

INTELLIGENT TRANSPORTATION SYSTEMS BENEFITS, COSTS, DEPLOYMENT, AND LESSONS LEARNED

2008 UPDATE



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September 2008

1. Report No. FHWA-JPO-08-032	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned: 2008 Update		5. Report Date September 2008	
		6. Performing Organization Code	
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9. Performing Organization Name and Address Noblis 600 Maryland Ave., SW, Suite 755 Washington, DC 20024		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-05-D-00002	
12. Sponsoring Agency Name and Address Department of Transportation Research and Innovative Technology Administration Intelligent Transportation Systems Joint Program Office 1200 New Jersey Avenue, SE Washington, D.C. 20003		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes Jane Lappin—Task Manager			
16. Abstract Intelligent transportation systems (ITS) provide a proven set of strategies for addressing the challenges of assuring safety and reducing congestion, while accommodating the growth in transit ridership and freight movement. This report presents information on the performance of deployed ITS under each of these goal areas, as well as information on the costs, deployment levels, and lessons learned regarding ITS deployment and operations. The report, and the collection of four Web-based resources upon which it is based, have been developed by the U.S. DOT's ITS Joint Program Office (JPO) to support informed decision making regarding ITS deployment. This report discusses 17 different areas of ITS application. These chapters are divided into two sections discussing technologies deployed on the transportation infrastructure and those deployed within vehicles. The 14 different infrastructure applications discussed can be grouped into ITS strategies applied to roadways, transit, management and operations of transportation systems, and freight movement. Lessons learned during ITS planning implementation and deployment, are highlighted throughout the report and in a chapter following the review of ITS applications.			
17. Key Word Intelligent Transportation Systems, ITS, Benefits, Costs, Deployment Statistics, Lessons Learned		18. Distribution Statement No Restrictions This document is available to the public	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price N/A



EXECUTIVE SUMMARY

Intelligent transportation systems (ITS) provide a proven set of strategies for addressing the challenges of assuring safety and reducing congestion, while accommodating the growth in transit ridership and freight movement. ITS improve transportation safety and mobility, and enhance productivity through the use of advanced communications, sensors, and information processing technologies encompassing a broad range of wireless and wireline communications-based information and electronics. When integrated into the transportation system's infrastructure, and into vehicles themselves, these technologies relieve congestion, improve safety, and enhance American productivity.

This report presents information on the performance of deployed ITS, as well as information on the costs, deployment levels, and lessons learned regarding ITS deployment and operations. The report, and the collection of four Web-based resources upon which it is based, have been developed by the U.S. DOT's ITS Joint Program Office (JPO) to support informed decision making regarding ITS deployment.

To support the deployment of ITS and to address the challenges facing the U.S. transportation system, the JPO has developed a suite of knowledge resources. This collection of Web-based resources provides ready access to information supporting informed decision making regarding deployment and operation of ITS to improve transportation system performance. Information presented in these online knowledge resources is the basis for this document. The four knowledge resources are the ITS Benefits Database (www.itsbenefits.its.dot.gov), ITS Costs Database (www.itscosts.its.dot.gov), ITS Deployment Statistics Database (www.itsdeployment.its.dot.gov), and the ITS Lessons Learned Knowledge Resource (www.itslessons.its.dot.gov).

This report discusses 17 different areas of ITS application. These chapters are divided into two sections discussing technologies deployed on the transportation infrastructure and those deployed within vehicles. The 14 different infrastructure applications discussed can be grouped into ITS strategies applied to roadways, transit, management and operations of transportation systems, and freight movement. Lessons learned during ITS planning, implementation, and deployment, highlighted throughout the report, are discussed in a chapter following the review of ITS applications and summarized at the conclusion of this executive summary.



Intelligent Infrastructure

ROADWAYS

Roadway applications of ITS include strategies applied to arterial roadways, freeways, crash prevention and safety, road weather management, and roadway operations and maintenance.

Arterial Management

Studies demonstrate the ability of traffic control ITS applications to enhance mobility, increase efficiency of the transportation systems, 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. 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.¹ Based on a series of surveys of arterial management agencies in 78 of the largest U.S. metropolitan areas, half of traffic signals in these metropolitan areas were under centralized control through closed-loop or computer control in 2006.

Freeway Management

There are numerous ITS strategies to improve freeway operations. Metropolitan areas that deploy ITS infrastructure including dynamic message signs (DMS) to manage freeway and arterial traffic, and integrate traveler information with incident management systems can increase peak period freeway speeds by 8 to 13 percent,² improve travel time, and according to simulation studies, reduce crash rates and improve trip time reliability with delay reductions ranging from 1 to 22 percent.³ In Minneapolis-St. Paul, the benefit-to-cost ratio for a ramp metering system was estimated at 15:1.⁴

The Florida DOT (FDOT) deployed 31 DMS in Broward County including associated structures, foundations, controllers, cabinets, and installation, plus approximately 37 miles of in-ground fiber optic communications at a cost of \$11 million. Annual operating costs were estimated at \$22,320 and annual maintenance costs were estimated at \$620,000. FDOT coordinates with other agencies to verify incident and congestion locations and then posts traveler information on the DMS along effected routes.⁵

Ramp meters now manage access to 13 percent of freeway miles in the country's 78 largest metropolitan areas, up from 9 percent in 2000. As of 2006, surveillance—consisting of loop detectors, radar detectors and acoustic detectors—is used to collect data on traffic conditions on 45 percent of freeway miles in the country's 78 largest metropolitan areas, up from 22 percent in 2000.

Crash Prevention and Safety

Road geometry warning systems can improve safety on highway ramps or curves that experience a high incidence of truck rollovers. Downhill speed warning systems have decreased truck crashes by up to 13 percent at problem sites in Oregon and Colorado.⁶ As part of an evaluation of automated truck rollover warning systems, the Pennsylvania DOT researched systems in other states. The cost of these systems varied significantly, ranging from \$50,000 to \$500,000, as did their configurations: invasive and non-invasive detection, weight-based versus simplified speed class algorithms, and system calibrations for warnings.⁷ The three most widely adopted systems are curve and ramp speed, rail crossing warning systems,

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and pedestrian safety systems. Next in popularity, and adopted by about half as many states, are downhill warning systems, intersection collision avoidance systems, and animal warning systems.

Road Weather Management

High-quality road weather information can benefit travelers, commercial vehicle operators, emergency responders, and agencies who construct, operate, and maintain roadways. Evaluation data show that 80 to 94 percent of motorists who use traveler information Web sites think road weather information enhances their safety and prepares them for adverse road weather.⁸ Studies have found that anti-icing programs can lower snow and ice control costs by 10 to 50 percent and reduce crash rates by 7 to 83 percent.⁹ Nine respondents to a fixed automated spray technology (FAST) survey indicated that cost of installations varied greatly, \$22,000 to \$4 million, depending on coverage area, site location, accessibility of existing utilities, system functionality and features, and market factors. Operations and maintenance (O&M) costs of FAST systems are relatively low compared to the installation costs.¹⁰ State DOTs disseminate weather warnings to public traveler information agencies in 26 states, traffic management agencies in 22 states, and incident management agencies in 21 states.

Roadway Operations and Maintenance

ITS technologies deployed for roadway operations and maintenance activities can have system-wide impacts. Network simulation models estimate that smart work zones can reduce total delay by 41 to 75 percent.¹¹ In addition to improving mobility, work zone ITS can improve safety. Evaluation data show that areas equipped with speed monitoring displays can decrease vehicle speeds by 4 to 6 mi/h,¹² and reduce the number of speeding vehicles by 25 to 78 percent.¹³ Work zone ITS deployment costs ranged from \$100,000 to \$2.5 million with the majority of systems ranging from \$150,000 to \$500,000.¹⁴

TRANSIT

Several applications of ITS for transit management have been deployed.

Transit Management

Fleet management applications, including automatic vehicle location (AVL) and computer-aided dispatch (CAD) systems, can improve both the experience of transit riders and the efficiency of transit operations by enabling more efficient planning, scheduling, and management of transit assets and resources. Transit agencies have reported reductions in fleet requirements ranging from two to five percent as a result of improved fleet utilization.¹⁵ Data from transit systems in Portland, Oregon; Milwaukee, Wisconsin; and Baltimore, Maryland show that AVL/CAD systems have improved schedule adherence by 9 to 23 percent.¹⁶

Mobile data terminals (MDTs) are an important component of transit fleet management systems. MDTs are multifunctional on-board devices that support two-way communication between the vehicle and the control center. Capital costs for MDTs typically range between \$1,000 and \$4,000 per unit with installation costs frequently between \$500 and \$1,000.¹⁷

The use of AVL on fixed-route buses has expanded rapidly during this period, growing from 32 percent in 2000 to almost 60 percent in 2006.

MANAGEMENT AND OPERATIONS

ITS strategies for improving transportation system management and operations include: transportation management centers, traffic incident management, emergency management, electronic payment and pricing, traveler information, and information management.

Transportation Management Centers

A transportation management center (TMC) integrates a variety of ITS applications to facilitate the coordination of information and services within the transportation system. Integrated transportation management systems supported by TMCs have the potential to improve traffic management, traveler information, and maintenance operations, and enable more effective use of agency personnel and resources.¹⁸

The cost of TMCs can vary greatly. Primary cost drivers include the size of the facility, the number of agencies present, and the number of functions performed by the facility.¹⁹ The capital cost of physical components can range from \$1.8 million to \$11.0 million per facility,²⁰ and have O&M costs that range from \$50,000 to \$1.8 million per year.²¹

In a survey of 102 freeway management agencies and 170 arterial management agencies conducted in 2006, capabilities reported by a high percentage of both types of TMC include incident management, network surveillance and data collection, dissemination of data to travelers and other agencies, as well as traffic management for special events and evacuations.

Traffic Incident Management

Traffic incident management programs have demonstrated success under each of the goals of ITS: mobility, safety, efficiency, productivity, energy and environment, and customer satisfaction. This success builds from the ability of the programs to significantly reduce the duration of traffic incidents, from 15 to 65 percent, with the bulk of studies finding savings of 30 to 40 percent.²²

One component of successful traffic incident management programs are service patrols for which State DOTs can spend from \$5.6 million to \$13.6 million per year.²³ Service patrols have also been the subject of numerous benefit-to-cost analyses over the course of their deployment, with 26 studies of the programs completed in 23 U.S. cities between 1994 and 2005. These studies document benefit-to-cost ratios ranging from 2:1 to 36:1.²⁴

Sharing data on the type, severity, and location of traffic incidents is a common practice of traffic incident management agencies. Sixty-eight (68) traffic incident management agencies in the country's 108 largest metropolitan areas share traffic incident data with public safety agencies, which tend to reciprocate the sharing of these data.

Emergency Management

ITS applications for emergency management can improve the efficiency of transportation capacity during emergencies, increase productivity for hazardous material (HAZMAT) shipping operations, and improve overall traveler safety and security. Evaluation data collected from a number of studies suggest that customer satisfaction with emergency management is largely positive. Stakeholders perceive positive impacts and indicate that these technologies are widely accepted. Contraflow freeway operations in South Carolina enabled a 76 percent increase in traffic volumes.²⁵ The HAZMAT Transportation Safety and Security Field Operational Test found that the technologies that enhance the safety and security of HAZMAT transportation operations range in cost from \$250 to \$3,500 per vehicle.²⁶ As of 2006, 80 percent of emergency management vehicles in the 108 largest metropolitan areas operate under computer-aided dispatch, an increase from 67 percent in 2000.

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Electronic Payment and Pricing

Electronic toll collection (ETC) is one of the most successful ITS applications with numerous benefits including delay reductions, improved throughput, and fuel economy. On freeways, variable pricing strategies are effective at influencing traveler behavior. Although initial public support for such tolls may be low, research indicates that road users value time savings and are willing to pay a price to avoid congestion and delay.²⁷ In California, for example, public support for variable tolling on State Route 91 was initially low; but after 18 months of operations, nearly 75 percent of the commuting public expressed approval of virtually all aspects of the express lanes program.²⁸

Electronic fare payment can yield customer satisfaction, productivity, and efficiency benefits for transit agencies. In a study of a hypothetical full deployment of ITS in three U.S. cities, the annualized life cycle costs for electronic transit fare payment systems were estimated at \$5.9 million for Seattle, Washington; \$2.4 million for Cincinnati, Ohio; and \$1.1 million for Tucson, Arizona.²⁹

Deployment of electronic toll collection is nearly universal, with more than 90 percent of toll plazas and more than 80 percent of toll lanes in the 78 metropolitan areas equipped with ETC. Many transit agencies are also offering customers the option of electronic payment. Customers can pay with magnetic card readers on more than 60 percent of transit buses in these 78 metropolitan areas and pay with “smart cards” on nearly one-third of transit buses in these 78 metropolitan areas.

Traveler Information

Evaluation of traveler information services has shown benefits in improved on-time reliability, better trip planning, and reduced early and late arrivals. Studies show that drivers who use route-specific travel time information instead of area-wide traffic advisories can improve on-time performance by 5 to 13 percent.³⁰ Recent evaluation data show that customer satisfaction with regional 511 deployments range from 68 to 92 percent.³¹ The 511 Deployment Coalition conducted an in-depth cost analysis based on the experience from nine 511 deployers. On average, the statewide systems cost approximately \$2.5 million to design, implement, and operate during the first year. Metropolitan systems cost an average of \$1.8 million to design, implement, and operate during the first year.³² The two most popular media for distributing traveler information in the 78 largest U.S. metropolitan areas are Web sites and e-mail, followed by automatic telephone and pagers. Thirty (30) of the 78 metropolitan areas use dedicated TV to distribute traveler information and 18 use kiosks, a medium which has seen no growth in recent years.

Information Management

Data archiving enhances ITS integration and allows for coordinated regional decision making. Traffic surveillance system data as well as data collected from commercial vehicle operations, transit systems, electronic payment systems, and road weather information systems have been the primary sources of archived data available to researchers and planners. Studies have demonstrated the cost savings that can be achieved by agencies making use of archived ITS data.³³ A study reviewing over 60 data archiving programs documented substantial returns on the investments made in the programs.³⁴ Stakeholders making use of archived data also had positive experiences to report.³⁵

The costs to develop archived data management systems (ADMS) vary based on the size of the system and features provided. Based on limited data available from a study of six transportation agencies that have established ADMS, costs for one system was \$85,000 and \$8 million for another.³⁶



Survey data from 546 arterial agencies, 147 freeway agencies, and 219 transit agencies found the most common uses for archived data by arterial management agencies were traffic analysis, traffic management, operations planning and analysis, and capital planning. Most common uses for archived data reported by freeway agencies were traffic analysis, operations planning and analysis, dissemination to the public, and performance measurement. Transit agencies most frequently reported using archived data for operations planning, performance measurement, safety analysis, and dissemination to the public.

FREIGHT

ITS deployed to improve freight transportation include those addressing commercial vehicle operations and intermodal freight.

Commercial Vehicle Operations

Evaluations of ITS applied to commercial vehicle operations have shown substantial improvements under the safety, mobility, and productivity goal areas. For example, electronic credentialing reduced paperwork and saved carriers participating in the Commercial Vehicle Information System and Networks (CVISN) Model Deployment 60 to 75 percent on credentialing costs.³⁷ Both motorcoach and truck drivers held favorable opinions of commercial vehicle electronic clearance, while a survey of Maryland motor carriers found that carriers with large fleets (25 or more vehicles) conducting business with State agencies value electronic data interchange and Internet technologies more than small fleets.³⁸

To help States track their own progress in deploying CVISN technologies, a self-evaluation requirement was included in the partnership agreements between the U.S. DOT and individual States. States now in the planning, decision-making, or early deployment stages can learn from the experiences of others; and States further along in the deployment process can learn new ideas that might help them improve their existing systems and networks.³⁹ To this end, a process for reporting CVISN costs data was established, and the results of the costs data collection and analysis were published and the costs data were imported to the ITS Costs Database. The reader is encouraged to access the ITS Costs Database for complete details of CVISN unit costs.

Benefit-to-cost ratios range from 2:1 to 12:1 for electronic screening,⁴⁰ 0.7:1 to 40:1 for electronic credentialing,⁴¹ and 1.3:1 to 6.1:1 for roadside safety inspection systems.⁴²

As of August 2007, 18 states had completed core deployment of CVISN and were working on expanding the core capability. Twenty-seven (27) states and the District of Columbia are in the process of deploying the core capability. Five states are in the process of planning and design of their core CVISN capability.

Intermodal Freight

Electronic supply chain manifest systems that automate the transfer of intelligent freight data between supply chain partners and government agencies have enabled freight operators to reduce administrative burdens, shorten processing times, and lower the cost of cargo movement. Initial field operational tests indicate that these automated tools, when applied to a domestic supply chain, can reduce the time it takes to accept and process cargo transfer documents by more than 50 percent.⁴³

Asset tracking technologies can monitor the location and identity of containers in real time. A study found that basic in-vehicle tracking equipment ranged from \$429 to \$995 per vehicle. Advanced in-vehicle tracking equipment (multiple sensors) ranged from \$1,290

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to \$2,275 per vehicle. Basic costs for asset tracking—tracking of trailers whether tethered or untethered—ranged from \$139 to \$500 per unit. Mid-range costs ranged from \$375 to \$450 per unit.⁴⁴

Intelligent Vehicles

VEHICLES

In-vehicle ITS include collision avoidance, driver assistance, and collision notification technologies.

Collision Avoidance

For passenger vehicles, collision warning systems can have a significant impact on vehicle safety. In an estimate developed jointly with industry, the U.S. DOT estimates that widespread deployment of integrated countermeasure systems could prevent over 48 percent of rear-end, run-off-road, and lane change crashes, representing 1.8 million target crashes.⁴⁵

Collision warning systems are still somewhat in the experimental stage and have had only limited application to date.⁴⁶ Rollover warning or roll stability control systems have limited commercial availability. Rear-impact warning or rear-end impact prevention systems are still in the research and development phase.⁴⁷ Some of the collision avoidance systems are available as factory-installed options, as standard items included in the base cost of a vehicle, or as a component of an upgrade package.

Driver Assistance

Evaluations have documented the performance of in-vehicle navigation systems, driver communication systems, adaptive cruise control (ACC), and roll stability control. In-vehicle navigation and route guidance systems have gained mainstream acceptance and are widely available in private vehicles. When linked to sources of current traffic congestion information to provide dynamic routing, one study found that the devices could reduce traffic congestion and thereby provide additional network capacity.⁴⁸

Several studies have been completed assessing the potential of ACC, which is now available in some private vehicles. The most recent studies have found that the systems are most effective at improving safety when bundled with collision warning systems.⁴⁹ With widespread deployment, ACC has the ability to reduce vehicle emissions and increase the capacity of roadways.⁵⁰

While both cars and sport utility vehicles (SUVs) benefit from electronic stability control systems, the reduction in the risk of single-vehicle crashes was significantly greater for SUVs (49 to 67 percent) than for cars (33 to 44 percent).⁵¹ With respect to fatal single-vehicle crashes, however, the impacts were similar (59 percent reduction for SUVs and 53 percent reduction for cars).⁵²

On-board safety systems are offered as an option on some vehicles; but more often than not these systems are being packaged with comfort, convenience, and entertainment services. A consumer willing to pay for ACC, for example, may forgo the purchase if required to buy a more expensive package that includes unrelated and unwanted features such as climate-controlled front seats and a rear-view monitor. As a result, this bundling approach is deterring consumers from purchasing safety systems. Another side effect of bundling is the difficulty in determining the cost of each individual ITS technology.⁵³

Collision Notification

Evaluations to date have documented strong customer satisfaction with automated collision notification (ACN) systems. These benefits include a heightened sense of safety, as reported by travelers testing an early deployment of the systems in Washington State.⁵⁴ An evaluation of advanced ACN documented improved notification times for crashes reported by the ACN system, demonstrating a significant safety benefit that can be achieved using either type of ACN system.⁵⁵

In a recent study of private-sector deployment of ITS, the costs of telecommunications- and location-based services designed to assist motorists were estimated at \$350 per unit. The first year's subscription was included in the retail price of the vehicle with subsequent subscriptions sold on an annual basis. One basic safety and security subscription package cost \$199 per year with other packages costing \$399 and \$799 per year. The basic safety and security package included advanced safety features such as advanced ACN. It appears that the trend of telematics services is on the decline as several automakers have discontinued these services due to lack of consumer interest.⁵⁶

Lessons Learned

The lessons learned discussed in this report provide a synthesis of stakeholders' experience in the planning, deployment, operations, maintenance, and evaluation of ITS. Such learning is intended to foster informed decision making by the readers in their own ITS initiatives. For example, a planner may learn that including ITS projects in the State's long range transportation plan is a sensible way to take advantage of multiple project synergies and stable funding, and a traveler information Web site designer may learn that embedding a function for receiving customer feedback is essential to improving the usability of the site.

The lesson learned topics discussed in this report are: management and operations, policy and planning, design and deployment, leadership and partnerships, funding, technical integration, procurement, legal issues, and human resources.

Management and Operations

The lessons learned on management and operations (M&O) discuss decision-making approaches to implement, operate, and maintain transportation facilities with the intent of optimizing system performance and improving safety, mobility, efficiency, and reliability of the Nation's transportation infrastructure. M&O approaches may include operations structure and strategy, M&O plans and programs, systems data and storage, performance measurement and evaluation, and M&O tools and models. Key lessons learned are summarized below:

- Coordinate across jurisdictions, share resources, and create procedures that do not threaten individual agencies' roles.
- Continually seek ways to make operations more effective when deploying ITS.
- Evaluate and upgrade maintenance programs on an ongoing basis.
- Strengthen interest in data archiving systems among traffic managers.
- Provide an avenue for operators and customers to get involved in the planning process, incorporate operational performance measures in strategic and long-range plans.
- Design Web sites with usability in mind and obtain feedback from customers.

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Policy and Planning

The lessons learned on policy and planning discuss policies and approaches used to incorporate the consideration of ITS products and services in the transportation planning process. Such policies and approaches may include the development of policies used to elicit buy-in from regional stakeholders, as well as preparation of planning documents such as a regional ITS architecture, an ITS strategic plan, a concept of operations, a long-range transportation improvement plan, or use of traffic analysis tools to assist in evaluating alternatives. Key lessons learned are summarized below:

- Develop ITS stakeholder policies to ensure efficiency, consistency, and interoperability in deploying integrated systems.
- Develop a formal ITS data sharing policy.
- Learn the successful approaches to ITS planning.
- Anticipate challenges in planning and deploying ITS in a rural environment.
- Use the National ITS Architecture and other tools for effective ITS planning.
- Include ITS in the State's long-range transportation plan to take advantage of project synergies and stable funding.

Design and Deployment

The lessons learned on design and deployment discuss approaches used in the design and completion of an ITS project including the choice of appropriate ITS technologies, use of ITS standards and systems engineering, ITS software development, and construction and implementation techniques. Design and deployment lessons include experiences in project management, requirements and design, standards and interoperability, implementation, quality assurance and testing, and design tools and models. Key lessons learned are summarized below:

- Make use of flexible methods and accepted techniques for successful project management.
- Design and tailor system technology to deliver an ITS project that meets the needs of the users and the customers.
- Recognize interoperability as an important issue in achieving the vision of a nationwide 511 system.
- Cultivate commitment by the Federal Highway Administration and/or other appropriate agencies at the Federal level.
- Consider that advanced traveler information system deployment in rural and/or remote areas presents special challenges.
- Implement a limited-deployment fare pass system before implementing a region-wide fare card system.
- Conduct rigorous testing prior to deployment of an ITS project.
- Conduct a requirements analysis to determine the most appropriate ITS telecommunications solution.

Leadership and Partnerships

The lessons learned on leadership and partnerships discuss the role of an ITS champion, partnerships that promote collaboration and cooperation among multiple agencies in deploying ITS, outreach and awareness efforts that make stakeholders knowledgeable

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and accepting of ITS, and organizational structures that facilitate efficient planning and implementation of ITS. Key lessons learned are summarized below:

- For regional ITS deployments involving multiple agencies, find an influential project champion for successful execution of the project.
- Forge regional partnership agreements capable of addressing the specific characteristics of individual partner agencies and their customers.
- Consider public-private, partnership-based unique financing methods as ways to cover costs for transportation projects.
- Consider several forms of customer outreach services, with a focus on customer convenience.
- Conduct systematic surveys of and interviews with customers periodically to reliably assess customer satisfaction and to design strategies to improve satisfaction.
- Consider a consensus organizational model to help assure support and participation of partners in a regional ITS deployment, but beware of potential delays in implementation.
- Clearly define the organizational structure and establish an ITS Program Coordinator to ensure an effective ITS program.

Funding

The lessons learned on funding discuss approaches to sourcing of funds, including Federal, State, regional and local, private, funding source combinations, and innovative financing. For the five-year period from 2005 to 2009, Federal funding for highways and transit is established by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). State and local agencies play a large role in financing, owning, and operating highway, and ITS systems and networks. Private financing refers to ways that State and local agencies can collaborate with the private sector to develop unique opportunities for funding ITS projects. Innovative financing for transportation is a broadly-defined term that encompasses a combination of specially designed techniques that supplement traditional highway financing methods. Key lessons learned are summarized below:

- Clarify Federal funding regulations for projects that are service-oriented and do not deliver tangible products.
- Distribute financial resources equitably according to agency capital cost shares.
- Leverage State assistance in the procurement and funding of ITS technologies for rural transit.
- Consider partnering with neighboring agencies and non-traditional stakeholders.
- Consider public-private partnerships and unique financing methods as ways to cover costs for ITS projects.
- Examine multiple funding sources and anticipate unforeseen costs associated with deploying ITS.
- Consider development impact fees, special assessments, and other innovative mechanisms to help finance ITS projects, and management and operations strategies.

Technical Integration

The lessons learned on technical integration discuss approaches that facilitate the technical connection of dispersed ITS elements for efficient information sharing and control in



transportation management and operations. Such integration may occur among multiple systems, agencies, and regions. Technical integration is a multi-faceted concept that may include functional integration, jurisdictional considerations, and the integration of legacy systems. Key lessons learned are summarized below:

- Assess user needs and follow accepted usability engineering practices when developing interactive systems to develop usable systems.
- Use ITS standards when developing systems to maximize vendor flexibility and data exchange compatibility, and ensure comprehension by agencies.
- Create systems and plans that allow information sharing and coordination among regional agencies and states.
- Consider developing an emergency response plan that coordinates command, control, and communications among regional agencies.
- Comply with standards and select proven commercial off-the-shelf technology (hardware and software), when possible, to save money and facilitate integration with existing legacy systems.
- To identify and resolve system integration issues with existing legacy equipment, plan on adequate development time and thorough system testing to ensure systems are working properly after system integration.

Procurement

The lessons learned in procurement address critical steps in the acquisition of ITS projects and captures stakeholders' experiences in work allocation, method of award, contract form, contract type, and terms and conditions. Key lessons learned are summarized below:

- Determine agency capability level when selecting the most appropriate ITS procurement package.
- Maintain owner control and consistent oversight to keep a project on time and on budget.
- Utilize flexible procurement methods that allow for thorough and detailed negotiations.
- Consider dividing a large ITS project into manageable task orders.
- Consider performance-based contracts, including incentives and penalties, during the procurement process.
- Create policies to specifically address software and technologies including intellectual property rights that are brought into, enhanced, and developed during a project.

Legal Issues

The lessons learned in legal issues provide insights on intellectual property, liability, privacy, and rules and regulations. Many of these areas, such as liability and intellectual property, are not unique to ITS and apply to many other domains, whereas others, such as privacy, have particular relevance and application to ITS, as new ITS technologies can often raise concerns about privacy. Key lessons are summarized below:

- Address intellectual property rights (IPR) early to develop a clear policy and increase efficiency.
- Understand the IPR issues concerning software development and technology and develop a clear policy to address these issues.
- Develop written policies to address liability issues early.

- Carefully consider data sharing issues to effectively balance information sharing needs with data security measures for ITS applications.
- Plan and create policies and rules that address electronic toll collection, enforcement, and data sharing issues.
- Develop a regional information sharing policy to help define information access and compensation arrangements.
- Consider legislative authority and institutional arrangements to help affect policy changes.

Human Resources

The lessons learned on human resources provide insights on managing staffing needs for ITS projects including personnel management, recruiting, retention and turnover, and training. ITS projects involve application of engineering, electronics, and computer information technology principles. Therefore, the human resource needs for ITS projects vary significantly from the traditional transportation engineering projects of facility construction and operations. Key lessons are summarized below:

- Develop a staffing plan flexible enough to accommodate both routine and emergency conditions.
- Consider different staffing arrangements to meet various scheduling demands at a transportation management center.
- Evaluate technical and support staffing needs to close gaps in ITS operational support.
- Involve staff in the ITS planning and deployment process.
- Create meaningful career paths and adopt optimal workload conditions for successful operations staff hiring and retention.
- Train staff throughout the deployment of a project to ensure successful implementation and use of ITS resources.
- Provide training to maintenance crews before introducing a maintenance decision support system.
- Implement cross-training mechanisms to allow task-transfer to handle variable staffing needs.

Detailed narratives for the key lessons noted above are presented in the Lessons Learned chapter of this report. For additional guidance, the U.S. DOT's ITS Lessons Learned Web site (www.itslessons.its.dot.gov), which served as the basis for this synthesis, contains a significant body of knowledge on all topic areas discussed in this report.

This report presents many benefits based on evaluations of deployed ITS, deployment and operations costs, as well as lessons learned during ITS planning and operation. The level of ITS deployment in the United States and worldwide continues to increase. As experience with ITS deployment and operations continues to accrue, the Web-based ITS Knowledge Resources developed by the ITS JPO will be updated to provide convenient access to this information, enabling informed ITS decision making.

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ENDNOTES

1 The estimate of \$2,500 to \$3,100 is based on information from the following sources:

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INTRODUCTION

Mobility and safety challenges are increasing on the Nation's transportation system. A recent study estimated the cost of traffic congestion in U.S. cities for 2005 at \$78 billion, with 4.2 billion hours of delay and 2.9 billion gallons of fuel wasted.⁵⁷ Fatalities on U.S. highways rose to 43,443 in 2005.⁵⁸ Public transportation systems provided 10.1 billion trips in 2006, the highest in 49 years, with continuing increases documented through the first three quarters of 2007.⁵⁹ Freight volume on U.S. highways is expected to increase to 22.8 billion tons in 2035, up from 11.5 billion tons in 2002.⁶⁰

Intelligent transportation systems (ITS) provide a proven set of strategies for addressing the challenges of assuring safety and reducing congestion, while accommodating the growth in transit ridership and freight movement. ITS improve transportation safety and mobility, and enhance productivity through the use of advanced communications, sensors, and information processing technologies encompassing a broad range of wireless and wireline communications-based information and electronics. When integrated into the transportation system's infrastructure, and into vehicles themselves, these technologies relieve congestion, improve safety, and enhance U.S. productivity.⁶¹ Vehicle infrastructure integration has the potential to enable many services presently provided by infrastructure- or vehicle-based ITS to benefit from enhanced communication between vehicles and the infrastructure.

ITS deployment can impact transportation system performance in six key goal areas: safety, mobility, efficiency, productivity, energy and environment, and customer satisfaction. A wide variety of performance measures are used across the evaluations discussed in this report to assess ITS performance under each of these goal areas. *Safety* is measured through changes in crash rates or other surrogate measures such as vehicle speeds, traffic conflicts, or traffic law violations. *Mobility* improvements have been measured in travel time or delay savings, as well as travel time budget savings, and on-time performance. *Efficiency* findings document the capability of better managed transportation facilities to accommodate additional demand, typically represented through increases in capacity or level of service within existing road networks or transit systems. *Productivity* improvements are typically documented in cost savings to transportation providers, travelers, or shippers. Benefits in the area of *Energy and Environment* are typically documented through fuel savings and reduced pollutant emissions. *Customer Satisfaction* findings measure, usually through surveys, the perception of deployed ITS by the traveling public.

This report presents information on the performance of deployed ITS under each of these goal areas, as well as information on the costs, deployment levels, and lessons learned regarding ITS deployment and operations. The report, and the collection of four Web-based resources upon which it is based, have been developed by the U.S. DOT's ITS Joint Program Office (JPO) to support informed decision making regarding ITS deployment.

To support the deployment of ITS to address the challenges facing the U.S. transportation system, the JPO has developed a suite of knowledge resources. This collection of four Web-based resources provides ready access to information supporting informed decision making regarding deployment and operation of ITS to improve transportation system performance. Information presented in these online knowledge resources is the basis for this document. The four knowledge resources are the ITS Benefits Database, ITS Costs Database, ITS Deployment Statistics Database, and the ITS Lessons Learned Knowledge Resource. A fifth Web site, the ITS Applications Overview, provides access to information from each of the knowledge resources using an organization scheme similar to that used in this report.

Additional information on each finding cited in this document can be found in the online knowledge resources, along with links to the original source documents, when available. See the "About This Report" section, below, for more information on accessing specific citations in this report online. Each of the knowledge resources is briefly described below. Additional information about each resource is available online including details about each site's organization, frequency of updates, and how to contribute information to the resources. When visiting the Web sites, follow the link to the "About This Site" and "Frequently Ask Questions (FAQ)" pages of each site for this information.

ITS Benefits Database

The major objectives of the ITS Benefits Database, available online at www.itsbenefits.its.dot.gov, are to:

- Document findings from the evaluation of ITS deployments pertaining to the effects of ITS on transportation systems performance.
- Provide transportation professionals with convenient access to the benefits of ITS deployment so that they can make informed planning and investment decisions.

Within the ITS Benefits Database, findings from ITS evaluations are presented in a concise summary format. Each benefit summary includes a title in the form of a short statement of the evaluation finding, context narrative, and identifying information such as date, location, and source, as well as the evaluation details that describe how the identified ITS benefit was determined. The ITS Benefits Database documents all findings of ITS evaluations, regardless of outcome, and includes several findings of neutral impact and a few examples of negative impacts under particular goal areas. The Web site includes a useful search capability and also presents findings through several organization schemes including the ITS application areas discussed in chapters of this report, the ITS goal areas, and by location.

ITS Costs Database

The ITS Costs Database, available online at www.itscosts.its.dot.gov, was established as a national repository of cost estimates for ITS deployments. The purpose of the ITS Costs Database is to support informed decision making by transportation leaders.

OPERATIONS/ITS HELPLINE

1-866-367-7487

ITS APPLICATION OVERVIEW

www.itsoverview.its.dot.gov



The ITS Costs Database contains estimates of ITS costs that can be used for developing project cost estimates during the planning process or preliminary design phase, and for policy studies and benefit-cost analyses. Both non-recurring (capital) and recurring or operations and maintenance (O&M) costs are provided where possible.

Two types of cost data are available: unit costs and system cost summaries. The primary difference in the two types is the level of aggregation. Unit costs are the costs associated with an individual ITS element, such as a video camera for traffic surveillance or a dynamic message sign. A range of costs (e.g., \$500 to \$1,000) is presented for the capital cost and annual O&M cost of each element as well as an estimate of the length in years of its usable life. Unit costs are available in two formats: unadjusted and adjusted. (Adjusted costs are available in Appendix A.) System cost summaries are the costs of an ITS project or portion of an ITS project such as the cost of expanding a statewide road weather information system or the detailed costs for a signal interconnect project. Each entry describes the background of the project, lists the ITS technologies deployed, and presents the costs and what the costs covered.

ITS Deployment Statistics Database

The ITS Deployment Tracking Project collects and disseminates information on the level of deployment and integration of ITS technology nationally. Information is gathered through a series of national surveys, covering metropolitan as well as rural deployment. Data have been collected in a series of national surveys conducted in 1997, 1999, 2000, 2002, 2004, 2005, and 2006. In the most recent survey, conducted in 2006, information was gathered from 108 of the largest metropolitan areas, shown in figure 1 on page 6. Within each metropolitan area, agencies involved with freeway, arterial, and transit management; public safety (law enforcement and fire/rescue/emergency medical services); and toll collection were surveyed. Statewide and rural deployment information was also gathered in a survey of each of the 50 states concerning ITS deployment for crash prevention and safety, road weather management, operations and maintenance, and traveler information. More than 2,100 agencies were covered in the 2006 survey, with a response rate nearly 90 percent. The deployment statistics database serves as a source of information on ITS deployment for the U.S. DOT, State and local transportation agencies, researchers, vendors, and the general public. Results from this survey and all previous national surveys are available online at www.itsdeployment.its.dot.gov. The Web site also provides access to survey results in the form of downloadable reports and fact sheets.

ITS Lessons Learned Knowledge Resource

A lesson learned is the knowledge gained through experience or study. It is a reflection on what was done right, what one would do differently, and how one could be more effective in the future. The ITS Lessons Learned Knowledge Resource, available online at www.itslessons.its.dot.gov, provides the ITS professional community with access to those lessons learned from others' experiences. This knowledge resource serves as a clearinghouse to document and share experiences of transportation practitioners in their planning, deployment, operations, maintenance, and evaluation of ITS to enable informed decision making regarding future ITS projects and programs. ITS lessons are collected primarily from case studies, best practice compendiums, planning and design reviews, and evaluation studies. The ITS Electronic Document Library, the Transportation Research Board's Transportation Research Information Services, international transportation literature databases (e.g., Transport), and conference proceedings are major sources for the documents that are reviewed. Interviews of subject matter experts are also used as sources of new lessons.

THE FOUR WEB-BASED KNOWLEDGE RESOURCES PROVIDE TOOLS TO SUPPORT INFORMED DECISION MAKING REGARDING THE DEPLOYMENT AND OPERATION OF ITS.

The lessons learned in this knowledge resource are based on the experiences of one or more ITS stakeholders from numerous ITS projects and programs in the country. Thus, a major focus for lessons presented in this document has been to gather typical field evidence—evidence-based lessons learned—that other stakeholders could benefit from learning.

Narratives of field evidence for selected key lessons are interspersed throughout this report, while more extensive details for the same and many other lessons can be found on the ITS Lessons Learned Web site (www.itslessons.its.dot.gov). A full chapter of this report is dedicated to the presentation of a synthesis of lessons on key areas of interest, such as ITS planning, procurement, and legal issues.

ITS Applications Overview

The ITS Applications Overview, available at www.itsoverview.its.dot.gov, provides access to each of the four knowledge resources described above, organized by the ITS application areas described in this report. The Web site also provides additional information regarding each ITS application including:

- Evaluation documents available from the ITS JPO
- Related U.S. DOT initiatives and other program activities
- Other resources available through the JPO's ITS/Operations Resource Guide
- Points of contact within the U.S. DOT.

About this Report

Eighth in a series of reports based upon evaluation results collected by the ITS JPO, this is the first to include information on ITS deployment statistics. Deployment information is drawn from selected findings of the ITS Deployment Tracking surveys conducted by the ITS JPO. It is also the first to more fully discuss a variety of important lessons learned through ITS deployment and operation, now presented in a series of chapters containing the results of a synthesis of ITS lessons learned knowledge. Sample lessons were provided in the previous version of this report—*Intelligent Transportation Systems Benefits, Costs, and Lessons: 2005 Update*—and in the online knowledge resource launched in September of that year. Previous versions of the report included information on ITS costs, beginning with the 2003 edition, while the original five reports in the series discussed ITS benefits.

Report Organization

Following this introductory chapter, this report begins discussion of 17 different areas of ITS applications. These chapters are divided into two groups discussing technologies deployed on the transportation infrastructure and those deployed within vehicles. The 14 infrastructure applications are further divided into groups of ITS strategies applied to roadways, transit, management and operations, and freight movement. Each chapter broadly describes the various ITS technologies that are typically deployed within a particular application area such as freeway management or commercial vehicle operations. A broad discussion of significant findings from the collected studies within the benefits, costs, and deployment knowledge resources follows. The chapters conclude with a series of specific highlighted findings from the knowledge resources, presented in a tabular format. Significant lessons learned are presented as sidebars within each chapter.

Another chapter of this report includes a synthesis of the lessons learned collected in the ITS Lessons Learned Knowledge Resource. Nine sections present this information

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according to significant lesson topic areas such as management and operations, and policy and planning.

A brief conclusion is followed by two significant appendices. Appendix A presents adjusted unit costs (in 2006 dollars) for ITS components, drawn from the ITS Costs Database. Appendix B documents the volume of information available in the ITS Benefits Database, ITS Costs Database, and ITS Lessons Learned Knowledge Resource, presenting the number of findings available for each of the ITS application areas discussed in this report. The concluding references section includes useful information for accessing information on each cited reference within the knowledge resources, further described below.

Accessing Source Documents Online

Many of the findings presented in this report include numbered annotations further described in the “Endnotes” section near the end of the document. These endnotes provide reference information and short identification numbers that can be entered into the Knowledge Resources Web site search feature to quickly access more complete information on the cited finding and a link to the cited source document, if it is available online. The identification numbers are labeled Benefits ID, Costs ID, and Lessons Learned ID. For example, the second endnote includes the following citation:

² Birst, Shawn and Ayman Smadi. “An Evaluation of ITS for Incident Management in Second-Tier Cities: A Fargo, ND Case Study,” Paper Presented at ITE 2000 Annual Meeting. Nashville, Tennessee. 6–10 August 2000. Benefits ID: 2007-00335

Visiting the ITS Benefits Database, at www.itsbenefits.its.dot.gov, and entering 2007-00335 in the search input box will provide direct access to the online summary of findings from this study. To access more detailed costs information, Costs ID numbers should be entered in the ITS Costs Database Web site, at www.itscosts.its.dot.gov, and Lessons Learned ID numbers will provide access to the relevant entries in the ITS Lessons Learned Knowledge Resource, at www.itslessons.its.dot.gov.



