Smartest

Simulation Modelling Applied to Road Transport European Scheme Tests

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Best Practice Manual

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1 INTRODUCTION

1.1 Advantages of micro-simulation

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 which negates all the benefits produced by their construction.

An alternative approach to alleviate congestion is to develop Intelligent Transportation Systems (ITS) which 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 are used for incident management, speed control and parking guidance systems. Automatic Intelligent Cruise Control Systems allow fast moving platoons of motorway vehicles to be created and thus increase motorway capacities. Dynamic Route Guidance 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 of 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 also 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.

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 which 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 as shown below. 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 measures, such as pollution emissions are difficult to measure in the field. Micro-simulation tools are also capable of providing realistic training for system operators and users prior to implementation in the real world.

Micro-simulation packages can therefore be used to help solve short-term traffic management problems caused by accidents, heavy traffic levels, incidents, road works and events. A significant product of the SMARTEST project is this manual of best practice for use of enhanced micro-simulation tools. It is our desire, that this manual will support users in dealing with specific traffic management problems such as congestion, shock-waves caused by traffic disruption, harmful emissions etc. and to get the most out of existing simulation tools.

A review of existing models and simulation tools has been performed to find problem areas that need to be modelled when developing solutions to short-term traffic management. User requirements for micro-simulation have been identified via a questionnaire sent out to research organisations, official transport planners and private consultants. Users want to apply micro-simulation to evaluate on-line applications, control strategies and large-scale schemes and also to carry out product performance tests. The most popular objects and phenomena that users would like to be able to model include incidents, public transport stops, roundabouts and commercial vehicles.

Based on the identification of modelling gaps, enhancements of the four models AIMSUN, DRACULA, NEMIS and SITRA B+ have been made. Validation has been conducted based on existing data sets and on new data collected from test sites in Toulouse, Barcelona, Genoa and Leeds. A transferability study of the models has been made using test sites Stockholm and Leeds. The Best Practice Manual is based on the experience gained from testing and using the models.

1.2 Need for the manual

According to the user questionnaire, micro-simulation is considered as a necessary or useful tool for analysis of dynamic traffic conditions. The scale of application ranges from single roads up to city applications with a time horizon from today to several years into the future. Choosing the best traffic management solutions requires the use of tools, which produce realistic results in all traffic conditions. The tools need to be well validated and procedures for calibrating them and applying them consistently need to be defined.

Users are interested in obtaining indicators of traffic efficiency, expressed in terms of travel time, congestion, travel time variability, queue length and speed, safety and environmental indicators and vehicle operating costs. Transport telematics or technological functions that users most wish to be able to model using micro-simulation are adaptive traffic signals, co-ordinated traffic signals, priority to public transport vehicles, vehicle detectors, ramp metering, incident management, variable message signs, dynamic route guidance and motorway flow control.

According to the questionnaire it is also important that the most significant factors are taken into account and are based on validated field studies. The emphasis on validation is a reflection of the uncertainty concerning behavioural relationships. In the Best Practice Manual important issues from a user perspective, such as selecting a suitable micro-simulation package, and calibration and validation procedures are addressed.

1.3 Potential micro-simulation users

It is envisaged that the main users of the manual will be transport practitioners working in local authorities, central government and consultancies, as well as transport researchers and academics. The main users up to now seem to be researchers and only to a lesser extent local authorities. An objective for the Best Practice Manual is to enhance the use of micro-simulation for suitable dynamic transport problems and also to reach decision-makers as well as model users.

1.4 Scope of the manual

Traffic management problems caused by accidents, incidents, road works, events and heavy traffic are the main focus of the manual, which will be discussed in **Chapter 2**. One group of problems is related to avoidance of secondary accidents and maintaining road capacity following incidents. Another group is related to network capacity. A third group of problems is related to warning and advice. Demand oriented problems such as trip planning and automatic debiting will not be dealt with.

Simulation tools can be used on-line for dynamic traffic management or off-line for design and testing of control strategies. **Chapter 3** discusses the steps required to perform a traffic simulation study. This includes the choice of the area to be modelled, the collection of data to calibrate and validate the model and the analysis of the model outputs. Specific user requirements that are discussed in **Chapter 4**, are user friendliness, short lead-time before use, validated results, limited need for expensive data acquisition and high cost effectiveness when comparing quality of result and resources in time and money spent in the simulation. Based on the review of existing micro-simulation models a set of guidelines for selecting a suitable micro-simulation model is presented in **Chapter 5**.

In the Stockholm test-site, results from macro simulation as well as micro simulation runs are available. This has given an opportunity to compare the two different approaches, which may give an idea of the improvement in accuracy that can be expected from micro simulation modelling. This question is discussed in **Chapter 6**. **Chapter 7** describes the data you need when you work with a micro simulation model and the different ways to collect this data. Calibration and validation guidelines will be presented in **Chapter 8**. This includes examples from the five SMARTEST test sites Stockholm, Toulouse, Barcelona and Leeds. Both dynamic data and static data are needed for validation. Experience from the transferability study is also presented. A spread of European values for parameters, e.g. car following, desired speeds, emission rates etc. are provided. Further details on the processes involved in the formulation of scheme objectives are presented in **Chapter 9**. Examples of how the SMARTEST micro-simulation models have been enhanced to meet users' requirements are presented in **Chapter 10**.

Given the results from the evaluation and validation at the test sites and the comparison between macro and micro modelling, recommendations are made in **Chapter 11**. They concern when and how micro simulation models should be used in assessing the benefits of ITS investments as well as advanced control strategies for traffic management.

2 TRAFFIC MANAGEMENT PROBLEMS

2.1 Introduction

The traffic engineer is of course interested in studying the effects of measures in the traffic system. In addition, he/she wants to study effects of combinations of measures and co-operating systems. Micro simulation models are used for design and testing of control strategies that can solve traffic management problems. This chapter describes such traffic management problems; the problems, the transport telematics functions that could help solve them as well as the role of simulation. In chapter five of this document the perspective will be the reverse: a method for choosing a relevant micro simulation model for each problem is outlined.

Traffic management problems caused by accidents, incidents, road works, events and heavy traffic are the main focus of the manual. One group of problems is related to avoidance of secondary accidents and maintaining road capacity following incidents: Such problems are helped with telematic functions such as Incident management and Traffic Calming.

Another group is related to network capacity, dealt with by Adaptive Signals, Public transport priority, Motorway flow control and Ramp metering. Design of roundabouts and more conventional signal co-ordination are also used to this end.

A third group of problems is related to giving information, both warnings and on-trip advice. This advice is given by information on VMS-signs or by Dynamic route guidance. Trip planning measures as Parking Management and Public Transport Information are also in this group.

Demand oriented problems such as trip planning and automatic debiting will not be dealt with here (though DRACULA has a feature for congestion pricing).

2.2 Maintaining road capacity and avoidance of accidents

In an urban network where the effective capacity is sufficient, incidents will be the main problem. The remaining capacity during disruptions depends on the philosophy and strategy of the rescue organisation. Incident handling has so far often prioritised safety and security aspects, which in some cases lead to longer waiting times for vehicles queuing up behind the incident. These kinds of problems could be diminished by use of *incident management*, aiming to shorten the duration of time that an incident influences the traffic situation in the network.

Traffic calming is primarily a traffic management measure for controlling speed in built up areas. Effective traffic calming schemes are made up of a combination of measures. It is essential that traffic calming is set within a coherent policy framework, taking into account a range of transport and lane use policies

Incident management

The objective of incident management is to minimise effects of planned disturbances (such as road works) as well as those of unexpected incidents (such as accidents, vehicle breakdowns) and thus shorten the duration of an incident's impact on the traffic situation. Incident management can be improved by the use of new technology in each one of the four different phases of the incident's duration

- Incident detection
- Handling of information when the incident is reported
- Turn-out

- Clearance

Incident management involves collection and filtering of different emergency calls and supply of correct intervention schedule. It also transmits emergency communications to a control centre following a malfunction or an accident.

Automatic Incident Detection (AID)-systems may reduce the lead-time during rescue operations. They will however always be associated with time lags, processing time and turn out times as indicated by time-to-detect measurements.

Clearance time on the scene of the accident and processing time in the Traffic Management Centre (TMC) will be improved with Incident management.

Traffic calming

There are a large number of traffic calming techniques which can generally be classified into the following groups:

- Reallocation of carriageway space to non-traffic by redesigning and enhancing the street environment, such as widening footways, redefining road space to provide parking, using street furniture, etc.
- Road narrowing, such as use of build-outs, chicanes, pinch points, gateways.
- Speed interruption, measures such as road humps, bar-marking, speed cushions, central islands and small corner radii.
- Flow interruption, which includes measures to break-up a road into shorter sections to slow traffic, such as false roundabouts, mini roundabouts, junction priority changes, and the use one-way streets to make indirect routes.

Traffic calming measures can be further classified into two categories: *traffic management measures* and *network supply side measures*. The traffic management measures include the use of one-way streets and changes of junction priority, the aim of which is to manage the traffic flow without having to alter the road structure. In terms of network modelling, the first category can be covered within general traffic management modelling, hence will not be specified further in this document.

Most traffic calming measures, however, involve changes in the road surface either vertically or laterally to some degree. Some of them are unique to traffic calming schemes which are not normally represented in network models, such as road humps, speed cushions, and pinch points. A traffic-calming model needs to be able to represent a road with variable width and gradients, and to represent drivers’ behaviour in the presence of these measures.

2.3 Network capacity

Design and analysis of intersections is perhaps the most traditional and straightforward application of micro simulation, whether it be ramp junctions and weaving areas on motorways or urban intersections controlled by priority or signals.

Intersection control implies the improvement of traffic flow and capacity at intersections, based on the allocation of safe and effective priorities to different categories of road users.

Evaluation of *adaptive signals* is interesting bearing the present modernisation in mind. Adaptive signals as opposed to traditional co-ordinated signals need to be evaluated.

Public transport priority is interesting with regard to the different public transport priority systems throughout the world. It is important to show how advantages for public transport influence private cars and trucks, and how the trip time for passengers are influenced by the priority.

The local and global effects from traffic signal systems are of course crucial for intersection control. Any area-wide queue management strategy must also be considered. It is further necessary to take the redistribution effects into account.

To deal with *capacity problems on motorways* the use of a control strategy consisting of speed recommendations, speed limitations, lane closure and ramp metering is required in order to reduce congestion and the risk of accidents. The actuation of traffic signals and variable message signs is included, which allows speeds to be locally optimised.

Adaptive signals

Urban Traffic Control Systems (UTCS) test and evaluation has for a long time been one of the main application fields of microscopic traffic simulations. Many traffic control strategies already exist. There are also many under development. Due to this fact, it is clear that the simplest way to integrate them in the simulation process is to consider each of them as a *separate* software module, able to communicate with the simulation tool.

This of course implies that all the basic components addressed by such strategies (traffic signals, loop detectors, etc) are correctly modelled in the microscopic simulation tool, and that a communication protocol is available for data exchange between the strategies and the simulation tool.

Such specifications suggest the need for a framework, enabling fixed time traffic signal plans, signal plan changing strategies and more sophisticated adaptive signal strategies such PRODYN or SCOOT to be modelled.

Priority to public transport vehicles

The idea of developing priority systems for Public Transportation comes from the basic objective of giving priority to *person movement* as opposed to *vehicle movement*, that is to say to ease the movement of vehicles having a higher occupancy rate.

The strategies aiming at giving priority to Public Transport vehicles usually combine two kinds of techniques. The first one uses network layout, such as reserved lanes, and the second one deals with the development of specific traffic signal control algorithms, using information given by detectors able to detect and in some cases to communicate with PT vehicles (usually buses).

Roundabouts

A roundabout junction works, as a one-way circulatory system around a central island where entry is controlled either by give-way markings and priority must be given to traffic on the roundabout (for example the UK practice), or by signals.

Roundabouts are commonly used in a road network when either:

- traffic flows on major and minor traffic arms of a junction are at medium levels
- there is a large farside turning flow,
- the road changes in character from a fast flowing inter-urban road to a more congested urban situation,

- a U-turn facility is required.

The layouts of roundabout junctions are usually more complicated than other types of junctions such as signalised or priority junctions. Driving behaviour is also more complex due to the higher level of driver/vehicle interactions on the junctions.

Motorway flow control

The purpose of motorway flow control is to increase the capacity and to reduce the number of secondary accidents on motorways. This can be accomplished in two ways; by controlling the on-flow to the motorway, by ramp metering (described below), or by ensuring that the traffic on the motorway flows as fast and smooth as possible (Motorway Control System, MCS)

The capacity could be increased by control of the speed on the motorway. Saturation flow, that is the flow when the traffic situation becomes unstable, is higher at lower speed as braking and other small events have less impact on the traffic when the speed is lower. The saturation flow has its peak when the speed is around 70 km/h.

Motorway control is usually carried out through gantries over the motorways with variable message signs and warning lights.

Ramp metering

Ramp metering refers to controlling measurements on on-ramps of motorways and aims to even out the speed and thereby increase the capacity or the maximum flow on the motorway. Also the traffic safety will be improved as speeds become more evenly distributed.

Technically, ramp control is achieved by putting a traffic signal on the ramp. The cars are stopped and portioned out one by one in relation to traffic flow and speed on the motorway. In the simplest algorithms the flow from the ramp is controlled considering the flow and speed on the motorway. The control is switched on when the speed falls below a certain limit and switched off when the flow to the ramp has decreased.

Three different levels of ramp metering could be implemented:

1. On single ramps with local problems
2. On all ramps of a motorway corridor to optimise the flow on the motorway.
3. As a part of an integrated system flow is optimised both on the motorway and parallel side streets.

2.4 On trip information

Collective and Individual Traffic Guidance are both recognised as kernel functions of Traffic Management. While the former aims at supporting as much traffic as possible by supplying guidance information via collective information media (such as VMS/VDS panels or radio), the latter operates on the individual basis, guiding a specific subset of vehicles - the vehicles equipped with suitable on-board devices - towards their destinations.

Individual guidance information is provided to the driver by means of acoustic, optical or combined technologies. The best solution has not been fixed yet and depends on both the type of information to be communicated and on safety issues. Currently most of the systems provide guidance indications superimposed on a background map representation. LCD screens seem the preferred solution adopted.

Individual guidance is provided according to static route definition or dynamic route calculation. The dynamic solution is performed basing on current and foreseen traffic conditions and better fits to Traffic Management concepts.

Variable message signs

In the field of Traffic Information and Control, Variable Message Signs are normally intended as roadside equipment, such as panels and displays, able to provide drivers with dynamic information and recommendations established by higher level strategies.

The features of VMS (size, layout, technology) may differ significantly according to the environment (urban, extra-urban), the installation constraints and the application purposes (traffic information, traffic regulation, traffic guidance), but the information they communicate belongs to three general categories:

- information concerning current and forecast network conditions (provided by text messages and/or pictograms)
- suggestions about the direction to be followed to achieve specific destinations (expressed by text messages or by a combination of fixed and dynamic symbols and text)
- speed and traffic limitations (provided typically by pictograms).

Dynamic route guidance

Dynamic route guidance includes calculation of optimum routes in the network based on the user-optimum criterion. Navigation information for optimum routes in urban areas is based on current traffic conditions (including directions to the driver). The system might be static in interurban areas.

The control centre receives travel time information continuously by means of a communication link between vehicles and roadside devices. The centre calculates optimum routes for all potential origin-destination relations using user-optimum criteria - except for the protection of residential areas - to forecast new link travel times. It then transmits these link travel times via local distribution units (e.g. beacons or cellular radio stations) to the vehicles. The onboard computer assigns these to the individual destination based on the individually preferred combination of travel time, distance and price, and selects the relevant route. In combination with a position-finding system, the guidance system indicates the recommended direction at each intersection.

The average gain in travel time due to route guidance systems will be reduced with higher rates of market penetration if all drivers using the same route will get the same route proposal. This can be counteracted using efficient ‘multi-routing’ algorithms, which have to be developed in the future to cope with these situations.

Parking management

Parking services give information of parking space available in car parks and larger parking facilities in the destination area.

The occupancy and cost of different parking spaces near the destination and park-and-ride facilities will be displayed on an on-board monitor. This information could also be distributed via VMS, RDS/TMC, Information or Guidance Systems.

Parking information systems result in learning effects, which may be more important than other effects. Although the parking guidance systems were not used by many as their first choice, the parking search time was halved in Frankfurt, when this kind of system was implemented.

Public transport information

Public transport information includes the complete scheduled on-line description of travel opportunities for metro, trams, buses, trains, aeroplanes, ferries etc. available to users and real-time information on the delays to public transport at home or en route.

The control centre transmits current public transport facilities to fixed or portable units. The user feeds in his destination and the desired arrival time. He receives one or more appropriate trip recommendations. The information can be recorded on a smart card for portable use.

3 TRAFFIC SIMULATION STUDY

A traffic study with micro-simulation tools consists in comparing a traffic situation, that is called the reference situation, to many scenarios in which some changes have been performed (new intersection layouts, different traffic signal strategies, vehicle guidance strategies, reserved lanes for public transport, Advanced Transport Telematic Applications, etc.).

The methodology usually followed in this type of study can be decomposed into the following steps:

- Definition of the area to be modelled
- Definition of the different scenarios to be simulated
- Hypotheses retained for simulation
- Definition of the different output indicators used for scenario comparison
- Choice or definition of the strategies to be assessed
- Data collection
- Modelling
- Model calibration and simulation of the reference situation
- Simulation of the different scenarios
- Study of the simulation results and comparisons

The steps listed above often overlap with each other. For example, to define the area to be modelled traffic flows are needed and so some data collection has to be performed. Indeed, the traffic study does not usually proceed step by step as above. Iterative loops often occur. A visit to the site to obtain knowledge about the traffic situation is also always very helpful in conducting the study.

The **definition of the area to be modelled** consists of choosing which road sections are to be modelled and simulated. Many criteria can be taken into account to keep or to eliminate a road section of the model but, from our experience, this process can be summarised by answering the question: *has this road section an important influence on traffic?* If the answer is yes, the section should be kept. If not, it can be eliminated. Attention should be paid to the various forms that this *influence* can take. Many examples illustrate this point:

- a section with a very low traffic flow should be kept if a queue spills back on it to the previous intersection,
- a low traffic section incoming to a traffic light intersection can be eliminated but the intersection traffic plan should be kept to its original value (that takes the section into account)
- car parks should be kept when incoming and outgoing traffic are important during the period retained for simulation
- some sections that do not influence traffic in the reference situation should be modelled if this influence becomes important in the different scenarios (as it is the case for alternative routes, for example)

The **definition of the different scenarios** to be simulated depends on the objective of the simulation. If the objective is clearly identified, as for example to test a traffic signal control strategy on a particular section, scenarios are usually easy to define. If the objective is broader, as for example to evaluate the impact of segregated public transport lanes in the city, scenarios may be complex. Indeed, such objectives include many options (different kinds of traffic signal control strategies may be used, intersection layouts may be changed, traffic may be assigned differently in the network, etc.).

The **hypotheses retained for simulation** concern the choice of the elements and the phenomena that can be modelled at the microscopic level. Knowledge of the site is required to determine what has to be modelled:

- pedestrian crossings sometimes influence traffic,
- many vehicle types can be used but traffic may be often composed of only one (usually cars),
- number of lanes on each section (illicit parking may take on a lane so that it is not used in practice and so it should not be modelled),
- flared lanes approaching intersections can be very important especially when modelling traffic flows at signalised intersections.

The **definitions of the output indicators** that are used for scenario comparisons are related to the objective of the study. However, indicators that characterise the way that the particular simulation software performed simulation are to be examined in details (number of generated vehicles, number of vehicles that entered in and got out of the network, number of vehicles that had to wait outside of the network before their entrance and related waiting time, etc.). Other usual indicators are:

- global to the network (average speed, total travel time, total travel distance, number of stops and time spent at stops, average travel time and number of stops per vehicle, etc.)
- related to a specific vehicle type
- related to particular lanes or intersections.

The choice of the **strategies** to be assessed is related to the objective of the traffic study.

The **data collection** consists in gathering all required data to model and to calibrate the network. Many sources of information can be used (see chapter 7).

Modelling and model calibration are presented in chapter 7.

The **simulation of the different scenarios** consists in performing many runs of each scenario to be evaluated. Each simulation has to be monitored in order to avoid non-realistic traffic phenomena that could occur after some change in the conditions of the reference situation. For example, the traffic demand may be modified with regards to the one initially planned. The objective of this step is to obtain a simulation that could be the result of a real implementation of the scenario tested.

Study of the simulation results and comparisons requires a certain experience with traffic phenomena. Data obtained are usually treated with a spreadsheet so that comparison and graphical presentations of results can be established.

4 USER REQUIREMENTS

Simulation tools can be used on-line for dynamic traffic management or off-line for design and testing of control strategies. Simulation tools can also be used for large-scale testing of the effects of traffic management schemes as comprehensive field trials tend to be very costly. Specific user requirements are user-friendliness, short lead-time before use, validated results, limited need for expensive data acquisition and high cost effectiveness when comparing quality of result and resources in time and money spent in the simulation.

Results from the questionnaire study in the SMARTEST project

In order to identify user requirements for micro-simulation of traffic a questionnaire was sent out to known users of micro-simulation models in the field of transport planning, with particular emphasis on transport telematics applications. In practice we concentrated on reaching research institutes, official transport planners and private consultants in the SMARTEST team member countries. The questionnaire was also available on the SMARTEST home page on the World Wide Web together with general information about the project.

Questioning resulted in a sample of 44 useful respondents. Of these, six are users of one or more of the models included in the SMARTEST project.

Half of the sample represents research organisations and another quarter road authorities. All categories are represented by at least 4-5 interviews.

Type of organisation	Representation
Research organisation	50%
Road authority	27%
Consultant	14%
Manufacturer	9%

The 44 respondents represent 13 countries.

The sample of users that were included in the survey is not necessarily representative of the future model users. There was a clear geographical bias towards the United States, United Kingdom, France and Sweden, and there was a clear bias towards research organisations.

The respondents are fairly experienced with micro-simulation. Exactly half of the respondents are model developer themselves. About three-quarters have used simulation for some or many applications. Only 3 out of 44 have no own experience of micro-simulation. Users and consumers of micro-simulation results seem to be under-represented in the survey.

More than 80% of the users use traffic simulation for design and testing of control strategies. The second most common application for traffic simulation is the evaluation of large-scale schemes (45%). 20 % of the users use traffic simulation for on-line traffic management or for evaluation of product performance. Other areas of application are research and education.

More than fifty percent of all respondents regard micro-simulation models as a necessary tool for analysing traffic conditions. About one third state these models are also a useful tool. Only one single answer believes the existing micro-simulation models to be an unreliable method, which seems very promising, indeed. A few individuals report they are not quite sure and there are also some missing observations (no replies) to this question. As twenty-two (22) out of 44 respondents are model developers themselves, it seems that most other users have a somewhat temperate attitude to micro-simulation.

One respondent answered:

”It is a necessary tool if validated. It is an unreliable method if not validated. The aim of the model is essential as well as its limitations.”

Comments are more enlightening than the actual question. A good summary is probably that micro-simulation "is useful, but dangerous". Also, interesting comments are that ”short time parking, very frequent marginal behaviour and pedestrian integration are difficult”, and that ”they are not suitable for large travel time and large distance networks”.

Advantages and disadvantages with specific software are also related to the actual application that each survey person faces. Therefore, it may be that advantages or disadvantages associated with particular software may not necessarily be unique for that software.

From the comments on advantages as well as disadvantages, it can be concluded that functionality, validation, graphical interface and connection possibilities to other software are emphasised. Size limitations are also mentioned as an important restriction in some cases.

Applications are of interest vary in scale from regional applications to a single road. Thus, the network size in the applications varies from single intersections up to city networks of 500 links and 100 intersections.

65 % of the users say that they would use micro-simulation for corridor and intersection level applications respectively. Using micro-simulation for city application attracts 50 % of the users, so does using it for single roads.

Regional traffic analysis is today only possible on a macroscopic scale with models such as EMME/2 or SATURN. But nevertheless, 23 % of the respondents are interested in using micro-simulation for regional applications.

