Land-Use and Transport Integration in Scotland (LATIS)

TMfS:07 National Road Model Development

Report for Transport Scotland

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Background

LATIS Commission – Development of Modelling Framework

In August 2006 Transport Scotland commissioned MVA Consultancy to a Term Commission for the maintenance and enhancement of the Transport Model for Scotland (TMfS) and the accompanying Transport, Economic and Land-use Model of Scotland (TELMoS).

A central element of the Commission was to develop and deliver an enhanced 2007-based land-use and transport modelling system. MVA proposed a hierarchical modelling framework, with a single National Strategic Travel demand and Land Use Modelling framework as the upper tier, Regional Travel Demand Models as the mid-tier and detailed local models (eg microsimulation) as the lower tier. The National Modelling Framework has now been developed. It incorporates a number of technical enhancements and new and more robust data and will, in time, replace its predecessor, TMfS/TELMoS:05.

On 6 November 2008, the TMfS Term Commission changed its name to Land-Use and Transport Integration in Scotland (LATIS). The service is provided by Transport Scotland and their supporting consultants and offers a wide range of support and technical advice.

The LATIS service currently includes four distinct elements, as follows:

- a user engagement programme, consultations, discussions and advice on a range of transport and travel planning issues;
- the collection and provision of land-use planning data;
- the collection of transport data through the use of the Data Collection Contract; and
- a travel demand and land-use modelling suite.

The TMfS:07 and TELMoS:07 models are designed to deliver the fourth of these elements.

TMfS:07 & TELMoS:07 Model Reports

This report describes the development of the TMfS:07 National Road Model and is one of a series of eight documents describing the construction, calibration and validation of the TMfS:07 and TELMoS:07 models, as shown below:

TMfS:07 National Travel Demand Model

1. TMfS:07 Demand Model Development Report.

TMfS:07 National Road Model

2. TMfS:07 National Road Model Development Report; and
3. TMfS:07 National Road Model Calibration & Validation Report.

TMfS:07 National Public Transport Model

4. TMfS:07 National Public Transport Model Development Report; and
5. TMfS:07 National Public Transport Model Calibration and Validation Report.

TELMoS:07 National Land Use Model

6. TELMoS:07 Model Description Report;
7. TELMoS:07 Assembly of Planning Policy Inputs; and
8. TELMoS:07 Model Demonstration Report.

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1 Introduction

1.1 Overview

1.1.1 The National Road Model forms part of the overall 2007 TMfS model hierarchy (see Figure 1.1 below). It is a strategic model which has been prepared with a level of detail commensurate with appraising national policy and strategic land-use and transport interventions and providing a key source of transport supply and demand data.

1.1.2 TMfS:07 will also form the starting point for the development of Sub-Area and Regional models; providing assistance in preparation of model structure, input to base year development and providing a source of forecast year travel demand.

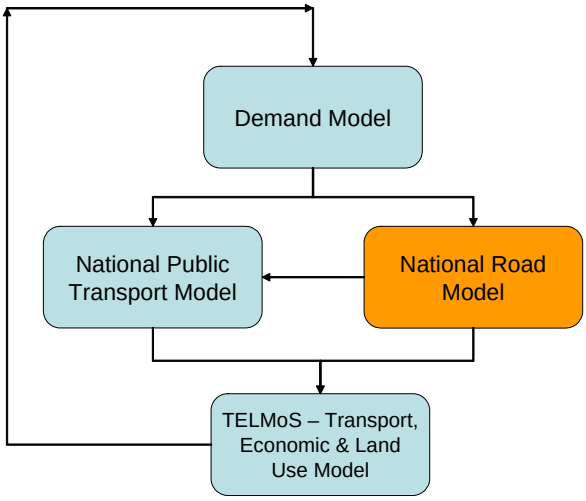


Figure 1.1 Simplified TMfS Model Hierarchy – National Road Model Interaction

1.1.3 The National Road Model has been developed using the GIS-based software package ArcGIS and Citilabs CUBE Voyager software.

1.2 Structure of this Report

1.2.1 The structure of the remainder of this report is as follows:

- Chapter 2 – describes Road Model network development and provides a description of the sources used;
- Chapter 3 – describes the matrix development procedure and data sources used to create the Road Model Assignment Matrices;
- Chapter 4 – describes the development of the Road Model Assignment procedure; and
- Chapter 5 – summarises the conclusions relating to the TMfS:07 National Road model development.

2 Network Development

2.1 Introduction

2.1.1 The TMfS:07 Road Network[1] is based on the Ordnance Survey (OS) MasterMap Integrated Transport Network (ITN) GIS data. This platform provides a geographically accurate representation of Scotland's road network which, in turn, allows the Road Model outputs to be used directly for noise and air quality analyses.

2.1.2 The Road Network has been designed to be more strategic in nature than its TMfS.05A predecessor. It includes all Scottish Motorways and A-Roads, a few strategically-important Scottish B-Roads and a 'skeletal' representation of the road network in England and Wales.

2.1.3 The remainder of this chapter covers the following aspects of the model:

- Zone System;
- Geographical Coverage;
- Node Convention;
- Attributes for Road Nodes and Network;
- Road Link Types and Capacity;
- Road Link Distance Checks; and
- Road Network Enhancements compared with previous TMfS Road Models.

2.2 Zone System

2.2.1 The TMfS:07 national model has the following 720 zones:

- 708 internal zones;
- four airport zones (Aberdeen, Edinburgh, Glasgow and Prestwick); and
- eight external zones covering England and Wales.

2.2.2 The main features of the new zone system are as follows:

- zones are generally larger than in previous versions of TMfS, in line with the more strategic nature of the TMfS:07 model;
- most zones are amalgamations of the 6,505 Scottish Neighbourhood Statistics Data Zones, with typically around 9 Data Zones per TMfS:07 zone;
- no zone crosses a Local Authority boundary; and
- where possible, there is at most one train station per zone - the exceptions to this 'rule' are described in Appendix B of the Demand Model Development Report.

[1] 'TMfS:07 Road Network' will be referred to as the Road Network throughout this report.

2.2.3 Some Data Zones do not lend themselves to creating suitable zones for a transport model, (for example where they represent two or more communities with significantly different connections to the strategic transport network). As a result it has been necessary to split a total of thirteen Data Zones within the TMfS:07 zoning system. All the relevant data zones were split along census output area boundaries. Full details of these can be found in Appendix B of the Demand Development Report.

2.2.4 The TMfS:07 zone in question are as follows:

- Barry and Carnoustie – Zones 572 and 573;
- Tranent and Wallyford – Zones 39 and 41;
- Millerhill and Bonnyrigg – Zones 54 and 56;
- Bishopton, Langbank and Erskine – Zones 407, 411 and 417;
- West Kilbride and Fairlie – Zones 218 and 217;
- Westhill West and Westhill East – Zones 594 and 598;
- Cullen and Buckie– Zones 644 and 645;
- Burntisland and Dalgety Bay East / Aberdour – Zones 493 and 497;
- Tayport and Newport-on-Tay – Zones 520 and 523;
- Auchinleck and Cumnock – Zones 195 and 197;
- Whitburn East and Addiewell / Stoneyburn – Zones 124 and 126;
- Breich and West Calder – Zones 125 and 134; and
- Oakley & Saline and Dunfermline North East– Zones 479 and 483.

2.2.5 The four main airport zones (Glasgow, Edinburgh, Prestwick and Aberdeen) have been defined separately from their underlying Data Zones. The airport zones are:

- Edinburgh Airport – zone 709;
- Prestwick Airport – zone 710;
- Glasgow Airport – zone 711; and
- Aberdeen Airport – zone 712.

2.2.6 Appendix A of this report reports the number of zones contained within each Local Authority Area and the ratio of data zones to TMfS:07 zones for that Local Authority.

