SCOOT Adaptive Signal Control: An Evaluation of its Effectiveness over a Range of Congestion Intensities

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ABSTRACT

This paper compares the performance of adaptive control using the Split, Cycle and Offset Optimization Technique (SCOOT) relative to a fixed-time plan based control. A four-intersection test corridor is modeled using the Corridor Simulation (CORSIM) program. Five sets of traffic flows were generated testing the corridor at increasing volumes from a volume to capacity (v/c) ratios of 0.7 through 1.1. The corridor was evaluated with pre-timed, actuated-coordinated, actuated-uncoordinated, and fully actuated strategies to determine the most optimal one. This was used in comparing SCOOT’s performance relative to the optimal signal timing. The corridor is controlled by SCOOT through the SCOOT-CORSIM Interface which allows an actual SCOOT system to get detector information from CORSIM and provide signal timing to CORSIM. Results of the test corridor show that SCOOT reduces delay by 8% at the 0.7 v/c, which increases to 13% at a v/c of 0.9. Minimal improvements are observed as the corridor approaches saturation. This indicates that substantial savings are available with SCOOT during under-saturated flow conditions and SCOOT helps postpone the onset of congestion, but SCOOT operates much like a fixed time system once flows reaches saturation. Two real-world corridors were tested with SCOOT reducing overall corridor delays by 14% and 11%. Further, this paper shows the importance of validating the SCOOT system properly. The simple activation of SCOOT, without any validation, provides a 219% increase in corridor delays over the fixed time plan. After validation, the results show a delay reduction of 8% over fixed time control. The validation findings dispel the idea that adaptive control systems are ‘plug and play.’
INTRODUCTION

Increasing traffic congestion is a constant source of frustration, time loss, and expense to both users and managers of transportation systems. Cities, counties, and state transportation agencies are persistently searching for ways to mitigate urban traffic congestion, while minimizing costs and maintenance requirements. In urban areas, traffic signals are a critical element in controlling traffic congestion. Most areas use timing plans that correlate to a specific time of day, such as morning and evening peak periods. Signal timings, however, do not change during this interval and are hence called “fixed-time” plans. While splits may vary under some coordinated-actuated control techniques, the offsets and cycles are typically constant. Fixed-time plans operate with the fundamental assumption that the flows are relatively stable and one cycle length is optimal throughout the two to three hour peak period. However, this flow stability is rarely the case, as traffic builds to a peak and then subsides throughout the period. This discrepancy implies that traffic signals operating under fixed time control may operate optimally for a short period when the actual flows match the design flows and thus the ‘optimized’ timings. However, during the other periods, the traffic signal system operates sub-optimally.

Adaptive Traffic Control Systems (ATCS) make constant changes in signal timings based on measured flow. The benefits of reacting to these flow variations are reduced delay, stops, queues, travel times, fuel consumption, and emissions. While there are several ATCSs, the United Kingdom (UK) based Split, Cycle and Offset Optimization Technique (SCOOT) (1) has been well established since its inception in 1981, with more than 170 installations world-wide. SCOOT improves network performance by adjusting signal timings in real-time in response to measured traffic flows. The University of Utah uses the SCOOT-CORSIM Interface to connect an actual SCOOT system to the Corridor Simulator (CORSIM) program developed by the Federal Highway Administration. SCOOT’s control of a simulated traffic network enables comparison to fixed-time plan based control.

This paper examines the benefits of using SCOOT over an optimized signal control for a simulated corridor operating at a range of congestion levels or volume-capacity (v/c) ratios. For the purposes of this paper, fixed-time control refers to pre-timed and actuated-coordinated systems. Although semi and fully-actuated timing is typically reserved for isolated, non-coordinated intersection, this paper also examines these signal timing strategies. The corridor is loaded with traffic at five different congestions levels from 0.7 to 1.1 v/c ratios, representing under-saturated to over-saturated conditions. First an updated fixed-time plan controls the corridor, afterwards SCOOT controls it. Measures of Effectiveness (MOEs) are then extracted and the comparisons are made.