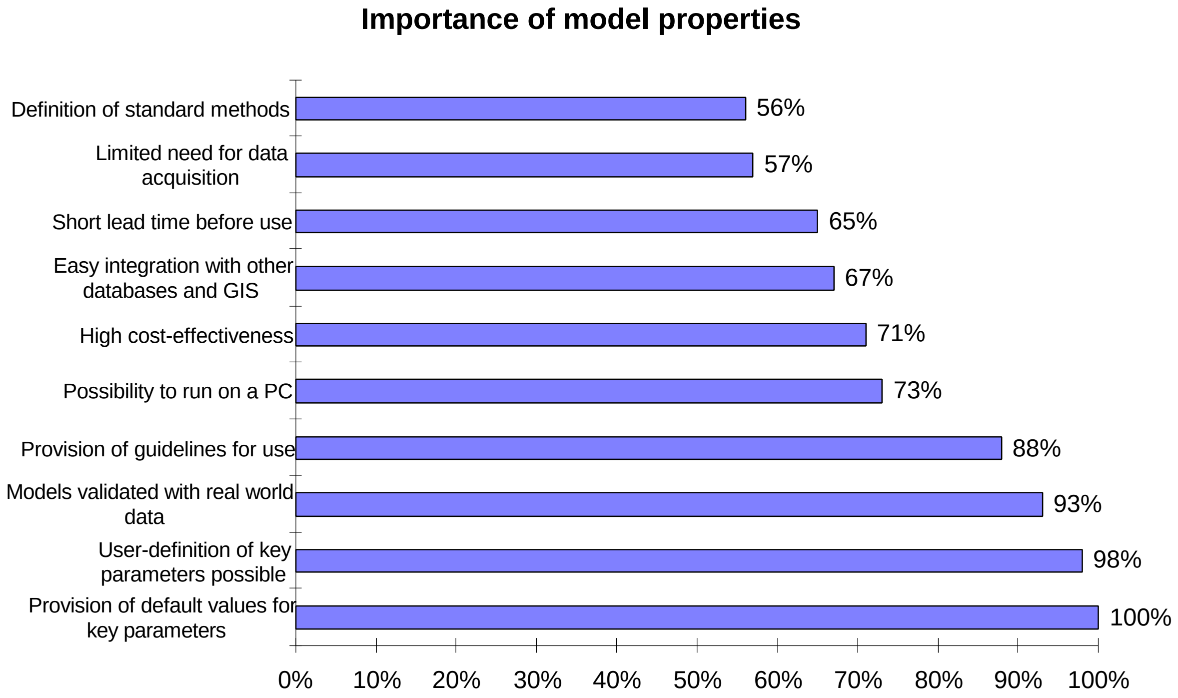
There is a great expectation that micro-simulation models should include incidents and public transport. Roundabouts seem to have been a problem in past models and should be included in any future enhancements. The interaction with pedestrians and the specific behaviour of commercial vehicles are also of importance. Concerning those items not explicitly mentioned, road geometry is the most frequent one, followed by several driver categories, traffic signal operation and road surface condition.

It seems that micro-simulation models will be used mainly for evaluations of efficiency, technical performance, and fuel consumption, and emissions. Safety and comfort indicators seem less interesting. Another interpretation is that the respondents are of the opinion that it is too difficult to use micro-simulation for safety or comfort assessment.

Both a user-friendly interface for input and editing and a graphical and animated presentation of results are crucial for users of micro-simulation models. Only one respondent thought that ASCII tables were sufficient for input and output.

The most frequent time span for micro-simulation runs will be 5 minutes up to 12 hours with the peak hour (0,5 - 2 hours) as a very marked median. Only one respondent said they would run the model for less than 5 minutes. Four respondents wished to use a time span of over 12 hours.

The crucial properties of micro-simulation models seem to be:



These results are confirmed in the ranking of the three most important properties that users were asked to give. Most important seems to be that the micro-simulation model should have been validated, but also that key parameters can be user defined and that the model will run on a low cost non specialist hardware.

The sample of users that are included in the survey is not necessarily representative of the future model users. There is a clear geographical bias, and there is a clear bias towards research organisations. Therefore, the results should be interpreted more in an indicative than in a conclusive way. Bearing this in mind, the user requirements could be summarised in the following way.

Users would like to be able to analyse a variety of specific applications, including on-line applications, control strategies, large-scale schemes and product performance tests. The scale of applications ranges from regional applications to single roads and the time horizon ranges from on-line to several years. The requested time span of the simulation is 5 minutes to 12 hours with an emphasis on the peak period.

There is then demand for:

Functionality which should include the possibility of modelling incidents, public transport, stops, roundabouts and commercial vehicles,

Relevance - which should give the user possibilities to express results in terms of

efficiency

travel time

congestion

travel time variability

queue lengths

speed

public transport regularity

safety

headway

interaction with pedestrians

overtaking

number of accidents

environment

exhaust emissions

noise level

roadside pollution levels

technical performance

fuel consumption

Telematics modelling ability

adaptive traffic signals

co-ordinated traffic signals

priority to public transport vehicles

vehicle detectors

ramp metering

variable message signs

incidence management

dynamic route guidance

motorway flow control

User friendliness

graphical user interface for input, editing and for presentation of results

Execution speed

execution times several times faster than real time

High quality performance, including

default parameter values provided

key parameters user defined

validated with real data

guidelines for use provided

runs on a PC

high cost-effectiveness

easy integration with Database and Geographic Information Systems

short lead time before use

limited need for data acquisition

standard methods for use defined

This is of course a tall order, and it is unlikely that all these requirements can be fulfilled within one single system. The questionnaire has nevertheless in many cases given clear indications concerning the relative importance of different factors, which may be helpful in future system development.

According to the questionnaire it is important that the most significant factors are taken into account and are based on *validated* field studies. The emphasis on validation is a reflection of the uncertainty concerning behavioural relationships. New knowledge about the effects of intelligent traffic systems will emerge continuously during many years to come. New functions, which meet new demands, will be developed. This indicates that the system should be as open as possible to changes in functional relationships. Driving behaviour that is concealed in the model system source codes and cannot be changed by anyone apart from the programmer is therefore not desired by the user and makes the system conservative and impractical. It must therefore be possible for the user to control the behavioural relationships that are used in the model and add new relationships based on newly acquired knowledge. The model system must therefore function as an “*open toolbox*”.

5 SELECTING A SUITABLE MICRO-SIMULATION PACKAGE

5.1 Introduction

The needs of different users of micro simulation models may be different. In this chapter some guidelines for selecting a suitable micro-simulation model will be presented.

The guidelines are given for general features of micro simulation models as well as for the specific requirements of each ITS application. Computer environment and commercial accessibility are of course fundamental issues when selecting a micro simulation model, but these features are not dealt with here.

Examples showing the features available in the four micro-simulation models that have been enhanced by the SMARTEST project (AIMSUN2, DRACULA, NEMIS and SITRA-B+) are given.

5.2 General features

5.2.1 Requirements

Facilities that are of practical importance, independently of application, and have been dealt with within the framework of the SMARTEST project are:

- Support for result analyses
- Interface with other programs
- Documentation and support

Network coding is a time consuming task, and proper calibration of uttermost importance for the reliability of the results. To this end the following features should be considered:

- Calibration parameters should be comprehensible and possible to measure
- Debugging facilities – to this end an animation facility is very useful
- Access to graphical network builder for input data
- Execution time

Some general *output indicators* that must be produced in applications are travel time and its variability, congestion, queue length, speed and public transport regularity. For evaluation of safety effects headway, interaction with pedestrians, overtaking, number of accidents, accident speed severity and time to collision are important indicators. For environment evaluation exhaust emissions, noise level and roadside pollution level are important parameters and for general technical performance the indication of fuel consumption is important.

5.2.2 SMARTEST examples

Animation is provided with all models but only AIMSUN2 has a built in graphical network builder.

In the table below some general *traffic phenomena* are listed as well as the SMARTEST models ability to model them.

Traffic objects - phenomena

Features vs Micro Sim Models	AIMSUN2	DRACULA	NEMIS	SITRA-B+
Incidents	Yes	Yes	Yes	Yes
Public Transport	Yes	Yes	Yes	Yes
Roundabouts	No	Yes	Yes	Yes
Commercial Vehicles	No	Yes	Yes	Yes
Pedestrians	No	No	No	No

Below is a summary of what indicators each of the SMARTEST models generates.

Efficiency indicators

Features vs Micro Sim Models	AIMSUN2	DRACULA	NEMIS	SITRA-B+
Travel Time	Yes	Yes	Yes	Yes
Congestion	Yes	No	Yes	Yes
Travel time variability	Yes	Yes	Yes	Yes
Queue length	Yes	Yes	Yes	Yes
Speed	Yes	No	Yes	Yes
Public Transport regularity	No	No	Yes	Yes

Safety indicators

Features vs Micro Sim Models	AIMSUN2	DRACULA	NEMIS	SITRA-B+
Headway	No	No	Yes	No
Interaction with pedestrians	No	No	No	No
Overtaking	No	No	Yes	No
Number of accidents	No	No	No	No
Accident speed severity	No	No	No	No
Time to collision	No	No	No	No

Environment Indicators

Features vs Micro Sim Models	AIMSUN2	DRACULA	NEMIS	SITRA-B+
Exhaust emissions	Yes	Yes	Yes	No
Noise level	No	No	No	No
Roadside pollution level	No	No	No	No

Technical Performance and Comfort

Features vs Micro Sim Models	AIMSUN2	DRACULA	NEMIS	SITRA-B+
Fuel consumption	Yes	Yes	Yes	No

5.3 Maintaining of road capacity and avoidance of accidents

5.3.1 Requirements

Incident management

When studying effects of incident management, i.e. the effect on traffic of short duration disturbances, the model should capture the following effects:

1. Incident duration and severity
2. Queue building up and re-distribution of traffic
3. Saturation flow during and after an incident, The driver behaviour should be realistic, and consider e.g. rubber-necking and emergency breaking.

If the first condition is not fulfilled then the model is of no use for evaluation of incident management. The model is good if the first and the second are both fulfilled. If in addition the third condition is fulfilled there will be an extra credit.

Traffic calming

To evaluate traffic calming measures the model must be able to represent

- Roads with variable width and gradients
- Drivers’ behaviour in the presence of these measures

5.3.2 SMARTEST examples

Incident management

All SMARTEST models can be used for incident management, which means that they cover both incident duration and re-routing following the incident. None of the models considers rubber necking or emergency braking.

Traffic calming

Of the four SMARTEST models only DRACULA and NEMIS can be used for simulation of traffic calming.

5.4 Network capacity

5.4.1 Requirements

Adaptive signals

Evaluation of adaptive signals is particularly important at present due to the large number of such systems being currently developed. The following questions are examples of what should be born in mind when selecting a model for evaluation of adaptive signals:

- Is it possible to show how adaptive signals can minimise delay when flows are varying?
- Is it possible to illustrate redistribution in the network caused by signal improvements?
- Is it possible to show how adaptive signals can reduce the scope of incidents.

- How can differences in performance be illustrated between different signal control systems such as Automatic updating of TRANSYT (AUT) and SPOT?

The essential effects and aspects that should be caught by a model concerning this application are, in order of importance:

1. Delay reduction due to second by second adaptation to the incoming vehicles
2. Capacity improvements on 15-min level
3. Location of detectors
4. Redistribution of traffic and upstream queuing problems and intersection dead-locks
5. Safety indicator, e.g. option zone vehicles, impact on vulnerable road users
6. Emission estimates based on individual trajectories

For Adaptive Urban Traffic Control, it is also highly desirable for the micro-simulation model to have an external interface to the UTC system.

Priority to public transport vehicles

The essential effects are the same as those for adaptive signals. Additional aspects that should be caught for PT priority are:

- Impact on private traffic
- Impact on vulnerable road users, e.g. stage skipping, cycle time
- Priority levels and regularisation index

Roundabouts

Driver behaviour when approaching and travelling on roundabouts is different to that at other types of road junction. A model of a roundabout should capture the following driver behaviour. Drivers should:

- get into the correct lane according to desired exit
- reduce speed
- give way to traffic on the roundabout unless road markings indicate otherwise
- watch out for traffic already on the roundabout, especially cyclists and motorcyclists
- when making nearside turning, approach in the nearside lane and keep to the nearside on the roundabout
- when going straight ahead, approach in the nearside or centre lane on a three lane road, or in the farside lane if the nearside lane is blocked on a two-lane road
- when making farside turning or going full circle, keep to the farside on the roundabout
- when there are more than three lanes at the entrance, use the most appropriate lane on approach and through the roundabout
- watch out for traffic crossing in front on the roundabout, especially vehicles intending to leave by the next exit
- give long vehicles plenty of room as they may have to take a different course, especially on a mini-roundabout where they may have to cross the centre.

Motorway flow control

Examples of questions that should be asked when selecting a model for evaluation of motorway control systems are:

- Is it possible to show how the capacity during an hour is influenced by lower recommended speeds at higher traffic flows? This will in principle imply a new speed-flow relationship when the recommended maximum speed is reduced as the average speed in the queue is decreasing.
- Which effects would an increased speed limit have in low traffic conditions where almost all drivers go faster than the speed limit today?
- Is it possible to illustrate how speed variance and time gaps are?
- How is it possible to model different control algorithms regarding recommended speeds?
- Which parameters can be tuned to get realistic effects.

The essential effects and aspects that should be caught are, in order of importance:

1. Impact of control strategy on gap distribution and reaction time
2. Capacity improvements on 15-min level
3. Adherence to lane closing procedures
4. Emission estimates based on individual trajectories
5. Automatic Incident Detection and location of detectors

To get the highest score in the modelling of motorway control strategies the simulation tool should be capable of being connected to the real controller in the same way as has been done for UTC. Alternatively, it should be possible to model the control strategy internally.

Ramp metering

The local signal effect for ramp metering systems is of course crucial. It must be possible to reproduce the control strategy in the model system. It should be possible to model different control algorithms.

The essential effects and aspects that should be caught concerning ramp metering are:

1. Different types of ramp control should be predefined
2. Capacity improvements on 15 min level
3. Safety indicators based on gap distribution
4. Emission estimates based on individual trajectories
5. Location of detectors upstream queuing problem and queuing discharge

5.4.2 SMARTEST Examples

Adaptive signals

As traffic signal control is well defined, and has been an implemented ITS application for many years, all SMARTEST models have the capability of representing the different types of traffic actuated control. All are able to interact with external signal control systems.

Priority to public transport vehicles

Similarly all the SMARTEST models can be used to assess PT priority systems.

Roundabouts

Specific roundabout models have been developed for SITRA-B+ and DRACULA. If roundabouts need to be modelled with either AIMSUN2 or NEMIS, then an approach where the roundabout is modelled as a series of T-junctions has to be used.

Motorway flow control

None of the SMARTEST models can model MCS systems explicitly, as they lack the control strategy module. However AIMSUN2 has the capability of being linked to, and interacting with such a control system if it is provided as an external module.

Ramp metering

Only AIMSUN2 is capable of the evaluation of ramp metering.

5.5 On trip planning, warning and advice

5.5.1 Requirements

Variable message signs

There are plans to establish or improve VMS systems in many cities around the world. How can VMS be modelled and isolated from traffic information? Does the programme consist of any generalised behaviour model for route guidance? The location of the sign, the content of the message, the reliability of the information are factors that are important for the reaction of the motorists. Which parameters can be tuned to illustrate this phenomenon?

Support for VMS modelling involves at least ability to model a share of the drivers diverting during the time period when the message is shown.

The model should have

1. A validated basic dynamic route choice model
2. Graphical interface to directly include information messages
3. Ability to model interpretation of messages of drivers
4. Tool for stochastic assignment of incidents

Collective traffic guidance modelling for on-line use involves four different aspects:

- Module which performs the collective traffic guidance strategy
- Representation of the infrastructures (signs) which are located in the network
- Driver behaviour model including interaction with VMSs
- Interface between the network/traffic model and the guidance strategy module.

Dynamic route guidance

Evaluation of dynamic route guidance requires very much from the route choice module in the model. This module must e. g.

- allow for the drivers not having perfect information. This disqualifies any equilibrium assignment approach.
- in addition give drivers different information about different parts of the network and a possibility to react on updated information in different ways.

The requirements on a model that could support an *on-line model* for dynamic route guidance is three-fold:

- It has to have an on-line input option
- It must be possible to make short-time predictions of the traffic situation
- It has to have an extremely low execution time.

In the DRG context, the following criterions are important:

1. Dissemination of on-trip information to guidance systems
2. Ability to directly include control algorithms of guidance systems
3. Ability to model compliance to not perfect information

Parking management

The essential effects and aspects that should be caught concerning parking management are:

1. The loading and redistribution process when parking facilities in an area become more scarce
2. The dependence between parking occupancy for on-street facilities and car parks in an area and the search time for parking
3. The improved search process with parking information

Public transport services

A model should be able to capture the following aspects of public transport information

1. More efficient use of public transport alternatives, especially for unfamiliar trips and linked journey using more than one line
2. Improved regularity due to priority at signals and on-line control
3. Comfort improvements due to confirmation of schedule and real time information
4. Resulting redistribution of trips by car to public transport

5.5.2 SMARTEST Examples

Variable message signs

AIMSUN2 and NEMIS support VMS modelling. However, it should be born in mind that all you can do with these models is to supply them with the proportion of vehicles that will take the advice given on the VMS. The models can be used to see what the effects are if the given share of vehicles diverts at the sign. It is up to the Traffic Management Centre to create suitable messages at suitable times to optimally manage the road network. Both AIMSUN2 and NEMIS have the capability of being linked to, and interacting with such a management system if it is provided as an external module.

Dynamic route guidance

All the models except DRACULA support Dynamic Route Guidance to some extent. As for collective guidance there is a difference between using a model for off-line evaluation of measures and using it on-line and automatically generating strategies for managing different traffic situations.

Parking management

The only SMARTEST model that supports parking management is SITRA-B+.

Public transport services

Public transport services can be modelled in all the SMARTEST models except for AIMSUN2. AIMSUN2 can model different vehicle types and reserved lanes, but it cannot currently model PT routes, stops or schedules. Such facilities however should be available in the next release of AIMSUN2.

6 COMPARISON BETWEEN MACRO AND MICRO SIMULATION

In the Stockholm test-site, results from macro simulation as well as micro simulation runs are available. This provides an opportunity to compare the two different approaches, which may give an idea of the improvement in accuracy that can be expected from micro simulation modelling.

Incident management

Macro-simulation (EMME/2)

Frequency of incidents, remaining capacity, the delay in detection and reporting of an incident and the turn-out time of the rescue service are important factors when predicting the probable effects of improvements of Incident management strategies.

The method of calculating incident management with EMME/2 was simulating a set of traffic incident situations based on realistic frequencies for different incidents and the effects of reducing the duration of these incidents. The scope of incidents has been surveyed for the Stockholm region (Kronborg, 1993). As a result, the frequencies for different roads have been assessed in Table 6.1.

Table 6.1 Assumed frequencies for different types of incident (Lind, 1996).

Frequencies (per million vehicle-km)	Motorways	Country roads	Urban roads
- major accidents	0.6	1.5	1.5
- minor accidents	1.5	1.5	1.5
- vehicle breakdown (in a lane)	8	8	8
- other obstacles (incorrect parking, lost cargo, congestion)	5	4	8
- road works	0.8	0.4	0.4

The resulting delays were calculated using a queue model (QSIM) based on the details above (Jepsen, 1994). These delays were then used as additional link times in the EMME/2 assignment procedure. A major accident of 45 minutes primary duration, for example, leads to a total breakdown of the motorway. This incident will result in an average delay, according to the queue model, of 22 minutes if it occurs in the middle of the day (11:00 am) and 53 minutes during the peak morning hour (7:30 am). Consideration was given to traffic flow, speed limit, bottleneck capacity, starting time and duration.

To simplify the calculation process, the rather complicated system above was simplified and QSIM calculations only made in the cases in Table 1.2.

Table 6.2 Capacity and duration for QSIM calculations (Lind, 1996a).

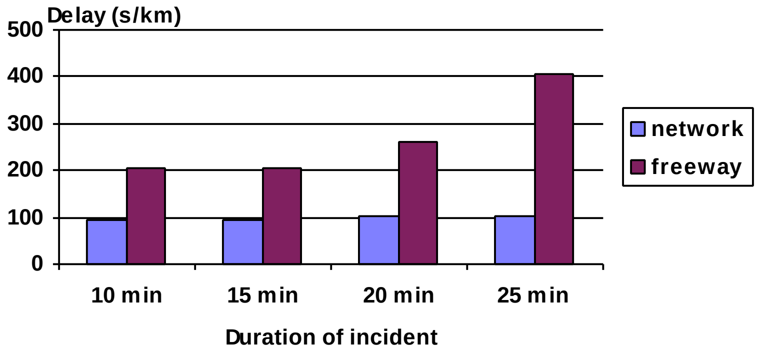
	capacity	duration
- major accident	0%	45 minutes
- minor accident	40%	30 minutes
- vehicle breakdown (in lane)	75%	20 minutes
- other obstacles	67%	30 minutes
- road works	80%	24 hours

To calculate the probable effects of incident management, the delays associated with individual incidents of varying duration have to be simulated.

Micro-simulation (AIMSUN2)

The main parameter to model incident management using micro simulation seems to be the duration of the incident. The duration of the incident reflects the time it takes to detect the incident, report it, process the information and clear the incident. A sensitivity analysis was made where the delay on the motorway and the network as a function of incident duration was simulated. Figure 1.1 clearly shows the non-linear growth in delay and the corresponding importance of reducing incident duration.

Figure 6.1 Incident management in AIMSUN2.



The effect on delay due to the incident seems to be modelled in a reliable manner, as far as can be judged from the animation of the simulation run. If the 20-minute incident specified is increased by 25 percent (5 minutes), the average delay for the vehicles using the freeway is increased by 60%. This is in reasonable accordance with queuing theory that says that the delay increases quadratically with incident duration. There is evidently a great potential in quicker incident clearance under these traffic conditions.

The reduction in capacity due to an incident is modelled as a blockage of a discreet number of lanes. It is not possible to specify a certain percentage of capacity reduction as in the macro-simulation, which would be useful if for instance half a lane was blocked. There are also two phenomena concerning incidents that are not modelled in AIMSUN2. The first is the fact that vehicles in the lanes that are not blocked by the incident or the queue drive slower than normal. However, this behaviour is going to be implemented in the next release of version 3.2. Secondly, the phenomenon of ”rubber necking” is not taken into account i.e. cars going in the opposite direction slow down to look what has happened.

Apart from these shortcomings, there seems to be good possibilities to model incident management in AIMSUN2.

On-trip information and VMS

Macro-simulation (EMME/2)

The method of calculation used for on-trip information was based on the simulation of a traffic system subjected to some form of interference. It took into consideration realistic frequency levels for different incidents in the traffic system and the effects resulting from the road-user being better informed, thus allowing new route choices to be made based on this information. As stated below, a range of factors must be assessed in order to calculate the effects of traffic information. Among other things, the quality of information must be specified and the behaviour assessed in the light of the expected reliability and timeliness of the information.

The efficiency of the traffic information system may be considerably reduced if the information chain from detection to reporting is not sufficiently rapid. If this is the case, many road-users may have driven straight into the traffic jam before the information reaches them. To assess this factor properly in the case of on-trip information, it is important to estimate the joint probability of detection and reporting.

Table 6.3 Reporting probability with on-trip information (Lind, 1996a).

Probability	Motorways	Rural roads	Urban roads
- major accident	90%	70%	80%
- minor accident	50%	25%	30%
- vehicle breakdown (in lane)	10%	5%	20%
- other obstacles	15%	5%	10%
- road works	90%	60%	70%

Automatic detection systems are used mostly on motorways and mobile telephones mostly in rural areas. The detection time was estimated to 3-5 minutes on a motorway, 5-10 minutes in an urban area and 15-30 minutes in a rural area. The processing time at the traffic control centre prior to information being issued was assumed to be 2-5 minutes. Information is thus sent out via VMS and RDS 5-35 minutes after the incident has occurred.

Traffic not affected by the incident was assigned according to the static equilibrium as interpreted by the EMME/2 system. The on-trip information was assumed to be provided as disruption information (location, probable duration) and alternative routes. It was assumed that only main roads were used in the regional traffic information as misunderstandings could easily occur otherwise.

Incidents were assigned at random to the road network based on disruption frequency data. The probability was assumed to be proportional to the number of veh.-km on each link.

Micro-simulation (AIMSUN2)

Modelling on-trip information

AIMSUN2 contains a route choice model for dynamic re-routing. At the start of the simulation, after the warm-up period, new shortest routes are calculated based on simulated travel times. If the dynamic option is chosen, new shortest routes are calculated during the simulation with an interval specified by the user. This means that for each time interval there is one specific path between two points in the network that is the shortest according to the simulated travel times.

