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Ann Arbor SCOOT Mobility Study

Evaluating the SCOOT Adaptive Signal Control Technology Through the Use of Big Data

Abstract:

Adaptive traffic signal control systems offer cities and local governments a cost-effective and dynamic means to optimize traffic flow. These systems work alongside existing traffic control, incorporating real-time traffic movement data to continually optimize signal timing. While adaptive traffic signal systems have been in existence for decades, few performance tests have been completed due to cost and manpower barriers.

The advent of “Big Data” technologies and methods makes possible a cost-effective way to study the effectiveness of traffic control systems. In Ann Arbor, Michigan, Siemens and its mobile data analytics partner, StreetLight Data, completed a test of the Siemens SCOOT adaptive traffic signal control system using these new techniques. The study shows that SCOOT is able to reduce travel times by 10 – 20 percent and provides a blueprint for traffic engineers wanting to complete similar studies to evaluate system performance.

This paper highlights the testing process, results and implications for future studies, and the further adoption of adaptive control technologies.

I. Background and Motivation

In 2015, the Mobility Division of Siemens Industry launched the Ann Arbor Center for Excellence in partnership with the City of Ann Arbor, Michigan. The purpose of the Center is to demonstrate how smart technology investments in transportation can help reduce congestion and pollution. Learnings from the Center are helping Siemens and local governments apply these technologies in ways that improve the standard of living for citizens while working within budget constraints.

A top priority for the Center was to complete a study on the performance of the Siemens SCOOT adaptive traffic signal control system, which has been used in Ann Arbor for more than a decade. Despite more than 200 system installations worldwide, there are few studies published about the effectiveness of this and similar traffic control systems. The most widely referenced studies in North America were completed during the 1990s.

The lack of studies is due primarily to the high cost barrier of conducting them, as well as statistical limitations of traditional research methods. The traditional form of before-after studies on traffic signal systems relies on the use of a large team of observers armed with stopwatches and click-timers completing test-drives through the target area. Studies can cost between $100,000 and $200,000 each and provide data on only a limited time period.

In the era of “Big Data”, where data is captured through a variety of new sources, these barriers are eliminated. By algorithmically processing the vast amount of mobile data that is captured and utilized for commercial fleet management, personal navigation, and other location-based applications, mobility analytics providers like StreetLight Data can now measure travel behavior and evaluate traffic performance over long periods of time, and within specific corridors or zones. These new technologies and methods made the Ann Arbor study possible.

II. About SCOOT Adaptive Traffic Signal Control

Siemens SCOOT (short for Split Cycle Offset Optimization Technique) is an adaptive control system and algorithm, which adjusts signal timing in real-time to match traffic patterns. The system was originally developed in the 1980s and has evolved over time as new technologies and expertise were introduced.

SCOOT adds a dynamic component to static control systems. Traditional traffic control systems rely on pre-programmed controls to manage traffic flow. For example, signals may have one program for the morning rush hour and another one for evening rush hour, and other settings for mid-day and overnight; however, these systems are limited in that they cannot adapt to actual conditions on the road, such as a University of Michigan football game or other events that do not conform to regular traffic patterns. Traditional systems also need to be reprogrammed over time, as population shifts and new construction impact traffic patterns; this is a significant investment for local governments.

SCOOT eliminates many of the shortcomings of traditional systems. By placing additional sensors within a traffic corridor that can communicate with the SCOOT system and traffic signals, the timing of lights can be continually optimized based on real conditions.

How SCOOT Works

SCOOT uses a detection device placed upstream from an intersection to monitor and signal congestion. The most common detection device is the same looped-wire traditionally used at the stop bar of an intersection. Video cameras and magnetometers are also viable detectors. The detection device sends data to a control computer every second in ¼-second bytes.

Detectors are usually placed about 300 to 400 feet back from an intersection. This allows the system to begin tallying cars approaching the light and make adjustments (such as giving or holding a green light) before a queue forms.