Figure 1 – Metropolitan Areas Surveyed Through the ITS Deployment Tracking Project

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Assessment of Intelligent Transportation Systems/Commercial Vehicle Operations Users Services: ITS/CVO Qualitative Benefits/Cost Analysis—Executive Summary, American Trucking Associations Foundation. Alexandria, VA. 1996. Benefits ID: 2007-00457

Automated Enforcement in Transportation, Institute of Transportation Engineers, Report No. IR-100. Washington, DC. December 1999. Benefits ID: 2007-00341

- 43 *Electronic Intermodal Supply Chain Manifest Field Operational Test Evaluation Final Report*, U.S. DOT Federal Highway Administration, EDL No. 13769. December 2002. Benefits ID: 2003-00254
- 44 *Hazardous Material Transportation Safety and Security Field Operational Test: Final Report—Deployment Team*, U.S. DOT Federal Motor Carrier Safety Administration. 31 August 2004. Costs ID: 2006-00100
- 45 *Integrated Vehicle Based Safety Systems: A Major ITS Initiative*, U.S. DOT, Report No. FHWA-JPO-05-019, EDL No. 14084. August 2005. Benefits ID: 2008-00572
- 46 Kittelson and Associates, et al. *TCRP Report 118: Bus Rapid Transit Practitioner's Guide*, Transportation Research Board, Transit Cooperative Research Program. Washington, DC. 2007. Costs ID: 2008-00148
- 47 *Private Sector Deployment of Intelligent Transportation Systems: Current Status and Trends*, U.S. DOT, Report No. FHWA-JPO-06-028, EDL No. 14266. February 2006. Costs ID: 2008-00175
- 48 *TravTek Evaluation Modeling Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-RD-95-090, EDL No. 4403. January 1996. Benefits ID: 2000-00078
- 49 *Evaluation of Intelligent Cruise Control System: Volume I—Study Results*, U.S. DOT, Report No. DOT-VNTSC-NHTSA-98-3, EDL No. 11843. October 1999. Benefits ID: 2007-00481
- 50 Bose, A. and P. Ioannou. "Evaluation of the Environmental Effects of Intelligent Cruise Control (ICC) Vehicles," Paper Presented at the 80th Annual Meeting of the Transportation Research Board. Washington, DC. 7–11 January 2001. Benefits ID: 2001-00202
- 51 Sources that support these findings:
 - Farmer, C. *Effect of Electronic Stability Control on Automobile Crash Risk*, Insurance Institute for Highway Safety. Arlington, VA. 2004. Benefits ID: 2008-00577
 - Ohono and Shimura. *Results From the Survey on Effectiveness of Electronic Stability Control (ESC)*, National Agency for Automotive Safety and Victims' Aid. 18 February 2005. Benefits ID: 2008-00578
 - Preliminary Results Analyzing the Effectiveness of Electronic Stability Control (ESC) Systems*, U.S. DOT National Highway Traffic Safety Agency, Report No. DOT HS 809 790. September 2004. Benefits ID: 2008-00579
 - "Update on Electronic Stability Control," *Insurance Institute for Highway Safety*, Status Report, Vol. 41, No. 5. 13 June 2006. Benefits ID: 2008-00580
- 52 "Update on Electronic Stability Control," *Insurance Institute for Highway Safety*, Status Report, Vol. 41, No. 5. 13 June 2006. Benefits ID: 2008-00580
- 53 *Private Sector Deployment of Intelligent Transportation Systems: Current Status and Trends*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-028, EDL No. 14266. February 2006. Costs ID: 2008-00175
- 54 Haselkorn, M., et al. *Evaluation of PuSHMe Mayday System*. Prepared by the Washington State Transportation Center (TRAC) for the Washington State Transportation Commission. September 1997. Benefits ID: 2000-00027
- 55 *Automated Collision Notification (ACN) Field Operational Test (FOT) Evaluation Report*, U.S. DOT National Highway Traffic Safety Administration, Report No. DOT-HS-809-304, EDL No. 13830. February 2001. Benefits ID: 2003-00252
- 56 *Private Sector Deployment of Intelligent Transportation Systems: Current Status and Trends*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-028, EDL No. 14266. February 2006. Costs ID: 2008-00175
- 57 Schrank, David and Tim Lomax. 2007 *Urban Mobility Report*, Texas A&M University, Texas Transportation Institute. September 2007.
- 58 "FHWA Safety," U.S. DOT Federal Highway Administration, Office of Safety, Web site URL safety.fhwa.dot.gov. Last Accessed 17 December 2007.
- 59 "Public Transportation Ridership Statistics," American Public Transportation Association, Web site URL www.apta.com/research/stats/ridership. Last Accessed 17 December 2007.

- 60** "Freight Facts and Figures 2006," U.S. DOT Federal Highway Administration, Freight Management and Operations, Web site URL ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/06factsfigures/index.htm. Last Accessed 17 December 2007.
- 61** "ITS Overview," U.S. DOT, ITS Joint Program Office, Web site URL www.its.dot.gov/its_overview.htm. Last Accessed 17 December 2007.
- 62** *National Strategy to Reduce Congestion on America's Transportation Network*, U.S DOT. May 2006.
- 63** "Integrated Corridor Management (ICM) Quarterly Newsletter—Spring 2007," U.S. DOT ITS Joint Program Office, Web Site URL www.its.dot.gov/icms/index.htm. Last Accessed 13 November 2007.
- 64** Sources that support these findings (individual cities implementing coordinated signal timing):
- Hetrick, Stephen and Curtis B. McCollough. "How to save \$4.2 Million a Year," *ITS International Newsletter*. June 1996. Benefits ID: 2007-00349
- Skabardonis, Alexander. "ITS Benefits: The Case of Traffic Signal Control Systems," Paper Presented at the 80th Annual Transportation Research Board Meeting. Washington, DC. 7–11 January 2001. Benefits ID: 2007-00356
- Sunkari, Srinivasa. "The Benefits of Retiming Traffic Signals," *ITE Journal*. April 2004. Benefits ID: 2007-00393
- Syracuse Signal Interconnect Project: Before and After Analysis Final Report*, Prepared by DMJM Harris for the New York State DOT. September 2003. Correspondence with DMJM Harris. Benefits ID: 2007-00398
- White, Jeris, et al. *Traffic Signal Optimization for Tysons Corner Network Volume I. Evaluation and Summary*, Virginia DOT, Report No. TPE. R7D.03.08.00. March 2000. Benefits ID: 2007-00395
- Additional sources that reference findings for two statewide programs (California and Texas):
- Skabardonis, Alexander. "ITS Benefits: The Case of Traffic Signal Control Systems," Paper Presented at the 80th Annual Transportation Research Board Meeting. Washington, DC. 7–11 January 2001. Benefits ID: 2007-00356
- Sunkari, Srinivasa. "The Benefits of Retiming Traffic Signals," *ITE Journal*. April 2004. Benefits ID: 2007-00393
- 65** Sources that support these findings:
- Hetrick, Stephen, and Curtis B. McCollough. "How to save \$4.2 Million a Year," *ITS International Newsletter*. June 1996. Benefits ID: 2000-00065
- ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results*, U.S. DOT, EDL No. 11323. September 1999. Benefits ID: 2007-00358
- Phoenix Metropolitan Model Deployment Initiative Evaluation Report (Final Draft)*, U.S. DOT, Report No. FHWA-OP-00-015, EDL No. 12743. April 2000. Benefits ID: 2007-00378
- Syracuse Signal Interconnect Project: Before and After Analysis Final Report*, Prepared by DMJM Harris for the New York State DOT. Syracuse, NY. September 2003. Benefits ID: 2004-00273
- White, Jeris, et al. *Traffic Signal Optimization for Tysons Corner Network, Volume 1: Evaluation and Summary*, Virginia DOT, Report No. TPE. R7D.03.08.00. March 2000. Benefits ID: 2000-00126
- 66** *Automated Enforcement: A Compendium of Worldwide Evaluations of Results*, U.S. DOT National Highway Traffic Safety Administration, Report No. DOT HS 810 763. July 2007. Benefits ID: 2008-00505
- 67** The estimate of \$2,500 to \$3,100 is based on information from the following sources:
- Conversation with Mr. Jerry Luor. Traffic Engineering Supervisor, Denver Regional Council of Governments (DRCOG). October 2006. Costs ID: 2007-00117
- Fee Estimate—Millennia Mall Retiming and Scope and Schedule—Millennia Mall Retiming*, Bid submitted by TEI Engineering to the City of Orlando, FL. October 2005. Costs ID: 2007-00113
- Heminger, S. "Regional Signal Timing Program—2005 Cycle Program Performance," Memorandum to the California Metropolitan Transportation Commission's Operations Committee. Oakland, CA. October 2006. Costs ID: 2007-00112
- Harris, J. "Benefits of Retiming Traffic Signals: A Reference for Practitioners and Decision Makers About the Benefits of Traffic Signal Retiming," Presented at the ITE 2005 Annual Meeting and Exhibit. Melbourne, Australia. 7–10 August 2005. Costs ID: 2007-00115
- Sunkari, Srinivasa. "The Benefits of Retiming Traffic Signals," *ITE Journal*. April 2004. Costs ID: 2007-00116

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

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.

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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 + Positive impacts
 ○ Negligible impacts * Mixed results
 ✘ Negative impacts blank Not enough data

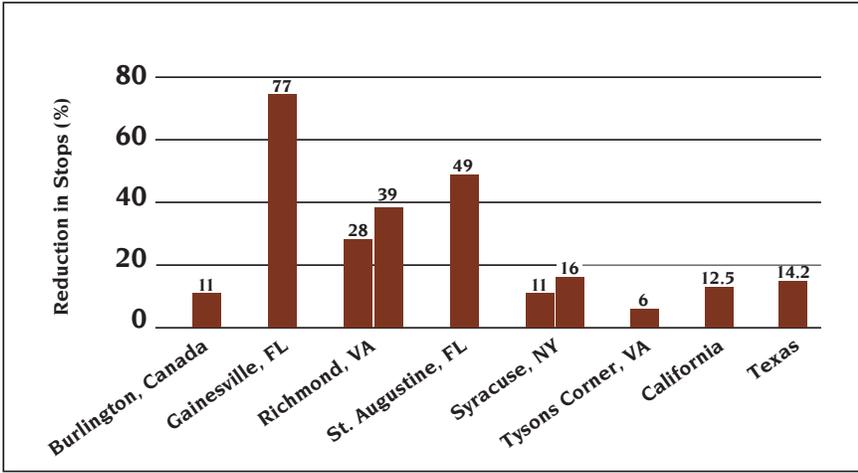


Figure 2 – Reduction of Number of Stops With Traffic Signal Coordination

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

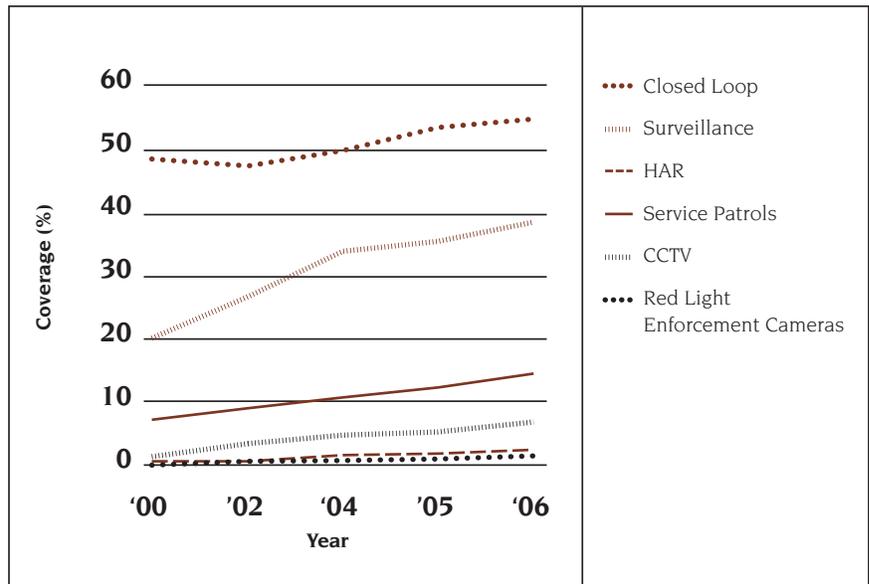


Figure 3 – Deployment Trends for Arterial ITS, 2000-2006

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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • Hardware, Software for Traffic Surveillance: \$131K-\$160K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>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:</p> <ul style="list-style-type: none"> • Upgrading the existing network of copper wire (twisted pair) traffic signal control communications network • Converting to fiber optic communications. <p>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</p> <p>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 \$65,000⁷¹</p>

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: <ul style="list-style-type: none"> • Signal Controller and Cabinet: \$8K-\$14K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • 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	
<p>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</p>	

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	
<p>Fifty-four (54) percent of signalized intersections in the country's 108 largest metropolitan areas operate under centralized computer control.</p>	
Benefits	
ITS Goals	Selected Findings
Safety	<p>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</p>
Mobility	<p>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</p>
Efficiency	<p>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</p>
Energy and Environment	<p>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</p>

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: <ul style="list-style-type: none"> • Signal Controller Upgrade for Signal Control: \$2.4K-\$6.0K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software, Integration for Signal Control: \$287K-\$383K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	
Sample Costs of ITS Deployments	
<p>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</p> <p>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</p>	
Benefit-Cost Studies	
<p>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</p> <p>California: A 2005 Oakland Metropolitan Transportation Commission analysis of its traffic signal coordination program yielded a benefit-to-cost ratio of 39:1.⁸⁶</p>	

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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: <ul style="list-style-type: none"> • Pedestrian Detection—Microwave: \$0.6K • Pedestrian Detection—Infrared: \$0.3K-\$0.5K Roadside Information subsystem: <ul style="list-style-type: none"> • Light-Emitting Diode (LED) Countdown Signal: \$0.306K-\$0.424K • Pedestrian Crossing Illumination System: \$26.8K-\$41K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • 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	

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.)

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: <ul style="list-style-type: none"> • Linked Signal System Local Area Network (LAN): \$23K-\$55K Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K • Dynamic Message Sign—Portable: \$18.6K-\$24K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • 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	

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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: <ul style="list-style-type: none"> • Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Labor for Lane Control: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>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</p>

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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>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</p> <p>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</p> <p>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</p>

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: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K • Dynamic Message Sign—Portable: \$18.6K-\$24K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • 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
<p>Unit Costs Data Examples (See Appendix A for more detail)</p> <p>Roadside Detection subsystem:</p> <ul style="list-style-type: none"> • Portable Speed Monitoring System: \$4.8K-\$14.4K • Traffic Camera for Red Light Running Enforcement: \$69K-\$126K <p>Roadside Information subsystem:</p> <ul style="list-style-type: none"> • Variable Speed Display Sign: \$3.5K-\$4.7K <p>Roadside Telecommunications subsystem:</p> <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
<p>Sample Costs of ITS Deployments</p> <p>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</p> <p>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</p>

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FREEWAY MANAGEMENT

ROADWAYS

There are numerous ITS strategies to improve the operation of the freeway system. Traffic surveillance systems use vehicle detectors and cameras to support freeway management applications. Traffic control measures on freeway entrance ramps, such as ramp meters, can use sensor data to optimize freeway travel speeds and ramp meter wait times. Lane management applications can promote the most effective use of available capacity on freeways and encourage the use of high-occupancy commute modes. Special event transportation management systems can help control the impact of congestion at stadiums or convention centers. In areas with frequent events, large changeable destination signs or other lane control equipment can be installed. In areas with occasional or one-time events, portable equipment can help smooth traffic flow. 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 dynamic message signs (DMS), highway advisory radio (HAR), even in-vehicle systems. (Other methods of providing traveler information, including those covering multiple modes or travel corridors, are discussed in the traveler information chapter.) Automated systems enforcing speed limits and aggressive driving laws can lead to safety benefits.

Several other chapters of this report discuss ITS applications relevant to freeway management. The traveler information chapter discusses the provision of information on traffic conditions to travelers on a regional basis. For example, technologies such as 511 and regional traveler information Web sites can provide important information to freeway travelers. Successful implementation of these strategies often requires collaboration with other agencies in a region, contrasted with the use of freeway DMS under the direct control of the freeway management agency. The crash prevention and safety chapter describes road geometry warning systems which have been helpful in addressing safety challenges on freeway downgrades and exit ramps. The electronic payment and pricing chapter discusses pricing strategies that are used on a growing number of freeways.

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 freeway 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.¹⁰⁵ Additional information on this initiative is available at the ITS JPO's Web site: www.its.dot.gov/icms.

TRAFFIC SURVEILLANCE IS USED TO COLLECT DATA ON 38 PERCENT OF FREEWAY MILES IN MAJOR METROPOLITAN AREAS.

FREEWAY MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance

- Traffic
- Infrastructure

Ramp Control

- Ramp Metering
- Ramp Closures
- Priority Access

Lane Management

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

Special Event Transportation Management

- Occasional Events
- Frequent Events
- Other Events
- Temporary Traffic Management Center

Information Dissemination

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

Enforcement

- Speed Enforcement
- High-Occupancy Vehicle Facilities
- Ramp Meter Enforcement

OTHER ITS KNOWLEDGE RESOURCE
CATEGORIES RELATED TO FREEWAY
MANAGEMENT

Refer to other chapters in this document.

Traveler Information

- Pre-Trip Information
- En Route Information
- Tourism and Events

Crash Prevention and Safety

- Road Geometry Warning

Electronic Payment and Pricing

- Pricing

Findings

Benefits

Metropolitan areas that deploy ITS infrastructure, including DMS to manage freeway and arterial traffic, and integrate traveler information with incident management systems can increase peak period freeway speeds by 8 to 13 percent,¹⁰⁶ improve travel time, and according to simulation studies, reduce crash rates and improve trip time reliability with delay reductions ranging from 1 to 22 percent.¹⁰⁷

Ramp control systems continue to be effective. Available data shows that ramp metering can improve mainline traffic speeds by 13 to 26 percent,¹⁰⁸ increase throughput by 5 to 30 percent,¹⁰⁹ limit ramp meter delay, and reduce crashes by 15 to 50 percent.¹¹⁰

Surveys conducted in the U.S. and Europe found large numbers of drivers said they had changed routes based on the information provided by DMS (85 percent in Houston, Texas; and 40 percent in Glasgow, Scotland).¹¹¹

Table 2—Measured Benefits of Freeway Management

Application	Measure	Benefits
Dynamic Message Signs	Freeway Travel Speed (Mobility)	Increase 8% to 13%
Ramp Metering	Freeway Speed (Mobility)	Increase 13% to 26%
	Freeway Throughput (Efficiency)	Increase 5% to 30%
	Crashes (Safety)	Decrease 15% to 50%
Automated Speed Enforcement	Number of Speeding Vehicles (Safety)	Decrease 27% to 78%

Several studies document safety improvements with the implementation of variable speed limits (VSL). These benefits stem from reduced speed variability and slower vehicle speeds during periods of hazardous traveling conditions. Another study documents increases in roadway capacity through more uniform traffic flow.¹¹²

Evaluation studies conducted in Canada, the Netherlands, Australia, and the United Kingdom show that roadways equipped with automated speed enforcement technologies can eliminate 27 to 78 percent of speeding vehicles.¹¹³ In the United Kingdom, large scale deployments have been cost-effective.¹¹⁴

Table 3 presents qualitative ratings of the impact of freeway management ITS applications under each of the six ITS goals. Many of the strategies have been found effective in improving safety. Studies of ramp metering and information dissemination have shown mobility improvements. Ramp metering has also been found to enable the freeway system to accommodate larger traffic volumes. Ramp metering, information dissemination, and speed enforcement programs have been found, in surveys, to be well received by the traveling public. More study of the impact of using freeway ITS to manage traffic at special events is needed.

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AVAILABLE DATA SHOW THAT RAMP METERING CAN IMPROVE MAINLINE TRAFFIC SPEED BY 13 TO 26 PERCENT.

Table 3—Freeway Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Surveillance	Enabling technology					
Ramp Control	+	●	●			●
Lane Management	+					
Special Event Transportation Management						
Information Dissemination	+	+				+
Enforcement	●					●
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + * blank 						

Costs

There are numerous ITS strategies to improve freeway operations. The costs of these strategies vary based on many factors including whether or not the deployment is part of a larger agency project and maintenance and operations costs, as many States are experiencing. The cost of Minnesota DOT (Mn/DOT) ramp metering operations in the Twin Cities metropolitan area in fiscal year 2000 was \$210,000 and included staff to monitor and adjust meter settings, conduct field reviews, and respond to inquiries from the public and media.¹¹⁵

The Florida DOT (FDOT) deployed 31 DMS in Broward County including associated structures, foundations, controllers, cabinets, and installation, plus approximately 37 miles of in-ground fiber optic communications at a cost of \$11 million. Annual operating costs were estimated at \$22,320 and annual maintenance costs were estimated at \$620,000. FDOT coordinates with other agencies to verify incident and congestion locations and then posts traveler information on the DMS along effected routes.¹¹⁶

Washington State DOT (WSDOT) deployed three HAR stations along the Blewett/Stevens Pass to provide weather and road condition information to travelers and State maintenance crews. One portable and two fixed HAR stations were deployed. Annual operations and maintenance (O&M) costs of \$1,000 per HAR station were based on prior experience to operate and maintain.¹¹⁷

In 2000, the installation and operational costs for 599 speed cameras (mobile and fixed) deployed during a two-year pilot study in the United Kingdom were estimated at £21 million.¹¹⁸



Benefit-Cost Studies

In Minneapolis-St. Paul, the benefit-to-cost ratio of a ramp metering system was estimated at 15:1.¹¹⁹

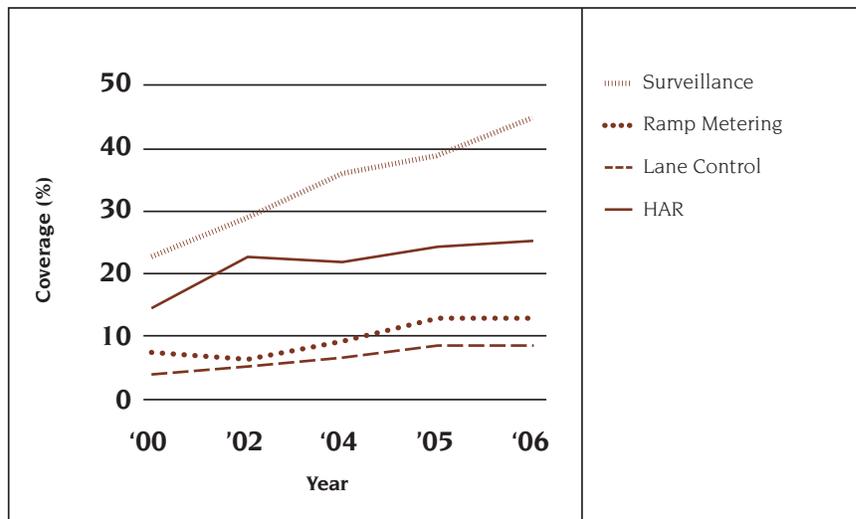


Figure 4 – Freeway Deployment Trends for 78 Major Metropolitan Areas

Deployment

Figure 4 shows deployment trends for four key ITS technologies in terms of coverage of metropolitan freeway miles. These data were collected through surveys of the 78 largest U.S. metropolitan areas from 2000 to 2006. The data show that significant progress has been made in deploying ITS technologies on freeways.

As of 2006, surveillance technologies—consisting of loop detectors, radar detectors, and acoustic detectors—are used to collect data on traffic conditions on 45 percent of freeway miles in the country’s 78 largest metropolitan areas, up from 22 percent in 2000. The percentage of freeway miles served by HAR nearly doubled in the same period; HAR now services nearly one-fourth of all freeway miles. The growth rate of HAR has slowed in recent years, however, and may be leveling off.

Two other freeway management technologies have experienced slower growth. Ramp meters now manage access to 13 percent of freeway miles in the country’s 78 largest metropolitan areas, up from 9 percent in 2000. Lane control strategies are used to manage travel on 9 percent of freeway miles in the country’s 78 largest metropolitan areas, up from 4 percent in 2000.

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 Freeway Management

Surveillance

Traffic surveillance systems use vehicle detectors and video equipment to support the most advanced freeway management systems. These sensors can also be used to monitor critical transportation infrastructure for security purposes.

Surveillance
Deployment
Surveillance is used to collect information about traffic conditions on 38 percent of freeway miles in the country's 108 largest metropolitan areas.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: <ul style="list-style-type: none"> • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K • Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Hardware, Software for Traffic Surveillance: \$131K-\$160K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>Florida: In 2006, FDOT District IV deployed 45 CCTV cameras and 106 vehicle detectors (67 side-fire radar stations). The cost of this Phase I deployment was \$2,845,462. The cost included installation and associated structures, foundations, cabinets, and controllers. The CCTV cameras and detectors make use of existing fiber optics communications. Maintenance costs for Phase I were estimated at \$254,000. Maintenance is contracted out and includes trouble-shooting and preventive maintenance. In 2007, the number of CCTV cameras increased to a total of 95 and the number of vehicle detection stations increased to a total of 170.¹²⁰</p> <p>Florida: FDOT examined design factors for CCTV video camera sites and how the design and maintenance issues impacted the life cycle costs. Pole height and effect on camera system performance, site placement and spacing, coverage area, environmental impacts, and use of camera lowering devices are detailed. The costs of several alternatives based on pole height and mounting with and without camera lowering devices are compared in the report. Camera site initial costs range from \$16,550 to \$27,550. Camera site life cycle costs range from \$403,650 to \$835,000.¹²¹</p>



Ramp Control

Traffic control measures on freeway entrance ramps, such as ramp meters, can use sensor data to optimize freeway travel speeds and ramp meter wait times.

Ramp Control
Deployment
Thirteen (13) percent of freeway access ramps in the country's 108 largest metropolitan areas are controlled by ramp meters. Three of these 108 metropolitan areas have the ability to close ramps automatically and give ramp access priority to transit vehicles on at least some of their ramps.

Ramp Control: Ramp Metering

Traffic signals on freeway ramp meters alternate between red and green to control the flow of vehicles entering the freeway. Metering rates can be altered based on freeway traffic conditions.

Ramp Control—Ramp Metering	
Benefits	
ITS Goals	Selected Findings
Safety	A study of the six-week shutdown of the ramp meters in Minneapolis-St. Paul, Minnesota found that ramp meters were responsible for a 21 percent crash reduction. ¹²²
Mobility	In Salt Lake Valley, Utah, a ramp metering study showed that with a metering cycle 8 seconds long, mainline peak period delay decreased by 36 percent or 54 seconds per vehicle. ¹²³
Efficiency	The Minneapolis-St. Paul, Minnesota shutdown study found that freeway volumes were 10 percent higher with ramp meters than they were during the shutdown. ¹²⁴ A study in Glasgow, Scotland found freeway volumes increased five percent with ramp metering. ¹²⁵
Energy and Environment	A simulation study of the Minneapolis-St. Paul, Minnesota system found 2 to 55 percent fuel savings at individual ramp metering locations along 2 modeled corridors under varying levels of travel demand. ¹²⁶
Customer Satisfaction	Most drivers believed that traffic conditions worsened when the Minneapolis-St. Paul ramp metering system was shut down and 80 percent supported reactivation. ¹²⁷ Fifty-nine (59) percent of survey respondents in Glasgow, Scotland found ramp metering to be a helpful strategy. ¹²⁸

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Ramp Control—Ramp Metering
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Control subsystem: <ul style="list-style-type: none"> • Ramp Meter: \$24K-\$49K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>Minnesota: The cost of Mn/DOT ramp metering operations in the Twin Cities metropolitan area in fiscal year 2000 was \$210,000 and included staff to monitor and adjust meter settings, conduct field reviews, and respond to inquiries from the public and media. This cost was for annual ramp metering operations on the approximately 230 miles of fully instrumented highway in the Twin Cities metropolitan area. State funds were used for ramp metering O&M.¹²⁹</p> <p>Colorado: The Colorado DOT implemented ramp metering to regulate the flow of traffic onto freeways as part of the Transportation Expansion (T-REX) project. Each ramp meter site costs approximately \$50,000, which includes the cost of the controller and approximately 15 percent mark-up for design.¹³⁰</p>
Benefit-Cost Studies
<p>Minnesota: A 2001 study of the ramp metering system in Minneapolis-St. Paul estimated the benefit-to-cost ratio of the ramp metering system at 15:1.¹³¹</p>

LESSONS LEARNED

Utilize public education and outreach in managed lane projects.

Use of managed lanes is a relatively new and complex concept to most travelers. Public understanding and acceptance are critical to the success of a managed lane project. Public education and outreach can take different forms including media coverage, surveys, and focus groups. Additionally, political champions who advocate on behalf of a project can help build public acceptance and can support any enabling legislation necessary for the managed lanes project.

- Provide ongoing public education.

Once the project has been implemented, it is important to continue providing the public with information. The Orange County Transportation Authority maintains a Web site for the State Route 91 Express Lanes that allows for online account applications and account maintenance. There is also a customer service center and an 800 number for customers' convenience. In addition, an advisory committee has been formed that includes representatives from several different transportation agencies and the general public. Based on the objectives of the project set by the community, the committee decides on future operational strategies and plans, as well as on the use of excess revenues.¹³³

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Lane Management

Lane management applications can promote the most effective use of available capacity on freeways to encourage the use of high-occupancy commute modes.

Lane Management
Deployment
Lane control equipment is used on 5 percent of freeway miles in the country's 108 largest metropolitan areas, according to a 2006 survey. According to the same survey, 15 of these 108 metropolitan areas have high-occupancy vehicle (HOV) lanes and 8 have reversible flow lanes. Only 5 of these metropolitan areas employ VSL and 11 use lane control to support emergency evacuation.

Lane Management: Pricing

Traffic surveillance, electronic payment, video, global positioning systems, and automated enforcement technologies can support the implementation of congestion pricing strategies, which adjust the cost of transportation facilities based on demand or the time of day.

Lane Management—Pricing
Costs
Unit Costs Data (See Appendix A for more detail)
Roadside Information subsystem: examples include <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K Toll Plaza subsystem: examples include <ul style="list-style-type: none"> • Electronic Toll Reader: \$2K-\$5K • High-Speed • Camera: \$7K-\$10K Toll Administration subsystem: examples include <ul style="list-style-type: none"> • Toll Administration Hardware: \$5.4K-\$8.1K • Toll Administration Software: \$39K-\$78K Roadside Telecommunications subsystem: examples include <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
California: Converting under-used HOV lanes to high-occupancy toll (HOT) lanes is often financially feasible. The primary capital cost includes plastic pylons, DMS, tolling and video enforcement equipment, and back-office processing systems. Implemented in April 1999, the cost to convert the existing HOV lane on I-15 in San Diego to a HOT lane was \$1.85 million . The facility is an eight-mile stretch of 2 reversible lanes in the median of I-15 about 10 miles north of San Diego. ¹³²

Lane Management: Lane Control

Lane control signs, supported by surveillance and detection technologies, allow the temporary closure of lanes to avoid incidents on freeways.

Lane Management—Lane Control	
Benefits	
ITS Goals	Selected Findings
Safety	Traffic surveillance, lane control signs, VSL, and DMS in Amsterdam, the Netherlands have led to a 23 percent decline in the crash rate. ¹³⁴
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Control subsystem: <ul style="list-style-type: none"> • Software for Lane Control: \$24K-\$49K • Lane Control Gates: \$78K-\$117K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	

Lane Management: Variable Speed Limits

VSL systems use sensors to monitor prevailing traffic and/or road weather conditions, and post appropriate enforceable speed limits on DMS.

Lane Management—Variable Speed Limits	
Benefits	
ITS Goals	Selected Findings
Safety	In Copenhagen, Denmark, a VSL system reduced mean vehicle speeds by up to five km/h and contributed to smoother traffic flow. ¹³⁵ In England, VSL supplemented with automated speed enforcement have reduced rear-end crashes on approaches to freeway queues by 25 to 30 percent. ¹³⁶
Efficiency	Combined with automated speed limit enforcement, an English VSL system has increased freeway capacity by 5 to 10 percent. ¹³⁷
Customer Satisfaction	A survey of motorists in Copenhagen, Denmark found that 80 percent of respondents had favorable impressions of VSL and traveler information posted on DMS near a work zone. ¹³⁸

LESSONS LEARNED

Provide travel time messages on dynamic message signs for normal traffic and recurring congestion conditions.

Travel time messages on DMS are not appropriate for every location, but they are proven successful in regions or corridors that experience periods of recurring congestion—congestion generally resulting from traffic demand exceeding available capacity and not caused by any specific event such as a traffic incident, road construction, or a lane closure. The DMS can provide dynamic travel time information instead of generic messages such as “congestion ahead” or “stay alert.”

- Generate travel times automatically.

Travel times should be generated automatically and not require a human operator to manually enter travel time data. All but one of the locations surveyed that provide travel time messages use automated processes to calculate the travel times. The majority of agencies surveyed use different technologies to measure the traffic flow including loop detectors, video detection systems, automatic vehicle identification transponders, and toll tags. The traffic data are processed to produce travel times over specified links between identified destinations. It is important to note that effective travel time messages do not require the data to be 100 percent accurate. Research has indicated that data with error rates of 20 percent produce useful traveler information. When presenting a range of travel times on DMS, the acceptable error rate may be even higher.¹⁴⁵

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Lane Management—Variable Speed Limits
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: <ul style="list-style-type: none"> • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor • Environmental Sensor Station (Weather Station): \$30K-\$49K Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Highway Advisory Radio: \$15K-\$35K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>Washington: WSDOT implemented TravelAid, a VSL system that changes as the weather does, along the Snoqualmie Pass (I-90) east of Seattle, Washington. Approximately 13 miles are operated with VSL during the winter months. The system consists of radar detection, six environmental sensor stations, nine DMS, and radio and microwave communications systems. Design and implementation costs were \$5 million (1997).¹³⁹</p>

Special Event Transportation Management

Special event transportation management systems can help control the impact of congestion at stadiums or convention centers. In areas with frequent events, large changeable destination signs or other lane control equipment can be installed. In areas with occasional or one-time events, portable equipment can help smooth traffic flow.

Special Event Transportation Management
Deployment
Fifty-seven (57) of the country's 108 largest metropolitan areas use portable transportation management systems, such as DMS, in various environments such as special event locations. Twenty-four (24) of these 108 metropolitan areas use temporary transportation management centers (TMC) or satellite locations for existing TMCs to support management of special event traffic.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Dynamic Message Sign—Portable: \$18.6K-\$24K Roadside Detection subsystem: <ul style="list-style-type: none"> • Portable Traffic Management System: \$78K-\$97K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)

LESSONS LEARNED

Display appropriate, concise messages on dynamic message signs to communicate effectively with travelers.

Design DMS messages to be brief, to the point, and have impact.

At typical highway speeds, the message posted on a DMS must be presented to motorists in about eight seconds or less. This translates to 8 words at 55 mi/h, 7 words at 65 mi/h, and 6 words at 70 mi/h. Therefore, the message must be concise and the words used must have impact.¹⁴⁶

- Construct travel time messages to benefit not only the local commuters but also unfamiliar motorists where there is a mixture of traveler types.

Successful practices from the Atlanta, Georgia area demonstrate that a relatively simple change to local information can benefit unfamiliar travelers as well. By including the distance to the destination in addition to the travel time, even those travelers unfamiliar with the area can determine the approximate level of congestion ahead.¹⁴⁷



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, or specialized information transmitted to individual vehicles.

Information Dissemination
Deployment
HAR provides information to travelers on 21 percent of freeway miles in the country's 108 largest metropolitan areas. Eighty-six (86) of these metropolitan areas use DMS to provide information to travelers on freeways.

Information Dissemination: Dynamic Message Signs

DMS are permanent or portable electronic traffic signs that allow operators to give travelers information on traffic conditions, incidents, weather, construction, safety, and special events.

Information Dissemination—Dynamic Message Signs	
Benefits	
ITS Goals	Selected Findings
Safety	A San Antonio, Texas deployment of DMS, combined with an incident management program, resulted in a 2.8 percent decrease in crashes. ¹⁴⁰
Mobility	A simulation study of the system deployed on the John C. Lodge freeway in Detroit, Michigan estimated that HAR and DMS in combination with ramp metering may reduce vehicle delay by up to 22 percent. ¹⁴¹
Customer Satisfaction	Mail-back questionnaires were sent to 428 drivers living near major freeways in Wisconsin to assess the impacts of posting travel time and traffic information on DMS throughout the state. A total of 221 questionnaires were returned and analyzed. The results indicated that 12 percent of respondents used the information more than 5 times per month to adjust travel routes during winter months, and 18 percent of respondents used the information more than 5 times per month to adjust travel routes during non-winter months. ¹⁴²

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Information Dissemination—Dynamic Message Signs

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Information subsystem:

- Dynamic Message Sign: \$48K-\$119K
- 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

Florida: In 2006, FDOT District IV deployed 31 DMS. The cost of deployment was **\$11 million** and included the signs, associated structures, foundations, controllers, cabinets, and installation, plus approximately 37 miles of in-ground fiber optic communications. The annual operating cost covered electricity and was estimated at **\$22,320**. Maintenance costs of approximately **\$620,000** included spare parts and labor for trouble-shooting problems, and preventative maintenance. DMS maintenance was contracted out. FDOT notes that employing an ITS maintenance contractor "... helps to avoid/minimize system downtime, reduces total cost of operation, improves effectiveness, and extends the life of ITS assets." Forty-one (41) additional DMS were planned for 2007.¹⁴³

Utah: The Utah DOT operates and maintains over 69 permanently mounted DMS on freeways and surface streets as part of the Utah advanced transportation management system (ATMS) known as CommuterLink. Portable message signs are also used along roadsides where there are no permanent DMS. The capital cost of the DMS system was **\$15.25 million**. Annual operating cost of the DMS system, **\$21,960**, is based on power consumption. The field devices and control centers are connected via a fiber optic network, which was installed as part of the ATMS deployment, at a cost of **\$51.176 million**. Annual maintenance cost for the fiber optic communication system is **\$50,000** and the annual operations cost is **\$150,000**.¹⁴⁴

Information Dissemination: Highway Advisory Radio

HAR uses low-power permanent or portable radio stations to broadcast traffic- and travel-related information to motorists using AM radio.

Information Dissemination—Highway Advisory Radio	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	In a mountainous region near Spokane, Washington, about one-third of commercial vehicle drivers interviewed would consider changing routes based on the information provided on a road weather information Web site and HAR system; however, few could identify viable alternate routes. ¹⁴⁸
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
<p>Roadside Information subsystem:</p> <ul style="list-style-type: none"> Highway Advisory Radio: \$15K-\$35K Highway Advisory Radio—Sign: \$5K-\$9K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> Software for Traffic Information Dissemination: \$17K-\$21K Labor for Traffic Information Dissemination: \$107K-\$131K (annually) <p>Roadside Telecommunications subsystem:</p> <ul style="list-style-type: none"> Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	
Sample Costs of ITS Deployments	
<p>Washington: WSDOT installed a system in the rural and mountainous region of Spokane to collect and communicate weather and road conditions, border crossing status, and other information to commercial drivers, the motoring public, and WSDOT maintenance crews. As part of this system, two mobile HAR systems were deployed at and near the cities of Republic and at Kettle. Broadcasts warned motorists of road construction, incidents, dangerous driving conditions and restrictions, and border crossing conditions and closures. The total cost of the Republic and Kettle HARs was approximately \$111,073. This cost included \$52,000 for two mobile HARs, and \$59,073 for signs, connectivity, clearing and other associated costs.¹⁴⁹</p> <p>Washington: WSDOT has implemented three HAR stations along the Blewett/Stevens Pass to provide weather and road condition information to travelers and maintenance crews. One portable and two fixed HAR stations were deployed. Capital cost including equipment, cabinets, antennas, and installation was \$15,000 for each fixed site, and \$30,000 for each portable unit. Annual O&M costs of \$1,000 were based on prior experience to operate and maintain.¹⁵⁰</p>	

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Enforcement

Automated enforcement systems—such as speed enforcement, HOV lane enforcement, and ramp meter enforcement—improve safety and reduce aggressive driving.

Enforcement
Deployment
Few jurisdictions use automated systems to enforce traffic laws on freeways. Seven of the country's 108 largest metropolitan areas use automated speed enforcement systems on freeways and 1 uses an automated system to enforce HOV restrictions.

Enforcement: Speed Enforcement

Automated enforcement technologies can assist with the enforcement of speed limit compliance. Still or video cameras, activated by vehicle detectors, can record vehicles traveling faster than the speed limit.

Enforcement—Speed Enforcement	
Benefits	
ITS Goals	Selected Findings
Safety	A study of 2 years of crash data following deployment of speed cameras at study sites throughout the U.K. found a 35 percent reduction in the number of people killed or seriously injured at camera locations. There was a 14 percent decline in the number of personal injury crashes. ¹⁵¹
Customer Satisfaction	Seventy (70) percent of survey respondents in the U.K. thought that automated speed and red-light enforcement cameras were a useful way to reduce crashes and save lives. ¹⁵²

Enforcement—Speed Enforcement

Speed Enforcement Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Detection subsystem:

- Portable Speed Monitoring System: \$4.8K-\$14.4K

Sample Costs of ITS Deployments

England, Wales and Scotland, U.K.: In April 2000, a system for speed and red light cameras was introduced in eight pilot areas in England, Wales, and Scotland, U.K. The Northamptonshire pilot consisted of 5 fixed camera sites and 45 mobile camera sites. Mobile enforcement was typically conducted on long stretches of roads known as red routes (corridors greater than 0.6 miles). Enforcement took place at 10 sites where the speed limit was 60 to 70 mi/h. The costs associated with camera enforcement and processing of fixed penalty notices were collected for the first two years. Costs increased for year two, 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 Northamptonshire area was comparatively new to camera enforcement. First year costs were **£1,702,404** and second year costs were **£2,247,838**.¹⁵³

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CRASH PREVENTION AND SAFETY

THE FOUR MOST WIDELY ADOPTED CRASH PREVENTION AND SAFETY SYSTEMS ARE CURVE AND RAMP SPEED WARNING, RAIL CROSSING WARNING, AND PEDESTRIAN SAFETY SYSTEMS.

ROADWAYS

A major goal of the ITS program is to improve safety and reduce risk for road users including pedestrians, cyclists, operators, and occupants of all vehicles who must travel along a given roadway. On the Nation's roadways, vehicle crashes at horizontal curves and intersections account for approximately 25 percent and 21 percent of fatalities, respectively. Nearly 13 percent of those killed in motor vehicle crashes are pedestrians and bicyclists, and more than 1 percent of crashes occur at highway-rail crossings.¹⁵⁴ Interstates and other freeway ramp curves can be dangerous locations because drivers must perceive the point at which to begin braking and slow down sufficiently to safely negotiate the ramp curve.

Road geometry warning systems warn drivers of potentially dangerous conditions that may cause rollover or run-off-the-road crashes on ramps, curves, or downgrades, and provide overheight warnings at tunnels and overpasses. Highway-rail crossing warning systems can reduce the potential for collisions at railroad crossings including catastrophic crashes involving school buses or hazardous materials carriers. Intersection collision warning systems use sensors to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross-traffic via roadside or in-vehicle displays. Pedestrian safety systems can adjust traffic signal timing to provide an appropriate WALK phase or activate in-pavement lighting or roadside warning messages to alert drivers of pedestrians present. Bicycle warning systems can detect cyclists on narrow stretches of roadway and provide drivers with advanced notice when entering bridges and tunnels. In rural areas, animal warning systems can detect large animals near the roadway, alert travelers, and deter animals from crossing while traffic is present.

In addition to the ITS technologies profiled in this chapter, the Cooperative Intersection Collision Avoidance Systems (CICAS) initiative, a major ITS initiative being conducted by the U.S. DOT has the potential to enhance crash prevention and safety. Through CICAS, the U.S. DOT is working with automotive manufacturers and State and local DOTs to develop and test autonomous-vehicle, autonomous-infrastructure, and cooperative communication systems that can help prevent crashes at intersections. For more information, visit the ITS JPO's Web site: www.its.dot.gov/cicas.