For guided vehicles, information on new shortest routes is given every time interval and hence they may change their route during the trip if the dynamic option is chosen. The program saves information about which routes have been the shortest during the last intervals, and the model distributes the guided vehicles among these routes according to a logit model. This means that not all guided vehicles use the present shortest routes but some stick to the older shortest routes. This gives certain inertia to the routing behaviour.

In summary, the following parameters can be used to tune the dynamic route choice:

- Fixed or variable routes
- Capacity weight factor for initial routes
- Proportion of guided vehicles for each vehicle class.
- Interval at which new routes are calculated.

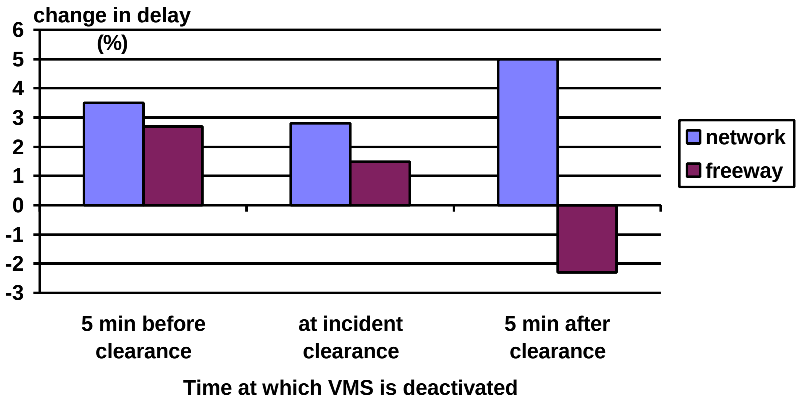
- Type of model to distribute drivers between routes, logit or binomial
- Number of routes to consider in the logit model
- Scale factor for weighing the routes in the logit model

Modelling VMS

Variable message signs can be modelled directly in AIMSUN2. The way to work with VMS differs depending on the type of demand data used as input, OD matrices or input flows and turning percentages. Since OD matrices are used in this evaluation, the description below refers to these more elaborate re-routing capabilities for modelling VMS in AIMSUN2 provided when using OD matrices.

In the SMARTEST Stockholm test network, there is a route choice between the freeway (western route) and the eastern arterial. In order to inform the drivers of the incident conditions, a VMS is positioned at intersection 1 (Järva Krog) visible for drivers heading south towards the downtown area or continuing on the southbound freeway. The chosen message is ”Accident at Haga Norra” referring to the incident scenario where a truck blocks the freeway at intersection 3. The behavioural assumption connected to this message is that 50% of the drivers with destinations in the southern urban part of the network divert at the location of the VMS and choose the alternative route. The sign is lit 3 minutes after the incident occurs, i.e. there is a delay that reflects the time it takes for the incident to be reported and processed by the traffic management centre. Then the message is active until the incident is cleared. In order to study the significance of the time the message is active, two additional simulations where run: the sign is turned off five minutes before the incident is cleared and five minutes after. Figure 6.2 shows the resulting delay per kilometre in the different cases.

Figure 6.2 Variable Message Signs in AIMSUN2.



The graph shows that there is an *increase* in delay on the network level due to this VMS strategy. As a whole, the impacts are quite complex and must be divided into sub-effects to be understood:

- When turning the sign on, a substantial portion of the drivers start changing lanes in order to make the turn to the off-ramp. This behaviour creates a disturbance in the freeway flow and the delay increases. This effect is probably exaggerated in the model and explains why there is an increase in delay on the freeway when the sign is activated for only a short time.
- If the sign is active for a longer time, the delay on the freeway decreases due to the fact that fewer drivers are stuck in the queues.

- Since the network delay increases, it is obvious that the alternative route is not better than the original despite the incident.

In conclusion, this example of VMS application was not very successful. If the incident impacts on the freeway traffic had been greater, there would possibly have been a positive effect of re-routing by VMS. Instead, it can be seen as a successful application of a VMS simulation – sometimes the result will be that VMS signs are not a good strategy.

Provided that the above factors are considered, there are good possibilities to model VMS effects in AIMSUN2.

Conclusion

In order to study local capacities of links, intersections and ramps or control strategies for Incident management and On-trip information, micro-simulation is very useful. The major problem up to date concerning ITS is however to get reasonable behavioural information to represent various ITS applications. For the innovative user, macro-simulation still offers good possibilities to model average network effects, as the behavioural assumptions seem to be more decisive than the modelling detail. In this case, results from micro-simulation can be used to produce input data to assignment models. In the long run, however, micro simulation offers better possibilities than macro-simulation to model various dynamic phenomena.

7 NETWORK AND TRAFFIC DATA

This chapter describes the data you need when you work with a micro simulation model and the different ways to collect data. Data collection may be accomplished in many ways and below the most common ways are described. Data collection requires a lot of resources but is a very important part when working with micro simulation models. It is important to keep in mind that you cannot get better results than the quality of the input data.

Network data

To be able to study a real traffic system with a micro simulation model, the traffic network has to be coded with the proper level of detail.

The network data includes section data (location, length, number of lanes, lateral lanes, speed limit, detectors, VMS, Reserved lanes, ramp metering) and junction data (allowed turnings, signal groups, phases, stop and yield signs, prohibited blocking, yellow box).

Irrespective of the method it is in most cases necessary to visit the location and get all information that might be missed otherwise. Photos are also a good complement to information about details that can be missed when looking at for example a map.

As for a quality assurance of the coding, the best way is to run the simulation and look at the animation.

Drawings

The traditional way to collect network data is to collect data from drawings or maps. This is in the most cases time consuming and the quality of the final results is dependent of the quality of the underlying data. A problem with this method can be to find the drawings or maps. They can be find by different authorities and have different quality.

Use macro network as input data

If you already have the network for instance in EMME/2 it may be easy to use it as an input data. The EMME/2 network does not provide the required level of detail and elaboration of the nodes into intersections is necessary. It is however a fast method if the level of detail is not so important.

Collection of network data with DGPS

It is possible to collect data using Differential Global Positioning System (DGPS), by simply driving through the traffic network and registering objects using a portable computer. If the GPS receiver is not of the best quality you may need to post-processing with photographs and drawings.

Load a set of graphical images as a background

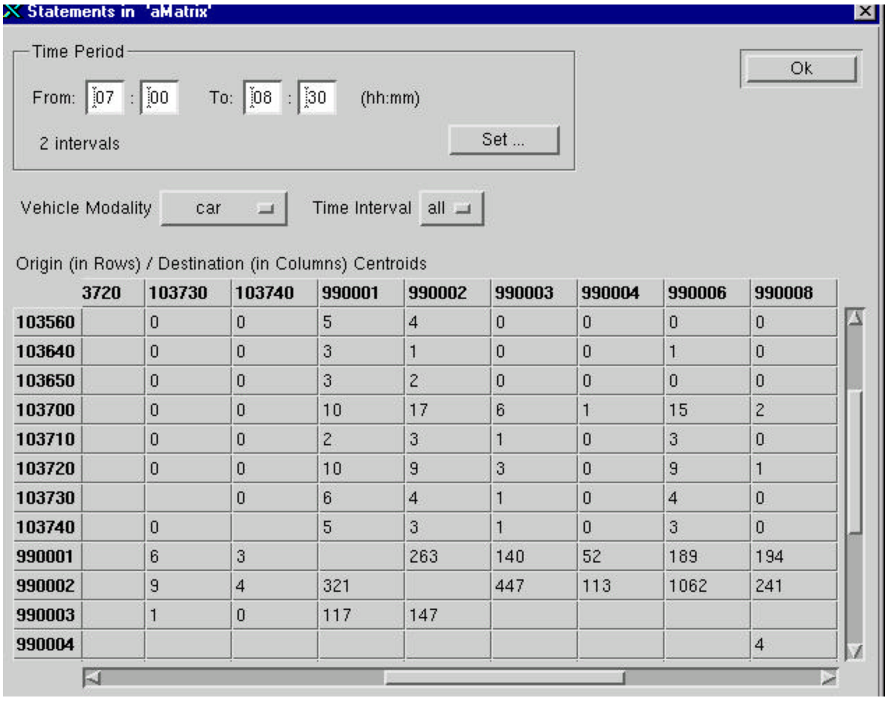
For some models a digital map can be used to simplify the coding. If the model has a graphical editor it is very easy to draw the network on top of the drawing (CAD or GIS file) or an air photo. Then you know the exact length between the intersections for example and you only need to add driving direction, number of lanes and so on.

Traffic demand data

The traditional way of representing traffic demand data in a micro simulation model is input flows and turning percentages. In some models there is also a possibility to import an OD matrix from EMME/2 or hand code them directly and assign them to the network.

An O/D matrix in AIMSUN2 contains three types of information:

- ❑ Vehicle types: Specified as types of vehicles in the same way as with the results container.
- ❑ Time intervals: Time intervals of different duration may be set in order to built a time sliced O/D matrix.
- ❑ Statement: Statements are the vehicle flow values mentioned before, composing the matrix-elements.



Time Period

From: 07 : 00 To: 08 : 30 (hh:mm)

2 intervals

Vehicle Modality car Time Interval all

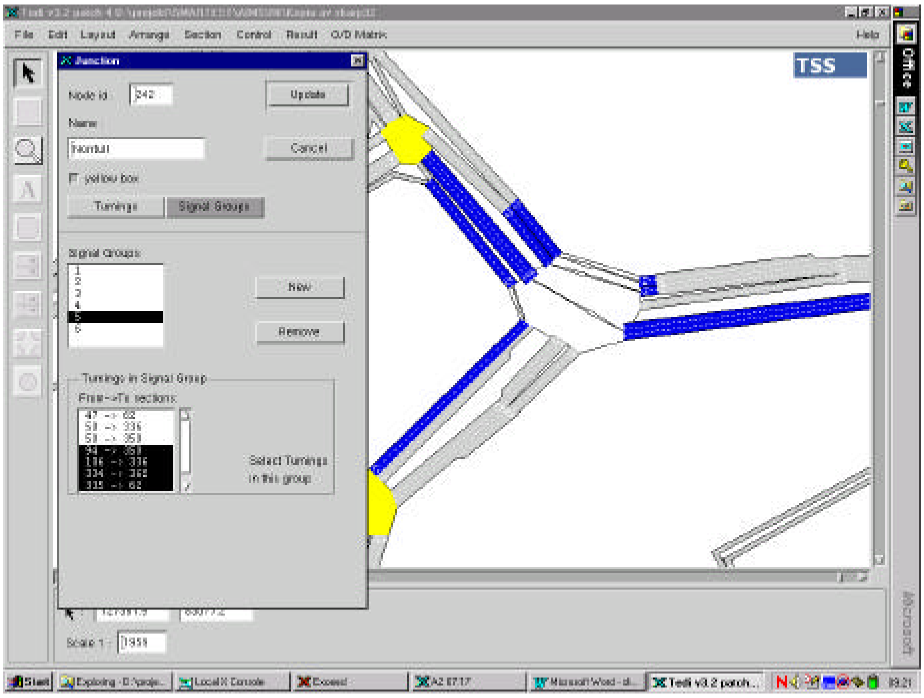
Origin (in Rows) / Destination (in Columns) Centroids

	3720	103730	103740	990001	990002	990003	990004	990006	990008
103560		0	0	5	4	0	0	0	0
103640		0	0	3	1	0	0	1	0
103650		0	0	3	2	0	0	0	0
103700		0	0	10	17	6	1	15	2
103710		0	0	2	3	1	0	3	0
103720		0	0	10	9	3	0	9	1
103730			0	6	4	1	0	4	0
103740		0		5	3	1	0	3	0
990001		6	3		263	140	52	189	194
990002		9	4	321		447	113	1062	241
990003		1	0	117	147				
990004									4

Figure 8.1 **O/D matrix in AIMSUN2**

Traffic control data

Traffic control data includes green time for signals and ramp metering. The input data needed for traffic signals is often provided from the local traffic authority. If you are not used to reading traffic control plans they sometimes can be difficult to understand.



Node id: 242

Name: Nordull

☐ yellow box

Signal Groups: 1, 2, 3, 4, 5, 6

Turnings in Signal Group

From-->To sections

47 -> 62
50 -> 336
50 -> 358
94 -> 358
136 -> 336
334 -> 362
335 -> 62

Select Turnings in this group

Scale 1 : 1959

Figure 8.2 **A junction as it is represented in AIMSUN2**

8 CALIBRATION AND VALIDATION PROCEDURES

8.1 Introduction

Calibration can be defined as the process of tuning the input data and the parameters in a model in order to create an agreement between simulation results and real word data. It is necessary to calibrate a model if the simulation results are to be trustworthy and used to support decisions in traffic management.

Validation can be defined as a comparison of model output with data independent from the calibration procedure.

To calibrate or validate a micro simulation model it is necessary to have access to measurements from the real traffic condition.

Before you do the calibration it can be of advantage if you have done a sensitivity analysis in order to obtain a better understanding of the parameters.

Calibration and validation data

In order to calibrate and validate the basic traffic modelling e.g. route choice, flows and speeds you use calibration and validation data. This data you can get from traffic measurement at different points in the network or if there is Motorway Control System you can get data from the detectors of this system.

Example of data that can be used:

- ❑ Flow and speed
- ❑ Travel time
- ❑ Headway
- ❑ Total queue time

- Maximum queue length in vehicle number
- Percentage stops
- Delay time

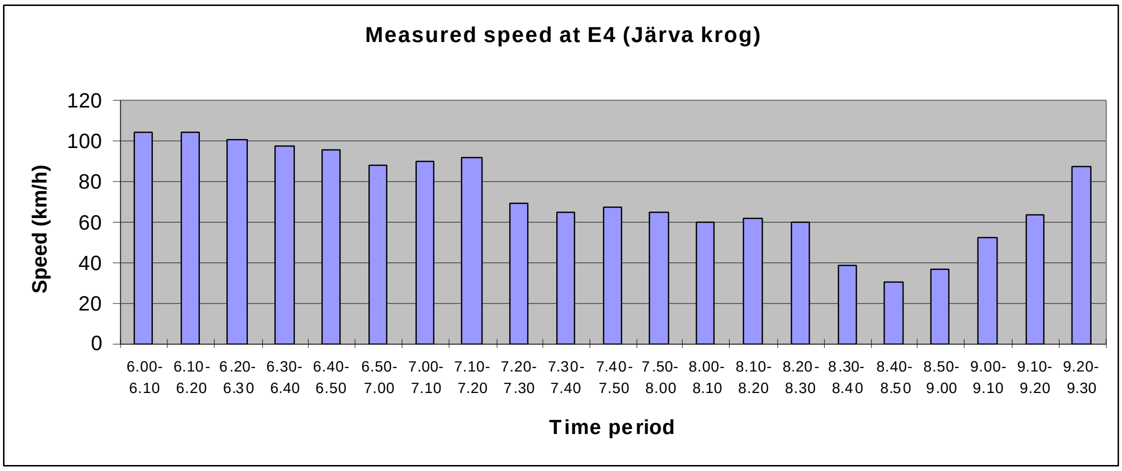


Figure 8.3 **Speed data from a detector that can be used to calibrate a model**

Sensitivity analysis

The sensitivity analysis is performed in order to obtain a better understanding of what factors have the highest importance for the model quality. Setting values for the different parameters in a model is part of the calibration process. If the calibration parameters are easily understood and possible to measure the sensitivity analysis and the calibration process will be easier understood. Of course you also need a lot of knowledge about the traffic behaviour in the city you study.

Sensitivity analysis is a time-consuming process because each parameter has to be individually analysed. The user can set the parameters depending on the characteristics of the traffic. These parameters can also vary from one country to another or from one environment to another.

The sensitivity analysis can be done in tree ways:

- Changing model parameters (route choice, global or local parameters, vehicle parameters)
- Changing the network (geometry changes)
- Changing the control plan (for instance changing the green time)

Calibration and validation process

Calibrating a dynamic traffic model is a difficult issue. Both traffic data and knowledge about the traffic behaviour is needed. A key problem in the calibration procedure is to model the through-put of traffic correctly, i.e. the maximum flow at the critical bottlenecks in the network. These maximum flows decide what the state of congestion is and hence the travel times and pollution levels are depending on a correct modelling of the bottlenecks.

Calibration the network capacity of a microscopic model is very different from a mesoscopic model or macroscopic model. At the micro level, the traffic throughput is decided by the driver behaviour, the vehicle parameters are easily understood and possible to measure. Examples could be acceleration rate or average headway.

Calibration step by step

The calibration examples presented below are from three test sites in the SMARTEST project (Stockholm, Toulouse and Leeds)

8.2 Stockholm – AIMSUN2

In Stockholm the focus has been on the calibration and therefore no explicit validation of AIMSUN2 in Stockholm has been done. The following calibration steps were taken for the Stockholm test site and AIMSUN2:

- A first simulation run including dynamic assignment was done
- The animation was studied in order to find errors in the coding.
- The graphical tools, like colouring vehicles by destination, were used to find unrealistic behaviour.
- Simulated section flows were compared to measurements
- The network and the signal timing were re-coded according to errors found
- Some crucial route choice parameters were studied in order to understand how they should be set. (The dynamic route choice model proved to be difficult to calibrate. Most of the parameters were abstract and not measurable.)
- A new simulation run was made and new comparisons with measurements were done.
- The freeway speed and flow conditions were studied in detail using measurements from detectors (se figure 8.2)
- The significance of certain model parameters was investigated in a sensitivity analysis.
- The knowledge gained in the two last steps was used to tune the model parameters further.

The freeway speed and flow conditions were studied in detail using measurements from detectors.

In the figure below is shown the result from one of the detectors from the MCS system in the Stockholm test site.

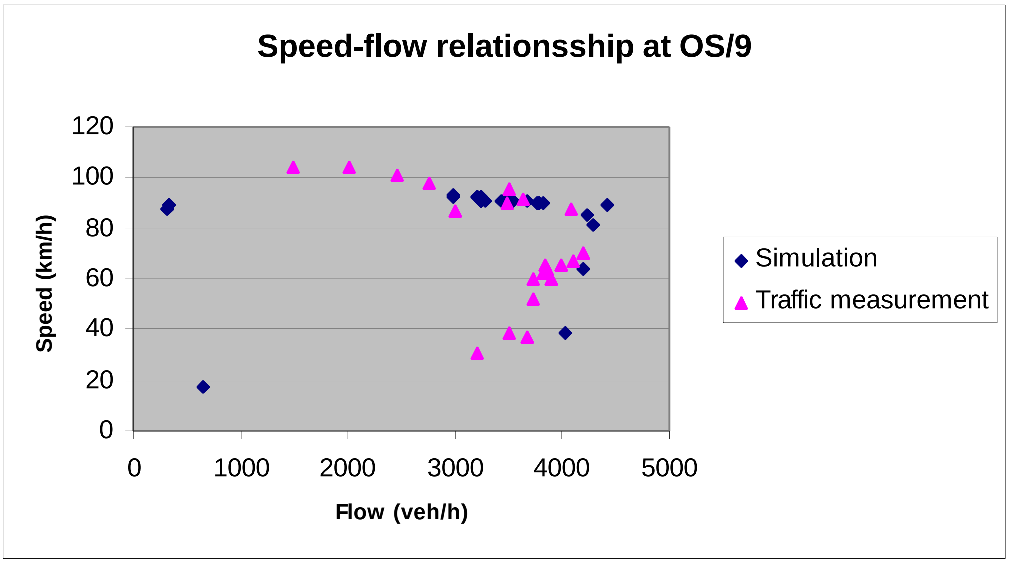


Figure 8.4 Calibration against speed-flow data in Stockholm

The final results from the calibration process in the Stockholm test site in shown in the figure below. In the figure you can see for some sections in the network the difference between the flow with EMME/2 and the flow after 3 different calibrations.

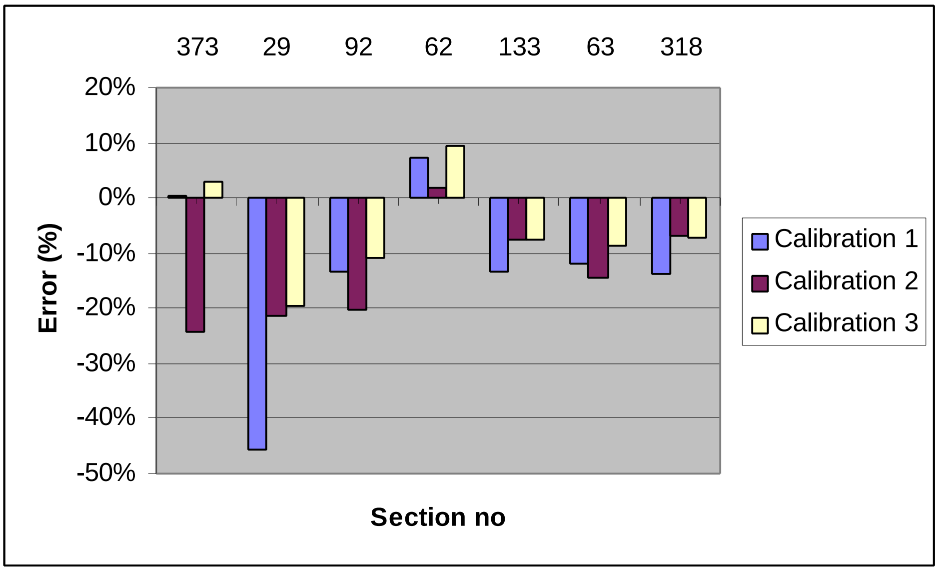


Figure 8.5 **The results from the calibration process for some of the sections in the Stockholm model**

Suggested calibration process based on experience from the Stockholm test site

From the knowledge and experience gained in the calibration and sensitivity analysis, the following calibration procedure is suggested:

1. Travel demand

Use a traffic planning package e.g. EMME/2 to calibrate the OD matrix against traffic counts. The calibrated matrix may then be input directly in TEDI, or the input flows and turning proportions resulting from the equilibrium assignment may be used. The former should be used if dynamic rerouting is of interest in the applications, and the latter if the route choice should be locked.

A more exact calibration would be obtained if a measured OD matrix is available in combination with measured flows and speeds.

2. Network coding

Visually check the coding by using model animation. Abnormal queues, frequent U-turns, blocked vehicles, unrealistic route choices, abnormal flows and speeds can be indicators of coding errors. Use the possibilities to colour the vehicles e.g. by destination to check for unrealistic route choices.

3. Flow

When the network coding is free from errors and adjusted to the known model Compare measured and simulated flows for as many sections as there is data available. Simulated detector data is preferred to section statistics.

4. Freeway flow and speed

Prediction of freeway travel times when flow is near capacity is very much depending on a correct modelling of ramps, weaving, headway, overtaking, courtesy yielding etc.

Produce speed-flow relationships for the freeway and compare with measurements. In case of disagreement, analyse the causes in terms of ramp coding, lane changing, model parameters that affect flow and speed.

5. Traffic modelling in urban environments

The travel time in urban areas depends mainly on the delay at the nodes, especially the signalised intersections.

Calibrate the signal timing plans, turning speeds and saturation flows using measured flows, queue lengths, speeds and travel times.

6. Fuel consumption

Calibrate the parameters in the fuel consumption model using data from floating car studies or similar.

8.3 Toulouse - SITRA – B+

The model calibration consists in checking that the simulation model results obtained for the reference situation are as close as possible to the measurements performed on the site. This is usually performed by an iterative process composed of simulation and result analysis where model parameters have to be tuned.

With SITRA-B+ intermediate simulation results can be written in the file *link_period_output.rel*. The generation period of this file has to be specified by the last parameter of the file *global_parameters.rel*. The graphical interface allows to monitor the simulation run to see if the model performs as desired. Vehicle movements in each intersection have also to be observed to check if the file *vehicle_movement.rel* is correctly completed.

It is required to plan a period to load the network before the study period. 15 minutes are usually enough with a demand divided by 2 or 3 comparing to the demand used for the study.

