1. INTRODUCTION

Transport Model for Scotland (TMfS) is a multi-modal transport demand and assignment model with an interactive Land Use model. The model area covers 95% of Scotland’s population. Figure 1 illustrates the area in white. The development of the model was commissioned in 2001 by the Scottish Executive in order to strengthen their modelling capability and to assist in its on-going commitments to integrate transport and land use modelling. The model development was undertaken by MVA.

![Figure 1: TMfS Model area](image)

TMfS is the fourth generation of the Central Scotland Transport Model (CSTM) series, with: significant enhancements in data sources to improve the model calibration (eg 2001 Census, Scottish Household Survey, RSIs, component model data); a 2002 Base Year; extensions to geographical coverage; additional modelling elements (eg an interactive Land Use model, Park and Ride modelling, modelling of congestion charging); and improved model structure.

The principal objective of TMfS is to enable the Scottish Executive and Local Authorities throughout Scotland to test the effects of and/or interaction between major inter-urban road and public transport schemes and major transport policy options in forecast years. Further objectives are to provide robust traffic forecasts on all Trunk Roads and to provide consistent information and modelling framework for local models. The Scottish Executive also make the model available to all local authorities and the Strathclyde Passenger Transport Executive for their own use in the assessment of transport schemes and policies.
The enhanced four-stage, multi-modal transport model contains all the principal traveller responses to policies or schemes such as route or destination change, switching between car or public transport and changes in frequency of trip-making.

The key model outputs include operational analysis, economic and financial analysis, environmental and congestion mapping, sub area models and select link analysis.

This paper provides an overview and description of TMfS and its role in providing a consistent modelling approach and framework throughout Scotland.

2. **MODEL OBJECTIVES**

The objectives of TMfS are as follows:

- provide **robust traffic forecasts on all Trunk Roads** within the model area over a twenty year horizon;

- **enable** traffic, economic and land-use **assessments of proposed major inter-urban road schemes** for Stages 1 (corridor assessment) and 2 (route option assessment) of the roads design process, as specified in the Design Manual for Roads and Bridges;

- **test the effects** of and/or interaction between **major inter-urban road and public transport schemes** and **major transport policy options**, such as:
  - schemes to improve inter-urban public transport;
  - schemes or policies aimed at reducing congestion in accordance with the Road Traffic Reduction Act, National Targets Act and the Transport White Papers;
  - schemes which introduce road user charging (road tolls or congestion charging);

- **provide consistent information** and a **framework** for **local scheme models**, as a basis for the development of Local Transport Strategies or with a view to testing potential strategies.
3. **MODEL STRUCTURE**

**Overview**

TMfS is an enhanced four-stage, multi-modal transport model programmed using elements of Citilabs Cube software suite. The model contains the principal traveller responses to policies or schemes such as:

- **Route Choice** (to change route);
- **Mode Choice** (to change mode between public transport and car);
- **Destination Choice** (a longer term choice to change origin (for example 'where you live') or destination (for example 'place of work');
- **Trip Frequency** (to choose whether or not to make a trip); and
- **Peak Spreading** (to move the time of AM Peak journey from the peak hour to the shoulders of the peak period).

The main model structure is made up of the principal components outlined in Figure 2.

The Land Use, Demand and Assignment Models all function using the same zone system. This system contains 1096 zones within the modelled area (as illustrated in Figure 1) and 37 external zones which cover the rest of the UK mainland. Each zone is based on an aggregation of the 2001 census output area boundaries.
Land Use Model

The **Land Use Model** utilises local planning and economic growth assumptions to determine future levels of planning data. This information is in turn converted into Trip Ends (origins and destinations by travel purpose, time period, zone and car ownership) using National Trip End Model (NTEM) parameters. These levels of demand are then fed into the **Demand Model**.

