SCATSIM/VISSIM INTERFACE AS A PLATFORM FOR PERFORMANCE EVALUATION OF SIGNALISED INTERSECTIONS

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ABSTRACT

The purpose of the paper is to increase awareness of ATC systems, aid traffic engineers in making better assumptions about intersection principal parameters and enhance the Level of Service interpretation. The performance of signalised intersections is often being assessed by traffic engineers using a number of different tools available ranging from the deterministic, mesoscopic to microsimulation models. The conventional performance assessment often ignores or does not take sufficiently into account the effect an Area Traffic Control (ATC) system like SCATS has on operation of signalised intersections. With the latest advent of interfacing microsimulation with SCATS it is now possible to do a simultaneous measurement on a cycle by cycle basis of delay, queue length, number of stops, volume and cycle time length at all signalised intersections in the model. By Interpreting graphs produced from high resolution parameter measurement the paper clarifies the relationship between signalised sites and quantifies the effect linked intersections have on one another in both off-peak and congested conditions. Examples of this relationship range from imposing the higher then optimal cycle time at non-critical intersections to queue spill-overs onto upstream sites. The paper also gives examples on how this method can successfully be used for evaluation of unconventional phasing schemes like Rest-on-Red. Case studies presented here demonstrate that this method can successfully capture the effects of an ATC system on intersection performance in all its complexity and detail. After doing half a dozen traffic studies using SCATSIM/VISSIM interface the findings are shared in this paper.

INTRODUCTION

Methods for evaluation of signalised intersection performance have evolved over the last 60 to 70 years and were influenced by the application of the queuing theory which led to the development of a number of software packages around the world. In Australia and New Zealand the performance of signalised intersections is predominantly estimated using microscopic SIDRA INTERSECTION software. Also, numerous studies used other software packages which can evaluate multiple intersections and in some cases even optimise the cycle times, offsets and phasing designs (e.g. SATURN, TRANSYT, LINSIG etc.)

In parallel to the development of the above methods and theories the Area Traffic Control (ATC) systems have been developing since 1970s capable of adaptively adjusting the cycle time, offset and phase duration to suit prevailing traffic conditions. Although the discipline of adaptive engineering utilised many aspects of traditional queuing and traffic theory, it introduced a number of theories, rules and constraints which influence capacity of signalised intersections in its own way through the application of very complex algorithms. One such (ATC) system in use in all Australian capital cities is SCATS developed by RTA NSW (now Roads & Maritime Services). The way SCATS is set up and operates to improve the overall traffic conditions also means that adjacent intersections affect each other’s operation. This effect is a very dynamic in nature and can change from cycle to cycle. The commercially available software (some of which was mentioned above) can take into account the effect of an adaptive system only to a limited degree. This limitation can slightly be compensated by making better assumptions about some principal parameters for individual intersections. This however requires very intimate knowledge of SCATS system and regional/local settings. As a result many traffic studies ignore to appreciate this and treat intersections as isolated during assessment. One of the common
mistakes for example is instructing the software to optimise cycle time for non-critical intersections which underestimates the delay for minor (side) streets and right turns. This situation often creates the disparity between the assumptions (and results) in the traffic analysis and the true performance when commissioning a new traffic signal. It was also found in some traffic studies that they ignore the hierarchy between the SCATS sub-systems even if the tool used for the assessment requires this as an important input for setting up the model (e.g. LINSIG).

With the latest advent of interfacing microsimulation with SCATS it is now possible to do simultaneous measurements on a cycle by cycle basis of delay, queue length, number of stops, volume and cycle time length at all signalised intersections in the model. This interface was achieved in several traffic studies by integrating SCATSIM with VISSIM and this paper will share a number of findings from various traffic assessments carried out using this method. The ability to model the operation of a series of traffic signals explicitly opens a myriad of opportunities equally in performing the network assessment and learning about the adaptive systems. The main purpose of the paper is to demonstrate some of the common effects SCATS can have on intersection performance and therefore aid traffic engineers to avoid making wrong assumptions in certain situations. It is also very attractive method for SCATS operators and managers for testing some unconventional phasing designs (e.g. Rest-on-Red), new variation routines etc.

SCATSIM SETUP AND VALIDATION

SCATSIM/VISSIM interface requires the setup shown in Figure 1 and consists of:

- A Traffic Simulator (this interface uses VISSIM microsimulation package).
- SCATS (same as SCATS in real world except it runs faster and can be located on the same PC as the simulator).
- WinTraff (controller emulator which requires controller personalities). The controller emulation uses the same configuration data files as a real controller. WinTraff simulation can emulate up to 250 controllers.