In most situations, calibration consists in tuning model parameters to obtain the desired traffic flows on links, desired vehicle movements in intersections or desired traffic phenomena on links, like desired queue lengths. Many parameters can be tuned during calibration:

- To obtain the desired traffic flow on a link with traffic signals, it is interesting to count the number of vehicles that SITRA-B+ allows to pass at green time. Signal timings may then be slightly changed to obtain the desired value
- Intersection lanes have to be modelled with precision. Two intersection lanes leading to one output lane may result in many conflicts that make SITRA-B+ let out less vehicles than desired. A solution to this specific problem is to create the convergence point far enough from the intersection.
- Too many lane changing movements in a link can also reduce drastically link traffic flow, and particularly if the link is short. In such situations, network modelling can lead to create distinct links instead of one so that vehicle routes do not require lane changing any more. Very short links (less than 10 meters) should be avoided.
- When approaching traffic light intersections, it is sometimes required to adjust the approaching link layout (creation of a flare) to increase the capacity and to obtain desired queue length on upstream links (provided that at green time traffic may cross the intersection without generating conflicts).

Two functions developed in the context of the Project are submitted to a detailed evaluation plan: Public Transport services and Roundabout (appendix x).

Model validation of the roundabout

The figure below shows the graphical interface of SITRA-B+ (PC Version) and the roundabout network.

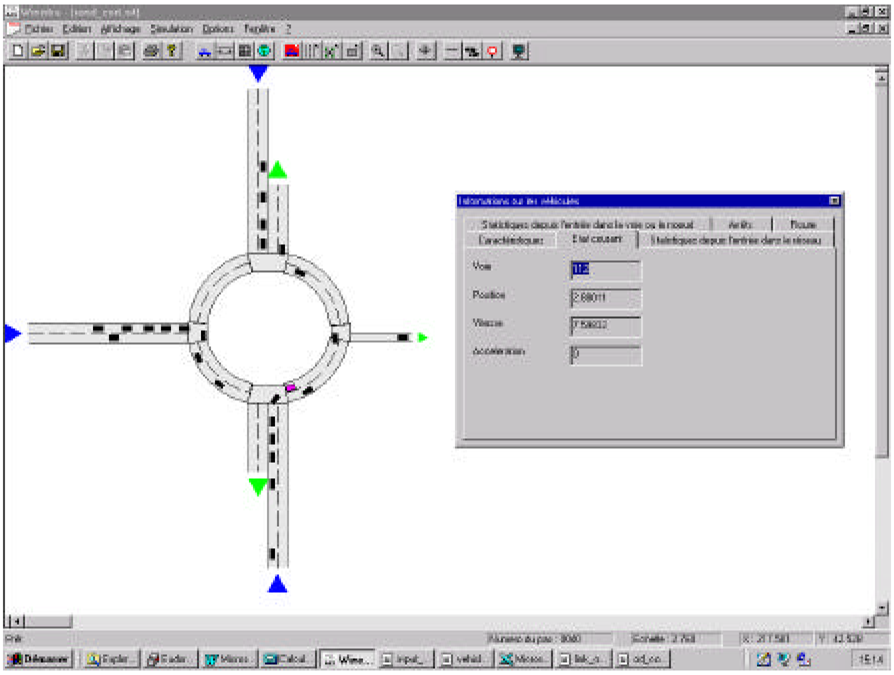


Figure 8.6 **Roundabout in SITRA- B+ evaluated in Toulouse**

The roundabout model validation consisted in simulating the test site roundabout with the measured demand and to assess SITRA-B+ results. Data analysis gave the following results:

Traffic flow for each input (veh/h)

Input number	Simulated flow	Observed flow	Difference
1	1164	1296	10,2%
2	1068	1200	11,0%
3	468	612	23,5%
Total	2700	3108	13,1%

Traffic flow for each output (veh/h)

Output number	Simulated flow	Observed flow	Difference
4	216	240	10,0%
5	948	1440	34,2%
6	1080	1428	24,4%
Total	2244	3108	27,8%

Traffic flow for each O/D (veh/h)

O/D number	Simulated flow	Observed flow	Difference
1 - 5	384	576	33,33%
1 - 6	612	720	15,00%
2 - 5	372	516	27,91%
2 - 6	432	684	36,84%
3 - 4	216	240	10,00%
3 - 5	192	348	44,83%
3 - 6	24	24	0,00%

The results obtained with the simulation of this roundabout shows differences in traffic flows from 0% to 44%. It is noticeable that the simulated flows at all entries are always less than the observed flows at the same points. This is due to the fact that the queues at entries were building (video is recorded at peak hour and queues are long at all entries) and the simulated roundabout is not able to let out as many vehicles as in real life. The "aggressiveness" and the "gap acceptance" parameters have to be adjusted in SITRA-B+ to consider the behaviour of drivers who are used to cross this particular roundabout. The videotape observation also shows a more complex lane choice and lane changing behaviours than the simulated one, which contributes to limit the capacity.

However, travel times for vehicles crossing the roundabout, as well as the general behaviour of drivers within the roundabout were satisfactory.

8.4 Leeds - DRACULA

A model of a small network in Leeds were studied using the DRACULA micro-simulation tool. The network contains just two key junctions on Sheepscar Street at Buslingthorpe Lane and Sackville Street.

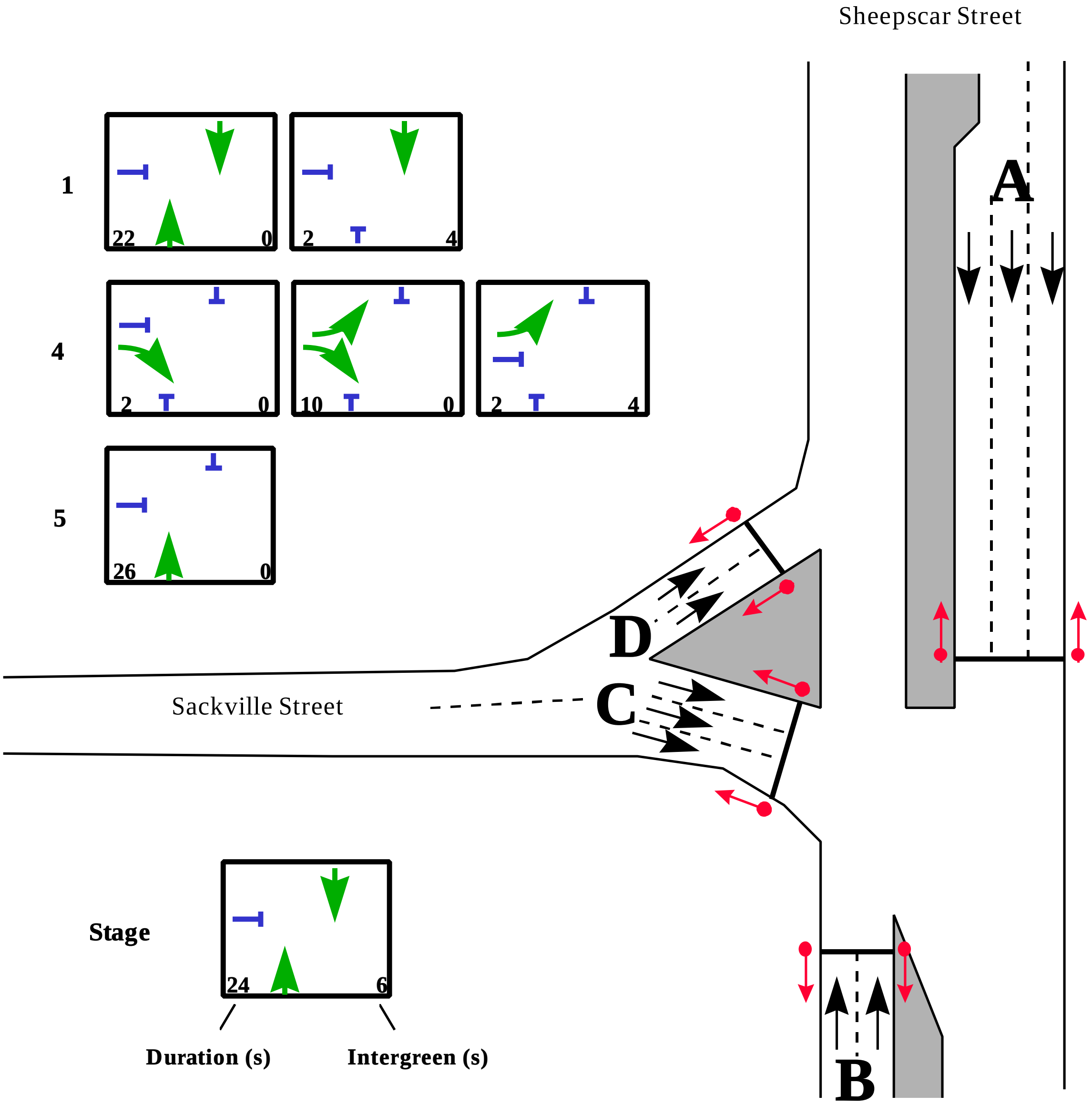


Figure 3: The Sheepscar Street / Sackville Street junction (4331)

Signal plans for all the signalised junctions and flow data within the test area was provided by Leeds City Council and used to code up the network in DRACULA.

8.4.1 Validation data

Statistical Considerations

When comparing simulation outputs with data collected from the real world it is important to ensure that sufficient data has been collected to estimate the values being compared to a desired accuracy. If the usual statistical assumptions are made regarding the normality of the data then it is possible to determine the confidence interval for a population mean. The confidence interval is a range on either side of the sample mean ($\bar{x}$). It is expressed as a function of a significance level, α, which usually has a value of 95%, and is given by the formula:

$$\left(t_L, t_U\right) = \left(\bar{x} - z_{1-a/2}\frac{s}{\sqrt{n}}, \bar{x} + z_{1-a/2}\frac{s}{\sqrt{n}}\right)$$

where $z_{1-\alpha/2}$ is that value in the standard distribution that has $1-\alpha/2$ area to the left of the mean. For a 95% confidence level, $\alpha = 0.05$ and $z_{1-\alpha/2} = z_{0.975} = 1.96$.

Saturation flows

Analysis of a video of the Sheepscar Street / Sackville Street junction, from the Leeds Urban Traffic Control centre, indicates that during the peak hour 2110 cars and trucks pass southbound (movement A in Figure 3). If this is broken down by lanes, approximately 640 vehicles per hour use the outside lane and 735 vehicles per hour use each of the other two lanes. The smaller number of vehicles using the outside lane is due to the presence of a flare on this approach. The junction is operating very close to capacity and it is not unusual if the queue in movement A sometimes fails to clear during the cycle.

Initial simulation runs with DRACULA, using default values of vehicle motion parameters, were unable to reproduce the observed saturation flows. The flows through the junction in the DRACULA model were lower than those observed. A study was therefore carried out using AIMSUN2 to discover how flows through the junction are affected by changing each of a number of key parameters.

The parameters chosen for examination were the:

- global reaction time / timestep (Default value = 0.75s)
- car acceleration rate (Default value = 2.8 m/s/s)
- car maximum deceleration rate (Default value = 8.0 m/s/s)
- car normal deceleration rate (Default value = 5.0 m/s/s)
- distance between stationary queued vehicles (Default value = 1.0m)

The reaction time is used in the car following rule to specify how quickly a vehicle reacts to changes in the speed of the vehicle in front of it. A reduction in the value of the reaction time allows vehicles in a queue of traffic to respond faster when the queue starts moving. Thus a reduction in the reaction time will increase the flow through the junction. By reducing the reaction time to 0.65 seconds it was possible to approximately replicate the observed flow rate. It is interesting to note that measurements of driver's reaction times give a typical value of about one second. It is however plausible that drivers in a queue of traffic are able to anticipate when the car in front of them is about to move, by observing both changes in the traffic signals and all the cars ahead of it in the queue. This would allow them to appear to have a faster reaction time than would be the case if they solely relied on seeing the car immediately in front of them move before starting themselves.

Having now approximately replicated the observed flow rate, an investigation was made to see how the flow rate deviated from the true values following systematic changes in the values of each of the chosen parameters. While each parameter was varied, all the other parameters were kept at their default value, apart from the reaction time, which was fixed at 0.65s. A set of four simulation runs, each using a different value of the random number seed, were used for each parameter value tested. The results are presented in Table 4.

Value	Lane 1	Lane 2	Lane 3	Total
Reaction Time (s)				
0.60	793.50	803.25	608.50	2205.25
0.65	**756.00**	**768.25**	**617.50**	**2141.75**
0.70	725.75	734.75	615.00	2075.50
Maximum acceleration rate (m/s/s)				
3.8	786.25	794.50	609.00	2189.75
1.8	699.25	700.25	597.50	1997.00
Maximum deceleration rate (m/s/s)				
5.0	770.25	786.50	615.25	2172.00
11.0	749.25	753.75	613.25	2116.25
Normal deceleration rate (m/s/s)				
6.0	785.75	794.50	615.75	2196.00
4.0	699.50	699.50	614.75	2013.75
Minimum distance between stationary vehicles (m)				
0.8	768.25	786.00	628.50	2182.75
1.2	746.50	751.00	591.00	2088.50

Table 4 : Flow rate as a function of vehicle motion parameters

Denoting changes in the flow rate as ΔF, reaction time as ΔR, maximum acceleration rate as Δa, maximum deceleration rate as Δd, normal deceleration rate as Δn, and minimum distance between stationary vehicles as Δg, simple approximate relationships can be derived for this junction to give the following values:

$$\Delta F = -1297.5\ \Delta R = 96.4\ \Delta a = -\ 9.3\ \Delta d = 91.1\ \Delta n = -\ 235.6\ \Delta g$$

These indicate that the flow rate can be changed by making small changes to the reaction time, by moderate changes to the acceleration and deceleration rates or the distance between stationary vehicles or by large changes to the maximum deceleration rate.

With the DRACULA model the reaction time is fixed at one second, the same as the simulation timestep. Therefore to increase the flows through the junction other vehicle motion parameters need to be adjusted. After adjusting various parameters in the DRACULA model, it was possible to obtain the following flows (average values over 5 runs) 716 in nearside lane, 710 in centre lane, 670 in offside lane. This is approximately in line with the observed values, the total being only 14 vehicles short of that observed.

Bus travel times

Data has been collected, using moving observers, on the journey times of buses between five bus stops and dwell times of buses at these stops for buses travelling down Sheepcar Street between Potternewton Lane and Sackville Street during the morning peak period. A summary of this data is presented in Table 5 and Table 6. The mean value, the number of observations (N) and the standard deviations (s.d.) are given. The upper and lower limits of the confidence interval, at the 95% confidence level, between which it is expected that the mean value will lie are also given in the tables. The final column in the tables shows the value output from DRACULA for these times.

Stops	Mean (s)	N	s.d.	Lower (s)	Upper (s)	DRACULA (s)
1-2	21.88	33	4.285	20.42	23.34	24.9
2-3	36.31	16	5.654	33.54	39.08	38.9
3-4	40.87	30	15.900	35.18	46.56	34.6
4-5	39.92	49	12.670	36.37	43.47	44.4

Table 5: Bus journey times between stops during the morning peak (08:00-09:00)

Stop ID	Mean (s)	N	DRACULA (s)
1	25.9	31	25.7
2	19.8	12	19.7
3	38.4	25	40.7
4	22.6	21	23.9
5	11.6	23	13.5

Table 6: Dwell times at stops during the morning peak (08:00-09:00)

As can be seen there is good agreement between the observed and the modelled journey times and bus stop dwell times.

Car Travel Times

A total of 42 journey times between the Buslingthorpe Lane junction and the Sackville Street junction were collected. These revealed a mean travel time of 62 seconds. Five runs of DRACULA give a mean journey time of 61.6 seconds from a sample of 10,399 observations.

8.4.2 Conclusions

By adjusting various key parameters it is possible to get good agreement between DRACULA outputs and real world data.

8.4.3 References

Liu, R., Van Vliet, D. and Watling, D. (1995) *DRACULA: Dynamic Route Assignment Combining User Learning and Micro-simulation*, Paper presented at PTRC, Vol. E, pp 143-152.

8.5 Transferability

In SMARTEST, we had an ambition to look at transferability. If we have a model developed using data at one site, how can this help with the analysis at another site, if we use the same micro-simulation models to assess different schemes in other towns? How confident can we be that the conclusions we draw at one site are valid at another site? The new site might be in a region with a different set of objectives, so different indicators will need to be used. Two transferability tests were conducted. The first concerned the AIMSUN2 implementation in Stockholm, the second looked at the use of DRACULA, NEMIS and AIMSUN2 on a site in Leeds.

8.5.1 AIMSUN2 in Stockholm (Swedish traffic)

The conclusions from this test were the following (based on version 3.2):

- A “weather parameter” is missing.
- In Sweden the driver’s choose the “right” lane (minimising future lane changes) as early as possible. In the model you can choose to change lane only on the section which is closest to the intersection.
- The on ramp behaviour could be improved. In most cities in Sweden you yield if you see a car approach from the ramp.
- A local parameter is missing. For instance in Sweden the capacity is higher on the ramp than on the motorway. This has been introduced in version 3.3.

8.5.2 DRACULA, NEMIS and AIMSUN2 in Leeds

Introduction

Three micro-simulation tools have been used in the study, namely:

- DRACULA
- NEMIS
- AIMSUN2

All three tools were used to model a road network in Leeds. Comparisons were made between the outputs of each of the tools and data collected from the real road network.

Other issues addressed include:

- the ability of each of the tools to model all the features found in the test network,
- whether default values for calibration parameters such as those for car following are valid at the test site and
- the sensitivity and robustness of the results.

The test network

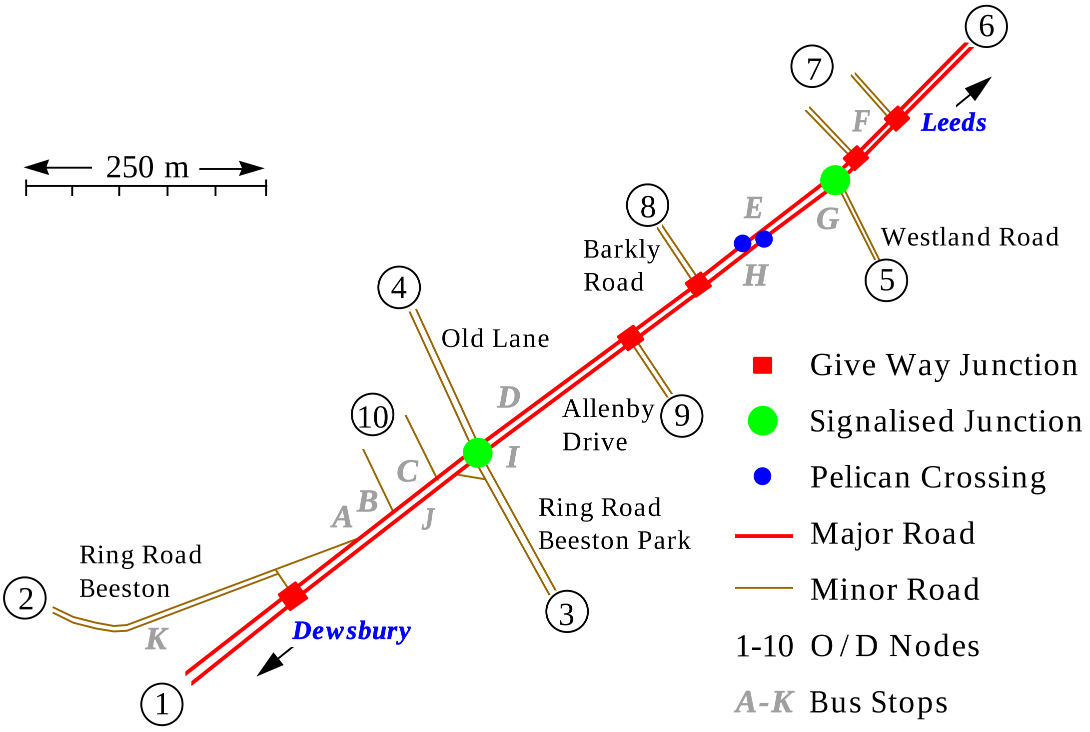


Figure 4: The Dewsbury Road - Leeds

A network in Leeds was chosen for this study because of the ready availability of suitable data to both define the network and to compare against model outputs. This data had been collected as part of the PRIMAVERA project (Fox et.al., 1995). PRIMAVERA developed advanced traffic management strategies for urban arterial roads. These strategies were developed with the aid of the NEMIS micro-simulation tool and then the best strategy was implemented on-street. Much data was collected, firstly to calibrate and validate the initial micro-simulation model of the network, then to evaluate the effectiveness of the new strategies on-street. Data was collected for both AM and PM Peak periods. The full PRIMAVERA network in Leeds consisted of ten signalised intersections along 3km of an urban arterial, namely the Dewsbury Road, classified as the A653. This is one of the main radial routes into Leeds, carrying approximately 23,000 vehicles per day. It is also a heavily used public transport corridor, peak bus flows being in excess of 36 buses per hour.

To simplify the transferability tests carried out by the SMARTEST project, a sub-network of the PRIMAVERA network was used. This consisted of a 1½ km segment of the Dewsbury Road, containing two signalised junctions and a pelican crossing (see Figure 4). The test network also contains a number of priority junctions, where minor roads join the main arterial. Bus stops are also present in the network. The network thus contains many features that are common in urban road networks in the UK. An additional feature of the test network is that there is only one route between each of the origin destination pairs, therefore route choice is not an issue to cloud the model evaluation. It was also decided to only carry out simulation runs of the AM peak period.

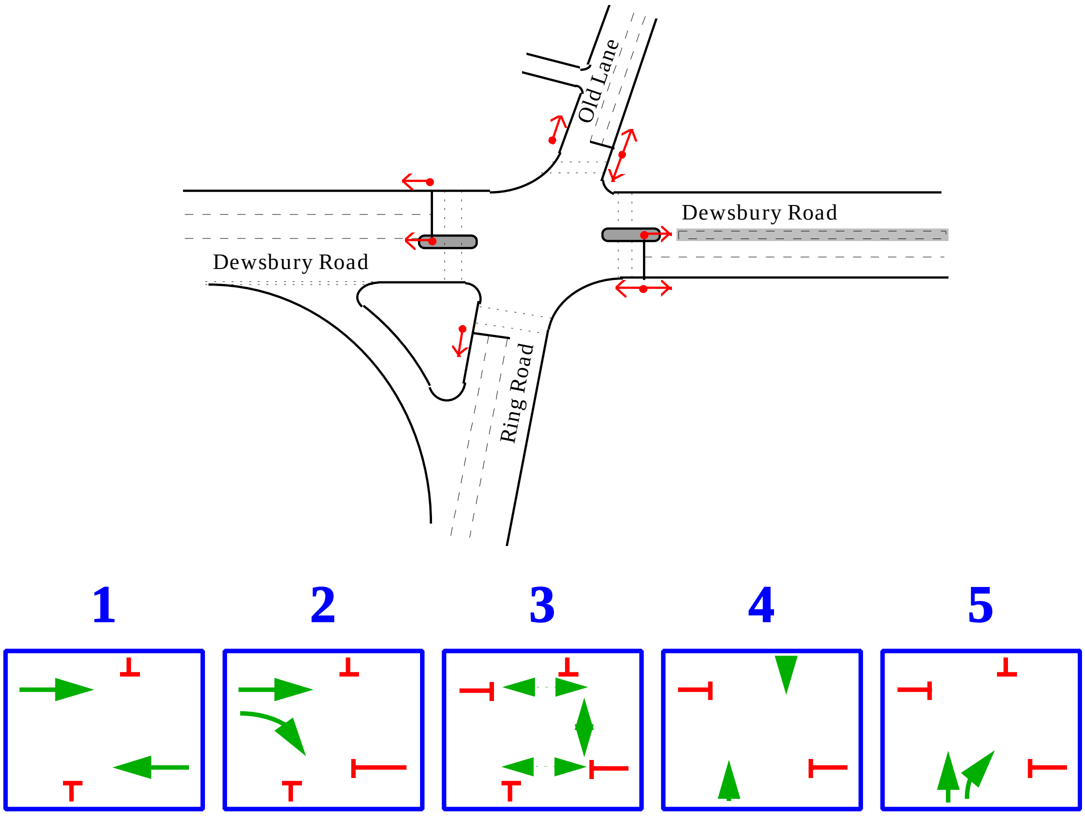


Figure 5: Old Lane / Ring Road Beeston Park Junction

The main signalised junction in the network is where Old Lane and the Ring Road Beeston Park meet the Dewsbury Road. This is a four arm junction with pedestrian facilities (see Figure 5). All the approaches are signalised, however the left turn from the Ring Road onto the Dewsbury Road is an unsignalised slip road. There are bus routes along each of the four arms of the junction.

