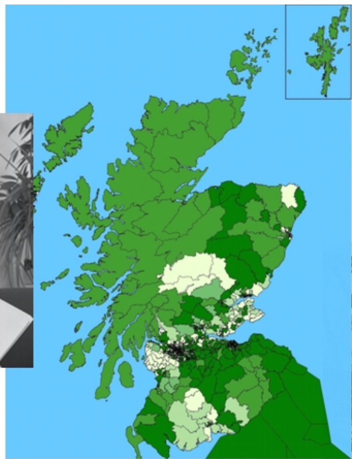
Land-Use and Transport Integration in Scotland

Non-Technical Guide to LATIS Modelling Suite

In Association With David Simmonds Consultancy

July 2009



Transport Model for Scotland

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1 Background and Context

1.1 Transport in Our Lives

Transport is something we use almost every day of our lives. We may travel to work on the train, take the bus to the shops, drive to a meeting or travel on board a plane or ship when going on holiday. Despite this, transport is something we think little about and tend to take for granted. It is also an unusual service, in that few people derive any ‘satisfaction’ from purchasing it.

Why is this? If we actually really thought about transport, we would realise that even though we take it for granted, its planning, management and implementation are extremely complex. The key issue is that transport as a good / service is generally a means to an end, as opposed to something people value in its own right. This gives government one clear objective: to minimise the monetary and social (particularly with regards to the environment) cost of travelling, thus boosting economic performance and social integration.

1.2 Is There a Need for a National Land-Use / Transport Model?

How busy will Scotland’s roads, trains and buses be in ten or twenty years time? Where and when should Transport Scotland and others build new roads or widen existing ones? How many people are likely to use a new or improved public transport service? What will the impacts of major developments be on the strategic transport network? How will the environmental impacts of Scottish traffic change over time? How will increasing fuel prices affect future travel patterns? Land-Use and Transport Integration in Scotland (LATIS) modelling suite is a tool that can assist in answering all of these questions.

There are many factors that affect how, where and when people travel. These include:

- the overall demographic and household structure of Scotland’s population and its visitors;
- the locations of houses, jobs and services;
- the level of car ownership;
- the extent and quality of the road network;
- the availability and attractiveness of public transport; and
- the location and scale of traffic congestion.

In addition, the number and travel patterns of the goods vehicles on our roads (ranging from the typical plumber’s van up to the largest articulated lorry) will change over time, in response to a wide range of influences on the economy, distribution costs and traffic congestion.

Transport Scotland, the Scottish Government and others need to predict the challenges which will be posed by these changing travel patterns, to help ensure that appropriate mitigation measures are in place when they are needed. They also need appropriate design and appraisal tools which will enable them to forecast the benefits and disbenefits of different schemes, policies and plans and their interactions.

LATIS modelling suite, containing the Transport Model for Scotland (TMfS) and the Transport, Economic and Land-Use Model of Scotland (TELMoS), is designed to provide these answers; by forecasting how the current observed pattern of travel in Scotland will evolve over time under the influence of the various factors (demographics, land-use, cost and availability of competing travel modes etc) which affect this travel demand. Its outputs also provide predictions of the corresponding impacts of these changing travel patterns on the economy, congestion, road accident casualties, public transport crowding, traffic emissions and so forth.

1.3 Overview

1.3.1 Aims and Objectives of the LATIS Transport Model

This section provides an overview of the objectives of the LATIS transport model, the Transport Model for Scotland (TMfS). Each version of the model has been developed with specific (additional) objectives in mind and the current version of the model, TMfS:07, is an amalgam of each of these earlier versions. This chapter provides a step-by-step commentary on this development, highlighting how it has shaped the current model and led to its inherent strengths and weaknesses.

Model Functionality

The current version of the model, TMfS:07:

- covers the whole population of Scotland;
- details the choices made by people on how, where, why and when they travel;
- has an interactive land-use model, which details the land-use transport interaction. This is known as the Transport, Economic and Land-Use Model of Scotland (TELMoS);
- is a large database of information;
- is a forecasting tool for scheme and policy appraisal;
- is a framework for extracting local areas (sub-areas) for more detailed analysis;
- is capable of including road tolling / pricing; and
- has a wide range of model outputs e.g.:
  - operational (e.g. analysing congestion or traffic patterns on specific parts of the road network);
  - economic (i.e. assessing the value of transport infrastructure and provision to society); and
  - emissions (i.e. providing current and forecast traffic emissions levels that can be used in environmental assessments).

TMfS:07 is focused on high-level, strategic movements between key towns and cities and along key ‘corridors’. As a result, TMfS does not currently include the following functionality:

- local movements within a ‘zone’;
- air travel;

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- motorbikes; and
- walking and cycling.

Before undertaking a more in-depth analysis of TMfS functionality, it is necessary to trace the development of the model from its inception to the present, to aid the user's understanding of its current form.

1.4 Model History

This section provides an overview of the development path of TMfS, from its incarnation as the Central Scotland Transport Model, through to its current version, TMfS:07.

1.4.1 Central Scotland Transport Model (CSTM)

The original incarnation of TMfS was the Central Scotland Transport Model (CTSM) and was designed as part of the Central Scotland Transport Corridor Studies (CSTCS) project. As the name suggests, the coverage of this model (shown in white in the figure below) was principally focused on the Central Belt of Scotland.

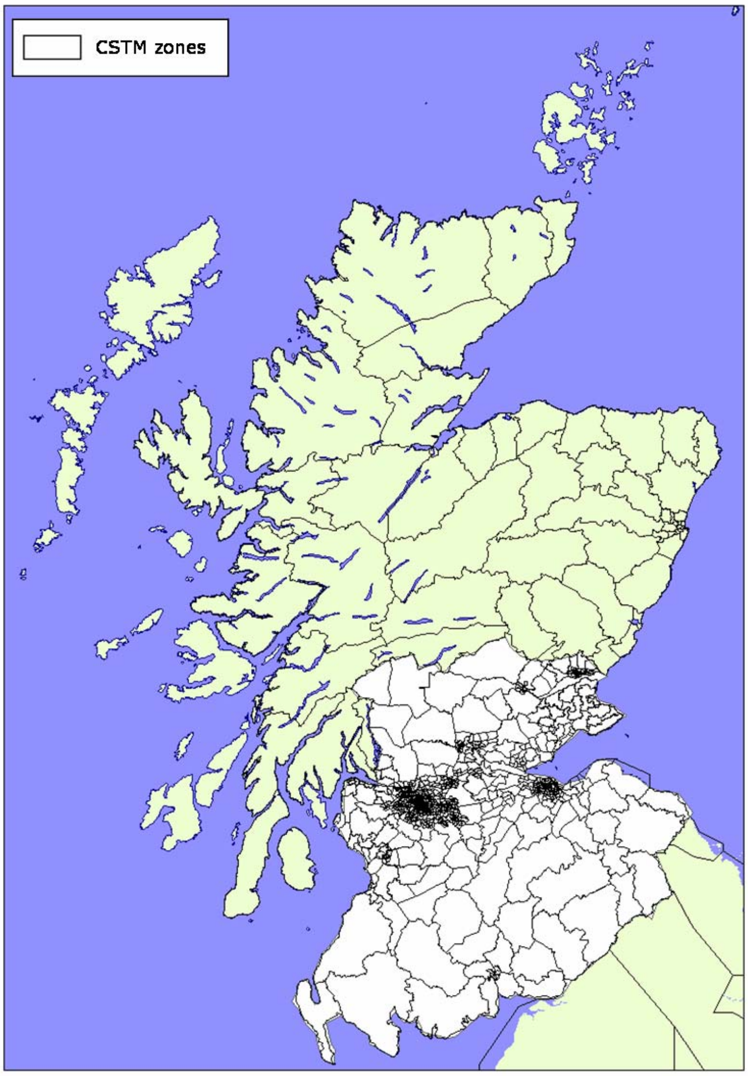

Figure 1.1 Central Scotland Transport Model Geographic Coverage (the black outlined sectors represent the models zone boundaries)

CSTM provided geographical coverage from the Scottish-English border to Dundee and South Perthshire. Angus, Aberdeenshire, Aberdeen City, Moray, Argyll & Bute, the Highlands, the Western Isles and the Orkney and Shetland Islands were not included in the CSTM model.

CSTM was highly detailed in Central Scotland, but considerably less so in areas outwith the Central Belt. The zone map in the figure illustrates large clusters of zones in and around Glasgow and Edinburgh and in other urban areas such as Falkirk, Stirling, Dundee, Dumfries, Kilmarnock and Perth.

However, the zones in some of the rural areas (notably Dumfries and Galloway, the Scottish Borders and Stirlingshire) were very large, indicating a lack of network and zone detail in these areas. A number of versions of CSTM were created, the final version being CSTM3A.

1.4.2 TMfS:02 and TMfS:05

MVA Consultancy and David Simmonds Consultancy were commissioned by the then Scottish Executive in 2001 to create TMfS as an extension of the CSTM series.

The initial version of TMfS (TMfS:02) had, as its name suggests, a 2002 base-year. One of the key aspects of this new commission was the extension of the model to Aberdeen and the North East. Aberdeen, in particular, benefited from a detailed zoning system and had a relatively good representation of the strategic road network. There was also a separate sub-area model of Aberdeen and Aberdeenshire (the Aberdeen Sub-Area Model - ASAM) created, using TMfS:02 as its parent model.

TMfS:02 had significant enhancements in data sources – new Roadside Interviews (RSIs) and journey time surveys were undertaken, additional network detail was added and new data sources were included in order to improve the calibration of the model. The zoning system was also adjusted so as to correspond with the zone boundaries of the 2001 Census output areas, thereby facilitating the incorporation of data from the 2001 Census and subsequent General Register Office of Scotland (GRoS) population estimates.

TMfS was expanded to include the remainder of Perthshire, Angus, parts of Moray and, as noted above, Aberdeenshire and Aberdeen City. However, as shown in the figure below, Argyll & Bute, the Highlands, most of Moray, the Western Isles and the Orkney and Shetland Islands remained external to the model.

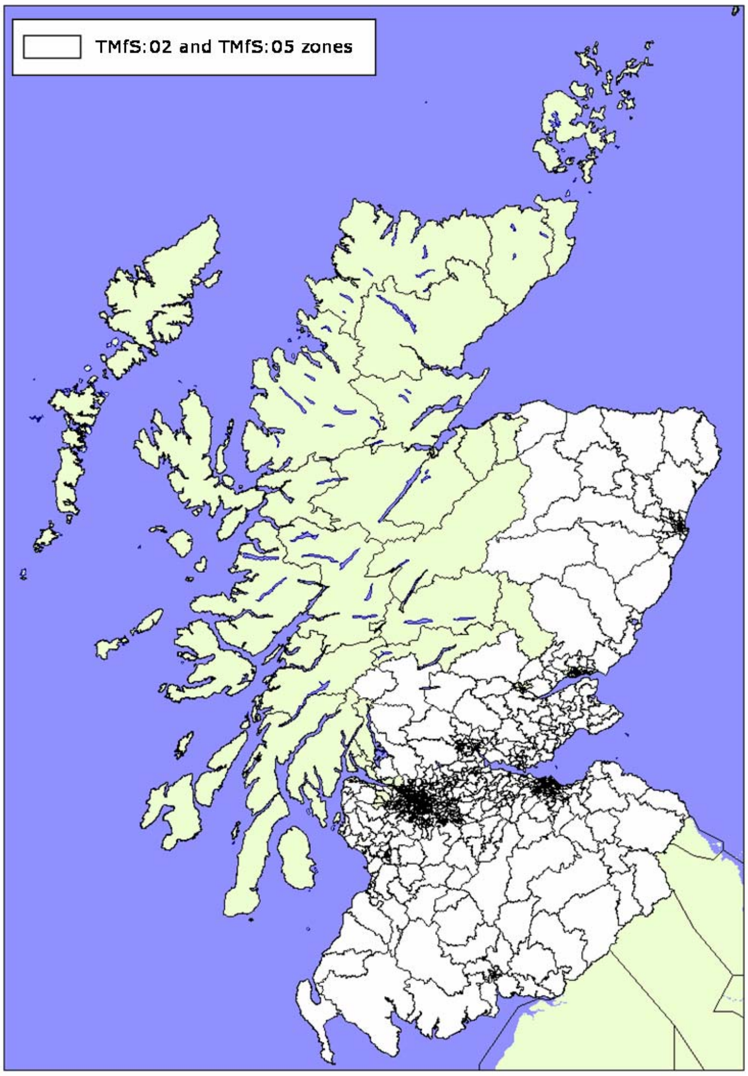

Figure 1.2 Transport Model for Scotland 2002 and 2005 Coverage

The primary zonal detail enhancement undertaken during the TMfS:02 commission was the inclusion of a detailed representation of Aberdeen City. This meant that TMfS now covered all of Scotland's cities except Inverness. However, the new zones added in areas such as Aberdeenshire were still relatively large. As a result, TMfS:02 does not capture a number of internal trips within this area.

Apart from the continued omission of the Highlands, Moray, Argyll and the islands, the most significant omission from TMfS:02 was local bus data for Dundee and Aberdeen.

TMfS:02 underwent a subsequent round of enhancements in late 2005 and 2006. The core objective of this programme was to re-base TMfS:02 to a 2005 base-year (TMfS:05). As part of this process, additional network detail was added in a number of core areas, such as the M77 extension between Malletsheugh and Fenwick and the Glasgow Southern Orbital road. In addition, a large number of inter-urban public transport services were updated to their new 2005 timetables and routes, additional traffic count data was incorporated and new journey time surveys were undertaken. Approved Local Authority planning data was also collected and fed into the LATIS Land-Use model, the Transport, Land-Use and Economic Model of Scotland (TELMoS). TELMoS is used to provide TMfS with a picture of how the land is currently used and how this may change in the light of new transport policies or investment, or conversely, it can assess the impact of 'doing nothing'. The TELMoS projections were then rationalised to reflect the national forecasts produced by the General Register Office for Scotland (GROS). That is, Local Authority estimates of development and demographic trends were reconciled with national forecasts.

1.4.3 TMfS:05a

In late 2006, Transport Scotland commissioned MVA Consultancy and David Simmonds Consultancy to a new three-year 'Term Commission for the Maintenance and Enhancement of the Transport Model for Scotland'. The key aim of this commission was to deliver a new national model, complete with data improvements and a package of enhancements. However, a further aim of the commission was to support the existing use of the model amongst the User Group. Initially, the key application requiring TMfS-based support was the Strategic Transport Projects Review (STPR), which is a review and prioritisation of the required transport schemes and policies in Scotland over the medium to long-term. A key premise of the STPR was that it was expected to cover the whole of Scotland. As such, in order to support the modelling needs of the STPR, and the TMfS User Group generally, TMfS:05 was extended to cover the whole of Scotland, the updated version being named TMfS:05a. TMfS:05a was the standard release version until the 2007-based enhanced modelling suite (TMfS:07) was completed in January 2009.

TMfS:05a provided a number of improvements over the incumbent TMfS:05, including:

- an improved representation of the transport network in the Highlands;
- a representation of ferry services;
- new Roadside Interview data for Ayrshire and Tayside; and
- a new accessibility analysis procedure.

1.4.4 TMfS:07

During 2008 a new, more strategic, version of the national model, TMfS:07, was developed. TMfS:07 represents a step change in the quality of the model with a number of technical enhancements and a considerable quantity of additional data. TMfS:07 and TELMoS:07 will form the standard release version of the model for the foreseeable future. The enhanced functionality of the model and updated dataset will allow for more detailed and robust analysis.

A key feature of TMfS:07 is the new hierarchical approach adopted in model development, with a high-level national model and more detailed regional Sub-models. Over time, TMfS:07 will be supplemented by regional models, the first of which is the new Forth Replacement Crossing Model. In line with TMfS:07 being more strategic than its predecessor, TMfS:05a, a number of changes in model form have been made, including:

- inclusion of the Highlands and Islands into the main demand model;
- a reduction in the number of zones;
- a more consistent zoning system with equal importance given to both rural and urban areas with the zone system based on Census data zones ; and

- where possible all rail stations were in a zone on their own.

This new approach provides a more proportionate distribution of zones between urban and rural areas and allows for quicker run times. The new zone system for TMfS:07 can be found in **Figure 1.3**.

Further enhancements to TMfS:07 include a georectified road and public transport network, High Occupancy Vehicle (HOV) modelling, Park and Ride as a separate mode in the demand model, and enhancements to TELMoS. The revised model has also benefited from the inclusion of a significant volume of new data including:

- 2007-based approved Local Authority planning data;
- ITN distance data;
- 2005-2007 SRTDb count data;
- the National Rail Travel Survey;
- Census Travel-to-Work data;
- inter-urban bus passenger origin-destination data;
- bus-based Park and Ride passenger origin-destination data; and
- additional RSIs, including on port-access roads.