The interface allows WinTraff to communicate simultaneously with the microsimulation and SCATS. The message passing process is shown diagrammatically in Figure 1. Wintraff receives data from the simulated vehicle detectors and passes volume and occupancy information to SCATS which recalculates phase splits and cycle time lengths and passes that information back to WinTraff. WinTraff then sends signal status messages (e.g. red, green, amber) to the simulated signal heads.
Figure 1: Message passing process in SCATSIM/VISSIM interface

The detailed description of SCATSIM/VISSIM validation process is beyond the scope of this paper. Figure 2 shows a sample of strategic monitor (SM) data collected from SCATS regional computer. During SCATSIM/VISSIM runs the SCATS component produces the equivalent simulated strategic monitor data which is then compared with observed SM files to produce comparison charts as in Figure 3. Intersection diagnostic monitor data can also be used in a similar manner, however it cannot distinguish signal group data and is limited to phase times only.

Figure 2: An example of strategic monitor (SM) data sample
Figure 3: An example of validation of average phase/green time length per cycle for strategic approaches in Figure 2 (circled in red)

SCATSIM/VISSIM METHODOLOGY

The process of setting up a SCATSIM/VISSIM model is similar to interfacing SCATSIM to any microsimulation software which is equipped with SCATSIM plug in. However the differences between commercially available software and their usefulness in traffic engineering applications appear to be more related to the available outputs and their format suitability to post processing. The choice of VISSIM was made due to the authors’ familiarity with the software, detailed gap acceptance and stop line flow discharge coding parameters and the text file outputs suitable for processing performance measures at the movement level.

The steps required to develop a SCATSIM/VISSIM model are:

1. Setting up a VISSIM model. In addition to common steps for developing a microsimulation model this step involves numbering of vehicle and pedestrian signal groups to correspond to SCATS physical outputs for given sites and coding of detector loops/pedestrian pushbuttons representing SCATS physical inputs.

2. Setting up SCATS region and signalised sites within the study area. This step involves either using existing signal site configurations (personalities) or writing configurations for new sites.

3. Validating model using SCATS historical Strategic Monitor (SM) data or Intersection Diagnostic Monitor (IDM) data which was explained briefly in the previous section.

4. Running the model 10 times with different random seeds and processing the model outputs.

This paper will focus on the 4th step and interpretation of the processed outputs using a number of case studies. It is needed to understand steps to create a chart (Figure 4) which will be used throughout the paper and which is an important tool to explain the site performance and its relationship to adjacent sites due to all being parts of the SCATS set-up.

The modelled period is divided into time slices approximately close to average cycle time of critical intersection within the SCATS region containing the study area. Therefore if the time slice size is 120 seconds (Figure 4) the model outputs values for the key parameters for 30 intervals if the modelling period is 1 hour (3600 seconds). The values from 10 model runs are averaged for each time slice producing the mean value for all intervals (Figure 4). The curves derived from these values are plotted on a background divided in areas coloured to represent the Level of Service (using HCM delay method).
The key parameters selected for outputs are the common performance measures used by traffic engineers:

- delay (seconds)
- number of stops (total or stops/vehicle)
- maximum queue length (meters)
- traffic flow (vehicles/modelled period)

The chart shown in Figure 4 represents the dynamic delay for a single intersection movement in SCATSIM\VISSIM model.

![Figure 4: The process of making cycle by cycle (dynamic) delay charts with LoS areas](image)

Using the steps described above similar charts for Queue length, Number of Stops and Traffic Flow/Volume can be produced (Figure 5 and 6).
Figure 5: An example of dynamic delay and queue length charts

Figure 6: An example of dynamic Number of Stops and Traffic Flow charts

CASE STUDIES

A number of SCATSIM/VISSIM models have been developed in Perth in the last couple of years. Selected case studies from these models will be used here to demonstrate how intersection performance could get impacted from being a component of an adaptive system like SCATS.
Case Study 1

This case study was part of the study carried out for Main Roads which investigated the most appropriate interchange design for Great Eastern Highway and Tonkin Highway. It is known among traffic engineers that modifications to the interchange geometry can affect the operation of adjacent intersections in many ways. The focus of this case study however is the effect that interchange geometry has on the phasing and cycle time. The three interchange options in this study are Parclo A1, Partial Parclo and Parclo A2. The interchange has two sets of traffic signals (site 1 and 2 in Figure 7). Being the master controller site 1 imposes cycle time to sites 2, 3 and 4 as a result of marriage between those sub-systems (Figure 7). Different phasing arrangement (Figure 8) and interchange geometry produce different cycle time profiles as shown in Figures 10 and 11.

