TRAFFIC MICRO-SIMULATION MODELLING

Traffic micro-simulation models represent individual vehicles explicitly

1. What is traffic micro-simulation modelling?

Road traffic micro-simulation models are one of the latest generation of commercially available traffic models developed in recent years. They model the movements of individual vehicles travelling around road networks by using car following, lane changing and gap acceptance rules. They are becoming increasingly popular for the development and evaluation of a broad range of road traffic management and control systems.

More traditional **macroscopic** traffic models typically provide an aggregated representation of traffic flow, expressed in terms of total flows per time period and averaged travel time per time period. In such models, all vehicles of a particular group are generally assumed to obey the same rules of behaviour. In macroscopic traffic assignment models (such as SATURN, VISUM, and EMME/2) the analogy can often be made between traffic flow and fluid flow.

Mesoscopic traffic assignment models such as CONTRAM move away from the flow analogy, and treat traffic demand as 'packets' in a dynamic fashion. Since each packet is treated individually, its location in the network at any point is known, as is the time of arrival at the destination.

Empirical models such as ARCADY, RODEL, and PICADY are based on mathematical relationships between highway geometry, traffic flow, and capacity derived from large scale surveys of existing junctions.

Established aggregate UK models such as TRANSYT, LINSIG, or OSCADY, utilize saturation flow formulae, time dependent queuing theory, geometric delay, and optimization routines to model isolated or linked traffic signals.

Microscopic (or micro-simulation) models (such as S-PARAMICS, Q-Paramics, VISSIM, AIMSUN, and DRACULA) explicitly represent individual vehicles, and hence attempt to replicate the behaviour of individual drivers. This makes them particularly appropriate for examining certain complex traffic problems (e.g. intelligent transport systems, complex junctions, shockwaves, effects of incidents).

The explicit representation of individual vehicles in the model lends itself in particular to the visual representation of individual vehicles in two dimensional (and three dimensional) graphical user interfaces, a capability of significant benefit in model de-bugging and presentation of results.

However, the greater 'realism' gained from the representation of individual vehicles (and hence drivers) introduces an additional level of complexity into the modelling process which should not be underestimated, and which is discussed further in this note.

2. Do I need a micro-simulation model?

The guiding principle must be to use the appropriate modelling tool for the job, taking into account the scope of the task, the needs of the stakeholders, and the resources available. Questions to be asked would include:

- Would a more traditional (non-micro-simulation) model meet the requirements? Are there particular issues that a traditional model cannot address? See Section 6.

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- Does the operation of the scheme need to be presented visually to the decision makers or the public?
- Is the micro-simulation being offered primarily to provide a visual presentation to decision makers? If so, could reliance on visual assessment be misleading?
- What type of transport network is under consideration (urban, suburban, inter-urban)? Some models are better at representing particular road types than others.
- What types of scheme are being considered? This can also have a major bearing on the choice of model used.
- How will traffic signals be represented? Simplistic fixed time signal plans are often used, but sophisticated vehicle actuation and priority signalling such as MOVA, and system wide UTC controllers such as SCOOT, UTOPIA, and SCATS are possible.
- Over what spatial area will the scheme have an impact? Is route choice an issue (some micro-simulation models depend on separate assignment models for routing information)? Is it cost-effective to model the network in fine detail over a wide area?

Method of traffic signal control is often an important consideration

- How detailed will the model need to be?
- What is the timetable and budget available for model development and scheme appraisal?
- Is environmental assessment a key issue? Modelling individual vehicles has some significant advantages when assessing exhaust emissions and air quality in a local area.

Before selecting a micro-simulation software package, be clear and explicit about your particular local needs. Does the functionality of the software meet your key requirements? All software packages have their strengths and limitations. Ask questions.

Guiding principles

It should be recognised that many of the guiding principles for traffic micro-simulation modelling are generic to all traffic modelling exercises, but the use of any new modelling technique has implications for training, familiarisation, appropriate application and resources.

- Use of the appropriate traffic modelling tool for the job is essential. Understand the strengths and limitations of the tool and ensure that it is capable of adequately representing the local traffic conditions. Confirm that the tool can be applied to support the purpose, needs, and scope of work, and can address the question that is being asked.
- Be explicitly aware of the time and resource requirements of the traffic modelling exercise. Do staff have the requisite training, knowledge, and experience to carry out the work?
- Robust and reliable traffic modelling depends on good data. This includes traffic micro-simulation modelling.
- It is critical that the modeller calibrate any traffic micro-simulation model to local conditions.
- Be aware that outputs from micro-simulation models may be in a different form, with different definitions, compared to more traditional aggregate models you may be familiar with.
- Prior to embarking on the development of a traffic micro-simulation model, establish its scope among the stakeholders, taking into consideration expectations, objectives, and an understanding of how the tool will support the decision-making process.