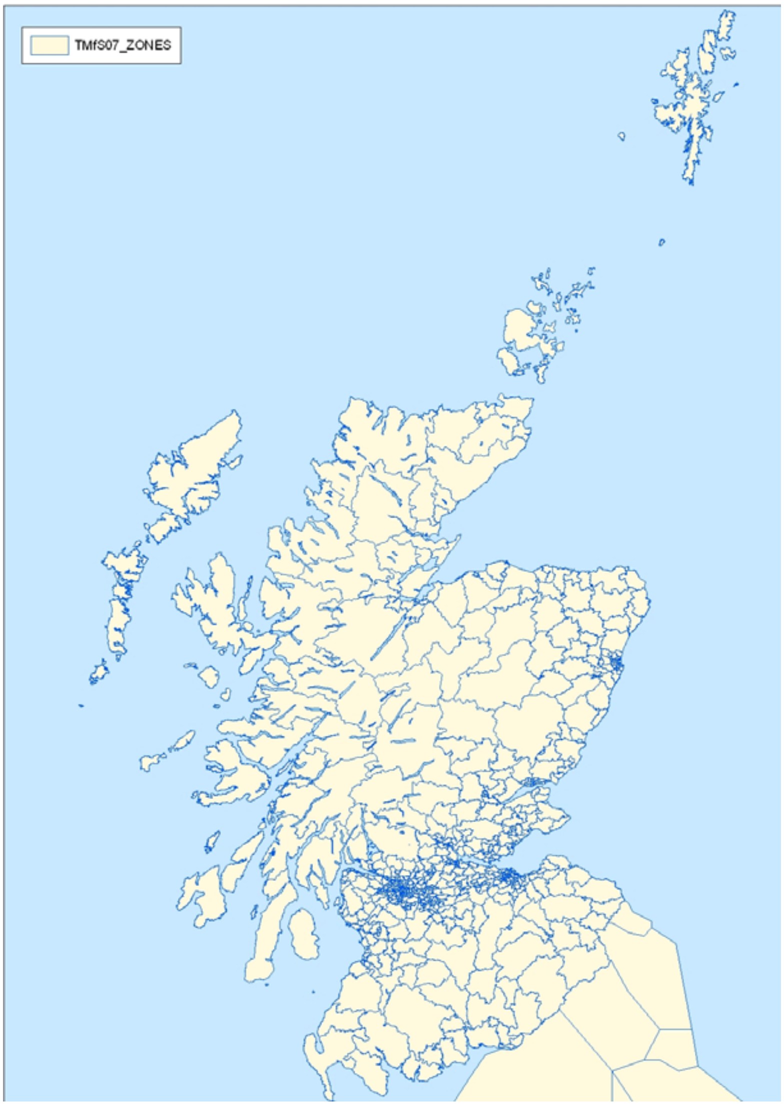

Figure 1.3 Transport Model for Scotland 2007 Coverage

2 The Principles of Transport Modelling

2.1 Overview

This section provides a brief introduction to the general principles of transport modelling, starting from simple concepts such as 'zones', 'matrices' and 'networks', building up to provide the reader with a basic understanding of how transport models such as TMfS work.

2.2 What Do Transport Models Do?

Transport models are a simplified representation of the movement of goods and people, designed to provide a quantitative and analytical framework that helps us to understand how the transport system works under current and future patterns of travel demand.

Transport modellers start by attempting to create as accurate a picture of the current functioning of the transport system as possible and then use the resulting model to predict how the system will operate under different scenarios. For example, how will the transport system operate if transport 'supply' is increased as a result of infrastructure investment or transport 'demand' falls as a result of a marked rise in the price of fuel.

Often different transport models are used to answer questions at different levels – for example:

- '*Where are the current and future traffic bottlenecks on a trunk road corridor*?' may require a strategic model covering numerous modes of transport;
- '*How much time saving benefit would a bypass generate*?', needs a traffic model which can predict congestion and rerouting effects; while
- '*What should the junction layouts on the bypass be*?' will require a model that has a detailed junction modelling capability.

2.3 Type of Transport Models

Transport models come in a variety of scales:

- **National** – models like the Transport Model for Scotland, which can be used for national policy testing using nationally consistent land-use assumptions;
- **Regional** – models that cover a relatively large area, such as a Regional Transport Partnership or City Region and requiring mode and route choice – may also require modelling of car parking – Strathclyde Partnership for Transport's (SPT) Strathclyde Integrated Transport Model (SITM) being an example;
- **Local Urban** – models that are largely local in nature, but still require a route choice capability (and possibly mode-choice) – may also include non-motorised modes;
- **Corridor Model** – typically a trunk road corridor – limited need for route choice, detailed modelling of junctions and (perhaps) overtaking behaviour; and
- **Local Junction Model** – no route or mode choice, detailed assessment of junction capacity and vehicle interaction.

2.4 Key Modelling Concepts

2.4.1 Zones

The area the model covers is divided into different zones which represent all of the different geographical areas which are generating the demand for travel (either as the starting or end point of the trips being modelled). Every zone in the model has individual characteristics that are determined by its planning data. The planning data for each zone are provided by the LATIS Land-Use model, the Transport, Economic and Land-use Model of Scotland (TELMoS), which contains approved Local Authority planning data. The key planning variables are the level of population, number of people employed within that zone and the number of households it contains, as well as their characteristics (household composition, car ownership etc). There are also a number of commercial planning variables, which consist of retail floorspace, office floorspace and industrial floorspace. All of these variables determine the demand for travel to and from each zone eg, if a zone contained a large number of office blocks then the demand for travel to that zone is likely to be high in the morning as people travel to work. Conversely, for a highly residential area, the demand for travel to the zone is likely to be high in the evening as people return from work.

The zone structure in a model will usually reflect the level of travel demand (eg small compact zones in urban areas which generate high levels of travel and larger zones in rural areas which may generate less demand for travel). Large or unusual generators of travel demand (such as airports, ports and the main roads entering the modelled area) will often be given their own zone, to allow their pattern of travel to be identified and modelled separately.

Defining the boundaries of zones is a task that requires careful consideration. In general, zone boundaries should take account of:

- natural barriers – eg rivers, railways, coast etc;
- administrative boundaries, such as Local Authority boundaries;
- distinctive land-uses (industrial estates, rural/urban boundaries etc);
- rail stations;
- census output areas; and
- available data sets.

Where possible, the zone boundaries should also take account of other boundary systems used by planners and other users of the model (Census output areas, datazones etc), provided this does not conflict with the need to model the travel behaviour robustly.

The combination of zones defines the zone system.

2.4.2 The Transport Network

The road network in a transport model consists of a representation of the relevant components of the road and junction network. This representation must be able to predict vehicle speeds under different traffic conditions, including the delays caused at key junctions. It is also necessary to represent the connectivity of the road network, so that the model can identify the relevant routes between each origin and destination on the network.

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A road network consists of a series of links and nodes. Links represent roads (or in some cases sets of roads) and a set of parameters which enable the model to predict how the speed of various types of vehicle travelling along the link will decrease as the volume of traffic increases or vice versa. These input parameters typically include a combination of the speed-limit, the number and width of lanes and other geometric parameters, such as the road gradient.

Nodes represent the connections between the links and often represent the various types of junctions (priority T-junctions, signalised junctions, roundabouts, motorway merges etc), where additional delays are incurred due to the interaction of traffic moving from one link to another.

A public transport network is often closely based on the road network, with additional links to represent railway lines, bus-only roads etc and the walking routes to and between bus stops and rail stations.

The public transport model will include, in a model which considers the pedestrian portion of trips, a representation of the relevant public transport services (including timetables, fares and journey times) and details of the interchanges between them, to enable the model to predict the time and cost of different public transport routes through the network.

Zone Centroids and Zone Connectors

A special node called the zone centroid is designated to each zone to represent the centre of the trips generated within it. These zone centroids are connected to the adjacent road and public transport networks by one or more zone centroid connectors which enable the demand associated with the zone to join the relevant road or public transport network at these various locations. These single zone centroids are a representation of all of the minor residential streets and rural roads which connect the houses/schools/offices/factories in a given zone to the modelled road or public transport network.

2.4.3 Model Hours

In general, different versions of the transport network are developed to represent traffic conditions and/or public transport services at different times throughout the day/week/year.

Weekday peak conditions (AM and/or PM) are the most commonly modelled, though weekday inter-peak conditions and/or weekend conditions and/or seasonal variations can also be included in the more sophisticated transport models.

Each modelled time period will display different trip and network characteristics. For example, the AM weekday peak is usually dominated by commuting and school travel, the inter-peak contains more shopping, leisure and ‘in-work’ trips, while the PM peak is often dominated by a range of return-home trips.

2.4.4 Trip Matrices

A matrix in a transport model is a table showing trips between every origin and destination zone within that model.

In a transport model, one or more matrices are used to represent the travel demand between each pair of zones in the model in the relevant modelled time period.

Building a Base Year trip matrix requires a significant amount of data collection which is used to inform modellers of base year (the year which the model data is based on) trips and their patterns. The remainder of this section details how these data are used for model development.

In order to build a base year Road Matrix, a number of different methods can be employed. Often as a starting point, Roadside Interview Surveys (RSIs) are conducted to interview a sample of drivers on roads, in order to determine their origin, destination and journey purpose. Traffic counts that are generally conducted at the same time as the interviews are used to scale up the interview data, to represent all traffic on the road. Other methods employed are to use Census data to understand the movement of people by postcode area, which can then be applied at the zonal level. Alternatively, as start point, a method by which each individual zone is considered based on its lane use and attractiveness, can be used to produce the number of likely trips that may start or finish in the zone, often called a ‘Gravity’ approach.

The public transport base year demand matrix is estimated using a corresponding combination of passenger interview surveys, bus and rail occupancy surveys, boarding and alighting counts and ticket data, to ascertain as much information about peoples’ origins and destinations as possible.

Data regarding origins and destinations of the vehicle and passenger trips obtained from these interviews are then aggregated into the relevant model zones for each matrix (road and public transport matrices) and for each modelled time period.

Gaps in the matrices (eg movements not covered by the roadside interview sites if this method has been employed) are then synthesised. This is where the total number of trips from each origin zone are allocated to destinations using a function which reflects the relative overall ‘attractiveness’ of the destinations and their distance from the specific origin zone. That is, the model allocates trips based on why people would want to go to a zone and how far away that zone is. The less attractive and the further away the zone is, the less likely a person will travel to it (and vice versa).

Many strategic transport models exclude inter-zonal movements (ie those starting and finishing in the same zone), since these trips are deemed to use only local roads, with no impact on the main transport networks being modelled. This assumption becomes more important as the size of zones increases, since the number of ‘missing’ intra-zonal trips in the model grows with the increasing zone size.

2.5 Calibration and Validation of the Model

Having developed a set of road and public transport base-year matrices, trips in these matrices are assigned (loaded onto the ‘empty’ networks) to the applicable model network by using various techniques (described in more detail later in this section). This process is referred to as model calibration.

The resulting travel demand on the network is then checked against a set of independent data, in a process known as model validation.

The calibration and validation of transport models is designed to ensure that the model provides as accurate a representation of the Base Year reality as possible. Calibration and validation for the road model is largely undertaken using a combination of RSIs, traffic counts, journey time surveys and Census travel-to-work data. Ticket sales data, public transport survey data, count data and bus journey time analysis are used to calibrate and validate the public transport model.

For road models this normally consists of checking how well the modelled flow matches observed traffic counts on a set of specific links and a comparison of various journey times through the modelled network against a corresponding set of observed journey times.

Public transport models are usually validated by comparing observed and modelled passenger volumes getting on and off at various key points on the public transport network.

As well as comparing absolute and percentage differences between observed and modelled travel demand, transport modellers frequently use a measure known as a GEH score to estimate the 'goodness-of-fit' between modelled and observed traffic and passenger flows. The GEH statistic is designed to overcome the limitations of validation measures, based on either absolute or percentage differences (which tend to underestimate/overestimate respectively the significance of differences on low flow links).

Areas of the model which fail to validate satisfactorily (ie there is a poor match between the modelled and observed data) are examined to understand the reason for the discrepancy between modelled and observed and the model is adjusted accordingly if possible. This process involves a large number of adjustments to the model to ensure a good match.

The calibration and validation processes are normally the final stages in the creation of the 'base year model'.

2.6 The Demand for Future Travel

Models are developed to give an indication of how demand for travel will change in the future, taking account of changes in future land-use, demographics and the transport network. The changes to the existing travel pattern can be estimated by considering four factors associated with predicting travel demand:

- trip generation;
- trip distribution;
- mode choice; and
- network assignment.

These aspects of travel demand modelling are discussed briefly below.

2.6.1 Trip Generation

In a base-year matrix, each zone represents an aggregation of all journeys from a certain geographical area. The process for forecasting how many trips in total would originate from and terminate in each zone in the future is known as trip generation.

The number of trips 'generated' by each zone is determined by the level of 'activity' taking place within that zone. Depending on the journey purpose, the factors which will determine the amount of trip-making to/from a given zone will include:

- the population and/or number of households (by car ownership);
- the number of jobs located in the zone;
- the amount of commercial floorspace – shopping, office, industrial etc in the zone; and
- the number and size of educational establishments in the zone.

The level of these activities is therefore largely determined by the planning data for each zone; changes in these planning data will result in corresponding changes to the numbers of trips leaving and entering these zones in the future year.

The starting point for demand models is usually to predict the total number of trips to and from each zone (known as trip ends – ie the start of a trip or end of a trip), usually for a typical 24-hour weekday period. Once these predicted changes have been made, they then need to be applied to the base-year matrices. This is done so that the resulting future-year demand matrix correctly reflects predicted changes.

2.6.2 Trip Distribution

Having changed base-year trip ends to future year trip ends, the future year trip ends have to be input into the distribution model, in order to create the future year trip matrices. Using a set of algorithms and parameters, transport models will distribute the trips generated by each zone to a set of destination zones. The demand model effectively distributes the set of trips from a given origin zone across all of the possible destinations, taking account of the likelihood of each particular origin-destination journey.

The combination of trip generation and trip distribution produces a future year total trip demand matrix.

2.6.3 Generalised cost and Generalised Time

A key element in the way in which trips are distributed is the cost of travel. It is important to note from the outset that cost, in terms of transport models, does not only refer to monetary expense, but also to the cost of travel time and the disutility of travel (ie negative travel factors such as waiting for a bus or sitting in traffic) in general.

Note also that not all time is perceived as being equal - for example, time waiting for public transport is generally perceived as being worse than a corresponding number of minutes spent on board the bus or train.

The overall cost of the journey can either be expressed as generalised cost (by assigning a monetary value to journey times) or as generalised time (by converting money costs to a corresponding number of minutes). Both of these approaches require an estimation of the traveller's value of time (usually expressed as either £/hr or pence/minute) of the traveller making the relevant choice(s). This value of time will vary between different groups of travellers. Groups with a high value of time will be willing to pay more money for faster journeys (eg paying tolls to avoid congestion), while those with a low value of time will be more sensitive to increases in money costs such as fares or parking charges.

Knowing the value of time for a given group of travellers enables us to estimate the generalised cost or generalised time for a journey and hence determine the 'attractiveness' of a particular journey.

The components of generalised time for vehicle trips will be:

- **monetary** – vehicle operating costs (fuel, wear and tear etc), parking charges, tolls etc converted to a corresponding amount of generalised time; and
- **travel time** – the vehicle occupants' travel time from origin to destination.

The elements of generalised time for public transport travel include:

- **access time (**walk time**) –** (perceived) time walking to and from the public transport network;
- wait time **–** (perceived) time waiting at the bus stop or station;
- **fare** – converted to generalised minutes using the value of time;
- Crowding – effects of crowding on board PT services
- **in-vehicle travel time** – possible weighted to reflect the quality of the PT vehicle; and
- transfer penalty – traveller's perception of the inconvenience of any interchange, expressed as generalised minutes.

If P&R is included as a separate mode the costs for this will be a combination of Highway and PT costs

2.6.4 Mode Choice

Mode choice refers to the decision travellers make, relating to which mode of transport they will travel on – ie car, bus, train, ferry etc.

Having created a future year matrix which shows the total demand for travel between zones, the mode split (ie division of journeys between each mode) of these trips is then estimated – that is, the model estimates how many trips will take place on each mode as this will not necessarily be in the same proportions as the Base Year. The share of modelled trips received by each of the main modes is calculated using a mathematical choice model which uses a combination of the generalised costs (or times) of the competing modes and a number of mode-choice parameters. These mode-choice parameters determine the sensitivity of the model to changes in the generalised costs and any behavioural bias between the modes.

The split of trips between the different modes leads to the division of the total travel matrix between the various main modes.

2.6.5 Network Assignment

When a provisional set of the future travel demand matrices for the road and public transport networks have been created, it is then necessary to estimate how these revised demands will change the costs of the competing modes of transport, for example by changing the location and extent of traffic congestion.

This is achieved by a process known as network assignment. There are separate road assignment and public transport assignment procedures.

