The benefits of microsimulation for large area models

Author :

Pete Sykes, Iain Clement, SIAS Limited
Nick Cohn, Niels van den Brink, Grontmij

ABSTRACT

There is a perceived wisdom amongst traffic modellers that a principal criterion for choice of modelling tool is the size of the road network, and that microsimulation is only suitable for small geographical areas. We challenge this notion, and demonstrate the benefits of using microsimulation for large models. By deploying microsimulation over a wide area, study boundaries can be defined with the aid of the model itself, and the problem of identifying the sometimes arbitrary limits to the modelled road network are diminished.

Introduction

Microsimulation is a well known technique for road traffic simulation in which the actions of every individual vehicle are evaluated at sub second intervals. Their interactions with the road network, the control systems and with the other vehicles on the network are determined and hence their journeys through the road network are reproduced. Thereafter when changes in the simulated road network or the control system are made, their effect can be determined and a benefit analysis undertaken.

To many transport professionals, the prefix “micro” in microsimulation is assumed to apply to the size of area that can be modelled not to the detail of the interactions. This overloading of the term leads them to assume that microsimulation can only be applied to small areas and some other technique must be used to model larger areas. While it is true that initially microsimulation was used for single junctions and the optimisation of traffic signals at a local level, in recent years, the combination of faster computers and new software developments has made it possible to apply microsimulation at a regional level. These regional microsimulation models are now being applied to answer questions that until recently were studied using static or semi-dynamic models. While microsimulation models do not yet typically contain the components of trip generation, distribution or mode choice, they provide added value at the regional level for testing traffic management strategies and detailed dynamic measures.

As our road network becomes more and more complex, the added value of standalone traffic management measures is no longer sufficient. Intelligent and dynamic measures applied at the network level are more often required for strategic traffic management. Microsimulation is now an important tool for testing combinations of, for example, ramp metering, dynamic route information and intelligent signalised junctions (such as SCOOT or Utopia Spot). However drivers are fundamentally selfish beings who act to maximise their benefit from changes in the road scheme. They learn of the effect of changes and change their behaviour accordingly. Hence implementing a junction improvement or an ITS system may reduce congestion in that area and drivers who previously had avoided that junction will now use it if it improves their journey time. The knock on effects can be wide ranging and the overall benefits may not be clear if only the area to be changed is modelled in detail.

Here we discuss the capabilities and the benefits of using microsimulation for the entire task rather than adopting a hybrid approach. We do this based on two specific case studies: the model of the Alkmaar region in the Netherlands and a study undertaken for the Scottish Executive on the provision of overtaking sections on single carriageway roads. The two case studies demonstrate technical as well as organisational elements of applying regional microsimulation models. The paper covers the most important steps in model development, validation and application, such as the data requirements, calibration methods, validation, application for traffic management strategies and a comparison with static regional models.

Alkmaar Region ***Using the simulation model as a planning tool***

In the Netherlands, the responsibility for planning and performing road maintenance as well as new road infrastructure is divided among national, provincial and municipal organisations. This division is based upon road classification. Each organisation creates its own roadworks program and because roadworks inevitably influence traffic conditions, an effort is made to coordinate the different programs within a given region.

In addition to roadworks, planning for and taking account of major events requires planning at a regional level to ensure accessibility and anticipate traffic problems. Ideally, this planning is done at the level of decision makers, practitioners and the public in order to optimise regional accessibility by way of joint planning, joint decision making and joint communication.

In the Alkmaar, North Holland region, the different organisations concluded that an automated tool would be useful for centrally coordinating the large number of projects and events. By visualising cumulative effects of projects and events, the authorities could gain insight into the interaction effects of different combinations of projects and could consequently make informed decisions. The decision was made to use a microsimulation model because of the capabilities for simulating temporary road conditions in a realistic manner, such as lane closures, detours and temporary situations at junctions. The ability to record vehicle-specific travel times was useful for establishing police and fire service travel times during construction and maintenance periods.

