

# Building and reporting on microsimulation models

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## ***Introduction***

Microsimulation is now an accepted tool for assessing the benefits of road traffic improvements. Microsimulation models work by evaluating the actions of every individual vehicle in a road network at sub second time intervals. As each vehicle attempts to find the best route to its destination it interacts with the other vehicles in the model. Its progress is controlled by traffic systems such as signals, variable message signs or broadcast messages and it is guided by the geometry of the road layout and any constraints imposed upon it.

As microsimulation directly models the roads and vehicles, any effect such as blocking back across junctions will automatically be included in the assessment of the scheme without the need to apply derived heuristics. Microsimulation models treat an area as an integrated whole rather than as a set of individual junctions operating independently and linked only by pre-supposed effects.

It is worth noting that microsimulation should be seen as distinct from animation. Although in some cases the movie visualising the movement of the road traffic may appear superficially the same, the key difference will be in the style of the data used to generate these images. A microsimulation system will require a detailed description of the road network, its links, junctions, road markings and signals. The knowledge encapsulated in each vehicle will be restricted to its physical capabilities, its desire to reach a destination and what it can derive from observing other vehicles in the system. A pure animation system will separate these two classes of data and treat them independently – the road system will be simply a backdrop and the vehicles will simply follow pre-defined paths independently of the backdrop and of each other. Hybrid systems may use some road information and make vehicles aware of each other but then pre-define other information such as route choice or lane use.

It is in the assessment of changes where the difference between hybrid systems and true microsimulation systems is seen. If for example lane use is prescribed then sub-optimal choices may be made after changes are made to the road layout. The modeller must remedy this by dictating a new lane choice. In a microsimulation system each individual vehicle will make the best decision at the appropriate time and lane use will be automatically optimised based on the driver's desire to get through the road network with as little delay as possible. Similarly if a change in a junction leads to a change in congestion then drivers will learn of this and react by changing route. This effect is automatic in true microsimulation but will be lacking in a hybrid or animated system.

This paper discusses the process of building and using a small microsimulation model. It will cover the data requirements and the process of building the model. A report on the effects of the proposed changes to a road system and an investigation into which changes produce the optimum results are the ultimate end products of the modelling exercise. We will show how this is done using S-Paramics microsimulation.

This paper is derived from the S-Paramics Consultancy Good Practice guide which will be formally launched at the S-Paramics User Group meeting in October 2005.

## **Data requirements**

Data requirements for microsimulation models fall into four categories:

- geographic – a map of the area
- physical – the physical characteristics of the road system
- demand – the data relating to the movement of vehicles in the network
- presentation – any extra objects that may be included to enhance presentation

### **Geographic**

A digital map of the area is essential. This may either be a drawing of the area in DXF or 3DS format or a map in a picture format such as an aerial photo or an extract from a digital map image.

The difference is in the accuracy of the layout available from the map. Typically a drawn format is very accurate and will show the layout of the road, its kerbs and the detail of the road markings. It is usually derived from the engineering or planning drawings held by a Local Authority. A picture based format may be easier to obtain and contain more “extra” data such as buildings, trees etc. However they are often limited in accuracy due to their inherent pixelation. Aerial photographs are often better dealt with under “presentation”.

Fig 1 shows a DXF drawing and a basic digital map image of the same area.



Figure 1 Drawing and map of the same junction

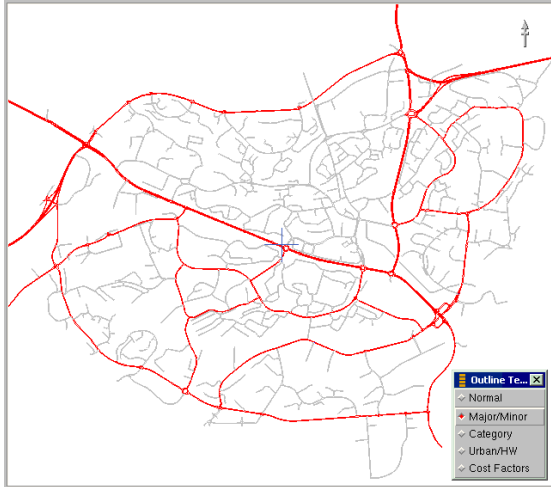
### **Physical**

The physical data enables the microsimulation model to accurately represent the road system, i.e.:

- speed limits
- road markings, turn arrows, lane restrictions or closures
- traffic signal operations (cycle times, stages, offsets, pedestrian provisions etc.)
- any on-street features that affects traffic flow (e.g. on street parking)
- public transport schedules and bus stop locations

Much of this will be collected from on site surveys.