Findings

Benefits

Road geometry warning systems can improve safety on highway ramps or curves that experience a high incidence of truck rollovers. Providing truckers with advanced notice of excessive approach speeds can reduce truck speeds by up to 8.3 mi/h. Several years of safety data collected at multiple sites show these systems can eliminate rollover crashes, and the impacts are sustainable. Downhill speed warning systems have also proven effective at mitigating risks to large trucks in areas with steep terrain. These speed advisory systems have decreased truck crashes by up to 13 percent at problem sites in Oregon and Colorado.¹⁵⁵

A nationwide survey evaluating overheight/overwidth warning systems found that eight states that deployed active infrared light or laser activated warning systems had fewer overheight load strikes on infrastructure components.¹⁵⁶ Although active warning systems were found to be more effective than passive ridged crossbeam structures or overhead suspended chain warning systems, human error was prevalent highlighting the need to thoroughly consider driver perception and compliance prior to deployment.

CRASH PREVENTION AND SAFETY CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Road Geometry Warning

- Ramp Rollover Warning
- Curve Speed Warning
- Downhill Speed Warning
- Overheight/Overwidth Warning

Highway-Rail Crossing Warning Systems

Intersection Collision Warning

Pedestrian Safety

Bicycle Warning

Animal Warning

DOWNHILL SPEED WARNING SYSTEMS
HAVE DECREASED TRUCK CRASHES UP TO
13 PERCENT AT PROBLEM SITES IN OREGON
AND COLORADO.

The need to reduce crashes at intersections has fostered considerable research to develop and evaluate cost-effective countermeasures. Initial research suggests that most drivers will respond to intersection collision warning systems and slow or stop appropriately.¹⁵⁷ These systems are currently being designed to transmit warning messages to in-vehicle systems and display warnings on roadside infrastructure.

Table 4 illustrates that evaluations have shown the safety benefits for deployed crash prevention and safety systems. Several evaluations have documented customer satisfaction with road geometry and highway-rail crossing warning systems. A study also indicated mobility, fuel consumption, and emissions improvements through a highway-rail crossing warning system.

Table 4—Crash Prevention and Safety Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Road Geometry Warning	●					●
Highway-Rail Crossing Systems	●	+			+	●
Intersection Collision Warning	+					
Pedestrian Safety	●					
Bicycle Warning						
Animal Warning	●					
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + ✱ blank 						
<ul style="list-style-type: none"> Positive impacts Mixed results Not enough data 						

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Costs

The initial costs of crash prevention and safety systems vary depending on the technology deployed, system configuration, and functionality offered. As part of an evaluation of automated truck rollover warning systems, the Pennsylvania DOT (PennDOT) researched systems in other states. The cost of these systems varied significantly, ranging from \$50,000 to \$500,000, as did their configurations: invasive and non-invasive detection, weight-based versus simplified speed class algorithms, and system calibrations for warnings.¹⁵⁸

Based on responses to a nationwide survey of states operating overheight detection systems, the initial costs of active laser or infrared systems vary considerably ranging from \$7,000 to \$70,000. Although costs data are not widely available, the operations and maintenance (O&M) costs are considered relatively minimal regardless of the type of system deployed ranging from \$1,000 to \$2,500. The wide variation in capital costs is due to the fact that each system vendor packages its system differently. Some vendors perform the equipment installation and the labor cost is included in the total deployment costs. Also, some vendors select from multiple systems the company offers to meet the needs of the customer. Most systems use line power rather than solar power to reduce O&M costs and increased reliability.¹⁵⁹

For six types of intersection collision warning scenarios, the cost of the design and equipment ranges from \$47,230 to \$73,320 per intersection. Design cost totaled \$19,980 and included data collection, analysis and system design, human factors testing, and software design. The remaining costs were for the equipment (e.g., dynamic message signs (DMS), loop detectors, controllers) and communication devices at one-fourth mile spacing.¹⁶⁰

Deployment

Crash prevention and safety systems are often deployed in non-urban settings to address specific safety issues at spot locations. Figure 5 shows the trends for the number of states adopting crash prevention and safety systems in statewide/rural locations from 2002 to 2006. The four most widely adopted systems are curve speed warning, ramp rollover warning, highway-rail crossing warning systems, and pedestrian safety systems. Next in popularity, and adopted by about half as many states, are downhill speed warning systems, intersection collision warning systems, and animal warning systems. Finally, bicycle warning systems are adopted by about a fourth as many states as the first three systems. The trend for adoption of crash prevention and safety systems in general is rapidly expanding, with the number of states adopting these systems increasing by a factor of two to three over the four-year period.

FOR SIX TYPES OF INTERSECTION COLLISION WARNING SCENARIOS, THE COST OF THE DESIGN AND EQUIPMENT RANGES FROM \$47,230 TO \$73,320 PER INTERSECTION.,

The 2006 survey of each of the 50 states about deployment of ITS technologies in rural areas and on a statewide basis is the source of deployment statistics presented later in this chapter, unless otherwise noted.

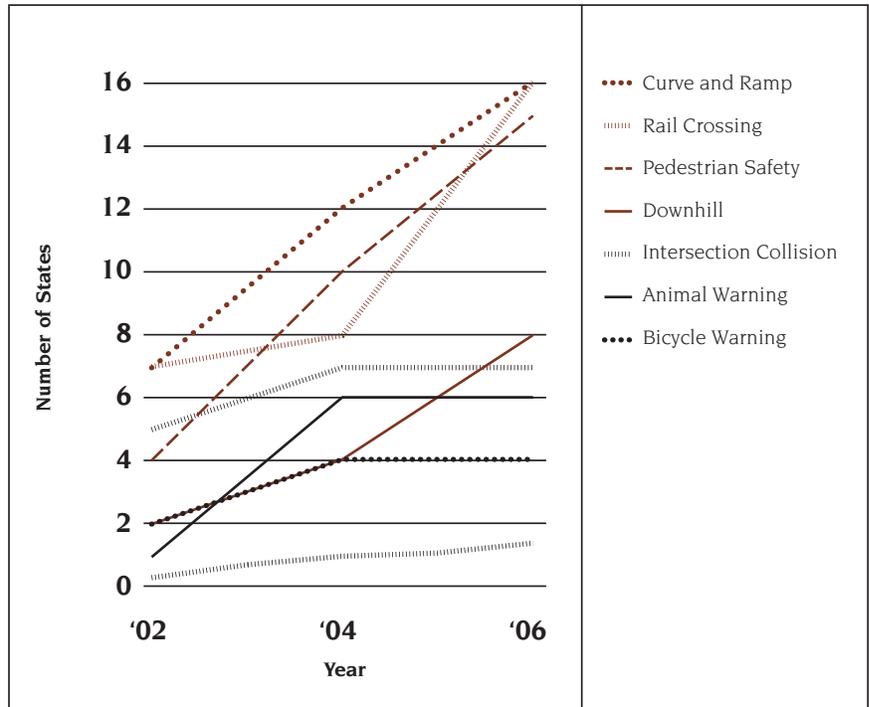


Figure 5 – Trends for Statewide/Rural Deployment of Crash Prevention and Safety Systems, 2002-2006

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Selected Highlights from the ITS Knowledge Resources on Crash Prevention and Safety

Road Geometry Warning Systems

Road geometry warning systems warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous conditions that may cause rollovers; crashes on ramps, curves, or downgrades; and collisions with roadway infrastructure, such as overpasses.

Road Geometry Warning Systems	
Deployment	
Overheight/overwidth warning systems that warn drivers of vehicles that are too tall or too wide to pass under bridges or through tunnels are used in 23 states. Systems that warn drivers of potentially dangerous speeds in a variety of situations are used by several states: approaching freeway ramps (11 states), curved freeways (11 states) and downhill grades (8 states).	

Road Geometry Warning Systems: Ramp Rollover Warning

Ramp rollover warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous approach speeds to freeway ramps.

Road Geometry Warning Systems—Ramp Rollover Warning	
Benefits	
ITS Goals	Selected Findings
Safety	Summary Finding: Rollover warning systems dramatically reduce crashes. A truck rollover warning system installed on the Pennsylvania Turnpike was designed to alert truck drivers of a dangerous curve at the Breezewood Interchange. During 21 months of data collection prior to the system deployment, 5 rollover crashes occurred. After deployment, only one crash occurred, which was attributed to a passenger car that went out of control and forced a nearby truck to make a reactive move and roll over. ¹⁶¹ Similar systems were deployed at three sites on the Capital Beltway outside Washington, D.C. where no crashes occurred during three years of post-deployment data collection. Trucks also reduced speeds by an average 8.3 mi/h when warnings were activated. ¹⁶²

Road Geometry Warning Systems—Ramp Rollover Warning

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Detection subsystem:

- Inductive Loops on Corridor: \$3K-\$8K
- Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor

Roadside Information subsystem:

- Dynamic Message Sign: \$48K-\$119K

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 Truck Tip-Over Warning System was deployed on I-70 eastbound just outside Idaho Springs to help prevent rollover crashes. The system consists of two piezo weigh-in-motion devices, vehicle detectors, four fiber optic message signs, computer and associated software, and controller cabinet. The system was deployed at a cost of **\$446,687**.¹⁶³

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Road Geometry Warning Systems: Curve Speed Warning

Curve speed warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous speeds on approach to curves on highways.

Road Geometry Warning Systems—Curve Speed Warning	
Benefits	
ITS Goals	Selected Findings
Safety	Summary Finding: Evaluation data collected in California and Oregon indicated that 69 to 76 percent of drivers surveyed reduced their speed in response to curve speed warning systems. ¹⁶⁴
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: <ul style="list-style-type: none"> Inductive Loops on Corridor: \$3K-\$8K Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor Roadside Information subsystem: <ul style="list-style-type: none"> Dynamic Message Sign: \$48K-\$119K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	
Sample Costs of ITS Deployments	
California, Colorado, Maryland, and Virginia: As part of an evaluation of automated truck rollover warning systems, PennDOT researched curve speed warning systems in other states. The cost of these systems varied significantly, ranging from \$50,000 to \$500,000 , as did their configurations: invasive and non-invasive detection, weight-based versus simplified speed class algorithms, and system calibrations for warnings. ¹⁶⁵	

LESSONS LEARNED

Use speed warning signs on dangerous curves to reduce truck speeds.

The Rural ITS Toolbox noted a relatively low-tech approach that was used by Colorado DOT to address high speed trucks in mountainous terrain. Colorado DOT has many highways that run through the mountains and have high truck traffic. The Colorado DOT's experience reveals the following with regard to reducing truck speeds on dangerous curves.

- Consider using simple radar speed detection devices in combination with dynamic message signs (DMS).

To convey to truck drivers their current speed and to warn them of impending curves ahead that can not be safely negotiated at their current speed, use simple radar speed detection devices in combination with DMS. The relatively low-cost system has seen dramatic results. Speed studies conducted before and after the system was installed revealed a reduction in 85th percentile truck speed from 66 to 48 mi/h.¹⁶⁶

Road Geometry Warning Systems: Downhill Speed Warning

Downhill speed warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous speeds in approach to downhill grades.

Road Geometry Warning Systems—Downhill Speed Warning	
Benefits	
ITS Goals	Selected Findings
Safety	A downhill speed warning system installed on I-70 in Colorado decreased truck crashes by 13 percent and reduced the use of run away truck ramps by 24 percent. ¹⁶⁷ Speed studies documented a decline in the 85th percentile truck speed from 66 to 48 mi/h. ¹⁶⁸
Customer Satisfaction	A small-scale study of truck drivers who experienced the downhill speed warning system in Colorado indicated that most drivers thought it was helpful. ¹⁶⁹
Downhill Speed Warning Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: <ul style="list-style-type: none"> • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	

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Road Geometry Warning Systems: Overheight/Overwidth Warning

Overheight/overwidth warning systems use roadside detectors and electronic warning signs to warn drivers of vehicles that are too tall or wide to pass under bridges or through tunnels.

Road Geometry Warning Systems—Overheight/Overwidth Warning	
Benefits	
ITS Goals	Selected Findings
Safety	An overheight/overwidth warning system installed at a tunnel in Pennsylvania worked well, with a few notable exceptions. One driver ignored the warnings given by the system. Another assumed that his truck was within the height limit because he did not receive a warning from the system when it was inactive due to mechanical problems. ¹⁷⁰ These experiences demonstrate the value of the systems when warnings are heeded, and the importance of maintenance to assure proper performance.
Costs	
Sample Costs of ITS Deployments	
<p>United States: Overheight detection and warning systems typically use infrared light or laser detection systems and warning signs with flashing beacons to warn drivers that their truck exceeds the height of an upcoming bridge or tunnel. Each approach requires a separate system. Installation costs range from \$7,000 to \$70,000 per system (including labor) depending on site conditions, customer needs, design costs, and availability of power. Reported O&M costs are relatively low, ranging from \$1,000 to \$2,500 annually.¹⁷¹</p> <p>Michigan: An active overheight detection and warning system installed in advance of a sub-standard bridge structure is estimated to cost \$110,000 based on data provided by manufacturers and State DOTs responding to a study conducted for the Michigan DOT. The system consists of an infrared transmitter, receiver, and a warning sign with alternating flashers. The cost estimate is based on the assumption that two installations are deployed one on each side of the bridge.¹⁷²</p>	



Highway-Rail Crossing Systems

Highway-rail crossing systems use detectors, electronic warning signs, and automated enforcement technologies to warn roadway traffic of approaching trains and discourage drivers from violating railroad crossing traffic controls.

Highway-Rail Crossing Systems	
Deployment	
Sixteen (16) states use systems that detect and warn drivers of approaching trains at highway-rail intersections. One state uses an automated enforcement system to detect drivers violating railroad crossing traffic controls.	
Benefits	
ITS Goals	Selected Findings
Safety	Installation of a “Second Train Coming” warning system at a light rail transit grade crossing in the suburbs of Baltimore, Maryland, led to a reduction of 26 percent of vehicles crossing the tracks between the two trains. ¹⁷³ In Los Angeles, California, installation of a similar system yielded a 14 percent reduction in risky pedestrian behavior. ¹⁷⁴
Mobility	The San Antonio, Texas simulations of increased traffic volumes indicated DMS with railroad crossing delay information may decrease system delay by seven percent. ¹⁷⁵
Energy and Environment	Noise levels were measured at a highway-rail intersection before and after installation of an automated horn system in Ames, Iowa. Analysis indicated that areas impacted by noise levels greater than 80 decibels decreased by 97 percent. ¹⁷⁶
Customer Satisfaction	Ninety-three (93) percent of pedestrians surveyed felt safety was improved by the installation of a “Second Train Coming” warning system at a light rail transit grade crossing in Los Angeles, California. ¹⁷⁷

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Highway-Rail Crossing Systems	
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Rail Crossing subsystem:	
<ul style="list-style-type: none"> • Rail Crossing Four-Quad Gate, Signals: \$90K-\$101K • Rail Crossing Train Detector: \$12K-\$17K 	
Roadside Detection subsystem:	
<ul style="list-style-type: none"> • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor 	
Roadside Information subsystem:	
<ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K 	
Roadside Telecommunications subsystem:	
<ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	

Intersection Collision Warning

Intersection collision warning systems use sensors to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross traffic, via external signage or in-vehicle warnings.

Intersection Collision Warning	
Deployment	
Seven states use intersection collision warning systems that use sensors to monitor traffic approaching intersections and warn drivers of approaching cross traffic.	
Benefits	
ITS Goals	Selected Findings
Safety	<p>Field testing of a warning system at a two-way, stop-controlled intersection in rural Virginia reduced vehicle speeds by 2.4 mi/h and increased the average projected time to collision from 2.5 to 3.5 seconds.¹⁷⁸</p> <p>Intersection collision avoidance systems deployed at intersections with high crash frequencies or high rates of severe injury are projected to recoup initial costs within one year through a reduction in crashes.¹⁷⁹</p>

Intersection Collision Warning
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: <ul style="list-style-type: none"> • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor Roadside Control subsystem: <ul style="list-style-type: none"> • Signal Controller and Cabinet: \$8K-\$14K Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
Virginia, California, and Minnesota: Infrastructure-only intersection collision avoidance systems deployed at high crash intersections in three states ranged in costs from \$47,995 to \$73,230 per intersection . Costs included design and capital costs. ¹⁸⁰

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Pedestrian Safety

Pedestrian safety systems can help protect pedestrians by automatically activating in-pavement lighting to alert drivers as pedestrians enter crosswalks. Other systems include count-down pedestrian traffic signals and pedestrian detectors that extend the WALK phase for pedestrians needing more time to cross a street.

Pedestrian Safety	
Deployment	
Fifteen (15) states use pedestrian safety systems to protect pedestrians by alerting drivers when pedestrians enter crosswalks.	
Benefits	
ITS Goals	Selected Findings
Safety	Automated pedestrian detection at signalized intersections tested in 3 U.S. cities reduced vehicle-pedestrian conflicts by 89 percent in the first half of the crossing and by 43 percent in the second. ¹⁸¹ The systems—tested in Los Angeles, California; Rochester, New York; and Phoenix, Arizona—also reduced the number of pedestrians who began crossing during the steady DON'T WALK signal by 81 percent. ¹⁸²
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: <ul style="list-style-type: none"> • Pedestrian Detection—Microwave: \$0.6K • Pedestrian Detection—Infrared: \$0.3K-\$0.5K Roadside Information subsystem: <ul style="list-style-type: none"> • Light-Emitting Diode (LED) Countdown Signal: \$0.306K-\$0.424K • Pedestrian Crossing Illumination System: \$26.8K-\$41K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	



LESSONS LEARNED

Thoroughly test, evaluate, and maintain animal warning systems.

Animal warning systems are relatively new, having yet to be deployed on a large scale nationally. It is likely that common problems will surface, which will need to be remedied. In order to mitigate emerging complications, deploying agencies need to develop a system that provides assurance that animal warning systems will be continually evaluated and maintained to the highest possible standard.

- Extensively test system components and specifications in environments similar to those experienced at potential animal warning system sites.

The specifications of all components of the system should be checked and compared to specific requirements in the contract including Federal and State regulations, the Federal Communications Commission regulations for radio signals, maximum heights, and break-away construction for objects placed in the clear zone. All system components should be designed to withstand their own weight, strong winds, heavy precipitation (including snow load and ice build-up), and in some cases, high humidity. The site-specific design for the location of posts and sensors should pay special attention to curves, slopes, rises, low areas, and vegetation in the right-of-way to avoid “blind spots” where the sensors cannot detect the target species. Final selection of equipment placement sites should be verified by an on-site electronic survey using a portable beam-break system.¹⁸⁵

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Bicycle Warning

Bicycle warning systems can use detectors and electronic warning signs to identify bicycle traffic and notify drivers when a cyclist is in an upcoming segment of roadway to improve safety on narrow bridges and tunnels.

Bicycle Warning	
Deployment	
Four states use bicycle warning systems that warn drivers of the presence of bicycles on narrow bridges and tunnels.	

Animal Warning

Animal warning systems typically use infrared or other detection technologies to identify large animals approaching the roadway and alert drivers by activating flashers on warning signs located upstream of high frequency crossing areas. These systems may also activate in-vehicle warning devices.

Animal Warning	
Deployment	
Six states have deployed animal warning systems that warn drivers of large animals approaching the roadway.	
Benefits	
ITS Goals	Selected Findings
Safety	In Switzerland, an animal warning system installed at 7 sites decreased collisions with large animals by 81 percent. ¹⁸³
Costs	
Sample Costs of ITS Deployments	
United States and Europe: The cost of animal detection systems vary depending on road length and the cost of research and development. The costs for planning, purchase, installation, and operation and maintenance on a one-mile section of roadway have been estimated at \$31,300 per year with a 10-year lifespan. ¹⁸⁴	

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ROAD WEATHER MANAGEMENT

STATE DOTs DISSEMINATE WEATHER WARNINGS TO PUBLIC TRAVELER INFORMATION AGENCIES IN 26 STATES, TRAFFIC MANAGEMENT AGENCIES IN 22 STATES, AND INCIDENT MANAGEMENT AGENCIES IN 21 STATES.

ROADWAYS

Adverse weather conditions pose a significant threat to the operation of the Nation's roads. According to the National Research Council, motorists endure more than 500 million hours of delay each year as a result of fog, snow, and ice.¹⁸⁶ Rain—which occurs more frequently than snow, ice, and fog—leads to greater delay. Furthermore, an investigation of vehicle crashes from 1995 through 2005 show that each year more than 673,000 people are injured and nearly 7,400 are killed in weather-related crashes.¹⁸⁷ The estimated cost of weather-related crashes ranges from \$22 billion to \$51 billion annually. These costs include travel delay, emergency services, property damage, medical and rehabilitation costs, productivity losses, insurance administration costs, legal and court costs, and the costs to employers.¹⁸⁸

Adverse weather not only affects safety but can also degrade traffic flow and increase travel times. Under extreme conditions (such as snowstorms), travel times can increase by as much as 50 percent.¹⁸⁹

The Road Weather Management program, within the Federal Highway Administration Office of Operations, is working to mitigate these impacts by developing strategies, tools, and technologies that promote safety, increase mobility, improve productivity, and protect the environment.

Agencies that operate and maintain roadways use surveillance, monitoring, and prediction to mitigate the impacts of adverse weather. Environmental sensor stations (ESS) and road weather information systems (RWIS) are used to provide transportation managers and maintenance personnel with actual and forecast weather and pavement condition data that can be used to implement advisory strategies, control strategies, and treatment strategies.

Information dissemination capabilities enable advisory strategies to provide information on prevailing and predicted conditions to both transportation managers and motorists. Posting fog warnings on dynamic message signs (DMS) and listing flooded routes on Web sites are examples of these advisory strategies.

Traffic control technologies enable agencies to enact control strategies that alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity. Reducing speed limits with variable speed limit (VSL) signs and modifying traffic signal timing based on pavement conditions are examples of control strategies.

Response and treatment applications are designed to improve efficiency and the effectiveness of treatment strategies, typically snow and ice control operations involving the application of sand, salt, and anti-icing chemicals to pavements to improve traction and prevent ice bonding. Winter maintenance vehicles can be equipped with automatic vehicle location (AVL) systems and mobile sensors to monitor pavement conditions and optimize treatment application rates. In problem areas where the roadway can freeze unexpectedly, such as bridges in cold climates, fixed anti-icing/deicing systems can be installed and activated automatically based on ESS data.

Several other chapters of this report discuss ITS applications relevant to road weather management. The roadway operations and maintenance chapter discusses asset management technologies, such as AVL that can facilitate efficient winter road maintenance. Also, the traveler information chapter discusses technologies valuable for disseminating weather-related information to travelers.

ROAD WEATHER MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance, Monitoring, and Prediction

- Pavement Conditions
- Atmospheric Conditions
- Water Level

Information Dissemination—Advisory Strategies

- Dynamic Message Signs
- Internet/Wireless/Phone
- Highway Advisory Radio

Traffic Control—Control Strategies

- Variable Speed Limits
- Traffic Signal Control
- Lane Use/Road Closures
- Vehicle Restrictions

Response and Treatment—Treatment Strategies

- Fixed Winter Maintenance
- Mobile Winter Maintenance

EXPERIENCE WITH ANTI-ICING PROGRAMS HAS DEMONSTRATED CRASH RATE REDUCTIONS FROM 7 TO 83 PERCENT.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO ROAD WEATHER MANAGEMENT

Refer to other chapters in this document.

Roadway Operations and Maintenance

Asset Management

Traveler Information

Pre-Trip Information

En Route Information

In addition to the technologies profiled in this chapter, two major road weather programs—the *Clarus* initiative and the Maintenance Decision Support System (MDSS)—have the potential to encourage the deployment of ESS and improve the availability and timeliness of high-quality road weather information. *Clarus* aims to leverage State DOT investments to create a road weather observation data management system that is national in scope. The initiative will build upon the RWIS that many state DOTs have been deploying for years, primarily in support of winter maintenance activities. MDSS is a decision support tool that integrates relevant road weather forecasts, maintenance rules of practice, and maintenance resource data to provide winter maintenance managers with recommended road treatment strategies.¹⁹⁰ Additional information on the *Clarus* initiative is available at the ITS JPO's Web site at www.its.dot.gov/clarus and information on the MDSS project is available on the Road Weather Management program Web site at www.ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#p3.

Findings

Benefits

Evaluation data show that 80 to 94 percent of motorists who use traveler information Web sites think road weather information enhances their safety and prepares them for adverse road weather conditions.¹⁹¹ Although quantitative impacts of road weather advisory systems are difficult to measure on a regional basis, warning systems that use flashers or DMS to alert drivers of reduced visibility or wind hazards have proven effective on short sections of roadway prone to these hazards.¹⁹² Evaluation data show that drivers pay attention to these types of warning systems and will slow down or speed up as recommended to improve traffic speed uniformity and reduce crash risk.¹⁹³

High-quality road weather information can benefit travelers, commercial vehicle operators, emergency responders, and agencies who construct, operate, and maintain roadways. RWIS are now a critical component of many agencies' winter maintenance programs. Accurate and timely road weather information helps maintenance managers react proactively before problems arise. Maintenance managers indicate that effective anti-icing and pre-wetting strategies reduce sanding applications by 20 to 30 percent, decrease chemical applications by 10 percent, and reduce chloride and sediment runoff in local waterways.¹⁹⁴ Evaluation data show that anti-icing programs can lower snow and ice control costs by 10 to 50 percent and reduce crash rates by 7 to 83 percent (figure 6).¹⁹⁵

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DATA FROM FIVE STATES SHOW THAT THE ADDITION OF VARIOUS ADVANCED TECHNOLOGY APPLICATIONS SUCH AS RADAR, SENSORS, AND CONTROL UNITS CAN ADD \$20,000 TO \$30,000 TO THE COST OF A REGULAR SNOWPLOW.

Costs

As with most ITS deployments, costs of road weather management systems vary based on several factors, including their scope, complexity and particular technology or technologies under consideration. Often costs are estimated based on similar systems because precise records are not available and multiple organizations involved in the deployment make traceability from various funding sources difficult.

Automated wind warning systems were installed at two rural Oregon locations to alert motorists of high crosswind conditions. Each automated wind warning system is estimated to cost \$90,000; annual operations and maintenance (O&M) costs are estimated at \$3,000 to \$3,500.¹⁹⁶

Nine respondents to a fixed automated spray technology (FAST) survey indicated that cost of installations varied greatly, \$22,000 to \$4 million, depending on coverage area, site location, accessibility of existing utilities, system functionality and features, and market factors. O&M costs of FAST systems are relatively low compared to the installation costs.¹⁹⁷

Based on data from early AVL implementers across the U.S., the capital costs of AVL systems are highly dependent on the level of software customization of commercial off-the-shelf packages, as well as the type of sensors installed on the maintenance vehicles and how the vehicle was equipped prior to the AVL installation. When the systems were installed was also a factor as the cost of AVL technology has dropped over time. Based on six deployments, the cost per vehicle ranged from \$1,250 to \$5,800. For several deployments, communications cost ranged from \$40 to \$60 per month per vehicle.¹⁹⁸ Data from five states show that the addition of various advanced technology applications such as radar, sensors, and control units can add \$20,000 to \$30,000 to the cost of a regular snowplow.¹⁹⁹

Road weather information can be disseminated to travelers via several media. In January 2003, Montana DOT implemented its 511 system to provide travelers with traffic and road weather conditions. The 511 traveler information system is a part of the Greater Yellowstone Regional Travel and Weather Information Systems project. Annual operating costs for 2004 were \$195,453 and for 2005 costs were \$195,930. These costs included contracted services and equipment leases, toll charges, marketing, and operations for the statewide alert system.²⁰⁰

Benefit-Cost Studies

Several benefit-cost studies of road weather management technologies have been conducted and all found positive benefit-to-cost ratios. Staff meteorologists, stationed at the transportation management center in Salt Lake City, Utah, provided detailed weather forecast information to winter maintenance personnel, reducing labor and materials costs for snow and ice control activities and yielding a benefit-to-cost ratio of 10:1.²⁰¹ A study of a weather and road condition controlled system of VSL signs in Finland showed favorable results for deployment along highly trafficked road segments. Starting benefit-to-cost ratios ranged from 1.1:1 to 1.9:1. The ratio was higher if safety assumptions were higher and there was greater use of higher speed limits.²⁰² With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety; benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1.²⁰³

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Deployment

A survey of each of the 50 states conducted in 2006 revealed that state DOTs collect weather information from ESS, the National Weather Service, and other sources and distribute it in real time to a variety of users. Table 6 shows the number of State DOTs that distribute weather warnings and forecasts to different types of organizations. State DOTs distribute real-time weather warnings most often with public traveler information agencies (26 states), followed by traffic management agencies (22 states), incident management agencies (21 states), state police (17 states), and public safety agencies (16 states). State DOTs send weather warnings to data archives and to private traveler information organizations in six states; five State DOTs distribute weather warnings to other States. The distribution of weather forecasts follows a similar distribution pattern with about half as many State DOTs sharing this more detailed weather information as share simple weather warnings.

The 2006 survey of each of the 50 states about deployment of ITS technologies in rural areas and on a statewide basis is the source of deployment statistics presented later in this chapter, unless otherwise noted.

Table 6—Communication of Weather Warnings and Forecasts Statewide

Agency Type Receiving Real-Time Distribution of Weather Information	Number of State DOTs Sending Weather Warnings	Number of State DOTs Sending Weather Forecasts
Traveler Information—Public Sector	26	15
Incident Management	22	10
Traffic Management	21	10
State Police	17	8
Local Government	11	4
Public Safety	16	6
Data Archiving	6	5
Traveler Information—Private Sector	6	2
Other States	5	4



LESSONS LEARNED

Provide adequate training to maintenance crews in order to build support for the use of an advanced decision support tool.

The Maintenance Decision Support System deployed by the Maine Department of Transportation (MaineDOT) offered a useful winter storm planning tool that supplemented other resources in some important ways. First, the MDSS added capabilities that the agency previously did not have including pavement temperature forecast trends, bridge and pavement frost forecasts, and a tool that could provide pavement treatment recommendations based on an analysis of multiple weather parameters. Second, the MDSS offered an integrated platform for the display and analysis of National Weather Service forecasts in a user-friendly geographical information system format. MaineDOT found its experience overall with the MDSS to be a beneficial one.

(Continued on next page.)

Selected Highlights from the ITS Knowledge Resources on Road Weather Management

Surveillance, Monitoring, and Prediction

Surveillance, monitoring, and prediction of weather and road conditions enable the appropriate management actions to mitigate the impacts of any adverse conditions.

Surveillance, Monitoring, and Prediction	
Deployment	
The use of sensors to track weather is popular among State DOTs. Thirty-eight (38) states use in-pavement or road sensors to track pavement conditions; the same number deploy ESS in rural areas. Fifteen (15) states use sensors to monitor water levels on roadways.	
Benefits	
ITS Goals	Selected Findings
Safety	In Vantage, Washington, the deployment of an automated anti-icing system on I-90 was projected to eliminate up to 80 percent of snow and ice related crashes. ²⁰⁴
Productivity	Through the Utah DOT Weather Operations Program, meteorologists based at the transportation management center use information from ESS in the field to provide detailed forecasts to winter maintenance personnel, saving \$2.2 million per year in labor and materials for snow and ice control activities. This reduction is approximately 18 percent of the 2004-2005 labor and material costs. ²⁰⁵
Customer Satisfaction	In interviews following the deployment of two new ESS equipped with pole-mounted closed circuit television (CCTV) cameras and sensors to measure an array of environmental conditions, the Washington State DOT road maintenance crews ranked pavement condition data from ESS as the most useful information, followed by camera images, and radar data on the Internet. The maintenance superintendent reported that the ESS data and camera images helped staff become more productive by allowing them to check road conditions in outlying areas and minimizing unnecessary trips. ²⁰⁶

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Surveillance, Monitoring, and Prediction

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Detection subsystem:

- Environmental Sensor Station (Weather Station): \$30K-\$49K
- Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K

Transportation Management Center subsystem:

- Road Weather Information System (RWIS): \$11K

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

Oregon: Automated wind warning systems were installed at two rural Oregon locations to alert motorists of high crosswind conditions. Message signs are located at each end of the corridor or bridge where motorists can decide to wait until the winds die down or to take a longer alternative route. The systems, which are similar, consist of a local wind gauge (anemometer) with continuous input to a flashing beacon on a static message sign. Communication to the warning signs is automated and is provided by using dial-up phone service. The warning signs are activated when average wind speeds reach a predetermined threshold. The severity is automatically recorded. Once verified by staff at the transportation management center, a warning message is posted to the Oregon DOT TripChek Web site. The signs are deactivated when the wind speed drops below the threshold. Each automated wind warning system is estimated to cost **\$90,000**; O&M costs are estimated to range from **\$3,000 to \$3,500 annually**.²⁰⁷

Ohio: In 2003, the Ohio Department of Transportation (ODOT) expanded its RWIS with the addition of 86 environmental sensor stations to the 72 already in operation. The 158 ESS provide coverage of all 88 Ohio counties, making it the largest deployment of RWIS ESS in the U.S. Information from the ESS is processed by a central server located in Columbus. The data are used by ODOT maintenance personnel to make road treatment decisions to control snow and ice. Eighty-six (86) ESS were installed with 2 more sites planned in the following construction season. The deployment was contracted as a product purchase wherein the vendor was responsible for equipment installation. ODOT required that the ESS be compliant with the National Transportation Communications for ITS Protocol and support wireless communication. The contract also included a two-year service agreement (recurring costs over 2 years) for maintenance support 365 days a year, 24 hours a day, and 7 days a week with penalties imposed for down sites. ESS expansion cost totaled **\$3.699 million** (2003).²⁰⁸

Maryland: A fog detection system is being planned in response to a serious multi-vehicle crash that occurred in May 2003 along I-68 near Big Savage Mountain in Maryland. The new system will make use of existing infrastructure at two locations and includes a new RWIS. The existing RWIS at Big Savage and Keyzers Ridge will be modified to identify low visibility conditions and alert drivers via warning signs. The third location, Friendsville, will be equipped with an ESS and warning signs. The cost to modify Big Savage and Keyser sites was **\$75,000 per location**. The cost of new infrastructure at Friendsville was **\$125,000**.²⁰⁹

LESSONS LEARNED

(Continued from previous page.)

Provide training to staff before introducing MDSS and provide ongoing support after implementation.

In order to achieve the full benefits of an MDSS, users need to fully understand how it works, how to interpret the information it offers, and how best to apply it in support of decision making. This type of training needs to occur before the tool is even introduced.

- Offer the MDSS tool initially to one of the State's more progressive crews.

An MDSS is more complex technology compared with many of the systems used throughout Maine and other States. MaineDOT selected Scarborough crews to test the new system based in part on their enthusiasm and willingness to work with the MDSS throughout the winter season. More progressive crews can serve as an example and can provide training to other crews.²¹²

LESSONS LEARNED

Integrate weather information into transportation management center (TMC) operations to manage traffic in a more responsive and effective way during weather events.

Weather events have both major and minor impacts on transportation management operations. During seasonal weather events, these impacts may include reduced traffic flow or increased traffic incidents. At other times, natural disasters (such as hurricanes, blizzards, and severe summer storms) have major impacts on transportation management operations. During these events, major routing changes, dramatic traffic bottlenecks, or complete transportation shutdowns may occur. Integrating weather information and systems across multiple agencies and organizations can help TMCs conduct their operations more effectively. TMCs must evaluate which concepts and specific methods will work best for them in meeting their needs.

- Continuously update weather information.

TMCs should have an automated process or other robust structure in place for the continuous updating of weather information. While this function may be performed using weather information from the Internet, more highly-integrated methods include contractor-provided surface transportation weather forecasts, field observers or probes providing scheduled weather and driving condition information, and meteorology staff located within the TMC forecasting and interpreting weather information.²¹⁶

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Surveillance, Monitoring, and Prediction

Benefit-Cost Studies

Utah: Staff meteorologists, stationed at the transportation management center in Salt Lake City provided detailed weather forecast information to winter maintenance personnel, reducing labor and materials costs for snow and ice control activities and yielding a benefit-to-cost ratio of 10:1.²¹⁰

Oregon: The benefit-to-cost ratios calculated for two automated wind warning systems deployed in Oregon were 4.13:1 and 22.80:1.²¹¹

Information Dissemination

Information dissemination technologies help road weather managers notify travelers of any adverse conditions.

Information Dissemination

Deployment

The Internet is the medium most commonly used by state agencies to disseminate weather information on a statewide basis; 37 states distribute weather information via Web sites. Other popular media for statewide distribution of weather information are DMS (reported by 29 states) and highway advisory radio (reported by 20 states). According to a 2006 survey of the country's 108 largest metropolitan areas, 49 metropolitan areas reported using DMS to disseminate weather advisories.

Benefits

ITS Goals	Selected Findings
Safety	A wet pavement detection system deployed on a temporary detour route along I-85 in North Carolina warned of wet pavement or standing water during rainstorms, yielding a 39 percent reduction in the yearly rate of crashes under wet conditions. ²¹³
Customer Satisfaction	Ninety-four (94) percent of surveyed users of a road weather information Web site covering roadways in Washington agree that the weather information made travelers better prepared for their trips. Over half of the respondents (56 percent) agreed the information helped them avoid travel delays. ²¹⁴

Information Dissemination
Costs
Unit Costs Data Examples (See Appendix A for more detail)
<p>Roadside Information subsystem:</p> <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Portable Dynamic Message Sign: \$18.6K-\$24K • Highway Advisory Radio: \$15K-\$35K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) <p>Roadside Telecommunications subsystem:</p> <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>Montana: In January 2003, Montana DOT implemented its 511 system to provide travelers with traffic and road weather conditions. The 511 traveler information system is a part of the Greater Yellowstone Regional Travel and Weather Information Systems project. The cost to implement the system was \$188,000 and included system development, voice recognition technology, marketing, and a one-time improvement for the addition of regional reports, AMBER (America's Missing: Broadcast Emergency Response) Alerts, homeland security alerts, and general transportation alerts. Operating costs for 2004 were \$195,453 and for 2005 costs were \$195,930. These costs included contracted services and equipment leases, toll charges, marketing, and operating cost for the statewide alert system.²¹⁵</p>

Traffic Control

Traffic control technologies improve traveler safety under poor weather conditions. A variety of technologies allow these control measures to be taken quickly in response to developing adverse weather.

Traffic Control	
Deployment	
Almost half of all states (24) use ITS technologies to manage traffic diversions in response to road closures due to weather events. The same number of states use ESS to determine the need to implement temporary restrictions on vehicles. Eight states use VSL to respond to weather conditions.	
Benefits	
ITS Goals	Selected Findings
Safety	A VSL system implemented along I-75 in Tennessee to control traffic during foggy conditions, and close the freeway if necessary, has dramatically reduced crashes. While there had been over 200 crashes, 130 injuries, and 18 fatalities on this highway section since the interstate opened in 1973, a 2003 report noted that only one fog-related crash occurred on the freeway since installation of the system in 1994. ²¹⁷
Mobility	An investigative study sponsored by the Minnesota DOT found that optimizing traffic signals along an arterial corridor to accommodate adverse winter weather conditions yielded an eight percent reduction in delay. The study also noted that the existing signal timing plans were sufficient to accommodate the lower traffic volumes and lower speeds during winter weather. ²¹⁸
Productivity	During a 1998 snow storm, the Minnesota DOT reduced roadway clearance costs by 18 percent on I-90 by activating a freeway gate closure system to limit vehicle interference and reduce snow compaction problems that increase work for plows. ²¹⁹
Customer Satisfaction	Survey results in Finland indicate that 90 percent of drivers found weather-controlled VSL signs to be useful. ²²⁰

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Traffic Control
Costs
Unit Costs Data Examples (See Appendix A for more detail)
<p>Roadside Control subsystem:</p> <ul style="list-style-type: none"> • Fixed Lane Signal: \$5K-\$6K • Signal Controller and Cabinet: \$8K-\$14K <p>Roadside Detection subsystem:</p> <ul style="list-style-type: none"> • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor • Environmental Sensor Station (Weather Station): \$30K-\$49K <p>Roadside Information subsystem:</p> <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Highway Advisory Radio: \$15K-\$35K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) <p>Roadside Telecommunications subsystem:</p> <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
Sample Costs of ITS Deployments
<p>Finland: Approximately 350 km of the main road network have been equipped with VSL signs; most systems are weather-controlled. The systems consist of DMS, ESS, traffic monitoring stations, and CCTV cameras. The number of units and spacing varies for dual carriageways and single carriageways. The average implementation costs on dual carriageways (divided highways) are 80,000 €/km (almost double the amount for single carriageways (roadway with no physical separation)). Communications cabling is the major cost driver. Average maintenance costs for dual carriageways, which include replacement investments for a 20-year life, are 3,500 €/km/year. Costs are at the 2004 level.²²¹</p>
Benefit-Cost Studies
<p>Finland: A study of a weather and road condition controlled system of VSL signs in Finland showed favorable results for deployment along heavily traveled road segments. Starting benefit-to-cost ratios ranged from 1.1:1 to 1.9:1. The ratio was higher if safety assumptions were higher and there was greater use of higher speed limits.²²²</p>

Response and Treatment

A variety of ITS applications are being deployed in the United States to support roadway treatments necessary in response to weather events. These applications may provide for automated treatment of the road surface at fixed locations, such as anti-icing systems mounted on bridges in cold climates. They may also enhance the efficiency and safety of mobile winter maintenance activities, for example, through AVL technologies on snow plows supporting a computer-aided dispatch system.

Response and Treatment	
Deployment	
Twenty (20) states use automatic bridge anti-icing systems and 13 states equip a portion of their snow plow fleet with AVL, communications, and sensors to track distribution of chemical treatments.	
Benefits	
ITS Goals	Selected Findings
Safety	Summary Finding: Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found crash reductions from 25 to 100 percent. ²²³
Mobility	In Finland, an RWIS that automatically communicated actual and forecast data to road maintenance personnel was estimated to save an average of 23 minutes per deicing activity and improve traffic conditions. ²²⁴
Productivity	Winter maintenance personnel indicated that anti-icing techniques limit snow/ice bonding on roadways, improve plow efficiency, reduce the time required to clear snow/ice from roadways, reduce maintenance costs (overtime pay and materials), and reduce the need for abrasive cleanup activities. ²²⁵
Energy and Environment	Winter maintenance personnel from several agencies indicated that use of RWIS decreases salt usage and anti-icing techniques limit damage to roadside vegetation, groundwater, and air quality (in areas where abrasives are applied). ²²⁶

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Response and Treatment

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Control subsystem:

- Automatic Anti-icing System—Short Span: \$22K
- Automatic Anti-icing System—Long Span: \$45K-\$446K

Roadside Detection subsystem:

- Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K

Transportation Management Center subsystem:

- Road Weather Information System (RWIS): \$11K

Roadside Telecommunications subsystem:

- Conduit Design and Installation—Corridor: \$50K-\$75K (per mile)
- Fiber Optic Cable Installation: \$20K-\$52K (per mile)
- 900 MHz Spread Spectrum Radio: \$8.2K (per link)
- Wireless: \$1.1K-\$1.7K (annually)

Sample Costs of ITS Deployments

Utah and Canada: Nine respondents to a FAST survey indicated that cost of installations varied greatly, **\$22,000 to \$4 million**, depending on coverage area, site location, accessibility of existing utilities, system functionality and features, and market factors. Three installations illustrate the median cost range:

A FAST installation on a bridge on I-315 in Utah cost **\$250,000**.