This paper begins with examining varying traffic flow conditions, the need for adaptive signal control, and various field installations of the SCOOT system. The paper then explains the SCOOT-CORSIM Interface developed at the University of Utah (2). Next, the paper describes the simulation modeling and results of a test corridor, two real-world corridors, and the conclusions drawn from these results. The paper concludes with some suggestions for further research.
BACKGROUND

Fixed-time plans assume that traffic flow remains constant over time. However, during any given day, traffic flow varies, as it peaks and then reduces. A pilot study was conducted in Salt Lake County to examine the daily flow fluctuations and variability over a period of time. In 2001, at Fort Union Boulevard and Union Park Avenue in Murray, Utah, traffic volumes were measured in 5-minute intervals between 4:00 PM to 6:00 PM on the third Thursday of every month. Figure 1 shows 5-minute flow variation on the December 20, 2001 and Figure 2 shows the variation in total 2-hour volumes at this intersection. This sample study shows that there are continuous fluctuations in traffic flow throughout the year. Fixed-time plans do not accommodate for these seasonal fluctuations nor do they account for the inter-peak period variations. Changing traffic flows thus require that these plans be updated every few years (3).

Insert Figure 1 here.

Insert Figure 2 here.

SCOOT computes the optimal signal cycle times in real-time for a network based on instantaneous flow conditions. Splits are then optimized for each intersection of the network for the critical cycle length. Offsets are also optimized in real time to achieve progression along corridors. Previous SCOOT evaluations have shown journey-time savings of up to 40%. Table 1 shows SCOOT comparison studies done 6 UK installations in the UK (4). Typical benefits in travel time, stops, delay, and fuel consumption are listed in Table 2 (5).

Insert Table 1 here.

Insert Table 2 here.

Apart from SCOOT, other ATCSs installed in the United States are the Sydney Coordinated Adaptive Traffic System (SCATS) (6), Optimized Policies for Adaptive Control (OPAC) (7), Real-time Hierarchical Optimized Distributed and Effective System (RHODES) (8), and the Los Angeles – Adaptive Traffic Control System. The basic philosophies of these systems and details regarding their location and installations are summarized in Table 3.

Insert Table 3 here.

Although these are evaluations of SCOOT and other ATCSs, they are specific to each installation. They vary in scope from installation to installation thus it is difficult to predict the benefit of ATCSs on a specific network. However, if an ATCS is linked to a simulation program, its performance can be evaluated for a wide range of networks prior to its installation. Rigorous evaluations can be made for a variety of network types over a
range of flows and other traffic conditions. The SCOOT-CORSIM Interface allows prospective users to evaluate the SCOOT system in a simulated environment.

THE SCOOT-CORSIM INTERFACE

SCOOT optimizes traffic network performance by minimizing the Performance Index (PI). The PI is the composite measure of delay, queue lengths, and stops at all approaches in the network. To minimize the PI, SCOOT changes cycle length, offset, and splits at each signal. SCOOT works in real time and communicates with vehicle detectors to gather flow and occupancy information. Next, it calculates optimized signal timings that are sent back to the local controllers. Since SCOOT is centralized, it communicates with all controllers instead of relying on non-centralized communication that usually requires time-consuming hardware installation. SCOOT is often characterized as an online version of the Traffic Network Study Tool (TRANSYT-7F) (9). Continuous modification of signal timings based on current flow conditions eliminates the need to update signal-timing plans. It also eliminates the aging associated with fixed time systems. SCOOT can also predict total delay and stops for the current signal timings over short, rolling horizons. However, it does not change signal timings in a large and disruptive manner. It uses frequent small alterations for short-term traffic demands. SCOOT is able to compensate for the longer-term traffic needs by adjusting for many of these small fluctuations.

