did not provide a full picture of demand over the network on a particular day. This resulted from the non-recording of season tickets used in the ticket sales information, and the inability of the ticketing database to match each ticket (particularly open tickets) with the time that a trip had been made.

The POWCAR dataset provides a comprehensive dataset of information for typical weekday commuting demand by rail in 2006. Nevertheless, this commuting demand will include a proportion of those who purchase tickets (and hence are included in the ticket sales information).

As such, whilst the POWCAR and Ticket Sales information provide a full inventory of weekday rail passenger demand, there was a high level of double-counting. The development of a demand matrix, therefore, required the isolation and elimination of the double counting such that a single representation of rail demand could be developed.

This resulting prior demand matrix was then assigned to the rail network to produce an initial estimate of network demand. This provided a raw estimate of demand through the network, which although representative at a high level required some further manipulation to provide more robust estimates of local activity. The process is outlined in Figure 5-2.

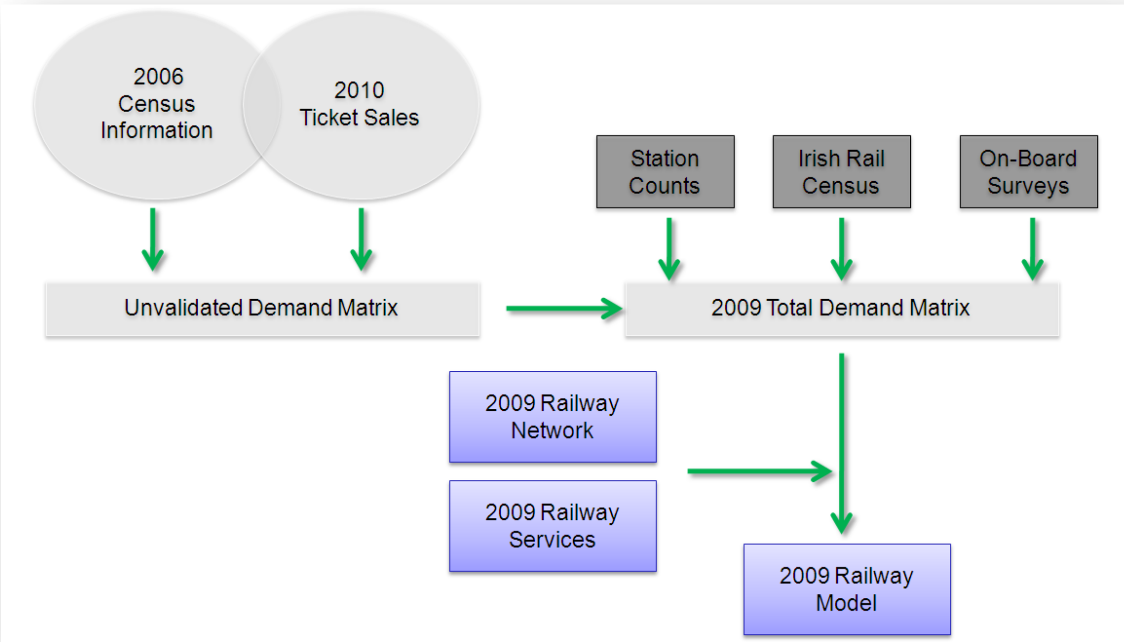

Figure 5-2 Rail Matrix Development

A 2006 commuting matrix was first developed based on the 2006 Census dataset. As the POWCAR dataset provides data on origin/destination trips on a zone by zone basis (as opposed to ticket information which only gives station to station data) the commuting trips were removed from the ticket sales dataset and replaced by the POWCAR data as part of matrix development as outlined in detail below.

The Irish Rail ticket sales dataset contains data on all types of ticket sales. The dataset was split into a number of sub-categories in order to provide an aggregate breakdown of sales, as follows:

- Adult Tickets;
- Child Tickets;
- Student Tickets;
- Concessionary Tickets; and
- First Class Tickets.

For the purposes of the NTpM the Adult, Child, Student and First Class tickets were aggregated together to form an 'Other' station to station matrix. Due to the fact that many users do not pay for rail travel and receive concessionary tickets, it was decided to create an additional station to station matrix called 'Other Concessionary'.

As the rail demand matrices created from the ticket sales database were in the form of a station-to-station matrix, as opposed to the required ultimate origin-to-destination format, a process of 'smoothing' was required. This was undertaken by distributing station trip ends to zones in the vicinity of the station (with the catchment defined by the existence of rail trips in POWCAR), in proportion to the number of rail trip ends in the POWCAR dataset.

As the commuting matrix was in the required format, the distribution of this matrix was used to reallocate the non-commuting demand. This was undertaken using the following process:

- The model zone system was divided into 88 sectors representing the catchment areas of each rail station;
- Commuting trip-ends for both origins and destinations were calculated at both a zonal and sector basis. This allowed for the proportions of zone trip-ends within a sector to be calculated for both origins and destinations;
- These two sets of proportions (origins and destinations) were then applied to the non-commuting matrix to allocate the demand to the likely ultimate origins and destinations.

In summary, commuter demand was sourced from POWCAR demand and the access/egress zone distribution was used to disaggregate ticket data for other purposes from station-station to zone-zone matrices.

The commuting (POWCAR) demand data relates to 2006 while all other trip purposes relate to a 2009 or 2010 demand (it was assumed that there was little change in demand between mid 2009 and mid 2010). Therefore the commuting demand was adjusted to reflect 2009 demand. In order to assess the required change in demand a comparison of aggregate yearly demand using the observed 2006 and 2009 demand was undertaken:

- 2006 observed aggregate demand = 43.351m
- 2009 observed aggregate demand = 38.798m
- Reduction in demand = 4.553m

The 2006 commuting demand takes into account trips made on Luas, therefore the rail trips with origins and destinations in zones along the Luas lines were removed from the commuting matrix to produce a 2009 daily commuting demand of 76,524, which equates to a yearly reduction of 4.78m as outlined below:

- Weekday to annual demand factors = 250
- 2006 annual demand = 95632*250 = 23.91m
- 2009 annual demand = 76524*250 = 19.13m

The 2009 commuting and unvalidated non-commuting demand is presented in Table 5-1. A conversion factor of 300 (6 days a week, 50 weeks a year) is applied to the daily **non-commuting** demand (as opposed to 250 for **commuting** demand) to establish annual demand.

Table 5-1 2009 Daily/Yearly Rail Demand (Pre-Calibration)

Trip Purpose	2009 Daily	*Factor*	2009 Annual Demand
Commuting	76,524	*250*	19.13m
Non-Commuting (uncalibrated)	68,563	*300*	20.57m
Total	**144,087**		**40.70m**

5.4 Assignment Parameters

5.4.1 Headway

The assignment used to apply the rail demand to the rail network is undertaken using the 'Headway Based Assignment' approach. The headway of each rail service was calculated based on the Irish Rail timetables and entered into the NTpM as a user defined attribute. Based on the assignment time interval between 07:00 – 22:00 (900mins), an hourly service between Dublin and Cork would have headway of 60mins, while a twice daily service between Dublin and Wexford would have a headway of 450mins (i.e. half the 15 hour operations represented).

5.4.2 Rail Generalised Cost

The generalised cost (impedance) of undertaking a rail trip is made up of three elements as follows:

- *Perceived Journey Time;*
- *Fare; and*
- *In-Vehicle Distance.*

Perceived Journey Time

The Perceived Journey Time (PJT) of a rail trip takes into account the weighted journey time elements that make up the total travel time between a trip origin and destination. The following journey time elements are included in the PJT:

- *In-Vehicle Time;*
- *Access Time;*
- *Egress Time;*
- *Walk Time;*
- *Origin Wait Time;*
- *Transfer Wait Time; and*
- *Number of Transfers*

Passengers prefer time spent on some parts of a journey over time spent on others, therefore a weighting to time spent on each different part of the journey which quantifies the level of dislike a traveller has for time spent on that bit of the journey relative to time spent in-vehicle is required. The weighting applied to each element of the journey In the NTpM is outlined in Table 5-2.

