ARTERIAL MANAGEMENT

FIFTY-FOUR (54) PERCENT OF SIGNALIZED INTERSECTIONS IN THE COUNTRY'S MAJOR METROPOLITAN AREAS OPERATE UNDER CENTRALIZED COMPUTER CONTROL.

ROADWAYS

Arterial management systems manage traffic along arterial roadways, employing vehicle 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. They also disseminate important information about travel conditions to travelers via technologies such as dynamic message signs (DMS) or highway advisory radio (HAR).

Many of the services possible through arterial management systems are enabled by traffic surveillance technologies, such as sensors or cameras monitoring traffic flow. These same sensors may also be used to monitor critical transportation infrastructure for security purposes.

Traffic signal control systems address a number of objectives, primarily improving traffic flow and 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 include those that provide the ability for proactive management of signal systems by allowing traffic conditions to be actively monitored, provide the ability to archive traffic data, 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. Pedestrian detectors, specialized signal heads, and bicycle-actuated signals can improve the safety of all road users at signalized intersections. Arterial management systems can also apply unique operating schemes for traffic signals, portable or dedicated DMS, and other ITS components to smooth traffic flow during special events.

A variety of techniques are available to manage the travel lanes available on arterial roadways and ITS applications can support many of these strategies. Examples include dynamic posting of high-occupancy vehicle restrictions and the use of reversible flow lanes allowing more lanes in the peak direction of travel during peak periods. Parking management systems, most commonly deployed in urban centers or at modal transfer points such as airports and outlying transit stations, monitor the availability of parking and disseminate the information to drivers, reducing traveler frustration and congestion associated with searching for parking spaces. Transportation agencies can share information collected by arterial management systems with road users through technologies within the arterial network, such as DMS or HAR. They may also share this information with travelers via broader traveler information programs. Arterial management systems may also include automated enforcement programs that increase compliance with speed limits, traffic signals, or other traffic control devices.

Information sharing between agencies operating arterial roadways and those operating other portions of the transportation network can also have a positive impact on the operation of the transportation system. Examples include coordinating operations with a freeway management system, or providing arterial information to a traveler information system covering multiple roadways and public transit facilities.

Several ITS applications that impact traffic operations on arterial roadways are discussed elsewhere in this report. Transit signal priority systems, discussed within the transit management chapter, can ease the travel of buses or light rail vehicles on arterial corridors and improve on-time performance. Signal preemption for emergency vehicles, discussed in the emergency management chapter, reduces the likelihood of crashes during incident response while improving response times. The electronic payment and pricing chapter discusses pricing strategies that are used on a growing number of arterial streets.

ARTERIAL MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance
- Traffic
- Infrastructure

Traffic Control
- Adaptive Signal Control
- Advanced Signal Systems
- Variable Speed Limits
- Bicycle and Pedestrian
- Special Events

Lane Management
- High-Occupancy Vehicle Facilities
- Reversible Flow Lanes
- Pricing
- Lane Control
- Variable Speed Limits
- Emergency Evacuation

Parking Management
- Data Collection
- Information Dissemination

Information Dissemination
- Dynamic Message Signs
- In-Vehicle Systems
- Highway Advisory Radio

Enforcement
- Speed Enforcement
- Traffic Signal Enforcement

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO ARTERIAL MANAGEMENT

Refer to other chapters in this document.

Transit Management

Operations and Fleet Management: Transit Signal Priority

Emergency Management

Response and Recovery: Emergency Vehicle Signal Preemption

Electronic Payment and Pricing

Pricing

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Recognizing that congestion has become a national problem, the U.S. DOT launched the National Strategy to Reduce Congestion on America's Transportation Network. One element of this strategy is to reduce congestion by promoting operational and technical improvements that have the potential to enable existing roadways to operate more efficiently.[62]

In addition to the individual ITS technologies profiled in this chapter, the Integrated Corridor Management (ICM) initiative—a major ITS initiative currently being conducted by the U.S. DOT—has the potential to improve arterial management strategies. The purpose of the ICM initiative is to demonstrate that ITS technologies can be used to efficiently and proactively manage the movement of people and goods in major transportation corridors by facilitating integration of the management of all networks in a corridor. The results of the initiative will help to facilitate widespread use of ICM tools and strategies to improve mobility through integrated management of transportation assets.[63] Additional information on this initiative is available at the ITS JPO's Web site: *www.its.dot.gov/icms*.