2.2.7 Figure 2.1 overleaf shows the TMfS:07 zone system.

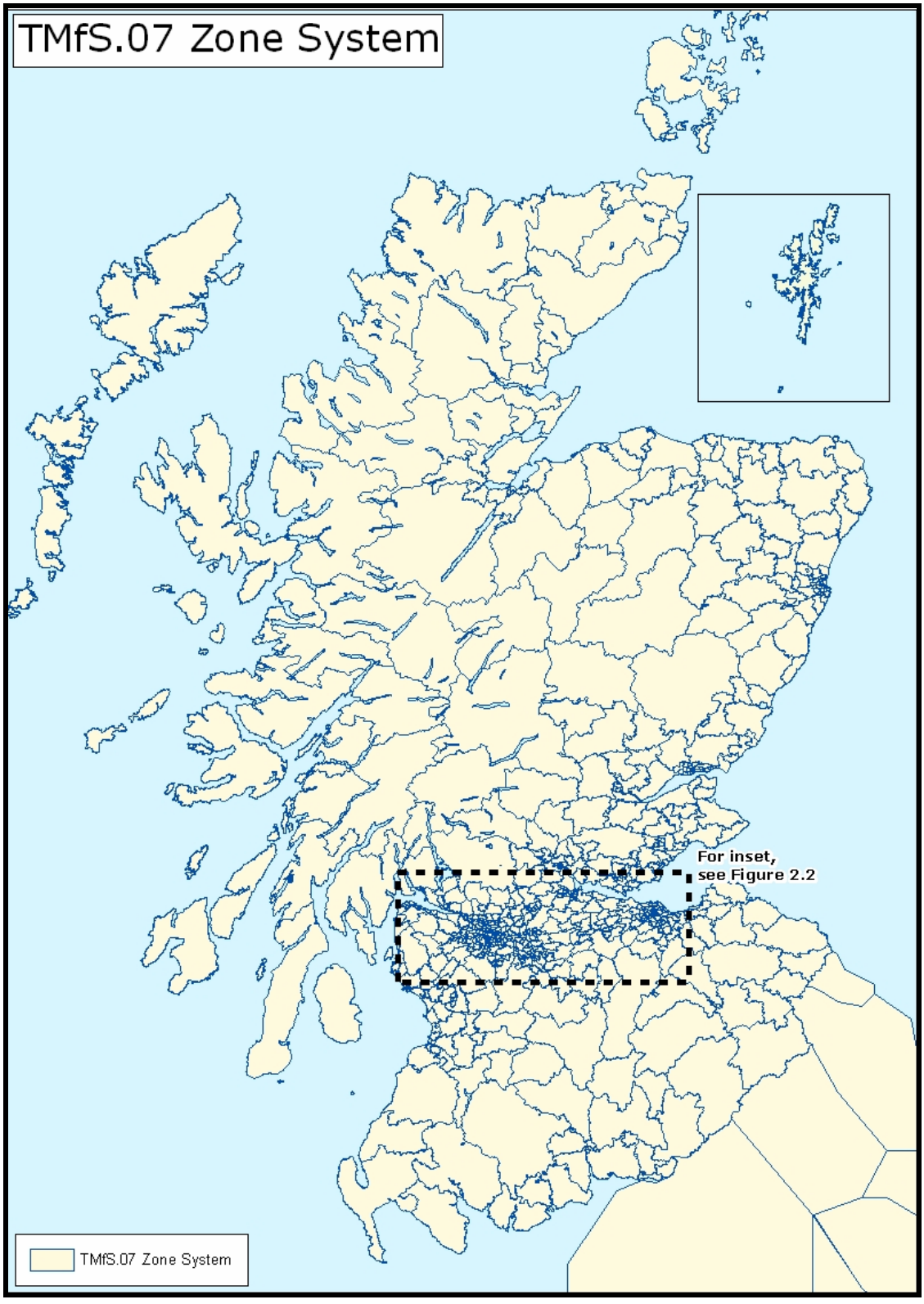


Figure 2.1 TMfS:07 Zone System

2.2.8 Figure 2.2 overleaf highlights the Central Belt zone system more clearly.

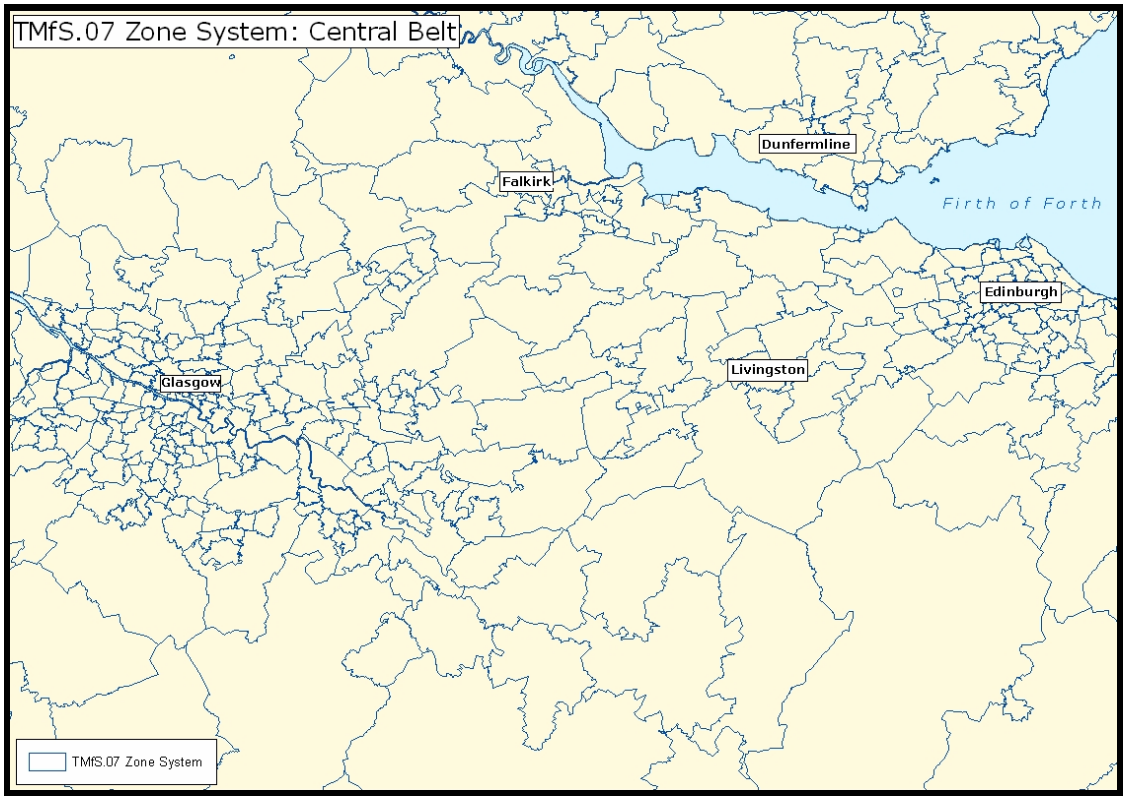


Figure 2.2 TMfS:07 Central Belt Zone System (Insert from Figure 2.1)

2.2.9 The TMfS:07 zone system is available in standard GIS 'shapefile' format on the LATIS website (www.latis.org.uk), along with an Excel spreadsheet containing the following information for each zone in the TMfS:07 zone system:

- Zonal Area (km^2);
- Zonal Population (from 2001 Census);
- Zonal Households (from 2001 Census);
- Zone Centroid coordinates;
- Zone Centroid length (km)[2];
- Zone to local authority list;
- Zone to train station equivalence list;
- Zone to airport equivalence list;
- Zone to Data Zone equivalence list.

[2] Zone centroid lengths have been calculated by considering the zone to be a circle and then calculating the average radial distance of the circle if all points within it are evenly distributed. From the zonal area the zone length can thus be calculated using the following formula:

$$\frac{2}{3}\sqrt{\frac{area}{\pi}}$$

2.3 Geographical Coverage

2.3.1 The TMfS:07 Road Model geographical coverage is highlighted in Figures 2.3 to 2.5.

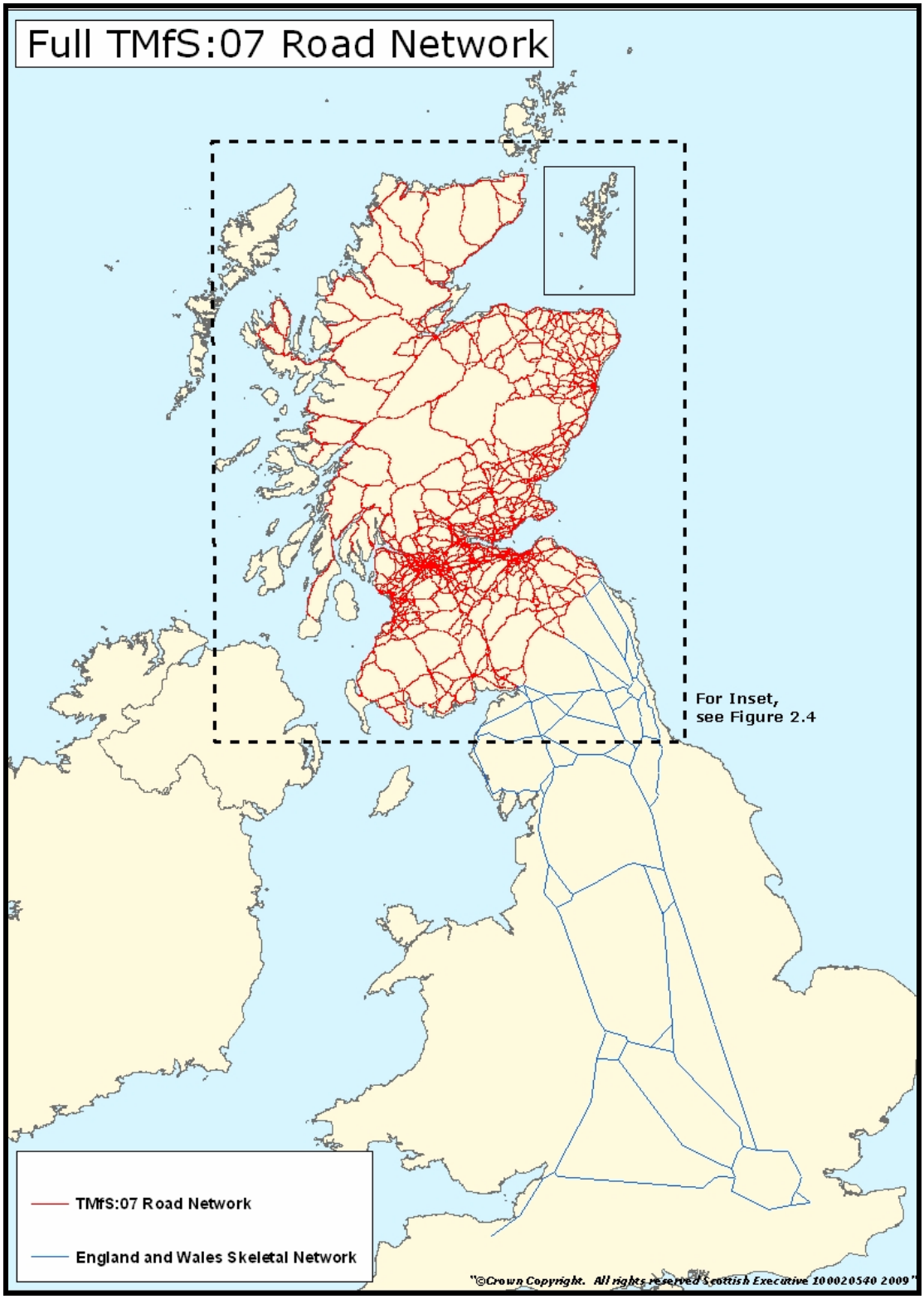


Figure 2.3 TMfS:07 Road Network & Geographical Coverage

2.3.2 Figure 2.4 illustrates the Road Model's representation of Motorways, Trunk A-Roads, A-Roads, B-Roads and minor roads. Figure 2.5 shows the same representation of road types for the Central Belt region.