Model area

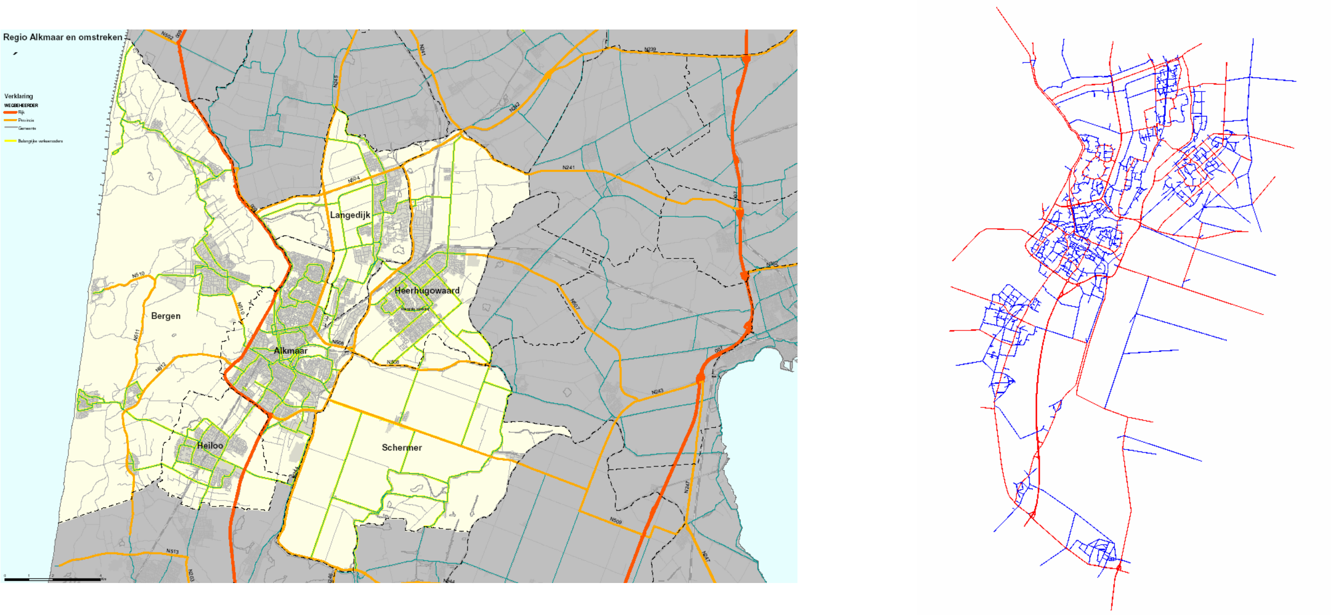

Figure 1

Figure 1 shows the area to be modelled and the corresponding S-Paramics road network. Figure 2 shows one example of a junction in the model

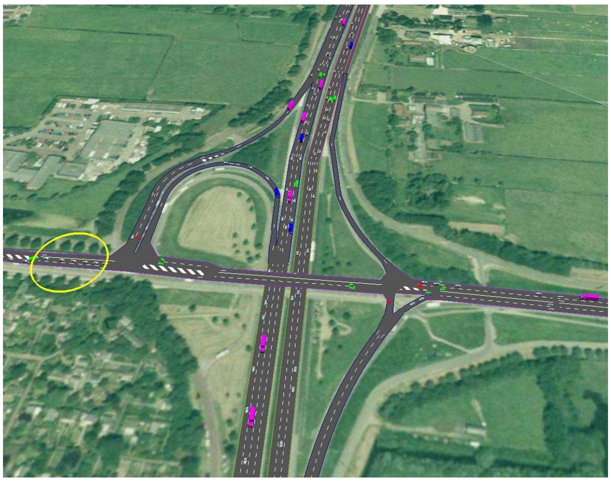

Figure 2

The simulation model was developed based on the conversion of an existing static model of Alkmaar. This meant that the core area of the model could be created efficiently and that network characteristics and matrices did not have to be recreated for a large portion of the model. Detailed traffic signals and road geometry were added to complete the model and all the traffic signals in the model were included as vehicle-activated signals. This was essential for a realistic simulation but also ensures that the available capacity of the road system is being used optimally.