In Ontario, Canada, a demonstration FAST installation on a bridge and approach was **\$300,000 Canadian dollar (CAD)** or **\$14.20/ft² (CAD)**. Operating costs were **\$15,000 (CAD)** or **\$0.70/ft² (CAD)**.

For later FAST deployments in Ontario, the cost of the basic spray systems ranged from **\$90/ft² (CAD)** to **\$370/ft² (CAD)** on two-lane structures. The cost for the advanced RWIS station associated with each FAST deployment was estimated at **\$93,000 (CAD)**.

O&M costs of the FAST systems are relatively low compared to the installation costs.²²⁷

Kansas: The Kansas DOT sponsored a study of the use of AVL technologies for highway maintenance activities, particularly snow removal. A statewide system equipping 585 vehicles was estimated to cost approximately **\$9 million** and about **\$800,000 per year** for maintenance. The implementation cost for a dedicated data channel to the existing 800 MHz radio system was estimated at **\$6 million**. The high communications cost is consistent with other AVL deployments. The AVL unit cost is estimated at **\$3,500 per vehicle**.²²⁸

Response and Treatment

Costs

United States: Based on data from early AVL implementers across the U.S., the capital costs of AVL systems are highly dependent on the level of software customization of commercial off-the-shelf packages as well as the type of sensors installed on the maintenance vehicles and how the vehicle was equipped prior to the AVL installation. When the systems were installed was also a factor as the cost of AVL technology has dropped over time. Based on six deployments, the cost ranged from **\$1,250 to \$5,800 per vehicle**. For several deployments, communications cost ranged from **\$40 to \$60 per month per vehicle**.²²⁹

Iowa, Pennsylvania, Wisconsin, Arizona, and California: The addition of various advanced technology applications such as radar, sensors, and control units can add **\$20,000 to \$30,000** to the cost of a regular snowplow.²³⁰

Benefit-Cost Studies

Utah, Minnesota, and Kentucky: Analysis of fixed anti-icing systems deployed on bridges in Utah, Minnesota, and Kentucky found benefit-to-cost ratios of 1.8:1 to 3.4:1.²³¹

Kansas: A Kansas DOT study found that the application of AVL to highway winter maintenance vehicles could result in a benefit-to-cost ratio ranging from at least 2.6:1, using conservative assumptions, to 24:1 or higher based on moderate assumptions.²³²

Washington and Finland: With more efficient application of anti-icing chemicals and abrasives, reduced maintenance costs, reduced delay, and increased safety, benefit-to-cost ratios for RWIS and anti-icing strategies range from 2:1 to 5:1.²³³

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ROADWAY OPERATIONS AND MAINTENANCE

ROADWAYS

Operating and maintaining transportation systems is costly. Many State DOTs are implementing ITS to better manage roadway maintenance efforts and to enhance safety and mobility on the transportation system. ITS applications in operations and maintenance focus on integrated management of maintenance fleets, specialized service vehicles, hazardous road conditions remediation, and work zone mobility and safety. Systems and processes are required to monitor, analyze, and disseminate roadway/infrastructure data for operational, maintenance, and managerial uses. ITS can help secure the safety of workers and travelers in a work zone while facilitating traffic flow through and around the construction area.

Information dissemination technologies can be deployed temporarily, or existing systems can be updated periodically, to provide information on work zones or other highway maintenance activities. Several ITS technologies can help State DOTs with asset management including fleet tracking and automated data collection for monitoring the condition of highway infrastructure. ITS applications in work zones include the temporary implementation of traffic management or incident management capabilities. These temporary systems can be stand-alone implementations or they may supplement existing systems in work areas during construction. Other applications for managing work zones include measures to control vehicle speeds and notify travelers of changes in lane configurations or travel times and delays through the work zones. In fact, work zone management systems are the most widely studied example of the information dissemination technologies mentioned above. ITS may also be used to manage traffic along detour routes during full road closures to facilitate rapid and safe reconstruction projects.

The roadway operations and maintenance technologies profiled in this chapter support the U.S. DOT's Congestion Initiative, as outlined in the May 2006 document *National Strategy to Reduce Congestion on America's Transportation Network*. One element of the national strategy is to reduce congestion by promoting operational and technical improvements that have the potential to enable existing roadways to operate more efficiently. One group of improvements identified in the national strategy is work zone safety and mobility.²³⁴ For more information, visit the Congestion Initiative Web site: www.fightgridlocknow.gov.

Findings

Benefits

ITS technologies deployed for roadway operations and maintenance activities can have system-wide impacts. Network simulation models estimate that smart work zones can reduce total delay by 41 to 75 percent.²³⁵ During freeway reconstruction projects, evaluation data suggest these technologies can cut traffic queues in half.²³⁶

In addition to improving mobility, work zone ITS can improve safety. Evaluation data show that areas equipped with speed monitoring displays can decrease vehicle speeds by 4 to 6 mi/h²³⁷ and reduce the number of speeding vehicles by 25 to 78 percent.²³⁸ In addition to controlling traffic speed, smart work zones improve driver behavior. Evaluation data show that dynamic lane merge systems help reduce driver confusion at merge points and reduce aggressive driving.²³⁹

In rural areas, ITS technologies can improve the efficiency and effectiveness of operations and maintenance activities. With improved communication links between operation centers and field equipment, maintenance personnel can spend more time improving

WORK ZONE ITS DEPLOYMENT COSTS RANGED FROM \$100,000 TO \$2.5 MILLION WITH THE MAJORITY RANGING FROM \$150,000 TO \$500,000.

ROADWAY OPERATIONS AND MAINTENANCE CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Information Dissemination

- Portable Dynamic Message Signs
- Highway Advisory Radio
- Internet/Wireless/Phone

Asset Management

- Fleet Management
- Infrastructure Management

Work Zone Management

- Temporary Traffic Management
- Temporary Incident Management
- Lane Control
- Variable Speed Limit
- Speed Enforcement
- Intrusion Detection
- Road Closure Management

SIMULATION MODELS ESTIMATE THAT SMART WORK ZONES CAN REDUCE TOTAL DELAY BY 41 TO 75 PERCENT.

roadway conditions instead of traveling to remote sites to manually update or confirm the operation of field devices.²⁴⁰

As depicted in table 7, evaluations have documented the ability of work zone management systems to positively impact transportation operations in five of the six ITS goal areas: safety, mobility, efficiency, productivity, and customer satisfaction. Highlights of these research findings are presented later in this chapter. Several studies have shown that providing information to travelers regarding work zone and other maintenance activities can reduce related congestion. As further illustrated in figure 7, automated work zone information systems (AWIS) have reduced delay from 46 to 55 percent in three locations studied.²⁴¹

Table 7—Roadway Operations and Maintenance Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Information Dissemination		+				
Asset Management	●					
Operations and Fleet Management	+					
Work Zone Management	●	●	+	+		+
● Substantial positive impacts		+ Positive impacts				
○ Negligible impacts		* Mixed results				
✘ Negative impacts		blank Not enough data				

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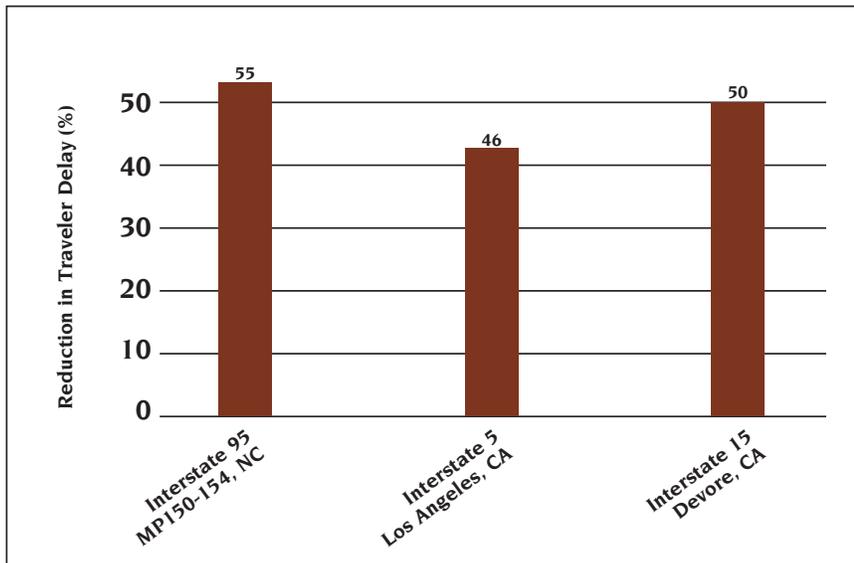


Figure 7 – Delay Reduction with AWIS

Costs

A review of work zone ITS deployments from 17 states showed that the costs vary greatly depending on several key factors: (1) purchasing vs. leasing system equipment, (2) temporary vs. permanent components of the project (e.g., equipment used in a work zone is later deployed as permanent equipment on the same or different project), and (3) size and function of the system. Costs ranged from \$100,000 to \$2.5 million with the majority of systems ranging from \$150,000 to \$500,000.²⁴²

Deployment

The use of ITS applications in work zones is popular among state DOTs. A survey of each of the 50 states conducted in 2006 revealed that state DOTs use a variety of media to disseminate information about work zones; 44 states use portable dynamic message signs (DMS), 39 states use the Internet, and 29 states use highway advisory radio (HAR). This same survey revealed that more than two-thirds (38) use ITS technologies such as lane control signs, portable DMS, and dynamic lane merge systems to notify travelers of changes in lane configurations approaching work zones. More than half of the states (29) use ITS technologies, either as stand-alone implementations or to supplement existing systems, to support temporary traffic management in work zones.

Respondents to the 2006 survey exhibited variability in their willingness to use ITS for asset management. Nine states use automatic vehicle location (AVL), computer-aided dispatch, and handheld computers supporting data entry and dispatch-field communications help manage vehicles; 39 states use sensors and automated data collection systems to monitor the condition of the highway infrastructure.

The 2006 survey of each of the 50 states about deployment of ITS technologies in rural areas and on a statewide basis is the source of deployment statistics presented later in this chapter.



Selected Highlights from the ITS Knowledge Resources on Roadway Operations and Maintenance

Information Dissemination

Information dissemination technologies can be deployed temporarily or existing systems can be updated periodically to provide information on work zones or other highway maintenance activities. Examples of these systems include dynamic message signs, highway advisory radio, Internet Web sites, wireless devices, and telephone services.

Information Dissemination	
Deployment	
Many states use a variety of media to disseminate information about work zones; 44 states use portable dynamic message signs, 39 use the Internet, and 29 use HAR.	
Benefits	
ITS Goals	Selected Findings
Mobility	Summary Finding: AWIS prevent severe congestion at work zones and reduce delay by 46 to 55 percent (see figure 7). ²⁴³
Mobility	In Devore, California, a real-time work zone traveler information system on I-15 contributed to a 50 percent decrease in maximum peak period delay. ²⁴⁴
Customer Satisfaction	In North Carolina, a survey of residents living near Smart Work Zone systems on I-95 found that over 95 percent of motorists surveyed would support use of these systems in the future. ²⁴⁵
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Dynamic Message Sign—Portable: \$18.6K-\$24K Roadside Detection subsystem: <ul style="list-style-type: none"> • Portable Traffic Management System: \$78K-\$97K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	

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Information Dissemination
Costs
<p>Sample Costs of ITS Deployments</p> <p>Minnesota: The Minnesota DOT’s Construction Office and Traffic Office developed a specification for a dynamic late merge system and worked closely with the vendor capable of providing the system. The deployed system provided guidance to motorists on proper lane usage via portable DMS. When a preset congestion level was reached, the signs were activated. When traffic returned to free-flow conditions, the signs returned to “dark mode.” The costs provided were based on four study locations: three in urban settings and one in a rural location. The cost of vehicle detection was approximately \$300 per day and three signs cost \$600 per day for a total cost of \$900 per day per direction.²⁴⁶</p> <p>Illinois: The Illinois DOT used work zone ITS in the I-64 add-lane construction project to monitor traffic, reduce congestion, and promote safety. The work zone ITS—also referred to as the Traffic Monitoring System—included 12 DMS located within and in advance of the work zone, and a total of 10 vehicle detection stations within and at the exit and entrance of the work zone. The data collected by the detectors were processed by a commercial off-the-shelf software package. Real-time information about traffic conditions was posted to the signs and automatically posted to a project Web site. The system was deployed for 30 months at a cost of \$14,500 per calendar month for a total cost of \$435,000. The total cost of the system was less than one percent of the total construction cost. The system was leased as part of the overall construction contract.²⁴⁷</p> <p>Illinois: The Illinois DOT (IDOT) decided to use ITS in a 40-mile work zone for a major bridge and highway reconstruction along I-55 south of Springfield. The ITS—referred to as the Real-Time Traffic Control System—consisted of 17 remotely-controlled portable DMS, eight portable vehicle detectors, and four portable cameras linked to a base station server via wireless communication. The system covered the work zone area as well as the northbound and southbound approaches to the work zone. IDOT indicated significant cost savings by leasing the system as a bid item. The cost of leasing the system was \$785,000, which represented approximately two percent of the total reconstruction contract cost of \$35 million. The system was deployed for a total of 16 months from February 2001 to May 2002.²⁴⁸</p>

Asset Management

Several applications help State DOTs with asset management including fleet tracking applications, as well as automated data collection applications for monitoring the condition of highway infrastructure.

Asset Management	
Deployment	
<p>Nine states use ITS technologies, such as automated vehicle location, computer-aided dispatch, and handheld computers supporting data entry and dispatch-field communications, to help manage maintenance vehicles; 39 states use sensors and automated data collection systems to monitor the condition of the highway infrastructure.</p>	
Benefits	
ITS Goals	Selected Findings
Productivity	<p>In Montana, weigh-in-motion (WIM) sensors were installed directly in freeway travel lanes to continuously collect truck weight and classification data at 28 sites. The study found that if freeway pavement designs were based on fatigue calculations derived from comprehensive WIM data instead of weigh station data, the State would save about \$4.1 million each year in construction costs. The pavement fatigue calculations based on WIM data were 11 percent lower on Interstate roadways and 26 percent lower on non-Interstate, primary roadways.²⁴⁹</p>
Costs	
Sample Costs of ITS Deployments	
<p>Southeast Michigan: The Southeast Michigan Snow and Ice Management project is a multi-agency AVL system that will use 500 highway maintenance vehicles equipped with global positioning system receivers and sensors to monitor snow plow use, rate of application for deicing materials, and air and road temperatures. Each vehicle will use 900 MHz communications, and transmit data to a centralized system where the data will be uploaded onto an Internet server and made available to other agencies. Nearly \$8.2 million has been spent to equip approximately 400 vehicles with sensors and communications infrastructure.²⁵⁰</p>	

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Work Zone Management

ITS applications in work zones include the temporary implementation of traffic management or incident management capabilities. These temporary systems can be stand-alone implementations or they may supplement existing systems in the area during construction. Other applications for managing work zones include measures to control vehicle speeds and notify travelers of changes in lane configurations or travel times and delays through the work zones. Systems for work zone incident management can also be used to more quickly detect incidents and better determine the appropriate degree of response needed, thereby limiting the amount and duration of additional capacity restrictions. ITS may also be used to manage traffic along detour routes during full road closures to facilitate rapid and safe reconstruction projects.

Work Zone Management	
Deployment	
<p>The use of ITS applications in work zones is popular among state DOTs. More than two-thirds of states (38) use ITS technologies—such as lane control signs, portable DMS, and dynamic lane merge systems—to notify travelers of changes in lane configurations approaching work zones. More than half of the states (29) use ITS technologies, either as stand-alone implementations or to supplement existing systems, to support temporary traffic management in work zones. Seventeen (17) states deploy temporary incident management systems to facilitate safe clearance of incidents that occur near work zones; 16 states use ITS technologies to manage traffic along detour routes during full road closures. Only two states (California and Tennessee) use automated work zone intrusion detection and warning systems, and only one state (Illinois) uses automated speed enforcement in work zones.</p>	
Benefits	
ITS Goals	Selected Findings
Safety	Summary Finding: In North Carolina and Arkansas, work zones equipped with AWIS had fewer crashes compared to similar sites without the technology. ²⁵¹
Mobility	A dynamic lane merge system deployed in a work zone outside Detroit increased PM peak period travel speeds by 15 percent. AM peak period speeds did not change. ²⁵²
Efficiency	In Minneapolis-St. Paul, traffic speed data collected at two freeway work zones indicated that when portable traffic management systems were deployed, peak period work zone traffic throughput increased by four to seven percent. ²⁵³
Productivity	The Illinois DOT reduced operating costs during the reconstruction of I-55 by deploying an automated traffic control system and eliminating the need for constant traffic monitoring. ²⁵⁴
Customer Satisfaction	The Illinois DOT reported a high level of satisfaction with an automated traffic control system deployed during the I-55 reconstruction project. ²⁵⁵

LESSONS LEARNED

Consider deploying ITS in a work zone to improve traffic safety and mobility during construction.

The Arkansas Highway and Transportation Department, upon undertaking a large and complex construction project, assessed the challenges associated with the extensive work zones and implemented an automated work zone information systems to cover the I-30 work zone corridor. The objectives of the AWIS were to improve safety and mobility during construction.

- Maintain flexibility when deploying ITS in highly variable environments.

Arkansas' effort to reconstruct and repair more than 350 miles of roadway was a large, complex undertaking with constantly changing configurations. As a result, the calibration of ITS became an important issue and required one full-time employee devoted exclusively to maintaining all sensors.

- Realize that ITS are just one part of a successful work zone management plan.

Intelligent transportation systems are only one part of a work zone management plan. ITS components can be instrumental in improving the safety of a work zone. However, they are not a cure all for eliminating the traveler's exposure to hazards that a work zone imposes. Based on Arkansas' experience, ITS helped reduce the number of crashes; but crashes, including fatal ones, were not fully avoided.



LESSONS LEARNED

Conduct necessary pre-implementation tests in order to secure smooth system operations.

In deploying ITS during rebuilding of the “Big I” interchange in Albuquerque, the New Mexico State Highway and Transportation Department found a number of ways to help ensure operational efficiency of ITS resources.

- Grant ample start up time when implementing new ITS technologies.

Problems will arise, such as with sensor operation, communications, license applications, component calibration, hardware, or software. These issues will take time to address and need to be identified as soon as possible before going “live”.

For instance, the mobile traffic monitoring and management system used by the department for the “Big I” interchange ITS deployment in Albuquerque was designed to be portable and use wireless communication. Wireless communication links were tested prior to the installation of field elements to ensure adequate bandwidth availability. The complete mobile traffic monitoring and management system was brought online two weeks prior to the start of construction allowing time for thorough pre-construction testing.

(Continued on next page.)

Work Zone Management
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: <ul style="list-style-type: none"> • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor • Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign—Portable: \$18.6K-\$24K • Highway Advisory Radio: \$15K-\$35K • Highway Advisory Radio Sign: \$5K-\$9K Roadside Detection subsystem: <ul style="list-style-type: none"> • Portable Traffic Management System: \$78K-\$97K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)

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Work Zone Management

Costs

Sample Costs of ITS Deployments

Michigan: Michigan DOT leased a dynamic lane merge system for an I-94 reconstruction project at a cost of **\$120,000**. The subcontract period of performance was for six months during each of two years. Each of the two six-month periods included installation, testing, and operation time. The system included five dynamic lane merge trailers spaced 1,500 feet apart and in advance of the work zone.²⁵⁶

Michigan: In Lansing, a planning study was conducted to evaluate the feasibility of implementing real-time work zone traffic information during a major freeway reconstruction and rehabilitation project on I-496. The total project investment was over \$40 million. The real-time traffic information component of the work zone management system was estimated to cost **\$1,900,000**. In addition, the costs for project design, contract administration, and construction engineering were estimated at **\$600,000**. Overall, the cost to design the system, furnish and install hardware and software components, and operate and maintain the system for the duration of one year was estimated at **\$2,500,000**.²⁵⁷

North Carolina: The North Carolina DOT leased its first smart work zone system along I-95 near Fayetteville at a cost of **\$235,000**. The lease consisted of three contract pay items: mobilization, monthly rental, and remobilization. The successful bid was guaranteed for 4 months usage not to exceed 10 months. The total bid breakout was: **\$75,000** for mobilization, **\$15,000 per month** for equipment rental, and **\$10,000** for remobilization.²⁵⁸

Benefit-Cost Studies

United States: Based on a review of work zone ITS deployments from 17 states, the estimated benefit-to-cost ratio ranged from 2:1 to 42:1 depending upon conditions and assumptions.²⁵⁹

Michigan: The use of ITS for temporary construction zone management in Lansing yielded a benefit-to-cost ratio of 1.97:1 and a net benefit of \$4,874,000. The benefit-to-cost ratio was calculated by dividing the benefits of the system (\$9,874,000) by the overall cost of the deployment (\$5,000,000 which included \$2,500,000 for opportunity costs).²⁶⁰

LESSONS LEARNED

(Continued from previous page.)

- Keep the future in perspective when planning and deploying a traveler information system.

Because New Mexico's State Highway and Transportation Department planned for future use, the agency used a combination of equipment purchases and rentals for its project to rebuild the "Big I" interchange in Albuquerque. Once the project ended, the department was able to reuse the purchased equipment as part of a permanent freeway management system.

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TRANSIT MANAGEMENT

FIFTY-SIX (56) PERCENT OF TRANSIT BUSES IN MAJOR METROPOLITAN AREAS ARE EQUIPPED WITH AVL TECHNOLOGIES.

TRANSIT

The transit industry in the United States consists of over 140,000 vehicles, 48 billion passenger miles of travel, and \$8.5 billion in passenger fares. Over the past 10 years the transit industry has grown by over 20 percent—faster than either highway or air travel.²⁶¹

Transit operations and fleet management ITS applications improve transit reliability through implementation of automated vehicle location (AVL) and computer-aided dispatch (CAD) systems which can reduce passenger wait times. The systems enhance security and improve incident management through improved vehicle-to-dispatch communications, enabling quicker response to aggressions, accidents and vehicle breakdowns. Speedy response to these types of incidents minimizes vehicle downtime and improves service reliability. Information on current vehicle location and schedule status can also support transit signal priority, which improves transit trip times and schedule adherence. Data records from AVL/CAD systems, along with automated passenger counters, are enabling a transition to improved transit planning and management strategies which rely on large quantities of data regarding system operations. This contrasts with many traditional management strategies which were developed to accommodate minimal data on system operations, limited by manual data collection requirements.²⁶² Vehicle monitoring technologies can allow transit vehicles to perform self-diagnostic tests and automatically alert maintenance personnel of potential problems, either immediately via AVL/CAD systems or through routine downloads at vehicle maintenance facilities.

Public access to bus location data and schedule status information is increasingly popular on transit agency Web sites. Passengers can confirm scheduling information, improve transfer coordination, and reduce wait times. In addition, electronic transit status information signs at bus stops help passengers manage their time, and on-board systems such as next-stop audio annunciators help passengers in unfamiliar areas reach their destinations.

Web-based multi-modal trip planners are in development, providing information on trip travel times by both automobile and public transportation services. The Federal Transit Administration is sponsoring development of such a system managed by the Regional Transportation Authority of Northeast Illinois. The system will enable Chicago area travelers to navigate an extensive network of bus and rail services, tollways, expressways, and major arterials. The concept of the Chicago area Web-based Multi-Modal Trip Planning System is to integrate driving itineraries, transit trip planners, and real-time monitoring systems to provide side-by-side comparisons of trip itineraries using transit, driving, or any combination of non-motorized modes such as biking and walking. The goal is to create a comprehensive decision support tool for choosing travel options that incorporate convenience, efficiency, and cost—from the traveler's perspective.

A growing role for ITS in the transit industry includes support for bus rapid transit (BRT). These transit lines typically supplement infrastructure-based improvements with transit ITS to provide service qualities approaching those of rail transit facilities. Infrastructure-based improvements to BRT lines include enhanced shelters, level boarding facilities, and priority treatments such as dedicated transit lanes or queue-jump lanes at congested intersections. ITS technologies typically deployed include transit signal priority and AVL/CAD for enhanced schedule performance, and improvements to traveler information that include in-vehicle annunciators and the provision of wayside arrival time information at major stops along the line.

TRANSIT MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Operations and Fleet Management

- Automatic Vehicle Location and Computer-Aided Dispatch
- Transit Signal Priority
- Maintenance
- Planning
- Service Coordination

Information Dissemination

- In-Vehicle Systems
- In-Terminal/Wayside
- Internet/Wireless/Phone

Transportation Demand Management

- Ride Sharing/Matching
- Dynamic Routing/Scheduling

Safety and Security

- In-Vehicle Surveillance
- Facility Surveillance
- Employee Credentialing
- Remote Disabling Systems

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO TRANSIT MANAGEMENT

Refer to other chapters in this document.

Electronic Payment and Pricing

- Transit Fare Payment
- Multi-use Payment

Traveler Information

- Pre-Trip Information
- En Route Information

Information Management

- Data Archiving

Collision Avoidance

- Obstacle Detection
- Lane Change Assistance
- Lane Departure Warning
- Road Departure Warning
- Forward Collision Warning
- Rear Impact Warning

Driver Assistance

- Precision Docking
- Coupling/Decoupling

ITS applications can also support transportation demand management activities including carpooling and ridesharing services, and enable flexible, door-to-door paratransit service that is typically provided for disabled travelers. Computer databases and Internet technologies can facilitate ride sharing and carpool matching services to reduce peak period travel along major commuter routes. Paratransit services increase public access to transit resources where coverage is limited or provide service to those who cannot access standard service. ITS can improve these services through data collection technology and software supporting better coordination of service providers and scheduling of trips, or by supporting innovative strategies, such as route deviation or zone-based demand-responsive feeder service to fixed routes. These latter strategies enable transit systems to provide access for those living in close proximity to scheduled transit services but unable to reach them. Use of ITS technologies to support paratransit services represents another growing area of transit ITS deployment. Applications for human services transportation that improve scheduling and service coordination among multiple providers can be cost-effective and provide enhanced service to travelers. Several of these concepts are included in the Mobility Services for All Americans (MSAA) initiative discussed below.

Transit ITS services include a number of other ITS applications that can help transit agencies increase safety and security, as well as enhance the operational efficiency of the Nation's transit systems. Advanced software and communications enable data as well as voice to be transferred between transit management centers and transit vehicles for increased safety and security, improved transit operations, and more efficient fleet operations. Transit management centers in several cities have the ability to monitor in-vehicle and in-terminal surveillance systems to improve quality of service and improve the safety and security of passengers and operators.

Several ITS technologies discussed elsewhere in this document have significant impacts on public transit systems. Electronic fare payment systems offer significant potential for transit agencies to streamline cash-handling processes and the potential for simplifying traveler access to multiple transit systems in a region. Also of interest are advanced traveler information systems (ATIS), which can include transit information, as in the case of the multi-modal trip planner discussed above. ITS data archiving can provide important information for transit planning and management. Finally, several vehicle-based collision avoidance technologies have been tested on transit vehicles and show promise for lessening the likelihood of crashes involving transit vehicles.

In addition to the ITS technologies profiled in this chapter, two major ITS initiatives will impact the development of ITS technologies for transit: MSAA and Integrated Corridor Management (ICM).

The goal of the MSAA initiative is to improve transportation services and simplify access to employment, healthcare, education, and other community activities by means of the advanced technologies of ITS and through extending transportation service partnerships with consumers and human service providers at the Federal, State, and local levels. Several ITS technologies profiled in this chapter will be deployed in support of this initiative including integrated vehicle dispatching and scheduling, AVL, communication systems, electronic payment systems/financial tracking and billing systems, and ATIS.²⁶³

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. The ICM

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initiative will also demonstrate how proven and emerging ITS technologies can be used to coordinate the operations between separate corridor networks (including both transit and roadway facilities) to increase the effective use of the total transportation capacity of the corridor.²⁶⁴

Additional information on both of these initiatives is available at the ITS JPO's Web site: www.its.dot.gov/msaa and www.its.dot.gov/icms.

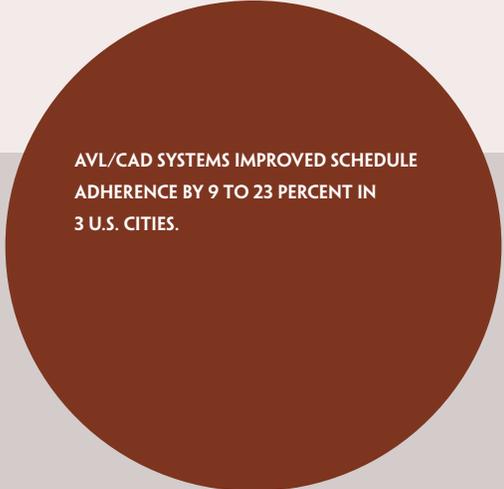
Findings

Benefits

Fleet management applications can improve both the experience of transit riders and the efficiency of transit operations by enabling more efficient planning, scheduling, and management of transit assets and resources. Transit agencies have reported reductions in fleet requirements ranging from two to five percent as a result of improved fleet utilization.²⁶⁵ For large agencies even small percentage gains can represent large amounts of actual operating cost savings.²⁶⁶ Deployment of AVL/CAD and scheduling software has enabled cost savings for paratransit providers through better planning of trips. An innovative application of these technologies has also demonstrated that agencies operating fixed routes can provide the option of demand-responsive services.

Improving schedule reliability improves travelers' experiences by reducing wait time anxiety and simplifying successful connections to other transit services. Data from transit systems in Portland, Oregon; Milwaukee, Wisconsin; and Baltimore, Maryland show that AVL/CAD systems have improved schedule adherence by 9 to 23 percent. The systems enable better monitoring of transit system status by transit dispatchers and allow appropriate responses to early arrivals, bus bunching, and other operational challenges as they arise.²⁶⁷ Figure 8 shows the range of documented experiences with improvements in transit travel times after the implementation of transit signal priority, with improvements ranging from 1.5 to 15 percent.²⁶⁸ Several studies show a range of measurements, typically representing measurements during peak periods and off-peak periods, or results for a variety of signal priority scenarios tested. Transit signal priority is often implemented on a conditional basis intended to help transit vehicles improve schedule performance by granting signal priority when vehicles are behind schedule. This practice can lead to a reduced need for recovery time in the scheduled trip and improve transit travel times. Archived data from AVL/CAD systems can also facilitate these types of schedule improvements.

Table 8 lists qualitative ratings for the impact of ITS applications for transit under each of the ITS goal areas identified by the U.S. DOT. These ratings demonstrate that each of the transit ITS applications have positive impacts on travelers' experiences. Applications supporting transit operations and fleet management provide substantial cost savings to transit operators, reduce transit vehicle emissions and energy consumption, and improve traveler mobility. Technologies supporting paratransit systems—listed under transportation demand management—have cost savings benefits for paratransit operators and improve customer experiences.



AVL/CAD SYSTEMS IMPROVED SCHEDULE
ADHERENCE BY 9 TO 23 PERCENT IN
3 U.S. CITIES.

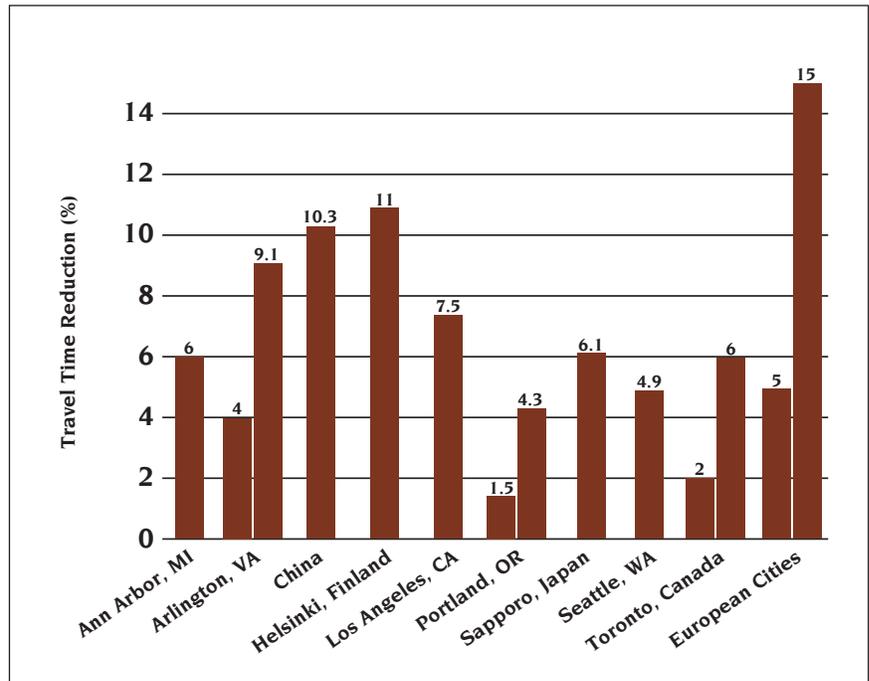


Figure 8 – Transit Travel Time Improvements with Transit Signal Priority

Table 8—Transit Management Benefits Summary						
	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Operations and Fleet Management		●	+	●	+	●
Information Dissemination						●
Transportation Demand Management				●		+
Safety and Security	+					+
● Substantial positive impacts + Positive impacts ○ Negligible impacts * Mixed results ✘ Negative impacts blank Not enough data						

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Costs

Based on survey results from over 100 transit agencies and equipment suppliers, the trend in mobile data terminals (MDTs) is more functionality and lower unit, installation, maintenance, and repair costs. MDTs are multifunctional on-board devices that support two-way communication between the vehicle and the control center. The majority of MDTs are used to download driver manifests, collect driver data such as sign on/sign off and start run/end run, count passengers boarding and alighting, and to function as an emergency alarm. Capital costs for MDTs typically range between \$1,000 and \$4,000 per unit with installation costs frequently between \$500 and \$1,000.²⁶⁹ In 2007, a comprehensive cost assessment of BRT components was conducted and found that on-board security systems typically cost approximately \$10,000 per vehicle.²⁷⁰

Deployment

Figure 9 shows deployment trends for three key transit management technologies from 2000 to 2006, based on a survey of the country's 78 largest metropolitan areas. The use of AVL on fixed-route buses has expanded rapidly during this period, growing from 32 percent in 2000 to almost 60 percent in 2006. The percentage of demand-responsive paratransit vehicles under CAD has grown equally as fast. In 2006, 56 percent of demand-responsive paratransit vehicles operated under CAD. About one-third of fixed-route buses are equipped with sensors that monitor vehicle components in real time, although deployment of this technology has leveled off in the past few years.

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.

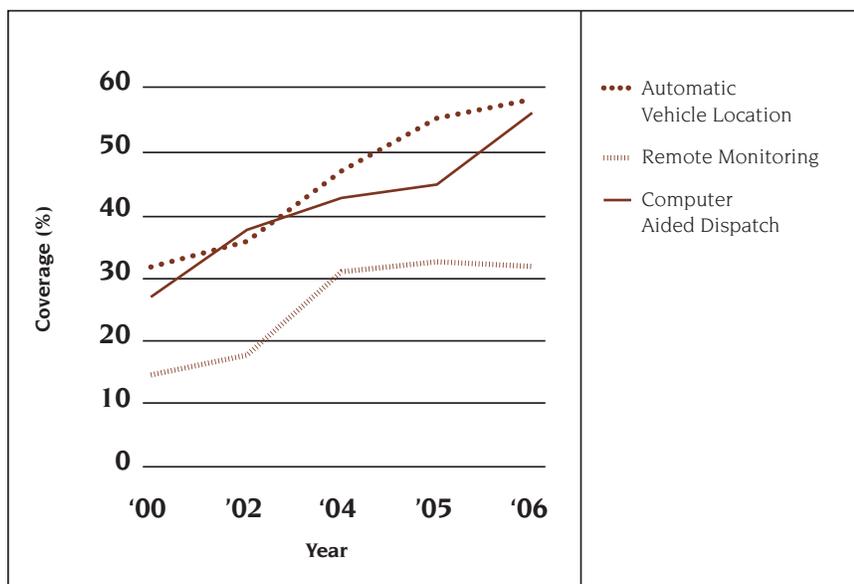


Figure 9 – Deployment Trends for Transit Management Technologies, 2000-2006

CAPITAL COSTS FOR MOBILE DATA
TERMINALS TYPICALLY RANGE BETWEEN
\$1,000 AND \$4,000 PER UNIT.



Selected Highlights from the ITS Knowledge Resources on Transit Management

Operations and Fleet Management

Transit operations and fleet management technologies improve transit reliability through implementation of AVL and CAD systems. These systems may also be implemented with in-vehicle self-diagnostic equipment to automatically alert maintenance personnel of potential problems. Automated passenger counters can provide additional data to support service planning. Service coordination, technologies can help assure connections between transit services at transfer points through a service commonly known as connection protection. Transit signal priority systems, through coordination with arterial management systems, can improve service quality and transit agency productivity.

Operations and Fleet Management	
Deployment	
<p>The use of ITS to support fleet management has experienced wide acceptance among transit agencies in major metropolitan areas. More than half (56 percent) of fixed-route transit buses in the country's 108 largest metropolitan areas are equipped with AVL; 56 percent of demand-responsive paratransit vehicles operate under CAD; and 30 percent of fixed-route transit buses are equipped with technology to monitor vehicle components in real time. Thirty-nine (39) percent of transit agencies in these 108 metropolitan areas archive data on transit operations for later use.</p>	
Benefits	
ITS Goals	Selected Findings
Mobility	Summary Finding: Studies from transit systems in Portland, Oregon; Milwaukee, Wisconsin; and Baltimore, Maryland show that AVL/CAD systems have improved schedule adherence by 9 to 23 percent. ²⁷¹
Mobility	In Eindhoven, the Netherlands, on-board computers recorded daily transit performance. This information was used to plan minimum transit route times and increase schedule reliability. ²⁷²
Efficiency	In Portland, Oregon, evaluation data show that AVL/CAD increased the effective capacity of the bus system by providing the same level of service to a greater number of travelers using the same equipment. ²⁷³
Productivity	Analysis of archived bus travel time and passenger load data from the AVL/CAD system deployed in Portland, Oregon found that scheduled time on 81 of 104 routes could be shortened while the remaining 23 required additional time. Identified schedule changes could potentially yield \$7 million in annual operating cost savings. ²⁷⁴

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Operations and Fleet Management	
Benefits	
Customer Satisfaction	The Connection Protection system deployed by the Utah Transit Authority helped assure connections between higher frequency light rail transit service and lower frequency bus routes. The system resulted in a small, but not statistically significant, increase in the number of travelers satisfied with their travel experience: 87 percent with Connection Protection compared to 85 percent without it. ²⁷⁵
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
<p>Transit Management Center subsystem:</p> <ul style="list-style-type: none"> • Upgrade for Automated Scheduling, Run Cutting, or Fare Payment: \$19K-\$39K • Integration for Automated Scheduling, Run Cutting, or Fare Payment: \$219K-\$486K <p>Transit Center Labor: \$100K-\$400K (annually)</p> <ul style="list-style-type: none"> • Transit Vehicle On-Board subsystem: • Cell-Based Communication Equipment: \$0.14K-\$0.23K • Global Positioning System (GPS)/Differential GPS (DGPS) for Vehicle Location: \$0.5K-\$2K • Trip Computer and Processor: \$0.1K-\$0.12K • Automatic Passenger Counting System: \$0.98K-\$9.8K 	

Operations and Fleet Management

Costs

Sample Costs of ITS Deployments

Worldwide: Costs data were obtained from various BRT projects either underway or planned and made available to transit professionals and policy makers in planning and decision making related to implementing different components of BRT systems. The data are representative of BRT development costs. On-board performance monitoring systems typically cost approximately **\$2,000 per vehicle** and AVL systems cost around **\$8,000 per vehicle**.²⁷⁶

Montana: The Billings METropolitan Special Transit, a paratransit service, spent approximately **\$43,500** to add AVL technology to its fleet of 15 vehicles.²⁷⁷

Massachusetts: The cost of the capital infrastructure for the Cape Cod Advanced Public Transit Systems—which included radio tower upgrades, local area network upgrades, 100 AVL/MDT units, and software upgrades—was **\$634,582**. This cost roughly represents **\$6,346 per unit** for 100 units. Given that the Cape Cod project was an early demonstration project, upgrades to the existing communications system were necessary. Such requirements and associated costs may not be required by other agencies deploying AVL/MDT capabilities.²⁷⁸

Michigan: The Flint Mass Transportation Authority (MTA) developed a plan to deploy ITS technologies to improve effectiveness and efficiency of transit service in Genesee County. The MTA budgeted **\$5,000 per bus** and **\$1 million** for the central system to implement a county-wide AVL system. The total capital cost was **\$1,750,000** for 150 vehicles with an estimated **\$250,000** for annual operations and maintenance (O&M) cost. To collect detailed transit passenger ridership information, the Flint MTA planned to install automatic passenger counters on 10 MTA fixed-route vehicles and rotated the vehicles with counters amongst all fixed routes. The costs were estimated at **\$50,000 (\$2,500 per vehicle)** and O&M at **\$10,000 per year**. On-board diagnostics are planned for 100 vehicles to support more efficient maintenance operations and on-road trouble-shooting. Costs are estimated at **\$200,000** for capital and **\$20,000 annually** for O&M.²⁷⁹

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Operations and Fleet Management: Transit Signal Priority

Transit signal priority systems use sensors to detect approaching transit vehicles and alter traffic signal timing to improve transit performance. For example, some systems extend the duration of green signals for public transportation vehicles when necessary.