![Diagram showing the relationship between sites in case study 1](image)

*Figure 7: The relationship between sites in case study 1*

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Option 1 (Parclo A1)" /></td>
<td><img src="image" alt="Option 1 (Parclo A1)" /></td>
</tr>
<tr>
<td><img src="image" alt="Option 2 (Partial Parclo)" /></td>
<td><img src="image" alt="Option 2 (Partial Parclo)" /></td>
</tr>
<tr>
<td><img src="image" alt="Option 3 (Parclo A2)" /></td>
<td><img src="image" alt="Option 3 (Parclo A2)" /></td>
</tr>
</tbody>
</table>

*Figure 8: Phasing at site 1 and 2 for 3 Options used in case study 1*
The dynamic delay charts as described in Figure 4 were produced from the 10 SCATSIM/VISSIM runs for the two right turn movements at site 3 and 4 (Figure 9). SCATSIM component of the model was used to extract the strategic monitor (SM) file with cycle time profiles. Using the same time scale cycle time profile plots were aligned with dynamic delay plots for right turn movements at site 3 and 4 (Figures 10 and 11).

![Assessed movements at sites 3 and 4](image)

**Figure 9: Assessed movements at sites 3 and 4**

The average cycle times and delays for the 3 options compared in Case Study 1 are shown in Tables 1 and 2. The table 1 shows how the average delay for the right turn at site 3 changes with cycle time changes. The average delay change for the right turn at site 4 is presented in Table 2.

<table>
<thead>
<tr>
<th>Option</th>
<th>Average Cycle Time</th>
<th>Average Delay for RT at site 3</th>
<th>Level of Service for RT at site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>142 seconds</td>
<td>73 seconds</td>
<td>LoS E</td>
</tr>
<tr>
<td>Option 2</td>
<td>113 seconds</td>
<td>59 seconds</td>
<td>LoS E</td>
</tr>
<tr>
<td>Option 3</td>
<td>100 seconds</td>
<td>54 seconds</td>
<td>LoS D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option</th>
<th>Average Cycle Time</th>
<th>Average Delay for RT at site 4</th>
<th>Level of Service for RT at site 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>142 seconds</td>
<td>91 seconds</td>
<td>LoS F</td>
</tr>
<tr>
<td>Option 3</td>
<td>100 seconds</td>
<td>64 seconds</td>
<td>LoS E</td>
</tr>
</tbody>
</table>

It is important to remember that demand volumes modelled in three options at the 2 sites (site 3 and site 4) are identical. The changes in performance are purely the result of different cycle time profiles for the 2 sites and the operation in Masterlink mode in which unused green time gets allocated to the stretch phase with consequences for the right turn movements both from minor road (site 3) and arterial road (site 4).
Figure 10: Delay variations for the RT movement at site 3 as a function of Cycle Time profile
Figure 11: Delay variations for the RT movement at site 4 as a function of Cycle Time profile

Case Study 2

In the previous case study it was demonstrated how master controller cycle time profile could affect dependent sites within the SCATS marriage tree during one hour in congested conditions. This case study is somewhat similar to the previous one as it looks again at a site with the cycle time imposed externally but it goes a step further by comparing its performance between Masterlink and Master Isolated modes. In Master Isolated mode all phase lengths are calculated from the SCATS split plans and cycle length, but the coordination point is ignored meaning the stretch phase does not receive or loose time to maintain coordination. This allows quicker change from the stretch phase when other phases are demanded.