Findings

Benefits

Table 1 summarizes the findings contained in the ITS Benefits Database and highlighted later in this chapter. Studies demonstrate the ability of traffic control ITS applications to enhance mobility, increase efficiency of the transportation system, and reduce the impact of automobile travel on energy consumption and air quality. The ability of both adaptive signal control and coordinated signal timing to smooth traffic can lead to corresponding safety improvements through reduced rear-end crashes. As shown in figure 2, studies of signal coordination in 5 U.S. cities and 1 Canadian city have shown reductions in stops from 6 to 77 percent, while 2 statewide studies have shown average improvements from 12 to 14 percent.[64] The figure depicts multiple findings for several studies, reflecting results under varying test scenarios, such as peak and off-peak travel periods or different test routes driven. The magnitude of the impact varies with the degree of congestion on the network, as well as the effectiveness of the traffic signal timing plans in place prior to the coordination activities. Reducing the number of vehicle stops can also have significant environmental impacts, by reducing the amount of acceleration required of vehicles traveling the corridor. Modeling studies in 5 U.S. cities have shown vehicle emission reductions ranging from no significant impact up to 22 percent.[65]

Studies of parking management systems demonstrate the potential of these systems to improve traffic flow in congested urban areas and improve travelers' experiences at major transportation facilities, such as airports and suburban transit and commuter rail stations.

A 2007 literature review by the National Highway Traffic Safety Administration (NHTSA) documented studies of speed enforcement camera programs worldwide, which reported crash reductions from 9 to 41 percent. The review also discussed rigorous studies of red light enforcement camera programs in 18 U.S. cities and 6 Canadian cities. The studies typically found a decrease in right-angle crashes and an increase in rear-end crashes, with the severity of the right-angle crashes and associated costs outweighing that of the rear-end crashes.[66] Customer satisfaction surveys have repeatedly shown strong support for the programs.

COORDINATED SIGNAL CONTROL CAN REDUCE VEHICLE EMISSIONS BY UP TO 22 PERCENT.

Table 1—Arterial Management Benefits Summary	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Surveillance						
Traffic Control	✚	●	●		●	
Lane Management						
Parking Management		●	✚			●
Information Dissemination						
Enforcement	●					●

● Substantial positive impacts
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
blank Not enough data

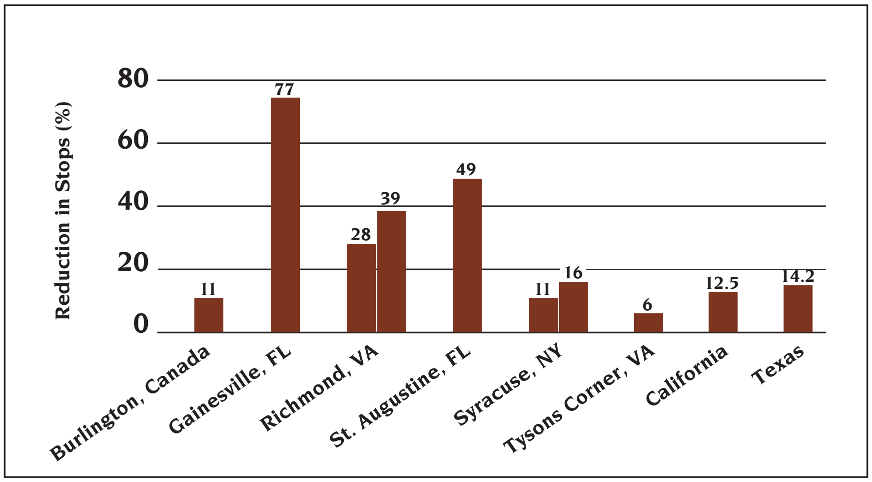

Figure 2 – Reduction of Number of Stops With Traffic Signal Coordination

Costs

Optimizing signal timing is considered a low-cost approach to reducing congestion. Based on data from six separate studies, the costs range from $2,500 to $3,100 per signal per update. While this range is reasonable, costs could be slightly more or less.[67] Well-trained technicians are needed to maintain traffic signal hardware so that the signal system is operating well and according to the timing updates. A current assumption is one traffic