Adapted from FHWA Guidelines for Applying Traffic Micro-simulation Modelling Software

3. Development of a base model

The data required to build a micro-simulation model is basically similar in scope to that required for more traditional macroscopic or mesoscopic models, but more intensive in detail. Data requirements include items such as highway geometry, traffic signal data, signing data, traffic demand data (turning counts, origin-destination matrix by mode, routing information), calibration data (saturation flows, journey times, queuing information). The principles of good practice to be followed for any traffic model development project apply equally to micro-simulation. The main additional element in the development process is the specification of the local parameters controlling the microscopic car following, lane changing and gap acceptance models.

Many current commercial micro-simulation models have the capability to explicitly represent a range of vehicle types, including buses and bus routes, motorcycles, and pedal cycles.

Some models have the capability to explicitly represent pedestrian interaction with the highway network, whilst others accommodate this implicitly, for example in pedestrian phases at traffic signals.

Representation of public transport

Technical characteristics of micro-simulation models

Transport system update mechanism. There are generally two types, Discrete Time Models, and Discrete Event Models. In Discrete Time Models, the system is updated at fixed time intervals, for example every tenth of a second. The majority of models use this method. In Discrete Event Models, the time periods between system updates vary in length and are triggered by events, such as changes in traffic signals. This type of model can have faster run times, but is less suited to systems which change frequently.

Representation of randomness. Stochastic Models are the most prevalent form, assigning driver and vehicle characteristics from statistical distributions using random numbers, e.g. drivers will accept a mean gap of 2.5 seconds with a Standard Deviation of 1.5 seconds. The sequence of random numbers generated depends on the particular method, and the 'seed' value selected. Changing the "seed" value produces a different sequence of random numbers, which in turn produces different values of driver/vehicle characteristics such as gap-acceptance, propensity to change lanes, aggressiveness, etc. This highlights the importance of carrying out multiple runs with different seed values to have confidence that the final result is stable and representative. Micro-simulation model results have been observed to vary by up to 25% simply by changing the seed value. Most models have the facility to replicate a model run by keeping the seed value unchanged.

Vehicle generation. At the beginning of a simulation run, the road network is empty. Vehicles are generated at the entry nodes of the network, so there is typically a 'build up' period whilst the network is being populated for the modelled time period.

Allocating driver/vehicle characteristics When a vehicle/driver is generated at a network entry node, the micro-simulation model assigns it certain characteristics. These would include vehicle characteristics such as vehicle type, acceleration/deceleration, maximum speed, turning circle, and driver characteristics such as aggression, gap acceptance criteria, desired speed, reaction time, etc. As discussed above, these are usually allocated on a random statistical basis.

Vehicle interactions. Micro-simulation models simulate the interaction between individual vehicles using car-following, lane-changing, and gap-acceptance 'rules'. The car-following rules define how the following vehicle responds to changes in the speed, acceleration, or braking of the car in front, usually using a target spacing or headway. This usually operates in a fail-safe mode, i.e. the vehicles cannot collide. Lane changing can be either mandatory (e.g. at a merge), discretionary (e.g. to maintain desired speed), or anticipatory (e.g. in anticipation of a delay or blockage downstream). Gap-acceptance, as the name suggests, determines a driver's propensity to accept a gap of a certain size (usually measured in time), either to merge into another traffic stream or change lanes.

4. Micro-simulation model calibration

Every micro-simulation program has a set of user-adjustable parameters which enable the analyst to calibrate the software to match locally observed conditions. A micro-simulation model attempts to 'internalise' all of the factors which influence driver and vehicle behaviour. Since it is clearly impossible in practice to explicitly identify and quantify all such factors, the commercially available software packages contain user-adjustable parameters controlling, for example, driver aggressiveness or car-following sensitivity, idealised decision points, physical extent of give-way zones, threshold speeds for give-ways, to allow the analyst to attempt to replicate locally observed conditions.

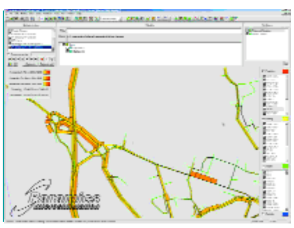
Such a calibration process can be a very time-consuming procedure, and it is important that the calibration is thoroughly documented, including the rationale for making particular interventions.

Key issues include:

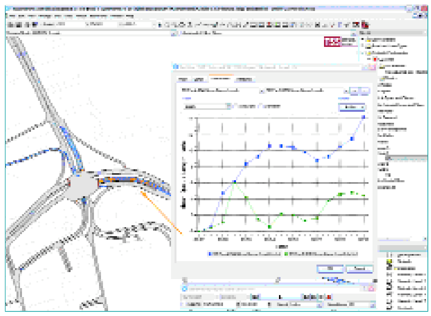
- Identification of required model calibration targets.
- Allocation of sufficient time and resources to achieve calibration targets.
- Selection of the most appropriate calibration parameter values to best match locally measured network capacity values.
- Selection of the calibration parameter values that best reproduce observed route choice behaviour.
- Calibration against overall network performance measures such as queues, delay and journey time.

It is important to note that since parameters are adjusted to replicate the observed local situation, there is often significant difficulty in coding new junctions/schemes with a given level of confidence as they can be highly sensitive to local factors (for example, junctions with restricted visibility, or with lighting or parking/pedestrian issues). Therefore, there may be an ultimate limit to the increased level of confidence possible using micro-simulation models.