The Corridor Simulator (CORSIM) is a microscopic simulation program that is a module of the Traffic Software Integrated System developed by the Federal Highway Administration. CORSIM uses algorithms to model the interactions of individual vehicles in a user-defined network. Each vehicle has stochastic properties such as vehicle length, driver aggressiveness, acceleration rate, minimum acceptable gap, and maximum free speed. After each simulation run, CORSIM generates an output file that enables extraction of commonly used Measures of Effectiveness (MOEs) such as delay and travel time.

The SCOOT-CORSIM Interface was developed at the University of Utah (2). SCOOT was not designed with a simulation interface like RHODES or OPAC. SCOOT expects actual detector inputs from field detectors to produce signal timings that will be returned to the signal controllers. The Interface allows the CORSIM generated detector data to be transmitted to the actual SCOOT system. The SCOOT generated timings are then returned and implemented into CORSIM. Therefore, SCOOT with detector data from CORSIM, operates as though it controls actual intersections, and thus performs as it would in the field. This Interface tests a SCOOT system in a CORSIM simulated environment.

Figure 3 shows the interface between SCOOT and CORSIM. CORSIM and the interface run on an IBM Compatible PC while the SCOOT system operates on a DEC Alpha machine. The directional arrows in Figure 3 represent the flow of information. Real-time detector information from CORSIM is sent to SCOOT, which returns updated signal timings. CORSIM then simulates these timings.

Insert Figure 3 here.
TEST CORRIDOR

A test corridor was developed to operate at varying congestion levels to compare the SCOOT performance with respect to fixed-time control. Figure 4 shows the layout of the corridor and a typical approach.

*Insert Figure 4 here.*

Corridor Geometry

The corridor has four intersections spaced 1,000 feet apart. Four-lane roads connect these intersections, with two lanes in each direction. At the intersections, the approaches have a 250 foot long left turn and right turn pockets in addition to the two through lanes.

Flows

This corridor was loaded with traffic generated using the Monte Carlo simulation technique. Flows were generated for a two-hour peak period in five-minute intervals providing twenty-four variations.

The Monte Carlo flow simulation technique generates random traffic flow within the provided capacity constraints. The number of vehicles entering the corridor within a two-hour period was fixed based on the number of lanes feeding traffic into the corridor and the congestion level. These vehicles were then normally distributed in five-minute intervals over the two-hour period. Five sets of flows were generated in a similar fashion thereby providing five congestion levels to operate the corridor at v/c ratios from 0.7 to 1.1. Figure 5 shows the profile for the varying volume generated for the corridor operating at 0.7 v/c ratio. Similar flow profiles were generated for other v/c ratios.

*Insert Figure 5 here.*

Fixed-Time Control

Once the geometry and flow information was gathered, Synchro 5.0 generated optimized signal-timing plans for the intersections along the corridor. For the generated flows, a Synchro analysis of four different signal-timing strategies provides the total corridor delay: pre-timed, actuated-uncoordinated, actuated-coordinated, and fully actuated. Table 4 describes the results from the Synchro analysis and shows that the minimal delay timing is pre-timed and actuated-coordinated. Coordination allows for shortened corridor delays because the analysis focuses on higher peak hour flow. This means that of the four timing strategies, the pre-timed and actuated-coordinated timings produce less corridor delay than the non-coordinated timing options. According to the Synchro analysis, actuated–coordinated and pre-timed produce the same corridor delay. Since the corridor delay is the same for both strategies, pre-timed control is selected for its simple CORSIM coding. This provides the most conservative comparison for estimating the benefits of SCOOT over an “optimal fixed-time plan.” Consequently, the optimal pre-timed plan control is compared to SCOOT control to determine the effect on delay.
Based on this assessment, a pre-timed control regime was simulated and flows were adjusted based on intersection peak-hour factors. Signals were allowed to operate in a four-phase pattern with permitted-protected left turn phasing. Five fixed-time plans were generated for the 5 v/c ratios. The flow, geometry, and signal timing data were used to construct the CORSIM file. CORSIM coding was based on instructions provided in the CORSIM User Manual (10).