The **Land Use Model** undertakes two principal functions. Firstly, it takes agreed scenarios regarding the Scottish economy, population and forecasts where people will live, how many will own cars, and where jobs will be located, combined with patterns of trade that give rise to freight transport. It takes account of planning policies and household, business and developer behaviour. The analysis provides inputs to the **Demand Model**, which forecasts the resulting travel patterns. Secondly, the **Land Use Model** is sensitive to the transport conditions modelled in the **Demand and Assignment Models** and shows how the growth or regeneration of different areas will be affected by transport policies, congestion, etc. over time.

The **Land Use Model** is an extension of similar modelling procedures developed for the Central Scotland Transport Corridor Studies, and is being implemented as a new model based on 2001 Census data. It draws on experience in modelling Edinburgh, Strathclyde and several regions in the North of England.

Demand Model

The **Demand Model** combines mode choice, destination choice, peak spreading and trip frequency, taking account of trip suppression and trip induction for five travel purposes. This turns the trip ends of the **Land Use** and **Trip End Model** into hourly assignment matrices for both Highways and Public Transport.

The **Demand Model** functions in person trips at time period level (AM Peak – 07:00-10:00, Inter Peak – 10:00-16:00 and PM Peak – 16:00-19:00) and by five travel purposes, namely:

- **Home Base Work (HBW)** – Travelling from home to work (and back again) – a typical commuting journey;
- **Home Based Other (HBO)** – Travelling from home to a Non-Work related location such as shopping or leisure;
- **Home Base Employers Business (HBEB)** – Travelling from home to a destination where you are in employers time;
- **Non Home Based Other (NHBO)** – 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 Employers Business (NHBEB)** – Travelling during employers time such as attending a business meetings through the day.
These travel purposes are further segregated by two person types, namely:

- non-car available; and
- car available.

Highways Assignment Model

The Highways Assignment Model undertakes the route choice element and assigns In-Work, Non-Work, LGV and OGV demand (with preloaded bus flows) to the road network. The assignment model operates for the AM Peak (08:00-09:00), Inter-Peak (1/6 of 10:00-16:00) and PM Peak (17:00-18:00) hours in units of PCUs.

The assignment process uses volume averaging capacity restraint that iterates until a user specified level of convergence is achieved. This modelling process is also capable of assessing congestion/toll charging.

The Highway network contains over 23,500 links and 1850 modelled junctions. It has been built using over 250 RSI surveys, calibrated to 475 one way link counts and validated to 421 one way link counts and 57 journey time routes.

Public Transport Assignment Model

The Public Transport Assignment Model assigns public transport trips between rail, bus and underground modes and calculates resultant travel costs. The Model includes over 1300 Public Transport Services and operates for the same modelled hours as the Highways Assignment Model, but in units of person trips.

The Highways and Public Transport Assignment Models provide transport costs back to both the Demand and Land Use Models.

Demand Model Convergence and ‘Looping’

The overall model process operates a looping process to achieve model convergence between the Demand and Assignment Models (as illustrated on the left hand side of Figure 2). The Demand Model has a specially commissioned convergence process for supply demand equilibrium, based on one of the algorithms currently implemented in DIADEM.

A further interactive looping process exists between the Land Use Model and the Transport Model whereby transport costs are fed to the Land Use Model at five year intervals.

Secondary Analysis

Secondary Analysis is where further analysis of model outputs for use in scheme and/or policy appraisal is undertaken (eg operational, environmental and economic analysis). This is discussed further in Section 6.
4. DATA SOURCES

A wide range of data sources were utilised to prepare both the Transport Model and the Land Use Model. The principal data sources were as follows:

- **2001 Census data.** This data was principally used within the Land Use Model. Aggregations of 2001 Census output area boundaries were also used to define the Transport and Land Use model zonal boundaries. This simplifies the process for local authorities to prepare planning data over the previous CSTM3 zone boundaries;

- **The Scottish Household Survey.** This data assisted in the development of some aspects of the demand model;

- **Donor Transport Models.** A number of transport models already existed within the TMfS modelled area, most notably: CSTM3 and 3A, KWAM (Kincardine Wide Area Model) and SITM4. These models provided such information as network and junction specification, demand and survey data;

- **Survey Data.** In addition to historic data, a related programme of road traffic data collection surveys involving a series of roadside interviews, classified traffic counts and journey time surveys throughout the modelled area was undertaken during 2002.