Larger area models require a hierarchic structure in the road network. This means that roads are classified into major and minor links according to their perceived status in forming routes through the model. In effect this differentiates the arterial routes from the rat runs. Drivers who



are categorised as “unfamiliar “ will bias their route choice towards the arterial routes. Fig 2 shows a typical road hierarchy in a model of a medium sized town. Very large models will also make use of “waypoints” to break long journeys into a set of smaller linked journeys. Drivers make micro-routing decisions appropriate to the sub task of getting to the next waypoints. They make macro-routing decisions to determine the choice of waypoints to reach their destination.

In small area models where route choice is simple, no hierarchy is required.

Figure 2 Road Hierarchy

## **Vehicles**

The vehicle based data is gathered for two reasons:

- 1) To determine the travel demand in the network and use this to build either a matrix of origin – destination trip counts or to define the number of vehicles following pre-determined paths.
- 2) To measure the behaviour of vehicles in the network and allow the model to be compared with these measurements to verify that it accurately represents reality.

### *Vehicle Demand*

The most fundamental data to be collected is a Manual Classified Count (MCC), which involves counting the number of vehicles that perform each movement at each junction during a particular interval and classifying these by vehicle type. This data will be used to build the demand matrix, a profile to that demand and disaggregate demand by vehicle type. For example, if one arm of a junction was required to carry larger numbers of HGVs than the other arms or if traffic demand was unequal over the modelled period with distinct peaks and troughs, then the MCC should be surveyed at sufficient detail to enable this behaviour to be included in the model.

In small area models, determining at which junctions to make the survey will be obvious from the model area. In larger area models it is not economically possible to survey every junction and the demand in the model must be inferred from land use data, census data, roadside interviews and any pre-existing data that may be obtained. This may then be refined in a matrix estimation process.

### *Vehicle Behaviour*

The purpose of collecting this data is to validate the performance of the model against what can be measured on the road network. Typically the data consists of:

- queue lengths: measured as either the length of the queue or the number of vehicles. The thresholds of behaviour that define a queue – i.e. the speed of the vehicles and their distance apart should be well defined as this aspect of data collection can be quite subjective.
- journey times: the time taken to traverse a defined path. This is measured by driving the route and timing the journey.

When we come to compare the model with the actual data measured on the road we will see how it is possible to quickly determine if the simulation model is performing the same way as the real road system by comparison with the survey data.

### **Presentation**

Finally, to assist in presentation of the simulation model to clients, it often helps to put the model in a geographical context. This can be done by including the original overlay as used to create the model, by including aerial photographs or by including a 3D landscape. Fig 3 shows an example of the same junction with:

- basic – no enhancement
- an aerial photograph and vehicle shapes
- 3D objects



Figure 3 Presentation options

It is quite simple to include 2D images such as aerial photographs or to add streetscapes by standing a picture of a building on its edge by the side of the road. 3D models may also be included as annotation to the simulation model. The modeller must determine what quality of presentation is required and gather the appropriate images or 3D models.

### **Model Building**

Model building is a two part process; constructing the physical network and adding the traffic demand.

The network construction phase consists of:

- constructing basic nodes and links
- configuring the road layout
- configuring the junctions

#### **Node and Links**

Nodes and links are the basic building blocks of the model. Nodes represent areas where there is a change in the characteristic of the carriageway, for example where there are junctions, lane gains or lane drops, pedestrian crossings, at the start and end of a curve, etc. Links connect the nodes to provide the carriageway for vehicles to travel on.

Essentially the nodes and links are placed using the digital map to position them. Links are categorised by their speed limit, number of lanes, major/minor designation etc.