Insert Table 4

**SCOOT Control**

Preparing the corridor to operate under SCOOT control requires three steps:

1. CORSIM input file modification
   The SCOOT-CORSIM Interface communicates flow and occupancy information from CORSIM to the SCOOT computer. Upstream presence detectors were placed 750 feet upstream in the through lanes to facilitate this detection and transmission process. A presence detector was also placed 200 feet upstream in each left turn pocket to detect the number of left turning vehicles. The layout of detectors on a typical approach is shown in Figure 4. With three detectors per approach, a total of 48 upstream detectors in the corridor. The four intersections were also flagged in CORSIM for external control to enable implementation of signal timings transmitted through the SCOOT-CORSIM interface.

2. SCOOT Setup
   The corridor was coded in with the following data: intersection, links, signal phasing patterns, and detector layout. This enabled SCOOT to receive real-time flow information from CORSIM, compute the updated timings and send them back to CORSIM for implementation on the corridor.

3. SCOOT Validation
   Validation is the process of setting up SCOOT so that it can accurately model the traffic flow behavior on the street, which in this case, was the simulated corridor. There were seven parameters that had to be validated in SCOOT: main downstream link, default offset, journey time, maximum queue clear time, start lag, end lag and saturation occupancy. For simulated network, the start lag and end lag depends on the setting in the CORSIM program. Once they were fixed in CORSIM they did not need revalidation in SCOOT. The main downstream link and the default offset were also coded during the SCOOT network setup, and as they did not change during the two-hour simulation, they were not revalidated.

   The remaining three parameters: journey time, maximum queue clear time and saturation occupancy did require validation. These parameters are typically validated by field observation whenever SCOOT is installed field. However, in this case, where the corridor is simulated, validation is based on observations from the simulation output file. The Traffic Visualization Utility of the CORSIM
program facilitates this process. The benefits obtained from SCOOT with and without validation are discussed in the results section. It is important to note that this validation process is critical in establishing a SCOOT installation.

It should also be noted here that the CORSIM input files for the fixed-time and SCOOT runs used the same random number seeds. This ensures that similar traffic conditions are generated in both scenarios, thereby providing a fair comparison of the two signal control strategies (10).

**TEST CORRIDOR RESULTS AND DISCUSSION**

ACCUSIM is a post-processor for the CORSIM output files that helps extract and process the MOEs. Results obtained from CORSIM simulations were extracted using the ACCUSIM software. Delay and travel time were used as MOEs to compare the performance of the network under the two-signal control strategies: SCOOT and fixed time. Delay was compared at intersection level and at overall corridor level. Table 5 shows delay benefits. Figure 6 shows the plot of percent benefit from SCOOT caused by reduction in delay at varying congestion levels.

Insert Table 5 here.

Insert Figure 6 here.

The results show that SCOOT improved the system performance compared to that achieved by fixed-time control, for the simulated traffic conditions on the test corridor. Delay improvements of up to 17% observed at individual intersections. Though the performance of some intersections deteriorated under SCOOT control at higher v/c ratios, SCOOT performs better at the corridor level. The benefits at different congestion levels, however, varied in a non-linear fashion. Benefits increased with increase in congestion until the corridor operated at saturated condition. This increase was likely because inflexible fixed-time plans caused higher delays at higher v/c ratios while SCOOT dynamically adjusted the split, cycle and offsets to minimize delay. Maximum benefits were realized at a v/c ratio of 0.9. However, minimal benefits were observed as soon as the corridor traffic flows approached saturated or over-saturated conditions. This result was likely because high traffic volume utilized most of the available green time and SCOOT had lesser flexibility to optimize splits.

**VALIDATION**

Validation is a key step in setting up SCOOT to model properly the on-street traffic flow conditions of a specific network. Validation is a one-time activity in SCOOT’S initial set-up and is primarily related to the geometry of the network and not the flow. Validation is also an iterative process to validate the saturation occupancy and journey time. Nine iterations were done in SCOOT before all required parameters were validated to the desired accuracy. Simulations were made after each subsequent validation to observe the benefits of that particular iteration. The validation curve in Figure 7
demonstrates the increasing benefits of validation for the corridor operating at the 0.7 v/c ratio.