The SCATSIM/VISSIM model was run for 8 hours between 9pm and 5am i.e. in off peak/night time traffic conditions. Due to the size of modelled period the time slices were 1 hour which allowed the monitoring of movement performance throughout the night. The eight hours simulation was carried out for six sites as part of the Rest-on-Red investigation. Being the off peak periods we rarely investigate the performance of intersections in early to late night time hours. Using the delay charts this study monitored the performance of all movements at six sites with and without Rest-on-Red mode during the night time hours. One of the requirements for the operation of Rest-on-Red is to switch off the masterlink mode and continue the operation in master isolated mode. This breaks any existing links with other sub-systems and the site starts using its own detector loops to determine the required cycle time. It was observed that for some sites performance disbenefits created by Rest-on-Red mode were more than counter balanced by improved performance in Master Isolated mode especially for right turns and side roads. In order to separate the improved performance without the interference of Rest-on-Red the model was set-up to turn the master isolated mode on without Rest-on-Red at 9pm and the results from these runs were compared to those in masterlink mode for the same site.
It is general practise in Australia and New Zealand to coordinate traffic signals in the direction of major traffic movements even at low traffic demand (mid-night) conditions, however it was apparent from this comparison that there is an optimal point in time suitable for switching the masterlink mode off and running the site in master isolated mode. Movements used for delay monitoring were shown in Figure 12 as 1, 2 and 3 where movement 1 runs during the stretch (phase A), movement 2 is the non-filtering (phase B or F) right turn from the main into a side street and movement 3 is (phase D or E) cross movement from side street across main street. Cycle time profiles from Masterlink and Master Isolated modes were aligned with delay charts for the three movements during the night time period (9pm to 5am) (Figure 13). Comparison of delay curves for Masterlink and Master Isolated mode reveals that the stretch phase movement (1) does not gain much from coordination with upstream sites in low traffic conditions after 10pm (Figure 13). On the contrary movements 2 and 3 experience significantly higher delays in masterlink mode. Switching to Master Isolated mode between 10pm and 11pm would significantly improve performance for movements 2 and 3 without too much sacrifice from the stretch phase movement 1. The performance improvements always need to be weighted against the traffic volume and the number of stops.

Figure 12: Movements compared for delay in Masterlink and Master Isolated mode during night time period (9pm to 5am)
Figure 13: Delays as a function of cycle time in Masterlink and Master Isolated mode during the night time period (9pm to 5am)
Case Study 3

This case study looks into the effects of changing the signal site configuration to an unconventional phasing like Rest-on-Red. Rest-on-Red (RoR) signal phasing is a localised site operation mode where the default state for all signal groups is red (including pedestrians) and the green light is only activated when a vehicle is detected by detector loops or pedestrian pushes a button. If applied, this mode of operation should be in use during certain times of the day, predominantly late in the evening till early morning. The discussion about safety benefits or dis-benefits of Rest-on-Red mode is beyond the scope of this paper.

After re-writing the signal personality the model was run for eight hours (9pm to 5am) and output processed to produce delay and number of stops charts for movement 1 in Figure 12. To isolate the effect of Rest-on-Red the results were compared with conventional phasing in master isolated mode. Even the small decrease in performance during the night time hours is captured (Figure 14) which confirms the suitability of the SCATSIM/VISSIM method for measuring the effects of personality changes in low traffic volume conditions. With small changes in performance the number of stops becomes more relevant measure in potential selection of Rest-on-Red candidate sites. The total number of stops (9pm to 5am) for this site more than doubles after switching to Rest-on-Red mode (Figure 15).

![Figure 14: Average delays during night time period with and without Rest-on-Red mode](image-url)
Case Study 4

The main goal of gating strategy is a better utilisation of green time in a cycle. The mechanism of gating lies in reallocating green times to other traffic movements when the through movement is blocked. A situation suitable for gating was identified in one of the modelled options during Great Eastern Highway/Tonkin Highway interchange selection study in Perth (Figure 16). The side street right turn (at site 4) was congested and particularly suffered after the queue spill over from a downstream intersection (site 3). This case study applied SCATS Variation Routine 83 (VR83) which caps the through movement green time. The green time for the through movement is capped by constraining the degree of saturation value which has the effect of giving less “voting” power for this movement. As a result side roads and minor movements get more opportunities to proceed as more green time is allocated to them. This strategy can only work in reducing delays for the side roads if sufficient storage room is available on the street for turning movements to queue which is not always the case in spillback situations.

Figure 15: Number of stops during night time period with and without Rest-on-Red mode

Figure 16: The queue spillback from site 3 to site 4
The SCATSIM/VISSIM model was run for the morning peak hour and the data extracted for processing. Mean maximum queue changes for site 3 are plotted in Figure 17 where blue line represent results from modelling runs without gating (no VR83 applied) and red dotted line derived from the option with gating applied at site 4 which reduces the green time for the through movement via VR83 routine.

![Figure 17: The mean maximum queue length changes at site 3](image)

The delay changes per cycle for the right turn at site 4 are shown in Figure 18 with line type and colours corresponding to those in Figure 17. It is evident from Figure 18 that delay changes at site 4 are related to mean maximum queue changes in the second half of the simulation when queue from site 3 starts interfering with the discharge flow rates of the right turn out of side street. Eventually the queue spillback prevents the right turn vehicles from proceeding into the main road. This results in large average delay (93 seconds) and LoS F. With VR83 routine applied the delay in the second half of the simulation is improved for the right turn without compromising further the through movement performance. The delay for the right turn drops down to 84 seconds which does not solve the problem for that movement but improves the overall experience for drivers.