#### **Road Layout**

Once the basic network of nodes and links has been added the road layout can be fine tuned. This involves ensuring that the carriageway in the model accurately reflects the carriageway on the ground. Then we use the link behaviour flags, modifiers and lane restrictions to get the correct lane usage and vehicle behaviour in specific areas as required.

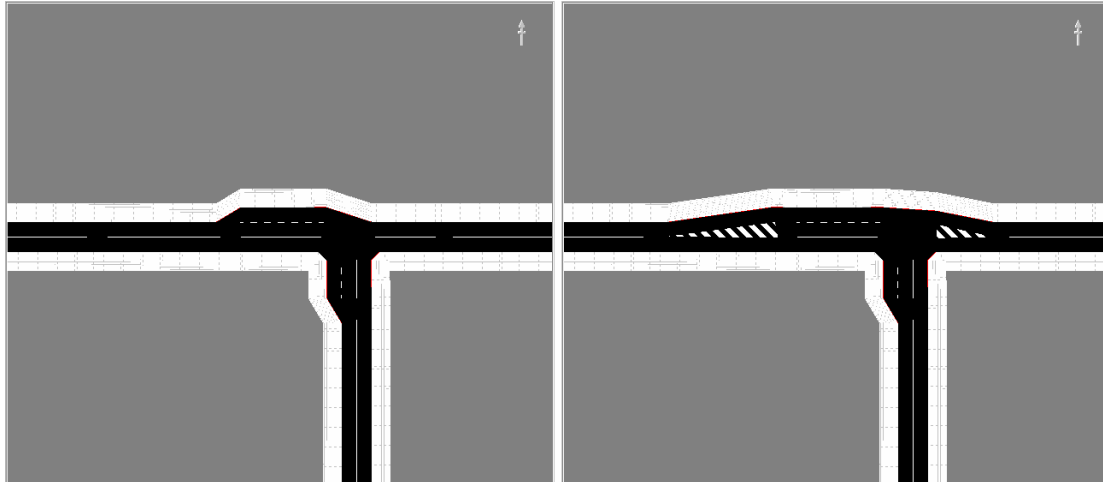


Figure 4 Refining a road layout

Figure 4 above demonstrates the process of refining a road layout. The junction on the left shows the basic coding. Note that there is a 2-lane section on the main carriageway showing lane gains and drops. This will operate like a bus lay-by in close proximity to a junction, and all west to east traffic will avoid using the built-out area.

The junction on the right shows the same basic road layout refined using 'wide start' and 'wide end' flags to alter the lane gain and drop and it can be seen that the 2-lane section is in fact a right-turning facility with a ghost island. With this road layout the west to east traffic will stick to the nearside lane and the additional lane will be used to queue right-turning vehicles.

This is just one example of the importance of accurately coding the road layout. There are many other flags, modifiers and lane restrictions that can be applied. The performance of the model will be greatly affected by ensuring that the road layout is accurately represented in the model.

### ***Junction Configuration***

Junctions will take one of three forms:

- priority intersection
- signal junction
- roundabout

At a priority intersection, the Junction Editor is initially used to check and refine the lane choice for each movement across the junction. Once the lane ranges are set the junction can either be signalised or left as a priority intersection. In the latter case only the priorities need to be set for the junction to be properly configured.

If the junction is signalised the phases and stages must be configured once the lane ranges are set.

Figure 5 shows the phase labels applied to a 4-arm signalised junction. The intergreen matrix is formed as the labels are applied to the various movements and this matrix can be filled in with appropriate intergreen times if required.

Once the phases are defined the stages are added. The various phases are assigned to stages and each phase can have late cut off and early starts within the stage. Fig 6 shows the S-Paramics stage configuration interface.