Table 5-2 PJT Weighted Factors

Journey Section	Weighted Factor
In-Vehicle Time	1
Access Time	2
Egress Time	2
Walk Time	2
Origin Wait Time	2
Transfer Wait Time	2
Number of Transfers	2 mins per transfer

Skim matrices are calculated and weighted following the assignment of the rail demand matrices for each origin/destination zone pair in the NTpM. These skims matrices were then combined to calculate the Perceived Journey Time. A skim matrix of the In-Vehicle Distance is also required and is calculated following the assignment of the rail demand matrices.

Given the limited routing options available, these parameters are largely based on default assumptions that may be more appropriate for urban rather than inter-urban travel. There is some evidence for example that interchange penalties are perceived to be higher on longer journeys and perception of wait times tends to reduce with longer headways. This should be borne in mind when testing strategies that influence rail costs.

Fares

The NTpM includes fare information as an important component of generalised cost. Based on a selection of standard rail ticket fares between various stations, an average cost per km travelled was calculated as set out in Table 5-3. The ticket cost is based on a 5 day adult return ticket (2009 prices).

Table 5-3 Average Cost/km Rail Travel

To/From Dublin	Distance (km)	Cost (€)	Cost/km (cents)
Cork	267	71	13
Killarney	299	72	12
Limerick	206	58	14
Galway	202	48	12
Westport	258	48.50	9
Athlone	130	37.50	14
Sligo	214	44	10
Carrick-on-Shannon	160	39	12
Waterford	173	34.5	10
Kilkenny	130	32	12
Rosslare	147	28.5	10
Wexford	163	28.5	9

Tralee	342	72	11
Ballina	273	48.5	9
Ennis	247	58	12
		Average	**11**

The cost of 11c/km is applied to the In-Vehicle Distance skim matrix to produce a distance based rail fare matrix.

In-Vehicle Distance

In-vehicle distance was calculated directly from the NRM network. The data suggests that in 2009, that 5.5 million person km were travelled by rail on a typical weekday.

5.5 Trip Purpose

The NTpM requires demand to be split into 3 trip purposes, therefore the validated rail demand outlined above needs to refined. POWCAR information allows a 'Commuting' matrix to be defined, with residual patronage classed as either 'Business' or 'Other'.

The Irish Rail ticket sales dataset does not contain data on business trips. The development of the 'Business' matrix has been supported by the availability of market research information, collated between June and November 2009.

The market research found that business trips accounted for an average of 22% of the demand per line, although there remains some ambiguity in that information regarding the exact split between Commuting and Business. Therefore, the estimation of the 'Business' matrix was based on it being 22% of the non-commuting rail demand.

5.6 Car Availability

A number of assumptions were required regarding car availability in the NTpM. For commuting trips the Car Available (CA) & Car Non-Available (CN) split from the journey-to-work data was used. It was assumed that all business trips are CA.

For the 'Other' trip purpose data from the market research information was used, this survey indicated the following data regarding car ownership:

- 60% of Irish Rail passengers surveyed were car owners;
- 29% of Irish Rail passengers do not own a car; and
- 11% did not respond.

Therefore a 70/30 split was assumed between CA & CN for Other trips. Data from the tickets sales dataset indicated that 13.5% of 'Other' demand is OAP demand, for the purpose of the NTpM it is assumed that OAP trips are all car non-available. Table 5-4 below outlines the assumptions for each trip purpose.

Table 5-4 Car Availability Assumptions for Rail

Trip Purpose	Car Available	Car Non-Available
Commuting	✓	✓
Business	✓	x
Other	✓	✓
Other 'OAP'	x	✓

5.7 Calibration of the National Rail Model

Following checking of the rail network, the prior rail passenger demand matrix previously described was assigned to the rail network and a comparison of modelled and observed demand was undertaken. Following this a process of calibration was undertaken to adjust the rail demand.

A number of manual adjustments were made to the rail demand matrix using 'Flow Bundles' in VISUM. This process, which was undertaken at a rail corridor level, involves isolating demand at a single point on a rail corridor where observed data is available and factoring up or down the modelled demand to match observed data.

Following the manual adjustment of the rail demand using the 'Flow Bundle' process a Matrix Estimation (ME) exercise was undertaken in VISUM using the ME tool (TFlowFuzzy). ME involves the adjustment of observed data to modelled flows which is undertaken automatically in VISUM. ME was undertaken at 30 locations throughout the network, the results of which are illustrated in Table 5-5.

Table 5-5 Matrix Estimation Results

No.	From Station	To Station	Observed Persons	Modelled Persons		Actual	Δ (%)
				Pre	**Post**	**Difference**	
1	Sligo	Collooney	303	257	302	-1	0%
2	Collooney	Sligo	301	258	296	-5	-2%
3	Enfield	Kilcock	1057	1196	1061	4	0%
4	Kilcock	Enfield	922	1076	925	3	0%
5	Roscommon	Athlone	472	453	511	39	8%
6	Athlone	Roscommon	453	363	446	-7	-2%
7	Manulla Jnct.	Castlebar	284	96	258	-26	-9%
8	Castlebar	Manulla Jnct.	260	114	282	22	8%
9	Galway	Athenry	716	954	696	-20	-3%
10	Athenry	Galway	771	935	746	-25	-3%
11	Portarlington	Tullamore	1421	1398	1414	-7	0%
12	Tullamore	Portarlington	1498	1756	1485	-13	-1%
13	Woodlawn	Attymon	753	837	765	12	2%
14	Attymon	Woodlawn	718	869	724	6	1%
15	Ballinasloe	Athlone	1180	880	1099	-81	-7%
16	Athlone	Ballinasloe	1197	778	1124	-73	-6%
17	Limerick Jnct.	Limerick	588	917	610	22	4%
18	Limerick	Limerick Jnct.	731	1001	752	21	3%
19	Athy	Carlow	903	1227	915	12	1%
20	Carlow	Athy	987	1173	998	11	1%

21	Moneybeg	Waterford	688	814	679	-9	-1%
22	Waterford	Kilkenny	686	777	685	-1	0%
23	Thomastown	Waterford	427	544	431	4	1%
24	Waterford	Thomastown	435	505	439	4	1%
25	Wexford	Enniscorthy	149	126	139	-10	-7%
26	Enniscorthy	Wexford	126	136	118	-8	-6%
27	Arklow	Rathdrum	227	385	195	-32	-14%
28	Rathdrum	Arklow	196	349	171	-25	-13%
29	Wicklow	Kilcoole	235	1148	232	-3	-1%
30	Kilcoole	Wicklow	206	571	189	-17	-8%
			18890	**21893**	**18687**	**-203**	**-1%**

5.8 Validation

The acceptable values for modelled and observed flow comparison were adopted from WebTAG (Unit 3.11.2) which is the UK Department for Transport's guidance for public transport modelling.

The criteria state that:

Validation of the assignment should involve comparing modelled and observed:

- *Passenger flows screenlines and cordons, usually by public transport mode and sometimes at the level of individual bus or tram services; and*
- *Passenger boarding and alighting in urban centres.*

Across modelled screenlines, modelled flows should, in total, be within 15% of the observed values. On individual links in the network, modelled flows should be within 25% of the counts, except where observed flows are particularly low (less than 150).

