U.S. Department of Transportation

# Arterial Management: Traffic Control

## ITS Benefits, Costs, and Lessons Learned: 2014 Update Report

### Arterial Management

Surveillance
**Traffic Control**
- **Adaptive Signal Control**
- **Advanced Signal Control**
- **Variable Speed Limits**
- **Bicycle & Pedestrian**
- **Special Events**
- **Eco-Signal Priority**
- **Eco-Traffic Signal Timing**

Lane Management
Parking Management
Information Dissemination
Enforcement

### Highlights

- Adaptive Traffic Signal Systems coordinate control of traffic signals across a signal network, adjusting the lengths of signal phases based on prevailing traffic conditions.
- SPaT applications, used in the connected vehicle environment, have the potential to increase safety, mobility, and reduce environmental impact at traffic signals.
- Improved traffic signal control continues to be one of the most cost effective ways to improve safety and mobility in most jurisdictions.

## Introduction

*This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.*

Traffic signal control systems are the primary tools used to manage the flow of traffic on arterial street systems. The primary objectives of these systems are to improve traffic flow, reduce traffic delays, and increase safety. Adaptive signal control systems coordinate control of traffic signals along arterial corridors, adjusting the lengths of signal phases based on prevailing traffic conditions. Advanced signal systems allow proactive traffic management by allowing traffic conditions to be actively monitored and archived, and may include some necessary technologies for the later development of adaptive signal control. Coordinated signal operations across neighboring jurisdictions may be facilitated by these advanced systems. Other related systems can be used to improve the safety of all road users at signalized intersections, including pedestrian detection, specialized countdown signal heads, and bicycle-actuated signals.

Connected vehicle technologies are facilitating research in new advanced signal systems. The Intelligent Transportation System (ITS) ITS Joint Program Office's (JPO) Dynamic Mobility Applications (DMA) program is researching advanced signal operations under the Multi-Modal Intelligent Traffic Signal System (MMITSS) research bundle. One significant outcome from this research area is the Intelligent Traffic Signal System (ISIG) application. This application uses high-fidelity data collected from vehicles through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications as well as from pedestrian and non-motorized travelers. This ISIG application seeks to control signals and maximize flows in real time. The ISIG application also plays the role of an overarching system optimization application, accommodating transit or freight signal priority, emergency vehicle preemption, and pedestrian movements to maximize overall network performance.

Collecting data from vehicles in a connected vehicle environment has the potential to help agencies optimize their signal systems according to the locally determined objectives, whether they are focused more on safety, mobility, or the environment. Other area of connected vehicle and traffic signal research is with signal phase and timing (SPaT) data. Several connected vehicle programs are researching the potential of broadcasting SPaT data at intersections, allowing approaching (equipped) vehicles to know the current state of the signal, and then to determine if they will be able to proceed safely through the green light. This data has the potential to increase safety and mobility, and reduce environmental impacts at traffic signals.

**Benefit-Cost ratios for Traffic Control Systems range from 1.58:1 to 62:1.**

The ITS JPO's Applications for the Environment Real-time Information Synthesis (AERIS) program is also researching advanced signal systems to better understand and optimize for environmental goals. The AERIS Eco-Traffic Signal Timing application is similar to current adaptive traffic signal control systems; however, the application's objective is explicitly to optimize traffic signals for the environment rather than for mobility. See the case study below for more detailed information on this AERIS application.

# Benefits

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers. These systems make use of information collected by traffic surveillance devices to smooth the flow of traffic along travel corridors. **Advanced signal systems** include coordinated signal operations across neighboring jurisdictions, as well as centralized control of traffic signals which may include some technology applications for the later development of adaptive signal control.