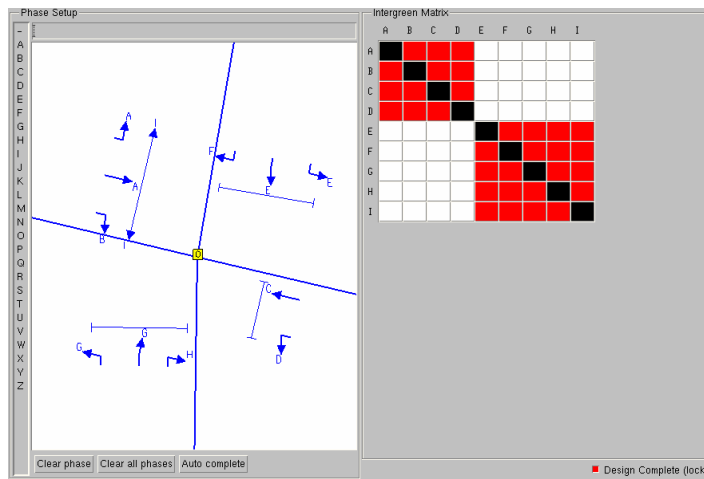


Figure 5 Phase intergreen matrix

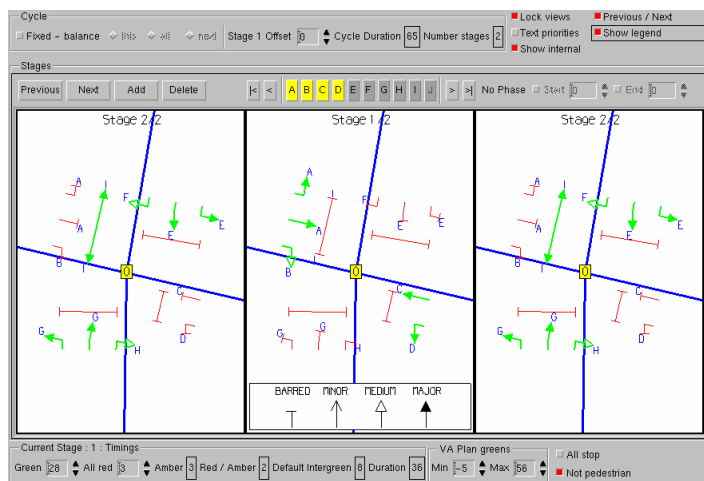


Figure 6 The stage configuration panel.

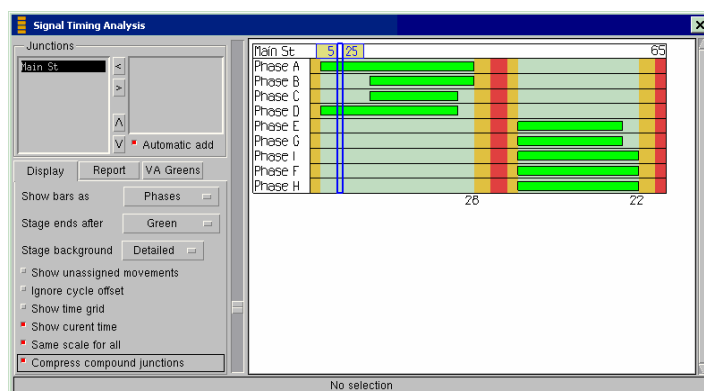


Figure 7 Signal timing analysis

Once the signals are configured the Signal Timing Analysis tool can be used to observe the signals in operation as the model runs. The tool allows any number of signalised junctions, regardless of cycle time etc., to be viewed simultaneously. Figure 7 shows the phases for a single signal junction as displayed in the Signal Timing Analysis tool. The display can be configured in a variety of different ways, can produce graphics for reports and movies, and can also display the effect of vehicle actuation if this is in operation at the junction.

Traffic signal junctions can also be modelled using flow control. Currently Paramics can link directly to SCOOT controllers and can simulate SCATS, CCOL and ALINEA. A MOVA simulator is in production in collaboration with the TRL.

### **Traffic Demand**

Once the road layout and junction configuration is accurately coded the traffic demand can be added. There are two methods of adding demand, fixed path routing and using OD matrices.

Fixed path routing allows a path through the network to be defined and traffic demand assigned to the path. Multiple matrix levels can be used, and release profiles can be applied to each path. Vehicles that are assigned to a fixed path cannot deviate from that route, regardless of perturbation and dynamic feedback.

OD matrices use a system of zones to add traffic demand to the network. Vehicles are assigned to each OD pair using a trip matrix. Multiple matrix levels can be used and release profiles can be assigned to each cell of the matrix if required. Vehicles determine their route from origin to destination using a generalised cost equation and will select the lowest cost route. Perturbation and dynamic feedback can be used to vary the chosen route.

