Deploying SCOOT in Seattle

Using Adaptive Signal Control to improve travel times and reliability in a growing Central Business District

Abstract:

Adaptive signal control technology (ASC) is growing in popularity in the United States because of its ability to automatically adjust in real time the timing plan of traffic signals based on prevailing conditions and traffic demands.

Siemens SCOOT is the ASC selected by the Seattle Department of Transportation (SDOT) to improve overall travel times and travel reliability in their busiest corridors. SCOOT determines traffic levels, predicts the flow of traffic, and adjusts the amount of time available to each movement through an intersection.

This paper discusses SDOT's implementation of SCOOT in its Mercer Corridor, a critical arterial that serves the City's growing South Lake Union technology hub.

Based on the successful deployment in June 2017, traffic signal performance measures have reduced travel times an average of 21% along the corridor during the busiest peak hours.

Other cities with growing downtown populations should take note that this type of technology can be a cost-effective way to manage traffic on busy arterials.

I. Background

Seattle's Mercer Corridor has been one of the City's most significant transportation challenges for more than 40 years. At the eastern end was the Mercer and Valley streets couplet, a circuitous one-way route that was constructed in the late 1950s as a temporary solution to provide access to I-5 as it was being built. The couplet remained in place after I-5 was built, slowing traffic and often leading to congestion backing up onto the freeway. The other streets in the area were also one-way, further slowing traffic.

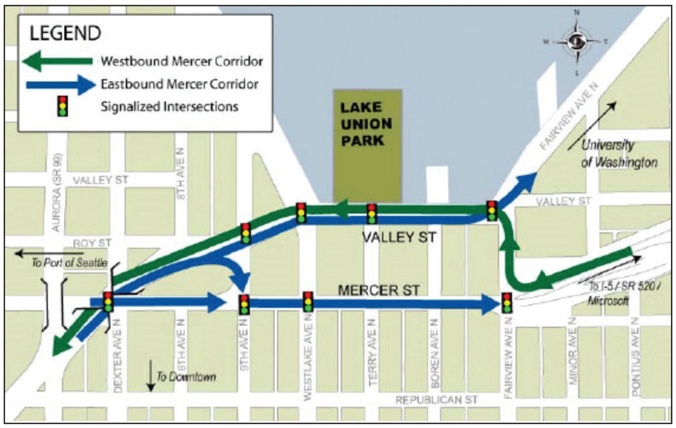

Figure 1: The Mercer Corridor Before Reconstruction

In recent years the bottleneck, nicknamed the "Mercer Mess," hindered access to Seattle's fastest growing neighborhood, the South Lake Union technology hub. The area is home to Amazon's headquarters, a future Google campus, the Bill and Melinda Gates Foundation, the Paul Allen Institute for Brain Science, and major biotech campuses for the University of Washington. The Seattle Center and Key Arena, which host major events, are farther west on Mercer. The corridor also includes a residential neighborhood with a small business district. At the eastern end are the on and off-ramps to I-5. About 31,000 people use the corridor during the weekdays.

Over the past few years, the Corridor underwent a major reconstruction that included turning Mercer, Valley, Roy, and all of the blocks in between into two-way streets. While this reconstruction helped unsnarl traffic, it didn't resolve congestion issues. For that the City of Seattle decided to implement adaptive signal control (ASC).

The Seattle Department of Transportation (SDOT) has been taking a strategic approach to tackling traffic congestion. As part of its Next Generation Intelligent Transportation Systems (ITS) program, SDOT has implemented a number of traffic control systems. It was important that the ASC system take advantage of existing equipment and integrate well with current and future traffic control systems.

Working with the Transpo Group, a transportation planning and engineering firm, SDOT performed a Systems Engineering process that documented existing signal infrastructure and identified operator needs for adaptive signal control.
An industry survey followed, which helped the City evaluate the most developed and deployed ASC systems, including ASC Lite, InSync, SCATS, SCOOT, OPAC, and LA ATCS. Using the Concept of Operations and System Requirements documents as guidelines, SDOT procured the Siemens SCOOT ASC system based on its ability to align with existing and future programs and be sustainable from a maintenance and operations perspective.