Whilst the visualisation of individual vehicle behaviour (either in 2 or 3 dimensions) is a useful aid in the calibration process, it should be noted that such a visual approach can be extremely time-consuming (for example, viewing the modelled average queue length on a particular approach over a modelled time period, and then repeating the process on other approaches/junctions). Traffic micro-simulation models also have non-visual data output, and software tools have been developed to assist the data analysis and model interpretation process.



Model calibration involves a range of factors



Queue lengths are one measure of calibration

5. Micro-simulation model validation

The Design Manual for Roads and Bridges states that 'Each stage of base year model development should be validated against independent data, so that any weaknesses in the model can be properly understood and remedial action taken'. This philosophy applies equally to micro-simulation models as it does to macroscopic traffic models. The key requirement is that the model can be shown to be robust and fit for the purpose for which it was developed and applied.

It is beyond the scope of this note to provide detailed guidance on micro-simulation model calibration and validation, but specific advice can be found in the references and sources listed at the end of this note.

A micro-simulation model will achieve validation if the transport system environment, vehicle dynamics, and driver behaviour have been accurately described for the local context and time period. Traffic micro-simulation models remain a simplification of real world behaviour, where the calibration process specifies an 'adequate' level of detail sufficient to achieve an acceptable level of validation.

6. Applications for micro-simulation modelling

Micro-simulation is particularly suited to the development, testing and evaluation of intelligent transportation systems (ITS).

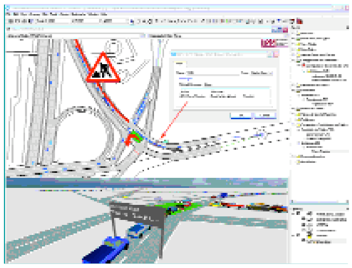
Many such systems interact with individual vehicles. Adaptive traffic signal control, public transport priority, and ramp metering systems react to vehicles approaching junctions.

Dynamic Route Guidance systems supply specific information to individually equipped vehicles. Intelligent Cruise Control systems adjust the speeds of equipped vehicles. If the scheme being appraised includes such interventions, then it would be appropriate to consider using micro-simulation techniques as part of the assessment process.

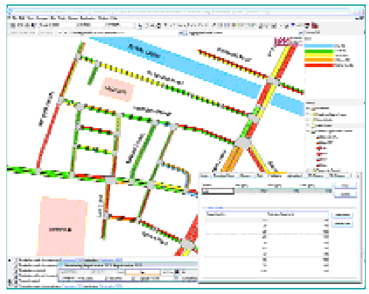
As noted earlier, the graphical visualisation capabilities of many of the commercial software packages also prove to be an effective means of communicating scheme proposals to non-specialists and lay people.

However, in this context a word of caution is appropriate: such visualisation can sometimes create a false sense of realism. The underlying algorithms in the traffic micro-simulation models (car-following, gap-acceptance, lane-changing) can sometimes struggle to create the correct numerical response in complex or competitive situations, for example at roundabout give-ways. This has been seen to lead to anomalous situations where, for example, vehicles apparently drive through each other. Seductive visual presentations may sometimes hide important quantitative assumptions.

Micro-simulation is often well-suited to model ITS applications



Traffic management at road works



Air pollution Assessment

7. Training requirements

Before embarking on the development of a micro-simulation model, it is advisable to seek specialist advice, and undergo adequate training. Many of the concepts in micro-simulation modelling, whilst intuitively familiar, are different to those in more traditional macroscopic modelling. In particular (depending on context), a multi-disciplinary approach may prove beneficial, utilising the skills of both transportation modellers and traffic engineers. Training courses are available from the software vendors, and generic micro-simulation courses will become more available as the knowledge base develops.

8. The future

Our current knowledge of the factors influencing driver behaviour is incomplete. As more research is done, our understanding will improve, and we will be able to specify micro-simulation models more robustly and with a greater degree of confidence. Complex micro-simulation models currently take a significant amount of time and resources to develop and operate. One significant factor is run time. However, recent history tells us that computer processing speed and power will improve as time goes by. Just as important is the time required to assess the results of any model run, which typically involves viewing a long period of model output in real time. This human aspect of the modelling process is less likely to be foreshortened by technological advances. It is certain that micro-simulation technology will become more ubiquitous in the years ahead as our understanding of driver behaviour becomes more refined, and our ability to represent this behaviour in analytical tools improves.

9. Useful References and Sources

It should be noted that technology is changing rapidly in this technical area, and references soon become dated. Practitioners should seek out the most current advice and guidance.

a) Design Manual for Roads and Bridges, Volumes 12 and 12a, Traffic Appraisal of Road Schemes. Department for Transport. TSO London.
http://www.standardsforhighways.co.uk/dmrb/index.htm

b) Interim Advice Note (IAN 36/01). The use and application of micro-simulation traffic models. Highways Agency. June 2001.
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c) Micro-Simulation Modelling Guidance Note for TfL. Transport for London 2003.
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d) Scottish Transport Appraisal Guidance (STAG). Appendix B: Modelling and Assessment Software. Scottish Executive.
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