Any number of matrix levels can be used to refine the traffic demand in the model. A common use of this would be to have heavy vehicles in a separate trip matrix from light vehicles to reflect the different travel patterns of each vehicle type. The different matrix levels can also be used, for example, to allow a development trips matrix to be added separately from the base trips matrix which enable the modeller to easily identify the new vehicles in the road network.

Release profiles are used to control the release of vehicles onto the network, and operate the same way for OD matrices and fixed paths. Traffic in a modelled area is rarely released in a uniform manner throughout the modelled period, and so release profiles are required to ensure that the observed build-up in the traffic peaks is replicated in the model.

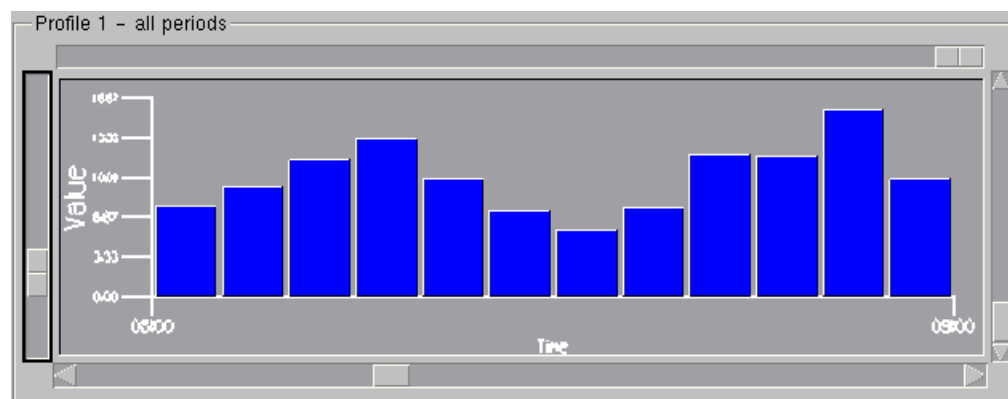


Figure 8 Release profiles

Figure 8 shows a release profile being added using the Demand Editor. Each bar represents the percentage of the traffic demand that should be released during each 5-minute interval.

Up to 64 release profiles can be added to the model, and these can be applied to an entire matrix, a matrix row, column or individual cell. They are very flexible and quick to apply.

### **Public Transport**

Scheduled public transport services can have a major impact on the study area. If there are a significant number of bus services operating within the model these will undoubtedly have an effect on the performance and capacity of the links and junctions they pass through. As such they form an important element of the traffic demand.

Scheduled services are not added as part of the OD matrix. These are added using the Busroute Editor. This allows the path that the buses, or other scheduled services such as trams, must travel along to be defined, and enables the user to add a timetable for those services to follow. The vehicles are released into the model at the prescribed time and make their way along the predefined path.

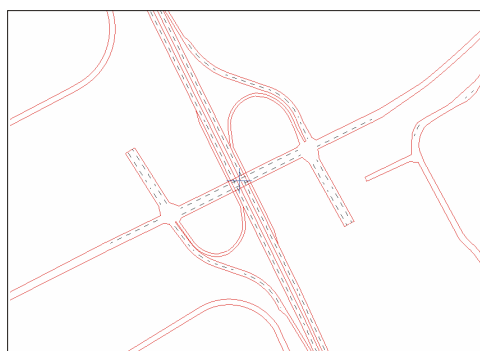
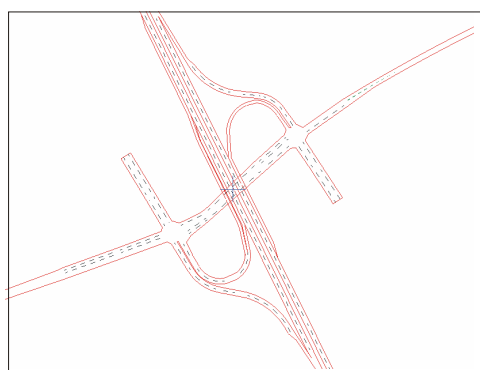
As the vehicles travel they will encounter bus stops placed throughout the model. The user can either code a simple dwell time for the services at the bus stops, or can use the more complex Passenger Loading Model to determine the dwell time based on passenger demand.