OPTIMIZED SIGNAL TIMING IS CONSIDERED A LOW COST APPROACH TO REDUCING CONGESTION. BASED ON DATA FROM SIX SEPARATE STUDIES, THE COSTS RANGE FROM 2,500 TO 3,100 PER SIGNAL PER UPDATE.

signal technician can maintain 30 to 40 signals. The average costs of a technician is $56,000 per year which includes salary, benefits (approximately 30 to 35 percent of salary), vehicles, parts/supplies, and other required items.[68]

A cross-cutting study was conducted to evaluate the deployment of advanced parking management systems in three new parking facilities. The study found that these systems cost between $250 to $800 per space to install depending on the type and level of information provided, level of effort required to install sensors, ease of access to communications and power supplies, and the signage required to convey parking information to drivers at appropriate decision points. A smart parking field test conducted for the California DOT and Bay Area Rapid Transit (BART) estimated capital cost at $150 to $250 per space; operations and maintenance (O&M) costs were estimated at $40 to $60 per space.[69]

Deployment

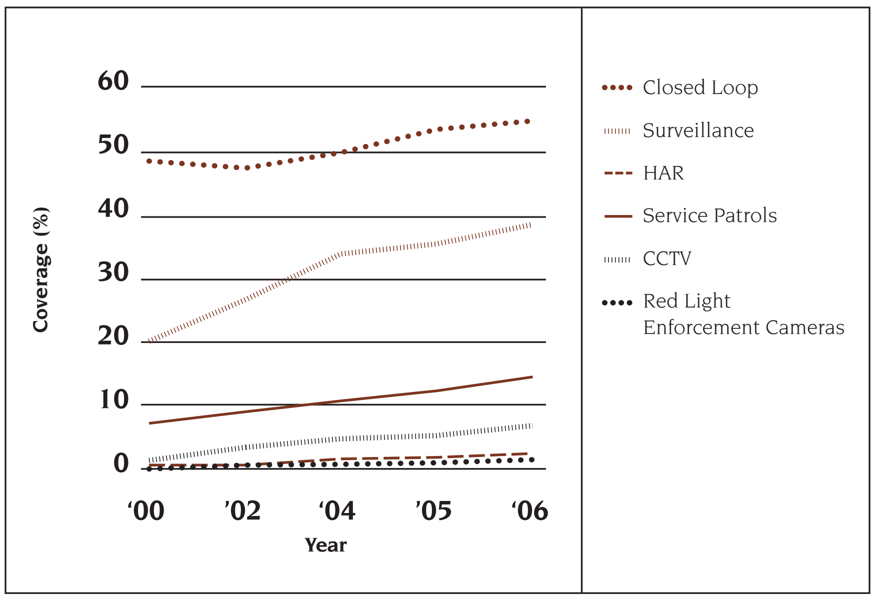

Figure 3 – Deployment Trends for Arterial ITS, 2000-2006

Figure 3 shows deployment trends for key ITS technologies supporting arterial management from 2000 to 2006, based on a series of surveys of arterial management agencies in 78 of the largest U.S. metropolitan areas. Half (50 percent) of traffic signals in these metropolitan areas were under centralized control through closed loop or computer control in 2006. The trend to bring traffic signals under centralized control has leveled off in recent years. In contrast, surveillance at intersections is growing rapidly, nearly doubling since 2000 to 39 percent of signalized intersections. Fifteen (15) percent of arterial street miles in these metropolitan areas were covered by service patrols, a trend which has been growing steadily since 2000. Deployment of closed circuit television (CCTV) cameras on arterial streets is still at a low level, albeit at a moderate rate of growth. HAR and red light enforcement cameras have yet to be deployed in large numbers.

In 2006, the survey of metropolitan areas was expanded to the country's 108 largest metropolitan areas. This survey is the source of deployment statistics presented later in this chapter.

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Selected Highlights from the ITS Knowledge Resources on Arterial Management

Surveillance

Many strategies for arterial management are enabled by traffic surveillance and detection technologies, such as sensors or cameras monitoring traffic flow. The surveillance and detection technologies used to monitor traffic flow in support of ITS applications can also be used to monitor key transportation facilities for security purposes.