The architecture of SCOOT works in parallel with existing central traffic management systems, such as the Siemens TACTICS system. SCOOT is initiated via a scheduler. Based upon data from the detector, SCOOT issues commands that are relayed to the traffic controller. If no SCOOT commands are issued over a period of three seconds the controller reverts to its default “background” mode.

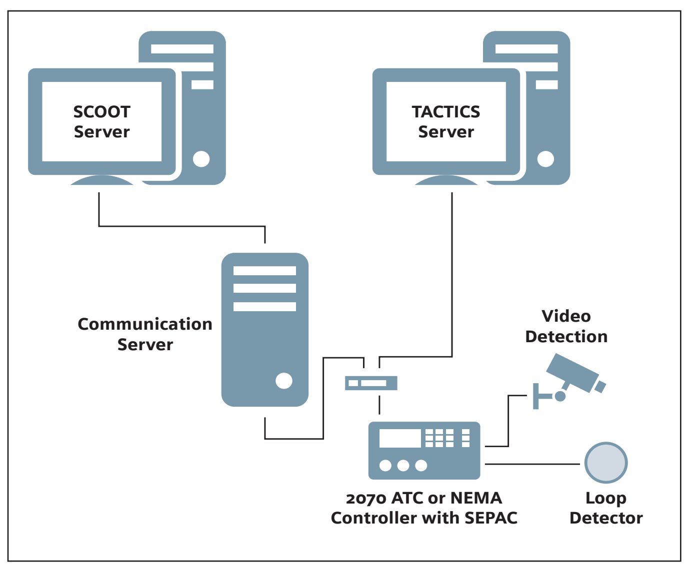


Figure 1. SCOOT Architecture

SCOOT Operations

A typical SCOOT implementation is comprised of multiple intersections all connected to the SCOOT Server, forming a network. The system continually makes calculations on every link in the network. The diagram (Fig. 2, below) shows an example operation where the gray area represents the traffic queue. The goal of SCOOT is to reduce the gray area, known as the split, which will reduce congestion and delays.

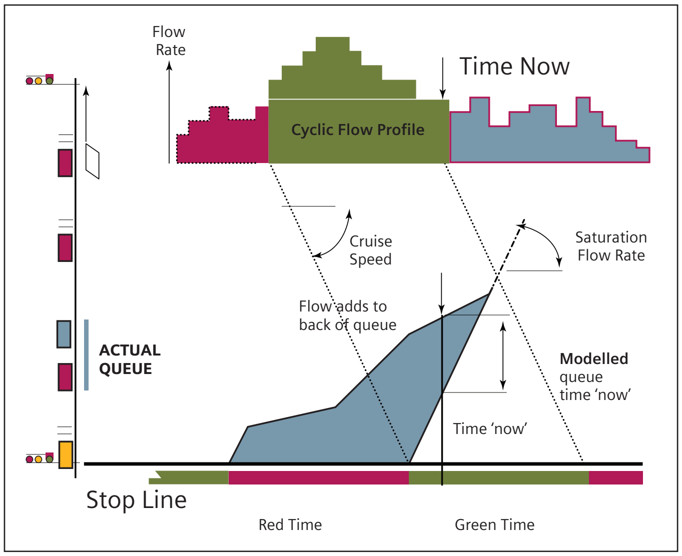


Figure 2. SCOOT Operations

Green times are continuously recalculated at every phase change of every intersection. Offsets between intersections are recalculated once per cycle, with cycle times recalculated every 2.5 or 5 minutes.