With S-Paramics it is possible to include different simulation periods within a single model. In this case, the morning and evening peak periods, the evening period, the interpeak period and a weekend period were modelled. This was important because the interpeak, evening and weekend periods contain extra available capacity that can be used for road works. The model results provide insight into the options for the time of day or day of week for carrying out specific works.

The model has added value for the development of an 'optimal' road works and phasing plan. The visualisation of the traffic situation for alternative plans is of particular importance to the involved organisations for establishing agreed priorities and making joint choices. The quantitative reporting is then required for testing and demonstrating that the choices result in the best possible accessibility in the region.

The model was validated for the current situation (2005), prior to the beginning of various major road works in the region. This was completed using available traffic counts and the Paramics matrix estimation facility. During this process, it was essential that the organisations involved were satisfied with the picture of regional and local traffic situations in the modelled periods and agreed that it was a realistic representation of the actual road system. Without trust in the model, the joint works planning process would have been much more difficult to achieve.

The simulation model provides detailed insight into the effects of road works and events. The forecast effects and the duration of road works are retained in a database. This data includes the rerouteing observed in the model, the initial mitigation measures planned for the event and any extra measures found to be required during testing. The database is a 'living' planning instrument and is continually updated and expanded.

Alkmaar Region *N242 Provincial Highway*

The largest road works project in the Alkmaar region is the reconstruction of the provincial highway N242. With this specific project in mind, a regional accessibility index was developed to aid in establishing the best works phasing and planning. This index was expanded for use with all projects in the region. It consists of the following elements:

- Travel times for emergency services
- Public transport delays, based on specific, trips and acceptable travel times
- The accessibility of office and industrial parks and the centres of regional towns
- Traffic conditions, determined by travel times on the Alkmaar ring and other major roads

The planning of the mitigation measures for all works and events is done in detail. It can include lowered speed limits, narrow or restricted lanes, turning restrictions and alternate route guidance. All of these measures may be implemented by hour and each temporary situation can have a significant effect on traffic conditions and on journey times.

All the relevant organisations were requested to submit their plans for road works and events and based on this information the accessibility index was evaluated. An inventory of 100 projects between 2005 and 2008 was collated and the planning group was requested to determine, using the simulation model, which works could be carried out concurrently. Optimal timings were found either by adjusting the hourly mitigation measures or by rescheduling the work to avoid combinations of events that caused excessive degradation to the accessibility index.

The use of the Paramics microsimulation model in the N242 works planning process showed that the iterative testing and visualisation of alternative planning and phasing works well in developing consensus among authorities and with the public. The accessibility index, which can be tailored to local requirements, makes it possible to evaluate design-and-construct proposals in an impartial way that is directly related to the quality and goals of a works project.

The regional scale model was necessary in order to include possible interaction effects between different road works and/or different mitigation measures. The detail in planning with the options of using ITS systems for dynamic speed control, lane restrictions and route guidance made the use of a microsimulation model essential and this had to be achieved on a regional scale to allow the effects of each change to properly propagate to their natural extent.

Scotland*: Using the simulation for economic assessment of overtaking sections*

On a single carriageway, a number of vehicles may be slowed by a single slow lead vehicle, typically an HGV or an agricultural vehicle. Consequently, vehicles will form a platoon behind the lead vehicle for as long as they are unable to pass it. If an improvement scheme includes carriageway widening to facilitate dedicated or opportunistic overtaking, then the benefit of the scheme will largely be felt by the vehicles that can now pass the lead vehicle, known as platoon dispersion. It is important to note that the benefit is not felt just over the length of the scheme but for some distance downstream. Microsimulation can capture this detailed effect and PEARS (Programme for Economic Assessment of Road Schemes) can translate it into a monetary value to be included in the overall cost benefit analysis.