  Public Transport surveys carried out for SITM4 were complemented by further rail and bus surveys within the TMfS data collection programme.

  The Scottish Roads Traffic Database was interrogated to provide further traffic count data. In addition, Local Authorities within the modelled area were approached for provision of any relevant Highways or PT based survey data that could assist in model development;

- **Planning Data.** Local Authorities within the modelled area were also approached to provide planning data for each TMfS zone. This data is used by the Land Use model, along with changes in transport costs from the Transport Model, to provide forecast planning data for each zone in the model.
5. MODEL APPLICATION

TMfS has a Base Year of 2002. Forecast trip ends for 2006, 2011 and 2021, in line with local authority planning data forecasts, have been prepared for the model at this time, although in theory, intermediate years could be prepared by interpolation.

TMfS, along with the Land Use model, provides an ability to forecast changes in both Land Use and travel patterns throughout the TMfS modelled area. The modelling package can be used to test different Highways and Public Transport infrastructure schemes or policy initiatives. In addition, the model can be used to analyse the transport demand consequences of different land-use and economic growth assumptions.

TMfS tests are defined using the convention of Reference and Variant Cases. These can then be analysed to compare the impacts of a range of Do Something options against a Do Minimum.

Since the development of CSTM3, this model package has been used for a wide range of transport assessments both as a strategic model and to provide further information for local transport assessments and local models – the latter exploiting the models further use as a database of information.

Throughout these applications, and considering the geographical coverage of TMfS, it offers a consistent modelling approach both for scheme assessments and to supply sub model data throughout a wide area. Consequently and dependant on the scheme or policy options being assessed, there can be significant data sharing and cost savings in utilising TMfS as a resource.
6. **MODEL OUTPUT**

The key model outputs available from TMfS are:

**Operational Analysis**

Including;

- **Link Flow Analysis.** This provides volumes of traffic (as a total, or broken down by vehicle classification) for links in the network (see Figure 3);

- **Select Link Analysis.** This provides routeing analysis for assigned vehicles at selected links (and combination of links) throughout the modelled network (see Figure 4);

- **Matrix data.** Zonal and sectored levels of demand which facilitate the analysis of modal and destination choice changes;

- **Junction and link delay analysis;** and

- **Journey Time Isochrones and route analysis (see Figure 5).**

![Figure 3: Flows](image1.png)  
![Figure 4: Select Link](image2.png)  
![Figure 5: Isochrones](image3.png)

Operational analysis can be presented in tabular (spreadsheet based) or graphic form (using a GIS system or Cube Graphics).
Economic and Financial Analysis

The Highways and Public Transport Assignment Models can provide the relevant inputs required to undertake cost benefit analysis and subsequent preparation of TEE tables. At present, the recommended software for undertaking further economic analysis of the model outputs is TUBA (prepared by DfT). In conjunction with operational analysis, toll revenues can also be calculated.

Land Use and Accessibility Analysis

Graphical and tabular analysis of changes in Land Use can be prepared. In addition, this can be linked to the operational analysis of the transport model to provide accessibility information (see Figure 6).

Figure 6: Planning Data Changes and Accessibility Analysis

Environmental and Congestion Analysis

Within TMfS, a method for undertaking emissions analysis is to use the MVA software ENEVAL (see Figure 7). ENEVAL was specifically developed to interrogate Cube model networks and extract the relevant speed and flow information for each Highway link and, thereafter, undertaken emissions calculations based on the most up to date DMRB guidance, for CO, CO₂, NOₓ, PM10 and HC.