Operations and Fleet Management—Transit Signal Priority	
Deployment	
Two percent of signalized intersections in the country's 108 largest metropolitan areas are equipped with transit signal priority.	
Benefits	
ITS Goals	Selected Findings
Mobility	Summary Finding: Experience in 13 cities in the U.S. and abroad show 1.5 to 15 percent improvement in bus travel time due to transit signal priority. ²⁸⁰ This range represents experience with a variety of transit service types under varying traffic conditions. Several studies show significant reductions in travel time variability, with a corresponding improvement in on-time performance.
Mobility	Transit signal priority implemented as part of the Metro Rapid BRT service in Los Angeles yielded travel time improvements of 7.5 percent and signal delay reduction of 36 and 33 percent on two test corridors. ²⁸¹
Productivity	In the central area of Chicago, a feasibility study indicated that driver assistance technologies and transit signal priority for BRT would be cost-effective for deployment on proposed busways. ²⁸²
Energy and Environment	Simulation of a transit signal priority system along a heavily traveled corridor in Arlington County, Virginia found a two to three percent reduction in fuel consumed by buses across a number of priority scenarios. ²⁸³
Customer Satisfaction	Surveys found that riders on Vancouver's 98 B-line BRT service, which implemented transit signal priority to improve schedule reliability, rated the service highly with regard to on-time performance and service reliability (an average of 8 points on a 10-point scale). ²⁸⁴

Operations and Fleet Management—Transit Signal Priority

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Control subsystem:

- Signal Controller Upgrade for Signal Control: \$2.4K-\$6K
- Roadside Signal Preemption/Priority: \$5K-\$6K

Transit Vehicle On-Board subsystem:

- Signal Preemption/Priority Emitter: \$0.5K-\$2.1K
- Preemption/Priority Transponder: \$0.07K

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: The need to upgrade or replace traffic signal software and controllers are key cost drivers in transit signal priority projects. Costs can be under **\$5,000 per intersection** if existing software and controller equipment can be used. The costs can rise to **\$20,000 to \$30,000** per intersection if software and control equipment are to be replaced.²⁸⁵

California: Stage one of the Watt Avenue corridor in Sacramento, California consisted of deployment of a transit priority system using Type 2070 controllers for 20 intersections, priority emitters for 60 transit vehicles, 14 closed circuit television cameras, 1 weigh-in-motion station, 4 DMS, and associated communication infrastructure. The fiber optic communication infrastructure connects the field devices with the County Traffic Operations Center (TOC) and the County TOC to the Caltrans/California Highway Patrol Regional Transportation Management Center. The cost to implement stage one was estimated at **\$1.5 million**.²⁸⁶

California: The Los Angeles County Metropolitan Transportation Authority, in partnership with the City of Los Angeles DOT, conducted the Metro Rapid Demonstration Program, a BRT full-deployment feasibility project, along two major arterials. The two Metro Rapid lines—Wilshire-Whittier and Ventura—began operations on June 24, 2000. A critical element of the Metro Rapid Program is the transit signal priority system. This system serves to improve on-time performance, provides real-time next bus arrival information to passengers waiting at bus stations, and assists fleet management by recording travel time for each bus run. The system is deployed at approximately 211 intersections, covering 42.4 miles along both Metro Rapid lines. The total cost for the system was **\$4,243,000**, which equates to approximately **\$20,000 per intersection** or **\$100,000 per mile**.²⁸⁷

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Information Dissemination

Information dissemination Web sites allow passengers to confirm scheduling information, improve transfer coordination, and reduce wait times. Electronic transit status information signs at bus stops help passengers manage their time and on-board systems such as next-stop audio annunciators help passengers in unfamiliar areas reach their destinations.

Information Dissemination	
Deployment	
<p>The use of ITS technologies to provide real-time transit information remains limited to a small portion of transit agencies. Ten (10) percent of transit terminals in the country's 108 largest metropolitan areas have in-terminal information systems that provide real-time transit information. Transit agencies in 18 of these 108 metropolitan areas use automated telephone systems to disseminate real-time transit schedule adherence status or arrival and departure times to the public. Transit agencies in 6 of the country's 108 largest metropolitan areas use in-vehicle systems for providing information on routes, schedules, and fares.</p>	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	<p>Summary Finding: Evaluation data show that passengers who use real-time bus or tram departure information signs find them useful. At the Acadia National Park in Maine, 90 percent of visitors using the signs said they made travel easier.²⁸⁸ Several surveys in Helsinki, Finland found 66 to 95 percent of travelers regarded similar signs useful.²⁸⁹</p>
Customer Satisfaction	<p>The ROUTES (Rail, Omnibus, Underground, Travel Enquiry System) computerized travel enquiry system used by the London Transport in England helped 13 percent of travelers change their travel modes to transit, which generated an estimated £1.3 million of additional revenue for bus companies, £1.2 million for the underground, and £1 million for railways.²⁹⁰</p>

Information Dissemination

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Transit Management Center subsystem:

- Transit Center Hardware: \$8K-\$10K
- Transit Center Software, Integration: \$792K-\$1671K
- Transit Center Labor: \$100K-\$400K (annually)

Transit Vehicle On-Board subsystem:

- Cell-Based Communication Equipment: \$0.14K-\$0.23K
- Global Positioning System (GPS)/Differential GPS (DGPS) for Vehicle Location: \$0.5K-\$2K
- Trip Computer and Processor: \$0.1K-\$0.12K

Remote Location subsystem:

- Transit Status Information Sign: \$4K-\$8K

Sample Costs of ITS Deployments

Oregon: The Portland Tri-County Metropolitan Transportation District (TriMet) deployed a real-time traveler information system, Transit Tracker, beginning in 2001. Transit Tracker provides riders with a real-time estimate of the expected time the next transit vehicle will arrive. The system covers all light rail stops and each of TriMet's 7,700 bus stops. Information is available at all rail stations and 13 bus stops via phone and a dedicated Web site. A rough cost estimate for the field equipment (designing, purchasing, and installing the dynamic message signs (DMS) at 13 bus stops and all rail stations), servers, and Web development for Transit Tracker is **\$1,075,000**. O&M costs for Transit Tracker are estimated to be roughly **\$95,000 per year**.²⁹¹

Michigan: The Flint MTA identified the cost for an advanced traveler information system consisting of a fleet-wide on-board announcement system, real-time arrival-departure information, and a Web-based trip planner; **\$1.5 million** is budgeted for capital cost with **\$225,000 annually** for O&M cost.²⁹²

Worldwide: In 2007, a comprehensive cost assessment of BRT components was conducted and found that on-board security systems typically cost approximately **\$10,000 per vehicle**. On-board passenger information systems typically cost approximately **\$4,000 per vehicle** and signs at BRT stations typically cost **\$6,000 per sign**.²⁹³

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Transportation Demand Management

Transportation demand management services, such as ride sharing/matching and dynamic routing/scheduling, increase public access to transit service.

Transportation Demand Management	
Deployment	
<p>A significant number of transit agencies in major metropolitan areas use ITS technologies to improve transportation demand management efforts. Twenty-five (25) percent of transit agencies in the country's 108 largest metropolitan areas offer ride sharing and carpool matching services; 17 percent use AVL and CAD to support dynamic routing and scheduling; and 29 percent use ITS technologies to coordinate passenger transfers between vehicles or between transit systems.</p>	
Benefits	
ITS Goals	Selected Findings
Productivity	<p>An evaluation of scheduling software for the paratransit service in Billings, Montana found that the break-even point for savings as a result of the software implementation was a three percent improvement in efficiency, while the evaluation found that the software enabled a seven percent increase in rides per hour of service and an increase in rides per mile of just over three percent.²⁹⁴ Scheduling software enabled St. John's County in northeast Florida to reduce office staff from 9 to 4.5 full-time equivalents, despite a doubling of daily trips on the paratransit service, saving \$58,000 per year.²⁹⁵</p> <p>Route-deviation service can be less expensive than pure demand-responsive paratransit service while providing the additional important benefit of providing easy access to traditional transit routes for some patrons requiring door-to-door service. Experience with the Omnilink system in Prince William County, Virginia suggests that with less than 20 passengers per hour, adding 10 minutes of recovery time allows accommodation of one or two deviations per hour for routes taking approximately 35 minutes to drive without deviations.²⁹⁶</p>
Customer Satisfaction	<p>Interviews with transit operators and dispatchers for the consolidated transit service in Lake Tahoe, California found operators were generally satisfied with the MDTs deployed for communicating with dispatch. Dispatchers indicated that the precise location of the vehicles provided by the AVL system was useful. Both felt the scheduling capabilities provided were less than optimal for such a small demand-responsive service (five vehicles), but that the technologies provided useful capabilities for future service expansion.²⁹⁷</p>

LESSONS LEARNED

Adjust bus schedules to assure adequate time to accomplish rail-to-bus connections, given the risk of late train arrivals at connecting stations.

The Connection Protection system in Utah improves the reliability of transfers from the higher frequency light rail trains to the lower frequency bus services at connecting rail stations. Many transit agencies look to schedule adherence by their operators as a key performance indicator; hence, there is a built-in disincentive for bus operators to create delays by waiting for late arriving passengers.

- Coordinate bus schedules closely with rail schedules to maximize the likelihood of successful rail-to-bus connections.

Some of the bus operators in Utah commented that the rail and bus schedules are not adequately coordinated and adjusted to assure optimal connection time. The operators recommended making adjustments on the busiest routes first, as those are where the most problems are encountered.

Transit system managers need to examine the patterns of late train events at stations that service their bus routes and determine whether current bus schedules are adequately synchronized with the rail schedules. Adjustment strategies may include: extending the departure times from the stations serviced by rail, relative to the rail arrival schedules or building in additional recovery time at appropriate points on the bus route to allow operators to make up time and get back on schedule.³⁰³

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Transportation Demand Management
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transit Management Center subsystem: <ul style="list-style-type: none"> • Transit Center Hardware: \$8K-\$10K • Transit Center Software, Integration: \$792K-\$1671K • Upgrade for Automated Scheduling, Run Cutting, or Fare Payment: \$19K-\$39K • Integration for Automated Scheduling, Run Cutting, or Fare Payment: \$219K-\$486K • Transit Center Labor: \$100K-\$400K (annually) Transit Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Cell-Based Communication Equipment: \$0.14K-\$0.23K • Global Positioning System (GPS)/Differential GPS (DGPS) for Vehicle Location: \$0.5K-\$2K • Trip Computer and Processor: \$0.1K-\$0.12K • Automatic Passenger Counting System: \$0.98K-\$9.8K
Sample Costs of ITS Deployments
<p>Montana: The Billings METropolitan Special Transit System—a paratransit service that operates within the Billings, Montana city limits—deployed a computer-aided scheduling and dispatching software system at a cost of \$83,575. A software maintenance fee is charged at \$11,835 per year.²⁹⁸</p> <p>New Mexico: Client Referral, Ridership, and Financial Tracking (CRRRAFT), a Web-based system that integrates human services transportation with the daily operating procedures and administration of multiple rural transit agencies, cost about \$1 million to implement.²⁹⁹ Operating costs for CRRRAFT are about \$95,000 annually.³⁰⁰ Building on the success of CRRRAFT, the Alliance for Transportation Institute developed a plan and implemented smart card technology—the Intelligent, Coordinated Transit Smart Card Technology Project (ICTransit Card)—to provide cost-effective, seamless, and convenient transportation services in a rural setting. The cost of the ICTransit Card system is approximately \$635,700.³⁰¹ Operating costs for the ICTransit Card system are about \$93,000 annually with about \$40,000 shared with the annual operations for CRRRAFT.³⁰²</p>



Safety and Security

Advanced software and communications enable data as well as voice to be transferred between transit management centers and transit vehicles for increased safety and security. Transit management centers can monitor in-vehicle and in-terminal surveillance systems, sometimes including video, to improve quality or the safety and security of passengers and operators. Silent distress alarms enable drivers to notify dispatch of on-board security situations and remote disabling systems can prevent hijacking of transit vehicles.

Safety and Security	
Deployment	
<p>ITS technologies are used by many metropolitan transit agencies to enhance transit safety and security. Forty-three (43) percent of transit buses in the country's 108 largest metropolitan areas are equipped with in-vehicle surveillance systems, either audio or video, and 31 percent of transit depots in these 108 metropolitan areas were equipped with facility surveillance. In contrast, remote disabling systems remain far less popular, with only 2 percent of transit buses in these 108 metropolitan areas equipped with remote disabling systems.</p>	
Benefits	
ITS Goals	Selected Findings
Safety	In Denver, on-board silent alarms installed on Regional Transportation District buses contributed to a 33 percent reduction in bus passenger assaults between 1992 and 1997. ³⁰⁴
Customer Satisfaction	The Ann Arbor, Michigan transit authority installed on-board camera systems to increase safety and security. The cameras were often noticed by passengers, but the system only provided a significant feeling of additional security when respondents were traveling at night. Respondents to a survey rated police presence as giving them the greatest sense of security, followed closely by increased lighting. Emergency phones and video cameras had less impact. ³⁰⁵

LESSONS LEARNED

Enhance overall transit safety and security programs by implementing video assessment systems.

Transit management can achieve significant returns on most of its safety and security investments by deploying a video assessment system that leverages an agency's other safety and security assets. The primary advantage to video assessment systems is their ability to record and archive information for real-time and archival use.

For example, the New Jersey Transit (NJ Transit) video assessment system is effective because of the interdisciplinary, multi-agency, multi-jurisdictional way in which it is used. The functional requirements for the system were defined under the direction of the NJ Transit police chief, who worked closely with the head of the Information Technology Department who, in turn, specified the technical aspects of the system. The police chief culled requirements not only from transit operations, but from strong working relationships with the New Jersey State Police, Amtrak, New York City Metropolitan Transportation Authority, and the Port Authority of New York and New Jersey.³⁰⁸

Safety and Security
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transit Management Center subsystem: <ul style="list-style-type: none"> • Video Monitors for Security System: \$2K-\$5K • Hardware for Security System: \$13K-\$19K • Labor for Security System: \$293K-\$359K (annually) Transit Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Security Package: \$3.3K-\$6K Remote Location subsystem: <ul style="list-style-type: none"> • Closed Circuit Television (CCTV) Camera: \$2K-\$5K • Transit Status Information Sign: \$4K-\$8K
Sample Costs of ITS Deployments
<p>United States: Based on the results of a high-level scan on the use and adoption of advanced technology by public transit agencies, a video monitoring system costs approximately \$10,000 per vehicle. However, the addition of other integrated systems such as automated passenger counters, event recorders, voice annunciators, and equipment health monitoring may only cost a few thousand dollars more.³⁰⁶</p> <p>Michigan: The Flint MTA budgeted \$1,250,000 to deploy digital video systems fleet-wide (250 vehicles at an estimated cost of \$5,000 per vehicle). O&M costs were estimated at \$175,000 per year.³⁰⁷</p>

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TRANSPORTATION MANAGEMENT CENTERS

MANAGEMENT AND OPERATIONS

Transportation management centers (TMCs), sometimes called traffic management centers and traffic operations centers (TOCs), coordinate ITS operations. TMCs can be owned or operated by a single agency or multiple transportation agencies and perform an array of functions including data acquisition, command and control, computing, and communications for many types of ITS applications.

TMCs are integral to a variety of management and operations strategies discussed throughout this report: traffic incident management, emergency management, electronic payment and congestion pricing, traveler information, and information management. While some of these strategies can be implemented in a stand-alone manner, others cannot, and each is enhanced through participation in a TMC. Careful planning is needed to gain the best performance through participation in a TMC. For example, TMCs provide an opportunity for centralized collection of data collected by ITS; however, TMC performance requirements are necessary during archived data management systems development for the successful development of such a system.

Coordination through a TMC can also improve the performance of the various strategies discussed earlier in this report. TMCs are often the venue for the instantaneous communication and coordination among various transportation organizations that enable improved system performance. For example, inclusion of road weather management personnel in TMC operations can facilitate the implementation of a variety of traffic management strategies, in addition to snow and ice control, to mitigate the impact of inclement weather.

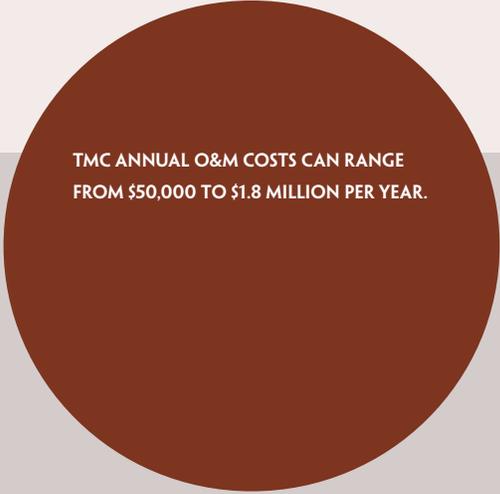
TMCs can be operated under several different business models. TMCs operated by a single agency have the simplest business model. These TMCs are able to focus resources on specific agency goals, coordination requirements, and explicit performance measures. Joint TMCs, however, are more complex. Joint operation of TMCs by multiple agencies complicates the task of TMC stakeholders and decision-makers charged with developing realistic planning and performance measures needed to rationalize TMC investments.

To date, most evaluation efforts that discuss TMC operations focus on specific programs such as incident management, emergency management, or traffic control. Since evaluation data that explicitly quantifies the impacts of integrated systems is limited, evaluators charged with determining the potential impacts of these deployments typically rely on estimation, simulation, and surveying techniques to approximate system impacts.³⁰⁹ Reports also include lessons learned to help improve operational procedures, strategies, and policies.

THE CAPITAL COST OF
PHYSICAL TMC COMPONENTS
CAN RANGE FROM \$1.8 MILLION
TO \$11.0 MILLION PER FACILITY.

TRANSPORTATION MANAGEMENT CENTER CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Transportation Management Centers



TMC ANNUAL O&M COSTS CAN RANGE
FROM \$50,000 TO \$1.8 MILLION PER YEAR.

Findings

Benefits

A TMC integrates a variety of ITS applications to facilitate the coordination of information and services within the transportation system. Some of these applications perform more effectively because they are supported by other applications within a TMC. As such, while it is difficult to isolate the impacts of a TMC and evaluate them using explicit performance measures, experts agree that without the enhanced operational coordination that a TMC offers, the result would be increased congestion, reduced traffic safety, and noteworthy inconvenience to the traveling public.

A TMC can be implemented as either a virtual system accessible via remote device(s) or a physical system where single or multiple stakeholder operators are located in a permanent structure and have centralized access to multiple applications. Co-locating stakeholder operators can improve interagency coordination and communications resulting in improved efficiency and productivity throughout the transportation network. For example, if one operator's system experiences failures, other operators may be able to implement mitigation responses to ease the impacts on the traveling public.

Overall, the benefits of a TMC vary greatly depending on its purpose, configuration, service responsibilities, performance, and level of integration. Integrated transportation management systems have the potential to produce the following benefits:

- Improved traffic management, advisory strategies, and control actions
- Improved timeliness and accuracy of information provided to the traveling public
- Increased efficiency of maintenance operations
- More effective use of personnel and resources
- Enhanced institutional, procedural, and operational integration and coordination³¹⁰

Costs

The cost of TMCs can vary greatly. Primary cost drivers include the size of the facility, the number of agencies present, and the number of functions performed by the facility.³¹¹ Planners typically examine the following cost categories to help assure costs are accounted for early and budgets can be adequately funded.

TMC facilities, communications, and hardware

The cost of a TMC can depend on the size and complexity of building construction, number of agencies housed, and functionality supported. As illustrated in figure 10, the capital cost of physical components can range from \$1.8 million to \$11.0 million per facility,³¹² and have annual operations and maintenance (O&M) costs that range from \$50,000 to \$1.8 million per year.³¹³ The higher costs reflect the complexity of a large facility that supports multiple agencies and integrates multiple functions. The lower costs are for a smaller facility that supports a single agency or agency function.

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Central hardware costs can exceed \$200,000 if regional communications and system integration are required, and the O&M costs for central hardware can range from \$40,000 to \$55,000 per year.³¹⁴ These costs, however, can be much less for smaller TMCs that do not incur large initial costs for computer systems and work stations, and do not require complex or customized communication systems. Another significant budget item is the visual displays needed for control room operations. The cost of video walls and monitors can range between \$100,000 and \$345,000, and the O&M costs can range from \$35,000 to \$55,000 per year.³¹⁵

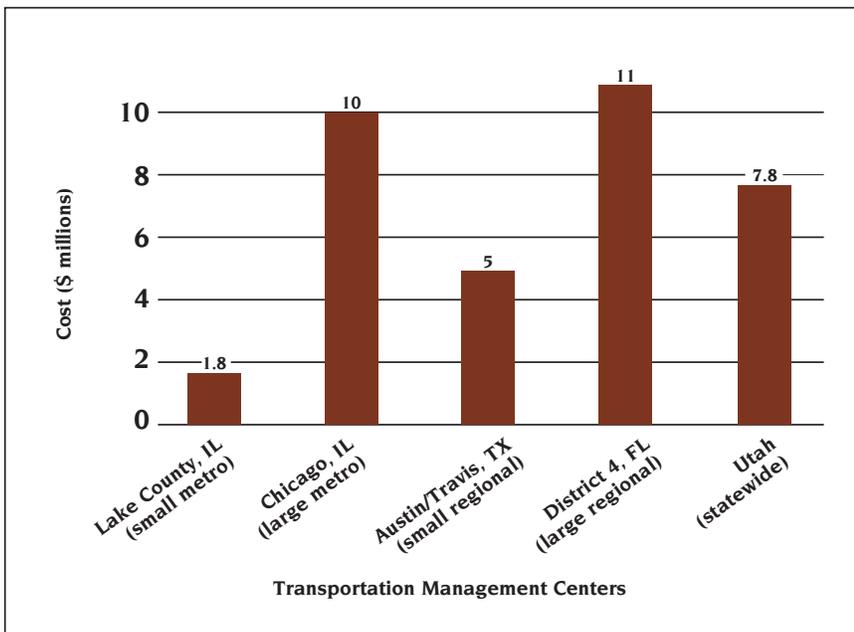


Figure 10 – TMC Initial Capital Costs

System integration and software

The cost of integration can vary depending on the current level of integration and specific operational needs of the transportation management system. Software integration costs vary significantly, ranging from \$250,000 to \$4.0 million. Annual O&M costs can range from \$50,000 to \$100,000.³¹⁶



Telecommunications

Establishing communications between TMCs and field devices can be the most expensive part of a transportation management system and require careful examination of life cycle costs with due consideration given to policy and technical issues. The Tennessee DOT evaluated the life cycle cost of leased service versus an owned service and concluded, based largely on the cost of maintaining a fiber optic communications plant, that leased services that included a favorable maintenance agreement would be more cost-effective.³¹⁷

The cost of installing fiber optic cable can vary greatly. Installation cost increases significantly in areas where new underground conduit is required. For Florida DOT District VI, the cost to install fiber optic cable in existing conduit was estimated at \$25,600 per mile.³¹⁸ However, in Broward County, where new conduit components were required, fiber optic communications cost between \$79,200 per mile and \$105,600 per mile.³¹⁹

Staffing requirements

Proper staffing and scheduling are needed for effective operations. Payroll costs typically account for the greatest percentage of a TMC operating budget. The number of operators, supervisors, and technical staff (i.e., software support, communications support, and systems engineering support) can depend on the size and complexity of the transportation management system, functional role of the TMC, and the hours of operation.³²⁰

The annual staffing costs for a medium to large TMC that provides peak period service or 24/7 operational support can range from \$280,000 to more than \$1.20 million depending on the number of TMC operators, administrative staff requirements, and level of technical support needed.³²¹ The labor costs for a smaller TMC that can provide part-time operator and technical support for limited incident management or special event coverage can cost between \$54,000 and \$130,000 per year.³²² In addition, training during the first year of operations is estimated at \$20,000.³²³

Operations and maintenance

TMC maintenance plans typically include life cycle cost estimates for building facilities, power supplies, central hardware and software, control systems, commercial off-the-shelf (COTS) products, video displays, Web sites, and media connections.³²⁴

Deployment

Figure II shows the functional capabilities of TMCs operated by freeway and arterial management agencies. The results are based on a 2006 survey of 102 freeway management agencies and 170 arterial management agencies. Capabilities reported by a high percentage of both types of TMC include incident management, network surveillance and data collection, and dissemination of data to travelers and other agencies, as well as traffic management for special events and evacuation. In general, a higher percentage of freeway TMCs report individual capabilities, indicating that they perform multiple functions to a greater degree than do arterial TMCs. Functions for which freeway TMCs have a particularly clear advantage are: providing en route information to travelers, conducting environmental monitoring, and carrying out road weather management. On the other hand, arterial agencies much more often report a capability for corridor management and traffic signal coordination.

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The 2006 survey of freeway management and arterial management agencies in the country's 108 largest metropolitan areas is the source of deployment statistics presented later in this chapter.

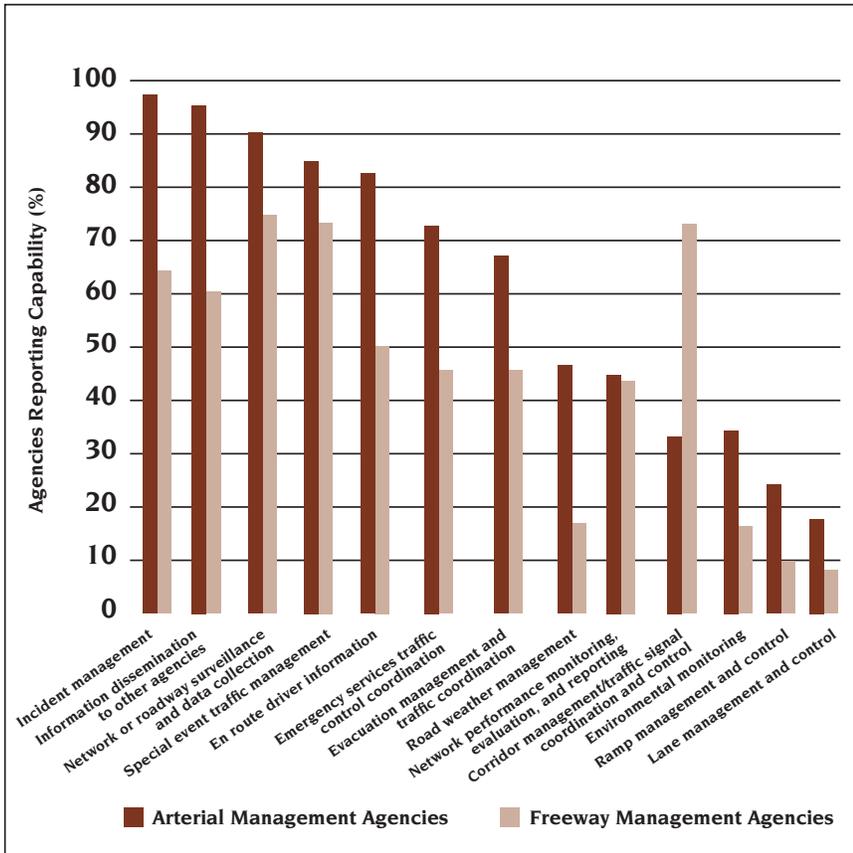


Figure 11 – Functional Capabilities of Transportation Management Centers



LESSONS LEARNED

Integrate emergency information into transportation management center (TMC) operations to improve performance and increase public mobility, safety, and security during regional emergencies.

The effects of both weather and emergency events on transportation operations can be significant and require an effective, coordinated response. Improvements in integrating emergency information into TMC operations result in improved public mobility, safety, and security. Lessons learned for enhancing operations during regional emergencies include:

- Co-locate operations of multiple agencies within the region.

The physical integration of operations leverages the resources of each agency to develop a center with more capabilities. The benefits of shared operations include reduced costs and increased awareness of the actions of other agencies.

- Create a restricted-access Web site for participating agencies.

A Web site with restricted access enables trained partner agencies with password accounts to share data, confident that the data have come from a trusted source, i.e., one of their TMC partners. Along the Pennsylvania Turnpike, TMCs and other authorized organizations access a Web site operated by the Pennsylvania Emergency Management Agency. The restricted-access Web site allows for a two-way flow of highly accurate incident information, with higher reliability than publicly-available Web sites.

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Selected Highlights from the ITS Knowledge Resources on Transportation Management Centers

Transportation Management Centers

TMCs are physical locations used to coordinate the activities of ITS operations. They can be owned or operated by a single agency or multiple transportation agencies and perform an array of functions including data acquisition, command and control, computing, and communications for many types of ITS applications.

Transportation Management Center
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transportation Management Center subsystem: <ul style="list-style-type: none"> • Basic Facilities and Communications for Large Area: \$4,314K-\$9,860K • Basic Facilities and Communications for Medium Area: \$4304K • Basic Facilities and Communications for Large Area: \$3766K • Video Monitors, Wall for Incident Detection: \$44K-\$80K • Software for Incident Detection: \$83K-\$101K • Labor for Incident Detection: \$751K-\$917K for multiple staff (annually) • Hardware, Software for Traffic Surveillance: \$131K-\$160K • Integration for Traffic Surveillance: \$219K-\$267K • Software for Traffic Information Dissemination: \$17K-\$21K • Integration for Traffic Information Dissemination: \$83K-\$101K
Sample Costs of ITS Deployments
TMC/Traffic Operations Center Facility <ul style="list-style-type: none"> • Illinois: Lake County TMC for advanced signal control cost \$1.8 million.³²⁵ • Texas: A shared regional transportation, emergency, and communications center in Austin and Travis Counties cost \$5 million.³²⁶ • Utah: The Utah DOT TOC that supports road weather management, traffic surveillance, incident management, ramp metering, signal control, and information dissemination cost \$7.8 million.³²⁷ • Illinois: The Chicago TMC that supports emergency management, signal control, and traveler information cost \$10 million.³²⁸ • Florida: Florida DOT District IV TMC shared by four agencies supports incident and emergency management, traffic surveillance, information dissemination, interactive traveler information services (511), and transit management at a cost of \$11 million.³²⁹

Transportation Management Center

Costs

Software and Integration

- **Virginia:** Integration of the Virginia State Police computer-aided dispatch system with the Richmond Smart Traffic Center for enhanced traveler information and incident location data cost **\$250,000**.³³⁰
- **Florida:** In Florida DOT Districts IV and VI, central software and integration costs varied between **\$250,000** for COTS products and **\$2 million** for custom designs requiring software development.³³¹
- **Illinois:** Software development and systems integration at the Chicago TMC cost **\$4 million**.³³²
- **Utah:** Software licensing and updates at the Utah DOT TOC cost **\$5 million**.³³³

Telecommunications

- **Illinois:** Life cycle cost estimates for four different communication network options designed to connect the Illinois DOT District 8 TOC to ITS field devices on 105 centerline miles of roadway range from **\$43 million** to **\$52.5 million**.³³⁴
- **Utah:** The fiber optic network installed through the Salt Lake Valley to connect the CommuterLink system with its field devices cost approximately **\$51.2 million**.³³⁵
- **Florida:** In District VI, the cost to install fiber optic cable in existing conduit over a distance of 21.3 miles was estimated to cost **\$25,600 per mile**. Annual cost estimates to lease telephone lines with T1 and T3 capability ranged from **\$5,600 to \$10,000** and **\$25,000 to \$132,000**, respectively.³³⁶
- **Florida:** In Broward County, the cost to install fiber optic cable in new conduit (with junction boxes, splicing, and terminators) was estimated to range from **\$79,200 to \$105,600 per mile**.³³⁷

Labor

- **Utah:** The costs of personnel working at the CommuterLink system are estimated at **\$400,000 per year**.³³⁸
- **Florida:** The labor costs to operate the TMCs in three DOT Districts ranged from **\$300,000 to \$1.2 million per year**.³³⁹
- **United States:** Estimated personnel operations cost (system operators, administration, and technical support)³⁴⁰
 - Regional TMC (27 staff, continuous 24/7 operations): **\$1.3 million per year**
 - Large TMC (seven staff, weekday 12/5 operations): **\$476,500 per year**
 - Medium TMC (four staff, weekday peak period 8/5 operations): **\$277,900 per year**
 - Small TMC (one staff equivalent, special event or incident response only): **\$53,600 per year**
- **Arizona:** Labor costs for the Arizona TMC are estimated at **\$920,000 per year**. Staffing includes four supervisors, nine operators, and three part-time interns that support 24/7 statewide incident management, traffic management, and traveler information functions.³⁴¹

LESSONS LEARNED

Prioritize constraints when designing a transportation management center (TMC) work schedule to help alleviate the complexity of scheduling problems.

TMC staffing and scheduling depends on a number of factors. Policies establish the work rules that are applied in the context of employee availability and preferences, work demands, and budgetary limitations, all of which create scheduling constraints. Conflicting constraints often cause problems that must be resolved by the schedule administrator to generate the most desirable schedule.

- Recognize that equipment availability and the size of a TMC are constraints because they limit the number of employees who can work during a shift.

The number of operators who can work during a shift is constrained by the number of workstations available, which in turn may be limited by space or funds. The consideration of equipment must also include contingencies if a piece of equipment should need to be repaired or replaced.

- Prioritize constraints when designing a work schedule.

The complexity of generating a staffing schedule increases as the number of constraints increase. One method to help alleviate the complexity of scheduling problems is to prioritize the constraints. A common method used to prioritize constraints using software is to classify each constraint as a hard constraint that must be satisfied or a soft constraint that may be violated to resolve scheduling conflicts.



Transportation Management Center

Costs

Operations and Maintenance

- **United States:** Estimated TMC operations cost (building O&M, utilities, communications equipment and services, computers and software licenses, and miscellaneous).³⁴²
 - Regional/Statewide TMC (continuous 24/7 operations): **\$1.8 million per year**
 - Large TMC (weekday 12/5 operations): **\$180,700 per year**
 - Medium TMC (weekday peak period 8/5 coverage): **\$109,400 per year**
 - Small TMC (special event or incident response only): **\$46,900 per year**
- **Arizona:** The Maricopa Association of Governments estimated it would cost **\$660,000 per year** to maintain regional communications between the TMC, local facilities, and public safety centers.³⁴³
- **Arizona:** Operating costs for the Arizona TMC are estimated at **\$1.08 million per year** with a breakout as follows:³⁴⁴
 - Equipment and supplies: **\$320,000**
 - Operations support: **\$300,000**
 - Utilities: **\$200,000**
 - Building maintenance: **\$120,000**
 - Software licenses: **\$100,000**
 - Training: **\$40,000**
- **Florida:** Florida District IV TMC maintenance costs range from approximately **\$294,000 (2005) to \$320,000 (2006) per year**.³⁴⁵

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TRAFFIC INCIDENT MANAGEMENT

MANAGEMENT AND OPERATIONS

Managing traffic incidents is a proven strategy for addressing significant portions of the Nation's traffic congestion problems. Approximately 25 percent of all delay is the result of incidents on roadways.³⁴⁶ Traffic crashes are the most time-consuming of these incidents, but the more numerous cases of stalled vehicles, roadway debris, and other incidents also contribute significantly to the problem.

Traffic incident management programs are widely deployed in metropolitan areas and are being extended into rural areas through a growing number of statewide programs. These programs make use of a variety of ITS technologies to successfully detect, manage, and clear traffic incidents; improving safety for travelers by reducing the risk of secondary crashes; and reducing time lost and fuel wasted in traffic backups.

To successfully manage traffic incidents, these programs utilize ITS deployed specifically to detect and manage traffic incidents, as well as components deployed for traveler information, freeway management, and arterial roadway management.

A variety of surveillance and detection technologies can help detect incidents quickly including inductive loop, microwave or acoustic vehicle detectors, and camera systems providing video surveillance of roadways. Information from wireless enhanced 9-1-1 systems, Mayday and automated collision notification (ACN) systems, as well as roadside call boxes can also help incident management personnel identify incidents quickly. Mobilization and response may include automated vehicle location (AVL) and computer-aided dispatch (CAD) systems, as well as response routing systems to help incident response teams arrive swiftly. Service patrols, which preceded the emergence of ITS technologies, are now frequently incorporated into traffic incident management programs. The patrol vehicles and staff, supported by an array of other ITS components, enable significant reductions in the time to respond to and clear incidents.

Several components of incident management systems help travelers safely negotiate travel around incidents on the roadway and facilitate the rapid and safe clearance of incidents and reopening of travel lanes. In some locations, incident management personnel can directly post incident-related information to roadside traveler information devices such as dynamic message signs (DMS) or highway advisory radio (HAR). On-site or transportation management center-based personnel can also relay messages to traveler information, freeway management, or arterial management systems, providing incident information to travelers via additional means including 511 systems and traveler information Web sites. Several technologies are available to speed the investigation of incident scenes and record necessary information for later analysis. Temporary traffic control devices help ensure the safety of incident responders and provide for the safe travel of vehicles around incident sites.

Traffic incident management programs are typically implemented concurrently with freeway management systems, but it is important to keep in mind that arterials can be included in incident management programs as well. Coverage of arterials by incident management programs is increasing: data collected in 2006 indicates that 6 percent of arterial streets have video monitoring for detection, and 11 percent have service patrols.³⁴⁷

Many of the techniques used to address unplanned traffic incidents are also used to manage operations during planned special events, which the freeway management chapter discusses in great detail. In addition, the emergency management chapter discusses ITS applied to larger scale emergencies such as hazardous materials incidents and evacuations for man-made or natural disasters.

SERVICE PATROLS COVER
ALMOST HALF (48 PERCENT)
OF FREEWAY MILES IN MAJOR
METROPOLITAN AREAS.

TRAFFIC INCIDENT MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance and Detection

- Detectors
- Imaging/Video
- Wireless Enhanced 9-1-1
- Mayday/Automated Collision Notification
- Call Boxes
- Traveler Reported

Mobilization and Response

- Automatic Vehicle Location/Computer-Aided Dispatch
- Response Routing
- Service Patrols

Information Dissemination

- Dynamic Message Signs
- Highway Advisory Radio

Clearance and Recovery

- Investigation
- Imaging/Video
- Temporary Traffic Control

**OTHER ITS KNOWLEDGE RESOURCE
CATEGORIES RELATED TO TRAFFIC
INCIDENT MANAGEMENT**

Refer to other chapters in this document.

Freeway Management

Special Event Transportation
Management

Emergency Management

Response and Recovery: Emergency
Vehicle Signal Preemption
Emergency Medical Services

In addition to the ITS technologies profiled in this chapter, the Next Generation 9-1-1 (NG9-1-1) initiative, a major ITS initiative currently being conducted by the U.S. DOT, has the potential to improve emergency communication which would, in turn, improve notification of traffic incidents. The NG9-1-1 initiative will establish the foundation for public emergency services in a wireless environment and enable an enhanced 9-1-1 system compatible with any communications device. The goal of the NG9-1-1 initiative is to enable the transmission of voice, data, or video from different types of communication devices to public safety answering points and onto emergency responder networks.³⁴⁸ Additional information on this initiative is available at the ITS JPO's Web site: www.its.dot.gov/ng911.

Findings

Benefits

Traffic incident management programs have demonstrated success under each of the goals of ITS, as summarized in table 9. The most significant finding is likely the ability of the programs to dramatically reduce the duration of traffic incidents, from 15 to 65 percent, with the bulk of studies finding savings of 30 to 40 percent (as shown in figure 12).³⁴⁹ These reductions in incident duration impact the safety of travelers through reduced likelihood of secondary incidents, affect the mobility and economic productivity of travelers through reduced incident related delay and associated costs, and impact the environment through reduced fuel consumption by idling vehicles. Service patrols are perhaps the most prominent and widely evaluated component of traffic incident management programs. Reports assessing customer satisfaction with the programs are unanimously positive.

Costs

As can be seen in figure 13, State DOTs can spend between \$5.6 million and \$13.6 million per year on service patrols. Regional service patrols are often in the range from \$1.5 million to \$2.5 million per year. However, for large, densely populated areas such as Los Angeles, California, the cost can be upwards of \$20.5 million per year, or as low as \$0.4 million in the Salt Lake City, Utah area. The cost of service patrols vary considerably depending on population, number of freeway miles covered, and the types and hours of services provided.³⁵⁰

Table 9—Traffic Incident Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Traffic Incident Management	●	●	●	●	●	●
● Substantial positive impacts	+		Positive impacts			
○ Negligible impacts	*		Mixed results			
✘ Negative impacts	blank		Not enough data			

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HISTORICAL DATA SHOW THAT SERVICE PATROLS HAD BENEFIT-TO-COST RATIOS RANGING FROM 2:1 TO 36:1.

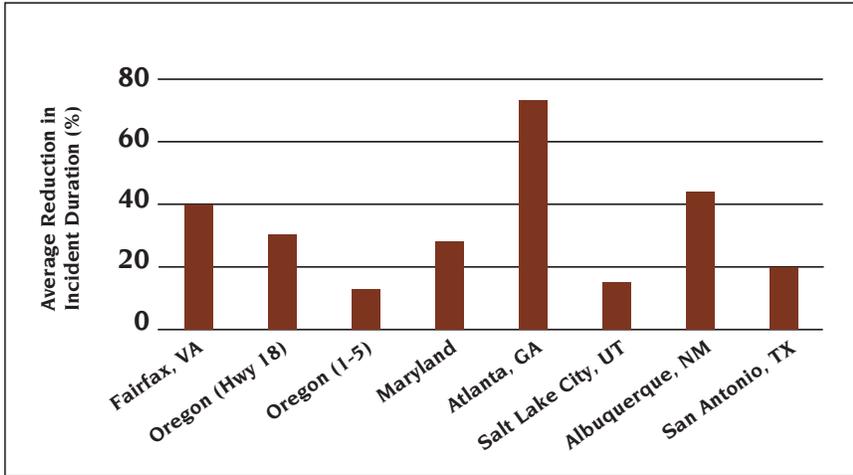


Figure 12 – Impact of Incident Management Programs on Incident Duration

Benefit-Cost Studies

Service patrols have also been the subject of numerous benefit-to-cost analyses over the course of their deployment, with 26 studies of the programs completed in 23 U.S. cities between 1994 and 2005. These studies document benefit-to-cost ratios ranging from 2:1 to 36:1.³⁵¹

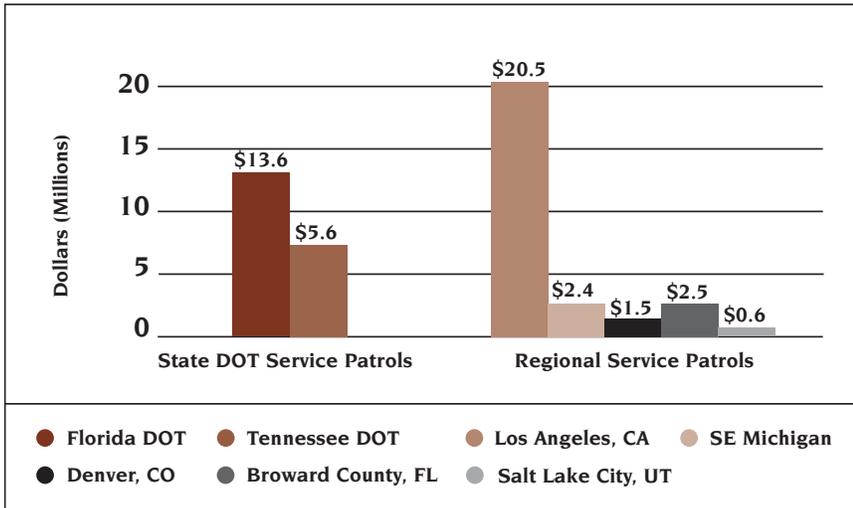


Figure 13 – Annual Cost Ranges of State DOT and Regional Service Patrols

SERVICE PATROLS POPULAR WITH TRAVELERS

Proactive incident management via service patrols represent a service heartily welcomed by travelers, as witnessed by these comments received by operating agencies:

- “This is the best service the State provides. I was back on the road within 30 minutes...He was very nice, friendly and was concerned for safety...” along I-55 in **Memphis, Tennessee**
- “The service was wonderful...great experience all around. Other States need to provide this also.” **Washington**
- “Very glad to see him. He got us off the side and in a safe location and was very reassuring. It would be excellent if every State had this service...” along I-75 in **Chattanooga, Tennessee**
- “...like a guardian angel. He replaced the tire, checked the air, and even removed a dead bird from our front grill. Within fifteen minutes of the ‘disaster’ we were on our way home” **Virginia**

Deployment

The use of ITS technologies to improve traffic incident management is common in major metropolitan areas. Figure 14 shows trends for the deployment of key traffic incident management technologies based on changes in coverage of surveillance technologies on freeways and arterial streets from 1997 to 2006. These data are from a survey of 78 major metropolitan areas conducted over this period. As figure 14 shows, surveillance of arterial streets lags behind that of freeways.

