New tools to evaluate Intelligent Transportation Systems - the SMARTTEST project

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INTRODUCTION

Traffic congestion is a major scourge of modern life. In the UK alone it has been estimated that congestion costs the economy £15bn every year. It is now commonly accepted that trying to solve the congestion problem by building new roads will not work and is unacceptable. Road building is not only expensive and damaging to the environment but it also only provides a temporary respite to the problem. Soon after new roads have been built they induce extra traffic that negates all the benefits produced by their construction.

An alternative approach to alleviate congestion is to develop Intelligent Transportation Systems (ITS) that help make more efficient use of the existing road space. Responsive traffic control systems have been developed which measure on-street traffic flows and adapt signal timings accordingly to minimise delays. They can also detect and give priority to Public Transport vehicles. Ramp metering systems ensure traffic on motorways flows smoothly. Roadside Variable Message Signs (VMS) are used for incident management, speed control and parking guidance systems. Automatic Intelligent Cruise Control (AICC) systems allow fast moving platoons of motorway vehicles to be created and thus increase motorway capacities. Dynamic Route Guidance (DRG) systems let equipped vehicles choose the fastest route to their destinations and respond to incidents and congestion in real time. Road charging and zone access systems allow extra revenue to be collected from drivers during periods of peak congestion.

Anyone considering using one of these new traffic management control or information systems needs to be able to predict the consequences of its introduction. They need to know both whether it works and how well it works, as it is often necessary to quantify the benefits of the new system so that they can perform a cost benefit analysis. Any disbenefits need to be identified to determine whether they are acceptable. For example a route guidance system might reduce queues in one part of the network but direct traffic through another part where it is not welcome, such as past a school or hospital or through a residential area. A wide range of performance indicators should be examined so that safety and environmental impacts can be assessed as well as efficiency. It is also useful to be able to optimise the operation of the new system to get the best out of it in the chosen location. Training in using the new system is required to ensure that it is operated correctly and efficiently.

The evaluation of these new systems to quantify their benefits can be difficult. One way would be to put the new system out on street in a before and after trial, but these trials can be difficult to assess. Many new systems are expected to have modest benefits, e.g. a new urban traffic control system may reduce travel times by less than 10%. Travel times however vary a lot from day to day anyway, so it is can be hard to determine whether any measured changes are due to the new system or simply due to chance. It is often difficult to determine whether any measured changes are due to the introduction of the new system or are due to inherent variability in the network conditions. A more promising approach is to use a traffic model to assess the system. Then the traffic engineer has complete control over the network conditions and before and after cases can be compared with greater confidence in the results.

THE ROLE OF MICRO-SIMULATION MODELS

Traditional traffic models often treat traffic as homogenous platoons that obey simple speed / flow relationships. Such models find it difficult to assess the effectiveness of ITS which often requires interactions between individual vehicles and the new systems to be modelled.

Micro-simulation models are becoming increasingly popular for the evaluation and development of ITS. These are computer models where the movements of individual vehicles travelling around road networks are determined by using simple car following, lane changing and gap acceptance rules.
Improvements in computer performance now mean that it is possible to model peak periods on quite large road networks (hundreds of junctions and typically tens of thousands of vehicles per hour entering the network) at the micro level with a typical office PC.

An essential property of an Intelligent Transportation System is that it responds to changes in network conditions. Many implemented systems interact with individual vehicles. Responsive signal control, public transport priority and ramp metering systems react to vehicles approaching junctions. Dynamic Route Guidance systems supply specific information to individually equipped vehicles. Intelligent Cruise Control systems adjust the speeds of equipped vehicles. Therefore to assess the potential benefits of using an Intelligent Transportation System it makes sense to use an assessment tool that is capable of modelling interactions at the level of individual vehicles.

Micro-simulation models, which can reproduce individual driver behaviour, should therefore be an essential part of any such assessment tool. Moreover, as individual vehicles are being modelled it is often possible to use the micro-simulator as a proxy for the real world and connect it to real systems directly. This negates the need to produce a model of the system being assessed. For example, suppose one wanted to evaluate the benefits of introducing a responsive Urban Traffic Control (UTC) system, such SCOOT, SCATS, UTOPIA or PRODYN. It is straightforward to link up one of these UTC systems to a micro-simulation package. The micro-simulator provides the UTC system with vehicle flows as simulated vehicles are counted by simulated detectors and the UTC system provides the micro-simulator with signal settings that it has determined will minimise costs.

Micro-simulation can be used to develop new systems and optimise their effectiveness. They can easily estimate the impacts of a new scheme by producing outputs on a wide range of measures of effectiveness. Many of these impacts, such as the amount of pollution emissions, are often difficult to measure in the field. Micro-simulation tools are also capable of providing realistic training for system operators and users prior to operation in the real world.