Surveillance
Deployment
Thirty-nine (39) percent of signalized intersections in the country's 108 largest metropolitan areas use electronic surveillance to monitor traffic.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Inductive Loop Surveillance at Intersection: $8.7K-$15.6K • Remote Traffic Microwave Sensor at Intersection: $17K • Closed Circuit Television (CCTV) Video Camera: $9K-$19K Transportation Management Center subsystem: • Hardware, Software for Traffic Surveillance: $131K-$160K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
California: The Cities of Concord and Walnut Creek investigated alternatives for transmitting real-time traffic video from field devices to each city's respective traffic operations center (TOC). During the design phase of the project, each city conducted a budgetary cost comparison to examine the capital costs associated with two alternatives: • Upgrading the existing network of copper wire (twisted pair) traffic signal control communications network • Converting to fiber optic communications. The capital cost for video over existing copper interconnect was **$95,910** for a five-mile corridor. The capital cost for video over new fiber optic cable was **$160,700** for a five-mile corridor.[70] **Washington:** The Washington State Department of Transportation (WSDOT) installed a system to improve traffic flow and reduce delay at two of the busiest intersections in the Puget Sound Region. The system consisted of five traffic cameras mounted on existing traffic signal support structures. Traffic engineers at the Washington State Traffic Systems Management Center were able to monitor traffic conditions and compensate for unnecessary signal delays by adjusting signal timing at each intersection. WSDOT was able to add surveillance to both intersections for **$65,000**[71]

LESSONS LEARNED

Partner with neighboring agencies, either formally or informally, to benefit from cross-jurisdictional traffic signal coordination.

Cross-jurisdictional signal coordination is an achievable goal for any size community regardless of the number of jurisdictions involved, the type of signal hardware and communication equipment, or even the philosophical differences in timing approaches. Partnering with agencies, either formally or informally, to manage institutional issues is key to implementing a successful cross-jurisdictional traffic signal coordination program.

- Address comfort levels when establishing formal or informal agreements among agencies.

In Philadelphia, the city's cross-jurisdictional signal program involves three agencies sharing information verbally, having established informal agreements between jurisdictions. As the agencies expanded the system, additional agreements were necessary. The partners found that the smaller municipalities prefer formal agreements reviewed by legal counsel. The agencies believe that the coordination agreements, whether formal or informal, have resulted in improved operations in terms of fewer crashes, more consistent speeds, and reduced air pollution.

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Traffic Control: Adaptive Signal Control

Adaptive signal control systems coordinate control of traffic signals across a signal network, adjusting the lengths of signal phases based on prevailing traffic conditions.

Traffic Control—Adaptive Signal Control	
Deployment	
Three percent of traffic signals in the country's 108 largest metropolitan areas are controlled by adaptive signal control.	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** Experience with adaptive signal control deployed in 5 cities demonstrated stop reductions from 10 to 41 percent. Smoothing traffic by reducing the number of required stops can improve traffic safety.[72]
Mobility	***Summary Finding:*** Studies from 11 cities in the U.S. and abroad found delay reductions from 5 to 42 percent after installation of adaptive signal control.[73]
Efficiency	A study of the integrated deployment of freeway ramp metering and adaptive signal control on adjacent arterial routes in Glasgow, Scotland found a 20 percent increase in vehicle throughput on the arterials and a 6 percent increase on freeways. Arterial traffic increased 13 percent after implementation of ramp metering and an additional 7 percent with the initiation of adaptive signal control.[74]
Energy and Environment	Adaptive signal control in Toronto, Canada has yielded emission reductions of three to six percent and fuel savings of four to seven percent.[75]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Control subsystem: • Signal Controller and Cabinet: $8K-$14K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)	
Sample Costs of ITS Deployments	
Texas: In November 2007, the City of Tyler deployed the Adaptive Control System-Lite, or ACS-Lite, technology along a 3.17-mile corridor. The deployment included the following costs: $150,600 for the software module, $38,400 for traffic communication system upgrades, and $357,900 for detection devices.[76]	

Traffic Control—Adaptive Signal Control
Costs
Virginia: In 2001, the Arlington County Department of Public Works, Traffic Engineering Division, funded 65 intersections (expandable to 235) under an adaptive signal control system. The project costing **$2.43 million** included software, hardware, roadside equipment, cabling, mobilization and maintenance of traffic, installation, training, maintenance and test equipment, and system documentation.[77]

Traffic Control: Advanced Signal Systems

Advanced signal systems include coordinated signal operations across neighboring jurisdictions, as well as centralized control of traffic signals, which may include some necessary technologies for the later development of adaptive signal control.