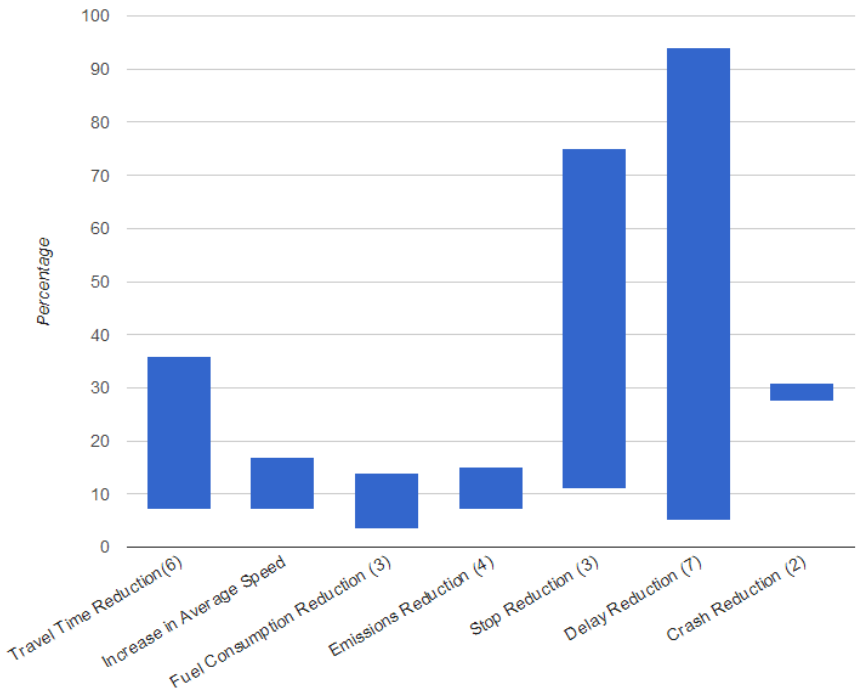


**Figure 1: Advanced Signal Control benefits found in the Knowledge Resource database from 2003 to 2013 (Source: ITS Knowledge Resources).**

***The online versions of the factsheets feature interactive graphs that contain all the data points included in the ranges. Here, each metric has a number after the text, representing the number of data points used to create the range; no number means only there was only one data point.***

Figure 1 shows the ranges of reported benefits from advanced signal control systems. Benefits range across several measures including safety, mobility and environmental improvements.

In August of 2012, New York City deployed an advanced traffic signal system that included an adaptive decision support system for 110 blocks of New York resulting in a 10 percent decrease in travel times throughout Midtown (2012-00810).

The data collected through the technologies applied for this system has allowed the City to use historical data and analytics to develop more sophisticated algorithms to continually improve the movement of vehicles throughout the traffic signal system.

**Adaptive Traffic Signal Systems** coordinate control of traffic signals across a signal network, adjusting the lengths of signal phases based on prevailing traffic conditions. As agencies continue to implement innovative technologies, and the costs to implement adaptive signal systems continue to decline, these systems become a viable solution to improve safety, mobility and the environment along an arterial.

According to FHWA's Every Day Counts (EDC) program, the main benefits of adaptive signal control technology over conventional signal systems are that it can:

- Continuously distribute green light time equitably for all traffic movements;
- Improve travel time reliability by progressively moving vehicles through green lights;
- Reduce congestion by creating smoother flow; and
- Prolong the effectiveness of traffic signal timing [1].