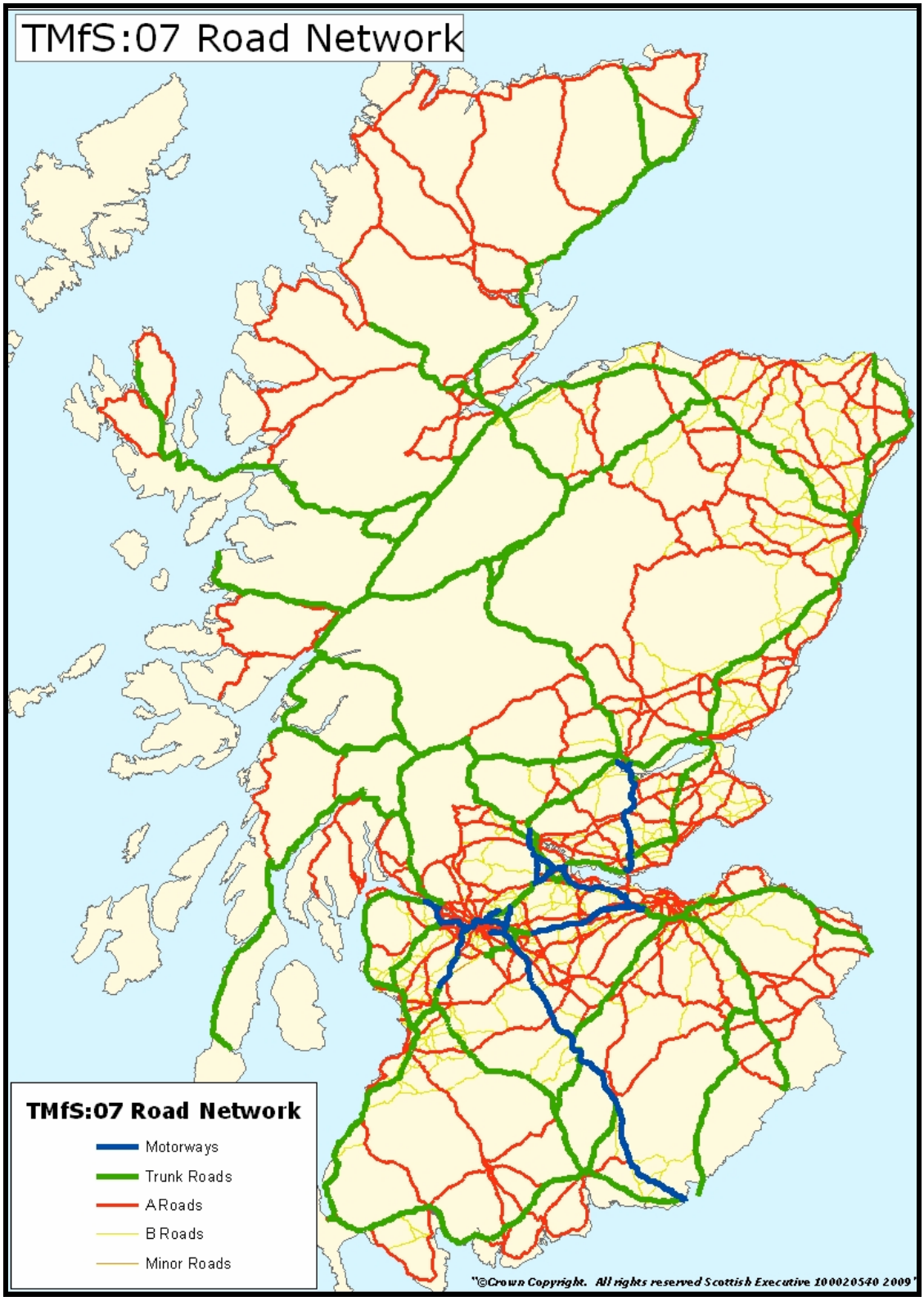


Figure 2.4 TMfS:07 Road Model Network (Inset from Figure 2.3)

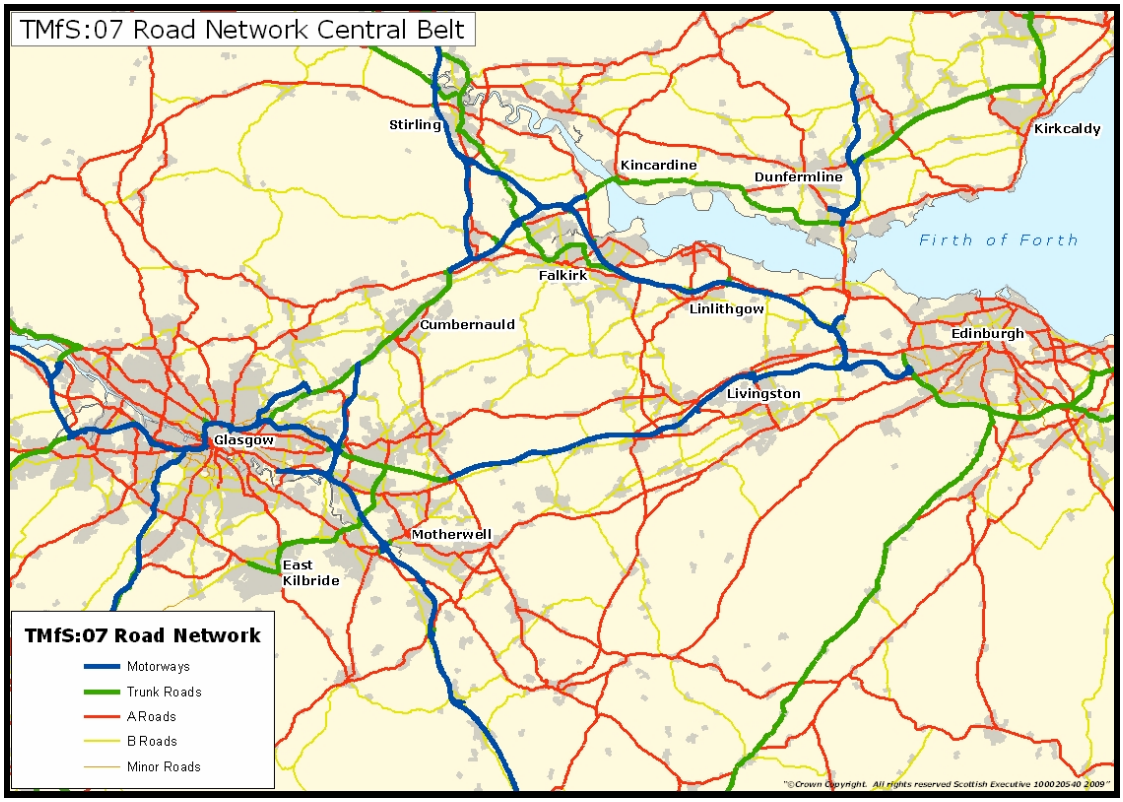


Figure 2.5 TMfS:07 Road Model Network – Central Belt Region

2.4 Node Convention

2.4.1 The following node convention applies to the Road (and Public Transport) network:

- Zones: 1 – 720;
- Road Nodes: 1,000 – 99,999;
- Rail Nodes: 100,000 – 149,999;
- Subway Nodes: 150,000 – 199,999;
- Ferry Nodes: 200,000 – 299,999; and
- Airport Nodes: 300,000 – 399,999.

2.4.2 The Road networks have been built up from the OS MasterMap file 'RoadLink_Line.' All Motorways and A-Roads within Scotland have been included, along with some B-Roads in the Central Belt, Scottish Borders and Aberdeenshire. A small number of strategically-important minor roads have also been included.

2.4.3 For England and Wales the same network has been used as in TMfS:05A but with an improved zoning system and representation of motorways and trunk roads. This is merely a skeletal network. The main border crossings into Scotland are all included.

2.4.4 The nodes in the road networks have been built up from the 'RoadNode_Point' OS MasterMap file. All nodes that coincided within the road network were selected and given a node number which is used within the road network.

