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.
• 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?
• 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.

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 Modeling 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 (satisfaction 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 high-way network, whilst others accommodate this implicitly, for example in pedestrian phases at traffic signals.
Key issues include:

- including the rationale for making particular
  calibration is thoroughly documented,
  consuming procedure, and it is important that
  observed conditions.

- the analyst to attempt to replicate locally
  points, physical extent of give-way zones,
  ling, for example, driver aggressiveness or
  the commercially available software packages
  locally observed conditions. A micro-simulation
  of user-adjustable parameters which enable
  targets.

- Allocation of sufficient time and resources
  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 characteris-
  tics such as gap-acceptance, propensity to
  change lanes, aggressiveness, etc. This high-
  lights the importance of carrying out multiple
  runs with different seed values to have confi-
  dence that the final result is stable and repre-
  sentative. 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 net-
  work 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 down-
  stream). 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 control-
ling, 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 sen-
sitive 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, view-
ing 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-sim-
ulation models also have non-visual data out-
put, and software tools have been developed
to assist the data analysis and model
interpretation process.

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
validation, but specific advice
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 roundabouts. 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.

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.


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

Traffic management at road works

Air pollution Assessment