SCOOT Benefits

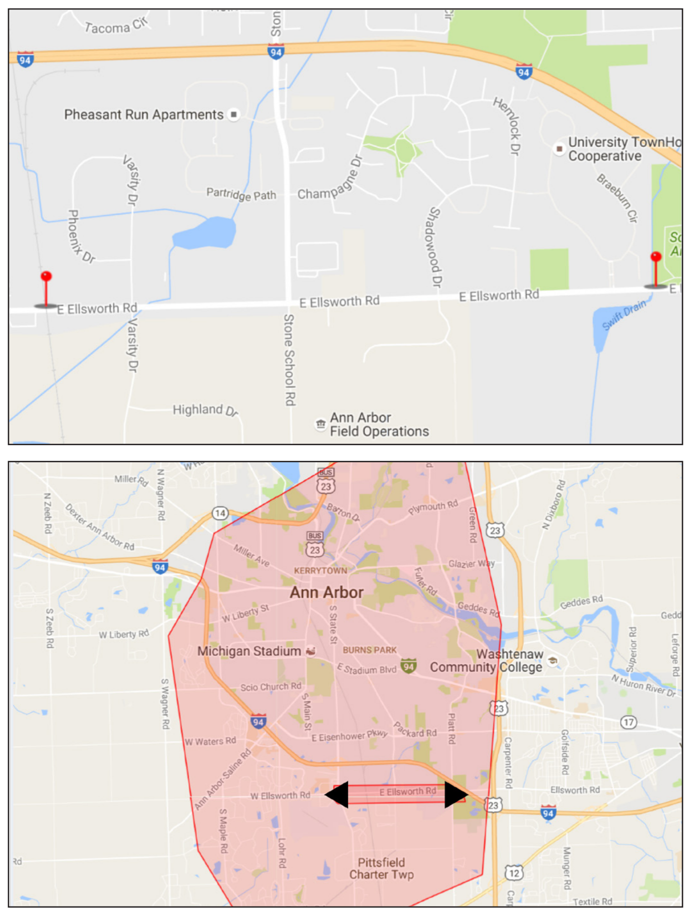
Using adaptive technology to dynamically adjust signaling, SCOOT significantly reduces congestion and queues, and improves traffic flow based on real-time conditions. Benefits of this system include:

- Improved quality of life for local citizens spending less time in traffic, which also leads to increased productivity for businesses
- Reduction in carbon emissions as a result of less congestion and idling
- Improved flow of traffic during special events and other non-recurring activities
- Timing of signals can automatically adjust to population shifts and new construction, without costly reprogramming

In Ann Arbor, the SCOOT system helps traffic officials better manage irregular traffic patterns caused by the University of Michigan. On any given weekday, an additional 130,000 people commute into this city of 113,000, while another 40,000 commute in the other direction. As a college town, Ann Arbor's traffic does not conform to standard morning and evening rush hour patterns and hosts many special events. Over the past 14 years, the City of Ann Arbor has taken advantage of the SCOOT system to help increase traffic flow.

III. Study Design and Implementation

The Ann Arbor study took place along the city's Ellsworth Corridor, a 2-mile stretch just a few miles south of the University of Michigan South Campus and Michigan Stadium. In November 2015, Ann Arbor extended its use of SCOOT to include this corridor. The Ellsworth Corridor was a well-timed corridor and recently re-timed. It is only a single-lane in each direction and experiences high volumes of traffic; it is frequently used as a bypass by many drivers looking to avoid congestion on nearby Interstate 94.



Figures 3 and 4. Ann Arbor's Ellsworth Corridor

The timing of the installation was fortuitous for Ann Arbor and Siemens. Big Data sources of detailed traffic information were becoming available from aggregators like StreetLight Data, with some data sets dating back to 2014. As a result, a comprehensive before-after study could be completed using data collected as far back as a year before SCOOT installation. To help with data acquisition and analytics, Siemens and Ann Arbor enlisted the help of StreetLight Data and its StreetLight InSight® web application.

About StreetLight Data

StreetLight Data is a mobility analytics provider that transforms trillions of geospatial data points from GPS and cellular devices into actionable metrics for transportation and urban planning, infrastructure design, business, and research.

StreetLight Data's metrics are accessed via *StreetLight InSight*, an easy-to-use web application that allows users to generate custom mobility analytics for specific projects. These metrics are also easier to generate and more accurate than traditional data collection methods; for example, surveys and license plate studies.