S-Paramics includes an overtaking model in which a vehicle will first assess its desire to overtake based on its target link speed and the achieved speed of the vehicle ahead. It will then assess its ability to overtake based on the gap available ahead of the vehicle to be overtaken and also the visibility of the road ahead and presence of an oncoming vehicle in that space. The manoeuvre will be initiated when both desire and gaps are present.

A recent commission for the Scottish Executive, on behalf of all UK government transportation departments, was designed to assist with the preparation of a new technical advice note for wide single 2+1 overtaking lanes looked at a number of parameters, including::

- economic scheme length
- extent of downstream benefit
- platoon lengths

In all cases, the benefits were compared to a reference base of either standard S2 (7.3m) or Wide Single WS2 (10.0m) carriageway. Wide Single WS2+1 carriageways comprise the development of a third traffic lane to provide dedicated overtaking. Traffic in the opposing direction is prohibited from overtaking.

Further benefits can be accrued through provision of alternating overtaking lanes arranged in either conflicting or non-conflicting configurations. In conflicting, or critical, configurations, the direction of alternate overtaking is towards the mid point of the scheme (nose to nose). In non-conflicting, or non-critical, configurations, the direction of alternate overtaking is towards the ends of the scheme (tail to tail). The differences to the driver lie in the changes in platooning levels, and hence gaps, in the oncoming traffic as the overtaking manoeuvre is to be attempted

A simulation model was developed to replicate a 15km section of single carriageway. The model was coded to include three sections; an approach length, a central study section followed by a run-out section. The approach, or lead-in, was around 4.5km in length in which overtaking was alternately allowed and barred, this ensured that realistic platoons had formed at the start of the study section. The study section varied in length according to the each test. The run-out, or downstream section, of 10km allowed a measure of downstream benefits.

The model was calibrated by adjusting the overtaking parameter so that the vehicle order change in the model matched that from a set of number plate matching surveys. In all models, the HGV proportion was fixed at 10% and both conflicting and non-conflicting overtaking lane arrangements were evaluated.

With the calibrated models developed, various test scenarios were replicated. For each scenario, an equivalent Do-Minimum scenario was also developed, against which the scheme was assessed. Both were modelled for opening year and design years, although it should be noted that PEARS can deal with multiple assessment years. Each Do-Minimum and Do-Something scenario was simulated 10 times using a random seed value to ensure a distribution of results. The assessment was then repeated for three or four different flow ranges.

The first assessment looked at economic justification for various scheme lengths. The test model assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. In all models, the HGV proportion was fixed at 10% with the flow range varied between 5,000 and 15,000AADT.

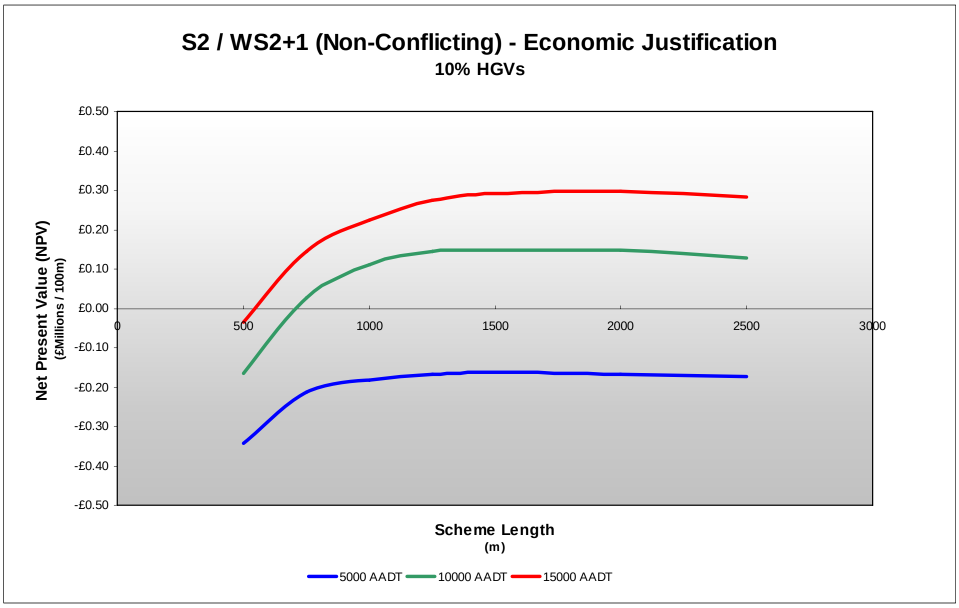

Figure 3 : S2 to WS2 Economic analysis

The results of the S2 to WS2+1 assessment are summarised in Figure 3.

