ABSTRACT

The Sydney Co-ordinated Adaptive Traffic System (SCATS) is a computer-based area traffic signal control system. It operates in real-time, adjusting signal timings throughout the system in response to measured variations in traffic demand and system capacity. A microscopic computer simulation model, called SCATSIM, has been used to demonstrate the benefits of SCATS adaptive traffic control under sudden changes of traffic flow conditions during peak flow periods. Quantitative comparisons of traffic control performance under SCATS and fixed-time traffic control techniques show the flexibility of SCATS adaptive control technique and its benefits over fixed-time control in reducing vehicle stops, traffic delays and, consequently, fuel consumption, and improving air quality by reducing vehicle emissions. A reduction of more than 20 per cent in both fuel consumption and vehicle emissions (CO and HC) was found for the case study reported here.

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1. INTRODUCTION

The Sydney Co-ordinated Adaptive Traffic System (SCATS) is a computer-based area traffic signal control system. It operates in real-time, adjusting signal timings throughout the system in response to measured variations in traffic demand and system capacity. This is a significant improvement over many existing traffic control systems which rely upon pre-timed signals or the fixed-time traffic control technique.

In most cities, an adaptive traffic signal control system, such as SCATS, can be used to cater for continuous fluctuations of traffic flows as well as sudden changes of traffic flow patterns.

TRANSYT has been accepted by many traffic authorities around the world for fixed-time traffic network design and evaluation. It has been considered the best available tool for preparing fixed-time traffic signal timings (Luk 1989).

An adaptive traffic network simulation model, SCATSIM, has been specially developed as part of the Roads and Traffic Authority research and development program on adaptive control technology.

In this paper, SCATSIM is used to study a case of sudden change in traffic demand during a peak flow period. This change may be due to traffic accident or lane blockage at side streets, where part of side street traffic is re-directed into the main road. Traffic entering the main road will also be re-directed in such a way that they will flow at an equal rate in both directions. This heavy traffic flow coupled with a requirement of an effective 2-way traffic signal coordination makes the control task difficult. A very simple arterial network without traffic filtering or shared lanes was selected for the exercise. Comparison of control performance of SCATS and of a fixed-time system (using TRANSYT setup) is presented. The flexibility of SCATS in traffic control and its benefits in reducing traffic delay, vehicle stops, fuel consumption and in improving air quality by reducing vehicle emissions are also discussed.

2. ADAPTIVE TRAFFIC CONTROL TECHNOLOGY

A summary of SCATS adaptive traffic control techniques and the SCATSIM traffic network simulation model are given in this section to assist the reader with information on the adaptive control system, its computer simulation model design and the procedures by which performance tests have been carried out.

2.1 SCATS Adaptive Control Techniques

SCATS is a computer-based area traffic signal control system. The principle of adaptive traffic control algorithms used in SCATS is based on three parameters: signal cycle length, split and offset. These parameters will be optimised after the end of every signal cycle in response to measured changes (by detectors) of current traffic flow and density.
SCATS offers a variety of operational modes ranging from fixed-time control to fully adaptive control mode. These modes can be manually over-ridden at any time. Further information on SCATS can be found in Longfoot (1982) and Lowrie (1982, 1992).

2.2 The Adaptive Traffic Network Simulation Model: SCATSIM

The RTA's traffic network simulation package, SCATSIM, has been available for some time (Fehon, Moore and Negus, 1986). However, it has not, until now, been properly tested and evaluated. SCATSIM has recently been modified extensively to improve both simulation logic and input/output facilities. The prediction of motor vehicle emissions, using a combined American-Australian computational algorithm, was also included in the simulation data analysis (Nguyen 1994).

SCATSIM has been used as a tool for evaluating new/updated SCATS algorithms. The software runs alongside the SCATS program. It is actually a full scale version of SCATS excluding the traffic network and local controllers. During simulation runs, SCATS sends updated signal group status to the simulated traffic network and SCATSIM returns to SCATS traffic flow and occupancy data (similar to that produced by local controllers).

SCATSIM requires a complete description of the traffic network (ie. intersections, approaches, lane usage, signal groups and detector locations) and a time-varying traffic flow input to the network. It is able to simulate a network of up to 16 intersections, 5 approaches per intersection, and 5 lanes per approach using 6 stage signal control. The maximum simulation period is 24 hours. A random generator is used to generate traffic movements. The user is able to test network performance under different arrival patterns by inputting different seed numbers to start a simulation session. The model is easy to use if the user has a basic knowledge of SCATS operations.

Other traffic control techniques, with known algorithms, can be simulated by SCATSIM.

SCATSIM records vehicle stop counts, travel time, speed related information of vehicle movements to a file which is later analysed to give system performance by approach, intersection, sub-area or whole network. Simulation results include: travel time, stopped time, traffic flow, level of service, traffic delay, vehicle stops, fuel consumption, average speed and vehicle pollutant emissions such as carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx).