Traffic Control—Advanced Signal Systems	
Deployment	
Fifty-four (54) percent of signalized intersections in the country's 108 largest metropolitan areas operate under centralized computer control.	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** Eight studies in the U.S. have demonstrated the ability of traffic signal coordination to smooth traffic flow, with stop reductions ranging from 6 to 77 percent. These reductions varied with the level of congestion along the corridor and the appropriateness of existing timing plans. [78]
Mobility	The Texas Traffic Light Synchronization program reduced delays by 24.6 percent by updating traffic signal control equipment and optimizing signal timing.[79] Signal coordination at 145 intersections in Syracuse, New York reduced the total delay experienced by vehicles during the AM, mid-day, and PM peak periods by 14 to 19 percent.[80]
Efficiency	A simulation study of re-timed traffic signals along two major arterials north of Seattle, Washington found a 7.0 percent annualized reduction in vehicle delay, accompanied by a 0.2 percent increase in vehicles traveling the corridor.[81]
Energy and Environment	***Summary Finding:*** Modeling studies of coordinated signal control in 5 U.S. localities found reductions in fuel use ranging from no significant change in Seattle, Washington to a 13 percent decline in Syracuse, New York.[82]

LESSONS LEARNED

Cooperate regionally to impact costs and performance of a cross-jurisdictional traffic signal system.

The success of a regional signal timing program depends on the willingness of the agencies to work together. Impacts on system costs and performance can be significant.

- Address comfort levels when establishing formal or informal agreements among agencies.

In Montgomery County, Maryland, a formal agreement between the Maryland State Highway Administration and the county was established for the maintenance of State-owned traffic signals, but there are no formal agreements to address signal timing. The county and the District of Columbia have met informally and agreed upon common cycle lengths for AM and PM peak periods on corridors that need to be coordinated.

- Take advantage of facilitation by regional governmental organizations.

The City of Greenwood Village, Colorado has both formal and informal agreements in place for coordinating traffic signals across jurisdictions. The Denver Regional Council of Governments is the lead agency and has partnership agreements with the City of Greenwood Village, the Colorado DOT, and Arapahoe County for the development of timing plans. Each jurisdiction maintains its own traffic signals, but there is a committee that meets regularly to discuss coordination issues.

Traffic Control—Advanced Signal Systems
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Control subsystem: • Signal Controller Upgrade for Signal Control: $2.4K-$6.0K Transportation Management Center subsystem: • Software, Integration for Signal Control: $287K-$383K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
United States: Optimizing signal timing is considered a low-cost approach to reducing congestion. Based on data from six separate studies, the costs range from **$2,500 to $3,100 per signal per update**. While this range is reasonable, costs could be slightly more or less. [83] **United States:** Well-trained technicians are needed to maintain traffic signal hardware so that the signal system is operating well and according to the timing updates. A current assumption is one traffic signal technician can maintain 30 to 40 signals. The average cost of a technician is **$56,000 per year** which includes salary, benefits (approximately 30 to 35 percent of salary), vehicles, parts/supplies, and other required items.[84]
Benefit-Cost Studies
Texas: The Traffic Light Synchronization program in Texas shows a benefit-to-cost ratio of 62:1, with reductions of 24.6 percent in delay, 9.1 percent in fuel consumption, and 14.2 percent in stops.[85] **California:** A 2005 Oakland Metropolitan Transportation Commission analysis of its traffic signal coordination program yielded a benefit-to-cost ratio of 39:1.[86]

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Traffic Control: Bicycle and Pedestrian

Pedestrian detectors, pedestrian-activated crosswalk lighting, specialized pedestrian signals (e.g., countdown WALK/DON'T WALK signals), and bicycle-actuated signals can improve the safety of all road users at signalized intersections and unsignalized crossings.