As the buses dwell at bus stops, and pull out into traffic lanes, the other vehicles in the model are delayed as they are in reality.

## ***Model Variants***

Once the basic model has been built we come to the principal task of the microsimulation modeller which is to evaluate different options and determine which is best in terms of travel benefits and cost effectiveness. Starting from a base model, changes are applied to it to include the different design scenarios and running the simulation enables the modeller to determine how each option performs. Tests may include changing the vehicle demand for a future year, modifying junction designs or making major changes to road layout. One example of a set of tests is shown here.

Scheme 1



Scheme 2

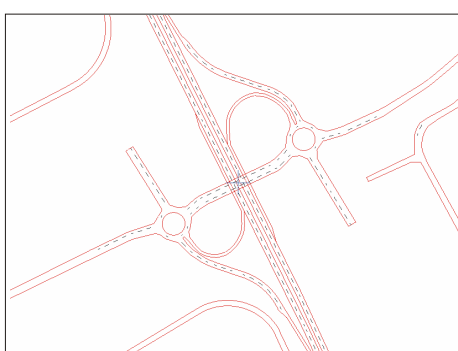
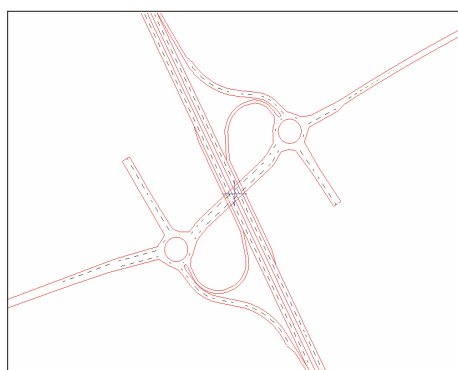


Figure 9 Sample model variants

This project was based about an arterial road through a Scottish town. The primary objective of the proposal was to improve public transport accessibility, journey times and reliability. The selected scheme also had to satisfy the following criteria:

- impact on general traffic flows
- pedestrian crossing facilities
- reserve capacity of new junctions

- flexible design
- incorporate development access

A selection of the S-Paramics models used to evaluate the design options for one junction is shown in Figure 9. In total four different major options were evaluated and each had a variant with a different layout. In this commission three different demand scenarios were used to evaluate the performance of each of the road layouts in future years.

## Reporting

Paramics can output a large variety of different statistics. The modeller defines which data is required and for many data types, such as turn counts, queue lengths etc., can set the interval at which the data should be gathered. There is a batch mode in S-Paramics to allow it to generate this output rapidly.

The data can be analysed using the S-Paramics Data Analysis Tool. As well as providing a direct interface to all the various data types, DAT can aggregate the results from any number of model runs and perform statistical analysis functions on the datasets, for example: averaging the data, determining the standard deviation, calculating confidence limits etc. DAT makes it easy to perform multiple runs of a scenario using different random seeds to obtain a statistically robust analysis.