![Figure 18: The dynamic delay chart for right turn at the site 4](image)
It is worth noting that plotting the outputs at high resolution (cycle by cycle) enabled detecting the effect of the gating SCATS routine which was the problem with some previous studies and trials using 15 minute intervals for similar comparison and the assessment.

Similar delay chart can be derived for the main road through traffic and other movements to establish overall intersection performance. The detailed evaluation of the intersection as a whole is beyond the scope of this paper.

Case Study 5

The last case study demonstrates the use of SCATSIM/VISSIM interface to model bus operation in the mixed traffic conditions. Buses enter the bus station via queue jump bus lane in the form of right turning pocket (Figure 19). The turning pocket length is 150 m which is sufficient during the first half of the modelling period (Figure 21). As the queue grows the queue jump bus lane is getting blocked and buses are caught in through traffic unable to get to the dedicated bus lane. As a result they start experiencing unstable operation and higher delays resulting in LoS F (Figure 20). High fluctuations of bus delays shown in Figure 21 demonstrate the impact of through traffic queues on individual buses which operate in 5 minute time headways.

Conventional performance analysis using deterministic software would have probably calculate considerably lower delays for 22 buses due to very low volumes. The ability to model the exact frequency of buses and demand calls for dedicated bus phases certainly improves the accuracy of delay estimates.

![Figure 19: Queue Jump Bus Lane at Murdoch Bus Station (yellow arrow)](image)
DISCUSSION

Area Traffic Control systems and their true impact have to a large degree been neglected in our current traffic engineering practice particularly when it comes to performance evaluation of signalised intersections. The complexity of the SCATS system prevents general practitioners from being more directly involved in modelling the operation of traffic signals. This creates inconsistency between traffic engineers who analyse, provide assessment and planning and engineers operating adaptive traffic systems like SCATS. The first group of engineers plays more proactive role, while the other group is more reactive as they have to maintain, adjust and operate the adaptive systems on a daily basis. Having a different agenda the two streams often operate in isolation without much opportunity to exchange their knowledge. To some degree this situation was caused by our inability to directly model and analyse signalised intersections with constraints imposed by SCATS which controls their operation and interaction between them.

It is unlikely ATC systems will ever improve without accurately quantifying the effect they have on individual intersections. The arrival of plugins which enabled the communication between SCATS and microsimulation packages is a big step forward to overcoming the gap that currently exists in our understanding of ATC systems. This adds another layer of complexity to an already complex process of setting up a microsimulation model. Apart from the knowledge in setting up
SCATS system in different parts of the network another difficulty in SCATSIM modelling are signal sites configurations (personalities) which often need to be modified or written from scratch. The area of adaptive engineering concerning personality generation is a discipline in its own right and requires a lot of experience and practise. However the risk free environment in using the interface presents a unique opportunity for traffic engineers to learn about adaptive engineering. The limited number of models created using SCATSIM interfaced with microsimulation packages is a library which will without doubt grow in the future and become an invaluable educational and reference base.

This paper demonstrates a range of different situations where processing of SCATSIM/VISSIM model outputs revealed extra details useful for the intersection analysis and not usually available as an output from conventional modelling packages. The main enhancements to the intersection performance assessment from using SCATSIM/VISSIM interface are:

- The SCATS hierarchy between sites is maintained during assessment. The hierarchy between signalised sites often imposes constraints to input parameters like cycle time. Modelling dynamic cycle changes improves the assessment particularly for right turns and side road minor movements.
- Single number representing delay is enhanced by a delay curve. By interpreting the shape of the curve it is possible to distinguish and rate movement performances even if the average delay is similar.
- The high resolution (cycle by cycle) delay and queue reporting makes it possible to detect and assess even small changes in performance due to personality changes (e.g. Rest-on-Red), SCATS variation routines or those caused by external factors (e.g. detector loop failures).
- Possibility to model longer off-peak periods and aggregate the performance measures by hour. This could be extremely useful in setting an optimal point to switch to Master Isolated mode of operation during night time.
- Improved performance assessment for movements that traverse more than one signalised intersection. This is especially useful in the movements delay comparison between new interchanges and the do-nothing at grade intersections.
- Improved performance assessment for low volume movements consisting of vehicles arriving at regular intervals (e.g. public transport vehicles).

Traffic engineering professionals are given the opportunity to be directly involved in tailoring ITS solutions, but this comes at a price of using more complex tools. Nevertheless we as a profession should embrace this challenge.

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