Traffic Control—Bicycle and Pedestrian	
Benefits	
ITS Goals	**Selected Findings**
Safety	Automatic pedestrian detection systems deployed at 4 intersection crosswalks in 3 U.S. cities resulted in a 24 percent increase in the number of pedestrians who began crossing during the WALK signal, and an 81 percent decrease in the number of pedestrians who began crossing during the steady DON'T WALK signal.[87]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: • Pedestrian Detection—Microwave: $0.6K • Pedestrian Detection—Infrared: $0.3K-$0.5K Roadside Information subsystem: • Light-Emitting Diode (LED) Countdown Signal: $0.306K-$0.424K • Pedestrian Crossing Illumination System: $26.8K-$41K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)	
Sample Costs of ITS Deployments	
Colorado: A downtown Boulder intersection has been equipped with a series of four flashing in-pavement lights per lane. This high-pedestrian-volume intersection is also equipped with two flashing pedestrian signs. The lights and signs are activated manually. The project cost ranging from **$8,000 to $16,000** included equipment and installation costs.[88]	

Traffic Control: Special Events

Arterial management systems can also smooth traffic flow during special events with unique operating schemes, incorporating elements such as special traffic signal operating plans, temporary lane restrictions, traveler guidance, and other measures.

Traffic Control—Special Events	
Benefits	
ITS Goals	**Selected Findings**
Mobility	A simulation study found that using a decision support tool to select alternative traffic control plans during non-recurring congestion in the Disneyland area of Anaheim, California could reduce travel time by 2 to 29 percent and decrease stop time by 15 to 56 percent.[89]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Control subsystem: • Linked Signal System Local Area Network (LAN): $23K-$55K Roadside Information subsystem: • Dynamic Message Sign: $48K • Dynamic Message Sign—Portable: $18.6K-$24K Transportation Management Center subsystem: • Software for Traffic Information Dissemination: $17K-$21K • Labor for Traffic Information Dissemination: $107K-$131K (annually) Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K • Fiber Optic Cable Installation: $20K-$52K	
Sample Costs of ITS Deployments	
Utah: The Utah advanced transportation management system (ATMS) includes a coordinated signal system. Over 600 of the 900 signals in the Salt Lake Valley are connected to the TOC. With the installation of the communication system and central traffic control system, monitoring and adjusting the signal system for special events is performed at the TOC. The cost of the signal system includes only the communication capability at **$2.2 million**. The signals were already in place prior to the ATMS implementation. Annual maintenance cost is **$15,000**.[90]	

LESSONS LEARNED

Hire properly trained staff to deploy and maintain traffic signal systems.

Without the proper knowledge of software, hardware, maintenance, and communications issues, the result is little improvement in operational conditions. A study on the nationwide best practices on deploying and operating traffic signal systems reveals the following experiences.

- Obtain access to telecommunication expertise.

Technical expertise in telecommunications is often overlooked by agencies. Many agencies believe hiring technical experts that are knowledgeable in telecommunications allows flexibility in traffic signal system designs. Without this expertise in-house, agencies must accept whatever options are presented by competing contractors.

- Recognize the need for and budget for continuing education to ensure success.

(*Continued on next page.*)

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Lane Management

Lane management applications can promote the most effective use of available capacity during emergency evacuations, incidents, construction, and a variety of other traffic and/or weather conditions.

Lane Management
Deployment
Lane management systems have yet to be used widely on arterial streets. Only five of the country's 108 largest metropolitan areas have high-occupancy vehicle restrictions on at least one of their arterial streets. Only 16 of the country's 108 largest metropolitan areas use reversible flow lanes on at least one of their arterial streets.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K Transportation Management Center subsystem: • Labor for Lane Control: \$107K-\$131K (annually) Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
London: Congestion charging in London improves efficiency, reduces pollution, and raises revenue for transit improvements. Championed by the Mayor of London, the program requires motorists to pay a fee of £8 per day to drive within the inner city of London on workdays between 7:00 AM and 6:30 PM. Enforcement is achieved using a network of fixed and mobile video cameras that record images of vehicles in the congestion charging zone. Optical character recognition technology and automatic number plate recognition computer systems interpret and decipher the license plate numbers and map them against a pay list. If the system shows a payment is outstanding, the image is checked manually to confirm the vehicle make and model matches the license registration before a penalty is issued. Images of vehicles in good standing are removed from the system. London congestion pricing annual O&M costs are estimated at **£92 million**.[91]

LESSONS LEARNED

(*Continued from previous page.*)

There is a tremendous need to keep employees current on the ever-changing technologies that influence the design, deployment, and operation of traffic signal systems. Agency staff should attend technical professional conferences, meetings, and seminars to stay current with technologies and practices as well as to become part of peer groups through which new information is available.