The other signalised junction in the network is a three arm junction where Westland Road joins the Dewsbury Road (see Figure 6).

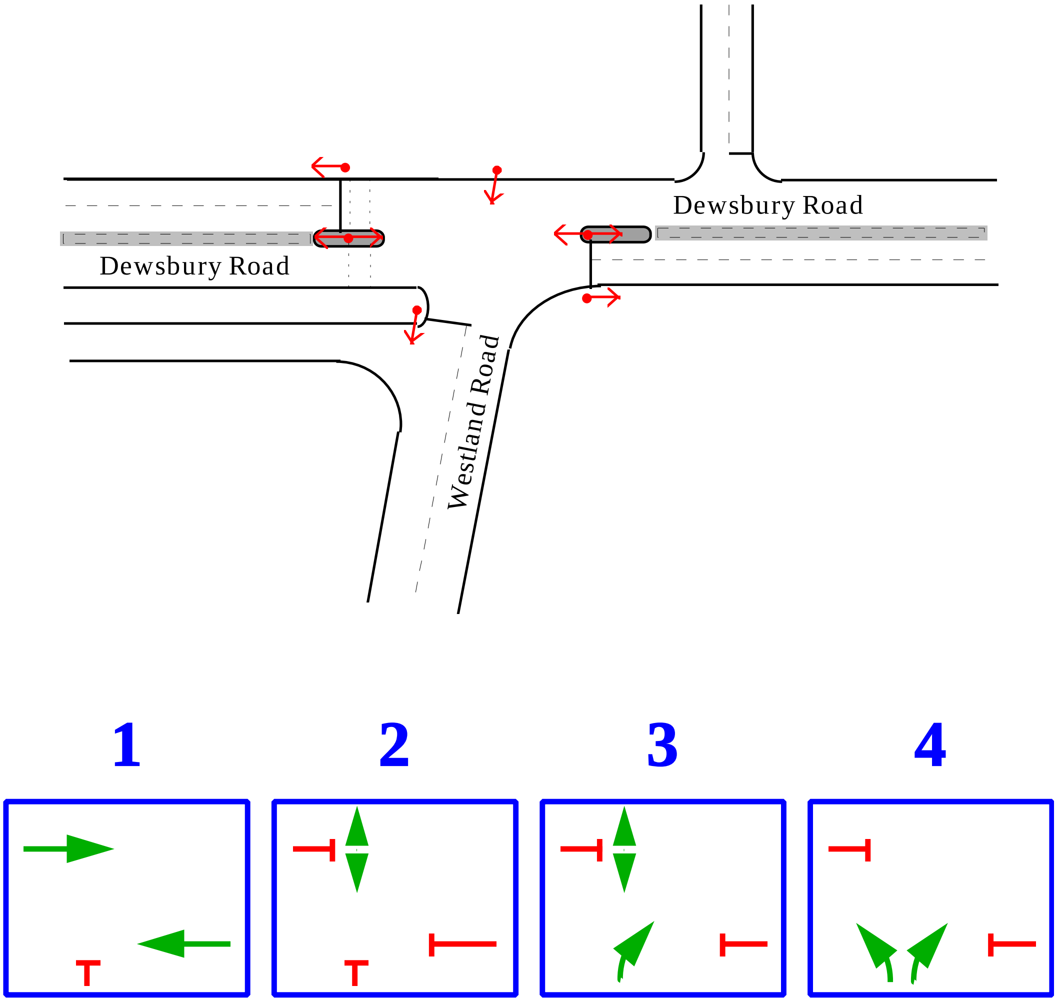


Figure 6: Westland Road Junction

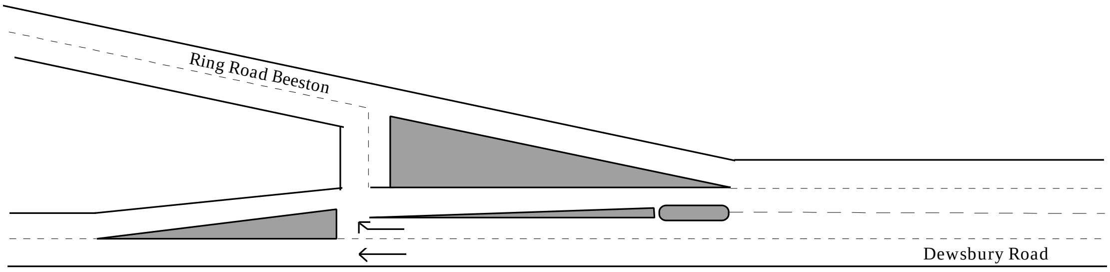


Figure 7: Junction with Ring Road Beeston

The major non-signalised junction in the network is at the south western end where the Ring Road Beeston merges with the Dewsbury Road. This is a quite complicated priority junction. There are separate lanes reserved for right turns from the Dewsbury Road into the Ring Road Beeston and for both left and right turns out of Ring Road Beeston on to the Dewsbury Road (see Figure 7).

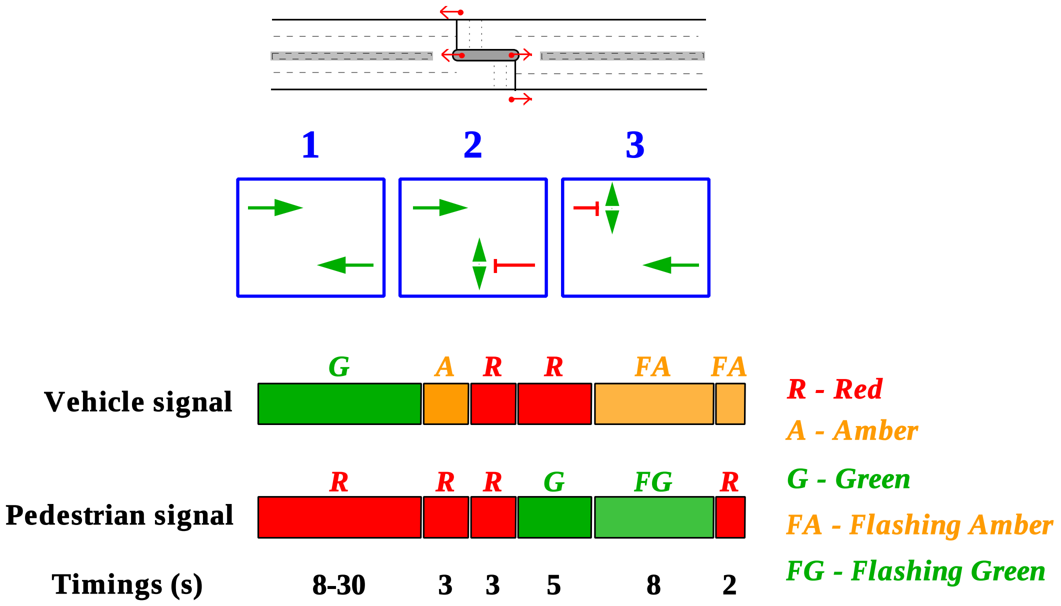


Figure 8: Barkly Road Pelican

There is also a staggered pelican crossing in the network. It is on the Dewsbury Road close to Barkly Road (see Figure 8).

Although the PRIMAVERA project developed traffic management strategies that utilised the SCOOT and SPOT adaptive signal control systems, at times the network also operated using signals controlled by fixed time plans. The data used for the SMARTEST transferability tests only related to those periods where the network was under fixed time control. These fixed time plans are given in Table 7. These include the cycle times and offsets and the durations of each phase and intergreen period in seconds. See each of the junction diagrams for details of movements associated with each phase.

Junction	Cycle Time	Offset	1	I	2	I	3	I	4	I	5	I
1	88	34	40	4	4	11	7	8	7	4	4	7
2	88	20	63	6	8	6			10	5		

Table 7: AM Peak fixed time plans

Junction 1: Old Lane. Junction 4: Westland Road.

Note that the Barkly Road pelicans are double cycled, i.e. they have a cycle time half of that for the rest of the network.

Bus routes go between many of the origin and destination nodes in the network. The bus routes associated with each origin and destination pair, along with their scheduled entry times at each origin during the AM Peak hour are shown in Table 8.

O	D	Buses	Route Number(Origin Start Times)
1	6	15	46(15,45), 117(5), 118(44), 201(10), 202(42), 203(25,55), 218(11), 220(41,51), 222(35), 226(26), X7(5), X16(20)
2	3	2	9(0,36)
2	6	4	2(0,15,30,45)
3	2	2	8(10,34)
3	4	2	74(0,30)
3	6	12	3(9,24,39,54), 24(4,34), 25(17,47), 77(11,41), 484(19,29)
4	3	2	74(19,54)
6	1	12	46(27,57), 117(43), 118(15), 201(26), 202(56), 203(11,41), 218(13), 220(43), 222(3), 226(0)
6	2	4	2(0,15,30,45)
6	3	10	3(8,23,37,52), 24(19,49), 25(4,34), 77(22,52)

Table 8: Bus Routes, frequencies and starting times during the AM Peak hour

Data Collected

Much data was collected during the PRIMAVERA project. In addition, a digital map of the area was available in AutoCAD format, which allowed the network geometry to be easily and accurately measured. The surveys carried out are summarised in Figure 9.

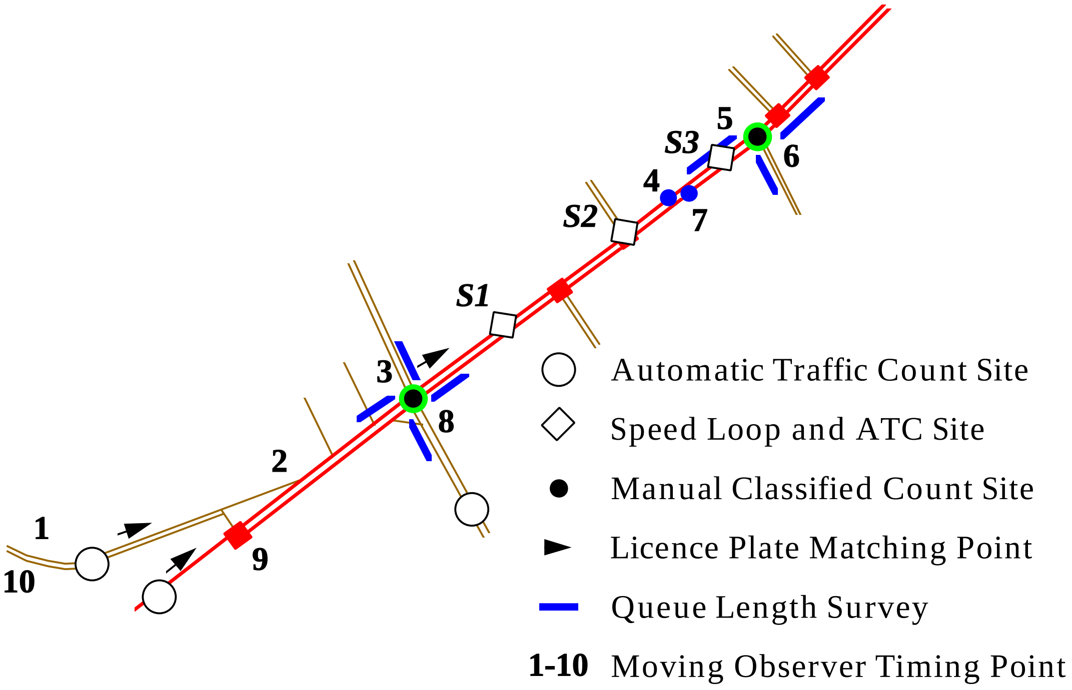


Figure 9: Field Trial Data Collection

Statistical analysis has been used to estimate the accuracy of the collected data. When comparing simulation outputs with data collected from the real world it is important to ensure that sufficient data has been collected to estimate the values being compared to a desired accuracy. If the usual statistical assumptions are made regarding the normality of the data then it is possible to determine the confidence interval for a population mean. The confidence interval is a range on either side of the sample mean. It is expressed as a function of a significance level, α, which usually has a value of 95%, and is given by the formula:

$$\left(t_L, t_U\right) = \left(\bar{x} - z_{1-a/2}\frac{s}{\sqrt{n}}, \bar{x} + z_{1-a/2}\frac{s}{\sqrt{n}}\right) \qquad (1)$$

where $z_{1-\alpha/2}$ is that value in the standard distribution that has $1-\alpha/2$ area to the left. For a 95% confidence level, $\alpha = 0.05$ and $z_{1-\alpha/2} = z_{0.975} = 1.96$.

The surveys on the PRIMAVERA network included:

- Automatic Traffic Counts, using loops, to measure traffic flows in both directions at three points in the network.
- Automatic Speed and Flow measurements as vehicles passed over at three data collection points on the Dewsbury Road.
- Manual Classified Counts at two of the junctions, to obtain turning movements for seven categories of vehicle.
- Travel time surveys both by number plate matching at three points in the network and by moving observers travelling in cars and buses around the network.
- Queue length surveys were carried out at the two signalised intersections.
- Bus waiting times at stops were measured by observers.

Flow Data

The Automatic Traffic Counts and the Manual Classified Counts have been combined to produce two Origin/Destination matrices for the AM Peak hour. The first matrix is for cars, the second for heavy goods vehicles (HGVs). These can be seen in Table 9 and Table 10.

	1	2	3	4	5	6	7	8	9	10	*Total*
1	-	-	90	26	32	470	25	30	30	-	*703*
2	-	-	50	13	16	240	10	15	15	-	*359*
3	110	110	-	241	40	230	5	5	-	-	*741*
4	22	22	215	-	10	50	-	-	5	-	*324*
5	12	12	5	1	-	80	5	-	-	-	*115*
6	150	180	100	10	200	-	25	-	30	-	*695*
7	10	10	5	-	10	25	-	-	-	-	*60*
8	-	-	-	-	25	150	-	-	-	-	*175*
9	10	10	5	5	5	25	-	-	-	-	*60*
10	-	-	-	-	-	50	-	-	-	-	*50*
Total	*314*	*344*	*470*	*296*	*338*	*1320*	*70*	*50*	*80*	*0*	

Table 9: The Car O/D Matrix for the AM Peak hour

	1	2	3	4	5	6	7	8	9	10	*Total*
1	-	-	4	1	4	11	-	-	-	-	*20*
2	-	-	3	-	4	12	-	-	-	-	*19*
3	8	2	-	-	-	10	-	-	-	-	*20*
4	-	-	-	-	-	1	-	-	-	-	*1*
5	5	1	-	-	-	17	-	-	-	-	*23*
6	8	3	10	4	4	-	-	-	-	-	*29*
7	-	-	-	-	-	-	-	-	-	-	*0*
8	-	-	-	-	-	-	-	-	-	-	*0*
9	-	-	-	-	-	-	-	-	-	-	*0*
10	-	-	-	-	-	-	-	-	-	-	*0*
Total	*21*	*6*	*17*	*5*	*12*	*51*	*0*	*0*	*0*	*0*	

Table 10: The HGV O/D Matrix for the AM Peak hour

Car Travel Time Data

Two “moving observers” were used to collect travel time data in the network. Staff drove a car round two defined routes and noted times as they passed specific timing points (see Figure 9). Data was collected on five weekdays in July and three weekdays in October 1994. The data relevant for the AM peak is presented in Table 11. This identifies the times between the various timing points, the number of observations (n), the mean travel time (seconds), the standard deviation of the travel time (seconds), the 95% confidence interval as given by equation (1), and the distance between the timing points (metres).

Link	n	Mean (s)	s.d.	C.I.	Length (m)
1-2	50	41.0	9.79	(38.3,43.7)	469
2-3	51	63.0	32.39	(54.1,71.9)	196
3-4	98	36.1	4.37	((35.2,37.0)	493
4-5	100	24.6	11.75	(22.3,26.9)	185
6-7	99	13.7	2.91	(13.1,14.3)	193
7-8	100	56.3	23.53	(51.6,60.9)	480
8-9	98	34.0	15.53	(30.9,37.1)	270
9-10	100	55.6	19.59	(51.7,59.4)	430

Table 11: Car Travel Times AM Peak (Moving Observers)

Queue Data

Queue surveys were carried out at the two signalised intersections in the network during the AM peak. Queue lengths were defined by the number of vehicles waiting at the moment the signals changed to green. The queues for the Old Lane / Ring Road Beeston Park junction can be seen in Figure 10. Unfortunately the queue on the Ring Road arm often extended beyond the visibility of the observer.

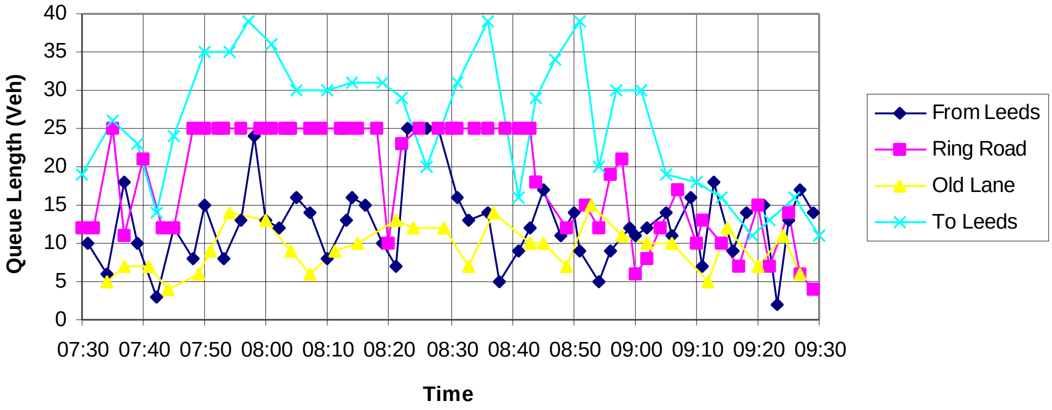


Figure 10: Queues on the Old Lane / Ring Road Beeston Park junction (AM Peak)

Figure 11 shows the queues on the Westland Road junction. Once again there were times when the queues on one of the arms (Dewsbury Road traffic going to Leeds) extended beyond the visibility of the observer.

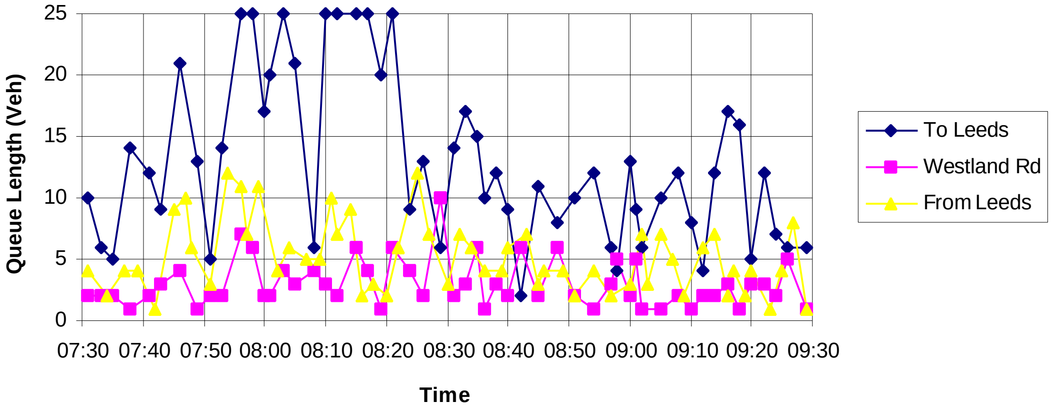


Figure 11: Queues on the Westland Road junction (AM Peak)

The data relevant for the arms where the queue was always fully observed are shown in Table 12. This identifies the various arms, the mean queue (vehicles), the standard deviation of the queue (vehicles), the number of observations (n) and the 95% confidence interval as given by equation (1).

	Mean	s.d.	n	C.I.
Old Lane Junction				
To Leeds	25.6	8.75	31	(22.5,28.7)
From Leeds	12.6	5.17	51	(11.2,14.1)
Old Lane	9.3	3.04	29	(8.2,10.5)
Westland Rd Junction				
From Leeds	5.2	2.87	53	(4.4,6.0)
Westland Rd	3.0	1.92	55	(2.5,3.5)

Table 12: Mean Queue Lengths

Modelling Approaches

All three micro-simulation models used similar network representations. Nodes represent junctions, and nodes are connected by links, each with a number of lanes.

Separate links are required for travel in each direction, i.e. none of the models allowed two-way movement on a link. This limitation can be important as it prevents overtaking via the oncoming lane if there is a suitable gap.

NEMIS has a minor limitation in that it can only model road networks where traffic usually drives on the right, so to model the UK network a mirror image has to be used. NEMIS also has a limit of four arms to a junction.

NEMIS is the only model that has provision for on-street parking.

AIMSUN2 has a very user friendly network builder that allows AutoCAD maps to be used as backgrounds. The road network model is then drawn over the top of this map. This allows an accurate network geometry to be specified without fear of error. AIMSUN2 was therefore the first model used to code up the Dewsbury Road network. The link lengths and their positions obtained from the AIMSUN2 model were then used to code up the NEMIS and DRACULA network models.

Car-Following and Lane Changing

Driver behaviour is modelled via a car following rule and gap acceptance and overtaking rules. These usually have parameters which characterise desired headways, reaction times, aggressiveness, awareness and acceptable gaps for lane changing and turning across opposing traffic flows. Due to difficulties in measuring these parameters few of them are ever measured directly. The modeller relies on indirect measurements such as average headways, lane usage or saturation flow measurements to justify the values used.

AIMSUN2 uses a car following law based on that suggested by Gipps (1981) and a lane changing rule based on Gipps (1986). NEMIS uses a different car-following law, based on a study by Donati and Largoni (1976). Key parameters for four different vehicle types have been determined.

Vehicle Types

Both NEMIS and DRACULA have a limit on the number of vehicle types allowed. DRACULA is limited to six types, namely Cars, Buses, Guided Buses, Taxis, High Occupancy Vehicles and Heavy Goods Vehicles. NEMIS allows seven types, namely five different types of private vehicle, plus buses and trams. AIMSUN2 allows multiple vehicle types to be specified.

Each vehicle type has associated with it a fixed set of parameters, such as acceleration and deceleration rates, vehicle length and car following parameters. Table 13 gives some of the default parameters provided for the various vehicle types used by each of the models.

DRACULA	Car	Bus
Maximum Acceleration (m/s/s)	2.5	2.5
Maximum Deceleration (m/s/s)	2.5	2.5
Length (m)	3.5	7.5

AIMSUN2	Car	Truck	Bus	Long Truck
Maximum Acceleration (m/s/s)	2.8	1.0	2.0	1.0
Maximum Deceleration (m/s/s)	4.0	3.5	3.0	3.5
Length (m)	4.0	8.0	9.0	12.0
Desired Speed (km/h)	90	70	60	70

NEMIS	All vehicles
Maximum Acceleration (m/s/s)	3.0
Maximum Deceleration (m/s/s)	5.0
Maximum Speed (km/h)	50.4

Table 13: Some default micro-simulation motion parameters

Public Transport

The main drawback of AIMSUN2 is that it does not currently directly model public transport. Although it is possible to model a bus vehicle type, it is not possible to specify routes, timetables or bus stops. This can be very important in urban networks where it is often difficult for other traffic to overtake buses at stops. Buses can therefore have a significant effect on traffic flow in the network.

DRACULA and NEMIS allow both bus routes and bus stops to be specified. Both specify the routes by defining a list of links to be followed. Both use a start time and a generation frequency to produce the bus schedules.

For DRACULA bus stops are associated with bus services. For NEMIS the stops on a route can be used by any of services that use the route. Both allow multiple stops on a link. DRACULA uses a simple wait time model for the bus stops based on a passenger arrival rate, although this is not service dependent. NEMIS just has a stop time based on a sample from a normal distribution of a fixed mean and standard deviation.

Traffic Flows

All three models have the ability to accept traffic flow data in the form of Origin / Destination (O/D) matrices. AIMSUN2 and NEMIS have built in route choice models. DRACULA uses the SATURN assignment model (Van Vliet, 1982) to calculate vehicle routes.

The vehicle generation models in DRACULA and AIMSUN2 assign an origin, destination and route to each vehicle as they are generated. NEMIS uses the results of its assignment model to produce turning percentages at each junction. So when a vehicle arrives at a junction, a random choice is made, based on the known turning proportions, to choose the direction the vehicle is to make.

AIMSUN2 is the only model that allows different O/D matrices for different vehicle types. This could be an important factor in the Leeds network, where HGVs have a slightly different O/D pattern to other vehicle types.

