

How microsimulation modelling can address the real-world problems of navigation in congested networks

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Microsimulation modelling has brought major benefits to traffic flow analysis through the representation of vehicle behaviour applied to individual driver vehicle units. The improved understanding of how drivers choose their speeds, headways, lanes and gaps has fed its

way into commercial microsimulation modelling software, although the process of route *choice* has hardly moved beyond equilibrium style techniques in some cases. This paper discusses some routeing problems encountered by modellers and outlines how

microsimulation assignment methodologies address real-world problems of navigation in congested networks.

The comments are made in the context of the author's experience as a practising traffic modeller using the S-Paramics software.

MODELLING DYNAMIC ADAPTIVE SIGNAL CONTROL

Traffic assignment is generally based around Wardrop's Principles (ref.1), which state that:

'The journey times in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route', and 'At equilibrium the average journey time is minimum.' This assumes that:

- All costs on all routes are constant over the assignment period.
- All drivers know the costs of all routes.
- Identical values of the cost components apply to all drivers and vehicles, by user class.

The result of the application of these rules is a constant demand on any network link in an assignment period. If this were true there would be no need for dynamic adaptive signal control (UTC). In reality, UTC is increasingly required because the Wardrop assumptions do not necessarily apply at the level of the individual driver. An analogy might be the breakdown of classical Newtonian mechanics in the context of quantum physics. In the case of *transport* modelling, the quantum level is represented by the person, while the vehicle represents the unit for the *traffic* modeller. At this level, an in-

dividual has only an approximate understanding of the cost of the intended route, based on familiarity with the road network and the likely prevailing traffic conditions.

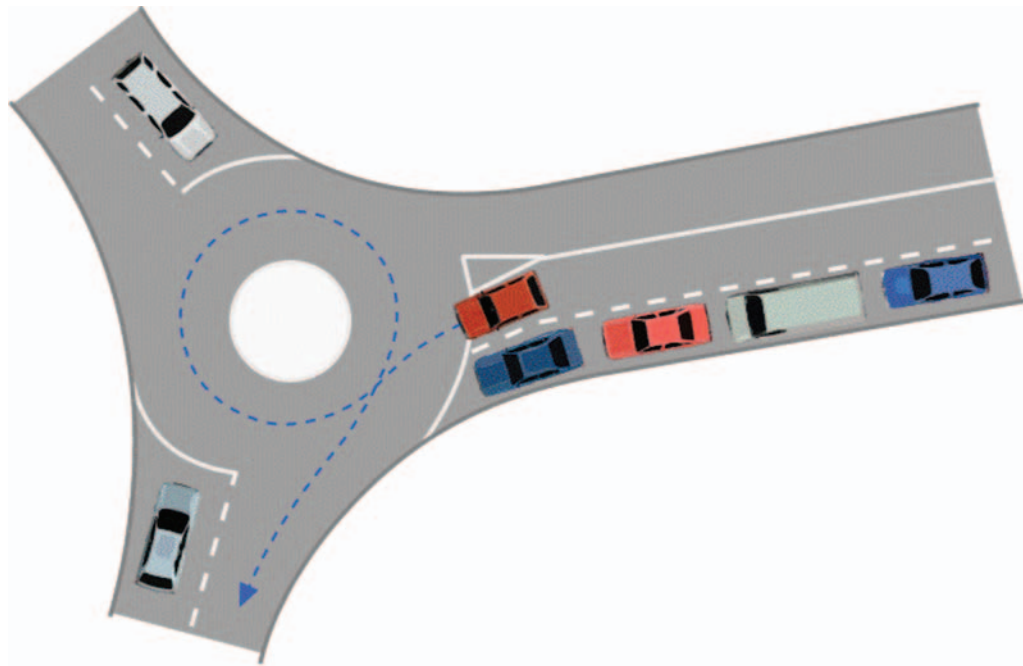
The deployment of UTC in the real world should reduce the overall delay experienced with fixed demand, although there is a danger of drivers diverting into the system from peripheral congestion. When the network has reached saturation, any signal optimisation technique will tend to operate to a total maximum capacity signal setting with little variation. The benefits of dynamic signal optimisation are realised when operating with atypical or less than maximum demand. In such circumstances, the signals will dynamically shift with traffic demands to minimise network delay.