THE SMARTEST PROJECT

In its Fourth Framework Programme the European Commission realised the importance of micro-simulation and put out a call for project proposals to develop microscopic modelling and simulation tools. The SMARTEST (Simulation Modelling Applied to Road Transport European Scheme Tests) project was funded to answer this call. The project started in March 1997 and was completed in July 1999. It was a multi-national collaborative effort. Partners came from the UK (University of Leeds, project co-ordinators), France (CERT and SODIT), Spain (UPC), Sweden (CTS and Transek) and Italy (Mizar and Softeco). Four micro-simulation tools were enhanced by the partners: AIMSUN2\(^4\) (UPC), SITRA-B+\(^5\) (CERT/SODIT), DRACULA\(^6\) (ITS) and NEMIS\(^7\) (Mizar) as part of the project.

The SMARTEST project was directed towards modelling and simulation of dynamic traffic management problems caused by incidents, heavy traffic, accidents, road works, and events. It covered: incident management, intersection control, motorway flow control, dynamic route guidance and regional traffic information.

The project's objectives were to:

- review existing micro-simulation models, so that gaps can be identified.
- investigate how the existing models can best be enhanced to fill the identified gaps, thus advancing the State-of-the-Art. Prime objectives of these enhancements were to ensure that they would be transferable across Europe and that they were based on sound statistical analysis.
- incorporate the findings of the study into a best practice manual for the use of micro-simulation in modelling road transport and to disseminate these findings widely throughout Europe.

The main outputs of the project were: a State-of-the-Art review of micro-simulation models, an enhanced set of micro-simulation tools for helping network managers solve their short term traffic management problems and a best practice manual detailing guidelines and procedures for their selection and use.
REVIEW OF MICRO-SIMULATION TOOLS

A review of existing models and simulation tools was performed to find problem areas that need to be modelled when developing solutions to short-term traffic management problems. A bibliographic search was carried out to find micro-simulation model developers. The search revealed the existence of fifty-seven micro-simulation models. A written questionnaire was sent out to each of the developers of these models. Thirty-two replies were received, allowing the simulation models to be analysed in a systematic fashion. Virtually all the major model developers replied to the questionnaire. The user requirements for micro-simulation models of traffic were also investigated. Data was again collected from a questionnaire, this time one was sent out to known users of road traffic micro-simulation models. In this way gaps that existed between current micro-simulation model capabilities and users’ requirements were identified.

Nearly all the models use a time stepping approach where the vehicles are moved around the road network using a fixed time step, typically at one-second intervals. Only three models use an event-based approach where the states of objects in the network are changed at discrete times in response to events on an event list. Simple car following, lane changing and gap acceptance laws are used to govern vehicle movements along road links.

The number of vehicles using the network is defined by specifying origin-destination (O-D) data. The routes vehicles take have to be determined from the input O-D data. This can be done using an assignment model. Some of micro-simulation models have an assignment model or a simple dynamic route choice model built-in. Others are closely integrated with a separate assignment model allowing common use of inputs and outputs. Some of the models do not do any assignment themselves; they assume that this will be done using an external model.

Most of the models have the capability of displaying an animation of the vehicles moving round the network as the simulation progresses. Very few have a graphical network builder, which can reduce the amount of time required to input the network details considerably (see Figure 1). Most of the models provide outputs that allow efficiency indicators to be measured. These usually include travel times, travel time variability, queue lengths and vehicle speeds. About half the models now include fuel consumption and pollution emission outputs allowing environmental objectives to be assessed. Very few models produce outputs to measure safety or comfort indicators.

Most of the models are flexible in the way that key parameters can be user-defined. Integration with other models and with other databases is not so easy. Typical execution speeds are of between 1 and 5 five times faster than real time.

Most of the micro-simulation models studied have been developed to quantify the benefits of Intelligent Transportation Systems, primarily Advanced Traffic Management Systems and Advanced Traveller Information Systems. The scale of application ranges from a small number of vehicles and intersections to a large number, about 200 nodes and many thousands of vehicles. Huge networks (300+ nodes and 1 million+ vehicles) can be considered by models that run on parallel architectures.

The models are usually used to estimate traffic efficiency in terms of speed and travel time, sometimes also considering congestion and queue length. They mainly concentrate on simulating traffic signal control, route guidance and traffic condition estimation. Motorcycles, bicycles, pedestrians, public transport, weather conditions and on-street parking receive little attention.

A total of fifty-one responses were received from the User Requirements Questionnaire. These came from fourteen different countries, mainly from the US, UK, France and Sweden. Half of the sample represented research organisations, another quarter road authorities, 14% were private consultants and 9% manufacturers.