Data Collection, Analysis and Validation

For the Ann Arbor study, detailed metrics on travel patterns along the Ellsworth Corridor were collected using *StreetLight InSight*. The metrics were derived from anonymous, archival GPS data that was originally recorded by smart phone apps and connected cars. The data, provided by StreetLight partner INRIX, was spatially and temporally precise, pinging every five meters and at intervals of a few seconds.

The *StreetLight InSight* web application analyzed more than 11,000 trips that traveled the entire length of the Ellsworth Corridor and an additional 30,000 trips that touched the corridor but did not go the full length. The data was gathered for the period of December 2014 through May 2016. Automated data processing and analysis took less than 15 minutes to run.

For the analysis, the *StreetLight InSight* data was categorized as Before SCOOT (December 2014 – October 2015), Transition (November 2015) and After SCOOT (December 2015 – May 2016). Data was then segmented by weekday versus weekend and time of day, including:

- Early AM (12AM – 6AM)
- Peak AM (6AM – 10AM)
- Mid-Day (10AM – 3PM)
- Peak PM (3PM – 7PM)
- Evening (7PM – 12AM)

Validation of the data through additional sources was limited due to a lack of comparable "before" data. SCOOT did not collect data before its implementation, and no additional travel time studies were conducted to compare against the *StreetLight InSight* data. For validation, a few metrics were collected from the SCOOT system and *StreetLight InSight* for December 2015, including speed as a share of free flow, and peak as a share of total daily flow. This data was then compared to data from the City of Ann Arbor which showed similar results, as seen in Figure 5, and Figure 6, below.

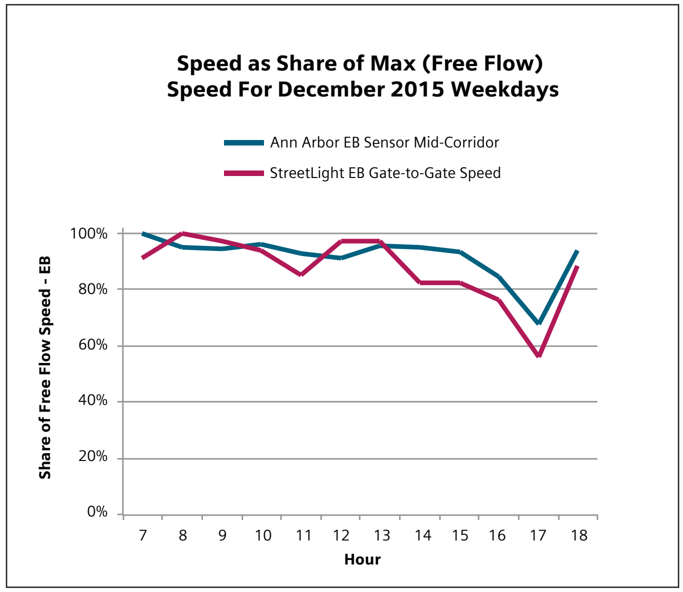


Figure 5. Speed as Share of Free Flow data from Ann Arbor (blue) and StreetLight Data (red)

Data from City of Ann Arbor	Peak hour as share of total traffic – City of Ann Arbor	Peak hour as share of total traffic – StreetLight trips
WB Peak Hour - 1700h	8.0%	8.1%
EB Peak Hour - 0800h	10.3%	10.1%

Figure 6. Peak Hour as Share of Total Traffic data from Ann Arbor (left) and StreetLight Data (right)

IV. Study Results

The results of the study show a clear decrease in average travel time between the endpoints of the corridor from the month before to the month after the implementation of SCOOT. Weekday travel times decreased 12%, from 236 seconds before implementation to 207 seconds after implementation. Weekend travel times decreased 21%, from 232 seconds before implementation to 183 seconds after implementation. Improved travel times confirmed expectations that the SCOOT system makes a significant impact in reducing average travel times.