2.5 Attributes for Road Nodes and Network

2.5.1 A number of attributes were allocated to each node and the links making up the road network. Appendix B of this report provides details of these node, road and ferry link attributes.

2.6 Road Link Types and Capacity

2.6.1 The road link-types used in TMfS:07 are in line with those stated in the Scottish Transport Statistics Note 24. This Link-type numbering system will allow analysis of model outputs to be easily compared with published statistics. Table 2.1 details road link types and the corresponding default link capacity (PCUs per lane) for inter-urban area links used in the Road Model.

Table 2.1 TMfS:07 Road Link Types & Capacity Per Lane – Inter Urban Links

Link Type	Description	Capacity Per Lane (PCUs)
1	Trunk – Motorway	2400
2	Trunk – Motorway slips	1800
3	Trunk A-Roads Non-built up	1800
5	Non Trunk A-Roads Non-built up	1600
9	Banned for Heavy Goods Vehicles (HGV)	Dependent on road type
10	Bus ONLY.	Dependent on road type
22	Zone-Road Connectors	Unconstrained
22	Zone-Ferry Connectors	Unconstrained
28	Ferry Routes – Banned for HGV	Dependent on ferry size
29	Ferry-Road Connectors	1000
30	Ferry Routes – Car and HGV allowed	Dependent on ferry size
31	Ferry Routes – Banned for both Car and HGV	Dependent on ferry size

Note: Link Type 22 has an unconstrained capacity meaning congested link speed equals free-flow link speed (50 km/hr).

2.6.2 Table 2.2 details corresponding road link-types and link capacity for links in urban and built up areas.

Table 2.2 TMfS:07 Road Link Types & TOTAL Capacity – Urban/Built-up Links

Link Type	Description	Total Capacity (PCUs)
4	Trunk A-Roads Built up	2500
6	Non Trunk A-Roads Built up	2000
7	Minor Roads – Non built up	1000
8	Minor Roads – Built up	1500

Table 2.2 Points to note:

Outwith the Glasgow City, Edinburgh City, Dundee City and Aberdeen City local authority areas the following link capacities apply:

- Linktype 4 (Trunk A-Roads Built Up), link capacity is 1600 pcus per lane;
- Linktype 6 (Non Trunk A-Roads Built Up), link capacity is 1600 pcus per lane; and
- Linktype 7 (Minor Roads – Non built up) and Linktype 8 (Minor Roads – Built up), link capacity is 1000 pcus per lane.

Link capacity through small towns (Urban = 1)

- Linktype 4 (Trunk A-Roads Built Up), link capacity is 1600 pcus per lane;
- Linktype 6 (Non Trunk A-Roads Built Up), link capacity is 1400 pcus per lane.; and
- Linktype 8 (Minor Roads – Built up), link capacity is 1000 pcus per lane.

Capacity on Approach to Rural Roundabouts

2.6.3 There is no explicit junction modelling undertaken in the TMfS:07 National Road Model. The congestion effects of traffic flow on a road link and / or junction delay at the end of a road link are included in the link-based flow delay relationships, which are discussed in Chapter 4 of this report. These relationships take as input the volume / capacity ratio for the road link.

2.6.4 For urban areas, standard road link capacities are applied to each link type. This is generally a reasonable approach as we are not necessarily interested in delays for each road link in the network separately, but more that the journey times over a collection of links are realistic.

2.6.5 For **Inter-urban** roads with relatively long sections between junctions, flow delay relationships have been applied and are designed to give road link speeds due to traffic interactions on the links themselves. They do not allow for the effects of the junctions at the end of these long stretches of inter-urban route. The default assumption is that these junctions are roundabouts and the capacity of the road links have been adjusted accordingly, by applying the following link capacities to the links which approach these junction nodes:

- Single carriageway – 1400 PCUs per hour; and
- Dual carriageway – 2100 PCUs per hour.

2.6.6 Appendix C provides further details of the calculations behind this approach to modelling the impacts of rural roundabout junctions.

Speeds on Urban and Rural Roundabouts

2.6.7 The Ordnance Survey (OS) MasterMap Integrated Transport Network (ITN) GIS data, the foundation for the Road Model network, contains a full list of locations for Scotland's roundabouts within the attribute 'NATUREOFRO'.

2.6.8 The links which make up the roundabouts have been attributed to the Cube-based networks and are located using the in the 'RDBT' volume field – this field will either be blank or contain the word 'roundabout.'

2.6.9 The default assumptions which have been applied to roundabouts to assist in achieving robust representation of travel times across the network are as follows:

- Urban = 0 (Rural area) = 35km/hr;
- Urban = 1 (Small town) = 35km/hr;
- Urban = 2 (Sub-urban area) = 35km/hr;
- Urban = 3 (Non-central area) = 35km/hr; and
- Urban = 4 (Central area) = 30km/hr.

2.7 Road Link Distance Checks

2.7.1 Table 2.3 highlights the results of the comparison between the Scottish Transport Statistics Note 24 (STS) and the TMfS:07 Base Year Road model network for Motorway and Trunk A-Roads only.

Table 2.3 TMfS:07 Road Model Motorway & Trunk A-Road Distance

Road Type	STS 2007 Distance (km)	TMfS:07 Road Model Distance (km)	Difference (km)
Motorway (excluding slip roads)	391	394	3 (+0.8%)
Motorway (including slip roads)	559	522	-37 (-6.6%)
Trunk A-Roads	2,847	3,000	153 (+5.4%)
TOTAL	**3,797**	**3,916**	**119 (+3.1%)**

2.7.2 The analysis shows there to be a comparable representation of the modelled distance for these strategic link types, with Motorway distance comparing very favourably.

2.8 Road Network Enhancements compared with previous TMfS Road Models

2.8.1 The TMfS:07 Road model contains many enhancements over previous TMfS Road models. Table 2.4 summarises the enhancements that have been achieved for the TMfS:07 Road model, together with a comparison with TMfS.05A.

Table 2.4 Key Road Model Network Enhancements & TMfS.05A Comparison

Feature	TMfS.05A	TMfS:07
Hierarchical System	**Single National Model** More detailed zone and network systems (in particular, within Glasgow and Edinburgh) than TMfS:07. Generic procedures for abstracting sub-area models with zone systems similar in detail to parent model.	**National Model** Designed for stand alone policy and strategy testing and to provide inputs to regional models. More aggregate zoning system, but with greater consistency of network detail than TMfS:05 and linkage methodology for creating regional and sub-area models. **Regional / Sub-Area Models** Sub-area models, such as the Forth Regional Model, will tend to have more detailed zone system and will typically be designed to appraise specific schemes. Procedures for ensuring consistency with National Model have been developed, to assist in creating standardised evidence tools for more robust appraisal.
Software Platform	**Citilabs TRIPS Software** With CUBE Manager.	**Citilabs CUBE Voyager Software** Road Model in Voyager, with CUBE Avenue or other Regional Road models (eg SATURN).
Zone System	1162 zones covering the whole of Scotland.	720 zones covering the whole of Scotland based on amalgamations of GROS/Scottish Neighbourhood Statistics Data Zones.

Feature	TMfS.05A	TMfS:07
Road Model	**Network Model** Based on networks from previous TMfS Road models, including junction delay models. Original sources go back to CSTM3 developed in 1997/8. Average parking charges added into cost skims at zonal level.	**Network Model** Road Model developed from scratch, using OS ITN data and using flow delay relationships rather than detailed junction modelling to represent congestion effects. Models developed in GIS, with files being directly input to CUBE Voyager software. Based on ITN MasterMap data to give better representation of actual road network (geo-rectification). Network is more strategic than TMfS.05A and has been constructed from Motorways and A-Roads only, with some B roads (secondary network) included in the Central Belt, Scottish Borders and Aberdeenshire. Turning bans and junction modelling are NOT included. Average city centre parking charges (by journey purpose) are added into the cost skims at zonal level, as for TMfS.05A.

3 Demand Matrix Development

3.1 Introduction

3.1.1 This chapter describes the development of the 'prior[3]' and final calibrated Road Model assignment trip matrices and will be split into the following sections:

- Matrix Development Overview;
- Data Sources;
- Demand Model Matrices; and
- Matrix Enhancements compared with previous TMfS Road Models.

3.2 Matrix Development Overview

3.2.1 Trip matrices were developed for two separate (but related) purposes as outlined below.

3.2.2 Firstly, the road assignment model requires origin-destination trip matrices by time period. These trip matrices represent car and goods vehicle movements.

3.2.3 These origin-destination matrices are used as 'prior' matrices for the development of the assignment models. They represent the starting point. The model development then makes adjustments to the matrices in the calibration process, so that assigned flows on selected links/groups of links match independently collected flow data.

3.2.4 Secondly, matrices of person trips by mode and journey purpose are required for the development of the demand model. These are built only for 'from' home trips in the morning and inter-peak periods. These matrices, along with travel cost matrices, are used for the calibration of the mode and destination choice models. This calibration of the demand model is discussed in the demand Model Development report.

3.2.5 In CSTM3 and TMfS.02/05 the matrices for the demand model development were derived from the calibrated assignment matrices by a factoring process. The process used in TMfS.02/05 was an enhanced version of that used previously in CSTM3. However, in both cases, the development of the demand matrices was dependent on the assignment matrices.