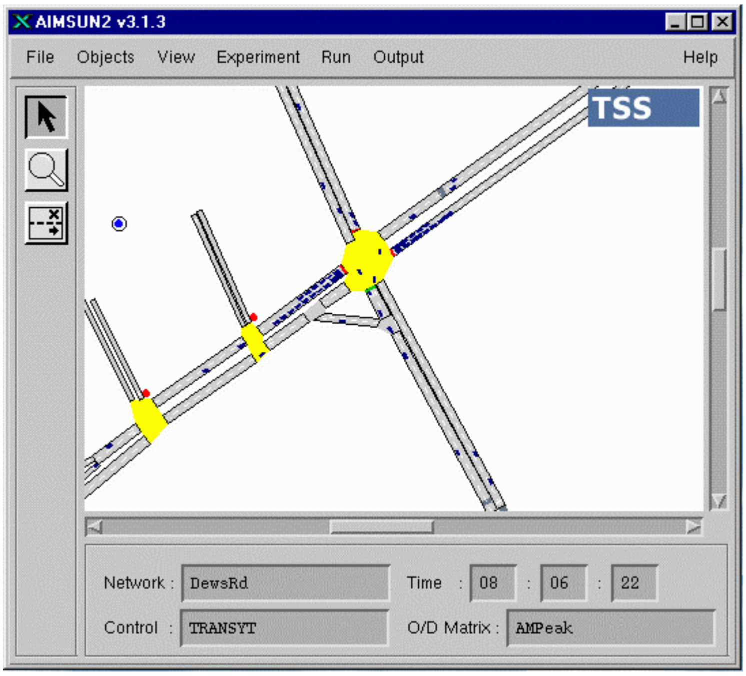
Traffic Signals

All the models have the capability of modelling traffic signals operating under fixed time control.

The pelican crossing can be modelled as a two arm junction with 1 stage and a long intergreen. None of the models directly allow the demand response feature of the pelican crossing to be modelled (or other demand responsive features that may be present at other signalised junctions in the network). Pelican crossings only show red to the traffic if a pedestrian has pressed a button to register their desire to cross the road. AIMSUN2 does have the ability to allow an external module to be developed to control signals in the network so it would be possible to write such a module (as a dynamic link library) to model the correct actions of a pelican crossing. Time constraints have however not allowed such a development. It has therefore been decided that as during the AM peak it is likely that the pelican crossing will be used nearly every cycle, it can be modelled as if it was used every cycle.

Simulation Results

The Leeds network has been coded up for each of the three micro-simulation models. Calibration and validation has been carried out.



Network : DewsRd
Time : 08 : 06 : 22
Control : TRANSYT
O/D Matrix : AMPeak

Figure 12: AIMSUN2 simulating the Leeds network

Averages from four different runs using different random number seeds for each run were used.

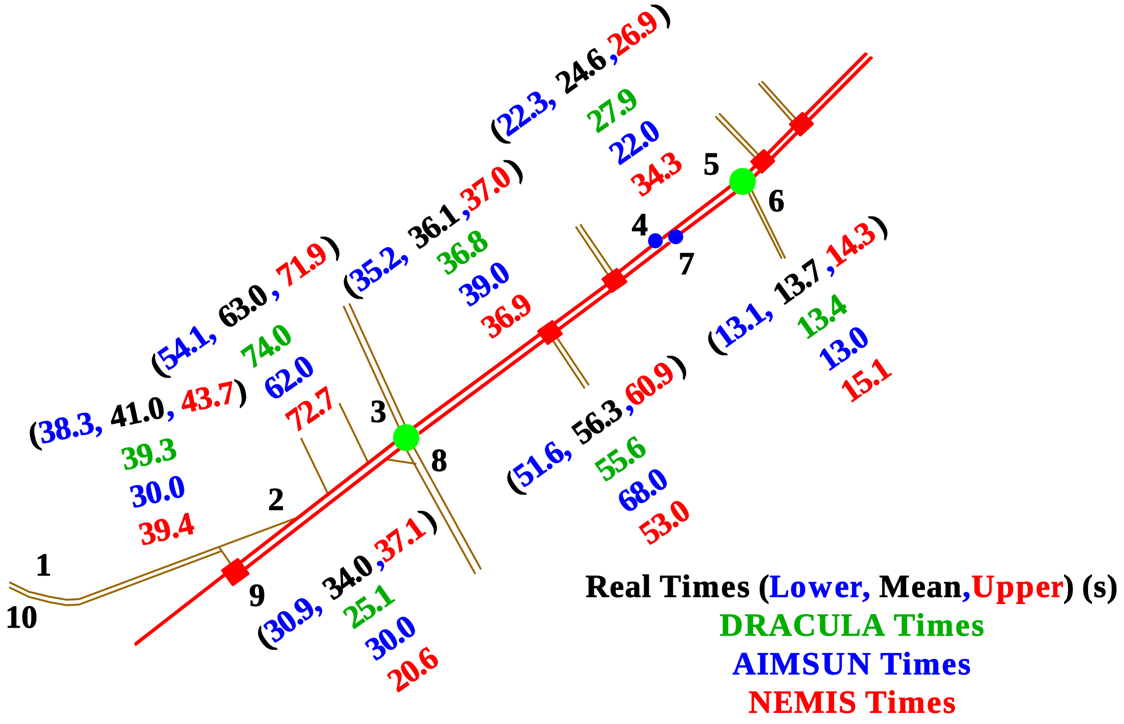


Figure 13: Link travel times from the different models

Figure 13 shows the link travel times from each of the micro-simulation models. These are compared with the actual travel times, as measured by moving observers and detailed in section 3.2.2. For each link, only the travel times for vehicles making the same turning movement at the end of the link as the moving observers were used in the analysis. As can be seen there is reasonably good agreement between the observed travel times and those output by the models.

Figure 14 shows a comparison of the queue lengths from each of the models. Here the agreement between reality and the model outputs is not so good. In particular the queue lengths from DRACULA and NEMIS are much longer than those observed for the Dewsbury Road link going into the Old Lane / Ring Road Beeston Park junction towards Leeds. This is a critical junction. The result indicates that both NEMIS and DRACULA have problems modelling junctions operating close to capacity.

Table 14 shows the times (in seconds) for each of the simulation models to model one hour in the AM Peak period. All the runs were performed on the same computer, which was a 200 MHz Pentium PC with 32Mb of memory. Runs have been carried out both with the graphics switched on and with them switched off. As can be seen, having animated outputs significantly slows down the simulation for all of the models. With the graphics switched off, both NEMIS and DRACULA are slightly faster than AIMSUN2. This can be partly explained by the fact that the AIMSUN2 runs were performed using the default step length of 0.75 seconds, whereas the DRACULA and NEMIS runs used a 1 second timestep.

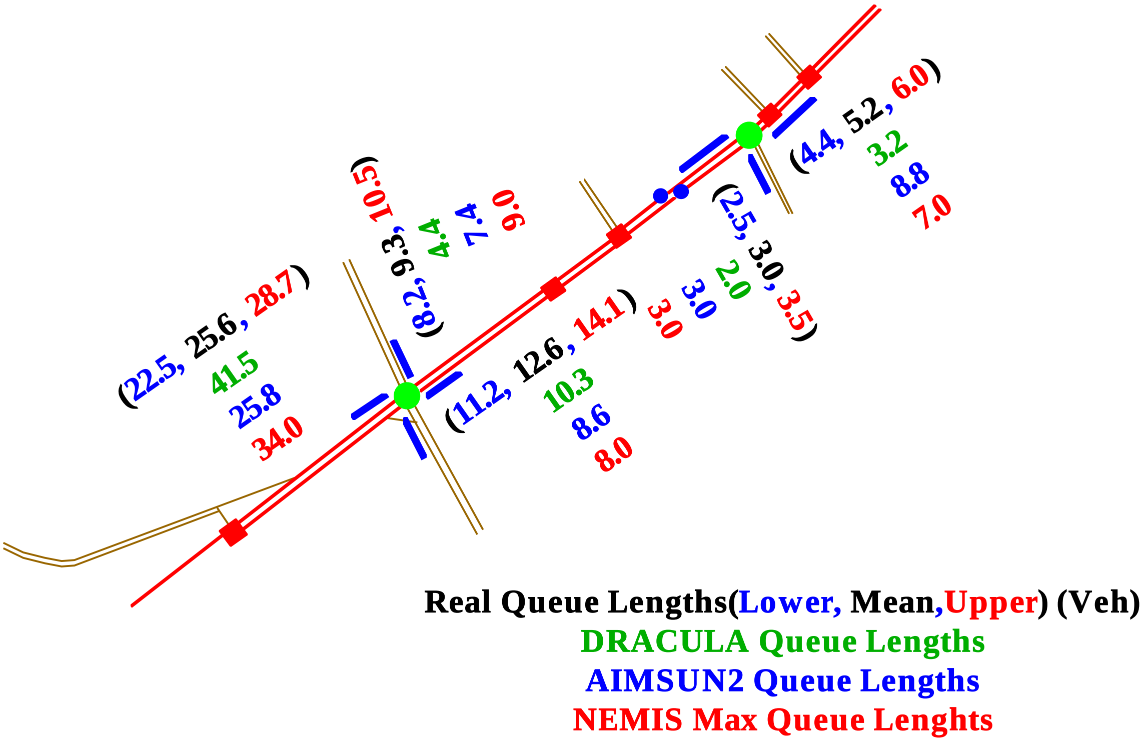


Figure 14: Queue lengths from each of the models

	Graphics on	Graphics off
DRACULA	68	24
AIMSUN2	375	39
NEMIS	64	24

Table 14: Simulation run-times (s) for one hour in the AM peak.

Conclusions

A variety of traffic data has been collected from a small urban road network in Leeds. This data has been processed and analysed so that it can be used in the calibration and validation of road traffic micro-simulation models.

Three micro-simulation models, initially developed to model traffic in different parts of Europe, have been used to model the traffic in the Leeds network. None of the models could represent all the features found in the test network, so some modelling assumptions had to be made to cover these cases.

The ability of the models to produce accurate representations of traffic behaviour has been investigated. All three models produce reasonably accurate outputs of travel times. Both NEMIS and DRACULA however have problems in modelling junction capacities accurately, which results in over estimations of queue lengths and travel times at junctions operating close to capacity.

References

DONATI, F. AND LARGONI (1976) Analisi del comportamento di una colonna di autoveicoli in condizioni perturbate, *Riunione Annuale AEL*, Sorrento, 1976.

FERRER, J.L. AND BARCELO, J. (1992) *Modelos microscopicos de simulacion de sistemas de guiado de veh'culos*. Research Report. Laboratori d'Investigació Operativa i Simulació, Universitat Politècnica de Catalunya.

FOX, K., MONTGOMERY, F.O. AND MAY, A.D. (1995a) Integrated strategies for urban arterials: DRIVE II project PRIMAVERA. 1: Overview *Traffic Engineering and Control*, **36**(5), pp268-271.

GIPPS, P.G. (1981) A behavioural car-following model for computer simulation. *Transportation Research Board*, **15-B**, pp. 105-111.

GIPPS, P.G. (1986) A model for the structure of lane-changing decisions. *Transportation Research Board*, **20-B**, pp. 403-414.

LIU, R., VAN VLIET, D. AND WATLING, D.P. (1995) DRACULA - Microscopic Day-to-Day Dynamic Modelling of Traffic Assignment and Simulation, Paper presented at the *Fourth International Conference on Applications of Advanced Technologies in Transportation Engineering*, Capri, Italy, 27-30 June 1995.

MAURO, V. (1991) Evaluation of dynamic network control: simulation results using NEMIS urban micro-simulator *Transportation Research Board Annual Meeting*, Washington DC.

VAN VLIET, D. (1982) "SATURN - A Modern Assignment Model", *Traffic Engineering and Control*, **23**, pp578-581.

8.6 General recommendations for calibration and validation

8.6.1 Network building

- If a digital map can be used then use it to help build the network.
- Try to avoid using short links where lane changing can take place.

8.6.2 Checking the basic model is correct

An animated display of the network in operation makes it easy to carry out basic checks that the model has been coded up correctly. Particular things that can be checked easily include:

- All the allowed turns at a junction are being used.
- Priority rules, give ways and stops, at junctions are being obeyed.
- Only public transport vehicles are using their reserved lanes.
- There are no unexpected queues anywhere in the network.
- Vehicle behaviour is appropriate for driving on the correct side of the road. This might not be obvious. It is easiest to always check that you have set the flag for driving on the correct side of the road appropriately.
- Signal phases and timings are correct. Observe each signalised junction second by second through a complete cycle and check that the phases are as expected. Then check the effective green times at a single signalised junction. If possible, choose a junction that is operating close to capacity, with little spare green time on any approaches. The effective green time at a junction is the proportion of the displayed green time that can sustain the saturation flow rate. In reality it is the displayed green time minus 2-3 seconds at the start of green while the flow rate rises from zero up to the maximum, plus 2-4 seconds at the end of the displayed green during the clearance interval, usually while the signal goes through amber to red. It is likely

that the build up to the saturation flow at the start of green will be modelled correctly, it is not always the case that the cut off at the end of green will be. If necessary add two or three seconds of extra green time at the end of each phase so that movement through the junction at the end of the phase reflects reality.

8.6.3 Checking saturation flows

A key parameter when modelling road traffic networks is the saturation flow. For different streams of traffic passing through a junction, this is defined as the maximum flow rate that can be sustained by traffic from a queue on the approach used by the stream. It depends mainly on:

- the number and width of entry and exit lanes available to that stream and the effects of parked vehicles, bus stops etc. on lane width;
- the proportion of turning traffic and
- the radius of turn; and the gradient of the approach.

Traffic composition also affects saturation flows.

It is important to get the saturation flows correct when modelling a road network. The saturation flow effectively defines the maximum amount of traffic that can travel through a junction in any given time period. If the saturation flow is incorrect then estimates of junction capacity, throughput, delay and queue lengths will all be wrong. For many traffic models the saturation flow is an input. The saturation flow is measured on-street at each junction and the value obtained is input into the traffic model. For a micro-simulation model the saturation flow is an output. Its value depends on parameters used to define vehicle motion as well as the geometry of each junction. If the vehicle motion parameters have been well chosen then the saturation flows produced by the model should approximately agree with reality.

A strategy that has been used with some success is to measure on-street values of saturation flows at a junction in the network under study that is operating closest to capacity. Then adjust the reaction time in the micro-simulation model of the network until the observed flows through the junction agree with the on-street measurements. The flows through other junctions in the network then often agree with the observed values as well. Some micro-simulation models do not allow changes to the reaction time, or it is equivalent to the simulation time step, which can be difficult to change. In this case the other parameters, such as vehicle acceleration rates or minumum distances between stationary vehicles need to be changed in order to get good agreement between the model and reality. Unfortunately this can often result in clearly unrealistic values of these parameters being chosen.

8.6.4 Checking route choice

Use a traffic assignment package e.g. EMME/2 or SATURN to calibrate the OD matrix against observed traffic counts. The calibrated matrix may then be input directly into the micro-simulation model.

A more exact calibration could be obtained if a measured OD matrix is available in combination with measured flows and speeds.

9 FORMULATION OF SCHEME OBJECTIVES

9.1 Introduction

A clear statement of objectives is needed in order to

- identify the problems to be overcome by the selected strategies;
- to evaluate the relative performance of alternative candidate strategies;
- and to assess the performance of the selected strategy when implemented in the field.

The use of objectives in this way follows the principles of Systems Analysis, as summarised in Figure 15.

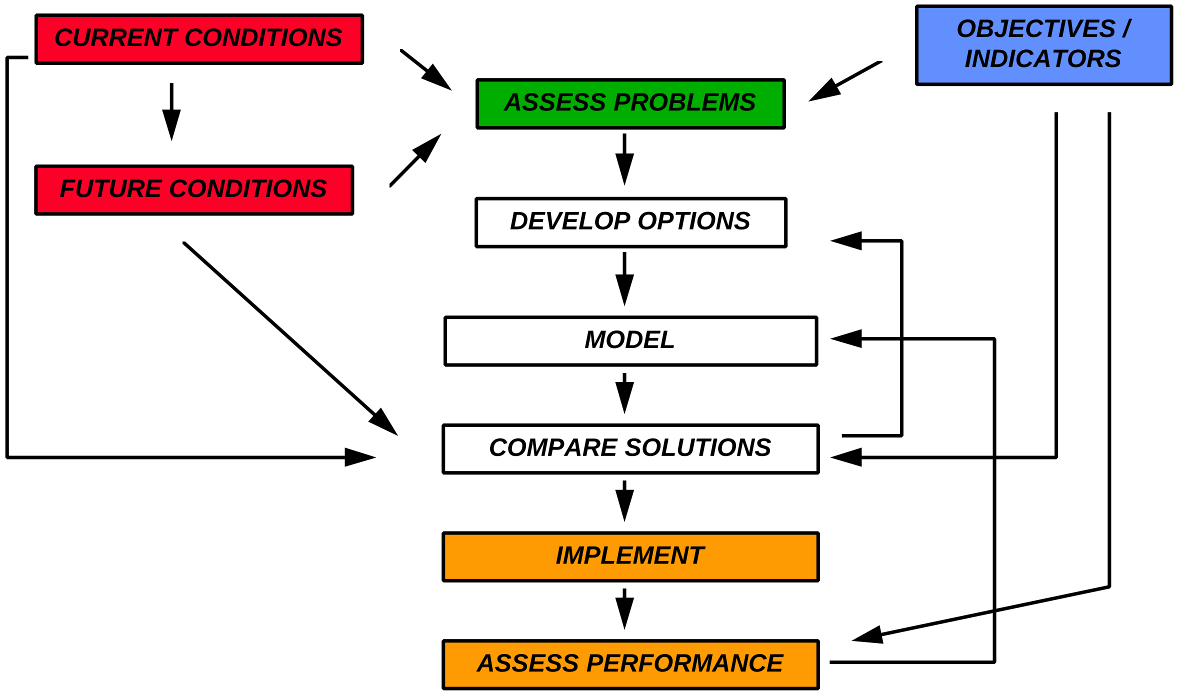


Figure 15: Scheme development and assessment

Objectives are defined and used to specify more detailed indicators of performance. These are then used initially, with data for the existing situation, to identify current problems, defined as indicators for which objectives are not currently being met. It is also possible, at this stage, to predict future conditions, and hence future problems.

The identified problems are then used as a basis for devising possible solutions. The long list of possible solutions generated in this way may then be screened to identify a suitable shortlist for further analysis. This is done by reference to the objectives and indicators. Further assessment of the shortlisted solutions, and combinations of those solutions into integrated strategies, is performed by simulation. The simulation process provides, as output, measures of performance against each of the objectives and indicators.

Finally, selected strategies are implemented either as field trials or as final schemes. For field trials, it is clear that a "before and after" evaluation is needed. Even with final schemes, such an evaluation is desirable, both for fine-tuning of the implementation and to provide experience of the performance both of the measures and of the accuracy of the simulation. A full Systems Analysis approach would then complete the cycle by regular monitoring of conditions to identify any new problems that required further treatment. Once again, the before and after tests and monitoring are based on the defined objectives, measured in terms of the specified indicators.

9.2 High level objectives

9.2.1 Introduction

The formulation of objectives is usually the responsibility of the local or central government body responsible for the road network in question. They can be specified very generally in the form of an overall vision for the area, of the kind now being specified in many cities' transport strategies. Such statements of vision provide a context for evaluation, but are usually too abstract to be used directly. They can be specified broadly as higher level transport policy objectives, such as efficiency, accessibility and safety. These are helpful in indicating the directions in which strategies should be developed, and the relative performance of alternative solutions. They do not, however, demonstrate whether a particular solution is adequate in its impact. To do this more specific, quantified objectives are needed. These are typically expressed in terms of thresholds, such as the avoidance of delays of over 60 sec at individual junctions. These can then be used directly to identify problems as objectives for which these thresholds are currently exceeded.

Quantified objectives, or indicators, are needed for evaluation purposes, but must be specified in the light of local requirements. The higher level transport objectives are, however, more generally applicable, and are outlined below. It should be emphasised that this is a suggested list of possible objectives; it will be for politicians or government officials to decide which are relevant in a particular situation.

9.2.2 Economic Efficiency

The efficiency objective is concerned with maximising the net benefits, in resource terms, of the provision of transport. This in turn involves maximising the difference between the consumer surplus of travellers and the resource costs of the provision, operation and maintenance of transport facilities. Consumer surplus can be thought of as the difference between the maximum that an individual traveller is prepared to pay to travel and the actual cost of that journey. Consumer surplus is therefore increased when travel time, operating costs and direct payments such as fares are reduced, and also when more travellers are able to travel as a result of reductions in those costs.

Efficiency defined in this way is central to the principles of social cost-benefit analysis, and a higher net present value from a cost-benefit assessment represents a more efficient outcome. However, it is based directly on the values which individuals assign to their journeys, and there has been some concern recently that the resulting emphasis on increases in the amount of travel, and in speed of travel, may not be wholly consistent with the needs of society.

9.2.3 Environmental protection

The environmental protection objective involves reducing the impact of transport facilities, and their use, on the environment of both users and non-users. Traditionally, the environmental impacts of concern include noise, atmospheric pollution of differing kinds, vibration, visual intrusion, severance, fear and intimidation, and the loss of intrinsically valuable objects, such as flora and fauna, ancient monuments and historic buildings through the consumption of land.

While some of these can be readily quantified, others such as danger and severance are much more difficult to define and analyse. Attempts have been made, with impacts such as noise and pollution, to place money values on them, and hence to include them in a wider cost benefit analysis, but it is generally accepted that it will be some time before this can be done reliably even for those impacts which can be readily quantified.

9.2.4 Safety

The safety objective is concerned straightforwardly with reducing the loss of life, injuries and damage to property resulting from transport accidents. The objective is thus closely associated with the concerns over fear and intimidation listed under environmental protection above, and these concerns could as readily be covered under either heading.

Although there are marked differences in detail between member states of the EU, it is common practice to place money values on casualties and accidents of differing severity, and to include these within a social cost benefit analysis. These values may include the direct costs of accidents, such as loss of output, hospital, police and insurance costs, and replacement of property and, more controversially, an allowance for the pain, grief and suffering incurred. To this extent, the safety objective has been subsumed within the efficiency objective. However, there are some misgivings about some elements of the valuation of accidents, and it is probably therefore helpful to estimate accident numbers directly as well.

9.2.5 Accessibility

Accessibility can be defined as "ease of reaching", and the accessibility objective is concerned with increasing the ability with which people in different locations, and with differing availability of transport, can reach different types of facility. In most cases accessibility is considered from the point of view of the resident, and assessed for access to activities such as employment, shopping and leisure. By considering accessibility separately for those with and without cars available, or for journeys by car and by public transport, the shortcomings of the existing transport system can be readily identified. It is possible also to consider accessibility from the standpoint of the employer or retail outlet, wanting to obtain as large a catchment as possible in terms of potential employees or customers. In either case, access can be measured simply in terms of the time spent travelling or, using the concept of generalised cost, in terms of a combination of time and money costs.

9.2.6 Sustainability

The sustainability objective was defined by the Brundtland Commission in 1987 as being the pursuit of 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. It can therefore be thought of in transport terms as a higher level objective that considers the trade-off between efficiency and accessibility on the one hand and environment and safety on the other. A strategy that achieves improvements in efficiency and accessibility without degrading the environment or increasing the accident toll is clearly more sustainable.

However, the definition of sustainability also includes considerations of the impact on the wider global environment and on the environment of future generations. Issues to be considered under this heading include the reduction of carbon dioxide emissions, which are a major contributor to the process of global warming, controlling the rate of consumption of fossil fuels, which are non-renewable, and limiting also the use of other non-renewable resources used in the construction of transport infrastructure and vehicles.

9.2.7 Economic regeneration

The economic regeneration objective can be defined in a number of ways, depending on the needs of the local area. At its most general it involves reinforcing the land use plans of the area.

If these foresee a growth in industry in the inner city, new residential areas or a revitalised shopping centre, then these are the developments that the transport strategy should be supporting. At its simplest it can do so by providing the new infrastructure and services required for areas of new development. But transport can also contribute to the encouragement of new activity by improving accessibility to an area, by enhancing its environment and, potentially, by improving the image of the area. The economic regeneration objective therefore relates directly to those of accessibility and environmental protection.