The validation curve shows the importance of validation following the setup of a SCOOT system. Before validation, SCOOT performed worse by 219% as compared to fixed-time control. Subsequent validations increase the benefits of SCOOT giving a maximum benefit of 8% for the corridor operating at 0.7 v/c ratio. This clearly indicates that SCOOT is not a ‘plug and play’ system. Rather, it needs extensive validation during its installation. However, once validated, no further validation was necessary at the other congestion levels or as flow varies.

*Insert Figure 7 here.*

**TESTING REAL WORLD CORRIDORS**

Two real-world corridors are modeled to establish the validity of the test corridor results. One is in downtown Salt Lake City, with 700 foot spacing. The other is adjacent to the E-Center. The E-Center is an entertainment complex located in West Valley City, about 9 miles south of Downtown Salt Lake City, Utah. It hosts sporting events and music concerts. Data was collected there during a concert. It has large unevenly spaced intersections with an average of 1500 foot. The data is five-minute flows from the PM peak period. Geometry and signal phasing along with the current signal timing was also collected. Synchro provides updated signal timing for the specific flows observed. This produced fewer delays than if the observed existing timing had been used. Furthermore, it provides a conservative assessment of SCOOT’s operational benefits.

**Salt Lake City Downtown Corridor**

Eight intersections along State Street, the major north-south corridor, are modeled as shown in the gray band in Figure 8. Geometry, volumes and timing plans generated two CORSIM input files, two CORSIM input files are generated: one for Synchro timings, the other for SCOOT control. A v/c analysis of the corridor shows that it operates at a 0.85 v/c ratio.

*Insert Figure 8*

**E-Center Corridor**

This corridor was selected because it is adjacent to the E-Center complex. Five intersections along 3500 South are modeled. Figure 9 shows the layout of the E-Center network with the gray band demarcating the 3500 South corridor. Traffic volume data was collected in 5-min intervals from 5:00 PM to 7:00 PM during a concert at the E-Center. The average v/c ratio of the corridor was 0.83.

*Insert Figure 9*
Real-World Corridor Modeling Results

Table 6 represents the benefits of SCOOT over fixed-time control. SCOOT reduces delay, queue length, and corridor travel times for the two real-world corridors. SCOOT delay reductions at individual intersections ranged from –16% to +28%. The results indicate that SCOOT reduced overall corridor delay by 14% on the Downtown corridor and 11% on the E-Center corridor. On the downtown corridor, SCOOT reduced both queue length and travel time by 5%. On the E-Center corridor, SCOOT reduced queue length by 10% and travel time by 8%.

Insert Table 6

CONCLUSIONS

The SCOOT-CORSIM Interface developed at the University of Utah allows the testing of simulated networks under SCOOT control. Modeling of the test corridor operating at different congestion levels identified the benefits of SCOOT compared to fixed-time plans. The result is an anticipated benefit of SCOOT for a given congestion level. This was tested on two real-world corridors in the Salt Lake Valley.

1. Delay reductions for SCOOT over fixed-time control at 0.7 v/c ratio were 8%, which increases to 13% at 0.9 v/c ratio. These reduce to a 0% difference for the over-saturated 1.1 v/c ratio. SCOOT thus performs better at under-saturated traffic flow conditions and these benefits improve as the corridor approaches saturation. This implies that SCOOT helps in delaying the onset of congestion. However, as the traffic on the corridor reaches saturation, the benefits from SCOOT are minimal and it performs as a fixed time control system for over-saturated conditions. This is also true for any of the actuated signal control methods. All directions demand maximum green times and therefore constrain any demand dependent optimization to operate as fixed-time.