Microsimulation models are typically developed for areas where the network is close to capacity, and the modelled period will normally comprise the peak period with 'warm up' and 'cool down' shoulder periods where demand is lighter. Applications include network interventions, structure/local plan impact assessment, roadworks assessment, event planning, etc. For many assessments, the use of fixed time plan traffic signal settings in simulation models will be sufficiently robust, although delays will be overestimated when the network has not reached saturation. During the period of demand build up, the higher delays in an area of UTC may lead to vehicles diverting, and so the

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8 The challenges of assignment

Figure 1:
Where there is low demand for right turning traffic a small proportion of drivers will seek to minimise their delay by using the right hand lane and performing a $>360^\circ$ turn at the roundabout to avoid the left lane queue.



volume of traffic here may be unrealistically low. Following the peak period when demand starts to fall, the lack of delay minimisation in the system will lead to a slower dispersal of traffic than would happen in reality.

The use of fixed time plan settings in a model does not allow for the assessment of the benefits of introducing UTC systems. If these can be properly modelled, then we have a mechanism for testing responses to unusual traffic behaviour, as occur near roadworks or events. Modelling can indicate how UTC might benefit from temporary changes to accommodate such scenarios.

UTC poses an analytical challenge in that the capacity of an area under dynamic signal control is dependent upon the demands put on it, while the demands put upon it will be dependant on the capacity it can provide. This compounds the level of uncertainty, which all traffic management solutions should be designed to cater for. Within this context, the application of purely equilibrium assignment techniques is questionable, and likely to be inappropriate for providing as-

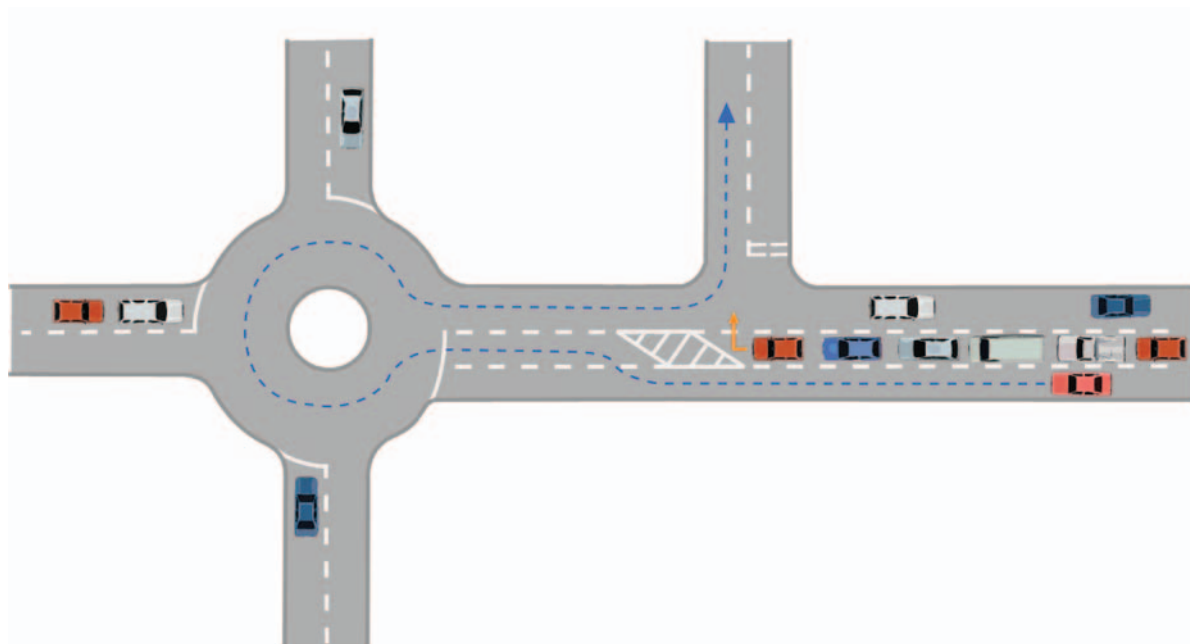
signment in contemporary traffic networks subject to demand responsive elements such as UTC and many types of ITS including ramp metering and VMS.