A validation exercise was undertaken which compared modelled flows against a set of independent counts not used during the calibration process. The validation results are presented in Table 5-6 and indicate that all modelled passenger flows are within 25% of observed passenger flows except on a number of sections where the observed passenger flow is less than 150 persons. Therefore the model satisfies the validation criteria in terms of individual link flow as outlined above.

Table 5-6 Validation Results (Individual Links)

No.	From Station	To Station	Observed Persons	Modelled Persons	Actual Difference	% Difference
1	Collooney	Ballymote	339	320	-19	-6%
2	Ballymote	Collooney	336	319	-17	-5%
3	Ballymote	Boyle	352	356	4	1%
4	Boyle	Ballymote	346	354	8	2%
5	Boyle	Carrick	377	379	2	1%
6	Carrick	Boyle	377	381	4	1%
7	Carrick	Dromod	433	407	-26	-6%
8	Dromod	Carrick	439	419	-20	-5%
9	Dromod	Longford	491	437	-54	-11%

10	Longford	Dromod	478	453	-25	-5%
11	Longford	Edgeworthstown	664	617	-47	-7%
12	Edgeworthstown	Longford	653	579	-74	-11%
13	Edgeworthstown	Mullingar	742	674	-68	-9%
14	Mullingar	Edgeworthstown	729	630	-99	-14%
15	Mullingar	Enfield	1015	981	-34	-3%
16	Enfield	Mullingar	904	860	-44	-5%
17	Roscommon	Castlerea	430	387	-47	-10%
18	Castlerea	Roscommon	442	458	16	4%
19	Castlerea	Ballyhaunis	397	368	-29	-7%
20	Ballyhaunis	Castlerea	404	425	21	5%
21	Ballyhaunis	Claremorris	384	358	-26	-7%
22	Claremorris	Ballyhaunis	374	409	35	9%
23	Claremorris	Manulla Jnct.	340	316	-24	-7%
24	Manulla Jnct.	Claremorris	322	350	28	9%
25	Castlebar	Westport	164	170	6	4%
26	Westport	Castlebar	138	173	35	25%
27	Tullamore	Clara	1294	1257	-37	-3%
28	Clara	Tullamore	1313	1297	-16	-1%
29	Clara	Athlone	1278	1234	-44	-3%
30	Athlone	Clara	1274	1274	0	0%
31	Ballinasloe	Woodlawn	733	756	23	3%
32	Woodlawn	Ballinasloe	693	708	15	2%
33	Attymon	Athenry	755	761	6	1%
34	Athenry	Attymon	721	724	3	0%
35	Carlow	Moneybeg	752	740	-12	-2%
36	Moneybeg	Carlow	797	760	-37	-5%
37	Thomastown	Waterford	481	461	-20	-4%
38	Waterford	Thomastown	460	459	-1	0%
39	Rosslare	Rosslare Euro	20	12	-8	-40%
40	Rosslare Euro	Rosslare	13	15	2	15%
41	Wexford	Rosslare	39	26	-13	-33%
42	Rosslare	Wexford	47	31	-16	-34%
43	Enniscorthy	Gorey	166	139	-27	-16%
44	Gorey	Enniscorthy	140	123	-17	-12%
45	Gorey	Arklow	191	160	-31	-16%
46	Arklow	Gorey	164	140	-24	-15%
47	Rathdrum	Wicklow	229	203	-26	-11%
48	Wicklow	Rathdrum	186	179	-7	-4%

The rail demand split by trip purpose and car availability used in the 2009 NTpM are presented in Table 5-7. As the NTpM only caters for 3 trip purpose, the 'Other' and 'Other Concessionary' demands are aggregated.

Table 5-7 NTpM Rail Daily Passenger Demand

Trip Purpose	Car Available	Car Non-Available	Total
Commuting	66,653	10150	76803
Business	12,892	-	12892
Other	36,571	18258	54,829
Total	**116,116**	**28,408**	**144,524**

The final rail demand therefore highlights the influence of car availability on passenger demand – particularly for 'other' trips, where approximately 50% of passengers are defined as 'Car Non-Available'.

5.9 Conclusion

The National Rail Model therefore validates well to observed data, with little change in the matrix total following the calibtation exercise. This result reflects the significant quantum of data incorporated into the rail modelling exercise, and the level of refinement retained within the rail demand model (all intercity and suburban rail stations are included).

National Inter-Urban Bus Model

6.0 National Inter-Urban Bus Model

6.1 Overview

The challenges associated with the development of a model which reflects base year bus demand data on the inter-urban bus network have already been noted. Given the sensitivities in collating existing data into a single matrix, it was considered that the development of a National Bus Model should instead focus on the construction of a 'specimen' bus demand matrix. This matrix would reflect a typical level of demand on currently available services and would support the functioning of the VDM module. More accurate bus demand information could be substituted at a later date following the development of a protocol for access to and use of commercially sensitive information on bus demand.

6.2 Zone System

The same zoning system is used for all transport modes. In the bus model, each zone is associated with a specific bus stop (or cluster of stops in the case of urban areas). An example of how bus stops are connected to the NTpM zones is illustrated in Figure 6-1.