Public safety agencies are beginning to take advantage of ACN systems to detect incidents. As of 2006, public safety agencies in 11 of the country’s 108 largest metropolitan areas have access to ACN and public safety agencies in eight of these 108 metropolitan areas have access to advanced ACN that includes information on the severity of a vehicle crash. Public safety agencies in 11 of these 108 metropolitan areas have access to commercial ACN systems such as OnStar®.

Sharing data on the type, severity, and location of traffic incidents is a common practice of traffic incident management agencies. Sixty-eight (68) traffic incident management agencies in the country’s 108 largest metropolitan areas share traffic incident data with public safety agencies, which tend to reciprocate the sharing of these data. Forty (40) traffic incident management agencies in these 108 metropolitan areas share traffic incident data with arterial management agencies.

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 unless otherwise noted.

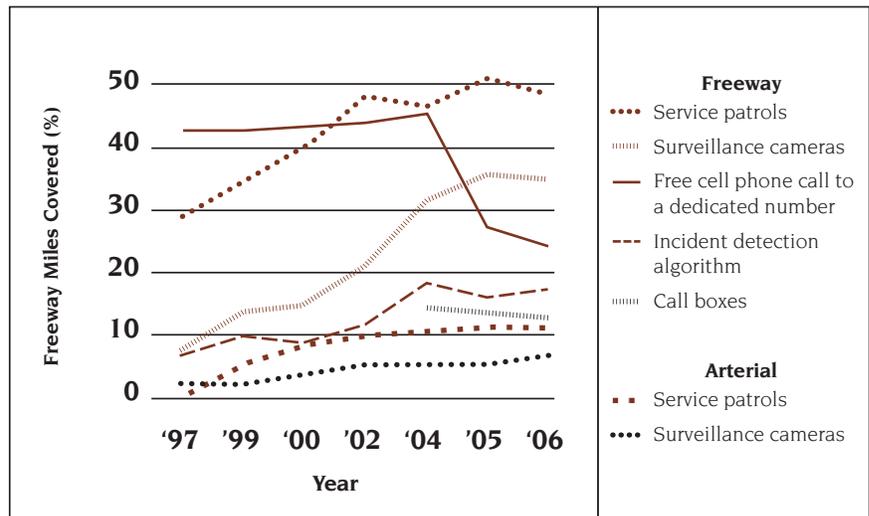


Figure 14 – Deployment Trends for ITS Technology on Freeways and Arterials Supporting Incident Management

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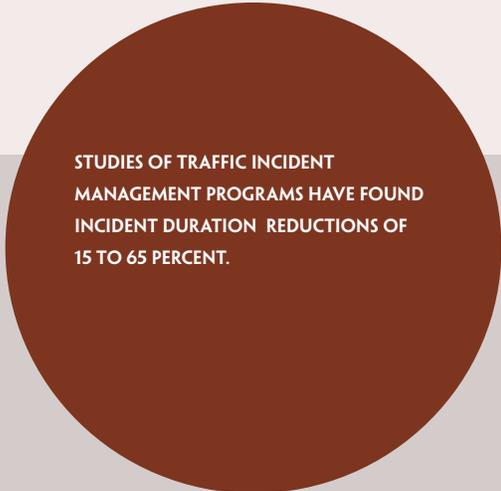
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Selected Highlights from the ITS Knowledge Resources on Traffic Incident Management

Surveillance and Detection

A variety of surveillance and detection technologies can help detect incidents quickly including inductive loop or acoustic vehicle detectors, and camera systems providing frequent still images or full-motion video. Information from wireless 9-1-1 systems, Mayday, ACN systems, and roadside call boxes help incident management system personnel identify incidents quickly.

Surveillance and Detection	
Deployment	
A variety of technologies are used to detect incidents. Traffic surveillance cameras monitor 34 percent of freeway miles in the country's 108 largest metropolitan areas. Free cellular telephone calls to a dedicated number are available for 24 percent of the freeway miles, automatic incident detection systems monitor 17 percent, and call boxes monitor 12 percent.	
Surveillance and Detection	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	Transportation management center staff in Pittsburgh indicated that a real-time traffic information system used to monitor traffic density and congestion was useful and helped improve coverage for incident management. ³⁵²
Surveillance and Detection	
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: <ul style="list-style-type: none"> • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor • Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K Transportation Management Center subsystem: <ul style="list-style-type: none"> • Software for Incident Detection: \$83K-\$101K • Labor for Incident Detection: \$751K-\$917K for multiple staff (annually) Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	





LESSONS LEARNED

Develop an incident management program strategy and plan.

Incident management yields significant benefits through reduced vehicle delays and enhanced safety to motorists through the reduction of incident frequency, and improved response and clearance times. Across the nation, many existing incident management programs have delivered significant and measurable benefits. Many communities have found that it is necessary to prepare a strategic plan to develop a strong incident management program.

- Consider the needs of the program's customers—the traveling public.

To achieve high levels of information dissemination, efforts should be coordinated with the media and employers in the area.

- Adopt a structured strategic planning process for incident management at the regional and statewide levels.

(Continued on next page.)

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Surveillance and Detection	
Costs	
Sample Costs of ITS Deployments	
<p>Utah: The Utah CommuterLink advanced transportation management system includes over 230 cameras to observe incidents and congested areas. Camera coverage is primarily on freeways and grade-separated facilities; however, there are some deployments at key intersections on surface streets. The capital cost of the cameras, \$8.4 million, includes the cameras and installation. Operational cost of the cameras is \$75,600 per year.³⁵³</p>	

Mobilization and Response

Mobilization and response may include AVL and CAD systems, as well as response routing systems, to help incident response teams arrive swiftly.

Mobilization and Response	
Deployment	
<p>Sixty-three (63) of the country's 108 largest metropolitan areas use AVL/CAD on fire, rescue and/or emergency medical services (EMS) vehicles and 95 of the country's 108 largest metropolitan areas use AVL/CAD on law enforcement vehicles, to assist in locating and assigning appropriate response to traffic incidents.</p> <p>Service patrols cover nearly half (48 percent) of freeway miles and 11 percent of arterial miles in the country's 108 largest metropolitan areas.</p>	
Benefits	
ITS Goals	Selected Findings
Safety	The Coordinated Highway Action Response Team in Maryland reduced incident duration and related secondary incidents by 29 percent in 2002, eliminating 377 crashes within its coverage area. ³⁵⁴
Mobility	Summary Finding: Traffic incident management programs have reported reductions in incident duration from 15 to 65 percent. ³⁵⁵
Productivity	Summary Finding: Delay savings identified in studies of freeway service patrols implemented in Minneapolis-St. Paul, Minnesota; Denver, Colorado; Northwest Indiana; and Oregon documented annual benefits of \$1.2 million to \$3.2 million, through reductions in incident-related congestion. ³⁵⁶
Energy and Environment	Reductions in incident-related delay also lead to fuel savings and related emissions reductions. A benefit-to-cost analysis of Florida's Road Ranger service patrol documented a savings of 1.7 million gallons of fuel across the state in 2004. ³⁵⁷

Mobilization and Response	
Benefits	
Customer Satisfaction	Summary Finding: Service patrols are well-received by the public. Operating agencies often receive thank you letters from grateful motorists assisted by service patrols. (See sidebar on page 106.) ³⁵⁸
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Transportation Management Center subsystem:	
<ul style="list-style-type: none"> Labor for Incident Response: \$107K-\$131K (annually) 	
Sample Costs of ITS Deployments	
<p>Tennessee: The Tennessee DOT HELP program began in July 1999 for the purposes of reducing traffic congestion, improving safety, and assisting motorists in distress. HELP is a component of the DOT's statewide ITS program called SmartWay. Annual operating costs include salaries, vehicle operation and maintenance, fuel, supplies, and other related operating costs. The total annual operating cost for FY 2006 was \$6.5 million. Total annual operating cost for FY 2005 was \$5.6 million.^{359, 360}</p>	
<p>Florida: Road Ranger is the name of the highway service patrol program in Broward County, Florida. The Road Ranger program includes contracted services and leased vehicles. The program utilizes 11 vehicles covering approximately 58 centerline miles on portions of I-95 and I-75, and all of I-595. Road Rangers provide 24-hour service. The 2006 annual operating cost for Florida DOT District IV Road Ranger Program was \$2.5 million.³⁶¹</p>	
<p>Florida: The Severe Incident Response Vehicle (SIRV) program provides a 24-hour incident command station and support to Florida DOT and Road Rangers during major incidents such a tractor-trailer rollovers, hazardous material incidents, and fatalities. The SIRV services are contracted out. Originally launched as a pilot program, the SIRV program was awarded in October 2006 with funding through 2012. The 2006 annual operating cost for the SIRV program was \$500,000.³⁶²</p>	
<p>Virginia: One of the findings in a 2003 Virginia DOT Concept Study was that there would be significant benefit to integrating the Virginia State Police (VSP) Division I CAD system and the Richmond Smart Traffic Center (STC). Data from the VSP CAD system would contain near real-time status of events dispatched to the police. The development of the STC integration was completed during 2003-2004; project costs were \$249,200.³⁶³</p>	

LESSONS LEARNED

(Continued from previous page.)

With a structured strategic planning process, multiple agencies can participate in the program knowing that their needs are understood by their partners. The process should include a detailed analysis of resource needs, with each partner agency's contribution to the resource pool clearly defined. The phased implementation plan should be a multi-agency effort.

- Develop a combined strategy and implementation plan for coordinated arterial signal control during incidents.

Route diversion has proven to be an effective tool, especially during major incidents. Professionals that control the arterial traffic signals and those that run the freeway management systems usually operate out of different divisions and sometimes different agencies. A combined strategy and implementation plan will bring these groups together to coordinate effective diversion routes.³⁶⁶



Mobilization and Response
Benefit-Cost Studies
<p>Georgia: The Highway Emergency Response Operators motorist assistance patrol program and NaviGator incident management activities in the Atlanta area saved more than 187 million dollars yielding a benefit-to-cost ratio over 4:1.³⁶⁴</p> <p>Indiana: The Hoosier Helper freeway service patrol program in Northwest Indiana had a projected benefit-to-cost ratio of nearly 5:1 for daytime operations, and over 13:1 for 24-hour operations.³⁶⁵</p>

Information Dissemination

Information dissemination systems help travelers navigate safely around incidents. Incident management personnel can provide incident-related information directly to travelers.

Information Dissemination
Deployment
<p>Many traffic incident management agencies use roadside systems to notify travelers of traffic incidents on both freeways and arterial streets. Seventy-nine (79) percent of traffic incident management agencies in the country's 108 largest metropolitan areas disseminate traffic incident information on freeways using DMS and 46 percent use HAR to do so. Sixteen (16) percent of traffic incident management agencies in the country's 108 largest metropolitan areas disseminate traffic incident information on arterial streets using DMS and 6 percent use HAR.</p>
Costs
<p>Unit Costs Data Examples (See Appendix A for more detail)</p> <p>Roadside Information subsystem:</p> <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Portable Dynamic Message Sign: \$18.6K-\$24K • Highway Advisory Radio: \$15K-\$35K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually) <p>Roadside Telecommunications subsystem::</p> <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)

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Information Dissemination
Costs
Sample Costs of ITS Deployments
<p>Florida: In 2006, Florida DOT District IV deployed 31 DMS. The cost of deployment was \$11 million and included the signs, associated structures, foundations, controllers, cabinets, and installation, plus approximately 37 miles of in-ground fiber optic communications. The operating cost covered electricity and was estimated at \$22,320 per year. Maintenance costs of approximately \$620,000 included spare parts, and labor for trouble-shooting problems and preventative maintenance. DMS maintenance was contracted out. Florida DOT notes that employing an ITS maintenance contractor "... helps to avoid/minimize system downtime, reduces total cost of operation, improves effectiveness, and extends the life of ITS assets." Forty-one (41) additional DMS were planned for 2007.³⁶⁷</p>

LESSONS LEARNED

Provide joint training among incident re-sponse agencies to improve response times and on-site management.

Training and knowledge of incident responders provides the necessary details to deploy the appropriate personnel and equipment. Training the responding agency personnel on a regular basis helps improve coordination, communication, and trust among agencies and other responders (e.g. safety service patrols, towing and recovery service providers, fire, rescue, and EMS). Fostering these relationships improves response times and on-site management of an incident, resulting in improved clearance times.

- As an example, at the TransGuide Center in San Antonio, regional partners participate in three variations of training activities: mock incidents, tabletop exercises, and classroom workshops. Each activity is structured in such a manner as to encourage participation by each responder.

Joint training among agencies may improve relationships and the understanding of each agency's role in the effective clearance of an incident.³⁷⁰



LESSONS LEARNED

Cultivate relationships with fire, rescue, and emergency medical service agencies when developing a coordinated multi-agency traffic incident management program.

The transportation communities' objectives of improved incident response and clearance include: safe and timely removal of all vehicles, wreckage, and debris, and restoring the roadway back to its full capacity, while maintaining the safety of the responders and motorists. Fire, rescue, and emergency medical service agencies have different priorities when responding to traffic incidents. Their first concern is the safety of the victims and motorists. Getting traffic flowing again is a secondary issue. Including fire, rescue, and EMS in the planning and development of an incident management program and maintaining consistent communication will help secure their cooperation during an incident. Traffic management agencies may even want to consider providing the fire, rescue, and EMS agencies with an enticement, such as providing a CCTV feed for video surveillance. Goodwill gestures help cultivate multi-agency ties. Effective communication through relationship building is key to a successful incident management program.³⁷¹

Clearance and Recovery

Several technologies are available to speed the investigation of incident scenes and record necessary information for later analysis. Temporary traffic control devices help ensure the safety of incident responders and provide for the safe travel of vehicles around the incident site.

Clearance and Recovery
Deployment
Fifty-four (54) percent of law enforcement agencies in the country's 108 largest metropolitan areas use automated measuring equipment to investigate major traffic incidents. More than two-thirds (69 percent) of freeway management agencies and one-third of arterial management agencies in these 108 metropolitan areas use temporary traffic control devices, such as portable DMS and lane control technologies, to help ensure the safety of traffic incident scenes.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transportation Management Center subsystem: <ul style="list-style-type: none"> Automated Incident Investigation System: \$14.1K
Sample Costs of ITS Deployments
<p>Arizona: Computer-aided incident investigation equipment was purchased as part of the Phoenix, Arizona model deployment to reduce incident clearance time and improve the quality of crash investigations. The initial cost of the project, \$147,000, included hardware, software, and training. Operating and maintenance costs were \$4,305 per year (not including labor).³⁶⁸</p> <p>Minnesota: Minnesota DOT and the Minnesota State Patrol have implemented a pilot automated field reporting system that enables law enforcement officials to use an in-vehicle computer to record and submit incident information. Costs are \$8,000 to \$10,000 per vehicle.³⁶⁹</p>

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EMERGENCY MANAGEMENT

EIGHTY (80) PERCENT OF EMERGENCY MANAGEMENT VEHICLES IN MAJOR METROPOLITAN AREAS OPERATE UNDER COMPUTER-AIDED DISPATCH.

MANAGEMENT AND OPERATIONS

In the United States, there are over 400 tropical storms, hurricanes, tornadoes, and hazardous materials (HAZMAT) incidents that require evacuation each year. In order to minimize loss of life and improve safety, prompt action is required from multiple agencies before, during, and after each event. Responders must reach the scene, victims must be evacuated, and clearance and recovery resources must arrive on time. Each day, smaller scale emergencies occur in communities and emergency responders must travel quickly and safely to fires, traffic crashes, or crime scenes. ITS applications for emergency management aim to improve public safety by giving agencies the tools and equipment they need to plan for and implement response actions quickly and efficiently.

Safe and secure transport of HAZMAT includes vehicle tracking, roadside detection, driver authentication, and route planning. Vehicle-mounted hardware provides the capability to track HAZMAT shipments and support the notification of management centers when a shipment deviates from its intended route. Roadside detectors can monitor for the presence of hazardous shipments in sensitive areas and, if electronic tag information is available on the detected vehicle, confirm that the shipment is on the expected route. Driver authentication technology can confirm that the individual operating a HAZMAT vehicle is authorized to do so and report operation by unexpected drivers to public safety entities. ITS can also provide assistance to commercial vehicle operators via electronic route planning services, ensuring compliance with HAZMAT shipment restrictions along planned travel routes.³⁷²

Advanced automated collision notification (ACN) and telemedicine address the detection of and response to incidents such as vehicle collisions or other incidents requiring emergency responders. In rural areas, response time for emergency medical services is greater than in metropolitan areas, resulting in more severe consequences for those in need of medical assistance. Advanced ACN systems can notify emergency personnel and provide them with valuable information on the crash including location, crash characteristics, and possibly relevant medical information regarding the vehicle occupants. Telemedicine systems provide a link between responding ambulances and emergency medical facilities, enabling doctors to advise emergency medical personnel regarding treatment of patients en route to the hospital. ACN systems are also discussed in the collision notification chapter of this report.

The freeway management chapter discusses how lane management techniques such as reversible flow lanes are often used for evacuation during emergencies. The collision notification chapter discusses systems that notify emergency responders when crashes occur.

A variety of sensors deployed on the transportation infrastructure can help provide an early warning system to detect large-scale emergencies including natural disasters (hurricanes, earthquakes, floods, blizzards, tsunamis, etc.) and technological and man-made disasters (hazardous materials incidents; nuclear power plant accidents; and acts of terrorism including nuclear, chemical, biological, and radiological weapons attacks). In the event of a large-scale emergency, ITS applications can assist with response management through services such as the tracking of emergency vehicle fleets using automated vehicle location (AVL) technology and two-way communications between emergency vehicles and dispatchers. When responding to emergencies of any scale, emergency vehicle signal preemption implemented through coordination with arterial management agencies, can speed the safe arrival of emergency responders on scene. Evacuation operations often require a coordinated emergency response involving multiple agencies, various emergency centers,

EMERGENCY MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Hazardous Materials Management

- Tracking
- Detection
- Driver Authentication
- Route Planning

Emergency Medical Services

- Advanced Automated Collision Notification
- Telemedicine

Response and Recovery

- Early Warning System
- Response Management
- Emergency Vehicle Signal Preemption
- Evacuation and Re-Entry Management
- Emergency Traveler Information

CONTRAFLOW FREEWAY OPERATIONS
IN SOUTH CAROLINA ENABLED
76 PERCENT INCREASE IN TRAFFIC
VOLUMES.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO EMERGENCY MANAGEMENT

Refer to other chapters in this document.

Freeway Management

- Lane Management: Emergency Evacuation

Collision Notification Systems

- Mayday/Automated Collision Notification
- Advanced Automated Collision Notification

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and numerous response plans. Integration with traffic and transit management systems enables emergency information to be shared between public and private agencies and the traveling public. This communication and cooperation also enables the use of the variety of ITS information dissemination capabilities to provide emergency traveler information.

Improvements in the command and control of emergency management can lead to increased cooperation among agencies. An interoperable communications network and the use of common terminology between agencies can lead to more reliable and effective emergency operations. Studies of ITS deployed to enhance emergency response have shown the potential of these technologies to assist organizations in improving emergency response actions.

The Emergency Transportation Operations initiative, undertaken by the U.S. DOT's ITS Joint Program Office (JPO), supports the development of new tools, techniques, technical guidance, and standards necessary for state and local agencies and their private sector partners to improve emergency management. Effective real-time management of transportation during major incidents results in more timely responses to highway and HAZMAT incidents, and shorter incident durations. This initiative aims to improve the management of all forms of transportation emergencies through the application of ITS technologies. Advances in in-vehicle communication and information systems will provide access to essential real-time data about an incident and about transportation conditions on all routes throughout the affected region.³⁷³ Additional information on this initiative is available at the ITS JPO's Web site: www.its.dot.gov/eto.

Findings

Benefits

ITS applications for emergency management can improve the efficiency of transportation capacity during emergencies, increase productivity for HAZMAT shipping operations, and improve overall traveler safety and security (see table 10). Evaluation data collected from a number of studies suggest that customer satisfaction with emergency management is largely positive. Stakeholders perceive positive impacts and indicate that these technologies are widely accepted.

The HAZMAT Safety and Security Technology Field Operational Test (FOT) tested a variety of technologies designed to improve the security of HAZMAT shipments. In this study, it was estimated that the technologies would reduce the risk and vulnerability of HAZMAT shipments and therefore reduce the potential consequences of a terrorist attack on HAZMAT shipments by 36 percent. Through improved operations for carriers, the technologies were found to have a payback period of 3 to 34 months across the range of technologies and shipment types studied.³⁷⁴

Successful operations for emergency management require agencies to communicate and coordinate effectively with little or no notice at times when resources may be limited. To help optimize the effectiveness of available resources, agencies can use ITS technologies to prioritize, allocate, track, and coordinate the deployment of personnel, supplies, and equipment.³⁷⁵ Different agencies, however, can have different core missions and are sometimes unaware of the capabilities and priorities of other agencies. Transportation agencies, for example, may focus on reducing the time to restore normal traffic conditions, while an emergency services agency may focus on improving safety for responders.³⁷⁶ Although

goals and objectives may differ significantly between agencies, most officials agree that ITS technology can be used to promote interagency coordination and improve emergency management. This coordination can beget significant improvements in evacuation and re-entry management, such as the 76 percent increase in traffic volumes accomplished with freeway contraflow operations in South Carolina as residents returned following a hurricane evacuation.³⁷⁷

TECHNOLOGIES THAT ENHANCE THE SAFETY AND SECURITY OF HAZMAT TRANSPORTATION OPERATIONS RANGE IN COST FROM \$250 TO \$3,500 PER VEHICLE.

Table 10—Emergency Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Hazardous Materials Management	●			●		
Emergency Medical Services						*
Response and Recovery			●			
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts ✚ Positive impacts * Mixed results blank Not enough data 						

Costs

The HAZMAT Transportation Safety and Security FOT was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. Part of the assessment included collecting cost data for the different technologies. The study found that the technologies that enhance the safety and security of HAZMAT transportation operations range in cost from \$250 to \$3,500 per vehicle. These estimates represent only the hardware installed on the trucks in commercial quantities. The costs provided did not reflect the price of servers and dispatch systems amortized over the number of vehicles since this can vary widely depending on customer setup. While none of the technologies tested was described as prototypes, several had limited prior field usage outside of government applications.³⁷⁸

The Federal Highway Administration initiated a study to explore the benefits and costs of fully deploying operational strategies and integrating ITS in metropolitan areas. Seattle, Cincinnati, and Tucson were selected as large, medium, and small metropolitan areas, respectively. Strategies included for Seattle and Cincinnati were identified through the next 25 years and brought forward to the current year (2003); while those for Tucson were forecasted for 2025. One of the strategies identified was emergency management systems. For each of the three metropolitan areas the amount of deployment and coverage were identified. Deployment data included the number of emergency vehicles and ambulances equipped with control service, AVL, and telemedicine. Percentages of emergency vehicles



and ambulances defined the amount of coverage. The annualized life cycle costs of emergency management systems were estimated at \$1.8 million for Seattle, \$1.8 million for Cincinnati, and \$2.1 million for Tucson.³⁷⁹ See sample costs of ITS deployments in the tables below for more specific examples of other emergency management systems.

Deployment

Figure 15 shows deployment trends for three key ITS technologies used in emergency management from 2000 to 2006, based on a multi-year survey of the country's 78 largest metropolitan areas. As of 2006, 80 percent of emergency management vehicles operate under computer-aided dispatch (CAD), an increase from 67 percent in 2000. As of 2006, 20 percent of emergency management vehicles are equipped with in-vehicle navigation, up from almost no deployment in 2000. Also as of 2006, 6 percent of emergency management vehicles were equipped with the on-board equipment needed for emergency vehicle preemption. Additionally, 21 percent of traffic signals in the country's 108 metropolitan areas were equipped with the roadside components of emergency vehicle preemption.

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.

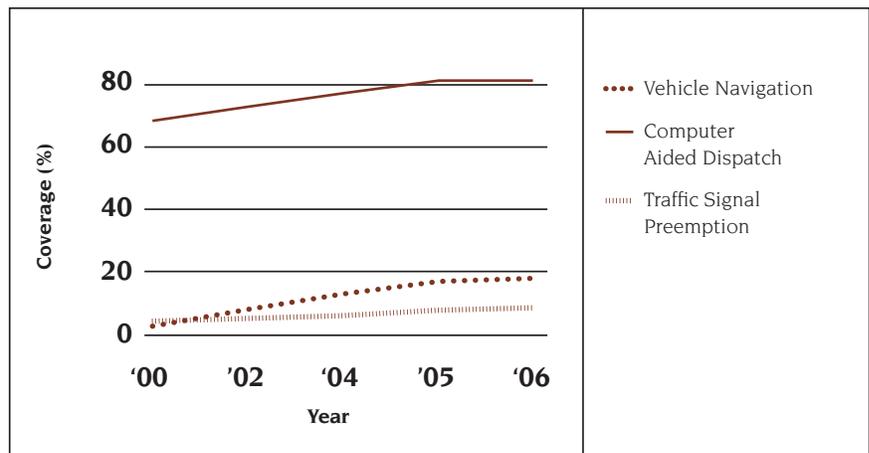


Figure 15 – Deployment Trends for Emergency Management Systems

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Selected Highlights from the ITS Knowledge Resources on Emergency Management

Hazardous Material Management

ITS applications associated with HAZMAT shipments can accomplish four major functions intended to provide safe and secure transport of hazardous materials by road:

- Vehicle-mounted hardware provides the capability to track HAZMAT shipments and support notification of management centers when a shipment deviates from its intended route.
- Roadside detectors can monitor for the presence of hazardous shipments in sensitive areas and, if electronic tag information is available on the detected vehicle, confirm that the shipment is on the expected route.
- Driver authentication technology can confirm that the individual operating a HAZMAT vehicle is authorized to do so and report operation by unexpected drivers to public safety entities.
- ITS can also provide assistance to commercial vehicle operations via electronic route planning services, ensuring compliance with HAZMAT shipment restrictions along planned travel routes.

Hazardous Material Management	
Deployment	
<p>ITS technology to assist emergency management agencies in managing hazardous materials shipments is not widely used. For example, only four of the country's 108 largest metropolitan areas use roadside detectors to monitor for the presence of hazardous shipments in sensitive areas. Only five of these 108 metropolitan areas use vehicle-mounted hardware to track HAZMAT shipments and detect when a shipment deviates from its intended route. In contrast, 24 of these 108 metropolitan areas use driver authentication technology to confirm that the individual operating a HAZMAT vehicle is authorized to do so.</p>	
Benefits	
ITS Goals	Selected Findings
Safety	<p>The HAZMAT Safety and Security Technology FOT tested a variety of technologies intended to improve the security and operational efficiency of HAZMAT shipments. A qualitative assessment found that the technologies tested, combined with best practices in motor carrier driver and safety management, and incident response, had the potential to improve the safety of HAZMAT shipments by truck.</p> <p>The study also found that combinations of the technologies tested had the ability to improve security by addressing shipment vulnerabilities. The tested technologies were estimated to reduce by 36 percent the potential costs of terrorist attacks.³⁸⁰</p>

Hazardous Material Management

Benefits

Productivity

The HAZMAT Safety and Security Technology FOT found that many of the technologies tested yielded productivity benefits to motor carriers in the form of more efficient operations, with the combined technologies of wireless communications with global positioning system (GPS) capabilities providing the greatest benefits. The time period of payback of investment costs was 3 to 34 months across the range of technologies and shipment types evaluated.³⁸¹

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Fleet Management Center subsystem:

- Software Upgrade for HAZMAT Management: \$19K-\$39K
- Hardware Upgrade for HAZMAT Management: \$3K
- Electronic Cargo Seal Reader: \$0.3K-\$1.4K

Commercial Vehicle On-Board subsystem:

- Electronic Cargo Seal—Reusable: \$0.034K-\$0.42K
- Autonomous Tracking Unit: \$0.35K-\$0.8K

Sample Costs of ITS Deployments

United States: The HAZMAT Transportation Safety and Security FOT was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. Part of the assessment included collecting cost data of the different technologies. Fleet-wide management software and licensing to support mapping and tracking of HAZMAT shipments ranges from **\$10,000 to \$33,000**. Biometric systems evaluated consisted of predominately fingerprint and, to a lesser degree, facial recognition technologies to provide secure access for authorized personnel. Most systems evaluated were compatible with smart cards and other technologies. The average cost of a complete biometrics system is **\$1,000**.³⁸²

Benefit-Cost Studies

United States: Assuming full deployment across the motor carrier industry, the combined benefit-to-cost ratios, across all load types and technology combinations in the HAZMAT Safety and Security Technology FOT, range from 1.3:1 to 96.9:1. These ratios include benefits to motor carriers as well as societal benefits, with the proportion varying with, among other things, the potential consequences of a terrorist attack involving the goods shipped. Bulk fuel carriers are expected to experience 60 to 72 percent of the benefits, less-than-truckload carriers 81 to 92 percent, bulk chemical carriers 5 to 13 percent, and carriers of truckload explosives 1 to 3 percent.³⁸³

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Emergency Medical Services

Advanced ACN and telemedicine address the detection of and response to incidents such as vehicle collisions or other incidents requiring emergency responders. In rural areas, response time for emergency medical services is greater than in metropolitan areas, resulting in more severe consequences for those in need of medical assistance.

Emergency Medical Services
Deployment
Public safety agencies in 20 of the country's 108 largest metropolitan areas have access to ACN and public safety agencies in 10 of these 108 metropolitan areas have access to advanced ACN that includes information on the severity of a vehicle crash. Public safety agencies in 17 of these 108 metropolitan areas have access to commercial ACN systems such as OnStar®. More widespread is telemedicine, i.e., providing an audio and/or video link between responding ambulances and nearby emergency medical facilities. Telemedicine is in use in 46 of the country's largest 108 metropolitan areas.

Emergency Medical Services: Advanced Automated Collision Notification

Advanced ACN systems use vehicle-mounted sensors and wireless communication to notify emergency personnel and provide them with valuable information on the crash including location, crash characteristics, and possibly relevant medical information regarding the vehicle occupants.

Emergency Medical Services—Advanced Automated Collision Notification
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Emergency Response Center subsystem: <ul style="list-style-type: none"> • Emergency Management Communications Software: \$5K-\$10K • Hardware, Software Upgrade for Enhanced 9-1-1 and Mayday: \$102K-\$175K • Emergency Response Labor: \$73K-\$240K (annually)



Emergency Medical Services—Advanced Automated Collision Notification	
Costs	
Sample Costs of ITS Deployments	
<p>New York: The National Highway Traffic Safety Administration’s Office of Vehicle Safety Research conducted an ACN FOT to demonstrate the feasibility of fielding an ACN system and to measure the benefits of an ACN system to victims of motor vehicle crashes. The ACN test area covered rural and suburban areas of Erie County, New York. The dispatch center equipment capital costs were approximately \$23,300. These costs covered personal computers, uninterruptible power supplies, fax modems, Ethernet cards, phone equipment, and the purchase of software for the dispatch equipment at both the Erie County Sheriff’s Office and the Erie County Medical Center. The costs of developing the dispatch center equipment were \$152,400. These costs included dispatch system design, design and development of dispatch communications software, design and development of dispatcher user interface, system integration efforts, and conducting dispatcher system component tests. The costs of installing the dispatch center equipment at the sheriff’s office and medical center were approximately \$5,600. These costs included expenses to install computer equipment and telephone lines. The dispatch center training costs were approximately \$5,000. These costs included expenses for initial training and continuing tests at the sheriff’s office and medical center. The repair and maintenance costs for the dispatch center equipment were approximately \$15,000. These costs included expenses for routine maintenance checks, updating software, and resolving voice quality problems. These costs do not include routine operating costs such as monthly phone costs.³⁸⁴</p>	

Emergency Medical Services: Telemedicine

Telemedicine systems provide a link between responding ambulances and nearby emergency medical facilities, enabling doctors to advise emergency medical personnel regarding treatment of patients en route to the hospital.

Emergency Medical Services—Telemedicine	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	The LifeLink project in San Antonio, Texas enabled emergency room doctors to communicate with emergency medical technicians using two-way video, audio, and data communications. Technicians and doctors had mixed opinions about the system; however, it was expected that this technology would have more positive impacts in rural areas. ³⁸⁵

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Response and Recovery

In the event of a large-scale emergency, ITS applications can assist with response management through services such as the tracking of emergency vehicle fleets using AVL technology and two-way communications between emergency vehicles and dispatchers. Evacuation operations often require a coordinated emergency response involving multiple agencies, various emergency centers, and numerous response plans. Integration with traffic and transit management systems enables emergency information to be shared between public and private agencies and the traveling public. This communication and cooperation also enables the use of the variety of ITS information dissemination capabilities to provide emergency traveler information.

Response and Recovery
Deployment
The use of ITS technologies to improve emergency response and recovery is quite common of emergency management agencies and almost universal among law enforcement agencies. Emergency management agencies in 63 of the country's 108 largest metropolitan areas and law enforcement agencies in 94 of these metropolitan areas use AVL/CAD to assist in locating and assigning appropriate responders to incidents. Many emergency management agencies use ITS to support evacuation and re-entry management. Emergency management agencies in 37 of the country's 108 largest metropolitan areas and 81 law enforcement agencies in these metropolitan areas use integrated ITS and communications technology to coordinate evacuation management with different agencies.

Response and Recovery: Early Warning System

The variety of sensors deployed on the transportation infrastructure can help provide an early warning system to detect large-scale emergencies including natural disasters (hurricanes, earthquakes, floods, blizzards, tsunamis, etc.) and technological and man-made disasters (HAZMAT incidents; nuclear power plant accidents; and acts of terrorism including nuclear, chemical, biological, and radiological weapons attacks). Early warning systems monitor alerting and advisory systems, ITS sensors and surveillance systems, field reports, and emergency call-taking systems to identify emergencies and notify all responding agencies of detected emergencies.

Response and Recovery—Early Warning System

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Detection subsystem:

- Inductive Loops on Corridor: \$3K-\$8K
- Closed Circuit Television (CCTV) Video Camera: \$9K-\$19K

Transportation Management Center subsystem:

- Hardware, Software for Traffic Surveillance: \$131K-\$160K

Emergency Response Center subsystem:

- Emergency Response Hardware: \$8K-\$10K
- Emergency Response Software: \$68K-\$146K
- Emergency Management Communications Software: \$5K-\$10K
- Emergency Response Labor: \$73K-\$240K (annually)

Roadside Telecommunications subsystem:

- Conduit Design and Installation—Corridor: \$50K-\$75K (per mile)
- Fiber Optic Cable Installation: \$20K-\$52K (per mile)

Early Warning Costs

Sample Costs of ITS Deployments

Louisiana: In order to better manage hurricane-related evacuations, the Louisiana Department of Transportation and Development worked with the United States Geological Survey (USGS) to deploy information stations. The information stations—part of the USGS Hydrowatch program for monitoring hydrological data in flood-prone states—are fitted with vehicle detectors. These information stations gather and transmit real-time data on traffic and water level conditions along evacuation routes. Data are transmitted via satellite communications. An information station costs approximately **\$26,000** and operating and maintenance costs are approximately **\$14,000 per year**.³⁸⁶

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Response and Recovery: Response Management

Response management may include the tracking of emergency vehicle fleets using AVL technology and two-way communications between emergency vehicles and dispatchers. Integration with traffic and transit management systems enables emergency information to be shared between public and private agencies and the traveling public.

Response and Recovery—Response Management	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	<p>Survey responses collected from 166 key professionals at state and local agencies in five states (Kentucky, Georgia, Tennessee, North Carolina, and South Carolina) indicated the following ITS technologies have the highest potential to benefit emergency transportation operations:³⁸⁷</p> <ul style="list-style-type: none"> • Interoperable radio communications • Dynamic message signs • GPS and geographical information systems • CCTV roadway surveillance • Enhanced 9-1-1
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
<p>Emergency Response Center subsystem:</p> <ul style="list-style-type: none"> • Emergency Response Hardware: \$8K-\$10K • Emergency Response Software: \$68K-\$146K • Emergency Management Communications Software: \$5K-\$10K • Emergency Response Labor: \$73K-\$240K (annually) <p>Emergency Vehicle On-Board subsystem:</p> <ul style="list-style-type: none"> • Communications Interface: \$0.3K-\$2K • Signal Preemption Emitter: \$0.5K-\$2.1K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> • Integration for Traffic Information Dissemination: \$83K-\$101K • Labor for Regional Control: \$214K-\$262K (annually) 	
Sample Costs of ITS Deployments	
<p>Michigan: The Flint Mass Transportation Authority developed a plan to deploy ITS technologies throughout the agency. Establishing a back-up emergency management center for coordinated emergency response between agencies was identified as one of the longer term priorities. Costs were estimated at \$500,000 for capital and \$50,000 per year for operations and maintenance.³⁸⁸</p>	



LESSONS LEARNED

Effectively communicate plans for implementing contraflow operations during hurricane evacuations.

Most state emergency management officials recognize that providing contraflow operations (i.e., opening all lanes of a roadway to travel in a single direction) is an effective way to evacuate an area before a hurricane. However, understanding how the reversed roadways should function is essential for achieving acceptable levels of performance. Sharing information and coordinating with adjacent states at the agency level is vital to the success of an evacuation using contraflow lanes, as is educating the public to understand what is expected of them.

- Coordinate plans across state lines.

Talks between Mississippi and Louisiana officials resulted in an agreement in June 2003 for contraflow operations on I-59 in Mississippi to occur if Louisiana implements a contraflow plan on I-59 in Louisiana.

- Conduct face-to-face strategy meetings.

(Continued on next page.)

Response and Recovery: Emergency Vehicle Signal Preemption

Signal preemption systems for emergency vehicles use sensors to detect an approaching emergency vehicle and provide a green signal to the vehicle.

Response and Recovery—Emergency Vehicle Signal Preemption	
Deployment	
Preemption for emergency vehicles has nearly doubled from 2000 to 2006, and is deployed at more than 20 percent of signalized intersections. Six percent of the emergency vehicle fleet is equipped to operate traffic signals supporting preemption.	
Benefits	
ITS Goals	Selected Findings
Safety	A study in Houston, Texas found signal preemption reduced average emergency vehicle response times by 16 percent in 1 fire district, and by 23 percent in another. ³⁸⁹
Mobility	A simulation study in the Virginia suburbs of Washington, D.C. found emergency vehicle preemption caused minimal increases in average travel times (2.4 percent) for all traffic. ³⁹⁰
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Control subsystem: <ul style="list-style-type: none"> • Signal Controller Upgrade for Signal Control: \$2.4K-\$6K • Roadside Signal Preemption/Priority: \$5K-\$6K Emergency Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Signal Preemption/Priority Emitter: \$0.5K-\$2.1K Roadside Telecommunications subsystem: <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile) 	
Sample Costs of ITS Deployments	
Canada: Several intersections in British Columbia were equipped for emergency vehicle preemption. The siren of an emergency vehicle is detected and initiates a green signal for the oncoming vehicle. Pedestrian crossing signals are switched to DON'T WALK. When the system has been activated, a visual verification system (set of blue-and-white lights) indicates that the intersection is controlled by an emergency vehicle preemption system. The system costs \$4,000 per intersection , but can be less if multiple intersections are equipped. ³⁹¹	

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Response and Recovery: Evacuation and Re-Entry Management

Evacuation operations often require a coordinated emergency response involving multiple agencies, various emergency centers, and numerous response plans. Various communication technologies can support the management of evacuations, which may also include a variety of traffic and transit management activities.

Response and Recovery—Evacuation and Re-Entry Management	
Benefits	
ITS Goals	Selected Findings
Efficiency	<p>In South Carolina, dynamic message signs and highway advisory radio systems made it easier for hurricane evacuees to return home during the aftermath of Hurricane Floyd (1999). Traffic volume during the evacuation, when outbound traffic used only one side of the freeway, was 44 percent less than the traffic volume during the return trip when inbound traffic used both sides of the freeway.³⁹²</p> <p>An assessment of the hurricane evacuation plan in Hampton Roads, Virginia found that lane reversal is warranted for any hurricane predicted to make landfall as a Category 4 or 5 storm, and is strongly recommended for any Category 3 storm. In addition, the study found that with lane reversal, increasing ramp metering rates reduces ramp queuing and allows more efficient use of available mainline capacity.³⁹³</p>
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
<p>Emergency Response Center subsystem:</p> <ul style="list-style-type: none"> • Emergency Response Hardware: \$8K-\$10K • Emergency Response Software: \$68K-\$146K • Emergency Management Communications Software: \$5K-\$10K • Emergency Response Labor: \$73K-\$240K (annually) <p>Emergency Vehicle On-Board subsystem:</p> <ul style="list-style-type: none"> • Communications Interface: \$0.3K-\$2K • Signal Preemption Emitter: \$0.5K-\$2.1K <p>Transportation Management Center subsystem:</p> <ul style="list-style-type: none"> • Integration for Traffic Information Dissemination: \$83K-\$101K • Labor for Regional Control: \$214K-\$262K (annually) 	

LESSONS LEARNED

(Continued from previous page.)

In 2003, Mississippi sponsored a conference on emergency management practices called the EmTech.Com Symposium, and representatives from multiple State and Federal agencies attended. The consensus among participants was that meetings helping to coordinate across state and agency boundaries were very important.

- Educate the public about contraflow operations.

The Georgia DOT expanded its traveler information and its traveler assistance programs during evacuations and implemented a public education campaign creating maps, posters, and information sheets.³⁹⁴

LESSONS LEARNED

Utilize traveler information services to alert the public of disaster events and reduce public panic.

Advanced traveler information systems (ATIS), such as 511, are essential decision support systems that enable travelers to make informed decisions to manage their trip details. ATIS and 511 enable emergency management and transportation data to be integrated, providing richer real-time content to emergency service managers. Providing traveler information services helps improve the safety and mobility of travelers.

Site-specific traveler information devices, such as dynamic message signs and highway advisory radio, are becoming more common. ATIS, 511 telephone, and the Internet offer “on demand” information critical for calming a panicked public. In addition, ATIS and 511 coupled with automated feeds to the media allow broadcasters to provide approved vital information from emergency operations center managers to the public.

- Automate information integration using intelligent systems such as ATIS and 511.