PROBLEM MANOEUVRES FOR MODELLERS

On a multi-lane approach to a roundabout, queues build up in the left hand lane due to high demand for turning left. Queueing is slight in the right hand lane, where there is low demand for right turning traffic (see Figure 1). A small proportion of drivers will seek to minimise their delay by using the right hand lane and performing a $>360^\circ$ turn at the roundabout to avoid the left lane queue. This impacts on the capacity of the junction, as vehicles performing the $>360^\circ$ turn will conflict at every arm of the junction.

Although the $>360^\circ$ turn is not illegal, until traffic planners devise a way of universally designing this manoeuvre out, it

Figure 2:
At this former junction on the A725 east of Glasgow the manoeuvre shown was not uncommon as a long queue of vehicles built up waiting to turn right at the priority junction.



will remain a real effect, and a real problem for traffic modellers because the possibility of its occurrence is not generally recognised by assignment algorithms. In this example, a vehicle going right round the roundabout will go over the same section of road twice, and routeing algorithms do not generally allow this. If such behaviour is not replicated in the model, then the queues and delays relating to the different turning manoeuvres will be misrepresented. This will be a minor issue for isolated roundabouts in a wide area model, but elsewhere the problems of blocking back can significantly impact on network performance.

Some routes may *appear* to be unlikely, but make perfect sense to drivers on the ground. Prior to the introduction of a new roundabout on the A725 at its junction with the A8 east of Glasgow, the manoeuvre in Figure 2 was not uncommon, as a long queue of vehicles built up waiting to turn right at the priority junction.

Although routinely rejected by classical routeing algorithms, microsimulation is capable of replicating scenarios similar to those depicted above. The modeller must be aware of where it is appropriate to allow unorthodox manoeuvres, but ensure that they are effectively switched off where the model is not properly representing the situation on the ground.

DYNAMIC ASSIGNMENT

To properly evaluate networks which include such features as UTC, a modelling system should reflect individual driver route choice and enable this to be continually reassessed by the driver. Some microsimulation modelling systems undertake *dynamic assignment*, which provides a considerable extension to equilibrium-style route finding, which is restricted to the initial phase of microsimulation assignment to inform a modelled driver of the best options based on a traditional perception of generalised cost. As delays start to build up in the system, information is fed back to modelled drivers who can then choose to amend their routes as they see fit.

To minimise computation time, S-Paramics microsimulation uses routeing tables rather than 'trees' to assign vehicles to a route through a model. Routeing tables for every decision point in the network (likened to the 'links' and 'nodes' of a classical modelling system) are continually built for each destination, so the variable generalised costs to all destinations are known as they vary throughout the assignment period. Once a vehicle has entered a network modelled by microsimulation, its initial origin is no longer relevant. For example, in a simple 20 zone network, the 20x20 OD trees of a classical modelling system is replaced by a table for each decision point of the next-link-to-enter for each of the 20 destination zones.

Information on delays building up in the network is fed back to the vehicles in the model at a user controlled frequency, typically every two minutes. Feedback is computationally expensive and the largest single factor in the time it takes to run a microsimulation model with dynamic assignment enabled. If longer feedback intervals produce acceptably valid models, the user may choose to balance this against model run times. The delay feedback information is smoothed to reduce the impact of random fluctuation, and there are controls on the proportion of the delay from the feedback interval which is allowed to influence the routeing tables.