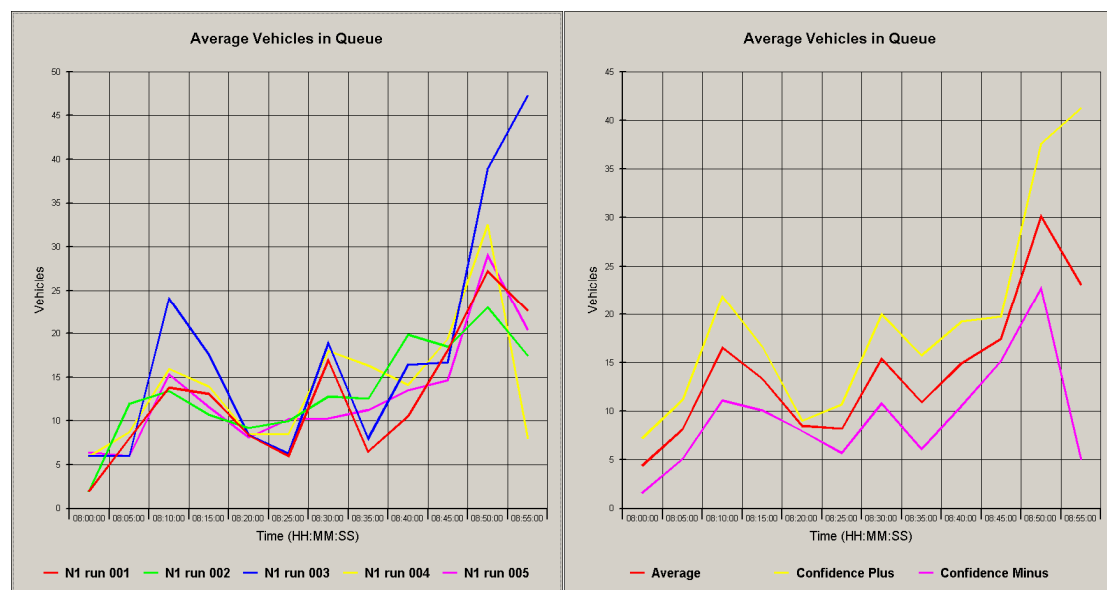


Figure 10 Queue data

Figure 10 above shows the accumulation of queued vehicles within a cordon. Each line on the chart on the left represents a different run of the simulation achieved using different random seeds to represent daily variation within the model. The individual runs can then quickly be compared and aggregated in a number of ways. The chart on the right shows the same data, but aggregated to produce an average of the 5 runs and with 95% confidence limits plotted.

Different model variations can also be plotted against each other. This allows the modeller to compare different schemes, and because the analysis is undertaken using a number of different runs of each scenario the modeller can have confidence that the comparison is an accurate one.

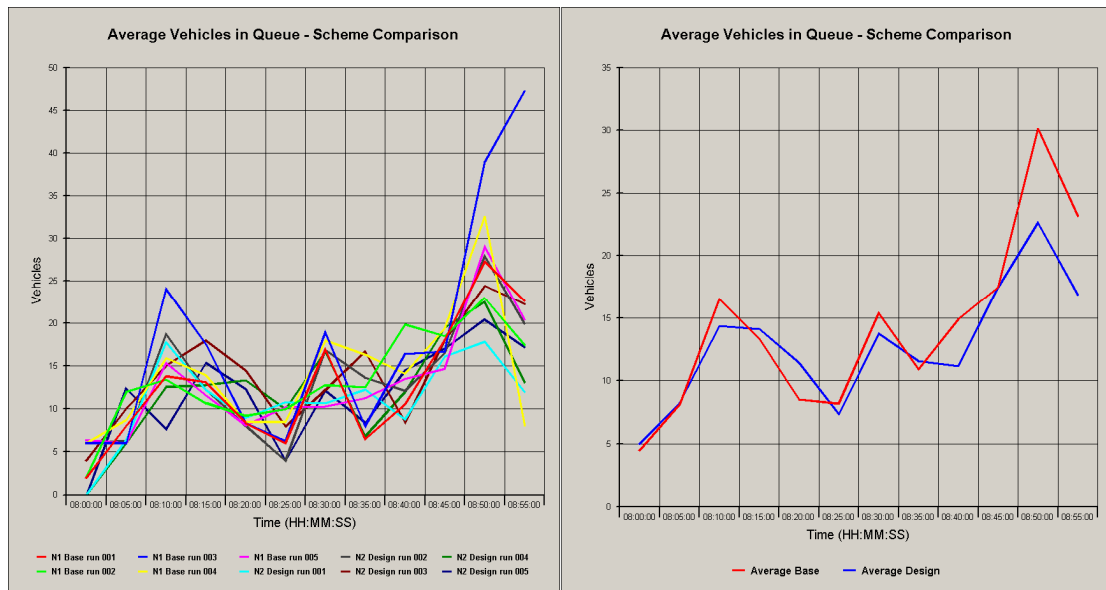


Figure 11 Aggregating runs

The chart on the left in Figure 11 shows ten individual model runs; five from the Base model and five from the Design. The chart on the right shows the average of the two datasets plotted simultaneously and allows the modeller to interpret the impact of the scheme. In this case the Design scheme does not adversely affect queues in the study area (this is taken from a single junction model) despite the fact that there is an increase in traffic demand resulting from a proposed development. In fact there is a slight reduction overall due to amelioration measures proposed in the design. A good result!