SCATSIM has been throughly validated against TRANSYT. For details of validation results, refer to (Nguyen 1994).
3. TRAFFIC CONTROL PERFORMANCE TESTS

3.1 Run Test Procedure

The procedure selected to test the performance of SCATS is described as follows:

3.1.1 A simple traffic network of four 2-stage and one 3-stage intersections, without traffic filtering and shared lanes was used as shown in Figure 1. A set of peak-hour traffic flows entering the network is generated for the simulation.

3.1.2 Traffic flow data from this network are entered into the TRANSYT-8 program for fixed-time system setup at different cycle lengths.

3.1.3 TRANSYT-8 results (as cycle length, stage split and offset) are used for setting up SCATS data for fixed-time mode run.

Cycle length for optimal fixed-time control setup is selected from simulation data analysis results for minimum network fuel consumption.

3.1.4 In another run (using the same random seed number for the fixed-time mode run), SCATS is switched to adaptive mode while SCATSIM generates similar traffic flow conditions.

3.2 Selection of Traffic Flow Conditions

To demonstrate the flexibility of SCATS, a case study of sudden change in traffic demand during a peak flow period was simulated. Side street traffic is re-directed into the main road in such a way that traffic in the main road will flow at equal flow rates in both directions. Heavy traffic flows in both directions on the main road require an effective 2-way traffic signal coordination. This control task is difficult.

Each simulation session was set to run for six hours (from 0 to 6:00). This consisted of one hour for traffic build-up from an empty network (0 to 1:00) and five hours of main simulation (1:00 to 6:00). Sudden traffic changes occurred between 2:00 and 3:00 as shown in Figure 2. Three hours of simulation after the sudden change interval was adapted to ensure the clearing of any traffic congestion caused by the sudden traffic change.

3.3 Traffic Control Performance Variables

Comparisons of performances under both fixed-time (using TRANSYT setup) and SCATS adaptive modes operating under similar traffic conditions were carried out. Fuel consumption, level of service, total network vehicle stops and traffic emission rates (CO, HC, NOx) were used as the basis for comparison.
3.4 Performance Test Results

Under the given traffic flow conditions, the signal cycle length for fixed-time control (70 seconds) was selected based on the minimal network fuel consumption criteria as shown in Figure 3.

Each pair of simulation tests (ie. fixed-time and SCATS adaptive) was repeated three times, with different seed numbers. Hourly averages of all simulation runs (fixed-time and SCATS adaptive control) are shown in Table 1. Typical performance results at 5-minute intervals of the set No.1 are shown in Figure 4.

4. DISCUSSION AND CONCLUSION

Under steady flow conditions with the same traffic flow rates as used in TRANSYT data input, fixed-time control performs slightly better than SCATS adaptive as seen in Table 1. The principal reason for those differences is that SCATS adaptive control algorithms continuously aim at the predicted traffic conditions in the next cycle and may over- or under- estimate real traffic demands due to random traffic generation.

In real life, traffic flow volumes always fluctuate. It was found that when traffic starts to fluctuate around the averages, or there is sudden change in traffic patterns, traffic flows are unpredictable and SCATS controls traffic more efficiently than the fixed time mode. Depending on the magnitude of traffic flow variations, the higher the changes, the more efficient traffic control from SCATS is expected.

For the sudden change of traffic conditions as set out in this paper, it is found that SCATS is able to provide much better performance than fixed-time control by giving:

- 30% reduction in fuel consumption,
- 25% reduction in CO and HC emission,
- 15% reduction in NOx emission

Level of Service B in SCATS adaptive control is recorded, compared with LOS of C or D range found under fixed-time control mode (Figure 4). LOS criteria are derived from Highway Capacity Manual (TRB 1985).
The cycle length and split plots, shown in Figure 4, illustrate the flexibility of SCATS adaptive control at intersection #100. During this period, SCATS selected appropriate split plans of short green times on side street (stage B) due to its light traffic flow and, consequently, gave more green time (stage A) to heavy traffic movements along main road. At the same time, signal cycle lengths were continuously adjusted in response to the traffic entering the network randomly. Adjustments of offsets between signals also allowed traffic to move through the network effectively. On the contrary, detailed fixed-time control performance results, given in Table 2, show significant increases in traffic delay, vehicle stops and, consequently, fuel consumption and vehicle emissions at the main road entrance (intersection #100 and #500) and the critical intersection #300. For these reasons, the network performance seems to be unchanged during SCATS adaptive control (in Figure 4).

These results are based on the average values as shown in Table 1. The above simulations clearly demonstrate the advantages of SCATS adaptive traffic control technique over fixed-time control.