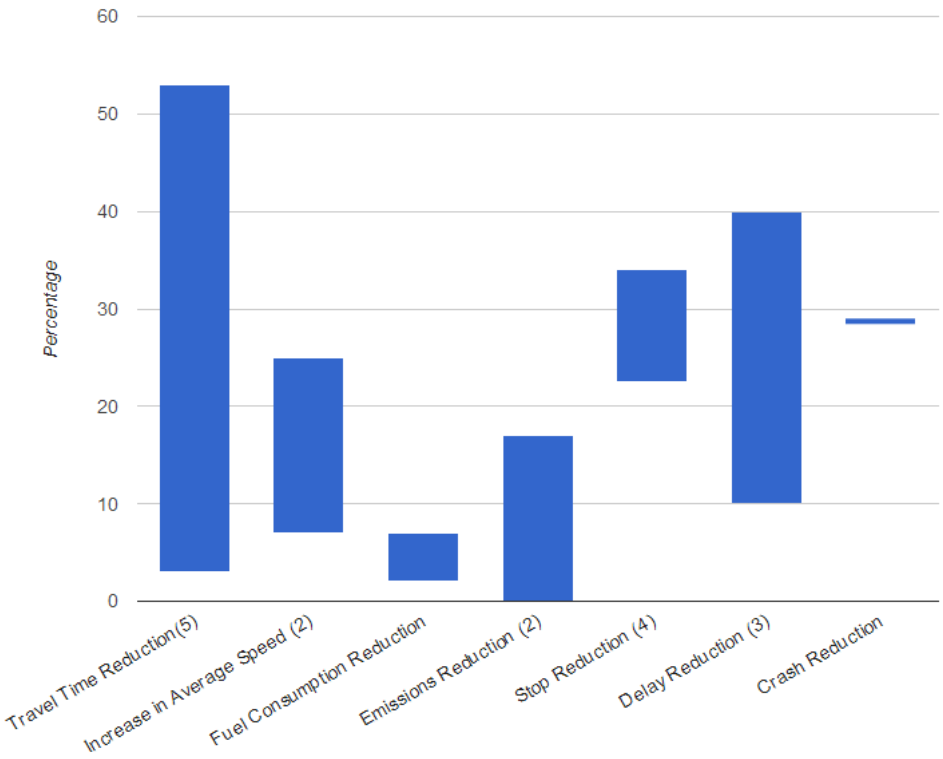


**Figure 2: Adaptive Signal Control benefits found in the knowledge resource database from 2003 to 2013(Source: ITS Knowledge Resources).**

Figure 2 shows the ranges of reported benefits from adaptive signal control systems. Benefits range across several measures including safety, mobility and environmental improvements. In July of 2012 the Colorado Department of Transportation (CDOT) released its evaluation of two different adaptive signal systems on two different corridors. The mobility benefits for both corridors combined included 9-19 percent improvement in travel times and an increase in average speed by 7-22 percent. The environmental benefits found by CDOT included a 2-7 percent reduction in fuel consumption and a reduction of pollution emissions by up to 17 percent (2012-00809).

Table 1: Benefit-Cost Ratios for selected Traffic Control Systems

| Selected Findings | Benefit-Cost Ratio |
|---|---|
| In Oakland County, Michigan a two-phase project to retime 640 traffic signals resulted in a benefit-cost ratio of 175:1 for the first phase and 55:1 for the second. (2007-00313) | 175:1 Phase 1<br>55:1 Phase 2 |
| The Traffic Light Synchronization program in Texas demonstrated a benefit-cost ratio of 62:1. (2008-00507) | 62:1 |
| Integrated Corridor Management (ICM) strategies that promote integration among freeways, arterials, and transit systems can help balance traffic flow and enhance corridor performance; simulation models indicate benefit-cost ratios for combined strategies range from 7:1 to 25:1. (2009-00614) | 7:1 to 25:1 |
| Adaptive signal control, transit signal priority, and intersection improvements implemented during the Atlanta Smart Corridor project produced a benefit-cost ratio ranging from 23.2:1 to 28.2:1. (2011-00758) | 23.2:1 to 28.2:1 |
| Installation of adaptive signal control systems in two corridors in Colorado had benefit-cost ratios ranging from 1.58 to 6.10. (2012-00807) | 1.58:1 to 6.1:1 |
| A decentralized adaptive signal control system has an expected benefit-cost ratio of almost 20:1 after five years of operation, if deployed city-wide in Pittsburgh. (2013-00822) | 20:1 |

In addition to traffic signal control systems that primarily focus on vehicle interactions, there are traffic signal systems that are designed to improve pedestrian safety at roadway crossings. The High-Intensity Activated Crosswalk (HAWK) pedestrian beacon assists at pedestrian crossings by stopping vehicles so that pedestrians can cross the roadway and then permits the drivers to proceed as soon as the pedestrians have passed. A HAWK crossing uses several visual cues to alert drivers to the possible presence of a pedestrian. These visual cues include a unique beacon configuration, high visibility crosswalk markings, a stop bar approximately 50 feet from the crosswalk, 8 inch wide solid lane lines between through travel lanes, and signs that read “Pedestrian Crossing” or “School Warning.”