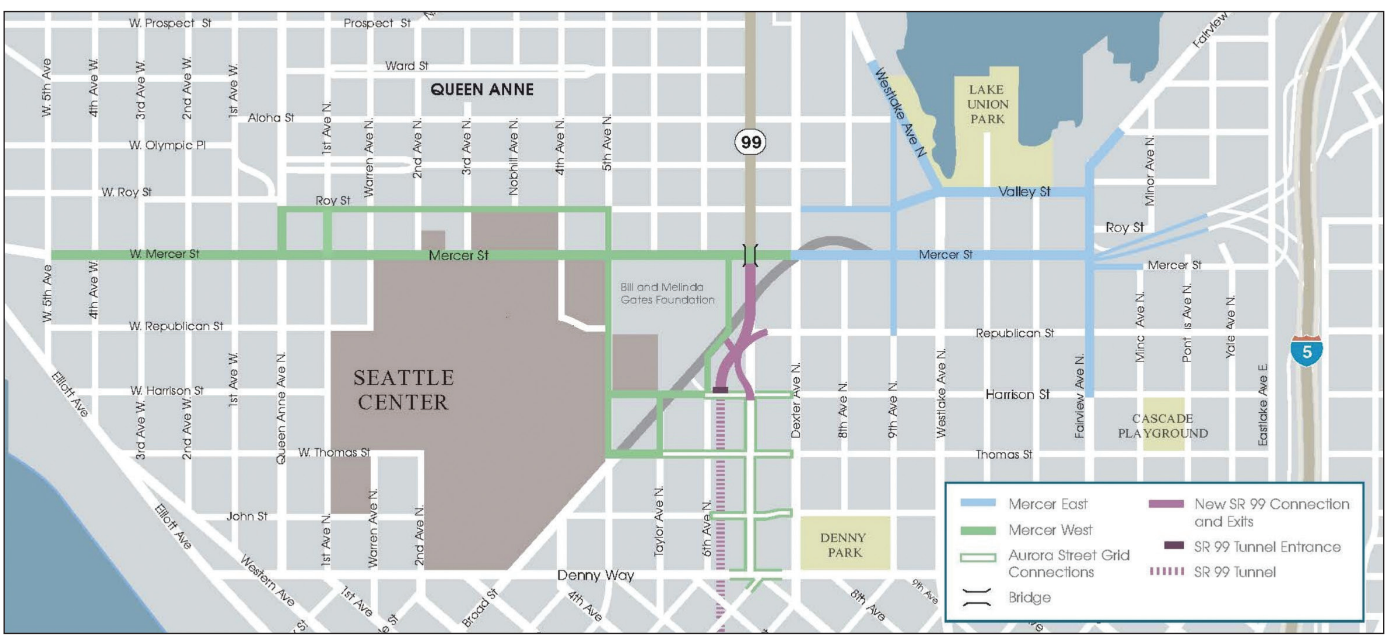

Figure 2: The Mercer Street Corridor After Reconstruction

Figure 3: Mercer Street Corridor with Bill and Melinda Gates Foundation in the Foreground

II. About SCOOT

Siemens SCOOT (short for Split Cycle Offset Optimization Technique) is an adaptive traffic signal control system and algorithm that adjusts signal timing in real-time to match traffic patterns. Traditional traffic control systems use programmed traffic plans that depend on the time of day for implementation. For example, Seattle has specific AM and PM Peak plans, Off Peak, and Late Night plans. SCOOT adds a dynamic component that takes real-time conditions into account in order to relieve congestion.

SCOOT determines traffic levels, predicts the flow of traffic, and adjusts the amount of time available to each movement through an intersection. It uses detectors at every intersection to continuously measure traffic levels and update signal timing plans. It optimizes the signal timings at each intersection to minimize delays and stops. SCOOT also has the ability to change the offsets, the cycle length, and the splits. Timing changes are small enough to avoid major disruption to traffic flow and frequent enough to allow rapid response to changing traffic conditions.