S-Paramics microsimulation was designed from the outset to model at all scales, and various dynamic assignment refinements have been adopted to deal with the sheer size of

some strategic models. Clearly, there would be chaos if all drivers responded to delay information in the same way, and did not differentiate between major signposted and minor routes. *Familiarity* provides a mechanism to disaggregate vehicles into those that can change route in response to information about network delays and those that cannot. As in the case of traditional routeing trees, there is a different set of tables for each driver/vehicle type. A driver who is unfamiliar with the network will behave differently from a local driver. By varying the familiarity of drivers, microsimulation provides a mechanism for vehicles unfamiliar with the road network to more likely remain on the main roads, by increasing the cost of minor routes for unfamiliar vehicles. The model may also reflect features such as access to broadcast information, or active route guidance, for which additional routeing tables can be built.

There is no limit to the number of influences on route choice which can be simultaneously modelled, and although validating such effects is not trivial, there are now sophisticated tools in place to enable the building of robust models. Ignoring the problems of calibrating and validating congested traffic models should no longer be considered an option for contemporary modellers.

S-PARAMICS INCORPORATES SOME FEATURES TO DEAL WITH REAL-WORLD ROUTEING BEHAVIOURS

Strategic Route Corridor

This defines an area for which perturbation is temporarily disabled to ensure that a modelled driver chooses a lowest cost strategic route. As microsimulation models have become larger and more complex, two tiered routeing (see below) is now seen to have wider general application.

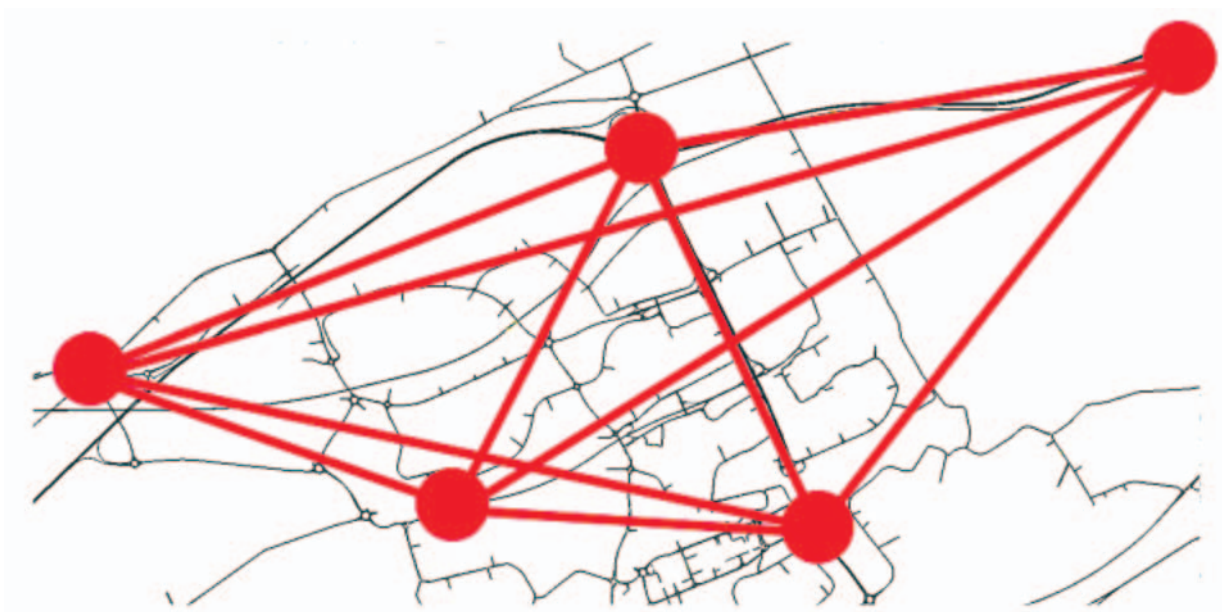
Waypoints

To avoid all vehicles on a given route with the same level of familiarity responding in identical fashion, in common with other modelling systems microsimulation applies *perturbation* by a choice of variably constrained methods and application classes. A resulting danger of perturbation is that more vehicles will be prone to take nonsensical routes, for instance preferring to use the slip roads at grade separated junctions even in uncongested conditions. Perturbation over long journeys is particularly problematic, and can give rise to eccentric routeing at the urban ends of a long inter-urban journey.