9.2.8 Finance

Financial considerations act primarily as constraints on the design of a strategy. In particular, they are a major barrier to investment in new infrastructure, or to measures which impose a continuing demand on the revenue account, such as low fares. In a few cases, the ability to raise revenue may be seen as an objective in its own right, and it is clearly the dominant objective for private sector participants in a transport strategy. The finance objective can therefore be variously defined as minimising the financial outlay (both capital and revenue) for a strategy or as maximising revenue.

9.2.9 Equity

While all of the above objectives can be considered for an urban area as a whole, they also affect different groups of people in society in differing ways. The equity objective is concerned with ensuring that the benefits of transport strategies are reasonably equally distributed, or are focused particularly on those with special needs. Among the latter may be included lower income residents, those without cars available, elderly and disabled people, and those living in deprived areas. The equity objective will also be concerned with avoiding worsening accessibility, the environment or safety for any of these groups.

9.2.10 Practicability

The other major constraints on strategy design and implementation are practical ones. Issues under this heading include the availability of legislation; the feasibility of new technology; the ability to acquire land; and the simplicity of administration and enforcement of regulatory and fiscal measures. Public acceptability can also be considered under this heading. Flexibility of design and operation, to deal with uncertainties in future demands or operating circumstances, may also be important. The practicability objective can therefore be defined as ensuring that policies are technically, legally and politically feasible, and adaptable to changing circumstances.

9.3 Development of specific indicators

It is not appropriate to specify general indicators and thresholds to be applied uniformly for every scheme being assessed, since requirements and the potential for improvement will be different for different sites. However, this section now suggests a number of indicators that might be used for each of the objectives listed in section 9.2 except practicability.

Objective	Possible indicators
Economic efficiency	Delays for vehicles (by type) at junctions Delays for pedestrians at road crossings Time and money costs of journeys actually undertaken Variability in journey time (by type of journey) Costs of operating different transport services

	Change in numbers of journeys in total and by vehicles
Environmental protection	Levels of different local pollutants (CO, HCs, NOX, particles) Noise levels Vibration Visual intrusion Townscape quality (subjective) Fear and intimidation (subjective) Severance (subjective)
Safety	Personal injury accidents by user type per unit exposure (for links, junction, networks) Insecurity (subjective)
Accessibility	Activities (by type) within a given time and money costs for a specified origin and mode Weighted average time and money cost to all activities of a given type from a specified option by a specified mode
Sustainability	Environmental, safety and accessibility indicators as above CO2 emissions for the area as a whole Fuel consumption for the area as a whole
Economic regeneration	Environmental and accessibility indicators as above, by area and economic sector
Finance	Operating costs and reviews for different modes Costs and revenues for parking and other facilities Tax revenue from vehicle use
Equity	Indicators as above, considered separately for different impact groups

Table 15: Development of specific indicators

At this stage it is necessary to decide which indicators are to be used and how they are to be measured both in the field and in the simulation. Table 16 shows an example of the way in which this might be done when assessing a new urban traffic management scheme. It identifies, for each quantifiable indicator, a set of criteria to be used, the spatial and temporal disaggregation involved, the data collection methods and the statistical tests employed in identifying significant changes. The indicators used were generated by first considering the expected benefits from the scheme. Some of these, such as stress, are not readily measurable, and have to be inferred from other information or assessed by professional judgement. The remainder can be measured.

IMPACT	CRITERIA OF EFFECTIVENESS	CRITERIA OF RESPONSE	DATA COLLECTION	STATISTICAL TEST
Journey Time	Reduced JT for route/link	Mean JT for route/link AM Peak and interpeak	Number plate matching or floating observer (F) Simulation output (S)	z or t for difference in means
	Reduced variance in JT for route/link	Variance (JT) for route/link AM Peak and interpeak		F for difference in variance
Vehicle Operating Cost (OC) and Fuel Consumption (FC)	Reduced OC and FC for vehicles for whole route	Mean FC for buses for whole route	Data from bus operators(F) Simulation output (S)	z or t for difference in means
	Reduced congestion for vehicles route/link	Total number of stops for vehicles AM Peak and interpeak	Manually in field (F) Simulation output (S)	Contingency for no. of stops
Operational	Improvement in bus journey time reliability	Variance in buses journey time AM Peak and interpeak	Manually in field (F) Simulation output(S)	F for difference in variance
Traffic Flows	Reduced or no change in traffic flow for whole route	Mean traffic flow for whole route	Loop detectors (F) Simulation output (S)	z or t for difference in means
Vehicle Occupancy	Increased bus occupancy. No change in other vehicle occupancy	Mean vehicle occupancy	Manually in field (F)	z or t for difference in means
Comfort	Increased comfort for drivers/passengers	Mean no. of stops for vehicles AM Peak and interpeak	Manually in field (F) Simulation output (S)	Contingency for no. of stops
Crossing delay/ Uncertainty/ Visual intrusion	Reduced or no change in crossing delay	Mean crossing delay for link	Manually in field (F)	z or t for difference in means
	Reduced queue lengths at junctions	Mean queue length for link AM Peak and interpeak	Manually in field (F) Simulation output (S)	
	Reduced mean traffic flow (TF) for link	Mean TF for link AM Peak and interpeak	Loop detectors (F) Simulation output (S)	
	Reduced mean speed at crossing point	Mean speed at crossing point AM Peak and interpeak	Loop detectors (F) Loop detectors (S)	
Stress	Reduced stress for drivers & passengers for whole route	Mean no. of stops and queue lengths AM Peak and interpeak	Manually/floating car (F) Simulation output (S)	z or t for difference in means
Safety	Increased safety for cars/pedestrians for route/link	Accident rate for route Conflict study for junctions	Police accident records (F) Manually in field (F)	
Speed	Reduced speed for route/link	Mean speed AM Peak and interpeak	Number plate matching or floating observer (F) Simulation output (S)	z or t for difference in means
	Reduced variance in speed for route/link	Variance (speed) AM Peak and interpeak	Loop detectors (F) Loop detectors (S)	F for difference in variance
	Fewer "speeding" vehicles for route/link	Proportion of vehicles exceeding certain speed AM Peak and interpeak		z or t for difference in proportions

Table 16: An example of measurement of indicators in the field and by simulation

10 ADAPTATION OF MODELS TO USER NEEDS

User needs

In chapter 2, user requirements have been discussed based on the SMARTEST questionnaire. Users would like to be able to analyse a variety of specific applications, including on-line applications, control strategies, large scale schemes and product performance tests. The scale of applications ranges from regional applications to single road cases, and the time horizon ranges from on-line to several years.

The most important requirements are demands for:

functionality - models should include the ability to model incidents, public transport stops, roundabouts and commercial vehicles,

outputs - which should give the user possibilities to obtain results in terms of

> *efficiency,* travel time, congestion, travel time variability, queue lengths, speed and public transport regularity,
>
> *safety,* headway, interaction with pedestrians, overtaking, number of accidents
>
> *environment,* exhaust emissions, noise level, roadside pollution levels
>
> technical performance, fuel consumption

ITS modelling ability - they should be able to model the following ITS functions: adaptive traffic signals, co-ordinated traffic signals, priority to public transport vehicles, vehicle detectors, ramp metering, variable message signs, incident management, dynamic route guidance and freeway flow control

This is of course a tall order, and it is unlikely that all these requirements can be fulfilled within one single system. The questionnaire has nevertheless in many cases given clear indications concerning the relative importance of different factors, which is most helpful for future system development.

According to the questionnaire responses it is most important that the micro-simulation models are based on *validated* field studies. The emphasis on validation is a reflection of the uncertainty concerning behavioural relationships.

Adaptation of AIMSUN2

New knowledge about the effects of intelligent traffic systems will emerge continuously during many years to come. This indicates that models should be ‘open toolboxes’. It must be possible for the user to control the behavioural relationships that are used in the model and add new relationships based on newly-acquired knowledge. Some advice concerning the possibilities to adapt parameters to various applications is given beneath.

Adaptive signals:

There are two ways of simulating traffic signals that adapt to the traffic conditions in AIMSUN2:

1. Use GETRAM Extensions to program a control logic that uses detector data to set the optimal green time for the different signal groups during the simulation.
2. Use a simplified approach to represent the effects of adaptation by adjusting the static green times in the control file. The way of representing the increased efficiency with traffic responsiveness is to relocate some time from the interphase to the green phase. Loading several con-

trol plans for different time periods during the simulation can represent pre-optimised signal plans. The optimisation itself must be carried out external to the model. Co-ordinated signals can be simulated using the offset parameter.

Public transport priority:

Public transport vehicles can be simulated in AIMSUN2 as a vehicle class. As for adaptive signal control, two techniques are possible.

1. Use GETRAM Extensions to program a DLL that reads the presence of a bus from a certain detector, changes the corresponding phase to green and all others to red for the time it takes for the bus to pass, and then sets the signal timing back to the original.
2. Use a simplified approach to represent the average effects of prioritisation on the static signal timings. Each bus causes the intersection control to add x seconds of green time on that approach while all other approaches have red light.

Motorway control system:

A coarse estimate of the smoothing and speed effects may be obtained in AIMSUN2 using the GETRAM Extensions:

1. Locate speed detectors and variable speed signs on the freeway.
2. Program a DLL that controls the message on the sign as a function of the detector value. Typically, when a low speed is detected, the recommended speed on the upstream sign is given a lower value to warn oncoming drivers that there is a queue ahead. With programming skills, this is done fairly easy using the built in functions ”Read Speed aggregated in the Last Detection Interval” and ”Activate a Message on a VMS”.
3. Set the corresponding change in section speed in the VMS dialog box as an Action related to the Message. Use the parameters ”speed acceptance” and ”max desired speed for vehicle type” to obtain the local effect on speed observed in the external behavioural model.
4. Run the simulation and study the effect on smoothing, average speed and average delay.

Ramp metering:

AIMSUN2 has explicit capabilities for simulating ramp metering. There are two types of ramp metering implemented in the program.

1. Green time metering which is modelled as a traffic signal. Parameters are green time, cycle time and offset.
2. Flow metering. The meter is automatically regulated in order to permit the entrance of a certain number of vehicles per hour. Parameters are platoon length and flow (veh/h).

Incident management:

Incidents are modelled in a rather straightforward manner in AIMSUN2.

1. In the dialog box, type in the length of the obstacle, starting time and duration of the incident.
2. During the simulation, the obstacle will appear at the specified time and the cars will start queuing behind it.
3. If an average situation should be modelled, a sample of typical incidents should be produced with some exogenous randomisation procedure.

Trip planning:

Micro-simulation is in principle good for trip planning, but important modules are missing. Assignment systems are recommended. Micro-simulation can be used to produce realistic dynamic effects of incidents.

On-trip information:

AIMSUN2 contains a route choice model for dynamic re-routing, which may represent radio or in-vehicle route guidance. The program saves information about which routes have been the shortest during the last intervals, and a model distributes the guided vehicles among these routes. This means that not all guided vehicles use the present shortest routes but some stick to the older shortest routes. This gives certain inertia to the routing behaviour.

The following parameters can be used to tune the dynamic route choice:

- Fixed or variable routes
- Capacity weight factor for initial routes
- Proportion of guided vehicles for each vehicle class.
- Interval at which new routes are calculated.
- Type of model to distribute drivers between routes, logit or binomial
- Number of routes to consider in the logit model
- Scale factor for weighing the routes in the logit model

Variable Message Signs:

Variable message signs can be modelled directly in AIMSUN2.

1. Position a VMS in the network and fill in the data in the VMS dialog box (identification name, type and wording for the possible messages).
2. Specify an Action. Three traffic variables may be affected by the message: speed, destination and new turn. An *external behavioural model must be available* when defining an action in order to judge the likely impact of the message on the driver behaviour.
3. The ”speed” option is used when the message is assumed to alter the speeding behaviour of the drivers. The value is set as the speed limit of the section.
4. The ”destination” and ”new turn” options both imply a re-routing. In both cases a compliance rate δ, $0<\delta<1$, must be defined i.e. the proportion of drivers that follow the message.
5. The ”destination” option is used when the message is assumed to change the destination of the vehicle. The message makes the driver take another route, and this route is outside the modelled network. Consequently, the driver is diverted to a new destination centroid where he exits the network.
6. The ”new turn” option is used when the drivers are assumed to divert and choose a new route within the modelled network. The drivers affected by the message are selected by their destination centroids.
7. The final step is to connect the messages of the VMS to the suitable actions (defined in AIMSUN2) using the VMS dialog box.
8. When VMS impacts are to be simulated, stop the simulation and activate a certain message using the VMS dialog box. Use the Reset option to deactivate the message.

Automatic debiting

Micro-simulation is in principle useful for simulating automatic debiting, but to reproduce network effects, generalised cost instead of time must be used in the route choice. Assignment systems are recommended. Some features in AIMSUN2 could however be used to produce input data to assignment models:

1. A useful feature is the delay metering. This feature can be used to simulate a tollbooth where the vehicles have to stop, pay a charge and then accelerate again.
2. One lane in each section can be defined as ”reserved”. This means that only the specified vehicle types can use them. This feature can be used to simulate HOT lanes.

Adaptive cruise control

There is no direct functionality in AIMSUN2 to model adaptive cruise control. Simulation of adaptive cruise control or intelligent speed adaptation (ISA) may, however, be achieved by introducing new vehicles with certain characteristics, using the various speed parameters:

- Speed limit for each section
- Speed acceptance (mean, variance, max and min). This stochastic parameter is multiplied with the speed limit to obtain a vehicle’s maximum speed given a certain speed limit. If speed acceptance=1 the maximum speed for a vehicle will be equal to the speed limit.
- Desired speed for each vehicle class (mean, variance, max and min). This parameter only applies if the value is lower than the speed limit multiplied with speed acceptance.
- Maximal turn speed for each turning movement.

Adaptation of NEMIS

NEMIS (NEtwork MIcro-Simulation model) is a micro-simulation tool developed for the micro-simulation of urban traffic (private and public) in large-scale networks. It is capable of modelling urban networks and vehicle behaviour in considerable detail and its usefulness in Urban Control Strategies Assessment and Evaluation have been widely demonstrated.

The sample of users included in the survey planned during the first year of the project, clearly underline that next millennium micro-simulator should include possibilities to model incidents, public services, roundabouts and all the (more or less innovative) telematics applications on which the real market is oriented.

Starting from previous considerations, some specifications regarding NEMIS modelling capabilities and operations are reported in the following sections.

Micro-simulation Aspects

The urban network model consists of an oriented graph composed of **Nodes** (private traffic O/D and intersections) and **Links** (one way road section between subsequent nodes).

On each Link, several kinds of lane can be defined:

- Ordinary (for private vehicles and buses)
- Ordinary plus trams (for private vehicles and buses)
- Reserved (public vehicles only)

- Reserved trams
- Ordinary plus parking spaces for private vehicles

Vehicle movement is determined by:

- car following rule (DIGIT)
- possible manoeuvres within the link (DIGIT)
- the choice of turning at the next junction (BASSOT)
- traffic light regulation and right-of-way rules (VIAS)
- implemented traffic control strategies and/or techniques

The choice of the car-following rule for NEMIS has been conditioned by the following two principal consideration:

1. As micro-simulation requires the application of the car following rule to every single vehicle in the network at every clock count, the rule should provide a model of driver behaviour that is as close to reality as possible, without involving a large number of complex calculations that would slow down the actual simulation.
2. The car-following rule implemented by the program should require only a few parameters that correspond to precise physical properties.

In the following, a description of this rule is reported.

Definitions

i	the current step
n	the examined vehicle
l	the preceding vehicle
X	the position of the vehicle
V	the speed of the vehicle
a,b,c,d	parameters defined below

Car-following rule

$$V_{n(i+1)} = aV_{n(i)} + bV_{l(i+1)} + c\left(X_{l(i+1)} - X_{n(i)} - d\right)$$

where

$$a = (a - kT/2)/(1 + kT/2 + k\,b)$$
$$b = k\,b(1 + kT/2 + k\,b)$$
$$c = k/(1 + kT/2 + k\,b)$$

and

T	is the time increment	
a	is a typical vehicle parameter depending on the mass *m* and the coefficient of friction *f*	$a = e^{-fT/m}$
b	is a parameter for smoothing the vehicles’ speed within the column or lane. The adopted value ensures optimal smoothing and thus represents the behaviour of an “excellent driver”	$b = T(1+a)/(2(1-a))$
d	is the minimum distance between a point on a vehicle and the same point on the vehicle ahead	

t_0	is a Volume/Speed relation parameter, denoting approximately the distance (in seconds) between vehicles moving with max speed	$Q = V/(Vt_0 + d_0)t_0$
K	Is the feedback gain parameter, whereby a vehicle copies the speed of the vehicle in front. High values of k are used for agile close moving vehicles.	$k = (1 - a)/t_0$

Effectively vehicles are classified by means of the three parameters a, d and t_0. A high value for a corresponds to heavy vehicles, a high value for d implies a long vehicle and a high t_0 is used for slow vehicles. The drivers ability may be modelled by the value given to b.

Table 10.1 Tried and tested value for a and t_0

	Small Car	*Large Fast Car*	*Large Slow Car*	*Heavy Vehicle*
a	0.925	0.95	0.95	0.97 to 0.98
t_0	2.0	2.0	3.0	4.0

The above model is completed by applying certain upper and lower bounds:

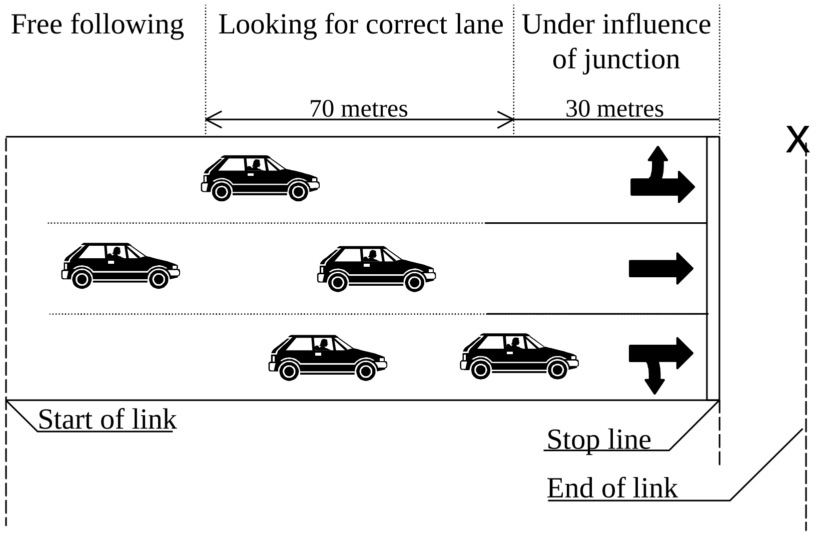
- maximum acceleration and deceleration dependant on the class of the vehicle
- maximum velocity for each type of road
- minimum velocity (fixed constant for all types of vehicle corresponding to the minimum velocity a vehicle can maintain whilst in stability)

Car movement parameters used by NEMIS are described into a section of the DIGIT input file. The values for the parameters listed above have been derived by calibration of a network simulating the Turin urban network. These values should therefore be copied initially for other networks, and may then be changed on the basis of any difference noted in the latter.

car-following parameter (a)	0.54	
car-following parameter (b)	0.385	
car-following parameter (c)	0.038	
car-following parameter (d)	6	[m]
maximum speed of vehicles	14	[m/s]
minimum speed in deceleration	5	[m/s]
minimum speed in acceleration	3	[m/s]
maximum acceleration	3.0	[m/s^2]
maximum deceleration	-5.0	[m/s^2]

Regarding vehicle movement within the link, three different zones can be defined on the basis of their effect on the movement itself.

Figure 10.1 Zones effecting movement within the link



Referring to Table 10.2 the three zones are described below:

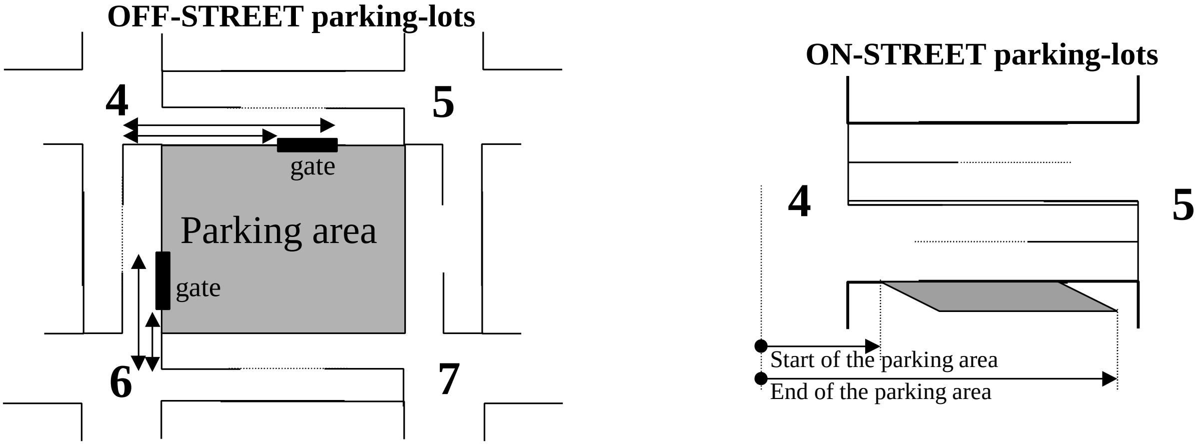
1. *Free following*: this is the first part of the link; the programs check if a vehicle needs to overtake. Overtaking takes place if the convenience and feasibility rules allow.
2. *Looking for correct lane zone*: in this zone lane changing is performed, in order to position vehicles into the correct lane for subsequent turning, and to distribute vehicles into queues.
3. *Under influence of junction zone*: the status of the vehicle in this region is influenced by the status of the traffic light. If the traffic light is RED and the vehicle is beyond Stop Line, it passes to next link, else it stops. If the traffic light is GREEN and there are no conflicts the vehicle passes to next link, else it stops accordingly.

According to previous description, short links (lower than 30 metres) are to be avoided.

Operational Aspects

Parking Areas

Figure 10.2 Off-street and On-street parking spaces



NEMIS has the capability to simulate **parking spaces**. Both types of modelled parking spaces (*on-street spaces* and *off-street spaces*) are described as parking areas joined to the adjacent lanes, which can be entered and exited by parking vehicles and have a specific number of spaces.

Parking areas are grouped by zones (set of parking lots accessible by links entering and leaving examined node) within the network and each one has its own coefficient of attractiveness.

The status of a single on-street parking lot may be “occupied” or “free”, whereas an off-street parking area may be “full” or “available”.

Public Transport Services

Each public transport service is represented by one or more route(s) crossing the network. Public vehicles are **buses** or **trams** and routes consist of sequences of lanes to be crossed by public vehicles.

The main aspects of this model are the following:

1. P.T. vehicles are generated at the terminus with a random headway depending on the nominal frequency and variation defined for the service. Each service has an independent random process as an own generation seed for random extraction is used.
2. Time spent by a vehicle at a stop is randomly extracted by a distribution that changes according to the service and stop. An average stop time and a standard deviation must be specified for each stop.
3. A P.T. vehicle that is moving on a link where no stops are located or that has already done all the stops on the link, can move as a private one, so it could change lane and overtake other vehicles.
   If the P.T. vehicle has still stops to do on the current link, it stays on the lane where the next stop is, following the vehicle in front.
4. It is possible to define a separate set of traffic lights for P.T. vehicles that use reserved lanes.

The NEMIS model do not take into account the possibility to have kerbside parking at the bus stop, furthermore no models for passengers generation are provided (time spent by a vehicle at a stop is randomly extracted by a distribution that changes according to the service and stop.).

Incident Simulation

NEMIS does not support any automatic incident generation algorithm. If it is necessary to simulate an incident (or better, an incident caused by an accident), it is possible to artificially reduce the capacity of the road where the incident takes place by positioning several stopped vehicles on each lane interested by the incident itself.

Stopped vehicles can be positioned (at the desired time) everywhere on the link and then removed at any time, allowing the simulation of different incident duration.

Pollution Modelling

A pollution model is already supported by NEMIS.

This model use, in order to estimate the amount of pollution that would be emitted by vehicles in the network, the following inputs:

- the current time
- the topology of the network
- the number of vehicles in the network
- the status (class of vehicle, lane the vehicle is travelling in, position within the lane, speed) of each vehicle in the network

- for each pollutant and vehicle class, look-up tables giving the amount of pollution produced as a function of vehicle speed and acceleration

The pollution outputs are the amounts of carbon-monoxide, unburnt hydro-carbons and nitrous-oxide emitted.