A HAWK pedestrian beacon deployment demonstrated a 69 percent reduction in crashes involving pedestrians. There was also a 15 percent reduction in severe crashes that result in injury and a 29 percent reduction in total crashes where the HAWK system was deployed (2013–00848).

## Costs

ITS Knowledge Resource database provides a variety of system costs for traffic control strategies including advanced and adaptive traffic control systems. As technology for adaptive traffic control systems continues to improve and mature, the costs to implement such systems continue to go down.

Adaptive signal control technologies (ASCTs) have been proven effective in providing operational benefits, but agencies in the United States have been slow to adopt these technologies. One of the major reasons for slow ASCT implementation is lack of knowledge about the operational and safety benefits and costs of ASCT. A nationwide report found that the cost of ASCT per intersection was estimated between $46,000 and $65,000. Excluding the outliers, with seven agencies reporting, the average cost to implement ASC technologies averages to $28,725 per intersection to implement. The average cost of ASCT was given by the type of system as well as the type of detection technology. The average cost of ASCT per intersection was highest when used with video detection and lowest when used with magnetometer detection technology (2013–00278).

Table 2 provides system costs on a per intersection basis derived from several projects across the country. Details for each of these projects can be found in the Knowledge Resource Database.

Table 2: Adaptive Signal Control Project Costs.

| Project Date | Total Project Cost | Number of Intersections | Cost per Intersection | Region | Cost ID |
|---|---|---|---|---|---|
| January 2013 | $28,725 | 1 | $28,725 (Average based on responses from 8 agencies) | Nationwide | 2013-00278 |
| July 2012 | $176,300 | 8 | $22,037 | Colorado | 2012-00273 |
| July 2012 | $905,500 | 11 | $82,318 (Includes infrastructure upgrades) | Colorado | 2012-00272 |
| 2010 | $65,000 | 1 | $65,000 | Nationwide | 2012-00249 |
| 2010 | $1,708,029 | 18 | $94,890 (includes infrastructure upgrades) | Georgia | 2011-00237 |

# Lessons Learned

**Commit to acquiring the proper level of staffing and knowledge required for the operations and maintenance of Adaptive Traffic Control System (ATCS) prior to deployment.**

Adaptive Traffic Control Systems (ATCSs) are powerful and complex tools that require a level of expertise for proper maintenance and operations. While ATCS may be viewed as a labor-reducing way of deploying signal timing plans, the experience of domestic and international ATCS agencies demonstrates the importance of having the level of staffing and knowledge in ATCS required for maintenance and operations. Key recommendations for ATCS agencies to consider in training, operations, and maintenance include the following.

- Beware of the perception that an ATCS is a hands-off type of system that will lower the labor or expertise requirements compared to standard traffic control systems.
- Be certain to receive ATCS training not only during the initial deployment of ATCS, but continuously throughout initial validation to solve operational problems or issues as they arise.
- Develop a working understanding of the principles of an ATCS.
- Beware that implementing successful ATCS operations may require a switch in the type of labor from maintenance to operations.

ATCS deployments can bring significant benefits to traffic performance, but it requires a commitment to training and acquiring proper levels of staffing for operations and maintenance. ATCS operations are sufficiently complex that traffic engineers, in general, need at least four to six months to acquire a general understanding of these systems (in contrast to an experienced signal timing engineer who needs about two months). Indeed, one of the most important ATCS issues for smaller agencies is retaining ATCS-proficient staff. Acquiring the proper knowledge and technical expertise to operate an ATCS empowers an agency to maintain the system and realize substantial benefits to users of the transportation network in which it is deployed (2012-00619).