3.2.6 For TMfS:07 a different approach was taken in which the demand model matrices and the assignment matrices were developed independently, but from the same data sources. This was made possible by the availability of data sources which were not available for TMfS.02, including:

- the 2001 Census Journey to Work data;
- the National Rail Travel Survey (applicable to Public Transport Model); and
- Origin-destination surveys of inter-urban bus travel (applicable to Public Transport Model).

[3] 'Prior' means pre-matrix estimation.

3.2.7 In addition, synthesis of matrices was carried out for car travel other than the journey-to-work purpose, and for to-home and non home-based travel. Furthermore, Road Side Interview Data (RSI) complemented the development of the heavy goods vehicle demand matrix.

3.3 Data Sources

2001 Census Journey to Work Data

3.3.1 The 2001 Population Census included questions relating to the location of the 'normal place of work' and main mode used for travel to the workplace. These Travel-To-Work data were based on all of the 2001 Census returns, rather than just the 10% sample which was available from the 1991 Census.

3.3.2 Standard output tables of the implied origin-destination pattern for the journey to work were obtained at Census Output Area level. It can be noted that in all tables of census data published by ONS individual cells with small values (1 or 2) are randomly given the values 0 or 3 in order to preserve anonymity. When aggregated to TMfS:07 traffic zone level, the effect of this random allocation will be small.

3.3.3 These tables represent home to workplace linkages and need further analysis before they can be treated as true origin-destination trip matrices suitable for use in transport modelling. Special Census Matrix Tools software developed for the Department for Transport (DfT) is available for further processing of these data and provides the following functionality:

- Aggregation to study area zone system;
- Split by main mode;
- Split by household car availability;
- Selection of suitable time period, eg annual average weekday; and
- Allowance for work trips which do not occur every working day.

3.3.4 These additional features were developed by including the results of analyses of the UK's National Travel Survey. Following an initial overview of the journey-to-work data, including comparisons with the National Rail Travel Survey data (public transport model related), these data were accepted as suitable for use in matrix development for TMfS:07.

3.3.5 In addition to journey-to-work data, the equivalent information for journey-to-education was also collected in the 2001 Census in Scotland, but not in the rest of UK. This enabled demand matrices for school and other education trips to be included in the TMfS:07 Demand Model.

Road Side Interview Data

3.3.6 Road-side Interview (RSI) data was used in the development of the HGV travel demand matrices. The HGV matrices were developed using existing TMfS:05A HGV demand, and growthing to the 2007 base year using linear interpolation between 2005 and 2012. The RSI data were then used to replace relevant HGV movements through the 69 RSI site locations.

The National Rail Travel Survey

3.3.7 This data source is discussed in the Public Transport Model Development Report.

Origin Destination surveys of Inter Urban Bus Travel

3.3.8 This data source is discussed in the Public Transport Model Development Report.

3.4 Demand Model Matrices

3.4.1 The demand model matrices were developed before the road assignment matrices. This allowed use of the 'to' home and non home-based matrix generation processes in the demand model to complete the origin destination matrices, where appropriate.

3.4.2 The demand matrices are in units of person trips, and cover the morning and inter-peak periods only. 'From' home trips form a relatively small proportion of evening peak trips and these are generated as a proportion of the inter-peak 'from' home matrices.

3.4.3 The data sources for the road matrices for the morning peak and the inter-peak period are summarised in Table 3.1. The matrices are also built separately by car availability segment, with a simplifying assumption that those in non-car-owning households do not make any trips by car.

Table 3.1 AM Peak and Inter Peak Road Demand Matrix Data Sources

Journey Purpose	Mode	Source
From Home to Work	Car Driver / Passenger	Census Journey to Work Data
From Home to Employer's Business	Car Driver / Passenger	Synthesised
From Home to Other	Car Driver / Passenger	Synthesised

3.5 Matrix Enhancements compared with previous TMfS Road Models

3.5.1 The TMfS:07 Road demand matrices include significant enhancements relative to previous TMfS Road Assignment models. Table 3.2 summarises the enhancements that have been achieved for the TMfS:07 Road model relative to TMfS.05A.

Table 3.2 Key Road Model Matrix Enhancements & TMfS.05A Comparison

Feature	TMfS.05A	TMfS:07
Base Data	**New Data Sources** Origin-Destination data collected for road travel at a limited number of roadside interview (RSI) survey sites. **Historic Data** Matrices from TMfS.02.	**New Data Sources** **Census 2001 Journey-to-Work Data** As analysed and presented in DfT software package Census Matrix Tools (CMT) covering from home to work trips by all modes and person segments. Also home to education trips isolated separately for Scottish data.
Base Matrices	Developed from RSI and matrices from TMfS.02. Some parts of the matrix partially observed and/or 'lumpy.'	Developed entirely from new data plus synthesis for car purposes other than commuting. Matrices contain trips for all feasible movements.

4 Assignment Model Development

4.1 Introduction

4.1.1 This chapter describes the development of the Road Assignment model.

4.1.2 The assignment procedure adopted for the TMfS:07 Road Model is carried out using the Citilabs CUBE Voyager HGHWAY module. The procedure is controlled by a 'Script' file which sets out the necessary input files, parameters and output files.

4.1.3 The road assignment model is based on a road network implementation which does not include explicit coding of junctions. It includes an implementation of the Time versus Cost methodology which allows a continuous distribution of the value of time to be used for converting monetary items in the generalised cost formulation into equivalent time units. This is primarily of value for implementations of road user charging and tolling.

4.1.4 For this reason the assignment procedure is a standard implementation of the 'Method of Successive Averages' (MSA) – or volume averaging – equilibrium method, as is the case in the previous TMfS:05 Road Models.

4.1.5 The Road Model includes five separate user classes which are assigned to the road network. These are: Car In-Work, Car Non-Work Commute, Car Non-Work Other, Light Goods Vehicles (LGVs) and Heavy Goods Vehicles (HGVs).

4.1.6 Previous TMfS Road Models included four separate user classes; the TMfS:07 Road Model disaggregates Car Non-Work trips in to two trip purposes as indicated above.

4.1.7 The remainder of this chapter will cover the following topics:

- Assignment procedure;
- Flow Delay relationships;
- Tolling Model;
- Heavy Goods Vehicle Speed cap;
- Road Model Output Files; and
- Assignment Model Enhancements compared with previous TMfS Road Models.

4.2 Assignment Procedure

4.2.1 Traffic is assigned to the Road network based on a Generalised Cost Function which takes the following form:

$$GC = a \times distance(km) + b \times time(mins) + c \times toll(pence)$$

where a, b and c are the parameters and GC is in generalised time.

4.2.2 Appendix D of this report highlights the base year Road Model Generalised Cost Function parameters for each of the five user classes. These parameters have been calculated in accordance with current (December 2008) DfT WebTAG guidance.

Road Model Convergence

4.2.3 The Method of Successive Averages (MSA) algorithm is used to find the equilibrium solution within the assignment procedure. The convergence criterion for the assignment is based on the gradient of the line of the graph of Iteration number versus Total Cost. This regression statistic is calculated using the following formula:

$$a = \frac{n\sum xy - \sum x \sum y}{n\sum (x)^2 - (\sum x)^2} / c$$

where *a* is the gradient, *x* is the iteration number, *y* is the total cost, *c* is the total cost on the current iteration and *n* is the number of iterations over which the regression is worked out, this is set by the parameter NOITR.

4.2.4 The regression statistic is normalised using the total cost of the current iteration, to leave it unit-less as a pure parameter. All summations are from current iteration number minus NOITR to current iteration number.

4.2.5 The Road Model is deemed to be globally converged if the regression value is less than the tolerance criteria (TOLERANCE) for a user defined number of consecutive iterations (NSUCC).

4.2.6 The following regression parameters have been used for the Road assignment model:

- NOITR = 10;
- TOLERANCE = 0.0001; and
- NSUCC = 3

4.2.7 The number of iterations required to reach convergence within the Base Year Road Model were:

- AM Peak Hour (08:00 – 09:00) – 50 iterations;
- Average Inter Peak Hour (1/6 of 10:00 – 16:00) – 19 iterations; and
- PM Peak Hour (17:00 – 18:00) – 63 iterations.

4.3 Flow Delay Relationships

4.3.1 Flow Delay Relationships are used to model the behaviour of travel speeds in congested road network conditions. Two types of equations are used in the Road Model.

4.3.2 When Volume (V) < = Road Link Capacity (C), the form of the flow delay relationship is:

$$T_C = T_0 \times (1 + TCCOEFF \times ((\frac{V}{C})^{TCEXP}))$$

where T_C is the congested travel time (mins), T_0 is the free flow speed (km/hr), TCCOEFF represents the coefficient term and TCEXP represents the exponential term in the Road Link Class specific congested time function.

4.3.3 When V > C, the form of the flow delay relationship is:

$$T_C = T_0 \times (1 + TCCOEFF) + A \times ((\frac{V}{C}) - 1)$$

where A is the slope of the line.

4.3.4 The value of A has been set to 7.5 minutes. This is consistent with the formulae for speed/flow curves for traffic flows beyond capacity as included in DfT Advice Note 1A.

4.3.5 The above two flow delay regimes are highlighted for 2-lane Motorways, Trunk A-Roads single and dual, non-Trunk A-Roads single and B roads in Appendix E.

4.3.6 The relationship between flow and speed is different for different types of road. Each road link has a Link_Class attribute. This attribute determines which flow delay relationship is attached to each road link. Appendix F at the end of this report shows the values of TCCOEFF and TCEXP associated with the different Link Classes.