The results of the assessments indicated that:

- S2 to WS2+1 would be difficult to justify economically in low flow situations (<5,000AADT)
- WS2 to WS2+1 would be easier to justify economically because of its lower scheme cost
- the optimum overtaking section length lies between 750m and 1,250m (1,000m)
- beyond 1,250m, there is little return for additional cost

The second of the assessments looked at the impact of downstream benefits on vehicle speeds. The test models again assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. Again, in all models, the HGV proportion was fixed at 10%.

The results of the S2 to WS2+1 assessment are summarised in Figure 4.

The result of the assessment indicated that:

- at 10,000 AADT, the benefit in increased vehicle speed is accrued for around +5km downstream
- at 5,000 AADT, lower initial differential between base and design speeds indicate that overtaking demand is satisfied earlier
- at 15,000 AADT, benefit is again of short duration as overtaking vehicles soon catch up on next platoon

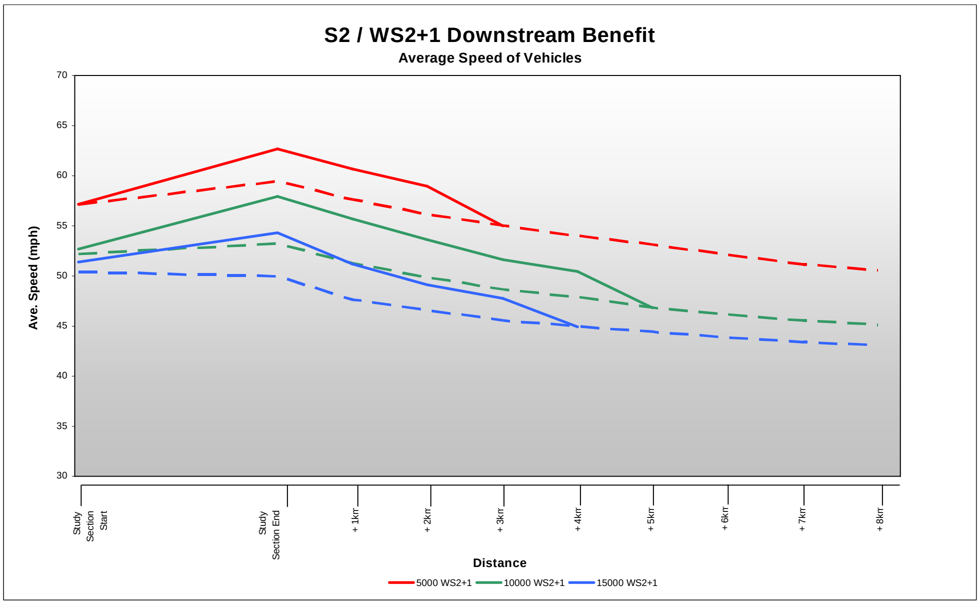

Figure 4 : S2 to WS2 Downstream Benefit

Note: All tests assume no overtaking occurs downstream and that benefits will be of longer duration if overtaking opportunities exist downstream. Combined with some of the other parameters being tested, the analysis suggests that 2+1 overtaking lanes should be located every 5 to 8km to allow optimum economic performance.

The last of the assessments looked at the impact of platoon dispersion. Again, these key traffic characteristics can only be captured using microsimulation techniques. The test models again assumed that the road would be upgraded from either a standard 7.3m S2 single carriageway or 10.0m WS2 wide single carriageway to 12.5m WS2+1 carriageway. Again, in all models the HGV proportion was fixed at 10%. The results of the S2 to WS2+1 assessment are summarised below in Figure 5.