Figure 4: SCOOT in Action in SDOT's Transportation Operations Center

For example, on a typical day the PM peak starts at 5:00 p.m. But on any given day there can be lighter traffic and the peak doesn't start until 5:30 p.m. SCOOT will detect the real-time traffic flow and run a lower cycle length, which is more efficient and can run more cars a lot faster. The opposite is also true. If rush hour begins earlier, SCOOT will initiate the peak plan earlier.

A proven system, SCOOT provides significant benefits:

- Faster travel times
- Reliable travel times
- Reduced emissions and fuel consumption
- Special events traffic management

III. Pre-deployment SCOOT Simulation

Transpo Group worked with Siemens and Western Systems to simulate the SCOOT system along the Mercer Corridor in before and after conditions based on current traffic volumes and turning movement counts. Before the system was implemented in the field, they used VISSIM traffic simulation software to create the corridor models supporting signal operations performance measurement. The before model incorporated standard time of day plans while the after model incorporated the SCOOT algorithm. This type of simulation accounts for small variations in driver behavior that can have a large effect on the throughput of the road network. For example, a transit stop, taxi drop-off or pick-up, and heavy trucks with slower acceleration than standard passenger vehicles can restrict or limit vehicle throughput, impacting overall delay in the network.

After SCOOT system deployment, Transpo Group measured actual corridor performance to validate the system and worked with the City to develop internal and external performance measures. These performance measures were derived from vehicle detection equipment including Sensys in-pavement sensors, EDI data aggregators, Acyclica Bluetooth/Wi-Fi readers, and transit agency data sources. The internal performance measures are used by SDOT to get a better picture of how the system is performing and to identify potential locations where improvements can be made. The external performance measures are shared with the public and include changes in average travel time, travel time reliability, and traveler savings. Travel time reliability is a measure of day-to-day variance in travel times along the same corridor. Corridors that have high reliability will take the same amount of time to drive each day, while corridors with low reliability will take a long time to drive one day and a short time the next. Improved reliability is important so that drivers can more accurately plan how much time it will take to get to their destinations. Traveler savings are calculated by applying travel times savings to average vehicle volumes and include emissions, fuel consumption, and value of time.

IV. Implementation

Mercer Corridor is the first SCOOT installation in Seattle. As the City's busiest corridor, it is the ideal location for an ASC system. There are a lot of elements at play that make it very dynamic, including the number of large employers, the Seattle Center and Key Arena, transit buses, street cars, bicyclists, pedestrians, and I-5. The changes in traffic patterns can be severe, making an ASC system an extremely useful traffic management tool.

Adding to the challenge is that the Mercer Corridor is composed of several parallel streets and numerous intersecting streets. The Mercer corridor includes Valley and Roy Streets as well as Mercer from I-5 to 5th Avenue West.

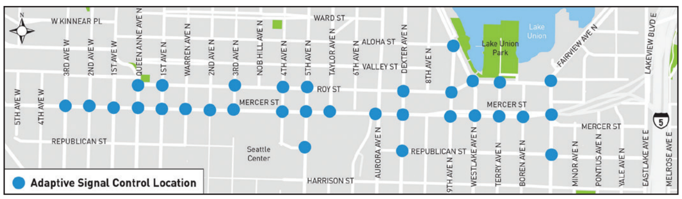

Figure 5: Mercer Corridor Adaptive Signal Control Locations

New hardware, magnetometers and video detectors were placed in the 33 intersections within the corridor. To ensure detection on the major corridors going into the system, an additional six intersections received detectors although they are not running SCOOT. The detectors were placed upstream from each intersection, about 300 to 400 feet back. This gives SCOOT time to tally cars approaching the light and make adjustments – such as holding a green light – before a queue forms.