The main gaps identified were a need for improved models for incident management, adaptive signal control, public transport priority, ramp metering, variable message signs, dynamic route guidance, public transport stops, vehicle detectors, roundabouts, parking and traffic calming measures. Better user interfaces and more work on validation of the existing models is also needed.
ENHANCEMENTS TO THE SMARTTEST SIMULATORS

Generic models and procedures were then specified and developed to fill the most important gaps. The new models and procedures were developed and validated using data collected from sites in Barcelona, Toulouse, Stockholm, Leeds, Turin and Florence. The SMARTTEST micro-simulation models have been enhanced to include the new models. Comparisons were made between the new model outputs and the data collected. Table 1 shows the enhancements that were made to the four SMARTTEST micro-simulation models during the project.

AIMSUN2

Improvements to the incident generation model included deterministic and random incident generation. Deterministic incidents are defined either through the user’s interface or by means of an incidents log file. Random incidents can be generated according to certain random distributions that are variable according to certain section characteristics.

The adaptive traffic signals improvements consisted of a new and more flexible definition of the traffic control plans and the development of a new interfacing protocol between AIMSUN2 and any external traffic control or management application. This link was implemented by the use of Dynamic Link Libraries (DLL) through which any user can implement or communicate any control or management strategy. Through this interfacing protocol it is possible not only to control any traffic signal but also any ramp metering or Variable Message Sign.

Regarding VMS and Dynamic Route Guidance Systems (see Figure 2), a better behavioural model that emulates the influence that routing information may have on the drivers was implemented. To achieve a better characterisation of the drivers, several former global parameters were transformed into local or individual parameters (i.e. compliance level and speed acceptance parameters).

A new Result Analysis Tool was developed. Its main functions are to define and conduct simulation experiments, to perform results analysis and make data representation and to provide statistical tools for model calibration and validation.

DRACULA

Improvements in the PT services model included a new bus stop model and the development of guided bus (see Figure 3) operations. New roundabout and traffic calming models were developed, which were calibrated and validated using data collected in Leeds.

The adaptive traffic signals improvements developed a link from DRACULA to a BALANCE UTC system. The improvements in the detector model in DRACULA concentrated on providing the BALANCE system with the on-street information it required. As well as the usual loop detector data this also included both public transport and emergency vehicle location information. PT Priority looked at the priority measures to both buses and trams that are provided by the BALANCE system. A test network in London was used to calibrate and validate the new models.

NEMIS

The main improvement to the NEMIS model was the standardisation of the interface between the micro-simulation model and external ITS applications. This activity involved producing an interface based on a TCP/IP communication protocol that was adopted to connect the computer where the model runs to the external strategy modules.

Parameters such as driver compliance to VMS and DRG indications were calibrated against the information made available by surveys conducted in the test-site by other projects. Data collection was also carried out to improve the calibration of the car following rule.

SITRA-B+

The improvements to the public transport services modelling consist of a better definition of routes, schedules and stops. The ability to model bus stop lay-bys, including new behaviour rules for pulling into or out at the bus stop, has been added.
A complete roundabout model was implemented. This new development addresses both driver and vehicle behaviour models. Simple rules were defined in order to deal with lane changing decisions both approaching and driving on the roundabout, and new behaviour parameters were introduced for the gap acceptance model when joining the roundabout. Video data from a test site in Toulouse was used for the validation of this roundabout model.

The Parking Management model improvements mainly deal with on-street parking. Parking places are not considered as destination or origin nodes, but as intermediary destination nodes with a given stopping probability. A series of parking spaces at precise locations is associated with each street parking node. Mean and standard deviations of parking duration are parameters that can be set by the user for each street parking set.

Improvements were also made to the VMS model and the Incident Management model.

BEST PRACTICE MANUAL

A best practice manual directed towards modelling and simulation of dynamic traffic management problems was produced. It covered incident management, intersection control, motorway flow control, dynamic route guidance and regional traffic information. It included:

- a methodology for defining scheme objectives and relating them to performance indicators,
- a set of guidelines for selecting a suitable micro-simulation model,
- a comparison of micro-simulation with macro-simulation,
- calibration and validation procedures, with examples from the SMARTTEST test sites,
- procedures to help ensure that scheme evaluation tackles issues such as robustness of conclusions, introducing variability and statistical significance,
- recommendations concerning when and how micro simulation models should be used.

A full description of the project and all the SMARTTEST project reports can be found on the project web site at: http://www.its.leeds.ac.uk/smartest/

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References


Figure 1: AIMSUN2 is one of the few micro-simulation tools with a graphical network builder
Figure 2: SITRA-B+, AIMSUN2 and NEMIS all enhanced their dynamic route guidance models
Figure 3: DRACULA can now model kerb guided buses
Figure 4: The new roundabout model in SITRA-B+
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Table 1: Improvements and new implementations in the SMARTEST models.

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