The processes involved in network assignment are often fairly complex, but essentially consist of a series of iterations in which the model assigns trips to attractive low cost routes through the network for each origin-destination pair. The model then introduces capacity restraints (congestion, crowding on public transport etc), re-estimates the costs of these routes and adjusts the route choice until none of the modelled trips can find a more attractive route. Once the model reaches this equilibrium position, it is deemed to have converged. In uncongested networks (where the costs of particular routes do not change much between iterations), this process will generally converge quickly and only a few iterations will be required. However, in large congested networks, it may take a large number of iterations before this process converges to a state where no new improved routes can be found for any origin-destination journey.

Conventional assignment models generally assume that the travellers' trips have 'perfect information' and are therefore aware of the costs of the various competing routes before they 'begin' their journey ie travellers know about congested parts of the network and can choose to avoid them.

2.7 Scenario Testing

2.7.1 Do Minimum and Reference Case Scenarios

As discussed above, forecasting requires:

- amendments to the base-year road and public transport networks, to reflect new schemes and policies;
- changes in any planning data assumptions; and
- different parameters to reflect changes in policies – eg toll values, car park charges, public transport fares etc.

These changes can be used to change the travel demand and the subsequent network assignments can be used to predict the corresponding changes on the road and public transport networks.

Transport models are generally used to test the impact of future schemes or policies. To do so robustly, it is necessary to first decide how the network will 'look' in the future, so that the scheme or policy can be tested accurately.

This requires the model user to define a scenario which includes all of the network changes which are 'likely' to take place between the base and future year.

This is usually undertaken in two stages – first a 'Do Minimum' scenario is created, which includes all committed schemes/policy changes – ie typically those which have already taken place, plus all those with full funding and approval.

The user then adds to this a set of schemes and policy assumptions which they deem 'likely' to take place and which are therefore needed to create transport networks which are most likely to represent conditions if the scheme(s) being tested goes ahead. This scenario is known as the 'Reference' case. Normally the Reference Case will remain consistent for a particular study (eg appraising different scheme options for a particular corridor), but may well vary between studies.

Note that the term 'Do Nothing' scenario, sometimes used, is taken to mean that the future year networks are identical to the Base Year – while this is convenient, it is rarely realistic as networks are most often constantly evolving.

2.8 Conclusion

The above analysis outlines some of the key principles associated with building and using a model such as TMfS. However, it should be remembered that this is largely a simplified introduction to modelling and greater detail on the actual technical processes undertaken can be found in the other documents referred to in this chapter.

3 TMfS and TELMoS Model Data

3.1 Overview

This chapter discusses the data used in the processes to build, calibrate and validate the current version of the TMfS model, TMfS:07. These data are described under the following three headings:

- planning data;
- trip matrix data; and
- calibration and validation data.

LATIS modelling suite, containing TMfS and TELMoS models, is essentially a large database of travel pattern, traffic count, public transport and Local Authority planning data. This chapter demonstrates what data is collected and how they are used, in line with the description in **Section 2**, the 'Principles of Modelling'. It should be noted that the focus in this section is on the data included within the TMfS:07 base-year model.

3.2 Planning Data

Planning data for the base-year (in this case 2007), are collected from all Scottish Local Authorities and allocated to the relevant zone in the model. These data are supplemented by a variety of other sources that assist in defining the travel patterns of each zone (eg their ability to produce and attract trips).

3.2.1 Local Authority Planning Data

Land-use and transport provision are closely related issues, with each being reactive to the other. New transport schemes or policies may influence Land-use changes in forthcoming years and likewise, Land-use pressures may necessitate investments in transport. As a result, TMfS must account for the impact of current and projected Land-use patterns on transport demand in Scotland.

TMfS understands how Land-use changes impact on transport through its Land-use model, TELMoS. For the use of TELMoS, David Simmonds Consultancy (DSC) collects planning data from each Local Authority concerning population, households, employment, office floorspace and retail floorspace. This provides an understanding of how Land-use looks in the base year – ie it is a picture of where the population currently lives, where households are located and where people work.

These data from TELMoS are assigned to their relevant TMfS zone, providing the base characteristics of each zone. That is, for each zone in the TMfS model, we have an understanding of how many people live there, the number of households, where its residents are employed and the number of jobs located within it. This provides a starting point for estimating how many journeys are generated and attracted by each zone. In short, TELMoS provides us with an understanding of how the land is used, while TMfS interprets the impact of this Land-use on the transport network.

3.2.2 2001 Census Data

The 2001 Census data have been used extensively within the development of the TELMoS Land-use model and are a key source in determining the characteristics of TMfS zones. TMfS zones are made up of collections of Census data zones, which facilitate the use of Census and other demographic data.

The Census is the most comprehensive and complete national survey of current trends and statistics in Scottish (and wider British) society. It provides data on the composition of households and family income. In addition, the Census also provides:

- details of the number of cars owned by each household;
- location (ie Census output areas), of home and normal workplace (or place of education); and
- normal mode of travel-to-work (eg car driver, car passenger, bus, train, cycle, walk etc).

Each of these aspects of the Census assists in supplementing the planning data obtained from Local Authorities. The aim of this process is to provide an accurate representation of where people live, travel to and from and how they do so in the 2007 base-year.

A key model variable obtained from the Census is household car ownership levels. The number of cars available to a household is an important factor in determining the mode of travel.

Another source of information in the Census is the travel-to-work (TTW) data. The TTW data provide information on where people live, where they work and how they generally travel between the two. Combining this with time-of-day profiles of commuter trips from the Scottish Household Survey Travel Diary data, allows us to produce robust representations of Travel-to-Work and Travel-from-Work patterns in any given modelled time period. This is particularly useful for the AM peak hour, given the high proportion of commuter trips in this time period.

Despite the comprehensive nature of Census data, it must be borne in mind that the Census has a number of inherent flaws, the most notable of which is its 'snapshot' nature – ie it captures only data for a specific point in time and thus may provide a false picture in certain areas. For example, the Census may be taken at a time of low unemployment or high seasonal employment, thus showing distorted employment patterns from the norm. In addition, the Census is only taken at 10 year intervals, meaning that Census datasets are starting to become out of date by the time they are published, and become increasingly so until the next Census year is published. (In TMfS:07 however, the Local Authority Planning data were used to convert the 2001 Census data into 2007 data)

Despite these issues, the Census provides the most complete and most reliable picture of national demographic and transport trends and is a critical component in developing the characteristics of the TMfS zones.

3.2.3 Scottish Household Survey

The Scottish Household Survey (SHS) provides further data to substantiate the characteristics of each zone. The SHS is a continuous cross-sectional survey covering approximately 15,000 Scottish households per annum and has been running continuously since 1999.

The householder with the highest income and a (possibly different) randomly selected adult in the household are asked questions covering a broad range of topics including: health, income and attitudes to a range of transport-related choices, including car and cycle ownership, public transport and cycle use, awareness of transport information, travel-to-work mode and so forth. In addition, the 'random adult' completes a 'Travel Diary', covering all 'significant' journeys made on the day immediately prior to the interview.

These data provide an important indication of how a sample of householders from zones within the TMfS model will travel, given the options open to them and allow us to more fully understand the profiles of trip-making by Scottish residents.

As the volume of time series data grows, this data source is also becoming increasingly powerful for identifying trends and other statistical patterns.

SHS data have been used within TMfS for a wide range of calibration and/or validation purposes (as described below). It is anticipated that the role of this dataset will continue to expand as the SHS and Travel Diary database increases.

3.3 Trip Matrices Data

As mentioned when discussing the principles of modelling, various datasets are used to assist in building base-year and estimating future total travel patterns in TMfS.

The matrix is essentially the product of matching every trip generated by a zone to the zones that receive those trips. However, in order for TMfS to establish where the trips generated are distributed to, the model must draw upon a combination of observed data sources, including:

- census travel-to-work data;
- Scottish Household Survey data;
- planning data from TELMoS;
- trip rates from TEMPRO;
- roadside interview data;
- public transport survey data;
- National Rail Travel Survey data (NRTS); and
- Park and Ride Site Survey data.

The first three data sources were discussed in Section 2, the remainder are outlined below.

3.3.1 Roadside Interview Data (RSIs)

RSI data allow modellers to understand where people are travelling from and to and why they are doing so. That is, they allow us to insert real travel patterns into the model, thus allowing it to better match the zones people are travelling from and where they are travelling to.

RSIs are the key data sources for providing travel patterns by journey purpose for the small subset of trips which pass the RSI sites. These patterns also provide additional information about the relative attractiveness of nearby zones, which can then be used to adjust other local trips which do not pass through any of the RSI sites.

RSIs involve interviewing a sample of motorists on a given road and asking them about their origin postcode, destination postcode and the purpose of their journey. Such surveys are generally conducted on 'average' weekdays in 'neutral' months. That is, model developers will attempt to select dates where traffic patterns represent the average, avoiding 'High Days and Holidays'.

Such surveys are normally undertaken between Tuesday and Thursday and in months such as May, March and September to November, although this can vary. Drivers are either be interviewed at the RSI site or given a freepost postcard survey form to complete and return.

The collected data are then checked and 'cleaned' to remove any 'unlikely' travel patterns and a factoring process is used to scale-up the results to match the corresponding full traffic count at the RSI site.

Figure 3.1 illustrates the RSI sites included in TMfS:07. The RSI sites are much more evenly spread across Scotland than for TMfS:05a, where sites were clustered around the central belt and Aberdeen.

The majority of RSI's were carried out in 2007, though some date back to 2005. Roadside Interview Data from 2005 and 2006 were 'uplifted' to the 2007 base year using year-on-year traffic kilometre growth for the relevant Local Authority.

It should be noted that RSIs cannot be undertaken on motorways, so alternative techniques are needed to determine the origin-destination and journey purpose pattern of motorway traffic (for example undertaking the surveys on all of the key entry and exit links).

Figure 3.1 TMfS:07 RSI Sites

3.3.2 Public Transport Passenger Interview Surveys

Public transport passenger interview surveys perform the equivalent public transport model function as RSIs do for traffic models, namely attempting to measure the origin-destination pattern, journey purpose and time-of-day profile of trips using the surveyed public transport route(s).

Passenger interview surveys are conducted by the interviewer (face-to-face or via reply-paid postcards), either surveying people at bus stops/train stations, or on board public transport vehicles. The survey is usually conducted on an 'average' weekday in a 'neutral' month.

It is often difficult to get adequate sample sizes from passenger interview surveys, particularly on infrequent routes with low patronage. However, other difficulties including on-board crowding and passengers' lack of willingness to take part make these surveys difficult to conduct cost effectively.

Traditionally, there has been a general lack of bus-based origin-destination data for TMfS and indeed for other transport models. As a result, the collection of such data for Aberdeen, Dundee, Edinburgh, Glasgow and Inverness was seen as important in improving the public transport element of the new national model. Given that these were inter-urban surveys, the data also provided valuable data for a range of other important towns including Stirling, Falkirk, Dunfermline, Livingston, Ayr, Kilmarnock and Cumbernauld.

An initial desk based review of timetables and routes was undertaken to identify where data collection was required and a cordon was defined around each city designed to capture all bus-based movements into and out of the urban area. Passenger interviews and accompanying occupancy survey were conducted between 7am and 7pm on a typical weekday. The collected origin-destination data was processed and demand matrices prepared suitable for incorporation in the national model.

3.3.3 National Rail Travel Survey Data

The National Rail Travel Survey (NRTS) is a survey of passenger trips on the National Rail system. It was designed to fill a gap in knowledge about who uses the rail network, where, when and for what purposes.

All stations in Great Britain were surveyed on weekdays during school term-times during the period 2000-2005. Data was collected from passengers by self-completion questionnaire, and passenger counts are carried out at the same time to give details of the volume of people using each station. This enabled the survey responses to be weighted up to represent all rail passengers. About 430,000 questionnaires were collected in total. The return rate of questionnaires was typically 20% to 30% of questionnaires distributed to passengers.

The data collected was subject to extensive cleaning and analysis to allow for double counting the balancing of flows between stations. The final files of processed survey records were made available to Transport Scotland for use in the development of TMfS:07.

The following information is available:

- Rail stations used;
- Time of travel;
- Access and egress modes;
- Origin and destination addresses;
- Trip purposes;
- Ticketing information; and
- Demographic information plus car availability.

The NRTS origin-destination data was processed and demand matrices prepared suitable for incorporation in the national model.

3.3.4 'Donor Models'

While TMfS is a particular type of model, the data underlying it could potentially be used in the development of other models - the Forth Regional Model (FRM) for example. Conversely, TMfS has in the past obtained data for matrix development from other models (donor models). .

The two principal models from which TMfS has drawn on are its predecessor, CSTM, and the Strathclyde Integrated Transport Model (SITM). The data used in the development of CSTM formed the basis of TMfS:02 but SITM has since 'donated' various RSI and public transport survey data.

The main benefit of such an approach is that TMfS can draw upon data from more detailed local models developed for specific purposes and specific local areas, thus providing a greater breadth of information for the process of estimating the pattern of travel. It also helps to ensure consistency between 'competing' models of the same area.

However, the strong data sources used to build TMfS:07 (eg Census Travel to Work and the National Rail Travel Survey) meant that no donor models had to be used to build the TMfS:07 matrices.

3.4 Calibration and Validation Data

Calibration and validation of TMfS is essential in ensuring that the model provides as accurate a representation of reality as possible. As outlined in **Chapter 3**, calibration and validation is largely undertaken using a combination of:

- **Road Model:**
  - RSIs;
  - traffic counts;
  - journey time surveys; and
  - Census travel-to-work.
- **Public Transport Model:**
  - NRTS data;
  - public transport survey and count data; and
  - bus journey time analysis.

The modelled representation of traffic and public transport patronage is calibrated to represent their corresponding values in reality and checked against a set of other independent data (validation).

3.4.1 RSIs

As mentioned above, RSIs provide an indication of where people passing through a certain point begin and end their journey and why they are making that journey.

When TMfS is assigned, the travel patterns in the model are checked against the corresponding RSI data to make sure that they reasonably reflect the observed RSI patterns.

3.4.2 Traffic Count Data

In order to understand how well the model reproduces observed traffic levels, the traffic flows generated by the model following assignment are compared to various real traffic counts conducted around the network. A set of traffic counts, generally in the areas where the model is more detailed, is used in calibrating TMfS – ie 'fine tuning' areas of the model to make it is as realistic as possible. Having completed the calibration process, the remainder of the counts are used to validate (check) that TMfS is behaving as expected.

408 traffic count sites were incorporated into TMfS:07 as part of the calibration process. The counts used in the validation process are illustrated in **Figure 3.2**.

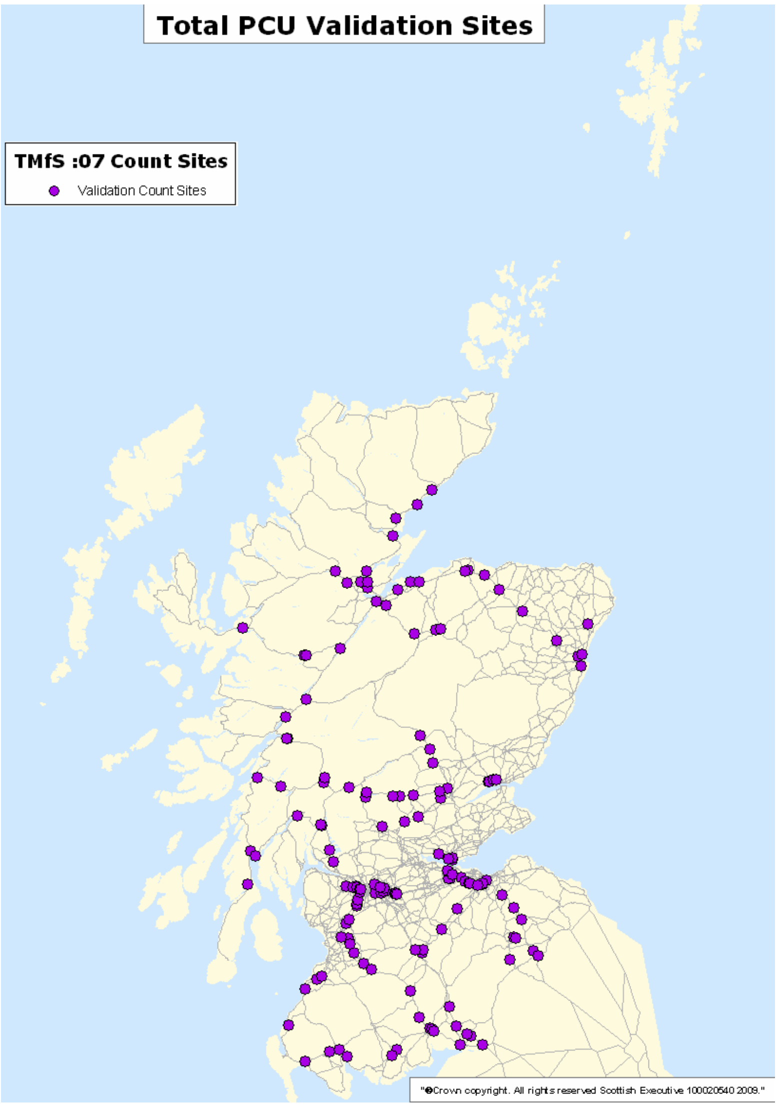

Figure 3.2 TMfS:07 Validation Count Site Locations

The traffic counts used in calibration are all included within the area covered by TMfS and cover all of the key roads within Scotland. The majority of counts were also undertaken in 2007 and came from the Scottish Road Traffic Database (SRTDb), which contains traffic counts from across the Scottish trunk road network.