Figure 7: Environmental Mapping
The ENEVAL procedure is based on road traffic flows and speeds. For every link in the network, levels of emissions values are calculated. Emissions can then be prepared by time period, annually, by link, by zone or by a user defined geographical area within the model (although there are limits to the accuracy of the model, with finer levels of disaggregation).

A further level of functionality within the TMfS modelling suite is to be able to map these emissions within a GIS system using a user defined grid system. This can be undertaken for either a single model scheme option or to compare model results (eg between a Do Minimum and a Do Something) across sub sections of or for the entire modelled area.

Congestion analysis is similar in approach to mapping environmental analysis in that a GIS system is used to present model output in a similar way (see Figure 8). General levels of congestion are calculated by adding up levels of delay for each link and junction in the Highways network and apportioning that delay to user defined grid square sizes.

In the application of this methodology, congestion is defined as ‘Vehicle Hours Lost by travel time below freeflow conditions’. This means that, as more traffic builds up on the network, traffic will generally travel slower (capacity restraint or ‘congestion’ effects), the travel time difference between freeflow and capacity restrained conditions is then calculated to be representative of levels of congestion. In theory, other formulations of ‘congestion’ could be applied to this methodology and subsequently mapped.
Sub Area Analysis

Sub area models of TMfS can be defined (see Figure 9) and data (with respect to network definition and demand) can be extracted and thereafter used to run undertake scheme option testing. In addition, the sub area model could be enhanced to provide a detailed local model.

TMfS (and previously CSTM3) has frequently been used to supply levels of demand and external (strategic) growth to a variety of local models (SATURN, VISSIM, PARAMICS and Cube models).

Model Database

The TMfS modelling suite also serves as a database with a wide range of transport and planning information, including both input (eg survey, network) data and output (eg flows, emissions) data from model results.

This data has a wide range of applications beyond the provision of data to other models.

A web site has been created to disseminate information about the model (including reports), provide a database of information and model output (see Figure 10).

The web site also contains a web based interactive GIS system where visitors can view, manipulate, interrogate and download TMfS map based information (see Figure 11).
7. MODEL AVAILABILITY

TMfS is available to all local authorities and the Strathclyde Passenger Transport Executive for use in the assessment of transport schemes and policies with agreement of the Scottish Executive. The model can also be made available to consultants working for local authorities on specific projects. With the agreement of the Scottish Executive, the model can also be run by MVA.

The model can prepared and provided as a Release Version on a project specific basis with authorisation from the Scottish Executive.

The Release Version includes;

- **TMfS.** This includes the Demand Model, Highways and PT Assignment Models, Base Year (2002) demand matrices, forecast trip ends for 2006 and 2011 (it is envisaged that additional forecast trip ends will be made available via the TMfS web site), example model run files, User Interface (see example screenshot in Figure 12), ENEVAL, Park and Ride assessment procedures, congestion and environmental mapping procedures, GIS tables;

![Figure 12: User Interface](image)

- **User Manuals** covering TMfS, ENEVAL, Congestion Mapping and Park and Ride processes; and

- Provision of **assistance** and **advice** on the use of the model from MVA.

The Release Version does not include Cube software, the Land Use Model or the Trip End Model.

It is envisaged that Technical Workshops and User Group meetings will be held to inform users of enhancements, to undertake training and to provide a forum for feedback from users of the model and model data.
8. CURRENT STATUS

TMfS was completed in August 2004 and has been used on a number of scheme and data provision projects. The model is currently available both as Release Version and on a bureau basis. It is also possible to extract information from the modelling database via the web site, through the Scottish Executive and MVA.

As part of the Scottish Executives quality assurance procedures for transport modelling, an independent technical audit of TMfS is being undertaken and is nearing completion.

There are ongoing enhancements to the model, most notably additions to the web site, planned enhancements such as the preparation of reference case options and potential enhancements such as the collection of up to date planning data within 2005. In addition, feedback from model users and model data users will also provide input to model development.

9. Further Information

Further information and background regarding TMfS and the contents of this paper can be obtained from:

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