4.3.7 The following Link Classes are used in **Urban Areas** (with free flow speed in brackets):

- 1 – Urban Central (32 km/hr);
- 2 – Urban Non Central – Single (42 km/hr);
- 3 – Urban Non Central – Dual (51 km/hr);
- 4 – Small Town (44 km/hr);
- 5 – Suburban – Single (54 km/hr);
- 6 – Suburban – Dual (44 km/hr);
- 7 – Urban Motorway (76.8 km/hr);
- 8 – Urban Motorway <70mph (92.8 km/hr);
- 20 – Roundabout Urban Central (30 km/hr); and
- 22 – Urban Dual 50mph (76.8 km/hr).

4.3.8 The following Link Classes are used in both **Urban** and **Rural Areas**:

- 9 – Ramp at Grade Separation (80 km/hr);
- 21 – Roundabout Elsewhere (35 km/hr).

4.3.9 Table 4.1 shows Link Classes which are used in **Rural Areas** with the free flow speed in brackets:

Table 4.1 Rural Area Link Classes (Free flow speed in km/hr)

Hilliness	Bendiness	Rural Single – B Road	Rural Single – A Road	Rural Dual	Motorway – 2 lanes	Motorway – 3 lanes
H	H	10 (61)	-	-	-	-
M	H	11 (66.7)	-	-	-	-
M	M	12 (72.4)	-	-	-	-
L	H	-	13 (78.2)		-	-
L	M	-	14 (83.9)	16 (105.6)	-	-
L	L	-	15 (89.6)	17 (107.2)	18 (108.8)	19 (110.4)

4.3.10 The free flow speeds in **Rural Areas** were calculated using the formulations in DMRB Volume 13, Section 1, Part 5. The following values are used to calculate the speeds:

For Hilliness

- High – 40;
- Medium – 20; and
- Low – 0.

For Bendiness

- Low – 0 (Visibility = 550);
- Medium – 75 (Visibility = 325); and
- High – 150 (Visibility = 100).

4.4 Tolling Model

4.4.1 The road assignment model includes an implementation of the Time versus Cost methodology which allows a continuous distribution of the value of time to be used for converting monetary items in the generalised cost formulation into equivalent time units.

4.4.2 The willingness to pay weighting is randomly sampled from a distribution that is representative of the total population and is varied from iteration to iteration for each of the five user classes. This is primarily of value for implementations of road user charging and tolling.

4.4.3 The willingness to pay weightings are available on request.

4.5 Heavy Goods Vehicle Speed Cap

4.5.1 An enhancement to previous TMfS Road Models is the implementation of Heavy Goods Vehicle (HGVs) free flow speed cap by link type. The speed caps are national HGV speed limits for HGVs > 7.5 Tonnes (see Table 4.2 below).

4.5.2 This added functionality to the Road Model assignment procedure will ensure HGVs cannot travel faster than they are legally allowed to in free flow conditions. (NB Modelled HGVs will travel at the relevant congested link speeds if these are slower than the HGV speed cap).

4.5.3 Furthermore, the HGV speed cap will allow for improved representation of HGV travel costs in the TELMoS land-use model and in economic scheme appraisals.

Table 4.2 HGV Free Flow Speed Cap by Link Type

Link Type	Description	Free Flow Speed (km/hr)
1	Trunk – Motorway	96
2	Trunk – Motorway slips	96
3	Trunk A-Roads Non-built up	64 (80 if Dual)
4	Trunk A-Roads Built up	48
5	Non Trunk A-Roads Non-built up	64
6	Non Trunk A-Roads Built up	48
7	Minor Roads – Non built up	48
8	Minor Roads – Built up	48

4.6 Road Model Output Files

4.6.1 The Road Model produces three default output files and three optional output files. These are:

Default Output Files

- Output Control File (*.prn). This text file details the input files and parameters for the assignment run. In addition, global assignment statistics such as average assigned vehicle distance (km) are printed;
- Output Road Model Network File (*.net). This binary file contains information such as road link traffic flows, congested road speeds and travel times; and
- Convergence Report File (*.prn). This text file summarises the global road network cost for each iteration and convergence level achieved.

Optional Output Files

- Output Path File (*.pth). This binary file contains traffic routing information for all non-zero origin destination movements for each iteration and is created only when the catalogue key 'Path File' is set to 'Y';
- Output Generalised Cost Skims (*.mat). This matrix file contains generalised cost information for each of the five user classes and is fed into the demand model. The file is created only when the demand model is NOT on the last loop and is controlled by the catalogue keys 'Current Loop' and 'Last Loop;' and
- Output Time, Distance, Toll and Generalised Cost Skims (*.mat). This matrix file contains Time, Distance, Toll and Generalised Cost skims for each of the five user classes and they are combined over ALL iterations. This file is created only when the catalogue key 'Skims' is set to 'Y.'

4.7 Assignment Model Enhancements compared with previous TMfS Road Models

4.7.1 The TMfS:07 Road Assignment model contains enhancements over previous TMfS Road Assignment models. Table 4.3 below summarises the enhancements that have been included within the TMfS:07 Road model, along with a comparison with TMfS.05A.

Table 4.3 Key Road Assignment Procedure Enhancements & TMfS.05A Comparison

Feature	TMfS.05A	TMfS:07
Road Model	**Assignment Model** User equilibrium based on method of successive averages, with tolls implemented through Time versus Cost method which takes account of distributions of value of time.	**Assignment Model** As for TMfS.05A but with improved run time performance due to more strategic network and the removal of detailed junction modelling. Commuting assigned separately from other travel purposes, using appropriate WebTag parameters. HGV national speed limits applied by road type (HGVs > 7.5T). Improved representation of HGV travel costs for TELMoS and economic appraisal.

5 Conclusions

5.1 Conclusions

5.1.1 The TMfS:07 National Road Model has been developed to appraise national transport and planning policy and strategic land-use and transport interventions. It provides a source of current and forecast national/strategic travel demand and associated demographic information.

5.1.2 This report has presented and discussed the development of the TMfS:07 National Road Model and has covered the following topics:

- Network and zone system development;
- Road Model travel demand matrix development; and
- Assignment model development.

5.1.3 There are number of enhancements to the TMfS:07 National Road Model over and above that of the previous versions, including:

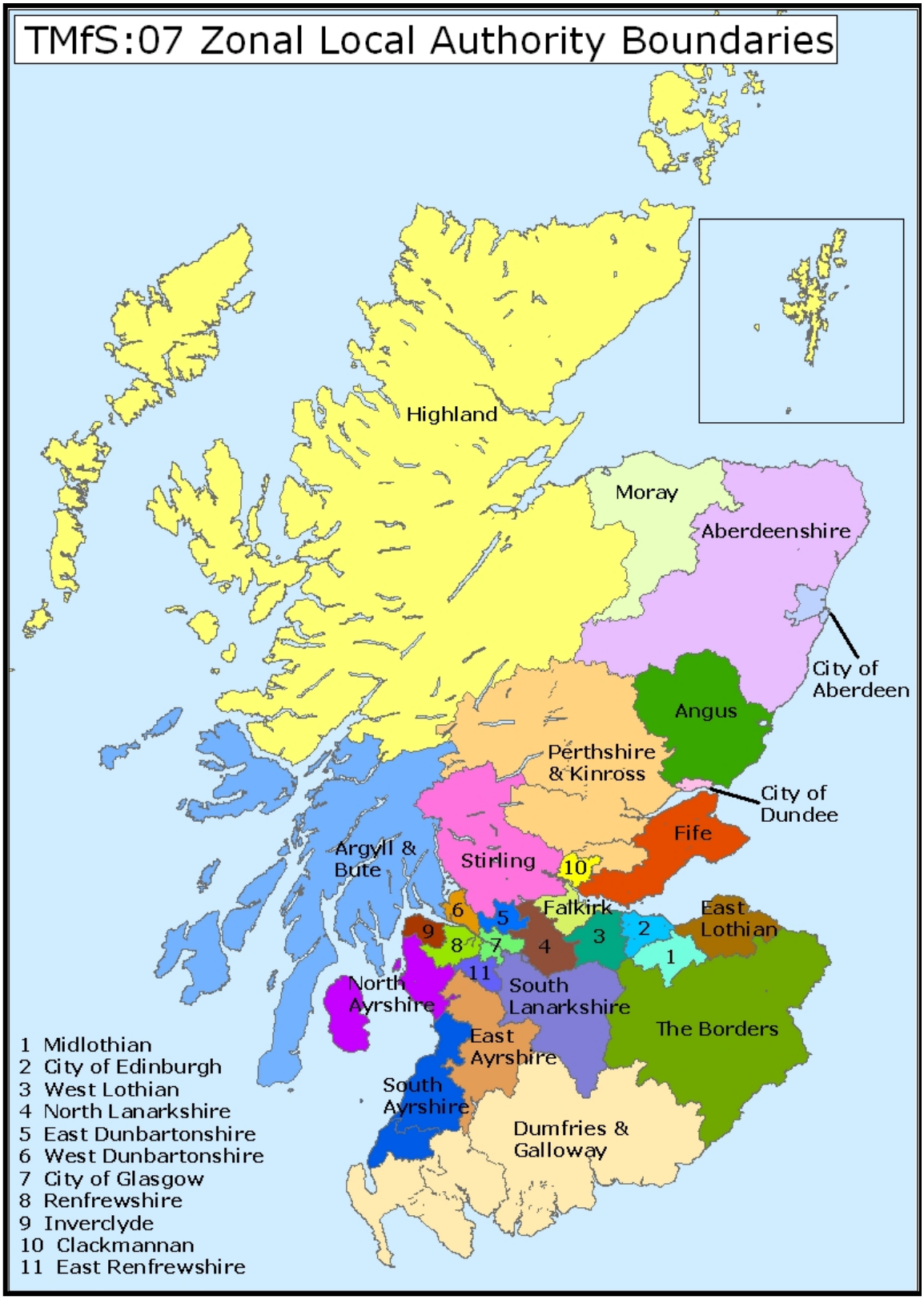
- Road Model developed 'from scratch' using latest GIS tools and datasets, including the ITN MasterMap data, to give an accurate 'geo-rectified' representation of the strategic road network;
- new travel demand matrices developed from 'first principles' to ensure much-greater consistency between land-use and trip-making in the base-year model;
- commuter traffic assigned separately from other travel purposes, using relevant WebTag behavioural parameters;
- HGV national speed limits incorporated to improve estimates of goods vehicle travel costs for use in TELMoS:07 and transport scheme appraisal;
- reduced model run times due to the new software platform, reduced network detail and the removal of the need for detailed junction modelling; and
- a wide range of software functionality enhancements (and associated 'future-proofing') achieved by the move to the CUBE Voyager software platform.