While the quality of calibration for every count (known as single point) is checked, counts are amalgamated into 'screenlines'. A screenline is a line drawn across a number of routes entering one area, thus providing a more complete view of total traffic entering that area. An example of a screenline is shown in **Figure 3.3**:

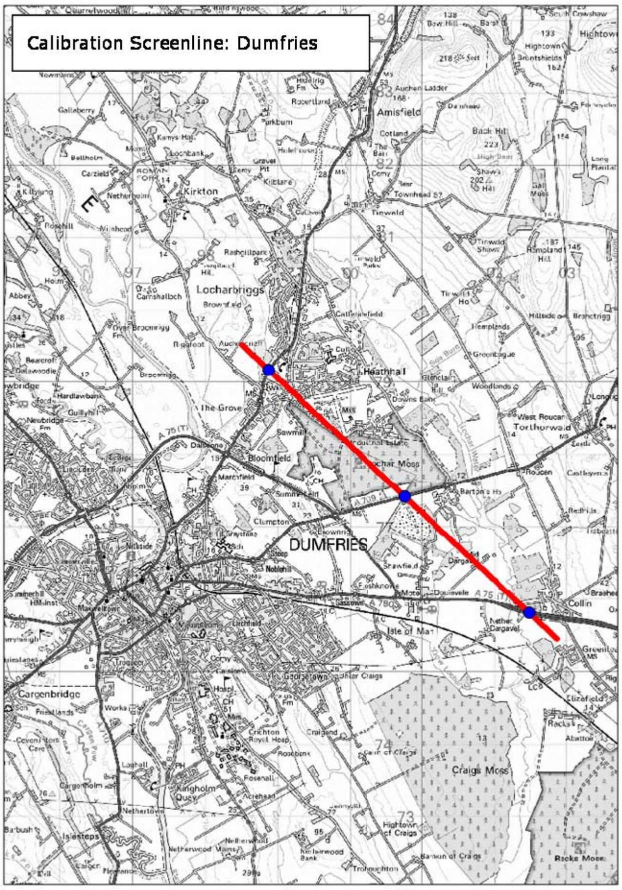

Figure 3.3 Calibration Screenline: Dumfries

Figure 3.3 shows a calibration screenline (the red line) covering Dumfries' three routes to the M74 – the A701, A709 and A75. Each blue dot represents a traffic count used in a fictional calibration of TMfS. Without the use of the screenline, it cannot be known how well the model represents actual traffic on each road. However, the screenline allows modellers to analyse combined travel patterns from the M74 to Dumfries (and vice versa), to check whether the total traffic is modelled correctly and whether there is too much traffic on say, the A701, at the expense of the A709. Modellers can then attempt to remedy any issues that remain with the calibration of traffic on these roads.

Particular attention is paid to the accurate calibration of critical sections of the road network, where the model must be relatively accurate to be of any value to the user. This process is referred to as 'Key Link Analysis' and is particularly important with regards to major bridges. For example, it is essential that traffic on the Forth Road Bridge in Edinburgh and the Kingston Bridge in Glasgow are calibrated well, otherwise the model will not accurately represent traffic into these cities. This is an issue on many links, such as in Aberdeen, where there are two bridges crossing the River Don (Persley Bridge and Bridge of Don) and it is important to represent traffic on these crossings as accurately as possible.

As is mentioned in Chapter 3, the quality of the calibration (i.e. how well the traffic flow from TMfS matches the real traffic levels) is measured by a score called the GEH, and TMfS is expected to fall within certain GEH targets. Calibration results are produced for single-point screenlines, key links and multi-point screenlines, with the results clearly discussed in a Calibration and Validation Report.

The techniques used to validate TMfS largely follow the same pattern as those used for calibration. Generally, validation is only undertaken for single-point screenlines, as it is just a 'check' that the model is functioning correctly. All validation results, along with a description of the techniques used, are included in a Calibration and Validation Report.

A word of warning must be included about calibrating and validating against observed traffic count data. While the majority of data currently included in TMfS are relatively new, most counts are for one day only. There is generally a high probability of errors with such counts, as they can be affected by seasonal variations in traffic, accidents and other factors. Manual counts are also subject to considerable human error. As a result, when calibrating and validating TMfS, it is important to consider the validity of the traffic count data used, as well as the outputs of the model.

3.4.3 Journey Time Analysis

The validation of TMfS also involves the use of journey time analysis. This technique involves comparing the journey time between two points in the model against a set of observed journey times.

Journey time surveys are generally undertaken by two people, with one person driving and the other recording the journey time between pre-determined timing points along the route. Such surveys involve the driver endeavouring to drive at the average speed on the given route (by passing as many vehicles as pass him/her). Journey time surveys are generally undertaken a number of times in each direction throughout the day and by more than one vehicle where possible. The enumerator should also note down any unusual activity along the journey time route – eg temporary traffic lights, accidents etc, so that the modeller understands how well the journey time represents a 'typical trip' along that road.

TMfS:07 incorporates numerous journey time routes throughout the modelled area. The modelled journey times are then compared with the set of observed journey times to determine whether the modelled estimate lies within the observed range.

It should be noted however, that the model may represent the journey time relatively accurately overall, but there may be significant differences in each segment of the journey time, meaning the model does not validate particularly well. As a result, the component journey times between individual timing points are compared against their corresponding journey time segments in the model, thus showing areas of potential divergence. If the actual journey time is believed to be correct, there is a need to make amendments in the model to make it validate better – eg checking the distances of links, changing the coding of key junctions etc.

In TMfS:07, observed and modelled journey times were compared against twenty-nine routes using ITIS journey time data and journey time data collected for the Strategic Transport Projects Review (STPR) Highland Model. A list of all journey time routes and results can be found in the 'TMfS:07 Road Model Calibration and Validation Report' and are illustrated in **Figures 3.4 and 3.5** below:

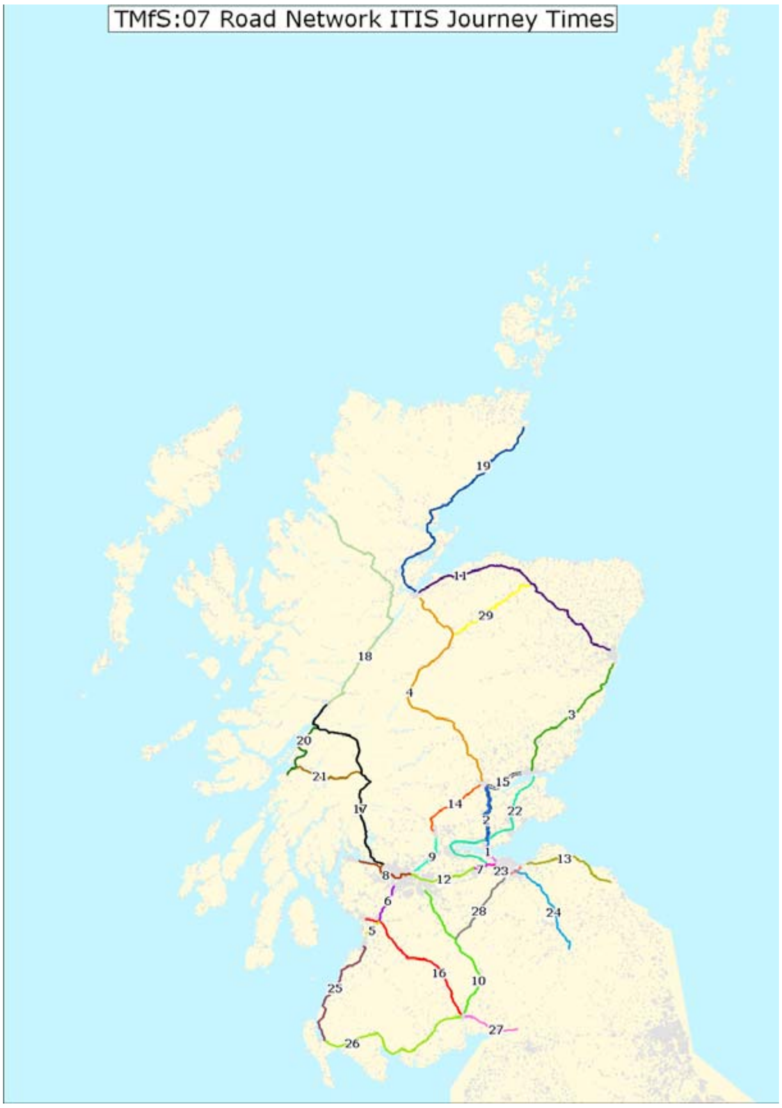

Figure 3.4 TMfS:07 ITIS Journey Time Routes

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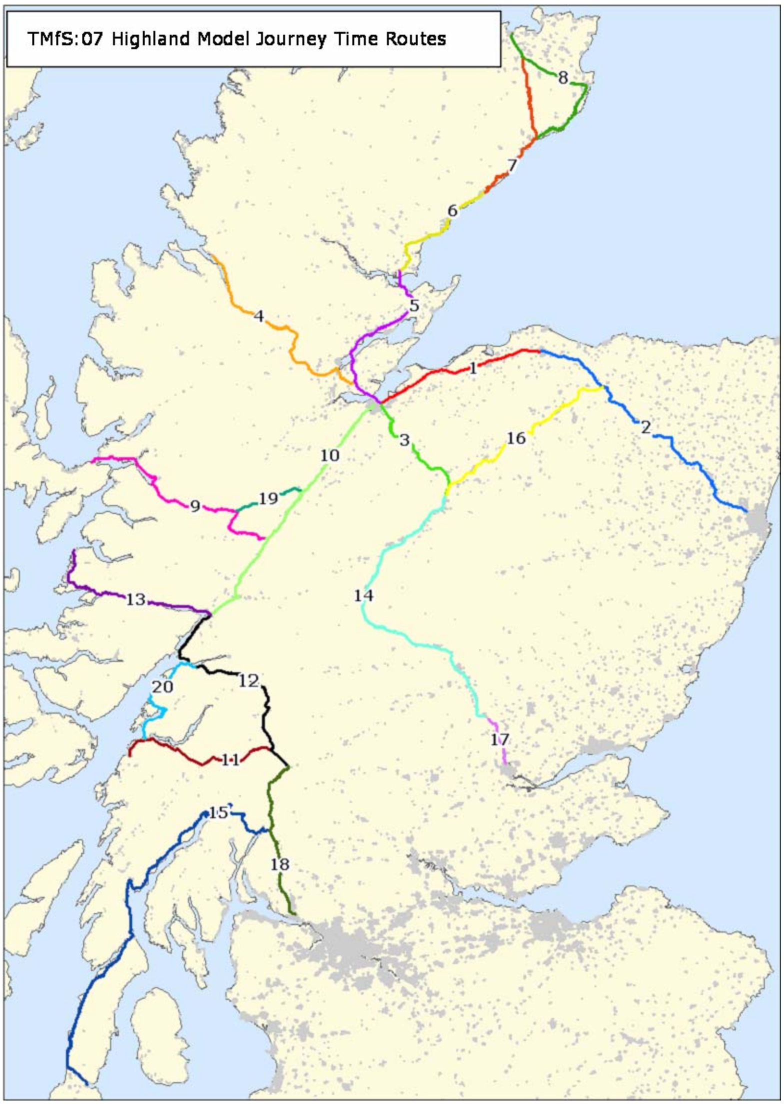


Figure 3.5 TMfS:07 Highland Model Journey Time Routes

Figure 3.4 shows the ITIS journey time data included in TMfS:07. This data was supplemented by a series of journey times for routes throughout the Highland region, shown in **Figure 3.5**.

The accuracy of journey time data must always be scrutinised by any potential model user. Information is provided in the aforementioned Calibration and Validation Report, but it should be kept in mind that the collection of such data is a manual exercise and subject to human error.

3.4.4 Public Transport Survey Data

Public transport survey data play a similar role in calibrating the Public Transport component of TMfS as RSI data play in calibrating the Road component of TMfS. When the Public Transport Model is assigned, the boarding and alighting by stop and patronage figures are calibrated against the survey data, so that the model provides as accurate a representation of actual travel patterns as possible.

3.4.5 Public Transport Count Data

Boarding and alighting counts are available for a number of bus stops and train stations in TMfS. The counts are used in a similar fashion to those of the Road Model, in that the aim is to match the modelled number of passengers boarding and alighting with their real-life equivalent.

3.4.6 Bus Journey Time Comparisons

Bus journey time comparisons are conducted in a similar fashion to car-based journey time comparisons, although without the need to conduct actual surveys. Bus timetables are used as a proxy for the journey times through the road network and compared against the equivalent journey times produced by TMfS for the same bus services. It is assumed that bus operators produce timetables with a strong understanding of congestion hotspots and peak vehicle requirements. As a result, it would be expected that TMfS would conform relatively closely to the said timetables, if it is to be considered suitably robust.

In general, such surveys tend to show that TMfS models bus journey times well. However, there is a tendency for the model to underestimate real journey times, as buses pass through housing estates, small villages etc, which are not included in TMfS because of its role as a strategic model. As a result, TMfS can often route services through the network more quickly than would be predicted by a timetable.

4 The Functionality of TMfS and TELMoS

4.1 Introduction

Previous chapters discussed TMfS and TELMoS model data. This section explains the components of these models and provides a more detailed structure and functionality of TMfS and TELMoS.

Before discussing the functionality of TMfS and TELMoS, it is necessary to briefly recap on the role of the two models and discuss how they interact.

Land-use and transport are closely related issues, each of which impacts on the other – the way in which we use the land influences the demand for transport and transport connections impact on how the land is developed.

In the Scottish modelling context, TELMoS is the tool used to provide a picture of land-use patterns and assess how transport interventions will impact on the way in which the land is used. For the use of TELMoS, David Simmonds Consultancy (DSC) collects planning data from each Local Authority concerning population, households, employment, office floorspace and retail floorspace. This provides an understanding of how land-use looks in the base year – i.e. it is a picture of where the population currently lives, where households are located and where people work.

These data from TELMoS are assigned to their relevant TMfS zone, providing the base characteristics of each zone. That is, for each zone in the TMfS model, we have an understanding of how many people live there, the number of households, where its residents are employed and the number of jobs located within it. This provides a starting point for estimating how many journeys are generated and attracted by each zone. In short, TELMoS provides us with an understanding of how the land is used, while TMfS interprets the impact of this land-use on the transport network.

The key capability of this modelling suite is that it allows the user to test how potential land-use changes affect demand for transport and how transport interventions and policies impact on land development.

4.2 TMfS Model Detail

4.2.1 TMfS Zones

The current TMfS:07 zone system can be seen in Figure 4.1 below. This zone system is more proportionately distributed between urban and rural zones than the TMfS:05A version which was zonally dense in urban areas.