- Consider the agencies' abilities to implement and maintain a traffic signal system before deployment.

If an agency does not feel it has the technical expertise to design a traffic signal system or develop the specifications, it should take a step back and seek the training necessary to improve the agency skill set before moving forward.

Parking Management

Parking management systems with information dissemination capabilities, most commonly deployed in urban centers or at modal transfer points such as airports, monitor the availability of parking and disseminate the information to drivers, reducing traveler frustration and congestion associated with searching for parking.

Parking Management	
Deployment	
Fourteen (14) of the country's 108 largest metropolitan areas collect data on parking availability and 11 disseminate these data to travelers.	
Benefits	
ITS Goals	**Selected Findings**
Mobility	Ten (10) parking facilities in downtown St. Paul, Minnesota are connected to an advanced parking management system that provides information on facilities with available spaces via 56 on-street signs (10 with dynamic displays). A study of downtown traffic found travel times were reduced by nine percent and the stopped time delay decreased by four percent.[92]
Efficiency	A smart parking system outside San Francisco, California provided the ability to reserve parking spaces at a transit station, either pre-trip or en route, with space availability displayed on roadside DMS. Surveys of participants found sizable increases in transit mode share (5.5 more transit commutes per month), a decreased average commute time (an average of 5 percent for a 50-minute commute), and a reduction in total vehicle miles traveled per participant of 9.7 miles per month.[93]
Customer Satisfaction	Baltimore/Washington International Thurgood Marshall (BWI) airport implemented a parking guidance system which directs travelers to individual available parking spaces. An October 2003 survey of BWI travelers found that 81 percent of surveyed travelers indicated that parking was easier at BWI than at the other airports they frequented and 68 percent agreed that parking was faster.[94]

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Parking Management
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Parking Management Center subsystem: • Entrance/Exit Ramp Meters: $2K-$4K • Tag Readers: $2K-$4K • Database and Software for Billing and Pricing: $10K-$15K • Parking Monitoring System: $19K-$41K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Maryland, Washington, Illinois: A cross-cutting study was conducted to evaluate the deployment of advanced parking management systems in new parking facilities constructed in Baltimore, Seattle, and Chicago. The study found that these systems cost between **$250 to $800 per space** to install depending on the type and level of information provided, level of effort required to install sensors, ease of access to communications and power supplies, and the signage required to convey parking information to drivers at appropriate decision points. The BWI airport installation was estimated to cost **$450 per space**, while the operations cost for the Chicago Metra Park-and-Ride facility is estimated at **$1,700 annually** to power the seven electrical signs in the system.[95] **California:** A smart parking field test conducted for the California DOT and BART integrated traffic count data from entrance and exit sensors at the Rockridge BART station parking lot with an intelligent reservation system to provide accurate, real-time parking availability information. Information was available on two portable DMS along Highway 24. Commuters could also check parking availability and make reservations via telephone, mobile phone, Internet, or personal digital assistant. Although capital and operating costs of the field test were donated, the capital costs are estimated at **$150 to $250 per space** and O&M costs are estimated at **$40 to $60 per space**.[96] **Washington:** In 2004, a study was conducted by the Transpo Group for the City of Bellingham Public Works to review existing parking management practices and policies. As a result of the study, a number of strategies and policies were recommended to improve and enhance overall parking management in Downtown Bellingham. In 2005, the Bellingham City Council adopted the strategy for Bellingham parking. A centralized pay station with automated ingress/egress control cost **$100,000**. The entrance/exit access control system cost **$30,000** and the parking accounting software package cost **$18,000 to $25,000.**[97]

Information Dissemination

Advanced communications have improved the dissemination of information to the traveling public. Motorists are now able to receive relevant information on location-specific traffic conditions in a number of ways including DMS, HAR, in-vehicle displays, and specialized information transmitted to individual vehicles.