2. Validation is an important installation requirement. A non-validated SCOOT system provided 219% worse than a fixed-time plan based control regime. However, after proper validation SCOOT reduced the corridor delay by 8%. This is important as many traffic engineers believe that these adaptive systems are “plug and play”. Validation of the system is important in producing positive results.

3. The testing of two real-world corridors showed SCOOT provides reduced delay, travel time and queue lengths over an updated fixed-time timing plan. From the simulation, a 14% reduction in overall delay was measured on the 8-intersection Downtown corridor. During a special event at the E-Center, an 11% reduced delay was achieved on the 5-intersection corridor.

This research connects an actual SCOOT system to a simulated environment that has not been available until now. Attempts have been made to utilize other simulation tools to “estimate” how adaptive control would work, but they are attempting to “simulate” the
adaptive control algorithms. By using an actual SCOOT system, the results are more reliable as the algorithms use the actual decision process instead simulated ones.

FUTURE RESEARCH

Now that a typical corridor has been modeled and compared under fixed-time and adaptive signal control regimes, future work will focus on expanding this research by varying intersection geometry and intersection spacing in the test corridor. This variation will help in studying the effect of changes in queue discharge rates due to changes in the number of lanes and platoon dispersion due to increased spacing. Future work will also focus on evaluating crossing corridors and entire networks operating at varying congestion levels. Since the SCOOT philosophy emphasizes network-wide optimization, such a study will compare the benefits of deploying SCOOT in networks versus corridors. In addition to CORSIM, an interface to VISSIM with SCOOT was also constructed and is currently evaluating SCOOT’s bus priority capabilities within simulation.
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### TABLE 1 SCOOT Comparison Studies

<table>
<thead>
<tr>
<th>Location</th>
<th>Previous Control</th>
<th>Journey Time Savings %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AM Peak</td>
</tr>
<tr>
<td>Glasgow, Scotland</td>
<td>Fixed Time (TRANSYT)</td>
<td>-2</td>
</tr>
<tr>
<td>Coventry, Foleshill</td>
<td>Fixed Time (TRANSYT)</td>
<td>23</td>
</tr>
<tr>
<td>Coventry, Spon End</td>
<td>Fixed Time (TRANSYT)</td>
<td>8</td>
</tr>
<tr>
<td>Worcester</td>
<td>Fixed Time (TRANSYT)</td>
<td>7</td>
</tr>
<tr>
<td>Southampton</td>
<td>Isolated Vehicle Actuated</td>
<td>40</td>
</tr>
<tr>
<td>Worcester</td>
<td>Isolated Vehicle Actuated</td>
<td>31</td>
</tr>
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TABLE 2 SCOOT Advantages Over Fixed-Time Coordination

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SCOOT vs. Fixed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time</td>
<td>Reduced by 8%</td>
</tr>
<tr>
<td>Vehicle Stops</td>
<td>Reduced by 22%</td>
</tr>
<tr>
<td>Vehicle Delay</td>
<td>Reduced by 17%</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>Reduced by 5.7%</td>
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</tbody>
</table>

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Paper revised from original submittal.
TABLE 3 Summary of Adaptive Control Systems Literature Review