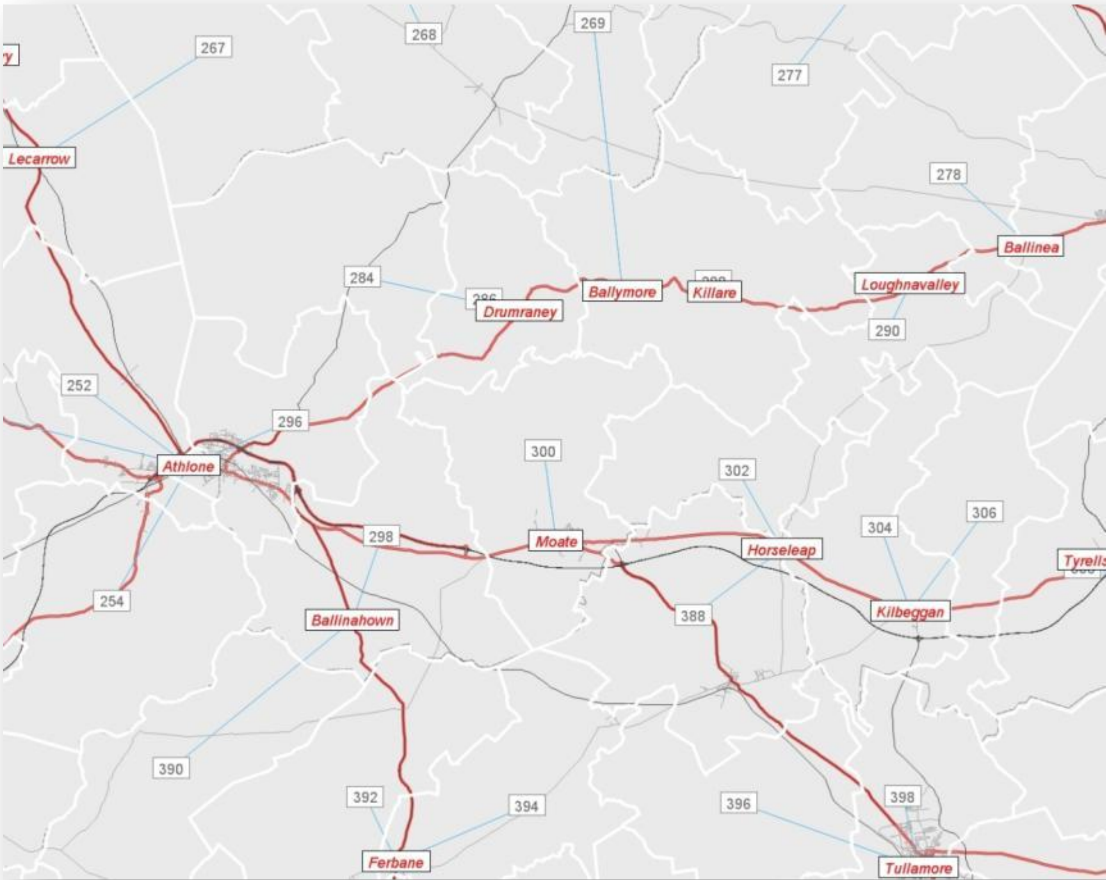

Figure 6-1 NTpM Bus Connectors

6.3 Bus Passenger Demand

For the development of bus passenger demand, the commuting matrix could be developed directly from POWCAR information for a typical weekday. Nevertheless, for non-commuting (business or 'other', there are no immediate datasets available, and surveying of bus passenger demand along regional or interurban routes carries a high degree of commercial sensitivity due to the current competitive environment in bus operations. As such, the commuting bus matrix has been derived as follows:

- Using information from all operators, an estimate of total annual patronage was derived. Only some operators quote demand data, whereas others were derived from likely patronage of known services.
- The total annual patronage was divided by 52 weeks and 6 days to get an approximation of weekday daily passenger numbers on these services.
- Some of the commuting demand, derived from the journey-to-work data, was inherently included in this number, but this commuting matrix also included local bus services. Therefore, the proportion of the total commuting trips included in the company patronage was estimated.
- For longer-distance trips, which are not served by local bus companies, all this commuting demand is likely to have used a bus service. The question is at what distance you place the cut-off between likely urban and inter-urban bus demand.
- The assumption used was that demand travelling over 8km was likely to be using an inter-urban bus service. In Dublin this is likely to be an overestimate as some of the local bus services provide routes longer than this, but outside Dublin this may be an underestimate as various coach companies provide the local services.
- These total trips have then been allocated to zones based on the relative population within each zone. This has been done everywhere expect Northern Ireland, which using this process gets a disproportionately large number of trip-ends. Within Northern Ireland the trip-ends have been set to zero for all zones except Belfast, which has an estimate of the trip-ends using the Dublin-Belfast route.
- These trip-ends form two of the three dimensions used in the matrix building process to create the bus non-commuting demand; the third being a trip-length constraint. This trip-length constraint uses the UK National Travel Survey to provide a likely trip-length pattern. The trip-lengths in this constraint were scaled down by a factor of 0.75 to take account of the different geographical sizes of the two countries.
- To seed a likely distribution of travel when performing the furnessing[7] procedure car 'Other' demand was used. This demand was converted from hourly demand to 'all-day' using the expansion factors developed for the calculation of AADT.

  The result of the furness then has certain sector-to-sector movements controlled to likely patronage (calculated by the number of services * capacity of 50 seats * 0.5 load factor), with the matrix finally controlled to the target number of total passengers.

[7] Furnessing describes the process of matrix manipulation to match defined row or column totals.

Table 6-1 2009 Daily/Yearly Bus Demand (Pre-Calibration)

Trip Purpose	2009 Daily	2009 Yearly Demand
Commuting	90,611	27.18m
Non-Commuting (uncalibrated)	39,451	11.83m
Total	**130,062**	**39.01m**

6.4 Assignment Parameters

6.4.1 Headway

The bus assignment also uses the 'Headway Based Assignment' approach. Services are approximated using a typical weekday headway. This approach is well suited to the busier routes, but requires some approximation for the less popular services.

6.4.2 Bus Generalised Cost

The generalised cost function used for the assignment of the bus demand is the same as for rail, except for the weighting factors that are applied to the individual journey time sections. The relevant weighting factors for bus are outlined in Table 6-2. It should be noted that these factors are based on established practice, and have not been calibrated.

Table 6-2 PJT Weighted Factors

Journey Section	Weighting Factor
In-Vehicle Time	1
Access Time	2
Egress Time	2
Walk Time	2
Origin Wait Time	2
Transfer Wait Time	2
Number of Transfers	5 mins per transfer

Given the limited routing options available and the synthesised demand data, these parameters are based on default assumptions that may be more appropriate for urban rather than inter-urban travel. There is some evidence for example that interchange penalties are perceived to be higher on longer journeys. This should be borne in mind when testing strategies that influence bus costs.

Based on a selection of standard bus fares between various locations, an average cost of 7c/km travelled was calculated. A comparison of standard bus fares and distance travelled is presented in Table 6-3. The ticket cost is based on a 5 day adult return ticket (2009 prices).

Table 6-3 Average Cost/km Bus Travel

To/From Dublin	Distance (km)	Cost (€)	Cost/km (cents)
Cork	252	22	4
Killarney	302	42.50	7
Limerick	195	22	6
Galway	206	19	5
Westport	250	28	6
Athlone	124	17.5	7
Sligo	207	23.5	6
Carrick-on-Shannon	153	28.5	9
Waterford	164	18	5
Kilkenny	123	15	6
Rosslare	162	30	9
Wexford	138	24	9
Tralee	293	42.5	7
Ballina	255	28.5	6
Ennis	234	30.5	7
		Average	**7**

6.5 Trip Purpose

The bus demand needs to be split into the 3 trip purposes for use in the NTpM. Once again, POWCAR information allows a 'Commuting' matrix to be defined. This non-commuting demand needs to be further split between 'Business' demand and 'Other' demand.

There is likely to be very little business inter-urban coach travel, and the UK National Transport Survey (NTS) backs this up, suggesting that 2.8% of coach demand is business related. This proportion has been used to split the non-commuting demand into 'Business and 'Other'.

6.6 Car Availability

For all trip purposes the bus demand is required to be allocated to either the Car Available or Car Non-Available categories. As with the proportion of business-related coach travel, the proportion for demand made by Car and Car Non-Available people has been taken from the UK NTS. To provide consistency with the rail demand, all 'Business' demand has been assumed to be Car Available, so only the 'Other' demand is required to be split. The result of this is to put 41% of bus 'Other' demand into the Car Non-Available category.

6.7 Calibration

As no data is available on the number of bus passenger at any location on the network, the calibration was based on controlling the number of passenger trips on sections of the bus network to a target value, set at 50% of bus capacity.

This process was carried out on various routes throughout the network and the demand matrices were adjusted using 'Flow Bundles' as required. The demand on the various routes was then plotted and a sense check was undertaken whereby the modelled passenger demand was compared against the target values.

An additional assessment was undertaken which compared aggregate observed yearly passenger demand (based on operator data) against modelled yearly demand. The results indicated a close match:

- 2009 observed aggregate demand (incl. commuting) – 40.2m;
- 2009 modelled aggregate demand - 40.8m;

The resulting demand split by trip purpose and car availability used in the 2009 NTpM is presented in Table 6-4.

Table 6-4 NTpM Bus Daily Passenger Demand

Trip Purpose	Car Available	Car Non-Available	Total
Commuting	60775	29836	90611
Business	1128	-	1128
Other	23097	16050	39147
Total	**85000**	**45886**	**130886**

6.8 Validation

The bus demand matrix is a purely synthetic matrix, constructed based on a series of practical assumptions and high level control totals. As such, validation of the final assignment is not appropriate due to:

- Challenges in collecting data to undertake the validation; and
- Commercial sensitivity in making validated bus demand data available through the National Transport Model.