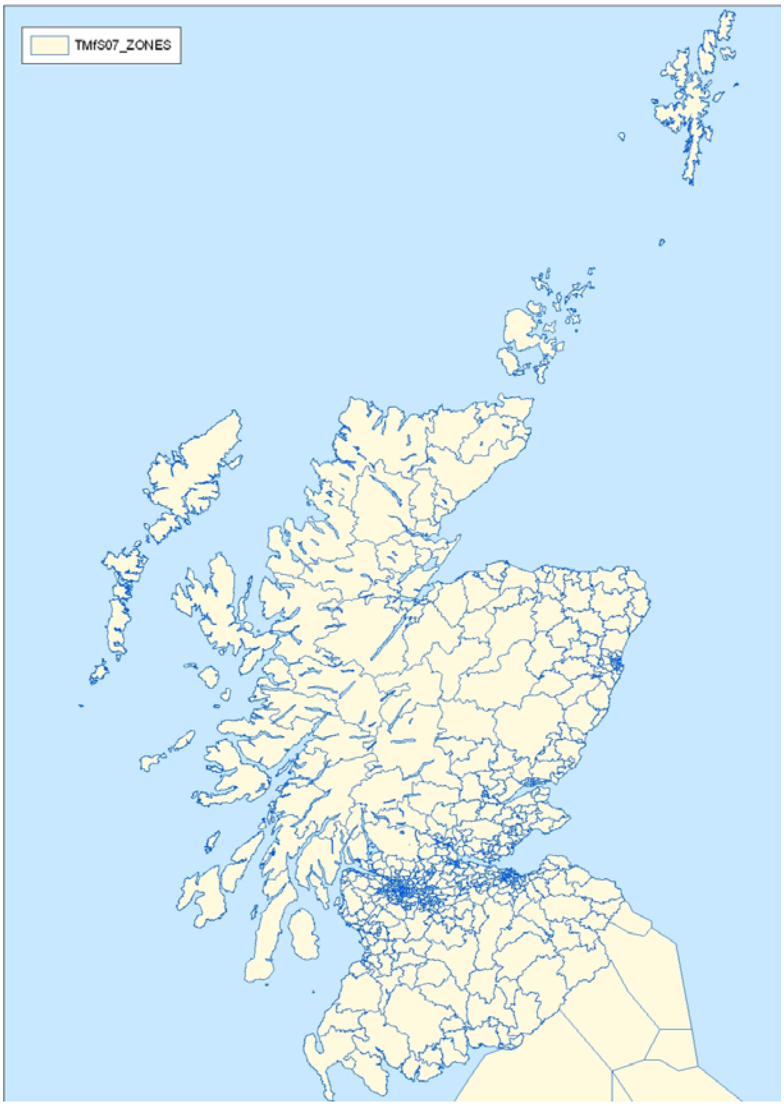


Figure 4.1: TMfS:07 Zone System

The zones in the TMfS/TELMoS model are mostly amalgamations of the 6,505 Scottish Neighbourhood Statistics Data Zones, with typically around nine 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 TELMoS database of land-use and demographic data (i.e. population, households, employment, office floorspace, retail floorspace etc) includes relevant base-year (2007) planning data for each of these zones, along with forecasts of how these data will change over time. The land-use data fed into TELMoS are requested from all Scottish Local Authorities. Following consultation with DSC, the Local Authorities provide Approved Planning Policy Inputs (APPI) for inclusion into TELMoS. These data detail what developments the Local Authorities expect to be brought forward in their areas over the requested time horizons.

The planning data stored for each zone includes:

- **population** in 88 categories based on car availability, household type and employment status);
- the number of **jobs**; and
- the amount of various different types of **floorspace** (retail, office, industrial etc).

Forecast changes in these variables over time help determine the corresponding changes in demand for travel to and from each zone.

The relevant base-year planning data in TMfS/TELMoS are collected from all Scottish Local Authorities and are updated regularly – typically every two to three years. That is, DSC goes back to the Local Authorities at these intervals and requests that they update the data they have provided with their latest projections of land-use for their area.

4.2.2 TMfS Transport Network

TMfS consists of a road network and a public transport network which are handled separately, in order to apply different modelling algorithms.

The TMfS road network includes all of the key trunk and principal roads in mainland Scotland. A detailed map of the TMfS:07 road network can be found in the 'TMfS:07 National Road Model development Report' which is available on the LATIS website at www.latis.org.uk.

Road Network

The level of network detail is an extremely important factor in determining the accuracy of the model – that is, how well it calibrates and validates. In the real world, all roads except motorways have a number of small contributory roads, ranging from minor country roads, to local access from small villages or private property. However, models such as TMfS cannot realistically include all roads due to a lack of traffic pattern data on these roads and the commensurate increase in the time it would take to run the model if they were included. The existence of such roads and the trips they generate nonetheless impact upon the reliability of TMfS where there is little detail in the model. In addition, in areas with large zones, there will be numerous internal trips that TMfS does not pick up, as they do not cross a zonal boundary.

The TMfS:07 Road Network 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. 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.

Turning bans and junction modelling are not included in TMfS:07, instead flow delay relationships modelling is used to represent congestion effects. The delay incurred on each arm is calculated by the amount of traffic on it and the speed at which it is travelling – the lower the traffic flow, the higher the speed and the less the delay (and vice versa).

Public Transport Network

TMfS:07 includes a number of public transport modes, including national and local rail services, urban and inter-urban bus services, domestic ferry services, the Glasgow Underground and the Renfrew-Yoker foot ferry. Air services and non-motorised modes (walking and cycling) are not represented in TMfS.

All TMfS inter-urban bus services (i.e. between key towns and cities) were updated as part of the 2007 rebase. This included significant changes to bus routings, frequencies and timetables. Traditionally, there has been a general lack of inter-urban bus-based origin-destination data for TMfS and as a result, the collection of such data for Aberdeen, Dundee, Edinburgh, Glasgow and Inverness was seen as important in improving the public transport element of the new national model. Given that these were inter-urban surveys, the data also provided valuable data for a range of other important towns including Stirling, Falkirk, Dunfermline, Livingston, Ayr, Kilmarnock and Cumbernauld.

All local rail service (i.e. non-cross border services) coding was updated to the Spring 2007 timetable during the TMfS:07 rebase exercise. This allowed for the inclusion of new routes and frequency amendments across all services. In addition, National Rail Travel Survey (NRTS) data were also incorporated into the model as part of the public transport validation process.

TMfS provides a good understanding of rail travel patterns as a result of NRTS data (see Section 3), which demonstrate movements from station to station.

4.2.3 TMfS Model Hours

TMfS has detailed network models representing three modelled time periods:

- average weekday AM peak hour (08:00 – 09:00);
- average weekday inter-peak hour – average hour between 10:00 and 16:00; and
- average weekday PM peak hour (17:00 – 18:00).

TMfS's Demand Model and appraisal tools use various annualisation factors, derived from Scottish Household Survey Travel Diary data, to scale up these three modelled hours when calculating corresponding travel demand in the week-day AM peak and PM peak periods (07:00-10:00 and 16:00-19:00 respectively) and in the evenings and at weekends.

4.2.4 TMfS Trip Matrices

TMfS:07 has different base-year demand matrices for cars in work time (i.e. business trips), car in commuting time, cars in 'other' time, light good vehicles, heavy goods vehicles and public transport person trips (split by those who are commuting, in work time and in 'other' time) for its three modelled time periods, representing average week-day travel demand.

The TMfS:07 matrices are developed from a wide range of data collected between 2001 and 2008. A summary of these data is provided in the TMfS Data Overview chapter.

Further information on the matrix development process can be found in the *'TMfS:07 Demand Model Development Report'* available on the TMfS website at www.tmfs.org.uk.

4.2.5 Calibration and Validation

The process of model calibration and validation is described in **Section 2**.

The data used to calibrate and validate the current version of TMfS were described in **Section 3**.

Further details on the calibration and validation of the Road and Public Transport Models can be found in the 'TMfS:07 Road Model Calibration and Validation Report' and the 'TMfS:07 Public Transport Model Calibration and Validation Report'.

4.3 Transport, Economic and Land-Use Model of Scotland (TELMoS)

This chapter provides a brief introduction to the Transport, Economic and Land-Use Model of Scotland (TELMoS). The aim of this section is to provide a simplified overview of the purpose of TELMoS and describe how it works and interacts with TMfS. Like TMfS, TELMoS is a complex model and the reader should refer to the TELMoS Model Description for more technical details.

4.3.1 TELMoS Model Detail

TELMoS works in interaction with TMfS. TELMoS supplies TMfS with forecasts of the land-uses which generate the demands for travel, and TMfS supplies TELMoS with the transport data which influence the subsequent location of households and jobs.

TELMoS forecasts future land-use, demographic and economic levels in single year steps, in order to reflect the gradual nature of land-use responses to change. Starting with a base year, it calculates the change over the next twelve months and outputs a set of forecasts for what is effectively 'year 1'. This output is then the starting point for the calculation of the next year's forecast and so on, for as many years as the forecast requires. This is in contrast to TMfS which describes transport supply and demand at particular points in time.

TELMoS comprises a number of different sub-models (economic, urban and migration models). Some of these operate at the TMfS zone level and calculate change in household and population numbers, car ownership levels, location and property markets, employment activity, physical development and environmental quality. Others work at area level and calculate change in economic activity and migration (the areas are based on travel-to-work patterns). The model recognises the way in which these different processes interact with each other.

For example, the opening of a new employment complex and the creation of new employment opportunities may attract people to move to an area. This in turn will increase the demand for residential property, affect rent levels (or house prices), which in turn may influence the rate of take-up of planning permissions for new housing development.

Some interactions take place within one year (mostly to ensure consistency, e.g. that people who leave an area are removed from its labour supply), but most involve a time lag, e.g. decisions to invest in housing in one year will have a series of impacts on residents, and hence on transport and other land-uses, in subsequent years. The overall structure of the model, and the main linkages between components, are shown in **Figure 4.2** below:

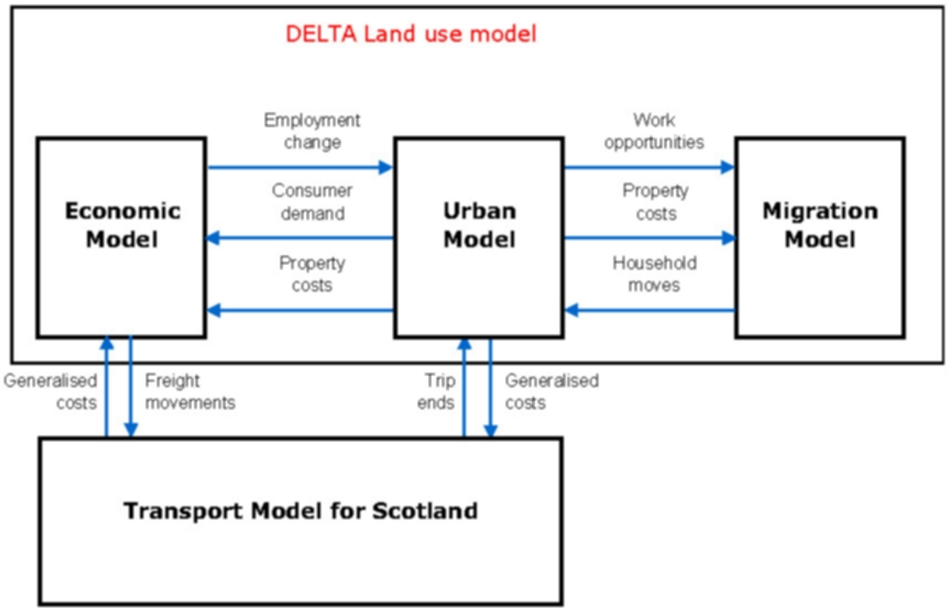


Figure 4.2 TELMoS Model Structure

The changes that determine population and employment change are implemented in such a way that the demographic and economic scenarios are fixed at the total Scotland level. These determine the total amounts of economic activity and employment and the total numbers of residents and households, which, over time, grow or decline in each area and move between areas. The changing distribution of economic activity influences the changes in distribution of households, and vice versa, and both of these influence the demand for residential and non-residential property.

The model forecasts are created to area and zonal levels, taking account of numerous factors and interactions including the planning policies and permissible amounts of development of each type in each zone/area. In forecasting, only the top-level scenarios and the zonal planning policy inputs are strictly fixed by the model user; everything in between is, to some extent, variable over time.

The distributions of households and economic activity are influenced, directly or indirectly, by the performance of the transport system, taking account of infrastructure, public transport services and congestion. Transport infrastructure and public transport services are inputs to TMfS specified by the model users; the location and level of congestion is generated within TMfS as a result of the interactions between economic activities and the travel of household members, given the available infrastructure and services.

The information used by TELMoS comprises four main types: information on the base year or starting point for the forecast, overall assumptions on the level of growth that is to be modelled in the forecasting period, information provided by local planning authorities regarding future development within their area and the assumptions about the ways in which the different parts of the model interact. These are described in more detail below:

- data for the model's base year are derived from the 2001 Census. This source provides a wealth of information relating to the levels of population, households, economic activity and car ownership across the area. Complementary information on floorspace relating to the seven land-use types that are used within the model are derived from other published sources;

- the economic and demographic processes are adjusted so that future levels of population and economic growth are consistent, at the national level, with agreed scenarios such as the GRoS population projections for Scotland;
- local planning authorities are consulted regarding the levels of likely development for the seven land-uses modelled by TELMoS. The information they provide is based largely upon their development plans, details of outstanding planning permissions and assumptions regarding windfall developments; and
- the third source is the wide range of technical coefficients that are used in the model's mathematical equations to calculate the relationships and the interactions between different parts of the land-use model. Some of these are derived from surveys that have been specially commissioned for that purpose, while others are taken from published research, across a range of academic disciplines including Geography, Planning, Economics and Regional Science. This approach contrasts with the conventional approach to calibrating a transport model such as TMfS, where – because it is assumed that the system is in equilibrium in the base year – it is possible to carry out extensive statistical calibration and validation in the base year.

4.3.2 Transport Forecasting Using TELMoS Outputs

The TELMoS output planning data show what the country will 'look like' in a specified year - that is, they show where people will live, how many households there will be and the average number of residents, the level of employment and where shops, offices, industrial and other modelled floorspace will be located.

The structure of the zone system will remain the same between the base year and the forecast year but, as noted above, the zones will contain the forecast year planning data. The transport modelling processes undertaken thereafter are identical to those explained in **Section 2**. To recap, the planning data will be used to identify the number of trips generated and received by each zone. The forecast year road and public transport network will be overlaid on top of the zone system and the model will be assigned. One important point to note is that the forecast year runs of the model cannot be calibrated and validated, as there are no data to calibrate and validate against.

Changes to forecast year road and public transport networks can be made, which will lead to changes in the generalised cost. These costs can then be fed back into TELMoS to investigate their impacts on land-use. TELMoS outputs can then be fed back into TMfS so as to assess the impact on traffic conditions.

4.4 Current TMfS and TELMoS Functionality

The principal components of the TMfS model include the Land-Use model, the Demand model and the Highway and Public Transport Assignment models. TMfS contains principal traveller responses to policies or schemes such as:

- route choice (a choice to change a route);
- mode choice (a choice to change mode between Car, Pt or Park and Ride);

- destination choice (a choice to change origin [e.g. a place of living] and/or destination [e.g. place of work]);
- trip frequency (a choice to choose whether or not to make a trip – applies to home based other trip only);
- macro time of day choice – a choice to move the time of travel from one time period to another;
- HOV Choice model – car trips can choose between single occupant trips or multiple occupant trips; and
- peak spreading (a choice to move the time of AM Peak journey from the peak hour to the shoulders of the peak period to avoid congestion and reduce travel time/travel costs).

4.4.1 Forecasting

Forecasting in TMfS consists of four separate sub-models as follows:

- TELMoS (the integral land-use mode of TMfS) and the Trip End Model;
- Demand Model;
- Road Model; and
- Public Transport Model;

The linkage between each of these sub-models is illustrated in **Figure 4.3** below:

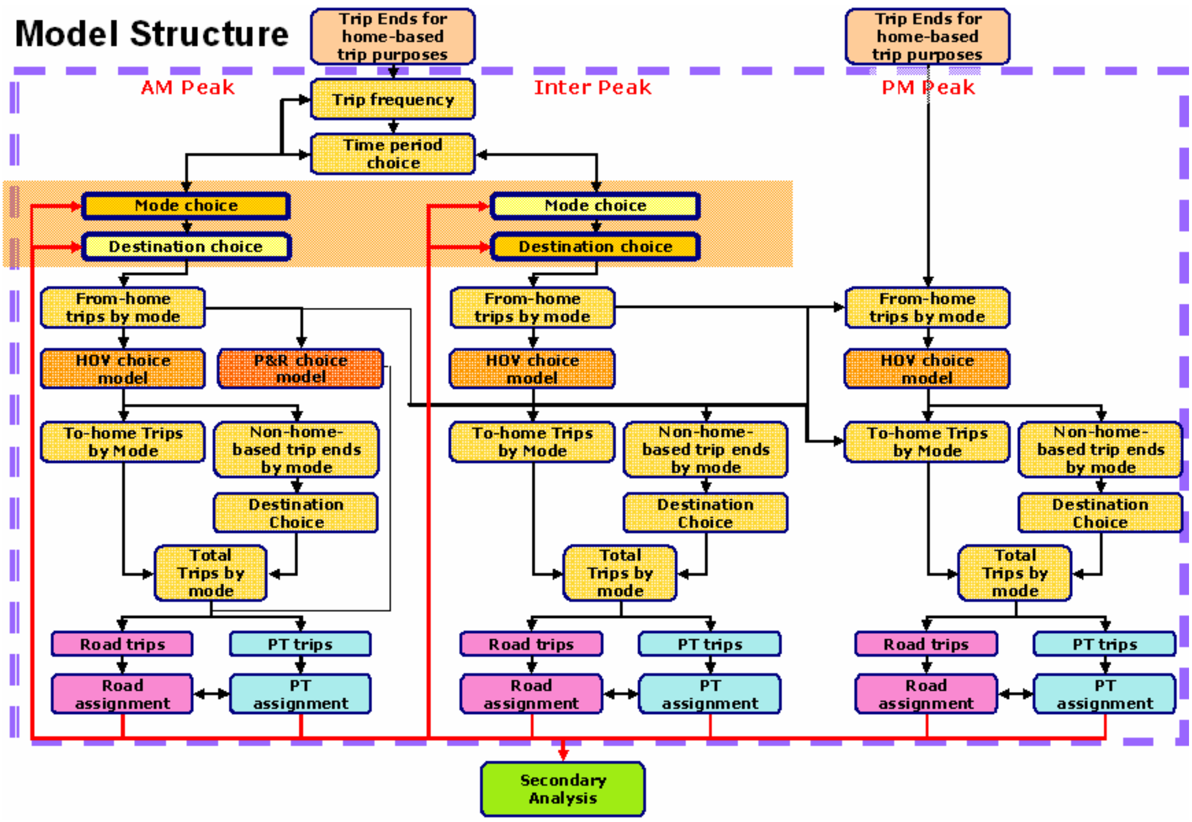


Figure 4.3 Overview of TMfS Model Structure

Figure 4.3 illustrates the process of running TMfS for a future year, as well as the outputs from these processes. The orange and yellow shaded boxes denote the stages of the demand model; the pink boxes denote the Road model and the blue the Public Transport model. Each stage is now explained in more detail below.