Information Dissemination
Deployment
Permanent DMS, portable DMS, and HAR are used on 2 percent of arterial street miles in the country's 108 largest metropolitan areas.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: • Dynamic Message Sign: $48K • Dynamic Message Sign—Portable: $18.6K-$24K Transportation Management Center subsystem: • Software for Traffic Information Dissemination: $17K-$21K • Labor for Traffic Information Dissemination: $107K-$131K (annually) Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Utah: The Utah DOT operates and maintains over 69 permanently mounted DMS on freeways and surface streets as part of the Utah ATMS. Portable message signs are also used along roadsides where there are no permanent DMS. The capital cost of the DMS system is **$15.25 million**. The annual operating cost of **$21,960** is based on power consumption.[98]

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Enforcement

Automated enforcement systems, such as speed enforcement and traffic signal enforcement, improve safety, reduce aggressive driving, and assist in the enforcement of traffic signal and speed limit compliance.

Enforcement	
Deployment	
Automated speed enforcement on arterial streets is in use in 27 of the country's 108 largest metropolitan areas; 27 of these 108 metropolitan areas use red light enforcement cameras.	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** A 2007 literature review by NHTSA documented studies of speed camera programs worldwide, which reported crash reductions from 9 to 41 percent.[99]
Safety	Analysis of red light enforcement camera programs in Phoenix, Arizona found reductions in right-angle and left-turn crashes of 14 percent and 1 percent, respectively, while rear-end crashes increased 20 percent. In Scottsdale, right-angle and left-turn crashes decreased by 17 percent and 40 percent, respectively, with rear-end crashes increasing 45 percent. In both cities, the programs had a positive economic impact due to the greater severity of right-angle and left-turn crashes. In Scottsdale, experience showed a larger impact on fatal and injury crashes and therefore a larger economic impact than in Phoenix.[100]
Customer Satisfaction	Fifteen (15) months after extensive deployment of automated speed enforcement cameras in the United Kingdom, a nationwide survey found 70 percent of those surveyed thought that well placed cameras were a useful way of reducing crashes and saving lives, while 21 percent thought that speed cameras were an infringement of civil liberties.[101] Public opinion surveys indicated 60 to 80 percent support for red light enforcement camera programs.[102]

Enforcement
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Portable Speed Monitoring System: $4.8K-$14.4K • Traffic Camera for Red Light Running Enforcement: $69K-$126K Roadside Information subsystem: • Variable Speed Display Sign: $3.5K-$4.7K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
United States: Red light enforcement cameras have been implemented in numerous cities throughout the U.S. The cost of equipping an intersection for red light enforcement depends on the geometry of the intersection and the number of lanes monitored. Typical implementation costs include camera, poles, loops, wires, and installation. Costs per intersection range from **$67,000 to $80,000**. The cost range represents the costs incurred per intersection for the city of Jackson, Michigan (low-end) and the city of San Francisco, California (high-end).[103] **United Kingdom:** In April 2000, speed and red-light cameras were introduced in eight pilot areas in England, Wales, and Scotland in the U.K. In Strathclyde, 28 fixed camera sites were established primarily in 30 mi/h zones. The costs associated with camera enforcement and processing of fixed penalty notices were collected for the first two years. Costs increased for year two (from **£204,330 to £740,896**), which may be due in part to the fact that not all of the sites were fully operational during the first year. In the second half of year two, the number of fixed penalties paid began to plateau, which may be due to increased compliance. In terms of enforcement history, the Strathclyde pilot was one of the more experienced. In Nottingham, two digital camera sites were implemented on its ring road. Mobile enforcement also took place at 7 mobile sites and 19 red-light sites. Most enforcement took place in 30 mi/h zones. The costs associated with camera enforcement and processing of fixed penalty notices were collected for the first two years. Costs increased for year two (from **£622,371 to £778,536**), which may be due in part to the fact that not all of the sites were fully operational during the first year. In the second half of year two, the number of fixed penalties paid began to plateau, which may be due to increased compliance. The Nottingham pilot had comparatively less experience with camera enforcement.[104]

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www.itsoverview.its.dot.gov

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