Where bus data becomes available in the future that can be incorporated into the models without raising such commercial sensitivity issues (there would appear to be no reason why total trip ends might not become available for example), it would be beneficial to incorporate such information into calibrating and validating the model. In the meantime, the NBM is considered suitable for examining the scale and sensitivity of impact of various infrastructural measures, tolling/road pricing and other policy interventions.

Variable Demand Model Construction

7.0 Variable Demand Model Construction

7.1 Modelling Guidance

The approach to the development, calibration and validation of the Variable Demand Model (VDM) used in the NTpM is based on the UK Department for Transport WebTAG guidance. WebTAG *Unit 3.10 – Variable Demand Modelling* provides guidance and best practice on variable demand modelling.

7.2 VDM Pivot-Point Model

The VDM works as a 'Do-Minimum Pivoting' model. Pivot point models take cost from a 'Do-Minimum' scenario as its starting point, and then forecasts the **change** in demand (mode share, distribution, etc) as a function of the changes in cost from the 'Do minimum' or trend based scenario. This approach enables some of the complex behavioural decisions which inform the base demand to be carried through to alternative scenarios. Such an approach is also referred to as 'Incremental' modelling and is a common form of demand modelling in large complex models.

The VDM used in the NTpM consists of two separate components developed using Python[8] software as follows:

- An interface with VISUM that is run from within the VISUM procedures. As well as directly manipulating the demand matrices, it also iteratively loops through the modelled demand segments; and
- A demand model, which is a function called by the interface, taking matrices from the interface and performing the necessary demand model calculations on them, before passing them back to the interface for return to VISUM. It also calculates demand / supply convergence, passing this back to the interface so that VISUM can determine when to stop iterating between demand and supply.

In essence, the VDM performs the following steps:

- Converts road vehicle demand from AM Peak and Inter Peak origin-destination to 15-hour production-attraction people matrices;
- Converts rail and bus origin-destination demand to production-attraction format to establish public transport matrices by rail and bus;
- Calculates logit composite costs for public transport using the costs from the rail and bus assignments and converting into generalised costs using standard economic parameter values;
- Calculates generalised costs for road travel using the time, distance and toll skims and NRA economic parameters (reference *PAG Unit 6.11: National Parameter Values Sheet*);
- Calculates logit composite costs across attractions separately for road and public transport for input to the mode choice model;
- Applies an incremental logit mode-choice model to create output origin (vector) matrices by mode. The mode choice model may be absent or restricted for certain

[8] Python is an open source programming language used to integrate systems within Windows (*www.python.org*)

segments, for example, car non-available trips will be unable to select road as a mode, and freight traffic will not use the mode choice model at all (the NTpM assigns all freight to road) – the scale of increments is smoothened by using the Method of Successive Averages (MSA);

- Applies an incremental logit distribution model to create output full matrices by mode;
- Calculates convergence gap numerators and denominators;
- Convert traffic matrices back from 15-hour production-attraction people matrices to AM peak and Inter peak origin-destination vehicle matrices; and
- Performs an incremental logit sub-mode choice between rail and bus demand using the new public transport demand, and convert from production-attraction to origin-destination.

A basic overview of the process in illustrated in Figure 7-1.

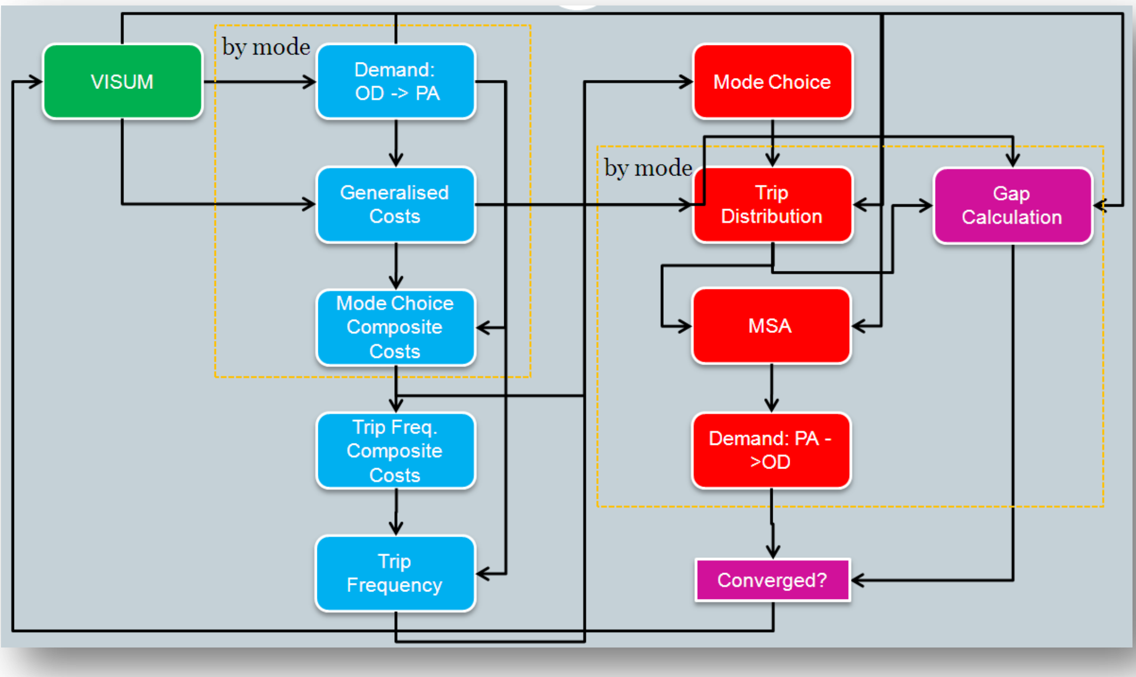

Figure 7-1 Basic Overview of VDM Process

7.3 Choice Structure

Following WebTAG (UK Government guidance) destination choice is assumed to be more sensitive than mode choice to travel costs. The choice structure is illustrated in Figure 7-2, and indicates that variable demand responses are more significant than mode share responses. The VDM process therefore follows this hierarchy in identifying the demand responses.