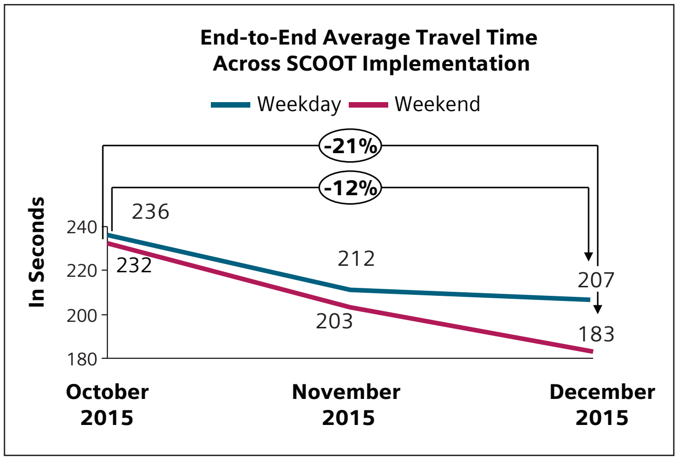


Figure 7. Reduction in End-to-End Travel Time Across Ellsworth Corridor

Another more practical way of looking at the results that accounts for the need for a reliable commute is to look at the success rate of completing the corridor in a set period of time. To that end, results were analyzed to compare how likely a traveler was to navigate the length of the two-mile corridor in less than 2, 3, or 4 minutes before and after implementation of SCOOT.

In all instances, the likelihood of completing the corridor in a timely manner increased with the introduction of SCOOT. The greatest increase occurred in the 3-minute window. Before SCOOT, a driver could expect to navigate the corridor in less than three minutes only 15% of the time on an average weekday. After implementing SCOOT, the likelihood of making it through the corridor in less than three minutes jumped to over 70%. Results were similar for the weekend, where the likelihood of making the trip in less than three minutes increased from 20% to more than 80%.