Dissemination of public information is often time-consuming and, if not planned properly, drains resources from the immediate emergency management efforts. Pre-event planning helps agencies identify how to better manage the information collection and distribution processes. ATIS and 511 strive to provide accurate, real-time information not only to residents with access to broadcast media, but also to truckers, tourists, and others in the impacted area.³⁹⁶

Response and Recovery: Emergency Traveler Information

Integration with traffic and transit management systems enables emergency information to be shared between public and private agencies and the traveling public. This communication and cooperation also enables the use of the variety of ITS information dissemination capabilities to provide emergency traveler information.

Response and Recovery—Emergency Traveler Information
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K • Dynamic Message Sign—Portable: \$18.6K-\$24K • Highway Advisory Radio: \$15K-\$35K • Highway Advisory Radio—Sign: \$5K-\$9K Emergency Response Center subsystem: <ul style="list-style-type: none"> • Emergency Response Hardware: \$8K-\$10K • Emergency Response Software: \$68K-\$146K • Emergency Management Communications Software: \$5K-\$10K • Emergency Response Labor: \$73K-\$240K (annually) Transportation Management Center subsystem: <ul style="list-style-type: none"> • Integration for Traffic Information Dissemination: \$83K-\$101K • Labor for Regional Control: \$214K-\$262K (annually)
Sample Costs of ITS Deployments
Pennsylvania: The Pennsylvania Turnpike Commission expanded its statewide advanced traveler information system to better inform motorists of traffic, weather, and emergency conditions along the turnpike. The overall project cost was \$8.2 million . ³⁹⁵

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ELECTRONIC PAYMENT AND PRICING

MANAGEMENT AND OPERATIONS

Electronic payment systems employ various communication and electronic technologies to facilitate commerce between travelers and transportation agencies.

Electronic toll collection (ETC) systems support the collection and processing of toll plaza transactions without requiring the driver to stop and pay manually, increasing operational efficiency and convenience for tollway travelers. ETC systems operate as either integrated multi-state systems such as the E-ZPass system, or single-state or single toll authority systems such as the Oklahoma Turnpike system. ETC can reduce fuel consumption and emissions at toll booths by minimizing delays, queuing, and idling time.

Transit fare payment systems can provide increased convenience to customers and generate significant cost savings to transportation agencies by increasing the efficiency of cash-handling processes and improving administrative controls. Public transportation users can select from a variety of fare products such as magnetic stripe cards (read-only or read-write), smart cards with varying levels of memory and computing power, or use credit cards to pay for transportation services.³⁹⁷ Fare transaction machines can read and write to multiple types of media and fare products, and regional processing centers can consolidate financial information and streamline fare transaction management for multiple transit agencies. Billing systems supporting transit fare payment can be used in the coordination of human service transportation, linking the reservation system to a payment system that tracks billing to different mobility programs depending on client eligibility.

Electronic parking fee payment systems can provide similar benefits to parking facility operators, simplifying payment for customers and reducing congestion at parking facilities.

Multi-use payment systems can make transit payment more convenient. Payment for bus, rail, and other public- or private-sector goods and services can be made simply by passing a smart-card-sized device over an automated transaction processor located at terminal gates, on-board bus fareboxes, or check-out counters of participating merchants. Fare transaction processors access information on smart cards and communicate account activity to a regional database. Centralized systems can track the location and activity of smart cards and limit unauthorized use of individual accounts. In addition, merchants who provide convenient access to smart card processors can be identified and receive special incentives for promoting use of transit services.

Congestion pricing, also known as road pricing or value pricing, refers to charging motorists a fee that varies with the level of congestion. Value pricing reflects the idea that road pricing directly benefits motorists through reduced congestion and improved roadways. To eliminate additional congestion, most pricing schemes are set up electronically to offer a more reliable trip time without creating additional delay. Pricing is different from tolling in that pricing strategies are used to manage congestion or demand for highway travel, while tolling is used to generate revenue to repay a bond or debt.

There are four main types of congestion pricing strategies.³⁹⁸

- Variable priced lanes including express toll lanes and high-occupancy toll (HOT) lanes.
- Variable tolls on entire roadways or roadway segments, i.e., changing flat toll rates on existing toll roads to variable rates based on congestion levels.
- Cordon charge, i.e., charging a fee to enter or drive in a congested area.
- Area-wide charge including distance-based charging or mileage fees.

The arterial management and freeway management chapters discuss pricing on these particular types of facilities, as a lane management technique.

NEARLY ALL (95 PERCENT) OF TOLL PLAZAS IN MAJOR METROPOLITAN AREAS ARE EQUIPPED WITH ELECTRONIC TOLL COLLECTION.

ELECTRONIC PAYMENT AND PRICING CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Toll Collection

Transit Fare Payment

Parking Fee Payment

Multi-use Payment

Pricing

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO ELECTRONIC PAYMENT AND PRICING

Arterial Management

Lane Management: Pricing

Freeway Management

Lane Management: Pricing

The electronic payment and pricing applications profiled in this chapter, particularly variable tolling and congestion pricing, are a key element of the U.S. DOT's Congestion Initiative, as outlined in the May 2006 document *National Strategy to Reduce Congestion on America's Transportation Network*. A major component of the Congestion Initiative is the Urban Partnership Agreement program, through which the U.S. DOT plans to partner with selected metropolitan areas to demonstrate strategies with proven effectiveness in reducing traffic congestion.³⁹⁹

Under the Urban Partnership Agreement, the U.S. DOT and its partners have agreed to demonstrate some combination of the following four strategies with a combined track record of effectiveness in reducing traffic congestion, collectively referred to as the "Four Ts:"

- Tolling—Implementing broad congestion pricing or variable tolling demonstrations.
- Transit—Creating or expanding express bus services or bus rapid transit (BRT), which will benefit from the free-flow traffic conditions generated by congestion pricing or variable tolling.
- Telecommuting—Securing agreements from major area employers to establish or expand telecommuting and flexible scheduling programs.
- Technology and operations—Utilizing cutting edge technological and operational approaches to improve system performance.

For more information, visit the Congestion Initiative Web site: www.fightgridlocknow.gov.

Findings

Benefits

ETC and variable pricing strategies help transportation agencies address traffic congestion.

ETC is one of the most successful ITS applications with numerous benefits related to delay reductions, improved throughput, and fuel economy. With advanced technologies such as open road tolling (ORT), toll transactions can be processed automatically at freeway speeds reducing the need for tollbooth barriers and improving performance. Concepts of ORT can be incorporated into new toll plaza designs or constructed at existing plazas that currently have speed-controlled, dedicated ETC lanes.

On freeways, variable pricing strategies are effective at influencing traveler behavior. In rural areas with little congestion, research shows that approximately 20 percent of motorists will modify their travel schedules to take advantage of off-peak toll discounts.⁴⁰⁰ In urban areas, however, where heavy congestion and extended peak periods are typical, demand management strategies may require large toll differentials.⁴⁰¹ Although initial public support for such tolls may be low, research indicates that road users value time savings and are willing to pay a price to avoid congestion and delay.⁴⁰² In California, for example, public support for variable tolling on State Route 91 was initially low, but after 18 months of operations, nearly 75 percent of the commuting public expressed approval of virtually all aspects of the Express Lanes program.⁴⁰³

Other pricing strategies such as cordon charging are also effective. In London, congestion charging remains politically sensitive, but evaluations have shown that the pricing program has been effective at reducing congestion and generating revenue for transit improvements.

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Table 11 illustrates that electronic payment and pricing strategies have had significant impact under many of the ITS goal areas. Electronic toll collection is a proven technology that greatly reduced toll plaza delays, with corresponding improvements in capacity, agency cost savings, and fuel consumption reductions. Transit fare payments can provide similar mobility improvements for transit travelers by simplifying the boarding experience, improving customer satisfaction, and making it easier to take advantage of transit services. Parking and multi-use payment cards have been well received by travelers in several implementations. Congestion pricing strategies, as discussed above, have shown improvements in mobility, productivity, fuel consumption, and customer satisfaction.

Table 11—Electronic Payment and Pricing Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Toll Collection	*	●	●	●	●	
Transit Fare Payment		●	●			●
Parking Fee Payment				+		●
Multi-Use Payment						●
Pricing		●		●	●	+
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + ✱ blank 						
<ul style="list-style-type: none"> Positive impacts Mixed results Not enough data 						

Costs

The Federal Highway Administration (FHWA) initiated a study to explore the benefits and costs of fully deploying operational strategies and integrating ITS in metropolitan areas. Seattle, Cincinnati, and Tucson were selected as large, medium, and small metropolitan areas, respectively. Strategies included for Seattle and Cincinnati were based on 2003 traffic conditions while those for Tucson were based on forecast traffic conditions for 2025. The analysis considered a 25 year period. The annual costs to implement, operate, and maintain each system were adjusted to 2003 dollars. One of the strategies identified was electronic transit fare payment. For each of the three metropolitan areas, deployment (the number of transit vehicles) and proportional coverage (the percentage of fixed-route transit vehicles) were identified. The annualized life cycle costs for electronic transit fare payment systems were estimated at \$5.9 million for Seattle, \$2.4 million for Cincinnati, and \$1.1 million for Tucson.⁴⁰⁴ See sample costs of ITS deployments in the tables below for more specific examples of other electronic payment and pricing systems.

A STUDY OF THE CONGESTION CHARGING SCHEME IN CENTRAL LONDON FOUND BENEFITS EXCEEDING COSTS BY A RATIO OF 1.5:1 FOR A £5 CHARGE AND 1.7:1 FOR AN £8 CHARGE.

Benefit-Cost Studies

A benefit-cost analysis of the central London congestion charging scheme suggests that the identified benefits exceeded the costs of operations by a ratio of around 1.5:1 with an £5 charge, and by a ratio of 1.7:1 with an £8 charge⁴⁰⁵.

Deployment

Figure 16 shows deployment trends for two forms of electronic payment—toll collection and transit fare payment—based on a multi-year survey of the country’s 78 largest metropolitan areas from 2000 to 2006. ETC is nearly universal, with more than 90 percent of toll plazas and more than 80 percent of toll lanes in the 78 metropolitan areas equipped with ETC. Many transit agencies as well are offering customers the option of electronic payment. Customers can pay with magnetic card readers on more than 60 percent of transit buses in these 78 metropolitan areas and pay with “smart cards” on nearly one-third of transit buses in these 78 metropolitan areas.

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.

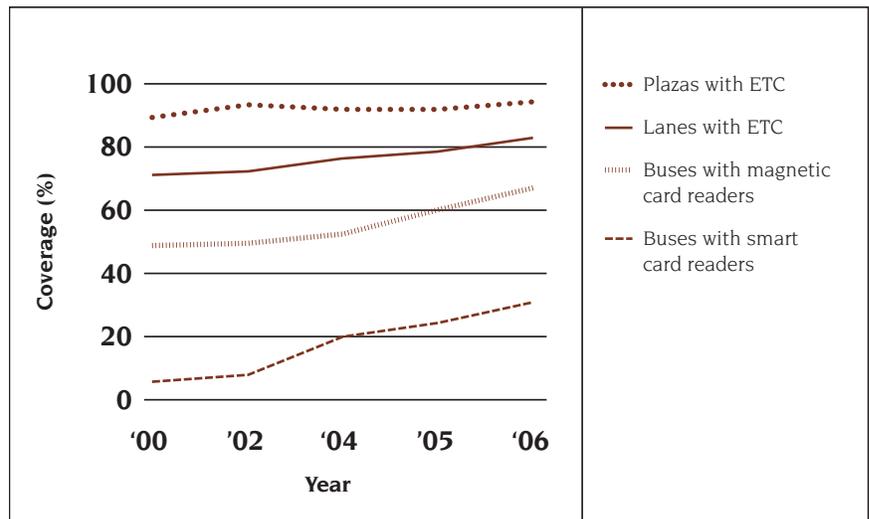


Figure 16 – Deployment Trends for Electronic Toll Collection and Fare Payment, 2000-2006

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Selected Highlights from the ITS Knowledge Resources on Electronic Payment and Pricing

Toll Collection

ETC supports the collection of payment at toll plazas using automated systems to increase the operational efficiency and convenience of toll collection. Systems typically consist of vehicle-mounted transponders identified by readers located in dedicated and/or mixed-use lanes at toll plazas.

Toll Collection	
Deployment	
ETC is nearly universal in major metropolitan areas. Ninety-five (95) percent of toll plazas in the country's 108 largest metropolitan areas are equipped with ETC.	
Benefits	
ITS Goals	Selected Findings
Safety	In Florida, the addition of ORT to an existing ETC mainline toll plaza decreased crashes by an estimated 22 to 26 percent. ⁴⁰⁶ An earlier experience in Florida found that driver uncertainty about toll plaza configuration and traffic speeds contributed to a 48 percent increase in crashes at plazas with traditional ETC lanes. ⁴⁰⁷
Mobility	In Florida, the addition of ORT to an existing ETC mainline toll plaza decreased delay by 50 percent for manual cash customers and by 55 percent for automatic coin machine customers, and increased speed by 57 percent in the express lanes. ⁴⁰⁸
Efficiency	On the Tappan Zee Bridge toll plaza in New York City, a manual toll lane can accommodate 400 to 450 vehicles per hour, while an electronic lane peaks at 1,000 vehicles per hour. ⁴⁰⁹
Productivity	On the Oklahoma Turnpike, the cost to operate an ETC lane is approximately 91 percent less than the cost to staff a traditional toll lane. ⁴¹⁰
Energy and Environment	An evaluation of ETC at three major toll plazas outside Baltimore, Maryland indicated these systems can reduce environmentally harmful emissions by 16 to 63 percent. ⁴¹¹

LESSONS LEARNED

Consider open road tolling to increase mobility at toll facilities.

Open road tolling is the collection of tolls by purely electronic means using gantry-based electronic tolling and enforcement systems. ORT provides the technological approach to enabling the use of pricing for traffic management without requiring vehicles to stop and pay a toll. In most existing charging schemes, vehicles are identified via a transponder. Vehicles without a transponder are identified by a video image of the license plate, which is then checked against a record of electronic toll collection account holders or vehicles registered by drivers who have paid a toll over the telephone or Internet. License plates that cannot be reconciled to an account and have not registered can be charged a premium fee using the auto registration to send an invoice, or are identified as violators and processed accordingly.

(Continued on next page.)

Toll Collection
Costs
<p>Unit Costs Data Examples (See Appendix A for more detail)</p> <p>Toll Plaza subsystem:</p> <ul style="list-style-type: none"> • Electronic Toll Reader: \$2K-\$5K • High-Speed Camera: \$7K-\$10K <p>Toll Administration subsystem:</p> <ul style="list-style-type: none"> • Toll Administration Hardware: \$5.9K-\$8.8K • Toll Administration Software: \$38K-\$76K <p>Roadside Telecommunication subsystem:</p> <ul style="list-style-type: none"> • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)
<p>Sample Costs of ITS Deployments</p> <p>Florida: To provide expanded mobility, the Miami-Dade Expressway Authority will convert toll operations to ORT during 2007 through 2011. The authority owns and operates a network of five expressway segments, which cover 31 centerline miles, in metropolitan Miami. The ORT program capital cost is estimated at \$56.5 million; \$20.8 million for project development, public outreach, and system-wide technology development (e.g., back office processing), and \$35.7 million for infrastructure and roadside technology along the five expressway segments. The fiber optic backbone needed to connect the roadside equipment to the host location will be provided by others; hence, the associated cost is not included in the above estimate.⁴¹²</p> <p>California: Four managed lanes are being planned along 26 miles of the I-5 North Coast in San Diego County. The project includes seven ETC sites, seven direct access ramps from local streets, and designated slip ramps providing access between the managed lanes and the general purpose lanes. The preliminary cost estimate for ETC (roadside equipment, structures, communication interface, and system tracking) on the managed lanes is \$1.7 million which includes a 30-percent contingency.⁴¹³</p>

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Transit Fare Payment

Electronic transit fare payment systems, often enabled by smart card or magnetic stripe technologies, can provide increased convenience to customers and generate significant cost savings to transportation agencies by increasing the efficiency of money handling processes and improving administrative controls.

Transit Fare Payment	
Deployment	
Nearly two-thirds (64 percent) of fixed-route transit buses in the country's 108 largest metropolitan areas are equipped with magnetic stripe readers and 31 percent of fixed-route transit buses in these 108 metropolitan areas are equipped with "smart cards."	
Benefits	
ITS Goals	Selected Findings
Mobility	Summary Finding: Proof-of-payment systems that use ticket vending/validating machines can reduce boarding times by up to 38 percent. ⁴¹⁵
Efficiency	In the Puget Sound region of Washington, a fare payment integration system that used joint passes to allow base fares to be transferred between agencies increased the percentage of riders that made transfers from 41 percent in 2001 to 60 percent in 2004. ⁴¹⁶
Customer Satisfaction	A Chicago Transit Authority survey of smart card users found that features related to convenience, rail use, and speed were most liked by program participants; 21 percent rated convenience over the magnetic stripe card as their single favorite feature of the system. The most desired features were the multi-use functions and ability to recharge the smart card via the Internet and credit card. ⁴¹⁷

LESSONS LEARNED

(Continued from previous page.)

- In Toronto on Highway 407, non-registered autos can use the electronically tolled highway, but are charged a hefty premium. Trucks, however, have to have a transponder and if not are considered violators.

ORT represents a significant technical jump compared to traditional tolling systems. From an operational point of view, the handling of violators and control of operational costs need to be carefully addressed. While using ORT can reduce costs associated with manual toll collection, the reduction in labor costs might be somewhat offset by the increase in need for image-based transactions and violation processing.⁴¹⁴

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Transit Fare Payment
Costs
Unit Costs Data Examples (See Appendix A for more detail)
<p>Transit Management subsystem:</p> <ul style="list-style-type: none"> • Upgrade for Automated Scheduling, Run Cutting, or Fare Payment: \$19K-\$38K • Integration for Automated Scheduling, Run Cutting, or Fare Payment: \$214K-\$476K • Further Software Upgrade for E-Fare Payment: \$38K-\$57 <p>Transit Vehicle On-Board subsystem:</p> <ul style="list-style-type: none"> • Electronic Farebox: \$0.6K-\$1.1K
Sample Costs of ITS Deployments
<p>Massachusetts: The Silver Line Waterfront Rapid Transit service represents a new branch of BRT to the South Boston waterfront and Logan International Airport. The Silver Line is being implemented in three phases. For Phase II, the Massachusetts Bay Transportation Authority installed two fare vending machines—one full service and one cashless—at each of the airport terminal stops. The total cost of the deployment was \$1.26 million. Full service machines cost \$35,494 each and cashless machines cost \$23,420 each. Construction and installation costs totaled \$275,000; infrastructure was an additional \$593,000.⁴¹⁸</p> <p>Washington D.C. Metropolitan Area: The Northern Virginia Transportation Commission worked closely with the Washington Metropolitan Area Transit Authority (WMATA) to develop a Regional Software Maintenance Agreement. This agreement protects and ensures the participation of smaller transit agencies in the Regional SmarTrip® Rollout. Prior to the agreement, the smaller agencies were expected to pay \$70,000 per year to maintain their fare collection systems. For many this amount was almost as much as the total farebox revenues. Under the agreement, smaller agencies will spend \$30,000 per year for the first two years, and approximately \$23,000 per year thereafter. Software support, trouble-shooting, updates, and technical support are included under the agreement.⁴¹⁹</p> <p>Worldwide: Costs data were obtained from various BRT projects, either underway or planned, and made available to transit professionals and policy makers in planning and decision making related to implementing different components of BRT systems. The data are representative of BRT development costs. On-board smart card fare collection systems typically cost approximately \$20,000 per vehicle and off-board smart card media systems cost around \$65,000 per machine.⁴²⁰</p> <p>New Mexico: Building on the success of Client Referral, Ridership, and Financial Tracking (CRRRAFT), the Alliance for Transportation Institute developed a plan and implemented smart card technology—the Intelligent, Coordinated Transit Smart Card Technology Project (ICTransit Card)—to provide cost-effective, seamless, and convenient transportation services in a rural setting. The cost of the ICTransit Card system was approximately \$635,700.⁴²¹ Operating costs for the ICTransit Card system are about \$93,000 each year with about \$40,000 shared with the annual operations for CRRRAFT.⁴²²</p>

Parking Fee Payment

Electronic parking fee payment systems can provide benefits to parking facility operators, simplify payment for customers, and reduce congestion at parking facility entrances and exits. These payment systems can be enabled by any of a variety of technologies including magnetic stripe cards, smart cards, in-vehicle transponders, or vehicle-mounted bar codes.

Parking Fee Payment	
Deployment	
Electronic payment systems at parking facilities are in use in 25 of the country's 108 largest metropolitan areas.	
Benefits	
ITS Goals	Selected Findings
Productivity	At the end of June 2004, the Washington, D.C. region Metrorail service required that contactless electronic payment cards be used to pay for parking at all Metrorail stations. In the following 2 months, purchases of the cards increased from 8,000 per month to 75,000 per month. ⁴²³
Customer Satisfaction	In the Washington, D.C. region, contactless electronic payment cards used to pay both parking fees and subway fares were considered easy to use by over 97 percent of card holders surveyed. Usefulness of the cards was rated at 4.85 on a scale of 1 (low) to 5 (high). ⁴²⁴
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Transit Management subsystem: <ul style="list-style-type: none"> • Integration for Auto. Scheduling, Run Cutting, or Fare Payment: \$219K-\$486K Parking Management subsystem: <ul style="list-style-type: none"> • Entrance/Exit Ramp Meters: \$2K-\$K4 • Tag Readers: \$2K-\$4K • Database and Software for Billing & Pricing: \$10K-\$15K • Parking Monitoring System: \$19K-\$41K 	
Sample Costs of ITS Deployments	
Washington, D.C.: WMATA expanded the capability of its SmarTrip® contactless smart card system by linking it to multiple bus and rail fare collection systems throughout the Washington, D.C. area. Since its introduction in early 1999, the SmarTrip® card has achieved significant market penetration for use in the WMATA Metrorail system and associated parking facilities. A Regional Customer Service Center performs cross-jurisdictional management, distribution, and reconciliation tasks. The cost of the center includes contracted services, a central database, a point-of-sale network and devices, and existing system software upgrades. Total capital cost: \$25.537 million (2002-2003). Operations and maintenance (O&M) cost: \$3.45 million per year (2002-2003). ⁴²⁵	



Multi-Use Payment

Multi-use payment systems can make transit payment more convenient. Payment for bus, rail, and other public- or private-sector goods and services can be made using transit fare cards at terminal gates, or at check-out counters of participating merchants located near transit stations. Multi-use systems may also incorporate the ability to pay highway tolls with the same card.

Multi-Use Payment	
Deployment	
Multi-use payment systems that can be used to pay for both transit fares and tolls are in use in 15 of the country's 108 largest metropolitan areas.	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	In Central Florida, smart cards designed to work with transit, parking, and ETC systems were evaluated during a field operational test. Focus group participants indicated that the card provided convenience and improved their transportation experience. ⁴²⁶
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Transit Management subsystem: <ul style="list-style-type: none"> • Upgrade for Automated Scheduling, Run Cutting, or Fare Payment: \$19K-\$39K • Integration for Automated Scheduling, Run Cutting, or Fare Payment: \$219K-\$486K • Further Software Upgrade for E-Fare Payment: \$39K-\$58K Transit Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Electronic Farebox: \$0.6K-\$1.2K 	

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Pricing

Congestion pricing, also known as road pricing or value pricing, employs the use of technologies to vary the cost to use a transportation facility or network based on demand or the time of day. Pricing strategies include: variable priced lanes, variable tolls on entire roadways or roadway segments, cordon charging, area-wide charging, and fast and intertwined regular lanes.

Pricing	
Deployment	
Congestion pricing remains uncommon in major metropolitan areas according to a 2006 survey. Only 3 of the country's 108 largest metropolitan areas (Chicago, Denver, and New York) employ congestion pricing on their freeways, and only 1 (Los Angeles) employs congestion pricing on arterial streets.	
Benefits	
ITS Goals	Selected Findings
Mobility	On the New Jersey Turnpike, E-ZPass participation and variable tolling were projected to decrease peak period traffic congestion at urban interchanges by 15 to 20 percent and have minimal impacts on non-turnpike diversion routes. ⁴²⁷ In London, congestion pricing (cordon charging) decreased inner city traffic congestion by about 20 percent. ⁴²⁸
Productivity	Congestion mitigating benefits of cordon charging in London enabled taxi drivers to cover more miles per hour, service more riders, and decrease operating costs per passenger-mile. ⁴²⁹
Energy and Environment	Congestion charging in London led to reductions in emissions of 8 percent in oxides of nitrogen, 7 percent in airborne particulate matter, and 16 percent in carbon dioxide when compared to data from 2002 and 2003 prior to the introduction of congestion charging. ⁴³⁰
Customer Satisfaction	In Minneapolis, Minnesota, survey data collected prior to the deployment of MnPASS Express Lanes (HOT lanes) on I-394 were examined to determine travelers' willingness-to-pay to avoid congestion. The results indicated that 59 percent of travelers would pay \$2 to save 20 minutes; 40 percent would pay \$2 to save 15 minutes; 23 percent would pay \$2 to save 10 minutes; and less than 10 percent would pay \$2 to save 5 minutes. Willingness-to-pay also decreased as toll rates increased. Virtually no one was willing to pay more than \$6 for any amount of time savings. ⁴³¹

LESSONS LEARNED

Consider various toll schemes to push traffic demand away from peak periods.

The advent of electronic toll collection has provided new tools for traffic management. Manual toll collection's inherent limitations did not provide the flexibility required to use pricing as a means to manage traffic. As a result, there are now a variety of toll schemes that may be employed to distribute traffic flow more evenly throughout the day.

- Implement time-of-day tolling as a means to push traffic demand away from peak periods.

Toll rates are fixed by time of day and day of week, usually at one-hour intervals. Peak prices on weekdays are generally highest and pricing is adjusted typically every few weeks based on hourly volumes. Setting prices based on time of day is relatively simple to implement from a technology perspective. When rate schedules are published, this approach is easy for the driving public to understand, but it does not offer the flexibility of other methods in updating the toll rates.

- Consider dynamic pricing, based on current conditions, to shift traffic demand.

Dynamic pricing adds a level of traffic management sophistication over time-of-day tolling. With dynamic pricing, tolls are based on actual traffic conditions, changing to maximize some specific objective such as speed, volume, traffic density, or travel time.⁴³⁴

Pricing

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Roadside Detection subsystem:

- Inductive Loop Surveillance on Corridor: \$3K-\$8K

Roadside Control subsystem:

- Fixed Lane Signal: \$5K-\$6K

Roadside Information subsystem:

- Dynamic Message Sign: \$48K-\$119K

Transportation Management Center subsystem:

- Hardware, Software for Traffic Surveillance: \$131K-\$160K
- Integration for Traffic Surveillance: \$219K-\$267K
- Software for Traffic Information Dissemination: \$17K-\$21K
- Integration for Traffic Information Dissemination: \$83K-\$101K

Toll Plaza subsystem:

- Electronic Toll Reader: \$2K-\$5K
- High-Speed Camera: \$7K-\$10K

Toll Administration subsystem:

- Toll Administration Hardware: \$5.4K-\$8.1K
- Toll Administration Software: \$39K-\$78K

Roadside Telecommunications subsystem:

- Conduit Design and Installation—Corridor: \$50K-\$75K (per mile)
- Fiber Optic Cable Installation: \$20K-\$52K (per mile)

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Pricing
Costs
<p>Sample Costs of ITS Deployments</p> <p>Georgia: In 2005, the Georgia State Road and Tollway Authority received a grant through the FHWA Value Pricing Pilot Program to investigate the application of value pricing to the high-occupancy vehicle (HOV)/BRT project along the I-75/I-575 corridors. The project entailed 26 miles, 9 points of access to the managed lanes, tolling equipment, and a back office system. Cost estimates of operational concepts for converting HOV lanes to managed lanes on I-75/I-575 ranged from \$20.9 million to \$23.7 million. Both plans assumed that tolls would be levied based on distance traveled. During the more congested periods higher toll rates (per mile rate) would be in effect, with lower per mile tolls in effect during lesser congested periods. The toll schedule would vary, but the pricing scheme would be fixed. HOVs were assumed to travel in the managed lanes at no charge.⁴³²</p> <p>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. O&M costs are estimated at £92 million per year.⁴³³</p>

LESSONS LEARNED

Include high-occupancy toll lanes to alleviate peak period congestion.

High-occupancy toll lane facilities charge single-occupancy vehicles (SOV) for the use of a high-occupancy vehicle lane. Access into the HOT lane remains free for transit vehicles, vanpools, and carpools. The toll charged for SOVs is dynamically adjusted to ensure traffic congestion does not exceed an established threshold for all vehicles in the HOV lanes. Toll collection is performed electronically to provide non-stop toll collection. Tolls are charged at fixed points along the facility.

As peak period congestion continues to be a problem throughout the United States, agencies are looking towards tolling technologies as a mitigation technique. Varying tolls based on the time of day and/or current traffic conditions allows agencies to shift traffic demand away from normal peak periods, resulting in a more effective traffic management process. The advent of HOT lane facilities provides the option for drivers willing to pay a premium to experience less congested travel, creating better traffic distribution across road networks.⁴³⁵

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TRAVELER INFORMATION

MANAGEMENT AND OPERATIONS

Public and private agencies that collect, process, and broadcast traveler information can help travelers make more informed decisions regarding departure times, route choice, and mode of travel. With timely traveler information, travelers can defer or delay trips, select alternate routes, or use transit services to help reduce congestion. Travelers may also decide to drive a different vehicle or use snow tires or chains based on weather-related traveler information. In recent years, traveler information seekers have come to expect reliable access to timely and detailed information about traffic conditions, weather conditions, transit schedules, work zones, and special events.

ITS applications providing traveler information can provide assistance to travelers prior to their trip or while en route. Pre-trip information includes traffic, road weather, transit, and work zone information most commonly posted on Internet Web sites, made available on 511 or other telephone systems, or broadcast on local media such as radio and TV. En route information can be made available via roadside or in-terminal message signs, or via various devices in the vehicle. These applications include technologies that collect real-time data from one or more agencies or sources, process the data into meaningful information useful to travelers, and then provide the information to travelers.

ITS can support tourism and special events by providing information to travelers in unfamiliar areas as well as travelers and patrons that need guidance during major events such as sporting events or concerts. These types of information services typically focus on traveler convenience and improving access to local businesses. Information provided can include features such as electronic yellow pages, parking availability, and options for electronic payment.

This chapter focuses on traveler information systems that typically draw information from multiple sources across a metropolitan area or region. The chapters on arterial, freeway, transit, traffic incident, and road weather management discuss experiences of agencies collecting information on the system for which they are responsible and providing it to travelers.

The traveler information ITS technologies profiled in this chapter are a key element of the U.S. DOT's Congestion Initiative, as outlined in the May 2006 document *National Strategy to Reduce Congestion on America's Transportation Network*.⁴³⁶ The Congestion Initiative highlights the need to advance low-cost operational and technological improvements to traveler information in order to reduce congestion.

In addition, the Integrated Corridor Management (ICM) initiative, a major ITS initiative being conducted by the U.S. DOT, seeks 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.⁴³⁷

Additional information on these initiatives is available at the Congestion Initiative and ITS IPO's Web sites: www.fightgridlocknow.gov and www.its.dot.gov/icms.

ALMOST ALL (93 PERCENT)
MAJOR METROPOLITAN
AREAS DISTRIBUTE TRAVELER
INFORMATION USING
INTERNET WEB SITES.

TRAVELER INFORMATION CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Pre-Trip Information

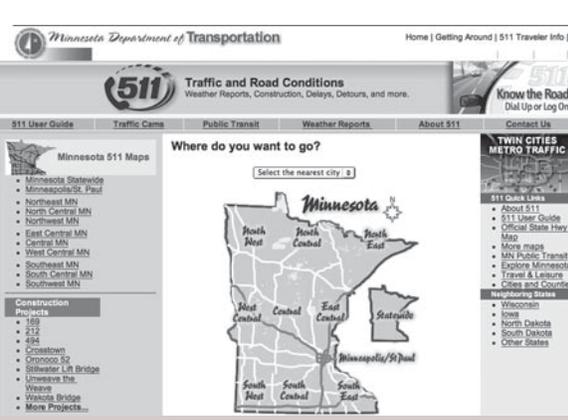
- Internet/Wireless
- 511
- Other Telephone
- TV/Radio
- Kiosks

En Route Information

- Wireless
- 511
- Other Telephone
- Radio
- In-Vehicle Systems

Tourism and Events

- Travel Services
- Advanced Parking



OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO TRAVELER INFORMATION

Refer to other chapters in this document.

Arterial Management

Information Dissemination

Freeway Management

Information Dissemination

Transit Management

Information Dissemination

Traffic Incident Management

Information Dissemination

Road Weather Management

Information Dissemination

Findings

Benefits

Evaluation of traveler information services show that these systems are well received by those that use them. Benefits are found in the form of improved on-time reliability, better trip planning, and reduced early and late arrivals. Studies show that drivers who use route-specific travel time information instead of area-wide traffic advisories can improve on-time performance by 5 to 13 percent.⁴³⁸ Although the overall number of people who use traveler information on a daily basis represents a relatively small portion of travelers in a region, demand can be extremely high during periods of severe weather, emergencies, or special events. Traveler information systems during these periods have recorded extremely high usage. Currently, the most successful traveler information systems are those that have been deployed with significant public sector support.⁴³⁹ 511 deployments, for example, have been very successful. Recent evaluation data show that customer satisfaction with regional 511 deployments range from 68 to 92 percent (figure 17)⁴⁴⁰

Table 12 summarizes the results of findings in the ITS Benefits Database, noting that traveler information systems have demonstrated the ability to improve mobility for travelers using them. The systems can also enhance network traffic distribution, modestly improving effective capacity and reducing fuel consumption and related emissions. As discussed above, several evaluations have documented positive customer satisfaction ratings for the systems.

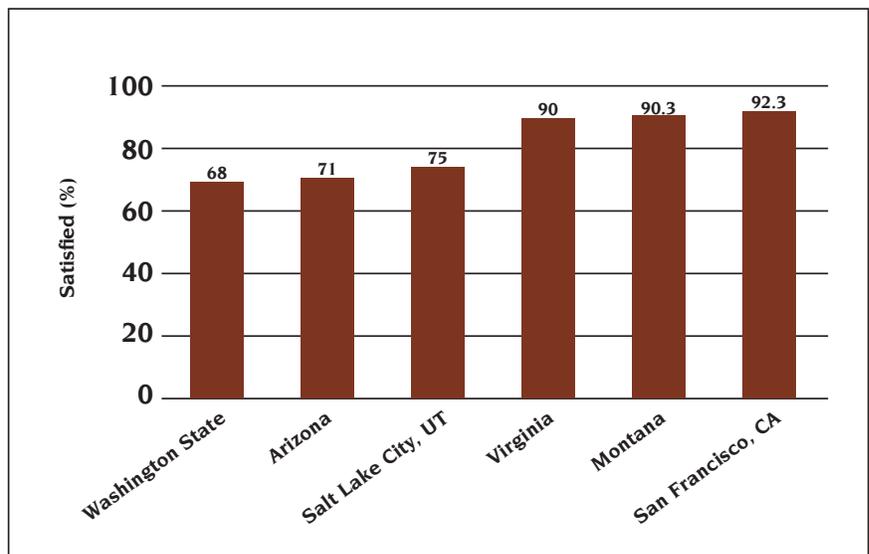


Figure 17 – Traveler Satisfaction with 511 Telephone Traveler Information Systems

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CUSTOMER SATISFACTION WITH REGIONAL 511 DEPLOYMENTS RANGES FROM 68 TO 92 PERCENT.

Table 12—Traveler Information Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Pre-Trip Information		+	+		+	●
En Route Information		+				●
Tourism and Events						●

● Substantial positive impacts + Positive impacts
 ○ Negligible impacts * Mixed results
 ✘ Negative impacts blank Not enough data

Costs

The 511 Deployment Coalition conducted an in-depth cost analysis based on the experience from nine 511 deployers. The nine 511 systems include six statewide systems—Utah, Arizona, North Carolina, Virginia, Kansas, and Washington—and three metropolitan/regional systems in Florida: Tampa, Southeast Florida, and Central Florida (see figure 18 below). On average the statewide systems cost approximately \$2.5 million to design, implement, and operate during the first year. The range is from just under \$1 million to just over \$5 million; however, most of the system costs were closer to \$1 million to \$2 million. On average the metropolitan systems cost \$1.8 million to design, implement, and operate during the first year. The range is from just over \$1.5 million to just over \$2 million.⁴⁴

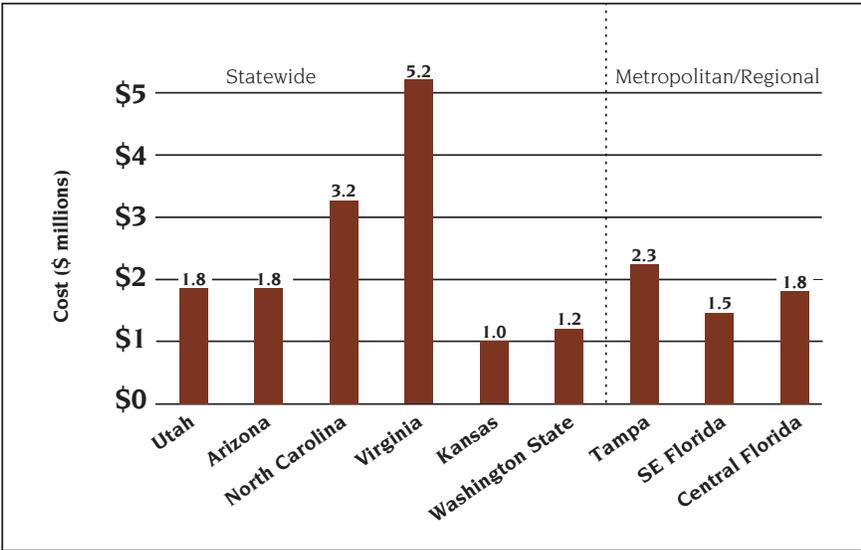


Figure 18 – Total Costs (\$ millions) of Nine 511 Deployments

Adapted from 511 Deployment Costs: A Case Study, 511 Deployment Coalition, November 2006

ON AVERAGE, STATEWIDE 511 SYSTEMS COST APPROXIMATELY \$2.5 MILLION TO DESIGN, IMPLEMENT, AND OPERATE DURING THE FIRST YEAR.

Deployment

Figure 19 shows trends for adoption of various traveler information media, based on a multi-year survey of the country's 78 largest metropolitan areas from 2000 to 2006. The two most popular media for distributing traveler information involve the Internet. Almost all of the 78 metropolitan areas use Web sites to distribute traveler information. E-mail is the next most popular medium, followed by automatic telephone and pagers. The use of these media continues to grow, whereas the use of facsimile as a traveler information distribution medium is on the decrease. Thirty (30) of the 78 metropolitan areas use dedicated TV to distribute traveler information and 18 use kiosks, a medium which has seen no growth in recent years.

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 unless otherwise stated.

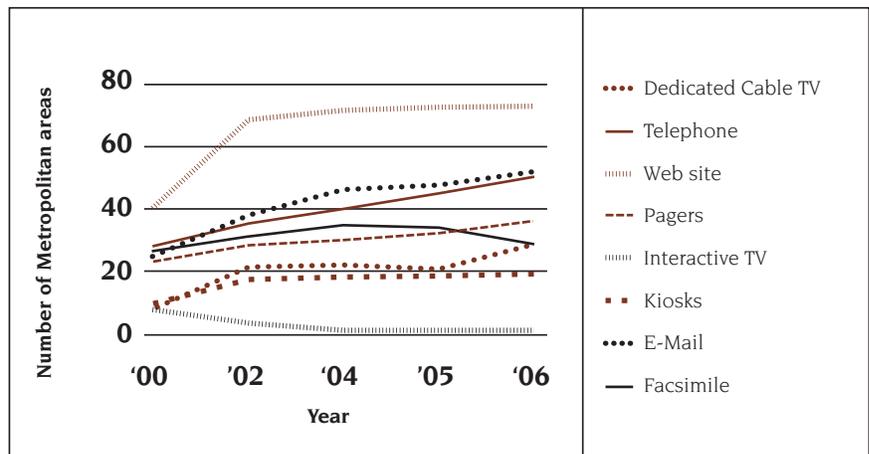


Figure 19 – Trends for Adoption of Traveler Information Media, 2000-2006

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Selected Highlights from the ITS Knowledge Resources on Traveler Information

Pre-Trip Information

Pre-trip traveler information provided via Internet Web sites, other wireless devices, 511 telephone numbers, other telephone services, television, radio, or kiosks allows users to make more informed decisions for trip departure, route choice, and mode of travel.

Pre-Trip Information	
Deployment	
<p>The most common medium for disseminating pre-trip information is the Internet, employed by freeway management agencies in 72 metropolitan areas and by arterial agencies in 52 metropolitan areas, out of a total of 108 metropolitan areas surveyed. Next in popularity was TV and radio, reported in 53 metropolitan areas for freeways and 47 for arterials. A 511 telephone information service for pre-trip information was reported in use by freeway and arterial agencies in 39 and 25 metropolitan areas, respectively. Kiosks were in use in 11 metropolitan areas.</p>	
Benefits	
ITS Goals	Selected Findings
Mobility	A simulation study in the Washington, D.C. area found that regular users of pre-trip traveler information reduced travelers' frequency of early and late arrivals by 56 and 52 percent, respectively. ⁴⁴²
Efficiency	Summary Finding: Modeling studies in Detroit, Michigan and Seattle, Washington have shown slight improvements in corridor capacity with the provision of traveler information. ⁴⁴³
Energy and Environment	In Boston, Massachusetts, a modeling study estimated that changes in travel behavior due to better traveler information would result in a 25 percent reduction in volatile organic compounds, a 1.5 percent decline in nitrogen oxides, and a 33 percent decrease in carbon monoxide. ⁴⁴⁴
Customer Satisfaction	During the 2002 Winter Olympic Games in Salt Lake City, Utah, a survey about the CommuterLink Web site showed that 41 percent of visitors and 70 percent of residents were aware of the Web site. Overall, 98 percent of visitors and 97 percent of residents who used the Web site said it worked well for them. ⁴⁴⁵



LESSONS LEARNED

Assess what users want when developing a traveler information Web site.

The number of traveler information Web sites has increased over time as has the quality of the sites and the users' expectations. The availability of additional real-time information as a result of the Federal Highway Administration Office of Operations Real-Time System Management Information Program will enable significant improvements in traveler information provision. Based on interviews with developers of top traffic and transit information Web sites, recommendations have been summarized on how developers of such Web sites should assess what their users want. The existing experience with traveler information Web sites should facilitate the dissemination of the information in an efficient and effective manner.

- Check out other existing Web sites.

TRIMARC (www.trimarc.org) provides travelers with information for the Interstate highway system within the greater Louisville/Southern Indiana urbanized area. The developers of this site accessed other traveler information sites for ideas to ensure ease of use, and consequently designed the site with the ability to click on signs or cameras to get more detailed information.