4.4.2 TELMoS and the Trip End Model

TELMoS provides the land-use data to TMfS in the form of population, household and employment data for each zone within the model, both for the base year and forecast years. The land-use and economic data input from TELMoS represent the first stage of using TMfS.

Using a pre-defined process, the land-use data obtained from TELMoS are converted into trip-ends, which provide a list of all origins (i.e. journey start points) and all destinations (journey end points), within the model. The origins are categorised by the time period of travel, the reason for travelling and the mode (car or public transport) used to travel. The destinations are characterised by time period of travel and journey purpose. The reconciliation of the origins and destinations takes place during the 'demand model stage'.

4.4.3 Demand Model

In order to understand the demand for travel, we must more fully understand how journeys are generated and conducted – i.e. why a journey occurs (e.g. travel to work, shops, education etc) and how people undertake that journey (e.g. their mode(s) of travel). In TMfS, this process of establishing where people travel to and from and how they get there is undertaken by the demand model.

In **Figure 4.3**, the yellow and orange shaded boxes represent the stages of the demand model.

The trip end data is fed into the demand model and for each trip, the demand model uses a set of parameters to establish how often a trip is made, the mode in which it will be made (i.e. car or public transport) and where the journey will end. Having gone through each of these stages, the demand model provides two outputs:

- vehicle trip matrices; and
- public transport passenger trip matrices.

The vehicle trip matrices show the demand (in vehicle trips) between all possible origins and all possible destinations in the model (that is, between all zones in the model). Similarly, the public transport passenger trip matrices show the demand for all passenger movements between each zone in the model, although it should be pointed out that at this stage, it does not split these passengers between bus, rail etc.

The matrices output by the demand model can be compared against the base year or between forecast years so as to understand how the demand for travel is changing over time. That is, we can establish whether demand is going up or down universally, as well as identify potential demand changes at the zonal level.

4.4.4 Road Model and Public Transport Model

So what is the relevance of the demand model processes to the road and public transport elements of TMfS? Essentially, the road and public transport network represent the transport supply, which accommodate the demand for travel, as expressed by the vehicle and public transport passenger trip matrices.

In **Figure 4.3**, the pink and blue shaded boxes represent the Road and Public Transport Models. As explained in the 'Principles of Modelling', TMfS assigns the demand for travel to the 'empty' road and public transport networks. The trips are loaded from each zone via the zone centroids. It is assumed in TMfS that all travellers have 'perfect information' of the travel choices available to them and will choose the route that offers the lowest generalised cost between their origin and destination. The model will iterate (repeat the process) until it equilibrates supply and demand (i.e. the model converges) and will produce generalised cost for trips between all zones in the model – that is, the model produces a matrix of generalised costs for travel between every zone. This matrix represents the lowest generalised cost routes for every trip in the network – i.e. the model is converged or in equilibrium

However, we know that the demand for travel is responsive to cost – if the costs of travelling rise, we are more likely to seek employment or shop closer to home for example. To this end, the generalised cost produced from the assignment process are fed back into the demand model, which will in turn produce a new demand for travel between every zone in the model based on the generalised cost. This process is known as iteration and will continue until such times as the matrices produced by the demand model have converged with those produced by the road and public transport assignment procedures. That is, if the equilibrium position is upset by the increase in transport costs, people's travel choices may change as a result of this. For example, if the price of fuel doubles, the number of trips (particularly leisure trips) is likely to fall and more people would be willing to use public transport for their trip if it represented a reduction in the generalised cost of travelling. The model interprets such changes by feeding the new travel costs back into the demand model, which recalculates the demand in light of such changes. The new matrices produced by the demand model are then re-assigned to the network to establish the new equilibrium position.

The assigned road and public transport models provide a basis for a whole range of analysis capable of being undertaken by TMfS. At a high level, the modeller can compare forecast year traffic flows with either the base year, or other forecast years, identifying pressure points on the network and the impact of schemes in the forecast year that are not in the base year. The assigned models also feed through into 'Operational Analysis', which is discussed in later in this section.

4.4.5 The Park & Ride Model

The Park and Ride model is run automatically within the Demand Model and contains the Park and Ride infrastructure associated with the relevant Base Year, 'Do Minimum' and 'Reference Case' networks. This includes parking at rail stations.

The model operates within the AM time period for home-based travel purposes (Home-Based Commute, Home-Based Other and Home-Based Employers Business). The model reverses the AM peak outputs to reflect the PM peak period. The process allows up to 250 Park and Ride sites to be included within the model.

The model calculates the use of Park and Ride sites by identifying the road and public transport travel costs associated with relevant travel movements.

The Park and Ride model cannot be run separately as it is an integral part of the demand model. In a similar way to adding new road and PT schemes, new P&R sites can be added and tested against a Reference case

The outputs of the Park and Ride model are Road and PT leg trip matrices which get added into the Road and PT assignments.

4.4.6 Analysing New Schemes and Policies

The key benefit of the forecasting process is that it allows for the testing of future infrastructure and policy schemes. For example, the impact of a new road scheme in 2017 could be tested against the 2007 base year or against alternative scenarios for the 2017 forecast year. TMfS would demonstrate the impact on travel patterns of a new scheme. But how would the model undertake such a scheme or policy analysis?

The new scheme is coded into the relevant road or public transport network. Both sub-models are then assigned producing generalised cost matrices for all trips between all zones in the model. These new cost matrices are then fed back into the demand model and the process described above is undertaken again.

Where a significant change in land-use and economic data occurs (for example, a doubling of the expected level of economic growth), the land-use model TELMoS would be re-run, providing new planning data for conversion into trip ends, which are in turn fed into the demand model.

At the end of the process, new assigned road and public transport networks are output, illustrating the effect of the new scheme on travel patterns. Such testing can be undertaken as many times as required and using different scenarios for each (e.g. new economic data, a new alignment for the road, an additional stop on a new train line etc). The outputs from this process can be used in a number of ways, as is described later in this section.

4.4.7 Do Minimum and Reference Case Scenarios

A description of the current default 'Do Minimum' and Reference Case scenarios can be found on the TMfS Website.

4.5 TMfS and TELMoS Outputs

The aim of this chapter is to provide an overview of the outputs available from TMfS/TELMoS and to provide guidance on how they should be used and interpreted.

4.5.1 Types of Analysis Available

TMfS, along with the Land-Use model (TELMoS), provides an ability to forecast changes in both land-use and travel patterns throughout the model area. The model outputs can be used to assess different road and public transport infrastructure schemes or policy initiatives and include:

- operational analysis;
- environmental and congestion analysis;
- demographic and land-use predictions;
- accessibility analysis;
- Labour Catchment analysis;
- economic, financial and accident analysis; and
- sub-area analysis.

The principles of each of these aspects of model functionality are explored below.

4.5.2 Operational Analysis

Types of operational analysis that can be undertaken by using TMfS are listed below:

- link flow analysis: this provides volumes of traffic (as a total, or broken down by vehicle classification) for links in the network;
- select link analysis: this provides routeing analysis (i.e. a picture of where traffic is coming from and going to) for assigned vehicles at selected links (and combination of links) throughout the modelled network;
- road network details: link lengths, number of lanes, speed limits and topography;
- matrix data: zonal and sectored levels of demand which facilitate the analysis of modal and destination choice changes;
- link delay analysis: to identify congested routes;
- journey time isochrones: (journey times radiating out from a specified location) and route analysis;
- public transport patronage analysis; and
- park & ride occupancy analysis.

Operational analysis can be presented in tabular (spreadsheet-based) or graphic form (using a Geographical Information System or a software package such as Cube Graphics).

4.5.3 Environmental Analysis

In recent years, the condition of the environment has become a cause of ever increasing concern. To this end, an environmental appraisal module (ENEVAL) has been developed specifically for TMfS. ENEVAL provides information on the amount of Carbon emitted.

As noted in **Section 2**, the TMfS road network consists of a series of links, which, following assignment, have a certain amount of 'traffic' on them. Nodes at intersecting roads represent junctions, which is where traffic queues often begin to form. Emissions tend to be lowest when travelling in a high gear at around 60 miles per hour and highest when cars are operating in the stop-start conditions that characterise queuing. The combination of traffic on links and queues at junctions, coupled with pre-determined engine types and their emissions profiles, provides a picture of the overall level of emissions.

This picture of total emissions is simply the sum of the emissions on every link in the network. This information can be presented in a variety of ways, including nationally or by Local Authority.

Intuitively, if ENEVAL can be used to provide the level of emissions in the base-year using the traffic flows generated by the model, it can do the same in any forecast year by using future year flows. This allows for the comparison of emissions by link, Local Authority or nationally between different modelled years. This function is extremely valuable as it allows policymakers to quantitatively assess the level of emissions from transport in future years, based on predicted future traffic.

ENEVAL can also be used as part of an environmental assessment of any given scheme. Again consider the example of a new river crossing. Keeping in mind that the new crossing would change travel patterns, ENEVAL could assess the total change in emissions for each potential scenario for the new crossing, comparing them against each other and against the 'Do Minimum' case emission levels.

The outputs from ENEVAL can also be shown graphically in a GIS system, such as MapInfo or ArcView. This is often the most simple but yet most effective way to present information on emissions to policymakers or other interested parties.

4.5.4 Congestion Mapping

Congestion is currently an issue that is very high on the policy agenda and TMfS provides a mapping package designed to assist in users' understanding of current and future congestion hotspots.

Congestion occurs when the amount of traffic on a road exceeds the capacity of that road. Queues often tend to form at junctions and the 'tailing back' effect reduces road capacity approaching that junction. That is, in terms of TMfS, congestion is caused when queues form at nodes (junctions) and tail back onto links (roads).

As with other areas of secondary analysis, congestion mapping can be carried out in the base-year and forecast years, using the respective traffic flows from each.

Essentially, the traffic flows and junction delays from TMfS are fed into a GIS system such as MapInfo or ArcGIS. The maps produced provide a clear indication of congestion hotspots both now and in the future and highlight areas for potential infrastructure and policy interventions.

Congestion mapping could be used to compare the impact on congestion with our different packages of interventions for a new river crossing. The outputs are easily understandable to those not familiar with transport modelling and would be highly beneficial for presentation to policymakers or other interested parties.

4.5.5 Demographic and Land-Use Forecasts

The Land-Use Model (TELMoS) uses local planning and economic growth assumptions and accessibility measures from the transport model to predict future demographic and land-use changes. A wide range of graphical and tabular analysis of changes in demographics and land-use are available from TELMoS. A full description of these is provided above.

4.5.6 Accessibility Analysis

TMfS:07 contains an accessibility analysis package, which is an add-on to the main TMfS model. The utility uses the output costs from the main model run, which are read into the accessibility programme, along with a number of user-defined parameters and outputs a range of accessibility measures. These measures can be for either origins or destinations and can be weighted by zonal attributes, such as 'number of households' or 'number of jobs'.

The accessibility utility enhances the functionality of TMfS, by allowing the model to compare a number of different tests and their impact on accessibility due to the introduction of a scheme or policy.

4.5.7 Economic and Financial Analysis

Economic analysis is perhaps the key operational analysis function that can be undertaken by TMfS. In the UK, considerable emphasis is placed on undertaking a thorough evaluation of a scheme before its construction is committed. For example, evaluation of a potential new river crossing would require the evaluation of all options and potential alignments of the route.

The Road and Public Transport Assignment Models can provide the relevant inputs required to undertake cost benefit analysis and subsequent preparation of Transport Economic Efficiency tables, a key part of any economic assessment undertaken using the Scottish Transport Appraisal Guidance (STAG) framework. At present, the recommended software for undertaking further economic analysis of the model outputs is TUBA, the Department for Transport's software package for assessing the economic case for a scheme. In conjunction with operational analysis, toll revenues can also be calculated.

In short, an economic assessment of a transport scheme involves identifying all of the costs and all of the benefits and comparing them to establish a cost-benefit ratio – this technique is known as cost-benefit analysis. However, one important point to note is that economic assessments include both monetary (such as fuel and car maintenance costs) and non-monetary (time, life and the environment) costs and benefits. As such, this type of analysis is known as social cost-benefit analysis (SCBA). As with TUBA, this chapter will not explore the various individual elements of SCBA but a detailed description of this can be found in any standard microeconomics textbook.

TUBA will assess the social cost-benefit ratio of a transport intervention over a 60 year time horizon, drawing in both the monetary and social costs and benefits outlined above and discounting them to current values.

As discussed above, TMfS can be used to assess the impact of each package of interventions on travel patterns throughout the TMfS network. These networks provide the necessary data to conduct a TUBA analysis – i.e. journey times, total vehicle operating costs, non-vehicle costs, environmental effects etc.

TUBA can then provide a social-cost benefit ratio for each package of interventions and will highlight the most valuable package. While the government may not choose to pursue this package of interventions (or even the scheme at all), linking TMfS to TUBA nonetheless provides an extremely valuable quantitative approach to assessing and comparing schemes.

4.5.8 Accident Analysis

Accident assessment is undertaken using the ACCDNT module. The ACCDNT model conforms to the NESA/COBA (Network Evaluation from Surveys and Assignments/Cost Benefit Analysis) conditions set out in the 2002 NESA Manual in the Design Manual for Roads and Bridges. The accident forecasts include number of accidents by severity, cost of accidents and distribution of accidents by area (Local Authority, regional and national level).

Accident analysis can provide quantitative evidence for the 'Safety' element of a STAG appraisal and can also be useful when designing safety improvements and launching safety initiatives etc.

4.5.9 Sub-Area Analysis

As noted in **Section 2**, TMfS focuses largely on strategic patterns. However, even with strategic transport schemes such as a new river crossing, there would likely be more local effects. For example, if the new river crossing was built alongside an existing bridge, but the current bridge is left open, there may be significant local effects in surrounding areas.

How does a large scale strategic model such as TMfS represent such local issues? The way in which this is done is to extract the relevant area of the model, creating a new smaller model known as a 'sub-area model'. This model can then be supplemented by additional data, a disaggregation of the zoning system (i.e. increasing the number of zones to make the model more detailed) and a more realistic representation of the network (i.e. the adding of more local roads and modelled junctions).

The most notable examples of sub-area models created using TMfS are the Aberdeen Sub-Area Model (ASAM) and the Dalkeith Sub-Area Model (DALSAM). Both models were designed to appraise specific schemes (the Aberdeen Western Peripheral Route and the A68 Dalkeith Northern Bypass) and were subject to a number of enhancements to zones, data and networks to make them better represent local travel patterns. A new sub-area Forth model has also been developed using TMfS:07, covering the outskirts of Edinburgh up to Perth.

Such a model could easily be created to assess, for example, a new crossing and is a function of TMfS that has the potential to be highly valuable to model users.

Sub-areas can be extracted for the base-year and forecast years.

Labour Catchment Analysis

This can be used to see how many people of working age (although it can be used for all age groups) are within a certain travel time of a zone or group of zones by the different modes contained within the model.

4.6 Application Note

TMfS and TELMoS models have been developed and audited to demonstrate that due skill and care have been applied to make best use of available data procedures. The quality of output is dependent on data inputs and the quality of the model in the area being tested.

Any potential user must be fully aware that model results require interpretation by the user and the necessary caveats and considerations kept in mind when using the model results to support and advise on any scheme or policy application.

5 Glossary

Annualisation Factors

Annualisation factors are used for the expansion of the data from the modelling periods so that it represents a full year. A number of separate annualisation factors may need to be developed to represent each of the modelled periods, and/or vehicle flows, modal shifts to public transport and congestion relief.

Average Weekday

An average weekday is a day where the volume of traffic/travel patterns most closely matches the 'average'. Average weekdays are generally Tuesday, Wednesday and Thursday. Monday and Friday tend to be less representative of average travel patterns due to a number of factors – eg people taking long weekends, organisations closing earlier on a Friday etc. When conducting surveys or gathering other data, it is advisable to undertake the collection on an average weekday, so as to get a reflection of 'true' travel patterns.