In reality, drivers perceive long journeys in terms of segments. For example going from city A to city B we may divide the journey into: Trip Origin to City A bypass; City A bypass to Motorway; Motorway to City B bypass; City B bypass to Trip Destination. Such a journey is broken up in the model through the use of *waypoints* to reflect real-world strategic driver behaviour. Along with OD zones these are linked into a spider macro network which sits 'on top' of the micro network. Link costs in the macro network are determined from the most efficient micro routes between waypoints. The introduction of waypoints creates a hierarchy of assignment, so S-Paramics simultaneously assigns at the micro and macro level to maintain its dynamic routeing integrity across strategic networks. Drivers in the 'real' micro network know which way to turn because the link routeing tables now include waypoints among the destinations. Perturbation and delay feedback can be set within both the micro and macro networks.

Waypoints are best summarised as enabling two-tiered routeing in a one-tiered network. In the real-world we think

Figure 4:
The conceptual
waypoint network
for strategic
routing coexists
with the real
microsimulation
network along
which vehicles
actually travel.
For clarity, not all
strategic links are
shown here.



of journeys simultaneously in terms of strategic and local objectives, and S-Paramics is able to reflect this behaviour in a context of dynamic feedback to produce plausible routes along their entire length.

Feedback coefficients

A time period modelled by microsimulation should start prior to the build up of congestion, and complete following the dissipation of the congestion. As congestion builds, delays in the system are fed back to drivers at regular intervals, but 'flipping' may occur, whereby the familiar drivers using one route will suddenly all switch to another. A feedback coefficient in the form of a damping factor is introduced to ensure that only a proportion of the existing network costs are included for ongoing routing calculations by combining existing costs with the costs from the previous interval. As congestion dissipates, carrying forward the costs from a previous interval can lead to vehicles avoiding congestion that no longer exists. This is overcome by the use of a feedback coefficient which is biased towards current costs for instances when the costs in the current interval are lower than in the previous interval.

AggrAw Feedback

Drivers' *aggression* and *awareness* are the principal determinants of behaviour which impact on car following and gap acceptance, from which all else follows in microsimulation. Response to delay is also considered to be influenced by both aggression and awareness, so drivers with high aggression and high awareness tend to reroute in response to small delays and vice versa. The aggression and awareness allocated by S-Paramics to each vehicle in the simulation are taken from normally distributed nine point scales, and are combined to produce one of 17 AggrAw vehicle types. Weighting factors are applied to the delay costs fed back to the vehicle based on the vehicle's AggrAw level to influence feedback at both the micro and macro levels.

A problem with applying AggrAw feedback is that it would appear to represent a spurious level of sophistication given the lack of observational data. This point is taken up below.

SUMMARY

The deployment of dynamic assignment techniques is necessary for robust assignment in road networks under UTC and other situations involving adaptive behaviour. A clear problem for validation is the lack of real-world research work and observational data. Some practitioners consider this sufficient reason for dismissing microsimulation as being 'too data hungry', but offer no plausible alternative. Considerable research is required to identify the default values applied to some fundamental parameters underlying microsimulation, but, rather than ignore them altogether, it is not unreasonable to assume that much of these are normally distributed. The software developers have provided a means to improve matters as our knowledge is updated. Provided that microsimulation models measure up to, and exceed, the demands of official guidance notes, there should be every reason to use them so long as the modeller has an understanding of how they reflect reality.

How do we know that dynamic assignment in microsimulation models works? The same question could be levelled at other assignment techniques, but the increasing confidence in microsimulation models derives from their underlying methodology based on principles that we as transport users and car drivers can relate to. The developers of microsimulation software have had the good fortune to work in a technological context where real life experience and common sense can be directly programmed into software. Readily available computer power and modern software development environments have enabled us to simultaneously represent thousands of drivers and vehicles *individually* with behavioural influences which reflect the real world. Microsimulation assembles them into a bigger picture which is both robust and recognisable.

REFERENCES

- [1] Wardrop, J. G., 1952. Some theoretical aspects of road traffic research, Proceedings, Institute of Civil Engineers, PART II, Vol.1, pp. 325-378.