The decision was also made to replace all the controllers in order to be able to use the latest SEPAC software and stronger processors, which are able to maintain communication 100 percent of the time. Once all of the hardware, detectors, and controllers were in place, SDOT began working on the database with Siemens and Western Systems. SCOOT sits on its own servers. This is important because if there any issues due to communications failure, the system can fall back on local control in SEPAC.

SDOT created all the links for the detectors and made sure all the intersections were properly input into in the database. Once the database was completed, SDOT began timing and fine tuning the system. The testing process included field observations and refinement of the parameters to ensure that the system operates well.

The SCOOT architecture works in parallel with Siemens TACTICS system, a traffic control system SDOT currently uses to monitor traffic signals. SCOOT is initiated via a scheduler. The detectors send data to a control computer every second in ¼-second bytes. Based on data from a detector, SCOOT issues commands that are relayed to the traffic controller. If no SCOOT commands are issued for three seconds, the controller reverts to its default "background" mode.

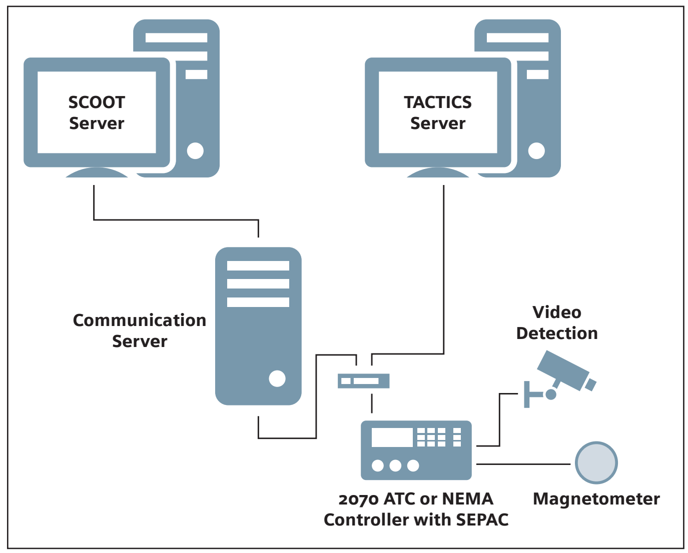

Figure 6: SCOOT Architecture

All 33 of the Mercer Corridor intersections are connected to the SCOOT server, forming a network. The system continually makes calculations on every link in the network. The goal is to reduce the split time, which will reduce congestion. Green light times are continuously recalculated at every phase change of an intersection. Offsets between intersections are recalculated once per cycle, with cycle times recalculated every 2.5 to 5 minutes.

V. Benefits of the Seattle system

With SCOOT, Seattle has seen overall improvements in the predictability of travel times and in special event timing. SCOOT can read the changes in traffic conditions and adjust the system so that it's much more reliable.

To assess the overall performance of the system, vehicle data is collected daily and compared to historical averages before SCOOT was in use. Reporting periods include the three-hour morning and evening peak travel times in both the eastbound and westbound directions during the five-day work week. These periods are when traffic volumes are at their highest.

Internal performance measures provide higher resolution metrics broken down by individual corridor segments and the complete corridor. Figure 7 (below) shows eastbound travel time along the complete Mercer corridor between Queen Anne Avenue North (Seattle Center) and Fairview Avenue (access to I-5).

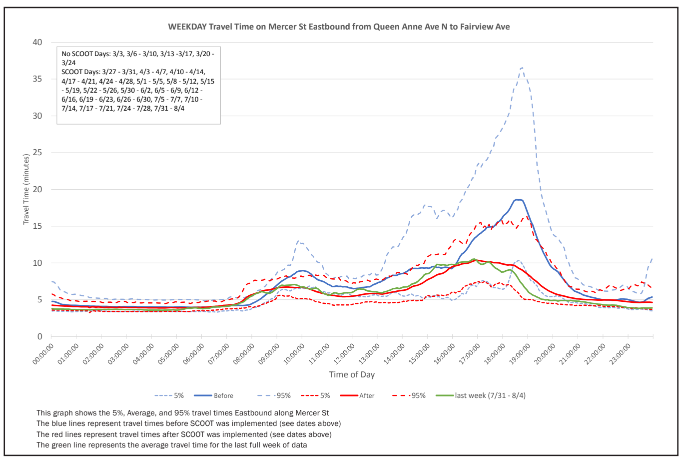

Figure 7: Internal Performance Measures: Yearly Savings Per Vehicle During Peak Periods

The following external performance measures show the changes to average speed, average travel time, travel time reliability at the end of July 2017 for the westbound and eastbound peak periods.