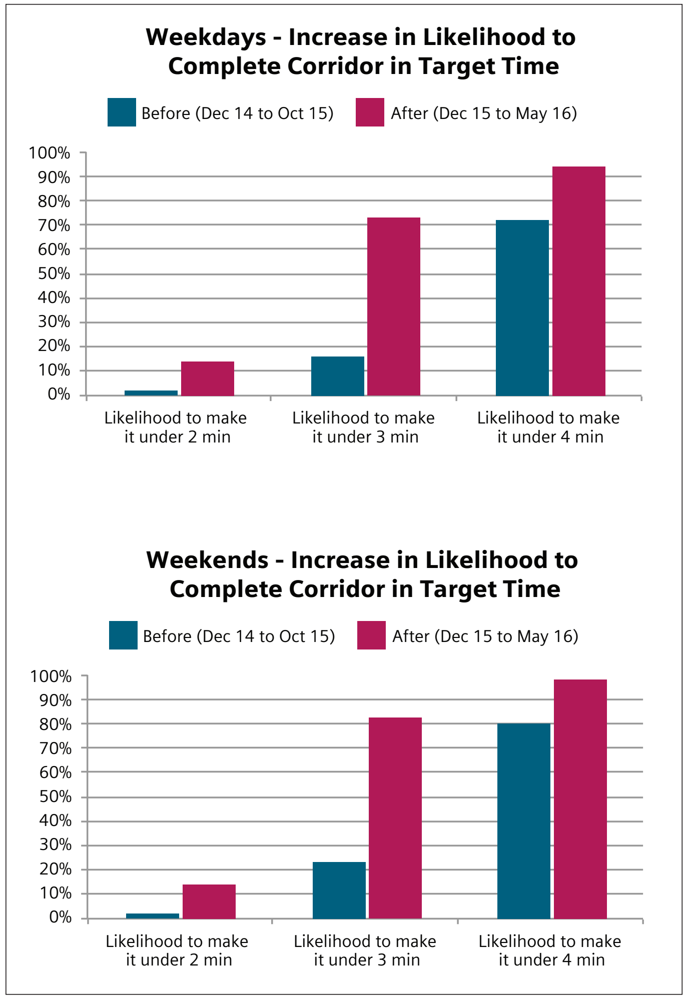


Figure 8. Likelihood of Completing Corridor in Target Time

Data showing the likelihood of completing the trip within a certain time period was delivered for each of the different periods within the day, and for weekdays and weekends. The impact of SCOOT was felt more on the weekends and during non-peak hours. This result was not a surprise as it has already been ascertained that during periods of heavy congestion – when a corridor is already loaded – signal timing has less of an impact on overall travel time than it does during periods of moderate or average flow of traffic.

Increase in Likelihood A Driver Can Complete the End-to-End Trip in Under....

Weekday	2 Min	3 Min	4 Min
1: Early AM (12am-6am)	11%	56%	22%
2: Peak AM (6am-10am)	12%	51%	19%
3: Mid-Day (10am-3pm)	10%	65%	22%
4: Peak PM (3pm-7pm)	8%	48%	30%
5: Late PM (7pm-12am)	19%	61%	16%

Increase in Likelihood A Driver Can Complete the End-to-End Trip in Under....

Weekend	2 Min	3 Min	4 Min
1: Early AM (12am-6am)	17%	63%	19%
2: Peak AM (6am-10am)	27%	52%	10%
3: Mid-Day (10am-3pm)	13%	64%	20%
4: Peak PM (3pm-7pm)	13%	62%	22%
5: Late PM (7pm-12am)	27%	71%	14%

Figure 9. The increase in likelihood that a driver will make it through the corridor in time targets by time interval. The values are the delta between the blue and red bar charts in Figure 8.

V. Implications

The Ann Arbor study – both its design/implementation and its results – carries wide-ranging implications for traffic management. Traffic engineers that have implemented, or are considering the use of, adaptive traffic control systems can benefit from its insights.

- The results of the study demonstrate the overall effectiveness of an adaptive traffic control system, specifically the SCOOT system. SCOOT reduced overall travel times by 10% to 20% and significantly increased the likelihood of meeting target times on a specific trip.
- Reduced travel times and enhanced flow of traffic, as demonstrated by the Ann Arbor study, lead to an improved standard of living, increased productivity and reduced carbon emissions. Adaptive control can be seen as an effective tool in raising the quality of life and sustainability within local communities.
- The use of adaptive control technology can directly save local governments and transportation departments funding over the long term. Adaptive systems do not need to be reprogrammed over time to adjust to demographic shifts or the changing landscape of a community; reprogramming and related survey/study costs can be eliminated.
- The Ann Arbor study provides a new reference point for traffic engineers pursuing the implementation of a SCOOT system, and a way to measure its benefits.
- The Ann Arbor study is the first of its kind using Big Data from an aggregator such as StreetLight Data. The cost of completing a study using this method is only a fraction of the cost (approximately 25% or less) of using traditional sources. Additionally, Big Data sources provide more data points over a longer period of time, improving the reliability of this and similar studies.
- The ability to conduct timely and cost-effective studies on adaptive control systems should make governments more open to adopting these systems, since effectiveness and Return on Investment (ROI) can be more easily demonstrated.
- A cost-effective method for completing transportation studies means that additional studies can be completed over longer periods of time to ensure that adaptive control systems continue to perform as designed, and perform under different operating conditions (main corridors, side streets, central business districts, etc.).
- Many air quality grants are linked to the estimated amount of air quality improvements that a project can generate. The Ann Arbor study can be used as a benchmark for such improvements. Additionally, insights from StreetLight Data and other sources provide needed data to make and test projections of air quality programs. These figures should help increase the number of new air quality program opportunities and help ensure that worthy programs get implemented.

About the Report

Siemens would like to thank the City of Ann Arbor for their support, including providing data and lending expertise on the Ann Arbor SCOOT system.

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