Wide area impacts can also be quickly determined using DAT. In larger models with route choice, localised congestion resulting from the implementation of a scheme in one part of a town can have an effect across the entire modelled area.

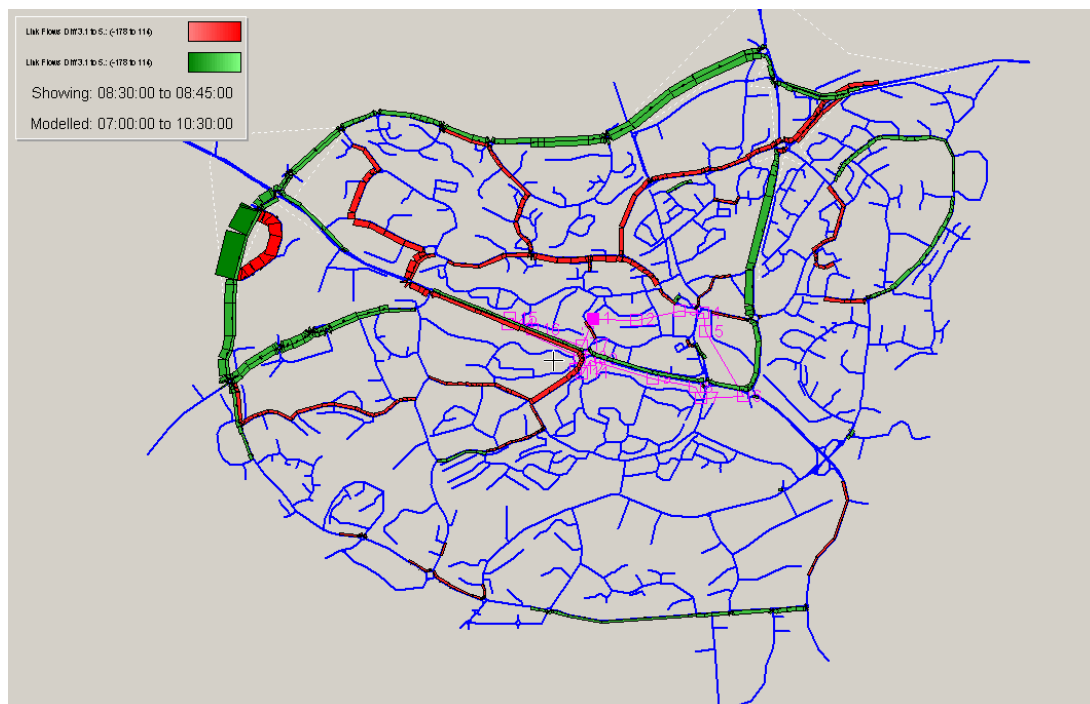


Figure 12 DAT routing analysis

In Figure 12, DAT has been used to determine the re-routeing effects created by upgrading the main orbital route to discourage through-trips in town. DAT has been configured to show traffic increases as green bars, and decreases in flow as red bars. The width of the bar shows the scale of the change. The amount of traffic in the model is constant as there is no proposed development. The figure allows the modeller to interpret the impact of the carriageway upgrade on the entire town; in this case one can conclude that trips through the centre of town have been displaced to the main orbital. Another good result!

The output from DAT can be presented in many ways; the charts can be fully customised from the fonts used to the scale of the X and Y axes, bar plots such as the one above can be animated and the animation saved to a movie file, the tables of data used to produce the charts and plots can be exported to third-party software such as spreadsheets and word processors.

## ***Conclusions***

Microsimulation is now an accepted tool for assessing the benefits of road traffic improvements. Its data requirements are not onerous and as the model building process is visually intensive it is hard to make serious errors as if it looks right, it probably is. The output is in the form of a movie file which can be feature rich with 3D representation or it can be functional and sparse according to the needs of the intended audience. Its strength is in data reporting where it can be used to quickly compare a base model and set of variants with a simple analysis or it can be used to investigate the detailed effects of changes with sophisticated graphical presentation of results.