The outputs can be summarised as following:

1. *detailed output*, at a constant user specified interval
   - the time

   for each vehicle:
     - the amount of pollution emitted during the interval
     - the total amount of pollution emitted by the vehicle

   for each lane:
     - the amount of pollution emitted during the interval
     - the total amount of pollution emitted in the lane
2. *summary output*, at a constant user specified interval
   - the time
   - the amount of pollution emitted during the interval
   - the total amount of pollution emitted

Traffic Calming Measures

NEMIS support the simulation of traffic calming measures. In particular, it is possible to define the speed limit on selected link within the network

Roundabouts

NEMIS does not support a specific model for roundabouts. In particular cases of needs, they can be simulated introducing several nodes (one for each entry/exit branch of the roundabout) connected by short links. In these cases, the internal links connecting each couple of nodes related to the roundabout can be described with a number of lanes greater the real and a little bit longer than the lower limit of 30 metres, in order to allow lane changing movements.

Telematics Application Modelling

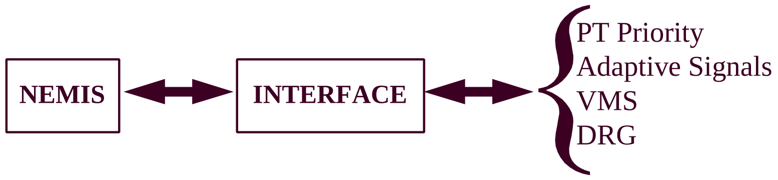
NEMIS allows users to simulate the following Transport Telematics Applications:

- Adaptive and Co-ordinated traffic control
- Public Transport Priority
- Collective Traffic Guidance (VMS)
- Individual Route Guidance (DRG)

The first two items (as well as the last two) can be simulated directly interfacing NEMIS with the external control units of the UTOPIA UTC system (e.g. SPOT).

An internal routine for VMS and DRG system simulation is also provided.

Figure 10.3 Transport telematics modelling abilities of NEMIS



Adaptive Traffic Signals and Public Transport Priority

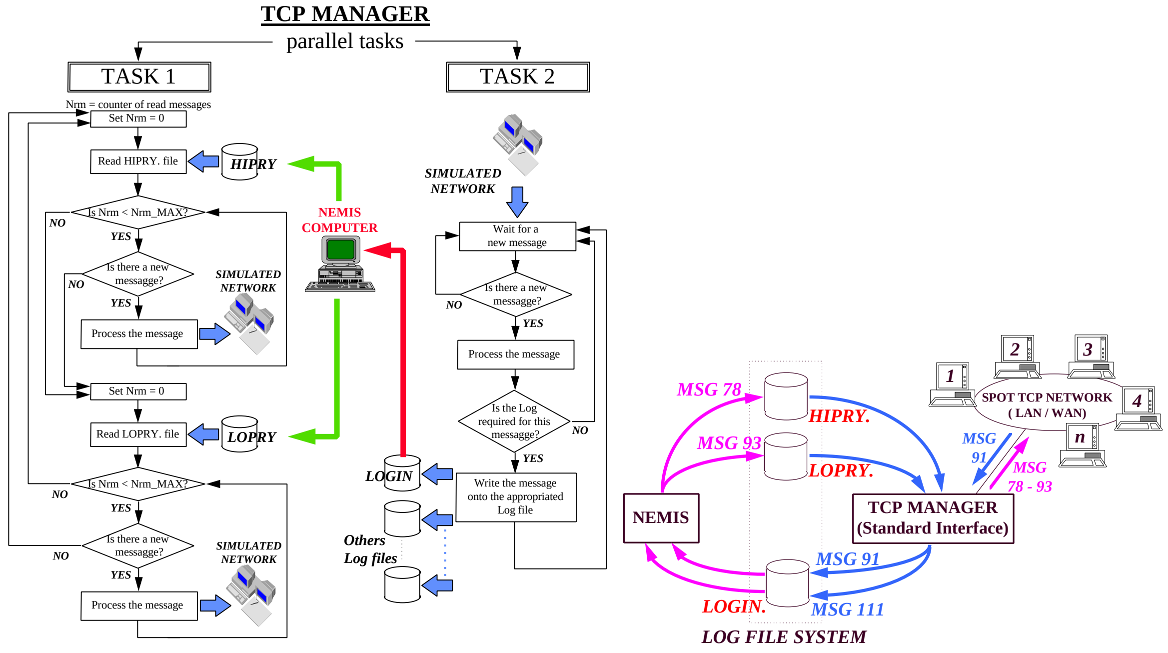
SMARTEST enhancements of NEMIS provide its users with a tool able to interface, directly and in an easy way, the external control strategies embedded in the SPOT unit (local multifunctional unit of the UTOPIA UTC system). The approach adopted provides to the micro-simulator NEMIS the capability and the tools necessary to evaluate the impact of particular adaptive control and public transport priority strategies (those implemented by UTOPIA) without prevent the simulation of control strategies ad-hoc developed by the user itself.

From the point of view of the NEMIS model adaptive control and P.T. priority are external strategies, that is tasks embedded within the local unit SPOT of the UTOPIA System.

For further information regarding the operation of the new developed interface, the reader should refer to Deliverable 6 of the SMARTEST project: “Simulation Report”, where all the components of the new interface are described with a great amount of details.

The flow chart of Figure 10.4 shows in a schematic way, the operation of the TCP MANAGER two main tasks and the interaction existing between NEMIS, the TCP MANAGER and the whole simulation network.

Figure 10.4 TCP MANAGER operation, Log File System and exchanged Messages



Variable Message Signs

The VMS model is based on the aggregation of micro-destinations in macro-destinations. A correspondence between macro and micro destinations is defined both to implement the model of the interaction between drivers and VMS (the driver needs to identify the possible macro-destination which corresponds or includes his micro-destination) and to fix the area addressable by the guidance strategy by means of each VMS.

Together with the description of the VMS network (identifier and position of the VMS within the network, description of the macro-destinations, etc.) the drivers compliance rate should be specified for each class of private vehicles. The level of drivers compliance should be determined on the basis of previous experience and available results.

Dynamic Route Guidance

For the Dynamic Route Guidance simulation, NEMIS adopts the concept of routing vehicle: a routing vehicle has capability to elaborate information and take decisions. It knows its final destination and, while no information is received from external control strategies, it behaves as a normal vehicle, trying to achieve its final destination. As soon as IRG information is received from an infrastructure of the network (such as IRED beacon), the routing vehicle calculates the best route for its destination. While no further information is received, the routing vehicle follows the best route for its destination calculated during last elaboration.

It comes that the route followed by a routing vehicles depends on the elaboration of all the available informations and so, due to the fact that information is provided by the external control strategy, on the routing strategy adopted. NEMIS supports a number of following DRG control strategies.

The control strategy applied is common to all the above solutions, and it is based onto the calibration of the link density to a nominal value. Also the calculation of the impedance and cost functions, as the calculations of the desired turning percentages is common to all solutions.

Together with the description of the network infrastructures (identifier and position of the beacons within the network) the drivers compliance rate and the penetration rate should be specified.

Assuming that for the routing vehicles the compliance rate could be assumed about 100%, the penetration rate (number of routing vehicles that will be generated) together with the selected control strategy, influences the results of simulations. Suggested penetration rate is 20% and, in any case, it should not overtake 50%.

Adaptation of SITRA – B+

The modelling step consists in filling in the input data files of SITRA-B+ with the data collected. This is a fastidious work, particularly if the area to model is large, that requires a large number of information due to the microscopic nature of SITRA-B+.

This section is intended to indicate some points to be taken care of when filling the input data files of SITRA-B+, and to give recommendations for using this microscopic traffic simulation model; those recommendations are sorted by topics such as network description or vehicle parameters, and also with reference to the newly developed functions in the frame of the SMARTEST Project. This section is not meant to replace the SITRA-B+ User Manual, but to complete it.

The International units system (metres for lengths, seconds for time) is used in the input data files.

Global Parameters

Among the simulation global parameters, the simulation step is specified in file *global_parameters.rel*; however, the only authorised value in the present version of SITRA-B+ is 1.0 second.

Network Functional Description

A two-level representation is used to describe an urban network with SITRA-B+. The first one (the macroscopic level) uses nodes and links entities, and the second one (the microscopic level) uses connection points and lanes.

Macroscopic Representation level

The following input files are used to describe the network geometry:

link.rel

Due to the roundabout model development, this file now includes new data fields:

- the link type, which enables to distinguish "ORDINARY" links from roundabout entrance ("RDB_ENTRANCE") links and "ROUNDABOUT" links
- the link length and the link radius, used to represent curved links on the graphical display.

Among the other parameters attached to a link, an important one is the saturation flow, expressed in vehicles per second AND PER LANE, which is used by the car-following model to derive the desired time headway between vehicles.

node.rel

Five node categories are available: INTERSECTION, INPUT, OUTPUT, PARK (for underground or multi-storey car parks) and STREET_PARK (along the roadside).

roundab.rel

This file enables to attach a subset of links and a subset of nodes (belonging to the INTERSECTION category) to each roundabout of the network. The links to be associated to a roundabout are both "RDB_ENTRANCE" and "ROUNDABOUT" ones.

Microscopic representation level

Two input files are used to describe the microscopic representation level:

lane.rel

The data fields associated to a lane enable to associate it with its macroscopic entity (a link or an intersection) and with its upstream and downstream connection points. Another important parameter is the free speed, which has to be entered in meters per second.

lateral_connection.rel

This file is used to list the authorised lane changing movements between adjacent link lanes or between a link lane and a lateral parking area.

Network Display

File *connection.rel* is used to draw the network layout on the graphical display:

connection.rel

This file, which is the main input file used to draw the network on the screen, contains the coordinates of all the connection points of the network, which themselves represent the beginning and ending points of the lanes (both link- and intersection- lanes). These coordinates can be extracted from a Geographic Information System if available.

Vehicle Description

The two following data files are used to describe the vehicle categories:

modality.rel

This file enables to associate an equipment level (like guidance equipment) to a vehicle category; it is then used in the demand description files to associate a dedicated set of input flows and initial assignment to each modality (for example non guided cars, guided cars, buses, lorries).

vehicle_type.rel

This file contains the parameters associated to each vehicle category; among those parameters, a particular attention should be brought to the following ones:

- car-following law coefficients C1 and C2: recommended values for those parameters are respectively 0.40 and 0.15, which offer a good compromise in terms of stability.
- maximum and minimum acceleration values: those parameters are also directly implied in the car-following process and in the possible occurrence of rear-end collisions.
- desired speed coefficient average and standard deviation values: those parameter are used to randomly assign to each generated vehicle a multiplicative coefficient, which is then applied to the free speed of each link travelled by this vehicle; it thus enables to:
    - model the behaviour of special vehicle categories like buses, to which an average value less than 1.0 should be assigned (they usually do not reach the free speed of the links they travel on)
    - model different driving behaviours, by choosing the speed distribution among vehicles of a same category, with the value of the standard deviation of this coefficient.
- finally, the four last parameters of this file are dedicated to the modelling of driver behaviour in roundabouts (aggressiveness and gap acceptance parameters).

Demand Description

Two files are used to describe the traffic volumes and initial assignment on a SITRA-B+ network: *demand.rel* and *route.rel*:

demand.rel

This file contains traffic volumes per Origin-Destination couple and per modality (for example cars and buses); it is important to note that flows are given in vehicles per second, and that origin and destinations are either input or output nodes or underground or multi-storey car parks; car parks located along the roadside are no more considered as origin or destination in SITRA-B+, but as intermediary "nodes" along a route.

Another particularity concerns scheduled vehicles like buses: although their schedule is given in another input file (*vehicle_schedule.rel*), one line must be entered in the *demand.rel* file for each

OD served by one or several bus services, with a 0.0 flow value; this is necessary in order to get PT services results in their dedicated output files.

route.rel

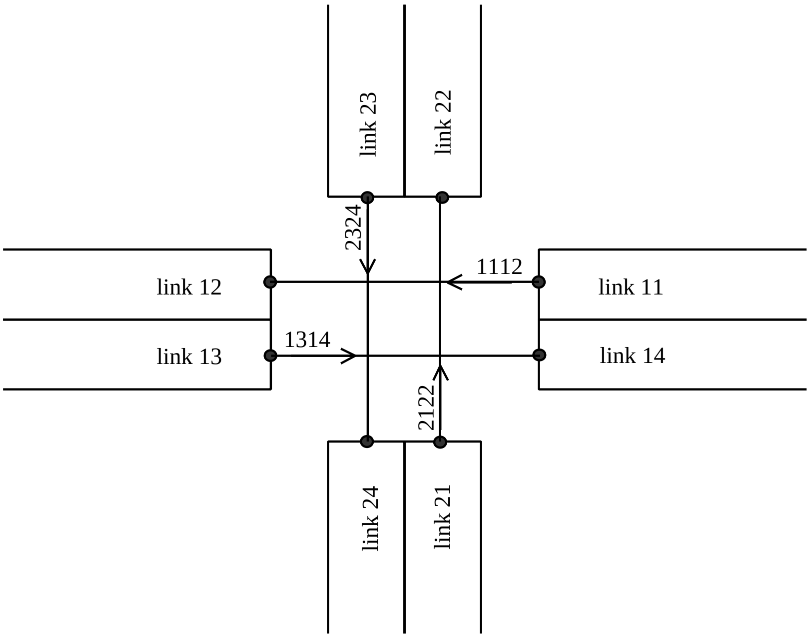
This file contains the description of each route in terms of a link list; in order to model the behaviour of drivers for using car parks along the roadside, we chose to associate to each of those pre-determined routes a list of STREET_PARK nodes and a list of respective stopping probabilities; thus, each time a newly generated vehicle is assigned to a given route, and if this route includes a non-empty list of intermediary STREET_PARK nodes, stopping events are randomly generated for this vehicle, taking into account the above stopping probabilities.

Traffic Movements In The Intersections

File *forbidden_movement.rel* contains the list of forbidden movements per intersection, a "forbidden movement" being described as a couple of intersection lane numbers: the originating lane and the ending lane; for example, on figure 1, if left turns are not authorised from link 11 towards link 24 and from link 13 towards link 22, the following lane number couples should appear in file *forbidden_movement.rel*:

From	To
1112	2324
1314	2122

Figure 10.5 A simple 4-arm intersection



Based on the assumption that the authorised movements list should be longer than the forbidden movements one, SITRA-B+ first considers that all movements are possible, and then removes those found in file *forbidden_movement.rel*.

Public Transport Services

Three input data files are used in Public Transport management by SITRA-B+:

bus_stop.rel

This file contains the description of all the network bus stops(geometrical and temporal characteristics); the bus stop length, which is not specified by the user, is automatically adjusted to the length of the bus ; concerning the stop time duration, the user can select the parameters of the Gaussian law (mean and standard deviation values) which is used to generate them, and the program automatically truncates the obtained values between 20% and 300% of the mean value.

vehicle_schedule.rel

This file is used to assign a schedule to each PT Service route; the mean value of generation time period is linked to the frequency on the bus line, and the standard deviation value of this time period enables the user to choose the degree of steadiness of bus generation times at the beginning of the simulated PT Service route: he can thus use a small value if the simulated generation point is a terminus, or a bigger one in another case.

vehicle_route.rel

This last file simply contains the description of each PT Service route in terms of a link list; the same link list (and consequently the same origin and destination) can be associated to different routes.

Roundabout Modelling

The 3 input data files implied in roundabout modelling have already been mentioned above:

- *link.rel and roundab.rel*, for roundabout functional description (see paragraph 5.3)
- *vehicle_type.rel*, for the driver behaviour model parameters (see paragraph 5.5).

Parking Management

Input data files implied in parking management, and more specially along the roadside, are:

- *node.rel*, for the functional description (see paragraph 5.3)
- *route.rel*, to link lateral car parks to predefined vehicle routes (see paragraph 5.6)
- and finally file *street_park.rel*:

street_park.rel

This file contains the geometrical and stopping time characteristics of the lateral car park, and also tells to which link it is attached and which vehicle category is authorised to use it; the number of parking lots is automatically deduced by SITRA-B+ from the parking area length and from the vehicle category length; the stopping time characteristics are used to randomly generate a stopping time for each concerned vehicle, using a truncated Gaussian distribution (as for a bus stop, the stopping time is truncated between 20% and 300% of the mean value).

Incident Management

Considering the way incidents are generated in SITRA-B+ (the vehicle to stop is the first one crossing the incident location after the incident starting time), this incident starting time (specified in input file *incident.rel*) will generally not be strictly respected, specially when flows are low in the link where this incident should occur.

Remaining gaps

By comparing the users' requirements and the models' capabilities it is possible to discover the most important gaps that the model developers should concentrate their future efforts on filling.

Model validation is a crucial issue. Users are not confident that the models have been sufficiently calibrated and validated. Therefore more real data must be collected for comparison with model outputs.

The users also appreciate the benefits of a user-friendly interface for network building and presentation of results. Few models have a network builder and interfaces with analysis packages and Geographical Information Systems could be improved.

Future micro-simulation models should ensure that they can model adaptive traffic signals, incidents and incident management systems, roundabouts, public transport priority at signals, variable message signs and dynamic route guidance. Environmental objectives are becoming of increasing importance, so models should be able to give outputs of fuel consumption and pollution emissions. All these new models will need to be well calibrated and validated.

The models might in the future need to be adapted to differently equipped user groups with different behaviour in relation to differences in available information. Differences in information quality (accuracy, timeliness) and the effects on reliability and user behaviour will also be dealt with.

11 RECOMMENDATIONS

Given the results from the evaluation and validation at the test sites and the comparison between macro and micro modelling, the following recommendations can be made.

Estimating the capacity of road links and intersections.

Micro-simulation is a very useful tool to enhance the understanding of the traffic process. Models are well adapted to study signalled intersections in detail and to analyse effects on capacity and delay of changes in control algorithms. Models are also well adapted to study the complex interaction between vehicles on motorways. Speed variations, lane-changing, merging and breakdown situations can be analysed. The following phenomena can be analysed with micro-simulation:

- Road links
- Controlled and uncontrolled intersections
- Roundabouts
- Merging
- Bus stops
- Parking
- Incidents

In SMARTEST, the modules concerning adaptive signals and roundabouts have been enhanced. Crucial driver behaviour models on motorways are lane-changing and merging between main stream and on-ramp traffic. This behaviour differs between countries. The attitude towards fellow motorists determines whether courtesy or forced merging is the normal behaviour.

The transferability studies in SMARTEST has pointed out that at least following parameters should be calibrated before use in a new traffic environment:

1. Compliance to speed limits
2. Type of signal control
3. Reaction time for free vehicles and dense traffic
4. Frequency of lane changes
5. Courtesy yielding or forced merging

Designing control strategies for traffic management.

Micro-simulation programmes are well adapted for traffic control measures. It is strongly recommended to use micro-simulation to analyse typical dynamic situations like the effect of events, road works and incidents in order to select a suitable control strategy and dissemination of information. Models are well adapted to analyse the formation and dissipation of queues at incidents. The following strategies can be analysed with micro-simulation:

- Adaptive traffic signals and public transport priority
- Motorway control and ramp metering
- Incident management
- On-trip information and VMS
- Road tolling and HOT lanes
- Cruise control and ISA

In SMARTEST, the modules concerning adaptive signals and motorway flow control have been enhanced. It is now possible to interface and connect the models to real-time control systems.

The transferability study in SMARTEST has shown that micro-simulation in principle is useful for dynamic route choice, but that a validated route choice model is missing. It can therefore be recommended to use micro-simulation foremost to analyse local route choice, where for instance the share of deviators in response to VMS is changed and the effects studied. If the global route choice is the main focus, the global behaviour must be validated with traffic counts on alternative routes in situations with and without incidents in the network.

The work in SMARTEST has also shown that micro-simulation in principle is very useful to analyse the dynamic effects of information strategies. The behavioural knowledge concerning the motorists’ reactions to information is however limited. The micro-simulation should in this case be used as an ‘open toolbox’. Behavioural information can either be gathered from the local environment or from experience from implementations in other contexts. In the first case, local relationships between VMS messages or distributed information and the road users’ responses can be estimated.

In the second case it is necessary also to study the transferability problem before using the results. Which factors are different and may affect the effects in the new context? The skilled user should be able to introduce new behavioural modules by altering parameters in the micro-simulation model or by introducing new modules. In AIMSUN2, it is possible to add own procedures (.dll) to represent new phenomena.

Assessing the benefits of infrastructure and ITS investments.

Micro-simulation programmes are useful in assessing the benefits of infrastructure and ITS investments, but should not be used alone if the network effects are important. Redistribution of traffic is normally of importance for extensive improvements of traffic signals, capacity improvements of motorways, ramp metering, pre-trip or on-trip information and for road tolling. In these cases an assignment system is recommended to analyse these effects. In many cases it is also of interest to include the effects on the balance between individual traffic and public transport. Demand and assignment models are then required to assess the total benefits of the investments.

The ideal system includes both demand, static and dynamic assignment and microscopic driver behaviour models. The dynamic route choice is a problem in most analyses and must be treated with sufficient care. Assignment systems are usually static and take not the dynamic characteristics of traffic into account. Micro-simulation systems do usually not include route choice. When dynamic route choice is included, this module is mainly based on theoretical assumptions and not sufficiently validated.

When assessing the benefits of infrastructure investments, micro-simulation can be used to analyse bottlenecks and capacity problems for crucial parts of the network. The deteriorating effects of incidents and the resulting queues can be studied. This can be used to produce more realistic delay functions in assignments systems.

When assessing the benefits of ITS investments, micro-simulation can be used to analyse dynamic local effects and to produce input data to assignment systems. The skilled user of assignment systems should be able to estimate the network effects of ITS investments in this way. As the behavioural information of ITS applications is limited, the results still rest on a number of crucial assumptions:

Adaptive signals: service level for various systems

Motorway control: compliance to recommended speed limits

Ramp metering: route choice and merging in metered situations

Incident management: timelag in detection and clearance

On-trip information: timelag in dissemination, quality and content of information

VMS: propensity to response to warnings and information

Road tolling: service level for various systems, price sensitivity

ISA: compliance to static speed limits, interaction with uncontrolled vehicles

Conclusion

a. Mesoscopic and microscopic simulation models are very useful for traffic control and in understanding the dynamic nature of traffic.

b. Proper calibration is very important. The new user should be prepared to spend an initial period for learning and calibration of a micro simulation package. It is very important that this requirement is fulfilled in order to get reliable results. It is risky to use untried micro-simulation models for new application areas when working under time pressure.

c. Graphical interface helps a lot, when searching deficient input data, and to aid understanding of the simulation results. It is also important to choose a simulation package where rapid support is available if something goes wrong.

d. The choice of software package depends on the application. Micro-simulation programmes are well adapted and can be recommended for traffic management problems.

e. Micro-simulation is in principle good for navigation and cruise control systems, but the dynamic route choice criteria are still doubtful.

f. There are still some features in micro-simulation that has to be enhanced. Examples are merging, lane-changing, group control of signals, consideration of public transport and 3D-visualisation.

g. Try to improve the dynamic route choice algorithms. Behavioural data must be gathered that can be used to calibrate dynamic route choice in response to queue observation, radio information, VMS and navigation systems.

h. Try to improve micro-simulation for safety assessments of vehicle-control systems. In order to capture safety aspects of cruise control and ISA, it might be necessary to increase the resolution in the model and to include safety indicators as time-to-collision (TTC) or acceleration noise.

i. Try to establish an integrated system for strategic and tactic evaluation of road and public transport including ITS features. Such a system can consist of:

    - a traversal matrix from the assignment model is used as input to micro-simulation,
    - a micro-simulation area is treated as an island with higher resolution in the assignment model or
    - a buffer network with limited representation outside the main area of interest in the micro-simulation

References

Smartest. Technical Annex. December 1996.

Review of Micro-Simulation Models. SMARTEST Deliverable D3. June 1997.

Simulation Report. SMARTEST Deliverable D6. May 1999.

Project Dissemination and Exploitation Plan. May 1999.

Modelling of ITS applications - Test of four dynamic models. DYMO final report. CTR in co-operation with Transek. April 1999.

Project Evaluation and Transferability Plan. SMARTEST Deliverable D2. July 1998

Update Specifications. SMARTEST Deliverable D4. February 1998.