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>Installations</th>
<th>Type of Installation</th>
<th>Processing Location</th>
<th>Central Computer</th>
<th>Field Controllers</th>
<th>Sensor Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCOOT</td>
<td>More than 170 Installations worldwide (4-600 intersections)</td>
<td>Field Installation, Simulation</td>
<td>Central</td>
<td>DEC Alpha</td>
<td>NEMA, 170, 2070, TCT and TR0141</td>
<td>Upstream end of controlled link</td>
</tr>
<tr>
<td>RHODES</td>
<td>4 Installations</td>
<td>Test Deployment</td>
<td>Distributed</td>
<td>Not Required</td>
<td>2070 with VME coprocessor</td>
<td>Upstream end of controlled link and stopbar</td>
</tr>
<tr>
<td>SCATS</td>
<td>More than 20 Installations (Australia, New Zealand, United States, China, Ireland, Hong Kong, Tehran)</td>
<td>Field Installation</td>
<td>Central for overall network control</td>
<td>PC with Windows ® NTTM</td>
<td>2070/2070N 170 NEMA-Delta 3N</td>
<td>Immediately in advance of stop-line</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distributed for local control of green phase</td>
<td></td>
<td>In Australia, microprocessor based Philips and AWA models</td>
<td>Minor intersections require side street sensors only</td>
</tr>
<tr>
<td>OPAC</td>
<td>2 Installations (Reston Parkway, Virginia and New Jersey)</td>
<td>Test Deployment</td>
<td>Distributed, except for central control of cycle length</td>
<td>PC with Windows ® NTTM</td>
<td>2070 with VME coprocessor 170 with 68360 processor LMD 9200</td>
<td>Upstream about 8 to 12s from stop line or upstream of worst queue of all through phases</td>
</tr>
<tr>
<td>LA-ATCS</td>
<td>1 Installation (City of Los Angeles)</td>
<td>Field Installation</td>
<td>Central</td>
<td>IBM PC</td>
<td>2070(new model) or 170</td>
<td>200 to 300 feet upstream of the stop-line</td>
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<tr>
<td>V/C</td>
<td>Pre-timed Control</td>
<td>Actuated Control</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Actuated uncoordinated</td>
<td>Actuated coordinated</td>
<td>Fully actuated</td>
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<tr>
<td>0.7</td>
<td>67</td>
<td>75</td>
<td>67</td>
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<td>116</td>
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<td>1.1</td>
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### TABLE 5  Delay Benefits from SCOOT on the Corridor at Different Congestion Levels

<table>
<thead>
<tr>
<th>Intersection ID#</th>
<th>V/C 0.7</th>
<th>V/C 0.8</th>
<th>V/C 0.9</th>
<th>V/C 1.0</th>
<th>V/C 1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FT*</td>
<td>SC*</td>
<td>% Ben*</td>
<td>FT</td>
<td>SC</td>
</tr>
<tr>
<td>1</td>
<td>32.1</td>
<td>29.0</td>
<td>10%</td>
<td>43.3</td>
<td>36.2</td>
</tr>
<tr>
<td>2</td>
<td>31.6</td>
<td>29.0</td>
<td>8%</td>
<td>38.4</td>
<td>35.7</td>
</tr>
<tr>
<td>3</td>
<td>28.3</td>
<td>25.6</td>
<td>10%</td>
<td>35.4</td>
<td>33.4</td>
</tr>
<tr>
<td>4</td>
<td>29.2</td>
<td>27.9</td>
<td>5%</td>
<td>36.0</td>
<td>33.9</td>
</tr>
<tr>
<td>Total</td>
<td>121.2</td>
<td>111.4</td>
<td>153.1</td>
<td>139.2</td>
<td>189.2</td>
</tr>
<tr>
<td>Average Benefit</td>
<td>8%</td>
<td>9%</td>
<td>13%</td>
<td>1%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*FT = Fixed Time Control, SC = SCOOT Control, % Ben = Percent benefit from SCOOT
TABLE 6 Comparing SCOOT and Fixed-Time Control

<table>
<thead>
<tr>
<th>Measure of Effectiveness</th>
<th>% Benefit of SCOOT over Fixed-time Downtown</th>
<th>% Benefit of SCOOT over Fixed-time E-Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Queue Length</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Travel time</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>
FIGURE 1  Daily flow variation in Murray, Utah on December 20, 2001
FIGURE 2 Yearly flow variation in Murray, Utah
FIGURE 3  SCOOT-CORSIM Interface
FIGURE 4 Layout of the test corridor and a typical approach
FIGURE 5  Total network volume at 0.7 volume-capacity ratio
FIGURE 6 Percent benefit from SCOOT at varying congestion levels
FIGURE 7  Benefits from subsequent validation attempts
FIGURE 8  Downtown Salt Lake City Corridor
FIGURE 9 E-Center Corridor