It is acknowledged that only a single case study of sudden traffic change in a simple arterial network is presented in this paper. SCATSIM is being used in the current research program which includes evaluation the performance of various adaptive traffic control techniques in SCATS, using both arterial and grid networks, in relation to:-

- adaptive SCATS control compared to fixed-time operation,
- fluctuation of traffic flow volumes at fixed averages,
- sudden unpredictable variations in network capacity (eg. due to incidents or temporary lane blockage),
- temporal variations in the daily flow profile, and
- networkwide changes in saturation flow (eg. effect of weather changes)

SCATSIM simulation model is now available to all SCATS users.
REFERENCES


### TABLE 1
SCATSIM data analysis: hourly average results of all runs.

| TRAFFIC COND’N: | FIXED-TIMES CONTROL | | | SCATS ADAPTIVE CONTROL | | | SET No. | (#) |
| | STEADY | SD.CHG | DIF(*) | STEADY | SD.CHG | DIF | | |
| Inflow traffic (veh/h) | | | | | | | | |
| 12292 | 11560 (+) | | | 12305 | 11555 | | 1 |
| 12316 | 11528 | | | 12309 | 11547 | | 2 |
| 12308 | 11554 | | | 12290 | 11604 | | 3 |
| Level of Service | C | D | | | C | B | 1 |
| | C | D | | | C | B | 2 |
| | C | C | | | C | B | 3 |
| Fuel consumption (L/h) | 1134 | 1565 | 38% | 1166 | 1151 | -1% | 1 |
| 1133 | 1511 | 33% | 1163 | 1154 | 0 | 2 |
| 1128 | 1481 | 31% | 1165 | 1150 | -1% | 3 |
| CO emission (kg/h) | 90.4 | 124.8 | 38% | 92.7 | 91.0 | -2% | 1 |
| 90.3 | 120.4 | 33% | 92.4 | 91.1 | -2% | 2 |
| 89.9 | 117.3 | 30% | 92.6 | 90.8 | -2% | 3 |
| HC emission (kg/h) | 15.2 | 21.2 | 39% | 15.6 | 15.2 | -3% | 1 |
| 15.1 | 20.5 | 36% | 15.5 | 15.3 | -2% | 2 |
| 15.1 | 19.9 | 32% | 15.6 | 15.2 | -3% | 3 |
| NOx emission (kg/h) | 28.0 | 33.8 | 21% | 27.9 | 28.6 | +3% | 1 |
| 28.0 | 32.7 | 14% | 27.9 | 28.2 | +2% | 2 |
| 27.9 | 32.6 | 17% | 27.9 | 28.3 | +1% | 3 |

Notes:

(*) Difference of performance results between steady flow and sudden change of traffic conditions.

(#) Each set results consists of 2 simulation runs (one at fixed-time and one at SCATS adaptive mode) using the same random seed input value.

(+) Compared with input data values of 12300 veh/h during steady flow traffic and 11567 veh/h during sudden change (ie 2:00-3:00) derived from Figure 2.

(‘) Vehicle fleet make-up of 10% heavy duty truck and calculated at calendar year 1993 vehicle emission control conditions.
<table>
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<th>Traffic cond'n:</th>
<th>I#100</th>
<th>I#200</th>
<th>I#300</th>
<th>I#400</th>
<th>I#500</th>
</tr>
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<tbody>
<tr>
<td>Average delay (s/veh)</td>
<td>STEADY</td>
<td>STEADY</td>
<td>STEADY</td>
<td>STEADY</td>
<td>STEADY</td>
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<td></td>
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<td>12.7</td>
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<td></td>
<td>+223%</td>
<td>+21%</td>
<td>+57%</td>
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<td>+112%</td>
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<tr>
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<td>2376</td>
<td>3245</td>
</tr>
<tr>
<td></td>
<td>+164%</td>
<td>+26%</td>
<td>+31%</td>
<td>-18%</td>
<td>+87%</td>
</tr>
<tr>
<td>Fuel consumption (L/h)</td>
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<td>184</td>
<td>276</td>
<td>210</td>
<td>270</td>
</tr>
<tr>
<td></td>
<td>+123%</td>
<td>+6%</td>
<td>+15%</td>
<td>-10%</td>
<td>+59%</td>
</tr>
</tbody>
</table>
Fig. 1 - The test network

NOTES: <> ----> STRETCH STAGE

Fig. 1 - The test network

NOTES: <> ----> STRETCH STAGE
Fig. 2- Traffic sudden change - Vehicle generation at terminals

Fig. 3- Selection of optimal CL for fixed-time control
- under steady flow traffic conditions
- using TRANSYT computing results
Fig. 4 - Traffic control performance results
Comparison of SCATS adaptive & FIXED-TIME controls