Appendix A – Number of Zones by Local Authority

Number of Zones by Local Authority

Local Authority	Number of TMfS:07 Zones	Number of Data Zones	Ratio
Dumfries & Galloway	21	193	9.2
The Borders	14	130	9.3
East Lothian	14	120	8.6
Midlothian	11	112	10.2
City of Edinburgh	60	569	9.5
West Lothian	24	211	8.8
South Lanarkshire	41	414	10.1
East Ayrshire	17	154	9.1
South Ayrshire	15	147	9.8
North Ayrshire	18	179	9.9
East Renfrewshire	13	120	9.2
City of Glasgow	78	694	8.9
North Lanarkshire	49	433	8.8
Falkirk	21	197	9.4
East Dunbartonshire	13	127	9.8
Renfrewshire	25	214	8.6
Inverclyde	15	110	7.3
West Dunbartonshire	13	103	7.9
Stirling	12	110	9.2
Clackmannan	7	64	9.1
Fife	49	453	9.2
Perthshire & Kinross	20	175	8.8

Local Authority	Number of TMfS:07 Zones	Number of Data Zones	Ratio
City of Dundee	19	179	9.4
Angus	14	142	10.1
Aberdeenshire	29	285	9.8
City of Aberdeen	26	247	9.5
Moray	12	116	9.7
Argyll & Bute	16	122	7.6
Islands	5	93	18.6
Highland	41	292	7.1
TOTAL	**712**	**6,505**	**9.1**


TMfS:07 Zonal Local Authority Boundaries
Highland
Moray
Aberdeenshire
City of Aberdeen
Angus
Perthshire & Kinross
City of Dundee
Fife
Argyll & Bute
Stirling
10
6
5
Falkirk
East Lothian
9
8
7
4
3
2
1
11
North Ayrshire
South Lanarkshire
The Borders
East Ayrshire
South Ayrshire
Dumfries & Galloway
1 Midlothian
2 City of Edinburgh
3 West Lothian
4 North Lanarkshire
5 East Dunbartonshire
6 West Dunbartonshire
7 City of Glasgow
8 Renfrewshire
9 Inverclyde
10 Clackmannan
11 East Renfrewshire

Appendix B – Attributes for Nodes & Network

Node Attributes

Attribute	Description
NODE	This is the shortened TOID from the ITN MasterMap Data. NODE = TOID – 4,000,000,000,000,000. This allows us to directly refer the network back to the MasterMap.
LA	Local Authority the node is within. This was obtained by undertaking a special query against the LOCAL_AUTHORITY shape file.
X	X Coordinate of the node.
Y	Y Coordinate of the node.
N	TMfS:07 node number.
BRIDGE_	This field is a **1** if the node is a 'bridging' point or **0** otherwise. The process to determine those nodes which are bridges was undertaken manually.
NO_OF_LINK	The number of links that connect into the node. If **BRIDGE_** = 1 then the number was reduced by two to remove the links passing under / over the point.
HEIGHT_M_	Height above sea level in metres. This was determined using a spatial join with the HEIGHTPT_POINT shape file.
RUR_RBT	This field is a **1** if the node is part of a rural area roundabout or **0** otherwise.

Road Link Attributes

Attribute	Description
TOID	Topographic Object Identifier. This information is derived from the ITN dataset. This allows us to directly refer the network back to MasterMap.
DESCRIPT1	Type of Road: Motorway, A Road, B Road or Minor Road. This information is derived from the ITN dataset.
NATUREOFRO	Nature of the Road: Dual Carriageway, Roundabout, Single Carriageway, Slip Road, Traffic Island Link at Junction or Traffic Island. This information is derived from the ITN dataset.

Attribute	Description
TOID_S	Shortened TOID from the ITN MasterMap Data. TOID_S = TOID – 4,000,000,000,000,000.
ROADNAME	Name of the road. This information is derived from a cross tabulation of the ITN ROADLINK_LINE with the ROAD_LINE shape files.
LA	Local Authority the link is within (defined as the LA the A-Node of the link is within). This was obtained by undertaking a spatial query against the LOCAL_AUTHORITY shape file.
Urban	This flag informs whether the link is in an urban area; a range of **0** to **4** inclusive applies. This was obtained by undertaking a spatial join with the DLUA_REGION shape file. 0 = Rural; 1 = Small town; 2 = Suburban Area; 3 = Non-Central Area; and 4 = Central Area. (Flag 4 was undertaken manually).
Trunk_Road	This field is a **1** if the road link is part of Scotland's trunk road network, **0** otherwise.
Link_Type	The Link Types within the Road Network are: 1) Trunk – Motorway; 2) Trunk – Motorway slips; 3) Trunk A-Roads Non-Built up; 4) Trunk A-Roads Built up; 5) Non Trunk A-Roads Non-Built up; 6) Non Trunk A-Roads Built up; 7) Minor Roads Non-Built up; 8) Minor Roads Built up; 9) Banned HGV; 10) Bus Only; and 22) Zone-Road Connectors. These have been attributed to each link based on **DESCRIPT1**, the **Trunk_Road** and **Urban** flags.

Attribute	Description
Capacity_L	Capacity per lane.
Number_Lan	Number of lanes on the link. This is defined as the number of effective lanes available to the general traffic.
HGV_Lane	This field is a **1** if the road link is HGV only, **0** otherwise. This information was obtained by cross tabulating the ROADLINK_LINE shape file with the Road Routing Information (RRI) data.
One_Way	This field is a **1** if the road link is one-way, **0** otherwise. This information was obtained by cross tabulating the ROADLINK_LINE shape file with the Road Routing Information (RRI) data.
Distance	Road link length in kilometres.
Speed	Free flow speed in kilometres per hour (km/hr).
Cap	Road link capacity.
Rev	Attribute required by Cube Voyager software to inform if the road link is to be considered as one or two-way.
Direct_No	TOID of the A-node of the Road link.
Direct_1	TOID of the B-node of the Road link.
A_Node	Shortened Version of Direct_No. A_Node = Direct_No – 4,000,000,000,000,000.
B_Node	Shortened Version of Direct_No. B_Node = Direct_1– 4,000,000,000,000,000.
A	Road link A-node.
B	Road link B-node.
Height_A	Road link A-node height in metres (m).
Height_B	Road link B-node height in metres (m).
Gradient	Calculation of gradient using **Height_A** and **Height_B**.
X_ANODE	A-node X co-ordinate.
Y_ANODE	A-node Y co-ordinate.
X_BNODE	B-node X co-ordinate.

Attribute	Description
Y_BNODE	B-Node Y co-ordinate.
Crow_Fly_D	Crow Fly distance (calculated using **X_ANODE**, **Y_ANODE**, **X_BNODE, Y_BNODE**).
Bendiness	This is the Ratio of Crow Fly Distance with actual Distance. Bendiness = Crow_Fly_D/Distance.
Bend	The 'Bendiness' of a link can be: **High** (Bendiness < 0.6); **Medium** (0.5 < Bendiness < 0.9); or **Low** (Bendiness > 0.8).
Hill	The 'Hilliness' of a link can be: **High** (Gradient >= 70); **Medium** (40 <= Gradient <70); or **Low** (Gradient < 40).
Link_Class	This field can be in the range of **1** to **22** inclusive. The Link Class of a Road link depends on Link Type, Area Type, Bendiness, Hilliness and whether the Road link ends in a junction. The Link_Class attribute determines which Flow / Delay relationship is applied to a Road link. Flow / Delay relationships are discussed in detail in Chapter 4 of this report.
Cap_ind_v_c	When traffic volume on a Road link is greater than capacity this attribute determines which Flow / Delay relationship is applied. There are four possible values in this field; only 1 and 3 are used: 1) No junction; 2) A-node is junction; 3) B-node is Junction; and 4) A-node and B-nodes are junctions. Flow / Delay relationships are discussed in detail in Chapter 4 of this report.
Toll_Light	Toll for light vehicles (Cars and LGV's) for crossing the 'tolled' Road link.