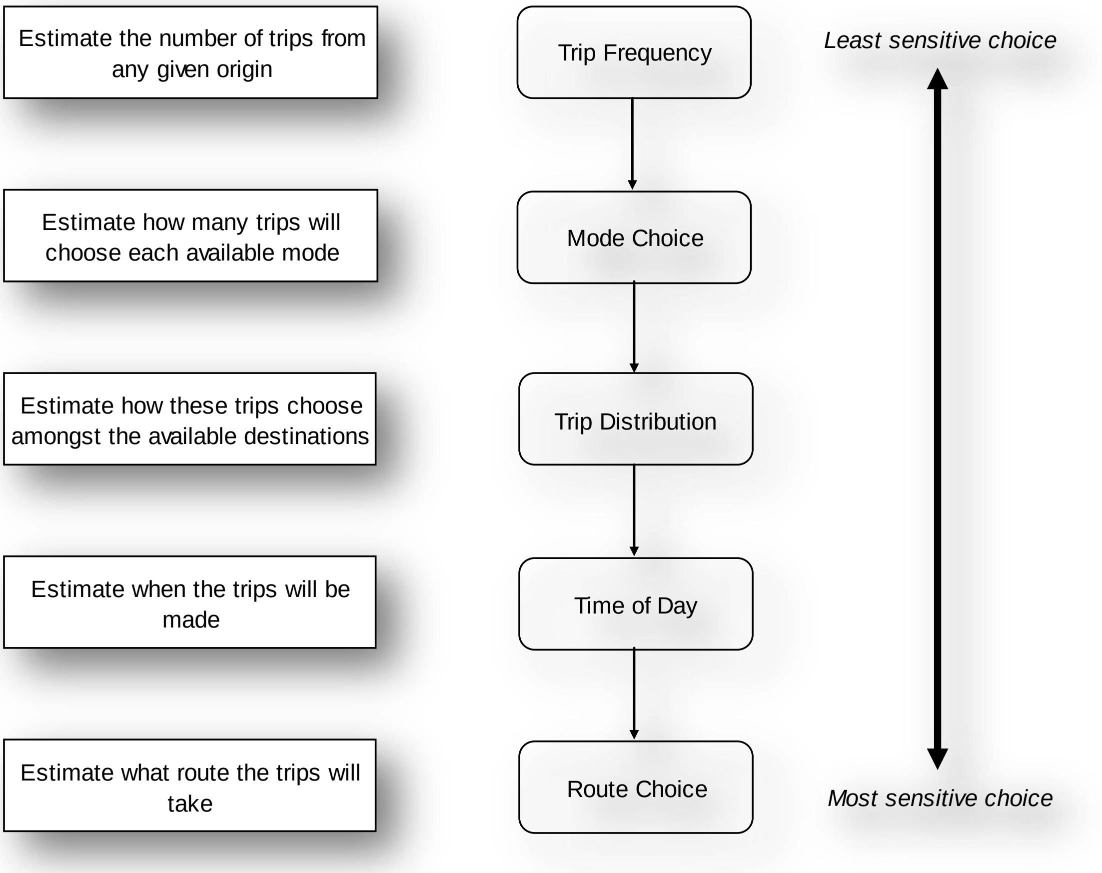

Figure 7-2 Choice Structure of VDM

7.4 Model Parameters

The VDM requires two sets of text input files, namely Economic Parameters and Modelling Parameters. Economic parameters are required for each trip purpose, and are set out in Table 7-1.

Table 7-1 Modelling Parameters

Parameter	Text Name	Source
Extent of interpretation of rail costs in exponential form	*AlphaLog*	Calibration
Sub-Mode Choice	*SubModeLamda*	Existing UK Model (EERM)
Distribution	*HLamda & PLamda*	UK WebTAG
Mode Choice	*ModeTheta*	UK WebTAG
Trip Frequency	*TFTheta*	UK National Travel Survey
Cost Damping	*CDTimePower, CDMoneyPower, CDTimeThresh & CDMoneyBase*	UK WebTAG
Proportions of travel from	*AMFromHome, IPFromHome,*	UK National

home	*PMFromHome, OFFromHome and AllFromHome*	Travel Survey

Economic parameters are required for each trip purpose and for each modelled year. Table 7-2 outlines relevant economic parameters.

Table 7-2 Economic Parameters

Parameter	Text Name	Source
Value of Time	*ValueOfTime*	NRA PAG[9]
Fuel Price	*FuelPrice*	NRA PAG
Fuel Efficiency	*Feff*	NRA PAG
Fuel Consumption	*FIA, FIB & FIC*	NRA PAG
Non-Fuel VOC	*NFA & NFB*	NRA PAG
Vehicle Occupancy	*AMVehOcc & IPVehOcc*	NRA PAG

7.5 Calibration

The model sensitivity and cost-damping parameters have been calibrated starting at UK WebTAG guidance to give an acceptable level of model sensitivity. The model parameters in the NTpM are set out Table 7-3.

Initial testing indicated that the sensitivity of response to rail cost changes was larger than would be expected. A term 'alphalog' was added to enable the cost changes to be represented as a logarithm of cost rather than an absolute form – effectively adopting an elasticity relationship. This is applied to weight the cost – x% of cost as a linear term and 91x% as the logarithm. The term represents a form of cost dampening – moderating the sensitivity of the model to long distance trips, and is applied only to the rail cost changes where evidence on sensitivity of response is available from the UK Passenger Demand Forecasting Handbook.

Table 7-3 Demand Model Parameters

Purpose	AlphaLog	H Lambda λ_d	PT Lambda λ_d	Mode Theta θ_m	TF Theta	SubMode Lambda λ_s
Commuting	0.33	-0.065	-0.033	0.68	0	-0.1
Business	0.33	-0.067	-0.036	0.45	0	-0.1
Other	0.33	-0.09	-0.036	0.53	0	-0.1
HGV	n/a	-0.03	n/a	n/a	0	n/a

7.6 Model Convergence

The VDM process uses the %GAP (network parameter) as a target for convergence. The %GAP is the percentage difference between the current generalised cost and the previous generalised cost (Denominator) divided by the previous generalised cost (Denominator)

[9] Values in the NRA Project Appraisal Guidelines are, in turn, drawn from the Departmental Common Appraisal Framework Guidelines.

%GAP = Numerator/Denominator

The convergence criterion for the demand model is:

- %GAP <0.1; or
- If more than 30 iterations are required then the model stops and convergence should be reviewed.

The %GAP network parameter is required to be less than 0.1 for convergence. If the %GAP is greater than 0.1 (and the model has not completed 30 iterations), then road costs are calculated and fed back into the demand model loop once again until convergence criteria is satisfied.

The public transport demand is only re-assigned after the final iteration to report flows as there is no capacity constraint built into the public transport assignments. (i.e. no matter what demand is assigned the same skim costs are produced)

Variable Demand Model Validation

8.0 Variable Demand Model Validation

8.1 Introduction

The UK Department of Transport WebTAG guidance provides details on the validation of variable demand models (*WebTAG Unit 3.10.4 – VDM Convergence Realism and Sensitivity*). The guidance states that:

> *"Once a variable demand model has been constructed, it is essential to ensure that it behaves 'realistically', by changing the various components of travel costs and times and checking that the overall demand response accords with general experience"*

The WebTAG guidance makes reference to the calculation of elasticities of demand, and how these can be used in the validation process. The guidance states that:

> *"The acceptability of the model's responses is determined by its demand elasticities. These demand elasticities are calculated by changing a cost or time component by a small global proportionate amount and calculating the proportionate change in trips made"*

8.2 Realism Testing

WebTAG recommends that the following 'realism tests' are undertaken using the base year model to understand the nature and scale of responses to a series of interventions, and that the results should lie within specified bands:

- Car Fuel Cost Elasticity;
- Car Journey Time Elasticity; and
- Public Transport Fare Elasticity

A number of such tests are outlined below.

8.2.1 Car Fuel Cost Elasticity

Evidence on fuel price elasticity[10] suggests a long term elasticity of fuel consumption to price of -0.12 calibrated from historic data. After allowing for behavioural changes (e.g. switching to more fuel efficient vehicles), the elasticity of traffic (vehicle kms) to fuel price is estimated at -0.12.

This is contrasted with studies synthesising international evidence which sets out a median elasticity of car traffic kms to fuel price of -0.31. While the difference is noted on, it is worth highlighting the statistical confidence of the econometric model parameters calibrated from the time series data. These imply some uncertainty, with a 95% confidence interval for the estimated sensitivity (-0.19) of about +/-0.2. Given the comparatively low value in comparison with the international evidence and the difficulties in assembling the time series data, it might be reasonable to conclude that the estimated value is towards the lower end of the international range and that the elasticity of vehicle

[10] *The Impact of Fuel Prices on Traffic and Fuel Consumption in Ireland, AECOM and Goodbody Economic Consultants, February 2010*

km to fuel price could lie between about -0.1 and -0.25.

A comparison of UK and Irish values of time and fuel prices for 2009 is set out in Table 8-1. The comparison indicates that fuel costs were about 10% lower in 2009 in Ireland than in UK. Furthermore, guidance on values of time used for economic appraisal would suggest that there is little difference in UK and Irish values of time. The inference is that national differences in prices and values of time might indicate a fuel price elasticity perhaps 10% (2009) and 20% (2008) lower than UK guidance, or around -0.25. There is no suggestion that the values should be identical, as to do so would ignore the particular social, cultural and spatial differences between both jurisdictions.