Base Year Model

In order to understand how travel patterns will change in the future, we must understand how the transport system 'looks' at present. That is, when building a model, we need to prepare a baseline against which forecasting can be undertaken. This base year model provides a representation of travel patterns for a specific year, with 2005 being the current base year of TMfS. That is, the current version of TMfS (TMfS:05a) reflects how transport 'looked' in 2005.

Boarding and Alighting Counts

Boarding and alighting counts involve counting the number of passengers getting on and off public transport at specified stops. Such data are generally used to validate the boarding and alighting patterns demonstrated by the model – that is, they are used to assess how well the model reflects observed boarding and alighting patterns.

Calibration

Before a model is used for forecasting purposes, we must be confident that it robustly represents current travel patterns and transport trends. This process is known as calibration and involves comparing different aspects of model outputs against actual data. For example, traffic counts on most links are compared against modelled traffic flows to determine how well they match, with the difference being expressed as a GEH score. Similarly, the number of passengers using public transport services is compared against actual count data, with the results again being expressed as a GEH. By using such techniques, the modeller can determine how well the model represents the present, so as to engender confidence in it when it is used for forecasting the future.

Capacity and Capacity Restraints

Every element of the transport network has a limited and relatively fixed capacity in the short-run. For example, roads can only take a fixed amount of cars before traffic jams build and the railways can only accommodate a certain number of train paths within their timetables. Similarly, platform lengths limit the size of trains and bus capacity can only be expanded with the procurement (or reorganisation) of bus stock and the recruitment of drivers. Transport models represent the 'cost' of traffic constraints through generalised costs, where factors such as traffic jams or rail crowding lead to increased generalised costs and provide an incentive to switch modes or routes.

- Census Output Areas

Census Output Areas are the smallest area size at which Census results are released, allowing for a finer resolution of data analysis.[1]

- Census Travel-to-Work

Census Travel-to-Work data provide estimates of the main mode of transport used and the average time taken to travel to work, using data from the Labour Force Survey (LFS).[2] These data facilitate the building of the AM peak matrices, by providing information on the origin and destination of ‘to-work’ journeys. These data can then be reversed for the PM peak, where we assume that people return home (‘to-home’ trips) after finishing work.

- Connectivity

Connectivity refers to how well a place is connected to the wider transport network and, in turn, key services, towns, cities and hubs. Areas closer to urban conurbations tend to have better connectivity, as they often benefit from high volume and more frequent transport links than rural areas.

- Convergence

The assignment procedure loads the trips from each zone onto the ‘empty’ road and public transport network via the zone centroid connectors. The model assumes every traveller has perfect information and attempts to route each trip through the network to its destination using the cheapest possible path (in terms of generalised costs). Once the model has managed to assign all of the trips in the most cost efficient manner, it will apply capacity restraints, thus meaning that the model will need to adjust the cheapest paths to account for congestion, public transport crowding etc. That is, it will reduce the speed that people can move through the network to their destination as a result of congestion, thus making alternative routes more attractive and the ‘travel time’ element of generalised cost more expensive. Once the model has completed this adjustment and has determined the optimum paths through the network, it is deemed to have converged. That is, every trip is travelling from its origin to its destination using the ‘best’ (ie lowest cost) route.

- Demand Model

The Demand Model uses the planning data output from TELMoS to establish the overall demand for travel between every zone in the model – that is, the demand model outputs a demand matrix. This matrix is then used to determine who will travel by road and who will travel by public transport (and which mode of public transport will be used, known as the sub-mode split), with the decision based on generalised cost. This process outputs separate road and public transport matrices to be fed into the assignment process. That is, by the time we have run the demand model, we know where everyone is coming from, going to and how they will travel. The assignment process calculates the best available routes for these journeys.

- Derived Demand

[1] http://www.statistics.gov.uk/geography/census_geog.asp

[2] http://www.statistics.gov.uk/STATBASE/Product.asp?vlnk=13735&More=Y

Derived demand is a demand for a good that in turn depends on the demand for another good. For example, the demand for transport into a town depends upon the demand to be in that town.[3]

Destination

The destination of a trip within TMfS is where it reaches its end point. Trips are considered to be one way, meaning that trips from home to work in the morning and from work to home in the evening are counted as two separate trips. The destination also refers to the 'final' destination, not where a specific mode of public transport is alighted – that is, if a person gets off a train at Bishopbriggs, their home, rather than Bishopbriggs station, would be the final destination.

Discounting

Assuming an economy is inflationary, the value of one pound today will be greater than the value of one pound tomorrow. That is, as inflation drives up prices, the purchasing power of one pound will decrease.

Transport schemes are generally appraised over a long period of time (typically 60 years), therefore policymakers must be aware of how future costs and benefits that accrue to a scheme relate to current day prices. This is particularly relevant for scheme benefits, as they tend to accrue over a longer period of time than costs. This is because most of the costs accrue in the initial building of a scheme, while benefits accrue as people use that scheme over time.

The method used to compare current and future costs and benefits of a transport scheme is known as discounting. That is, the future costs and benefits of a scheme are discounted to current prices using a discount rate. There remains some debate over what is the socially optimal discount rate.

Discount Rate

The discount rate is the rate used to equate the value of a pound received in the future, to the value of a pound received today.

Do Minimum Case

When using TMfS for forecasting, we need to be aware of changes in transport infrastructure between the base year model and the test years. To do this, we prepare a number of 'what if' scenarios, one of which is 'Do Minimum'. The 'Do Minimum' includes only schemes that are currently committed – that is, it is a minimal change alternative with which a new investment or policy can be compared, to help determine whether that investment or policy is worthwhile.[4]

Economic Assessment

An economic assessment is an evaluation of how a new scheme or policy affects economic welfare. An economic assessment involves undertaking a social cost-benefit analysis to determine the value of a scheme or policy to society. Under the STAG philosophy, an economic assessment is only one part of five assessment criteria, with others including an environmental assessment.

Environmental Assessment

[3] Powell, T., *The Principles of Transport Economics* (London, 2001), p. 278.

[4] Powell, T., *The Principles of Transport Economics* (London, 2001), p. 278.

An environmental assessment is a multi-faceted investigation of the environmental impacts of a transport scheme or policy.

External Zones

TMfS only considers travel patterns within Scotland. However, the model must take account of cross-border travel from England. As a result, England and Wales are represented by eight 'external zones', so as to show the different external routings into Scotland. With external zones, we are only interested in movements into the study area, as opposed to actual movements between external zones.

Forecast Year

The forecast year provides a representation of how we think transport and land-use will 'look' in the future. Forecast years can be built upon the different assumptions of the 'Reference Case' and 'Do Minimum' cases and allow modellers to test both the differences between each test in the forecast year, as well as the differences between the forecast year and the base year. The current forecast years included in TMfS are 2012, 2017 and 2022, to reflect the needs of the Strategic Transport Projects Review (STPR). However, it is possible to choose any forecast years, although this would require a review of the planning data and 'Reference/Do Minimum' cases for the chosen year(s).

Forecasting

Forecasting is the process by which a model is used to predict travel and land-use patterns in the future.

GEH

The GEH score is central to the calibration process. Calibration involves trying to match the modelled flow on links, to the actual volume of traffic on that same section of road in reality. For every link in the model, the difference between the modelled flow and the real count is calculated in the form of the GEH statistic. The closer to zero the GEH is, the better the match between modelled and observed flow. The GEH takes account of the difference of magnitude in counts – for example, one would not normally be concerned about a modelled flow which differed from a count by 40% if the count was only 100, but one would be if the count were 1,000. It is unrealistic to believe that the GEH can be close to zero for every link and the Design Manual for Roads and Bridges (DMRB) provides specific GEH targets for traffic models. However, it should be noted that even DMRB targets are somewhat unrealistic for a large strategic model such as TMfS.

Where a link has a GEH score outwith the recommended values, the characteristics of this link and those around it are analysed to assess why the GEH score is larger than recommended. Where possible, amendments are made to the TMfS network to make it more closely resemble the real road network. For example, the modeller may amend the distance of the link, the speed limit, the capacity of a road or the delay at a junction. The aim of this approach is to make the links more or less 'attractive' in order to try and better match the modelled flow with the observed traffic count. Calibration counts generally have a lower GEH score than validation counts because the 'better' data tends to be used during the calibration process.

Generalised Cost

A key element in the way in which trips are assigned and distributed is the cost of travel. It is important to note from the outset that cost, in terms of transport models, does not only refer to monetary expense, but also to the cost of travel time and the disutility of travel in general. This is known as generalised cost and its elements for car travel include:

- **monetary** – fuel, wear and tear on cars, parking and tolls; and
- **travel time** – travel time expressed as a monetary cost.

The elements of generalised cost for public transport travel include:

- **monetary** – fare(s);
- **travel time** – travel time expressed as a monetary cost;
- **transfer penalty** – inconvenience of interchange expressed as a monetary cost; and
- **walk time/wait time** – walk to public transport stop, wait at the stop and convenience and comfort while travelling expressed as a monetary value.

Iteration

The process of iteration is concerned with how a transport model reaches its equilibrium or 'best case scenario'. The aim of a model assignment is to ensure that every trip in the network is taking the lowest generalised cost route between the specified origin and destination. In order to do this, however, the model must test numerous combinations of routes to determine the most efficient package of movements. Each of these 'tests' is known as an iteration. The model initially assigns all trips down the one path (which is known as 'All or Nothing' assignment) and applies capacity restraints (which increase generalised costs). Successive iterations lead to the point where the model achieves equilibrium (converges) – ie every trip is taking the most efficient route from its origin to its destination. It should be noted that the iteration process assumes that all trips in the model have access to 'perfect information' – ie every trip maker knows every route from their origin to their destination.

Journey Purpose

The journey purpose is defined as the reason a person is choosing to make a trip. Such information is important in a model as it establishes details of trip patterns and provides an indication of how sensitive travellers are likely to be to policy changes. For example, if we consider two trip purposes, 'commuting' and 'leisure', we know that commuters are likely to be less responsive to policy changes because they have little flexibility in terms of the time that they are making a journey. Leisure travellers have more control over their need to make a journey and the time of that journey.

TMfS has five journey purposes:

- **home-based work** – travelling from home to work (and back again) – a typical commuting journey (NB : this travel purpose does not take place in employer's time);
- **home-based other** – travelling from home to a non-work related location, such as shopping or leisure;
- **home-based employer's business** – travelling from home to a destination where you are in employer's time as soon as you leave the house;

- **non-home-based other** – travelling from a non-home-based origin to a destination such as from work to shops during lunchtime or from shops to work; and
- **non-home-based employer's business** – travelling during employer's time, such as attending a business meeting through the day.

Journey Time Segment

When validating a model, journey time surveys are often split into a number of segments to determine how well the model represents each section of the total journey. It is possible for a model to accurately represent an overall journey time well, but still mask inaccuracies in modelling different sections. As such, it is important that the time taken to traverse each segment of a journey is analysed.

Journey Time Surveys

Journey time surveys are generally undertaken by one or more vehicles travelling between predefined start and end points (with agreed waypoints) along a route. The enumerator records the journey time between each waypoint and the overall start to end journey time. Enumerators are expected to drive at or near the speed limit and both overtake and to be overtaken, so as to represent an average vehicle.

A model uses journey time surveys to check how well it represents the actual journey time between the same two points. Where a marked discrepancy exists, the modeller must attempt to identify and rectify the problem. The model's representation of individual segments of the journey time can be checked against the actual journey time data between the selected waypoints.

Key Link Analysis

There are certain links that require very fine calibration so that the GEH score is relatively low. That is, there are key links with which we must be confident in what the model is telling us. Examples of such links are the Forth Road Bridge and the Kingston Bridge, as well as key sections of the Trunk Road network. Key links can be analysed in isolation, or as part of a wider key link screenline – for example the Bridge of Don and Persley Bridge in Aberdeen.

Land-Use

Land-use is a term intended to describe the way the land is used in terms of physical development (housing and commercial floorspace), households, population, economic activity and employment.

Links

Links represent the real road network and their features, such as the length, number of lanes, the capacity (ie the number of cars that can 'fit' on the road without causing congestion), the free-flow speed and some parameters which describe how the traffic speed decreases as the volume of traffic increases.

Matrix

A matrix in a transport model is a table showing trips between every origin and destination within that model. The table below provides an example of a matrix for a simple three zone model, where movements within zones are not accounted for (as is the case with TMfS).

Destination Zone				
Origin Zone	**1**	**2**	**3**	**Total**
1	**0**	6	9	**15**
2	4	**0**	4	**8**
3	7	1	**0**	**8**
Total	**11**	**7**	**13**	**31**

As can be seen from the table, inter-zonal trips like that between 'Origin Zone 1' and 'Destination Zone 1' are equal to zero as inter zonal movements are not taken into consideration. The same is also true for trips within zones 2 and 3. However, it can be seen that movements from 'Origin Zone 1' to 'Origin Zone 3' are equal to 9. The zone system and matrices contained within CSTM and latterly TMfS are essentially a larger version of the above table with more zones.

- Matrix Estimation

Matrices show all movements between every origin and destination zone pair within the geographical scope of the model. However, it is clearly not possible to obtain every person in Scotland's actual travel movements. As such, survey data collected are taken to be a representative sample of people on that road, bus route, rail route etc. Taken together, all collected data are expanded to represent the entire matrix – ie the total matrix is estimated based on the existing survey data.

- Matrix Infilling

In large models such as TMfS, it is impractical to hold data for every route, every bus service etc. As such, established techniques exist to 'infill' areas where gaps exist.

- Mode

Mode is the term used to describe the different means of transport included within the model. TMfS currently includes: cars, light goods vehicles (LGVs), heavy goods vehicles (HGVs), buses, trains (including subway and tram) and ferries. TMfS does not currently include air services, motorbikes, walking or cycling.

- Mode Choice

When assigning trips to a network, a model must allocate those journeys between the different modes of transport – this is known as mode choice. The mode choice of every trip in the model is determined principally by generalised costs (ie travellers will take the lowest 'cost' option available to them) and also by household car ownership levels.

- Modelled Junctions

There are four types of modelled junctions – roundabouts, traffic lights, priority junctions and motorway merges. Modelling a junction requires a number of pieces of information, including the number of junction arms, number of lanes etc. Given the number of junctions in Scotland, it is not possible to explicitly model every junction within TMfS. As such, only selections of key junctions are modelled, although this is nonetheless a relatively large number. Such junctions are important in ensuring that traffic flows through the model behave in a realistic fashion. Indeed, accurately modelling a junction (including geometry and delays) is an important element of the calibration process.

- Modelled Traffic Flow

Once a model is assigned, it will produce a modelled traffic flow on every link. This traffic flow represents the equilibrium position where no trip can find a 'better' (ie lower generalised cost) route through the network. The modelled traffic flow is what is compared against real traffic counts during the calibration process. The difference between the modelled traffic flow and the actual count is known as the GEH.

- Network Assignment

Network assignment refers to the process of loading all of the journeys (ie the trip matrices) onto the road and public transport networks. During the assignment process, the model iterates to find the cheapest generalised cost route through the network – ie the point where no trip can find a 'better' route through the network. Once a matrix is assigned, the assigned networks are then calibrated and validated to check how accurately they reflect actual travel patterns.

- Network Detail

Network detail refers to how well the model represents the real life road and public transport networks. TMfS is a strategic model, which is largely focused on inter-urban movements between key towns and cities. As such, it represents key inter-urban routes well, as it includes all trunk and principal A-roads, as well as a number of B-roads. However, the model does not represent more minor roads within cities or between small villages etc. The level of network detail is generally commensurate with the level of zonal detail. The reason for not including every road in Scotland is largely due to the disproportionate increase in model run times that this would necessitate.

- Neutral Month

Neutral months are months where travel patterns and traffic conditions are closest to the average. This is important when conducting survey work as surveys undertaken outside neutral months are generally unrepresentative of average travel patterns and will affect the accuracy of a model. For example, data collection in July and August would be affected by the school holidays, while December would be affected by Christmas. Generally, data is collected in neutral months such as February and November.

- Node

Nodes represent the connections between the links and often represent the various types of junctions (priority junctions, signalised junctions, roundabouts and motorway merges) where additional delays are incurred due to the interaction of traffic moving from one link to another. 'Dummy' nodes can also be used to split links, making the links more resemble their curvature in reality.

- Origin

The origin of a trip is the point where it begins. Trips are considered to be one way, meaning that trips from home to work in the morning and from work to home in the evening are counted as two separate trips. The origin also refers to the 'initial' origin, not where a specific mode of public transport is boarded – that is, if a person gets on a train at Bishopbriggs, their home (if that is where they have come from), rather than the station, would be their initial origin.