Attribute	Description
Toll_Heavy	Toll for heavy vehicles (HGV's) for crossing the 'tolled' Road link.
App_Rur_RB	This field is a **1** if the Road link is an approach to a rural roundabout, **0** otherwise. The attribute has been used in capacity manipulation for approaches to **Rural** roundabouts on single and dual carriageways. This is discussed in chapter 2.
Bus_Corrid	This field is a **1** if the Road link is on a bus corridor, **0** otherwise.
AM/IP/PM_Bus_Flow	This field contains time period specific bus preload information. This information is determined from the number of bus vehicles traversing a Road link in the specified time period.

Ferry Link Attributes

Attribute	Description
NATUREOFRO	Nature of the Road: 'Ferry Route' attribute assigned to all links.
ROADNAME	Ferry route name.
LA	Local Authority ferry route is mainly within.
Link_Type	The Link Types within TMfS:07 Ferry Network are as follows: 22) Zone-Ferry Connectors; 28) Ferry Routes – Banned HGV; 29) Ferry-Road Connectors; 30) Ferry Routes – Car and HGV allowed; 31) Ferry Routes – Car and HGV not allowed; and 32) Rail-Ferry Connectors.
Distance	Ferry Route Length in kilometres (km).
Speed	Speed including waiting times.
Cap	Capacity of ferry link per hour.
Rev	Attribute required by Cube Voyager software to inform if the road link is to be considered as one or two-way.

Attribute	Description
Link_Class	The link class for ferry routes is zero as they have no flow delay relationship associated with them.
Fare_Light	Ferry fare for Cars / LGVs in pounds (£).
Fare_Heavy	Ferry fare for HGVs in pounds (£).
A	Ferry link A-node.
B	Ferry link B-node.
X_ANODE	A-node X co-ordinate.
Y_ANODE	A-node Y co-ordinate.
X_BNODE	B-node X co-ordinate.
Y_BNODE	B-Node Y co-ordinate.

Appendix C – Approach to Rural Roundabout Capacity Calculation

The capacity of each arm of a roundabout, as described in DMRB Volume 13 Section 1, is dependent not only on the approach width and other geometric features at the roundabout but also the circulating flow at entry.

Assumptions for the characteristics which will have a small impact on capacity calculations are:

- φ which is the entry angle = 30 degrees; and
- **r** which is the entry radius = 20 metres (m).

The entry arm capacity for zero circulating flow is calculated as:

$\mathbf{Q} = 303 \times X_2$

where $X_2 = v + (e-v) / (1 + 2S)$

v = approach road half width

e = entry width at the roundabout

S = 0.2

Approaches to roundabouts on **Single** and **Dual** carriageways:

Single Carriageways

Assumption for **v** = 3.65m; **e** = 7.3m

Dual Carriageways

Assumption for **v** = 7.3m; **e** = 10.0m

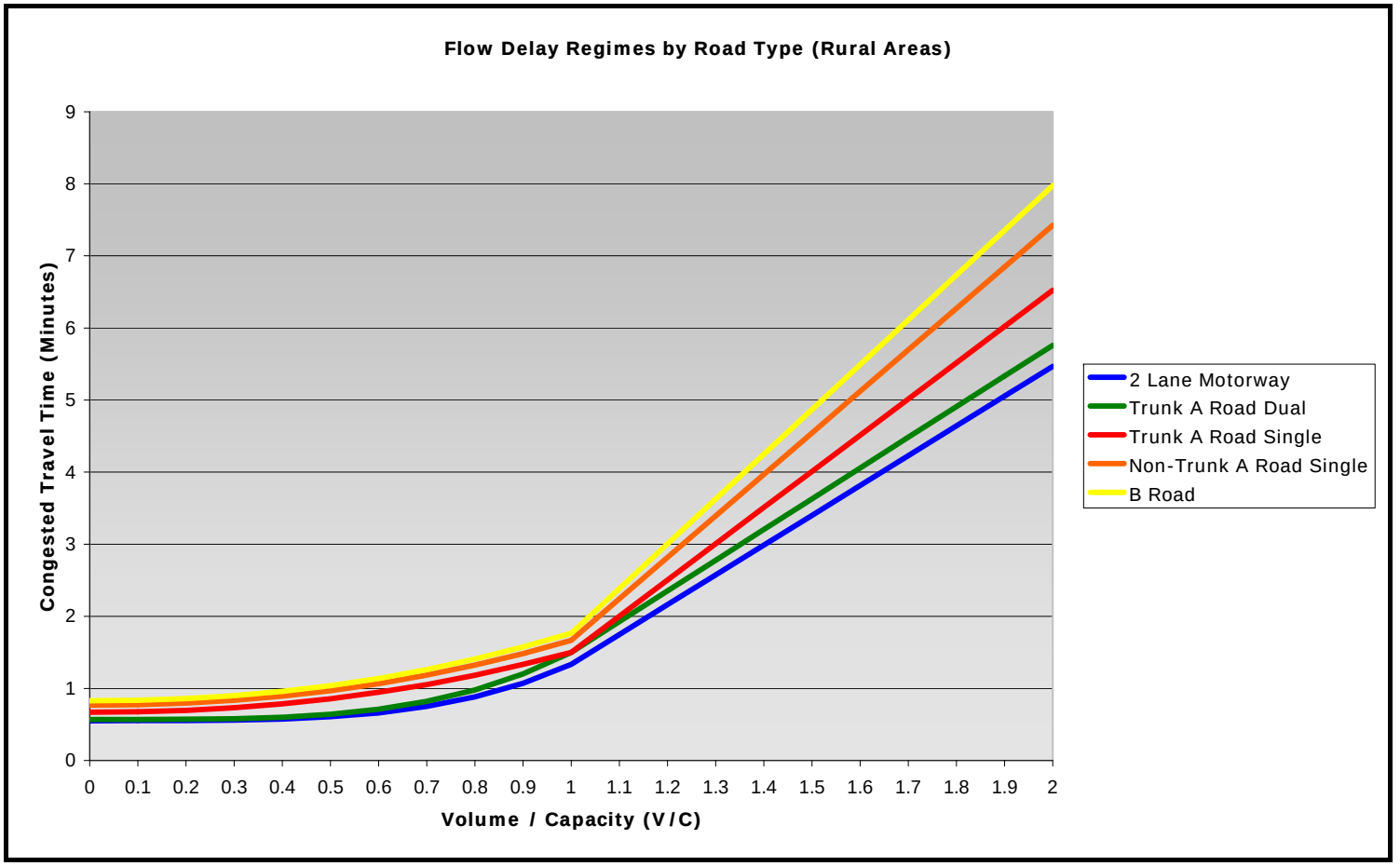
This the gives capacities at no circulating flow of about 1900 pcu/hr for single carriageways and 2800 pcu/hr for dual carriageways. These capacities reduce linearly to zero at circulating flows of between 4000 and 4600 pcu/hr. Since we do not know what the actual circulating flow will be (it is a function of the road assignment and will vary from site to site) an assumption of typical circulating flow is ¼ of the maximum. This then gives capacities which are ¾ of the maximum. Thus:

- for Single Carriageways – $\mathbf{Q_{single}}$ = 1400 pcus/hr; and
- for Dual Carriageways – $\mathbf{Q_{dual}}$ = 2100 pcus/hr.

Appendix D – Base Road Model Generalised Cost Parameters

User Class	Parameter	Value
Car In-Work	Time	1
	Distance	0.2329
	Toll	0.0503
Car Non-Work Commute	Time	1
	Distance	0.5299
	Toll	0.1448
Car Non-Work Other	Time	1
	Distance	0.3885
	Toll	0.1448
LGV	Time	1
	Distance	0.6805
	Toll	0.0225
HGV	Time	1
	Distance	2.1876
	Toll	0.0225

Appendix E – Flow Delay Regimes By Road Type (Rural Areas)



NB When V/C > 1, the road link is said to be 'saturated' or over-capacity. Hence from this point forward there is a steeper gradient to the graph meaning a rapid increase in travel times.

Appendix F – Link Class Coefficient & Exponential Terms

The relationship between flow and speed is different for different types of road. Each road link has a Link Class attribute, ranging from 1 to 22 inclusive, and an associated free flow speed. TCCOEFF represents the coefficient term and TCEXP represents the exponential term in the Road Link Class specific congested time function.

Link Class	TCEXP	TCCOEFF	Free Flow Speed (km/hr)
1	1.73	1.13	32
2	1.48	1.10	42
3	1.67	1.04	51
4	2.45	0.76	44
5	3.29	1.16	54
6	1.40	1.20	44
7	3.68	1.19	76.8
8	3.29	1.32	92.8
9	3.29	1.29	80
10	2.16	1.03	61.0
11	2.16	1.09	66.7
12	2.16	1.13	72.4
13	2.16	1.17	78.2
14	2.16	1.21	83.9
15	2.16	1.24	89.6
16	3.68	1.64	105.6
17	3.68	1.55	107.2
18	3.85	1.42	108.8
19	3.81	1.45	110.4

Link Class	TCEXP	TCCOEFF	Free Flow Speed (km/hr)
20	1.73	1.00	30
21	1.48	0.40	35
22	3.29	1.19	76.8

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