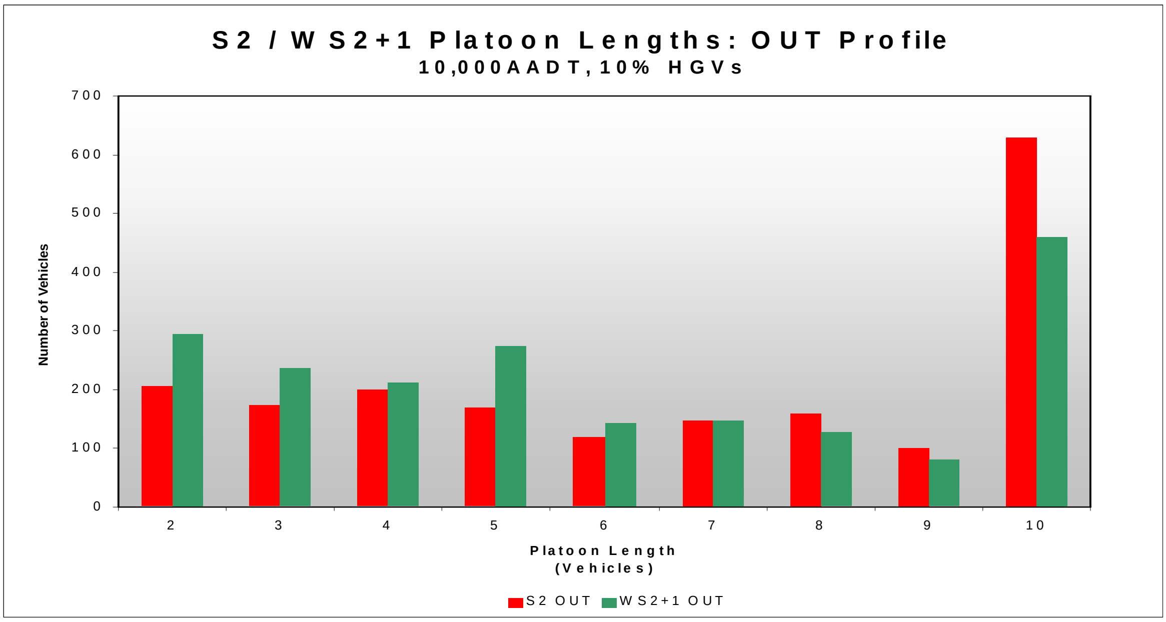

Figure 5 : S2 to WS2 Platoon Lengths

The analysis of the platoon profile exiting the study section clearly indicted a reduction in the number of longer platoons in favour of more shorter platoons of around 4 or 5 vehicles. The assessment concluded:

- number of vehicles in platoons >5 reduces from 60% to 48% of the total number of vehicles
- number of vehicles in platoons >10 reduces from 33% to 23% of the total number of vehicles

By evaluating the economic benefits in detail using a microsimulation model it is possible to capture very small changes in travel time and vehicle operating costs which would otherwise be lost. A cost benefit package such as PEARS then enables these savings to be translated in to monetary benefits and the overall cost benefit analysis of a proposed road improvement scheme made more accurately. However the main benefit is felt not in the area where the work is undertaken, it is felt for many kilometres downstream. Simply modelling the immediate area where the work is to be done will not capture the true effects of the work and modelling the wider area with macro level assignment techniques will not capture the detailed – but significant effect of the formation and dispersion of platoons of vehicles.

Conclusion

Both of these examples show the benefits of using microsimulation in the wider area in one homogenous model with sufficient detail to undertake the necessary analysis. Simple assignment methodologies cannot capture detailed effects and the benefits of a road improvement scheme are frequently due to the accumulation of just these effects. By drawing a line around where we use microsimulation and where we use assignment methods we are in effect stating that we know the limits of the effects of the changes which presumes the output of the modelling process. As shown in overtaking study – this is not necessarily true.