Table 8-1 Average Fuel Cost (80kph) (cents/km, 2002 prices)

Country	2002	2009
UK	6.08	6.13
Ireland	5.30	5.71

Source: UK, Irish guidance on fuel consumption rates, fuel pump prices, exchange rate, UK RPI and Irish CPI

Taken in the round, and subject to further evidence, we should expect the fuel price elasticity of the NTpM to be about, and possibly a little below, -0.2.

Within the NTpM, a test was execued which involved increasing fuel cost by 10%. The resulting elasticity of traffic (vehicle kms) to car fuel price is shown in Table 8-2. The result of -0.206 is consistent with expectations as set out above. The relatively low sensitivity of employer's business trip and higher sensitivity of Car Other is plausible and reflects the higher value of time of this segment. The sensitivity of commuting trips to fuel price is relatively low.

Table 8-2 Fuel Price Elasticity

Purpose	Car km to Car Fuel
Commuting	-0.124
Business	-0.148
Other	-0.305
All Car	-0.206

8.2.2 Car Journey Time Elasticities

Table 8-3 sets out the base year direct elasticities of the model to changes in car travel cost and time. The fuel related test involved a 10% increase in fuel cost, and the model was then run to convergence to reflect changes in congestion. The time related test was undertaken by increasing travel times by 10% and applying the demand model (a single iteration).

This reflects the 'doubly constrained' operation of the model – that land use – including employment – is not assumed to change as a function of travel costs, but may indicate a lack of sensitivity for this segment. However given the limited data available for calibration we have not sought to refine the model parameters in this respect.

The sensitivity of the model to car time reflects both the sensitivity to cost and the value of time and is best therefore considered as a verification of the model response rather than a target sensitivity to calibrate the model against. Car trips represent 96% of the person trips represented in the model and this is reflected in the low trip elasticity. The sensitivity of traffic (vehicle to time) is plausible – general research in the UK would indicate a range of up to -2 for this elasticity for example.

Table 8-3 Highway Elasticities

Purpose	Car km to Car Fuel	Car Trips to Car Time	Car km to Car Time
Commuting	-0.124	-0.020	-0.580
Business	-0.148	-0.001	-0.904
Other	-0.305	-0.008	-1.143
All Car	-0.206	-0.011	-0.882

8.2.3 Public Transport Fare Elasticities

The base year elasticity of demand to public transport fares and times is illustrated in Table 8-4. In both tests the model was run to convergence to reflect road congestion effects. Research into fare elasticities show a range broadly between -0.2 and -0.9 (in the longer term) with lower values in contexts with lower fares or for longer trips. The elasticities of -0.14 for trips and -0.41 for passenger km are plausible.

The response in respect of trips is much lower for business than might be expected. The model does not include local urban trips and the public transport trip length varies by purpose with an average of 24km for 'Commuting', 178km for 'Business' and 79km for 'Other'. The application of UK based evidence that values of time increase with trip length results in the lower sensitivity of the 'Other' purpose (in terms of trip kms) than for commuting trips in respect to fare changes. While the model sensitivities are not implausible, direct evidence of Irish elasticities or survey data from which to calibrate model coefficients would facilitate further refinement of the model calibration.

Table 8-4 Public Transport Elasticities

Purpose	PT Trips to PT Fare	PT kms to PT Fare	PT Trips to PT Time
Commuting	-0.223	-1.054	-1.221
Business	-0.077	-0.436	-2.934
Other	-0.307	-0.352	-2.953
All PT	-0.140	-0.414	-2.089

8.3 Illustrative Tests

In order to further validate the outputs of the model a number of illustrative tests were undertaken to assess the observed impact of several major public transport and road schemes. In order to do this the relevant schemes that have recently been completed were removed/closed in the NTpM and the model was run, the results of the model were then compared against observed data.

8.3.1 M1 Airport to Balbriggan

The M1 Airport to Balbriggan scheme was opened in June 2003 and is illustrated in Figure 7-1. The observed AADT data recorded in 2004 were:

- M1 – 53,000 AADT; and
- R132 – 35,000 AADT

The AADT on the M1 in 2008 was 80,000 - this indicates a growth of 51% on the M1 between 2004-2008. At a national level traffic growth between 2004-2004 was 16%, which indicates additional demand of 35% on the M1 over this period. This will reflect traffic induced by the scheme together with differences between local and national growth rates.

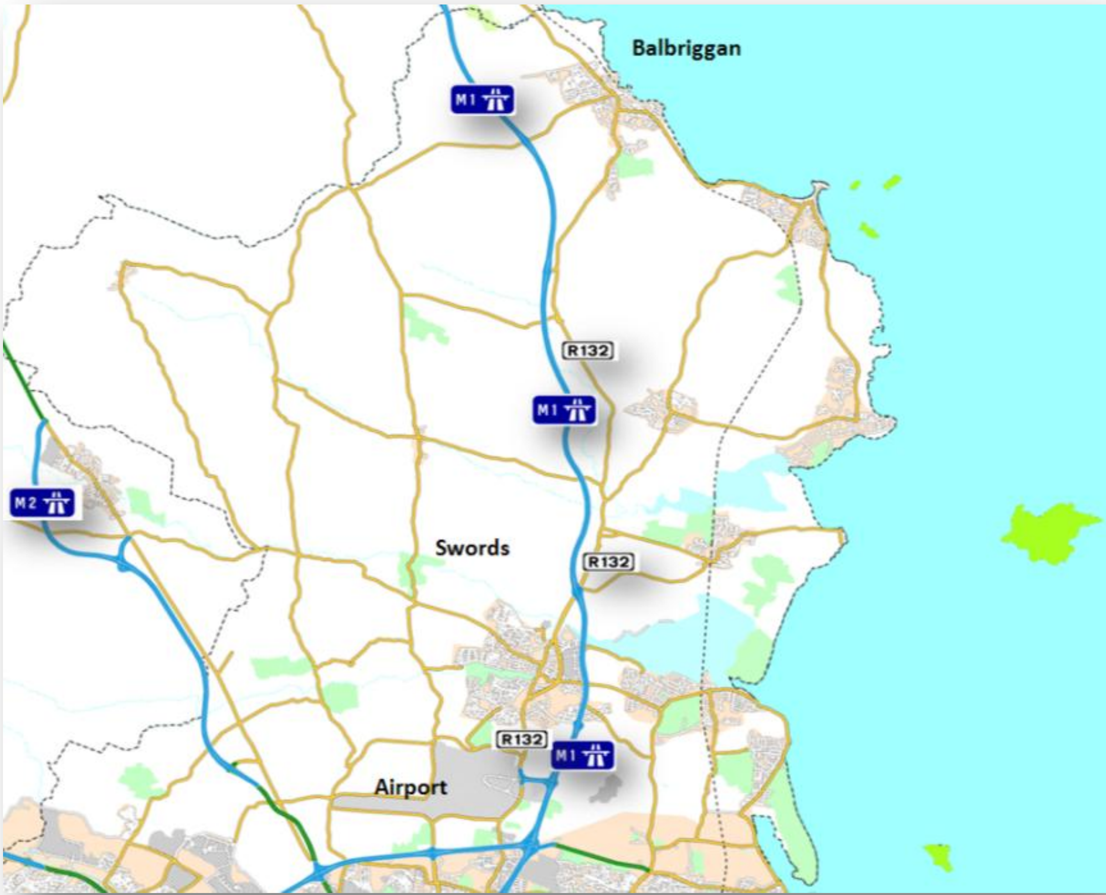

Figure 8-1 M1 Airport to Balbriggan

In order to assess the impact of induced demand, this section of the M1 was closed in the NTpM and the model was re-run. The inherent logic here is that the suppression effect of removing the link is broadly in line with the trip induction effect of providing the link. The model indicated that induced demand accounted for 39% of demand on the M1 in NTpM. The results are presented in Table 8-5.