WEST BOUND 3 HR PEAK	AVERAGE SPEED	AVERAGE TRAVEL TIME	TRAVEL TIME RELIABILITY	VEHICLES THROUGHPUT
AM	2.6 mph ↑	0.7 mins. ↓	3% ↑	4,890 vehicles
PM	3.0 mph ↑	1.5 mins. ↓	9% ↑	4,640 vehicles

Figure 8: External Performance Measures: Westbound Three Hour Peak Periods

The eastbound PM peak period, which is headed toward I-5 and is the segment with the greatest number of vehicles at 8,785, shows the greatest improvement. People driving during the eastbound PM peak are moving an average of 6.2 minutes faster and experiencing a 33% increase in travel time reliability compared to before SCOOT installation.

AVERAGE SPEED	AVERAGE TRAVEL TIME	TRAVEL TIME RELIABILITY	VEHICLES THROUGHPUT	EAST BOUND 3 HR PEAK
21.9 mph ↑	0.9 mins. ↓	3% ↓	5,465 vehicles	AM
4.5 mph ↑	6.2 mins. ↓	33% ↑	8,785 vehicles	PM

Figure 9: External Performance Measures: Eastbound Three-Hour Peak Periods

The volume data allows SDOT to calculate yearly time, carbon emissions, and fuel savings. The values are based on the average for a weekday commuter traveling westbound during the AM peak and eastbound during the PM peak. This is representative of a commuter driving into South Lake Union for work in the morning and driving home (to I-5) in the afternoon and reflect the highest volume periods during the day. Applying the time savings and average volumes during the peak periods, the following yearly savings can be calculated:

- Time savings: 36.4 hours per vehicle annually for a total savings of $4.8 million per year[1]
- Fuel savings: 31.67 gallons per vehicle annually for a total savings of $713,564 per year[2]
- CO2 emissions savings: 620.7 pounds per vehicle annually for a total reduction of $83,915 per year[3]