Output Networks

Before the assignment procedure is undertaken, we have a network in place which is known as an input network. This should be thought of as an empty network – ie there are no journeys taking place on it. When the model is assigned, we are putting all of the trips onto the network and the model iterates until convergence. Once this process is complete, we have what are known as output (or loaded) networks, where the model has determined how people will travel from their origins to their destinations. It is the output networks that are used to compare modelled traffic flows against actual traffic flows during the calibration process.

Park & Ride Model

The Park & Ride model takes into account those who wish to travel to Park & Ride (P&R) sites and make their onward journey by bus or train. The road and public transport matrices are assigned to create the output networks – the question the P&R model poses is: "How will travel patterns change if Park & Ride opportunities are introduced into the model"? P&R opportunities change the relative demand for travel by road and public transport, thus creating new road and public transport matrices. These matrices are then reassigned to give the new model equilibrium position.

Perfect Information

In transport models, all travellers are assumed to have perfect information. That is, it is assumed that every person making a trip knows all of the routes to their destination and which route is the most efficient – ie which route yields the lowest generalised cost. This is a reasonable assumption to make for day-to-day trips as the majority of travellers do have a preferred route which they have likely decided on through trying the alternatives available to them.

Planning Data

The demand for travel is very strongly influenced by demographic factors. Planning data provides current and expected levels of population, households, commercial floorspace, car ownership and employment. These factors combined are the key factors in generating travel.

Planning Forecasts

Changes in planning data over time affect the demand for transport and models like TELMoS must capture this change effectively if we are to understand the full impact of transport infrastructure investment and policies. This involves collecting forecast planning data from all Scottish Local Authorities, where they predict the population, employment and households in their area for the specified years. However, with each Local Authority making their own projections, there is potential for the combined population, households etc to exceed projected national totals. As such, TELMoS is used to rationalise these data to General Register Office for Scotland (GRoS) projections – that is, they are made to equal national forecasts through a number of modelling procedures. Following this process of collection and rationalisation, future year planning data projections from TELMoS are fed into TMfS to assist in determining future travel demand and travel patterns.

- Public Transport Assignment

The assignment process is broken down into separate public transport assignment and road assignment procedures which, in turn assign the public transport and road matrices created by the demand model. The public transport assignment process involves determining which public transport route travellers will take between their origin and destination.

- Public Transport Crowding

The mode of transport on which people travel is determined by the generalised cost of travel. Bearing in mind that generalised cost is not just a monetary cost, but also includes time waiting for transport, as well as the comfort of a journey, we can see that crowding is clearly an important aspect of this cost. Crowding on public transport evidently makes a journey more uncomfortable, thus increasing the generalised cost of such journeys. This affects travel demand, where travellers may switch mode of transport due to the extra 'cost' incurred as a result of crowding.

- Public Transport Matrix

The public transport matrix indicates the number of trips by public transport between every zone pair in the model.

- Public Transport Model

Once the demand model outputs the public transport demand matrices, these are fed into the public transport model for assigning to the public transport network. That is, the demand model creates a matrix of every public transport trip between every zone in the model. These are then loaded onto the 'empty' public transport input network and the model iterates until each of these journeys finds the best possible public transport routing for every journey. The output networks are then used in calibration and validation and subsequently in forecasting.

- Public Transport Network

The public transport network includes all of the roads in the road model (so as to accommodate buses) and the entire rail network. These are represented through a series of links and nodes.

- Public Transport Survey

A public transport survey involves boarding public transport and asking passengers questions about where they are travelling to and from and why they are doing so. The data collected is manipulated and incorporated into the model to inform it of public transport-based travel patterns.

- Rebase

All models have a base year, which reflects how transport and land-use patterns 'look' in that given year. For example, the current base year of TMfS:05a is 2005, meaning that bus and rail services etc are modelled, based on their 2005 timetables. Where necessary, the modeller can rebase the model to another base year, as was done when TMfS was re-based from a 2002 base year to a 2005 base year. This can be undertaken by updating a number of variables including planning data, the road network (to account for new infrastructure), and public transport networks and timetables etc.

- **Reference Case**

When using TMfS for forecasting, we need to be aware of changes in transport infrastructure between the base year model and the forecast years. To do this, we prepare a number of ‘what if’ scenarios, one of which is the ‘Reference Case’. The ‘Reference Case’ includes all of the ‘committed’ schemes that are in the ‘Do Minimum’, as well as a number of schemes that may go ahead, but are as yet not committed. The impact of the ‘Reference Case’ in undertaking forecasting is typically greater than that of the ‘Do Minimum’, because it represents additional changes to the picture presented by the base year model.

- **Road Assignment**

The assignment process is broken down into separate public transport assignment and road assignment procedures, which in turn assign the public transport and road matrices created by the demand model. Road assignment involves putting the demand for travel between every zone in the model onto the ‘empty’ road network. The model then undertakes the assignment procedure, where it attempts to find the ‘best’ path through the network for every trip through a process of iteration. Once the model converges (ie reaches equilibrium), the road output networks are then used in the calibration and validation process and forecasting.

- **Road Matrix**

The road matrix indicates the number of trips by road between every zone pair in the model. There are separate matrices for cars, light goods vehicles and heavy goods vehicles.

- **Road Model**

Once the demand model outputs the road demand matrices, these are fed into the road model for assigning to the road network. That is, the demand model creates a matrix of every road trip between every zone in the model. These are then loaded onto the ‘empty’ road input network and the model iterates until each of these journeys finds the best possible road routing for every journey. The output networks are then used in calibration and validation and subsequently in forecasting.

- **Road Network**

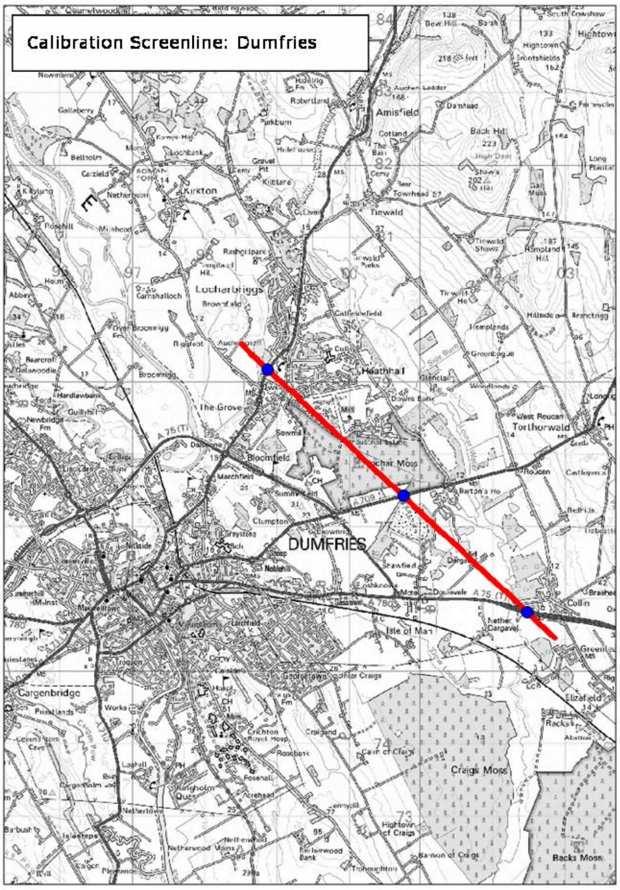
The road network includes all of the roads and junctions included in TMfS. These are represented through a series of links and nodes.

- **Roadside Interview**

A roadside interview (RSI) involves stopping a sample of motorists to ask them questions about where they are travelling to and from and why they are choosing to do so. The data collected are manipulated and incorporated into the model to inform of road-based travel patterns.

- **Screenline**

A screenline is a line drawn across a number of routes entering the one area, thus providing a more complete view of total traffic entering that area. An example of a screenline is shown in the diagram below:



The figure shows a calibration screenline (the red line) covering Dumfries' three routes to the M74 – the A701, A709 and A75. Each blue dot represents a traffic count used in a fictional calibration of TMfS. Without the use of the screenline, how well the model represents actual traffic on each road cannot be known. However, the screenline allows modellers to analyse combined travel patterns (from the M74 to Dumfries and vice versa) to check whether the total traffic is modelled correctly and whether there is too much traffic on say the A701 at the expense of the A709. Modellers can then attempt to remedy any issues that remain with the calibration of traffic on these roads.

- Select Link Analysis

Users are often interested in the travel patterns on certain key links on the network, such as the Forth Road Bridge. A select link analysis allows users to focus on the travel patterns and other aspects of one selected link on the network.

- Sensitivity Tests

Models are principally built for their capability to feed into evidence-based assessments of future transport and land-use patterns. However, when making such projections, one must be confident that the model in question is presenting a realistic view of the future. As such, models such as TMfS must be tested to ensure that their sensitivity to key factors, such as changes in fuel prices and public transport fares, are in line with industry guidance.

In addition, sensitivity tests allow for a 'what if' view when testing transport schemes or policies. For example, a new bypass may appear to deliver economic benefits to the country, if things such fuel prices, motoring costs and fares remain proportionally equivalent through time. However, such a bypass may not be beneficial if fuel prices were to treble because less people would be inclined to drive on it (and drive generally) due to the higher cost incurred. TMfS allows various such sensitivities to be tested, allowing for more informed policy decisions.

Single Point Screenline

A single point screenline is where the modelled flow and actual traffic count are compared at just one point. This differs from a multi-point screenline where we are looking for a general view of traffic entering or leaving an area. Single point screenlines are more common on less detailed areas of the network, such as in rural areas or on inter-urban trunk road corridors.

Social Cost-Benefit Analysis

Cost-benefit analysis is a technique used by businesses to identify whether a scheme is profitable – ie it is essentially a comparison of the benefits and costs of a scheme. This calculation is expressed as a benefit-cost ratio. Governments employ a similar methodology but investigate the social effects of a scheme or policy (such as social inclusion, the environment etc), rather than just the profit and loss equation. This technique is known as social cost-benefit analysis and is used as part of an assessment of all major transport schemes and policies.

Social Cost-Benefit Ratio

The social cost-benefit ratio of a transport scheme or policy reflects its value to society. It is essentially the ratio of the identified benefits of a scheme against the cost of that scheme. This technique is central to Transport Scotland's Scottish Transport Appraisal Guidance (STAG).

Strategic Transport Projects Review (STPR)

The STPR was commissioned to plan Scotland's future programme of investment in Transport across all modes with the aim of delivering real benefits to communities and businesses. The review will allow Transport Scotland to plan and prioritise projects and improvements to deliver an efficient, integrated transport network fit for the 21st centur, to grow the economy, provide key connections and open up opportunities. The STPR is the first time a nationwide, multimodal evaluation of Scotland's key strategic transport network has taken place. The scope of work is possible due to the devolution of additional rail powers to Ministers by the Railways Act 2005.

The STPR is:

- looking at what the picture of transport might look like in the future and prioritising investment to meet our national transport objectives to grow the economy, whilst minimising the impact on the environment; and
- allowing a whole range of schemes, important to communities and businesses across Scotland, to be judged not only on their local merits but alongside national transport priorities.

When complete in summer 2008, the review will recommend a programme of interventions for implementation between 2012 and 2022. This could include new infrastructure projects, better incentives for sustainable travel and more carefully targeted investment across the country. The programme will aim to make a significant contribution to delivering the National Transport Strategy.[5]

■ Strategic

Strategic traffic refers to inter-urban travel between key centres, ports, airports and other key transport hubs. TMfS is essentially focused on strategic inter-urban movements. For example, TMfS is well placed to provide analysis of travel between Edinburgh and Glasgow but less well placed to comment on movements between Haymarket and Princes Street in Edinburgh for example.

■ Sub-Area Model

TMfS is essentially a model focused on strategic inter-urban movements that are significant in a national perspective. However, the model provides a loose framework for developing more detailed models or looking at an area in more detail. That is, a sub-area model can be 'cut out' from the main model and enhanced to provide a better representation of the area in question. Perhaps the most notable example of a sub-area model is the Aberdeen Sub-Area Model (ASAM), which was developed to test the Aberdeen Western Peripheral Route.

■ Sub-Mode Choice

The demand model produces a public transport matrix that needs to be assigned to the 'empty' public transport network. However, the model has to determine how to split the total trips by public transport between the different modes of public transport. This is known as sub-mode choice and is undertaken when the public transport matrix is being assigned. Essentially, the model seeks the lowest generalised cost path through the network for every trip and allocates those trips to bus, train, subway etc.

■ Traffic Counts

A variety of different traffic counts are undertaken on the road network. Traffic counts are generally divided into different vehicle types. These counts are entered into TMfS and compared against the modelled flow on every link during the calibration and validation process.

■ Transfer Penalty

It is reasonable to assume that all travellers like to get to their destination without having to change mode (from car to bus for example), or make a change within a mode (ie bus to bus). As such, when calculating generalised cost, models include a 'transfer penalty'. This is essentially a pre-defined increase to generalised cost for each time a person transfers to another vehicle or mode of transport during a journey. Intuitively, a journey combination with two changes will be less attractive than a journey combination with only one change due to the higher generalised cost.

■ Transport Supply

Transport supply refers to both the physical infrastructure on which we travel (roads, railways, ports, airports etc) and the provision of transport services (car ownership, bus services, rail services, flights etc).

[5] http://www.transportscotland.gov.uk/projects/strategic-transport-projects-review

Transport Demand

Transport demand refers to demand for the use of transport supply, both in terms of the physical infrastructure and services provided. In TMfS, the transport demand is obtained by passing the planning data through the demand model – ie transport demand is represented by the road and public transport matrices.

Trip Distribution

Once the model determines the demand for travel from each zone, it must then decide where these trips will go to. Using a set of algorithms and parameters, transport models will distribute the trips generated by each zone to a set of destination zones. This means for every journey from each zone, the model will determine which zone this journey is travelling to.

Trip Generation

In the base year matrix, each zone represents an aggregation of all journeys from a certain geographical area. The process for predicting how many trips in total would originate from a zone is known as trip generation. The number of trips 'generated' by each zone is estimated by the activities taking place within that zone. Therefore, the total number of journeys from each zone is determined by the number of activities they possess, including:

- residential – journeys that start or finish at a person's home;
- employment – journeys to work;
- commercial – shopping, private business, leisure trips etc; and
- educational – school trips etc.

The level of these activities is determined by the planning data for each zone. The key factors for inducing journeys include:

- household composition;
- income;
- car ownership;
- employees; and
- commercial floorspace.

In a base matrix, the number of trips produced by each zone and number of trips attracted to each zone are called Trip Ends. Each trip has two ends. The attraction end is the end where the activity is (therefore, where the trip goes to), while the production end is the origin of the trip. A set of origin trip ends (productions) is obtained by summing the row totals to give the number of trips coming out of each zone and the destination trip ends (attractions) by summing the column totals for each zone to give the number of trips going to each zone.

Having obtained the base year trip ends, the future year trip ends are estimated by TELMoS, which uses a combination of planning data and the key factors influencing travel.

Validation

Validation is the process of checking the accuracy of the robustness of the calibration process. This involves, for example, checking modelled traffic flows against count data left over from calibration, checking modelled journey times against actual journey times for both cars and buses and comparing rail loadings against ticket sales data.

- Wait Time

When travelling by public transport, we generally have to wait at the bus stop or train station. Such a wait is generally not considered to be positive and thus adds to the 'cost' of our journey. TMfS includes an increase in the generalised cost of travel to represent this 'wait time'. In short, the longer the 'wait time', the greater the 'cost'.

- Walk Time

We often have to walk to a bus stop and sometimes have to walk to a train station when making a journey by public transport. Walk time is seen as another element of generalised cost incurred when travelling by public transport and this is represented in TMfS through a pre-defined parameter. In short, the greater the 'walk time', the greater the 'cost'.

- Zone Boundaries

Defining the boundaries of zones is a task that requires careful consideration. In general, zone boundaries should take account of:

  - natural barriers – eg rivers, mountain ranges etc;
  - administrative boundaries, such as Census Output Areas and Local Authority boundaries;
  - areas where the land is used in a similar fashion – for example, in TMfS, airports have a zone of their own as do industrial hubs such as Eurocentral; and
  - rail stations – where possible, there should not be more than one station in a zone.

- Zone Centroid Connectors

A special node called the zone centroid is designated to each zone to represent the centre of the trips generated within it. These zone centroids are connected to the adjacent road and public transport networks by one or more zone centroid connectors which enable the demand associated with the zone to join the relevant road or public transport network. These zone centroids represent all of the minor residential streets and rural roads which connect the houses/offices/factories in a given zone to the modelled road or public transport network.

- Zone System

The zone system describes all of the zones joined together.

- Zones

The study area of a model is divided into different zones which represent all of the different geographical areas which are generating the demand for travel in the model (either as the starting or end point of the trips being modelled). The zone structure in a model will usually reflect the level of travel demand (eg small compact zones in urban areas which generate high levels of travel and larger zones in rural areas). Large or unusual generators of travel demand (such as airports, ports and the main roads entering the study area) will often be given their own zone, to allow their pattern of travel to be identified and modelled separately.

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