Table 8-5 Observed/Modelled Comparison

Response	Observed from Available Data	Modelled
Induced Vehicle Demand	35%	39%

8.3.2 M6 Kinnegad to Galway

The phased construction of the M6 between Kinnegad and Galway was completed in December 2009, and is illustrated in Figure 7-2. An observed AADT of 10,500 was recorded in 2008 on the N6 East of Loughrea. Following the completion of the M6 the following AADT was recorded in 2010:

- M6 – 9,500 AADT; and
- R446 (Old N6) – 4,000 AADT

Reassignment of traffic from the old N6 accounts for 68% (6,500 AADT) of the demand on the M6. Assuming no growth between 2008 and 2010, this indicates an induced demand of 32% or 3,000 AADT.

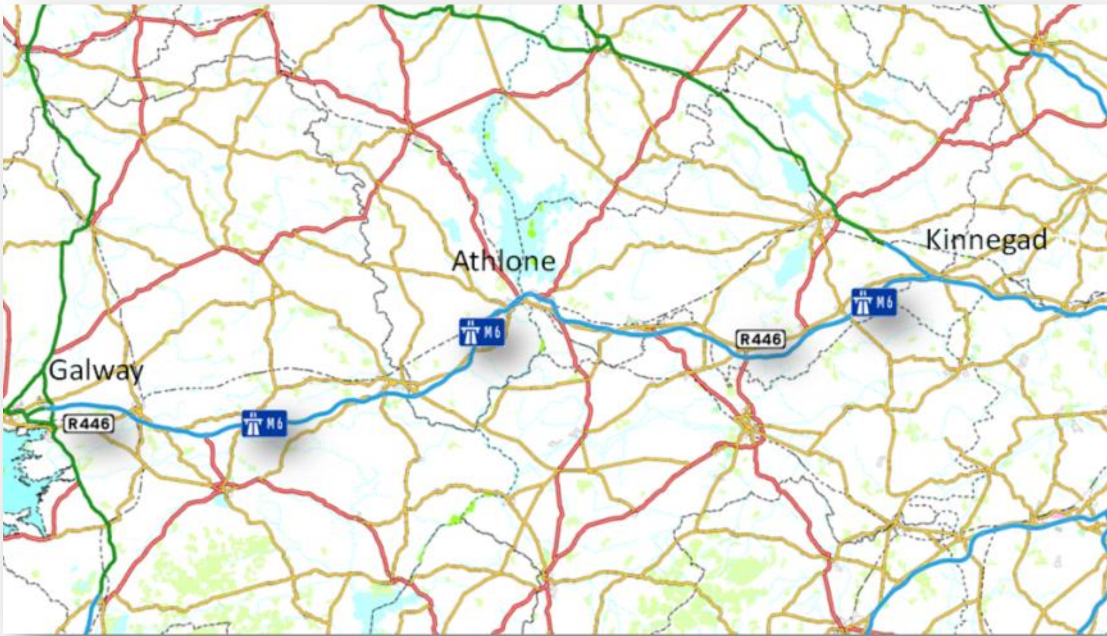

Figure 8-2 M6 Kinnegad to Galway

As before, the M6 was closed and the NTpM was re-run. The model indicated that induced demand accounted for 45% of demand on the M6 in NTpM. This is a significant demand response and correlates reasonably well with the 32% estimated from available data.

With respect to rail, Irish Rail indicated that demand along the Dublin-Galway rail corridor reduced by between 20-30% following the opening of the M6 motorway. The model indicates that passenger demand on the corridor reduces by 15-30% on individual links, while end to end passenger demand between Dublin and Galway is down 35-40%. All modelled/observed results are presented in Table 8-6.

Table 8-6 Observed/Modelled Comparison

Response	Observed	Modelled
Induced Vehicle Demand	32%	45%
Rail Passenger Demand	Down 20% - 30%	Link Flows Down 15% - 20%
		End to End Down 35% - 40%

8.3.3 Dublin to Cork Rail Corridor

The number of rail services travelling between Dublin and Cork was increased from 5 to 14 services in 2008. There was also a slight reduction in end to end journey time. Irish Rail have informally reported an increase of up to 100% in passenger demand, although this estimate has not been based on isolation of demand directly associated with the Dublin – Cork services.

Reviewing broader research evidence on rail demand elasticities (from the UK Passenger Demand Forecasting Handbook), the scale of change in demand that can be attributed directly to the change in service provision would be expected to be between 50% to 75%.

Figure 8-3 Dublin to Cork Rail Corridor

In order to assess passenger demand in the model, the number of rail services between Dublin and Cork was reduced to 5 (representing the do-minimum), and compared with a test using 14 services per day (representing the do-something). The model indicated that the passenger demand response of increasing services to hourly frequencies was 35-40% on the rail corridor with end to end passenger demand increasing by 50%.

8.3.4 Conclusion

The illustrative tests demonstrate that the model is producing credible responses when compared against observed data. This finding is equally applicable to both rail and road network interventions.

Conclusions

9.0 Conclusions

9.1 General

The National Transport Model has been developed by the National Roads Authority to assist in the appraisal of transport schemes, transport policies and traffic management measures. The model allows a more holistic approach to project appraisal, and provides a significant step forward in the quantification of demand, mode change and reassignment responses to transport measures.

The NTpM, finalised in mid 2011, is an enhancement of the National Traffic Model which was completed in 2008, and represented the first strategic level traffic model of Ireland. The NTpM incorporates the National Rail Model, developed with significant input from Irish Rail, and which was used to inform the 2011 Rail Investment Needs Review.

The NTpM provides a high level of functionality, allowing the following responses to be assessed:

- Changes in traffic assignment due to network changes, tolling, traffic management or public transport priority;
- Changes in mode share due to increases/decreases in travel time by car, public transport fares, fuel prices, tolling/road pricing or changes in public transport service levels;
- Demand responses to changes in the cost of travel, including fuel price, public transport fares, congestion, tolling/road pricing and other demand management policies;
- Calculation of costs and benefits based on outputs of travel time, congestion, vehicle kilometres and accident predictions on individual links and across the network as a whole (using project appraisal software); and
- The impact of network costs on future land use.

9.2 Ongoing Model Development

The development of the NTpM has led to the completion of a first generation Variable Demand Model that can reflect all these effects with various degrees of accuracy. Further aspects in the NTpM which are currently under development, and scheduled for completion by late 2011 are:

- Improvement in the level of detail in Northern Ireland – a significant quantum of traffic information has been received from Roads Service and is in the process of being collated to the NTM; and
- The development of an emissions module.

9.3 Future Enhancements

Finally, there are a number of further enhancements for the NTpM that are to be commenced during 2012 as follows:

- An update of the Land Use Models to include a higher degree of sensitivity between network costs and land use growth. Such an update will also require

some adjustment to the future settlement patterns, to account for the significant slowdown in housing completions around the fringes of major urban areas;
- Incorporation of improved data with respect to freight; and
- Updating all demand matrices to 2011 to coincide with the release of the POWCAR information from the 2011 Census.

The NTpM is available for use by government, local authorities, transport related state agencies, and research organisations. It is the intention of the National Roads Authority to maintain the NTpM in a manner which will ensure transparency and open access to transport related public bodies.