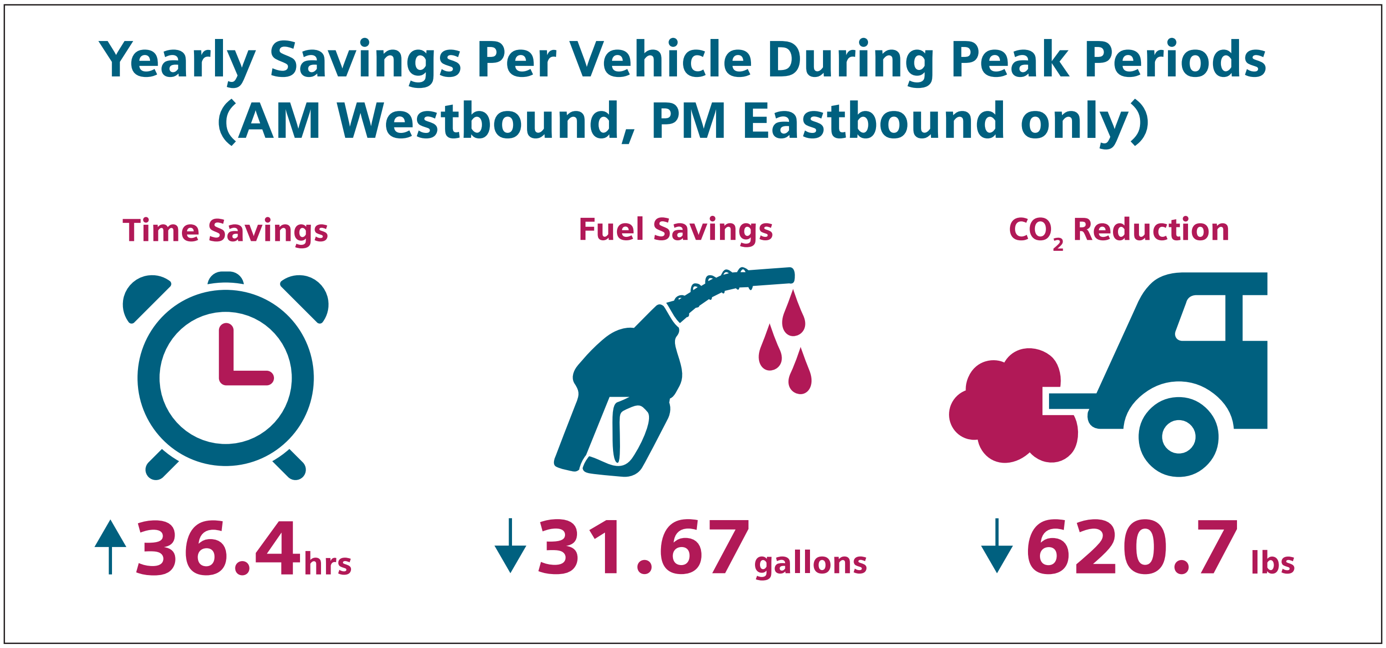

Figure 10: External Performance Measures: Eastbound Travel Time on Mercer

VI: Transit Implications and Planned Deployments

The improvements in reliability have had a positive effect on transit lines in the Mercer Corridor. Before the SCOOT implementation, SDOT supported transit signal priority (TSP) at a few Mercer Street intersections. To test SCOOT's impact on transit, SDOT decided to delay integration of TSP into the SCOOT algorithm, which the system does support. Even without TSP integration, SDOT is meeting the same level of service or better, including more predictable transit travel times. Integration of TSP is currently under evaluation, especially at key left-turn transit movements.

Now that the Mercer Corridor is fully deployed and operational, SDOT plans to expand the SCOOT system to the Denny Corridor eight blocks to the south. The Denny Corridor includes approximately 20 intersections and the project may include additional intersections between the two corridors. The City is also considering deploying SCOOT along the Madison Bus Rapid Transit corridor and the Roosevelt transit corridor.

Footnotes

1. Based on yearly time savings generated by vehicles during AM/PM peak periods multiplied by $17.67/hr multiplier for time value of money for passenger cars, sourced from 2015 Urban Mobility Scorecard, Texas A&M Transportation Institute, 2015.

2. Based on annual change in travel time for AM/PM peak periods; using conversion factors from Argonne National Laboratory, a passenger car that idles at 1,000 rpm with air conditioning on 50% of the time can be expected to consume 0.87 gallons of fuel consumed per hour and average cost of $3.00/gallon for fuel, sourced from Analysis of Costs from Idling and Parasitic Devices for Heavy Duty Trucks, Technology and Maintenance Council Recommended Practice Bulletin 1108, issued March 1995, reprinted 2003 by TMC/ATA; and Lutsey, N.P., J.P. Wallace, C.J. Brodrick, H.A. Dwyer, and D. Sperling, Modeling Auxiliary Power Options for Heavy-Duty Trucks: Engine Idling vs. Fuel Cells. Society of Automotive Engineers Report No. 2004-01-1479, October 2004.

3. Based on annual change in travel time for AM/PM peak periods; assumes 0.87 gallons of fuel consumed per hour and an emissions coefficient of 19.60 pounds of CO2 per gallon of gasoline, sourced from U.S. Energy Information Administration Carbon Dioxide Emissions Coefficients by Fuel, 2016.

About the Report

Siemens would like to thank the City of Seattle, Western Systems, and Transpo Group for their support, including providing data and lending expertise.

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