# Case Study – Eco-Traffic Signal Timing: Preliminary Modeling Results

The AERIS Eco-Traffic Signal Timing application is envisioned to be similar to current traffic signal systems; however the application's objective is to optimize the performance of traffic signals for the environment. The application collects data from vehicles, such as vehicle location, speed, and emissions data using connected vehicle technologies. It then processes these data to develop signal timing strategies focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real-time and adapts so the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact (2014-00912).

### Methodology

Preliminary simulation and modeling was conducted for this application using a 6 mile segment of El Camino Real in Northern California. The corridor contains 27 signalized intersections operating actuated coordinated signal timing plans; however for the purposes of this analysis, the baseline conditions assumed fixed timing plans. The modeling team used a genetic algorithm to optimize the traffic signal timing plans for the corridor with the objective of reducing fuel consumption and emissions. The genetic algorithm determined an optimal cycle length for the corridor, green times for each phase, and signal offsets for each signalized intersection. Phase sequences were not changed. To determine the optimal timing plans, outputs from the Paramics microsimulation model were sent to an Application Programming Interface (API) that interfaced with the Environmental Protection Agency's MOtor Vehicle Emissions Simulator (MOVES) model. Traffic and emissions outputs from Paramics and MOVES, respectively, were then sent to the genetic algorithm which developed new timing plans. These new timing plans were then sent back to Paramics and the process continued for numerous iterations until the genetic algorithm determined an optimal timing plan that reduced $CO_2$ emissions for the entire corridor. Sensitivity analysis included varying the following parameters: penetration rate of connected vehicles, congestion levels, percentage of trucks, and optimizing for emissions versus delay. The method used to determine optimized timing plans for this study considered an offline optimization approach. More advanced connected vehicle applications and algorithms may perform the optimization online, similar to adaptive signal control systems but leveraging connected vehicle data and technologies.

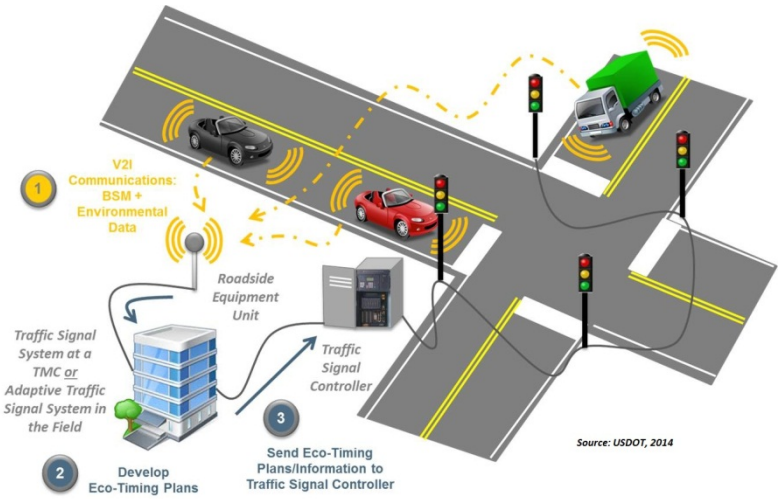


**Figure 3: Diagram of the AERIS Eco-Traffic Signal Timing application (Source: U.S. DOT).**

### Conclusions

- There is up to 5 percent improvement in fuel consumption and environmental measures at full connected vehicle penetration, with a 1 to 4 percent improvement at partial connected vehicle penetration in a fully coordinated network.
- Optimizing for the environment resulted in a 5 percent fuel consumption reduction, whereas optimizing for mobility resulted in 2 percent reductions in fuel consumption.
- Driving a typical vehicle 8,000 miles per year on arterials equates to $70 of savings per year per vehicle.
- SUV (lower MPG) savings are $110 per year per driver.
- A fleet operator with 150 vehicles would save $16,500 per year.

## References

[1] U.S. Department of Transportation. Federal Highway Administration. "Accelerating Innovation, Every Day Counts" Retrieved on January 7, 2014. http://www.fhwa.dot.gov/everydaycounts/technology/adsc/.

All other data referenced is available through the ITS Knowledge Resources Database, which can be found at http://www.itsknowledgeresources.its.dot.gov/.