(Continued on next page.)

Pre-Trip Information
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Information Service Provider subsystem: <ul style="list-style-type: none"> • Information Service Provider Hardware: \$23K-\$34K • Information Service Provider Software: \$267K-\$535K • Information Service Provider Labor: \$254K-\$363K (annually) Remote Location subsystem: <ul style="list-style-type: none"> • Informational Kiosk: \$11K-\$24K Transportation Management subsystem: <ul style="list-style-type: none"> • Hardware for Traffic Information Dissemination: \$3K • Software for Traffic Information Dissemination: \$17K-\$21K • Integration for Traffic Information Dissemination: \$83K-\$101K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually)
Sample Costs of ITS Deployments
<p>Alaska: The Alaska 511 traveler information system under the Condition Acquisition and Reporting System (CARS)/511 pooled-fund consortium cost approximately \$1.210 million to develop and implement. The system provides near real-time transportation system information. A consultant hosts the Alaska CARS and 511 databases. The Alaska Department of Transportation and Public Facilities pays annual fees to the consultant for these services. Operations and maintenance (O&M) costs were \$136,400, \$171,500, and \$170,300 for 2004, 2005, and 2006, respectively.⁴⁴⁶</p> <p>Arizona: The Arizona 511 Model Deployment included a number of key enhancements to the previous statewide 511 system. The total capital cost of the enhanced 511 system was approximately \$1.412 million with annual operating costs for the first year at approximately \$293,000. Operating costs for future years are estimated at \$210,000 annually. Federal funding for the model deployment totaled \$1.14 million. Remaining funding came from Arizona DOT and its 511 partners.⁴⁴⁷</p>

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En Route Information

En route traveler information provided via wireless devices, 511 telephone numbers, other telephone services, radio, and in-vehicle signing allows users to make informed decisions regarding alternate routes and expected arrival times.

En Route Information	
Deployment	
<p>The most common media for disseminating en route information are dynamic message signs (DMS) and highway advisory radio (HAR). DMS are in use to disseminate en route information on freeways in 86 of 108 metropolitan areas, and on arterials in 51 metropolitan areas. HAR was reported on freeways and arterials in 51 and 42 metropolitan areas, respectively. The types of en route information disseminated varied widely. The most common types of messages reported on freeway DMS were incident information (89 metropolitan areas), maintenance and construction information (83), and amber alerts (82). Next in popularity were congestion (59 metropolitan areas), diversions (56), and weather alerts (49). Less common were travel time (27 metropolitan areas), public service announcements (28), and special events (25).</p>	
Benefits	
ITS Goals	Selected Findings
Mobility	<p>In Houston, real-time travel time information posted on DMS influenced drivers' route choice. Eighty-five (85) percent of respondents indicated that they changed their route based on the information provided. (Of these respondents, 66 percent said that they saved travel time as a result of the route change, 29 percent were not sure). Overall, drivers were primarily interested in seeing incident and travel time information.⁴⁴⁹</p>
Customer Satisfaction	<p>Summary Finding: Customer satisfaction with regional 511 deployments range from 68 to 92 percent. In 2004, 92.3 percent of users surveyed in the San Francisco Bay Area were satisfied with 511 and, in Montana, 90.3 percent were satisfied. On the I-81 corridor in Virginia, 99 percent of users surveyed said they would call again.</p> <p>In 2005, the 511 model deployment evaluation project in Arizona found that 71 percent of users were satisfied. In Washington, satisfaction levels were at 68 percent and 87 percent of the callers said they would call again.⁴⁵⁰</p>

LESSONS LEARNED

(Continued from previous page.)

- Obtain feedback from users.

Developers of successful traveler information Web sites mentioned receiving user feedback and using these comments to address technical issues or update the information provided. Houston TranStar looks for continuous improvement, reviewing the site on a monthly basis and implementing new features every two or three months. Others, such as the Denver Regional Transportation District, have developed beta-test groups of Web site users who try out new features and comment on redesigns.⁴⁴⁸



LESSONS LEARNED

Pursue a vigorous 511 marketing program, especially to promote new types of information targeted to specific user groups.

The Arizona DOT Model Deployment featured a large number of enhancements to the existing statewide Arizona 511 system. Awareness of 511 and its various features is a necessary prerequisite to system utilization and the benefits associated with its usage. Therefore, marketing is a critical activity.

- Use dynamic message signs to advertise 511 systems to reach travelers en route.

The DOT conducted an aggressive marketing campaign using the region's DMS. The message, "Road Conditions, Dial 511," was posted simultaneously on all DMS located on Interstate and state highways throughout the state, 24 hours per day for a seven-day period. During the campaign, daily call volumes increased over 30-fold. The percentage of cellular phone calls also increased dramatically during this period, suggesting that many travelers who saw the DMS message called 511 while still en route.

(Continued on next page.)

En Route Information
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: examples include <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K Information Service Provider subsystem: <ul style="list-style-type: none"> • Information Service Provider Hardware: \$23K-\$34K • Information Service Provider Software: \$267K-\$535K • Information Service Provider Labor: \$254K-\$363K (annually) Remote Location subsystem: <ul style="list-style-type: none"> • Informational Kiosk: \$11K-\$24K Transportation Management subsystem: <ul style="list-style-type: none"> • Hardware for Traffic Information Dissemination: \$3K • Software for Traffic Information Dissemination: \$17K-\$21K • Integration for Traffic Information Dissemination: \$83K-\$101K • Labor for Traffic Information Dissemination: \$107K-\$131K (annually)
Sample Costs of ITS Deployments
<p>United States: Based on an in-depth cost analysis of the experience of nine 511 deployers, the total costs (to design, implement, and operate for one year) averaged approximately \$2.5 million among six statewide systems and \$1.8 million among three metropolitan systems. The nine systems represent conditions that others are likely to experience (e.g., large-scale deployments undergoing major enhancements, a variety of traveler information service offerings, system development from scratch). The average O&M cost ranged from under \$0.50 per call to just under \$2.50 per call.⁴⁵¹</p>

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Tourism and Events

Tourism and event-related travel information systems focus on the needs of travelers in areas unfamiliar to them or when traveling to major events such as sporting events or concerts. These services address issues of mobility and traveler convenience. Information provided can include electronic yellow pages as well as transit and parking availability.

Tourism and Events	
Deployment	
<p>In a 2006 survey of state DOTs, 40 states reported having a statewide Web site supporting travel services. Among the types of roadway information provided were work zone/construction (reported by 37 states), road closures (32), incidents (27), weather information (27), road surface conditions (24), closed circuit television images (26), detours (21), congestion (18), alternate routes (16) and speeds (15). Tourism information was also provided: special events (13 states), maps (13), points of interest (8), directions (6), hotel accommodations (6), and restaurants (4). Additionally, advanced parking systems supported travel services in metropolitan areas. In a survey of 108 metropolitan areas in 2006, 15 of the 108 metropolitan areas reported dissemination of parking availability on DMS on freeways and 12 metropolitan areas reported doing so on arterial streets.</p>	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	In Kentucky, 94 percent of travelers surveyed said they were satisfied with the information provided by 511 Tourism Service operators. ⁴⁵³
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Information subsystem: <ul style="list-style-type: none"> • Dynamic Message Sign: \$48K-\$119K Information Service Provider subsystem: <ul style="list-style-type: none"> • Information Service Provider Labor: \$254K-\$363K (annually) Remote Location subsystem: <ul style="list-style-type: none"> • Informational Kiosk: \$11K-\$24K Transportation Management subsystem: <ul style="list-style-type: none"> • Software for Traffic Information Dissemination: \$17K-\$21K • Integration for Traffic Information Dissemination: \$83K-\$101K 	
Sample Costs of ITS Deployments	
<p>Kentucky: The Kentucky 511 Traffic and Travel Information System was expanded to include tourism information services in southern and eastern Kentucky through ITS Integration Program FY 2002 funds. Implementation costs for the 511 Tourism Service were \$361,760. The costs to operate and maintain the 511 tourism service for 2003 to 2006 totaled \$4,138,213.⁴⁵⁴</p>	

LESSONS LEARNED

(Continued from previous page.)

- Be sure to market new information to the types of users who would be most interested in that information.

For a traditional roadway-oriented system, the addition of multi-modal information is not enough to stimulate significant usage of that information. The Arizona DOT found that simply adding new information to target other travelers such as transit users was not necessarily sufficient to stimulate use of that information. The lack of utilization of the new information types significantly impacted the ability of the 511 deployers to achieve objectives related to stimulating consideration of transit as an alternate mode. This suggests deployers may not necessarily assume there is latent demand for new information or that interested users will become aware of it without targeted marketing.⁴⁵²

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INFORMATION MANAGEMENT

ARTERIAL MANAGEMENT AGENCIES FREQUENTLY USE ARCHIVED DATA TO SUPPORT TRAFFIC ANALYSIS AND MANAGEMENT, OPERATIONS PLANNING AND ANALYSIS, AND CAPITAL PLANNING.

MANAGEMENT AND OPERATIONS

Intelligent transportation systems collect vast amounts of data on the operational status of the transportation system. Archiving and analyzing this data can provide significant benefits to transportation agencies.

Archived data management systems (ADMS) collect data from ITS applications and assist in transportation administration, policy evaluation, safety, planning, program assessment, operations research, and other applications. Small-scale data archiving systems can support a single agency or operations center, while larger systems support multiple agencies and can act as a regional warehouse for ITS data. Transportation management centers (TMCs) provide an opportunity for centralized collection of data collected by ITS. However, TMC performance requirements are necessary during ADMS development for the successful development of such a system. Example uses of archived ITS data include the following:

- Incident management programs may review incident locations to schedule staging and patrol routes, and frequencies for service patrol vehicles.
- Historical traffic information can be used to develop predictive travel times.
- Transit agencies may review schedule performance data archived from automatic vehicle location, computer-aided dispatch systems and/or automatic passenger counting systems to design more effective schedules and route designs, or to manage operations more efficiently.

The collection and storage of data on transportation system performance often occurs at TMCs. The transportation management centers chapter discusses TMCs in detail. In addition, the transit management chapter discusses the archiving and use of transit performance data.

Findings

Benefits

Data archiving enhances ITS integration and allows for coordinated regional decision making. Traffic surveillance system data, as well as data collected from commercial vehicle operations, transit systems, electronic payment systems, and road weather information systems have been the primary sources of archived data available to researchers and planners. As more advanced data analysis techniques develop and the efficiency of data reporting systems are improved, additional examples of the effectiveness of information management systems will become available.

As shown in table 13, results of studies to date have demonstrated the cost savings that can be achieved by agencies making use of archived ITS data. A study reviewing over 60 data archiving programs documented substantial returns on the investments made in the programs. Stakeholders making use of archived data also had positive experiences to report.

INFORMATION MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Data Archiving

ADMS COSTS VARY; ESTIMATES RANGE FROM \$85,000 TO \$8 MILLION DEPENDING ON THE SIZE OF THE SYSTEM AND FEATURES PROVIDED.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO INFORMATION MANAGEMENT

Refer to other chapters in this document.

Transit Management

Fleet Management: Planning

Transportation Management Centers

Table 13—Information Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Data Archiving	●			●		+
● Substantial positive impacts	+		Positive impacts			
○ Negligible impacts	*		Mixed results			
✘ Negative impacts	blank		Not enough data			

Costs

The costs to develop ADMS vary based on the size of the system and features provided. Based on limited data available from a study of six transportation agencies that have established ADMS, costs for one system was \$85,000 and \$8 million for another. Four of the six systems were developed jointly with a university. Typically, the state DOT pays for the development with the university hosting the system. Operations and maintenance (O&M) costs were in a closer range, \$150,000 to \$350,000; these costs were usually on an annual basis.⁴⁵⁵

Deployment

Table 14 shows the percentage of arterial, freeway, and transit management agencies that reported using archived data for various functions from a survey of the country's 108 largest metropolitan areas in 2004. The survey covered 546 arterial agencies, 147 freeway agencies, and 219 transit agencies. The most common uses for archived data by arterial management agencies were traffic analysis, traffic management, operations planning and analysis, and capital planning. Most common uses for archived data reported by freeway agencies were traffic analysis, operations planning and analysis, dissemination to the public, and performance measurement. Transit agencies most frequently reported using archived data for operations planning, performance measurement, safety analysis, and dissemination to the public.

The 2004 survey of the country's 108 largest metropolitan areas is the source of deployment statistics presented later in this chapter.

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Table 14—Archived Data by Agencies in 108 Metropolitan Areas in 2004

	Arterial Management	Freeway Management	Transit Management
Capital Planning and Analysis	18%	26%	26%
Construction Impact Determination	17%	16%	6%
Crash Prediction Modeling	4%	13%	3%
Dissemination to the Public	15%	40%	21%
Incident Detection Algorithm Development	4%	22%	2%
Performance Measurement	16%	37%	35%
Operations Planning and Analysis	22%	43%	48%
Safety Analysis	17%	28%	24%
Traffic Analysis	37%	55%	N/A
Traffic Management	25%	29%	8%
Traffic Simulation Modeling	17%	26%	N/A
Travel Time Prediction	4%	15%	N/A

LESSONS LEARNED

Consider requirements definition and system design issues for archived data management systems.

ADMS offer numerous potential benefits including the ability to plan for operations, evaluate system performance, and support future investment decisions. During the planning and design of an ADMS, there are a number of issues that transportation agencies need to consider to ensure the success of their project.

- Define the audience that will be the main system users so as to understand their data and application needs.

The Minnesota transportation management center's database format is structured to facilitate query response to support a broad range of users and applications. Data formats used by the system include commercially-available relational database applications. Moreover, system developers focused on ensuring that all data were centralized and distributed via the Internet.

- Use commercially-available or open-source software over proprietary or custom-designed systems.

Sharing of software code with other public sector ADMS developers may result in development of a set of standard practices to assure that minimum quality standards are addressed. Systems that rely largely on open-source software to address data collection can collect data via the Internet, CD-ROMs, or dedicated telephone lines.⁴⁶³

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Selected Highlights from the ITS Knowledge Resources on Information Management

Data Archiving

Data archiving is the collection, storage, and distribution of ITS data for transportation planning, administration, policy, operations, safety analyses, and research. Data archiving systems make use of a variety of software, database, and electronic data storage technologies.

Data Archiving	
Deployment	
Data collection and archiving were reported by arterial management agencies in 77 metropolitan areas, by freeway management agencies in 49 metropolitan areas, and by transit agencies in 38 metropolitan areas.	
Benefits	
ITS Goals	Selected Findings
Efficiency	In Portland, Oregon, the Tri-Met transit agency used archived AVL data to construct running time distributions (by route and time period) and provide enhanced information to operators and dispatchers. Evaluation data indicated that the reduced variation in run times and improved schedule efficiency maximized the effective use of resources. ⁴⁵⁶
Productivity	In Montana, weigh-in-motion (WIM) sensors were installed directly in freeway travel lanes to continuously collect truck weight and classification data at 28 sites. The study found that if freeway pavement designs were based on fatigue calculations derived from comprehensive WIM data instead of available weigh station data, the State would save about \$4.1 million each year in construction costs. The pavement fatigue calculations based on WIM data were 11 percent lower on Interstate roadways and 26 percent lower on non-Interstate primary roadways. ⁴⁵⁷
Customer Satisfaction	In Virginia, a Web-based ADMS was deployed to provide decision makers and other transportation professionals with traffic, incident, and weather data needed for planning and traffic analysis. An assessment of Web site activity (from 2003 to 2005) indicated that 80 percent of the Web site usage was devoted to downloading data files needed to create simple maps and graphics. Overall, users were pleased with the ability to obtain a variety of data; but they wanted more data on traffic counts, turning movements, and work zones, as well as broader coverage. ⁴⁵⁸



Data Archiving	
Costs	
Sample Costs of ITS Deployments	
<p>Washington, California, and Arizona: A study was conducted of six successful ADMS and included cost data from three of the agencies. The annual software upgrades for the California DOT Freeway Performance Measuring System ranged from \$150,000 to \$250,000 per year and required approximately 1.5 full-time equivalent positions. Biannual budgets, which included software improvements, ranged from \$250,000 to \$350,000 for the Washington State Transportation Center ADMS. The annual maintenance cost for the Maricopa County Arizona Regional Archive Data Server is estimated at \$150,000, but does not include hardware or software upgrades.⁴⁵⁹</p> <p>Virginia: In 2002, the Federal Highway Administration awarded a field operational test to the Virginia DOT to use archived data to effect transportation operations and management decisions. The scope of the project was expanded to include applications for transportation planners as well as operators. Virginia DOT has set aside \$300,000 annually to maintain and upgrade ADMS Virginia; maintaining the ADMS is estimated to require 1 to 1.5 full-time equivalent positions.⁴⁶⁰</p> <p>Nevada: The total cost of the Nevada DOT Freeway and Arterial System of Transportation (FAST) central system software design and development was approximately \$4.225 million. The software provides a fully automated freeway management system, plus the capability to receive, collect, archive, summarize, and distribute data generated by FAST. Of the \$4.225 million, the cost to develop the design for the implementation of an ADMS for FAST was approximately \$225,000. This cost included needs assessment, update of functional requirements, update of the regional architecture for the Las Vegas area, and system design.⁴⁶¹</p>	
Benefit-Cost Studies	
<p>United States: One study evaluating data archiving at more than 60 organizations found that data warehousing generated an average return on investment of 401 percent over 3 years.⁴⁶²</p>	

LESSONS LEARNED

Engage in marketing, training, and outreach of archived data management systems.

Successful ADMS require marketing, training, and outreach. Transportation professionals may not be aware that operational data are being archived and may not be cognizant of the potential uses and benefits of the data. The stakeholders also may need training in order to more effectively utilize the data.

- Inform users about the quality of the data they are using.
- Agencies use different methods for data quality assurance and they need to share this information with users so that the users can make any necessary adjustments in their analyses.
- Provide training classes for system users so that they understand the data and applications they are using.
- The Washington State Transportation Center developed a formal training class for the archive and analysis software. A Web site was also created to provide training support.
- Market the potential uses of archived ITS data to the transportation community.

Members of the University of Washington staff speak at national meetings about how the data archive is used and why it is valuable.⁴⁶⁴

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COMMERCIAL VEHICLE OPERATIONS

FREIGHT

With trucks responsible for much of the overall freight movement and carrying approximately two-thirds of the value of goods in the United States, traffic conditions and operational factors that result in unreliable delivery times and missed deliveries can have major business implications. Recent reports indicate that business inventories are creeping up and reversing the trend towards leaner logistics. In 2005, increased traffic congestion, unpredictable travel times, and higher fuel expenditures contributed to a 17 percent increase in inventory-carrying costs and a \$74 billion increase in trucking costs.⁴⁶⁵

ITS applications for commercial vehicle operations (CVO) are designed to enhance communication between motor carriers and regulatory agencies, particularly during interstate freight movement. ITS can aid both carriers and agencies in reducing operating expenses through increased efficiency and assist in ensuring the safety of motor carriers operating on the Nation's roadways.

The Commercial Vehicle Information System and Networks (CVISN) program has created a nationwide framework of communication links that State agencies, motor carriers, and stakeholders can use to conduct business transactions electronically. Electronic registration and permitting at State agencies allows carriers to register online, decreasing the turn-around time associated with permit approval. In addition, safety information exchange (SIE) programs have been implemented as part of CVISN to standardize the exchange of vehicle and driver safety information between states and jurisdictions. Enforcement personnel at check stations can use national database clearinghouses to confirm carrier regulatory compliance data and crosscheck safety assurance information.

The Federal Motor Carrier Safety Administration (FMCSA) has created the CVISN program with the goal of improving the safety and efficiency of CVO. The CVISN program includes a collection of information systems and communications networks that support CVO. These systems and networks include information systems owned and operated by governments, motor carriers, and other stakeholders. Nationwide CVISN deployment will be accomplished by developing and deploying information systems that will support new capabilities in three areas: SIE, credentials administration, and electronic screening. CVISN deployment in a state is measured by the achievement of a core capability within each of the three major capability areas.⁴⁶⁶

A State achieving a core CVISN capability is required to meet the following criteria:

- An organizational framework for cooperative system development has been established among State agencies and motor carriers.
- A State CVISN System Design has been established that conforms to the CVISN Architecture and can evolve to include new technology and capabilities.
- All the elements of the three capability areas have been implemented using applicable architectural guidelines, operational concepts, and standards.

Specific requirements for each of the three major capability areas are shown in table 15.

AS OF AUGUST 2007, 18 STATES HAD COMPLETED CORE DEPLOYMENT OF CVISN AND WERE WORKING ON EXPANDING THE CORE CAPABILITY.

COMMERCIAL VEHICLE OPERATIONS CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Credentials Administration

- Electronic Funds
- Electronic Registration/Permitting

Safety Assurance

- Safety Information Exchange
- Automated Inspection

Electronic Screening

- Safety Screening
- Border Clearance
- Weight Screening
- Credential Checking

Carrier Operations and Fleet Management

- Automatic Vehicle Location/Computer-Aided Dispatch
- On-Board Monitoring
- Traveler Information

Security Operations

- Asset Tracking
- Remote Disabling Systems



OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO FREEWAY MANAGEMENT

Refer to other chapters in this document.

Intermodal Freight

- Freight Tracking
- Asset Tracking
- Freight Terminal Processes
- Drayage Operations
- Freight-Highway Connector System
- International Border Crossing Processes

Table 15—CVISN Core Capability Requirements

Capability Area	State CVISN Core Capabilities
Safety Information Exchange	<ul style="list-style-type: none"> • ASPEN (or equivalent) at all major inspection sites. • Connection to the Safety and Fitness Electronic Records (SAFER) system to provide exchange of interstate carrier and vehicle snapshots among states. • Implementation of the Commercial Vehicle Information Exchange Window (or equivalent) system for exchange of intra-state and interstate snapshots and connection to SAFER for exchange of interstate snapshots.
Credentials Administration	<ul style="list-style-type: none"> • Automated processing (i.e., carrier application, state application processing, credential issuance, and tax filing) of at least International Registration Plan (IRP) and International Fuel Tax Agreement (IFTA) credentials: ready to extend to other credentials (intrastate, titling, oversize/overweight, carrier registration, and hazardous materials (HAZMAT)). Note: processing does not necessarily include e-payment. • Connection to IRP and IFTA clearinghouses. • At least 10 percent of the transaction volume handled electronically, with the state ready to bring on more carriers as carriers sign up and ready to extend to branch offices where applicable.
Electronic Screening	<ul style="list-style-type: none"> • Implemented at a minimum of one fixed or mobile inspection site. • Ready to replicate at other sites.

Electronic screening promotes safety and efficiency for commercial vehicle operators. Trucks equipped with low-cost, in-vehicle transponders can communicate with check stations. Communication equipment at the roadside can automatically query regulatory data as trucks approach these stations and issue a red or green light on in-vehicle transponders, so drivers know whether to continue on the mainline (bypass) or report to the station for possible inspection.

In the United States, there are currently two major national electronic screening programs, the North American Pre-clearance and Safety System (NORPASS) and the PrePass™ program.⁴⁶⁷ As of March 2008, the NORPASS program was available in 11 states and Canadian provinces and had an enrollment of more than 93,000 trucks, and the PrePass™ program was available in 28 states and had an enrollment of more than 423,000 trucks.⁴⁶⁸ The Oregon Green Light program has also reported significant growth. Since the first Green Light station was opened in 1997, 21 stations have been equipped and more than 40,000 transponders have been distributed.⁴⁶⁹

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Day-to-day CVO are supported by many other ITS technologies. Automated vehicle location (AVL) and computer-aided dispatch (CAD) technologies assist with scheduling and tracking of vehicle loads. On-board monitoring of cargo alerts drivers and carriers of potentially unsafe load conditions. Real-time traffic information dissemination helps carriers choose alternate routes and departure times and avoid traffic congestion and inclement weather. Asset tracking technologies enable motor carriers to monitor the safety and security of fleet assets and cargo.

Related to CVO technologies are technologies that facilitate efficient freight transport—especially across modal connections, such as truck-air, truck-rail and rail-sea—which are technologies discussed in the intermodal freight chapter.

In addition to the ITS technologies profiled in this chapter, the Electronic Freight Management (EFM) initiative, a major ITS initiative being conducted by the U.S. DOT, has the potential to enhance CVO and freight management. Through the EFM, the U.S. DOT seeks to develop service-oriented, Web-based technologies that will improve information exchange between multiple entities (both government and commercial) and increase the efficiency of cargo transfer. The new Web-based services are intended to improve the visibility of shipments in the supply chain, reduce redundant data entry, improve diagnostic tracking, simplify interfaces with government authorities, and enhance security.⁴⁷⁰ Additional information on this initiative is available at the ITS JPO's Web site: www.its.dot.gov/efm.

Findings

Benefits

Table 16 documents experience with the ITS applications for CVO. The various strategies that have been evaluated have shown substantial improvements under the safety, mobility and productivity goal areas. Electronic credentialing reduced paperwork and saved carriers participating in the CVISN Model Deployment 60 to 75 percent on credentialing costs.⁴⁷¹ Electronic screening has been shown to moderately reduce emissions through reduced congestion at inspection stations. Drivers and operating companies are generally satisfied with the various programs, though particular applications have been troubling to truck drivers in some instances. Both motorcoach and truck drivers held favorable opinions of commercial vehicle electronic clearance, while a survey of Maryland motor carriers found that carriers with large fleets (25 or more vehicles) conducting business with State agencies value electronic data interchange and Internet technologies more than small fleets.⁴⁷²

Table 16—Commercial Vehicle Operations Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Credentials Administration				●		●
Safety Assurance	●					
Electronic Screening		●		●	+	●
Carrier Operations and Fleet Management		●		●		●
Security Operations						
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + * Mixed results blank Not enough data 						

Costs

To help States track their own progress in deploying CVISN technologies, a self-evaluation requirement was included in the partnership agreements between the U.S. DOT and individual States. This self-evaluation was tied to the U.S. DOT's support of infrastructure deployment, and research and development in cooperation with the States. Self-evaluation reports are expected to foster the widespread deployment of CVISN through the sharing of timely, accurate, usable information among States. States now in the planning, decision making, or early deployment stages can learn from the experiences of others; and States further along in the deployment process can learn new ideas that might help them improve their existing systems and networks.⁴⁷³ To this end, a process for reporting CVISN costs data was established, and the results of the costs data collection and analysis were published and the costs data imported to the ITS Costs Database. Examples of the CVISN costs data are presented in the "Selected Highlights from the ITS Knowledge Resources on Commercial Vehicle Operations" section below. The reader is encouraged to access the ITS Costs Database for complete details on CVISN unit costs.

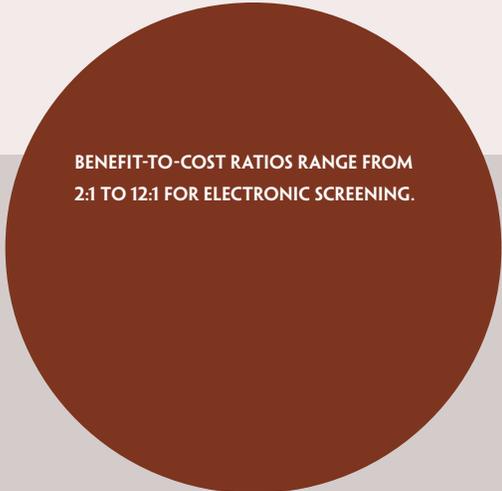
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ITS strategies were identified for “full” deployment scenarios to determine the potential benefits from a coordinated and complementary system in three metropolitan areas: Seattle, Tucson, and Cincinnati. The ITS strategies for CVO included weigh-in-motion (WIM), SIE, and a combination of screening and clearance for credentials and safety. For Seattle and Cincinnati, the average life cycle costs of the resources necessary to implement, operate, and maintain CVO estimated for 2003 conditions were \$23 million and \$23.1 million, respectively. For Tucson, the average life cycle costs of the resources necessary to implement, operate, and maintain CVO estimated for 2025 conditions was \$20.2 million. It is important to note for CVO, a portion of these costs are to the private sector for the equipment needed on commercial trucks to enable automated screening and clearance deployments at check stations. The number of trucks in the scenarios ranged from 53,000 to 60,000.⁴⁷⁴

Benefit-Cost Studies

CVISN technologies are cost-effective, increasing safety; simplifying credential checking and tax administration; and lowering the costs of freight handling, fleet management, and vehicle operations. Evaluation data have shown that costs and benefits vary depending on system configuration and cost, level of deployment, and the benefits of crash avoidance gained through increased compliance. Benefit-to-cost ratios range from 2:1 to 12:1 for electronic screening,⁴⁷⁵ 0.7:1 to 40:1 for electronic credentialing⁴⁷⁶, and 1.3:1 to 6.1:1 for roadside safety inspection systems.⁴⁷⁷



Deployment

As of August 2007, 18 states had completed core deployment of CVISN and were working on expanding the core capability. Twenty-seven (27) states and the District of Columbia are in the process of deploying the core capability. Five states are the process of planning and design of their core CVISN capability.

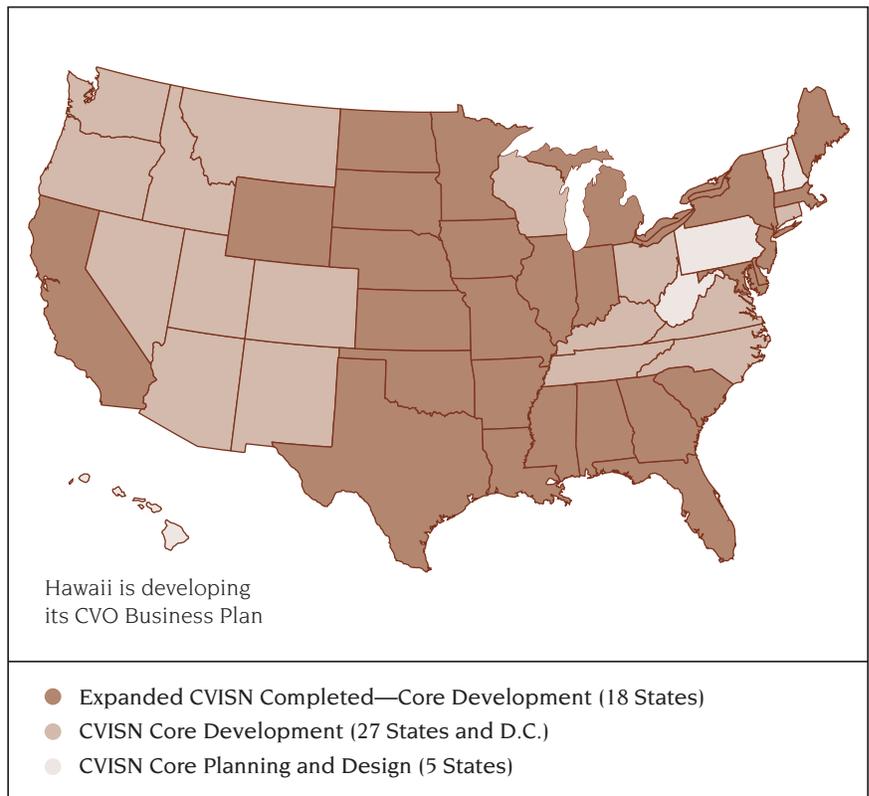


Figure 20 – Status of CVISN Deployment

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Selected Highlights from the ITS Knowledge Resources on Commercial Vehicle Operations

Credentials Administration

Electronic registration and permitting at State agencies allows carriers to register online, decreasing the turn-around time associated with permit approval.

Credentials Administration	
Benefits	
ITS Goals	Selected Findings
Productivity	Three motor carriers surveyed during the CVISN Model Deployment Initiative indicated that electronic credentialing reduced paperwork and saved them 60 to 75 percent on credentialing costs. In addition, motor carriers were able to commission new vehicles 60 percent faster by printing their own credential paperwork and not waiting for conventional mail delivery. ⁴⁷⁸
Customer Satisfaction	Approximately 50 percent of CVISN managers surveyed indicated that CVISN electronic credentialing systems can save staff time and labor, allowing additional support to be assigned to more critical agency functions. Comments from several State agencies show that CVISN electronic credentialing and safety inspection software can improve data quality, reduce clerical errors, and make it easier and less time consuming for carriers to apply for and renew credentials. ⁴⁷⁹
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Commercial Vehicle Electronic Credentialing/Administration subsystem: <ul style="list-style-type: none"> • State Employee Labor International Registration Plan (IRP) Credentialing (Legacy): \$46K-\$163K (annually) • Contractor Labor for IRP Credentialing: \$6.4K-\$17K (annually) • State Employee Labor International Fuel Tax Agreement (IFTA) Credentialing: \$13.8K-\$111.8K (annually) Vendor Labor for IFTA Credentialing: \$1K-\$19.2K (annually)	

LESSONS LEARNED

Ensure active oversight by knowledgeable government staff for complex ITS integration work.

As part of the national Commercial Vehicle Information System and Networks program, the State of Connecticut deployed a safety information exchange system. SIE is the electronic exchange of current and historical safety data and the supporting credential data regarding commercial motor carriers, vehicles, and drivers. In the CVISN deployment, Connecticut sought to establish and maintain an integrated statewide safety and credential data exchange network that links with regional and national data sources. Commercial Vehicle Information Exchange Window, a database storage and integrated software operating system, is being used by the State to access this information.

- Employ a technologically knowledgeable person to manage CVISN contractors.

(Continued on next page.)

Safety Assurance: Safety Information Exchange

Safety information exchange programs assist the safe operation of commercial vehicles, providing inspectors with electronic access to carrier and vehicle safety information from previous inspections.

Safety Assurance—Safety Information Exchange	
Benefits	
ITS Goals	Selected Findings
Safety	The results of field testing in Connecticut indicated that inspection selection systems supplemented with electronic sharing of safety inspection data increased out-of-service order rates by two percent. Modeling efforts estimated that the systems could prevent 84 commercial vehicle crashes per year nationwide. Further analysis indicated that if the system deployment was accompanied by a 10 percent increase in motor carrier safety compliance, then the number of crashes avoided would jump to 4,332 each year. ⁴⁸⁰
Customer Satisfaction	In 2000, a survey of Maryland motor carriers found that large fleets (25 or more vehicles) that conduct business with State agencies value electronic data interchange and Internet technologies more than small fleets. ⁴⁸¹
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Commercial Vehicle Safety Information Exchange (SIE) subsystem: <ul style="list-style-type: none"> • SIE Software Purchased Off the Shelf: \$6.1K-\$20.2K • State Employee Labor for New SIE Software Development: \$20K-\$121K • State Employee Labor for SIE: \$20.2K-\$67.1K (annually) • Contractor Labor for SIE: \$14.9K-\$42.6K (annually) 	

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Safety Assurance: Automated Inspection

Automated inspection equipment can be implemented to remotely test commercial trucks for faulty equipment, such as non-functioning brakes.

Safety Assurance—Automated Inspection	
Benefits	
ITS Goals	Selected Findings
Safety	Four States (Georgia, Kentucky, North Carolina, and Tennessee) participated in a year-long test to evaluate the performance of an infrared brake screening system designed to inspect commercial vehicles for brake problems as they enter weigh stations. Eighty-four (84) percent of vehicles selected for inspection had some form of brake impairment compared to 34 percent under ordinary inspection selection procedures. ⁴⁸³
Customer Satisfaction	In a survey of truck and motorcoach drivers, participants were asked about the utility of various ITS applications in commercial vehicles. Truck drivers held much less favorable opinions of automated roadside safety inspections than motorcoach drivers. ⁴⁸⁴

Electronic Screening: Safety Screening

In-vehicle transponders can communicate with inspection stations to pre-screen trucks for safety records.

Electronic Screening—Safety Screening	
Benefits	
ITS Goals	Selected Findings
Mobility	Most truck drivers and CVO inspectors surveyed during the CVISN Model Deployment Initiative felt that electronic screening saved them time. ⁴⁸⁵
Customer Satisfaction	Motor carriers surveyed during a model deployment of CVISN were concerned with the cost-effectiveness of electronic screening methods and the expansion of State regulation. However, most truck drivers felt that electronic screening saved them time. Inspectors also noted that CVISN saved time, and improved the accuracy and speed of data reporting. ⁴⁸⁶

LESSONS LEARNED

(Continued from previous page.)

Effective development and deployment of complex technologies require management of contractors by a government employee with knowledge of the technologies and good management skills. States have varying levels of in-house programming, computer hardware, and information technology capabilities. For States that plan to contract out significant portions of their CVISN software development, it is critical to have an internal staff member who can effectively represent the State's approach to administering commercial vehicle operations and enforcing regulations, so that the contractor-provided CVISN equipment and programs complement and extend the State's existing work processes.⁴⁸²

Electronic Screening—Safety Screening

Costs

Unit Costs Data Examples (See Appendix A for more detail)

Commercial Vehicle Electronic Screening (Pre-Clearance) subsystem:

- Mainline (High Speed) Weigh-in-Motion Scale: \$59.8K-\$249.2K
- Automated Vehicle Identification Equipment/System: \$50K-\$99K
- Contractor Labor for Electronic Screening Software Development: \$196.9K-\$200.1K
- Costs for Marketing, Outreach, Publicity: \$0.6K-\$5.6K (annually)

Benefit-Cost Studies

United States: Analysis of the CVISN Model Deployment Initiative considered start-up costs, operating costs, and crash avoidance from better, targeted screening over the expected lifetime of the technology. Without considering the cost-saving benefits of crash avoidance from increased motor carrier compliance, the study estimated that electronic screening would have a benefit-to-cost ratio of 2:1.⁴⁸⁷

Electronic Screening: Border Clearance

In-vehicle transponders can communicate with customs check points to pre-screen trucks for safety records, border clearance, and proper credentials.

Electronic Screening—Border Clearance

Benefits

ITS Goals

Selected Findings

Mobility

Simulation models of traffic on the U.S.-Canadian border at the Ambassador Bridge connecting Detroit, Michigan with Windsor, Ontario showed that electronic border clearance could save equipped trucks 50 percent of the delay through customs.⁴⁸⁸

Benefit-Cost Studies

United States: A study of electronic border clearance along the mid-continent transportation corridor from Minnesota to Texas technologies found that benefit-to-cost ratios for motor carriers ranged from 85:1 to 718:1.⁴⁸⁹

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Electronic Screening: Weight Screening

In-vehicle transponders can communicate with weigh stations to pre-screen trucks for compliance with weight regulations. WIM scales can be used for more efficient weight screening.

Electronic Screening—Weight Screening	
Benefits	
ITS Goals	Selected Findings
Mobility	A simulation study of an Indiana weigh station found that implementing WIM technology and equipping 40 to 50 percent of trucks with electronic screening transponders would significantly reduce queue overflows. ⁴⁹⁰

Electronic Screening: Credential Checking

In-vehicle transponders can communicate with weigh stations and customs check points to pre-screen trucks for proper credentials.

Electronic Screening—Credential Checking	
Benefits	
ITS Goals	Selected Findings
Mobility	In Colorado, an automated pre-screening system installed at three port-of-entry check stations allowed PrePass™ subscribers to bypass inspection stations if their credentials were in order. Evaluation data indicated that the automated system saved approximately 8,000 vehicle-hours of delay per month. ⁴⁹¹
Productivity	Pre-clearance systems that use interagency coordination to deploy interoperable electronic toll collection (ETC) and electronic screening systems improve the efficiency of motor carrier operations by saving them time and money. Interoperable applications incorporated into a single transponder can save carriers between \$0.63 to \$2.15 per event at weigh stations. The greater the number of interoperable applications incorporated into a single transponder, the greater the benefit. The estimated benefits realized by industry through participation in ETC and electronic screening, when combined through interoperability, double in value. ⁴⁹²
Energy and Environment	In Colorado, an automated pre-screening system installed at three port-of-entry check stations allowed PrePass™ subscribers to bypass inspection stations if their credentials were in order. Evaluation data indicated that the automated system saved 48,200 gallons of fuel per month. ⁴⁹³

LESSONS LEARNED

Be sure to identify and take into account features unique to each State when designing and deploying ITS technology projects across multiple States.

The use of the databases and human interfaces, developed as part of the field operational test projects, varied significantly among the participating States. Much of the variation had to do with the technological and institutional environment within each State.

- Be sure to account for State differences in the commercial vehicle operating environment.

Each State has a unique operating environment for commercial vehicles that will need to be considered when designing and deploying Commercial Vehicle Information System and Networks technologies intended to be integrated with out-of-state systems.

(Continued on next page.)

Electronic Screening—Credential Checking	
Customer Satisfaction	Drivers of trucks and motorcoaches were asked about the utility of various ITS applications in commercial vehicles. Both motorcoach and truck drivers held favorable opinions of commercial vehicle electronic clearance. ⁴⁹⁴

Carrier Operations and Fleet Management: Automatic Vehicle Location/Computer-Aided Dispatch

AVL and CAD can assist carriers with scheduling and tracking of vehicles and freight.

Carrier Operations and Fleet Management—AVL/CAD	
Benefits	
ITS Goals	Selected Findings
Mobility	In Europe, several projects investigated management systems designed to improve the operating efficiency of carriers. Centralized route planning systems reduced vehicle travel distances by 18 percent and decreased travel time by 14 percent. ⁴⁹⁶
Productivity	A survey conducted by the American Trucking Associations Foundation found that CAD systems increased productivity 5 to 15 percent by increasing the number of pickups and deliveries per truck per day. ⁴⁹⁷
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Commercial Vehicle subsystem: <ul style="list-style-type: none"> • Global Positioning System (GPS)/Differential GPS (DGPS): \$0.5K-\$1.8K • Cargo Monitoring Sensors and Gauges: \$0.13K-\$0.27K Fleet Management subsystem: <ul style="list-style-type: none"> • Vehicle Location Interface: \$10K-\$15K • Software for Tracking and Scheduling: \$10K-\$33K 	

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Carrier Operations and Fleet Management—AVL/CAD	
Costs	
Sample Costs of ITS Deployments	
<p>United States: The HAZMAT Transportation Safety and Security Field Operational Test (FOT) was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. Part of the assessment included collecting cost data of the different technologies. On-board monitoring technologies included software products to monitor engine diagnostics and vehicle maintenance that ranged in costs from \$10,000 to \$33,000.⁴⁹⁸</p>	

Carrier Operations and Fleet Management: Traveler Information

Targeted traveler information systems can help carriers choose alternate departure times, avoid traffic, and arrive on time.

Carrier Operations and Fleet Management—Traveler Information	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	The FleetForward operational test conducted by the American Trucking Associations Foundation provided commercial truckers with real-time traffic information to facilitate routing decisions and improve the operational efficiencies of motor carrier operations along the eastern corridor. Although operating efficiencies were not significantly impacted, 75 percent of motor carriers felt traffic information was a valuable tool for identifying congestion. ⁴⁹⁹

LESSONS LEARNED

(Continued from previous page.)

For example, during the design and deployment of the Safety and Fitness Electronic Records Data Mailbox, it became apparent that New York faced some significant challenges that other States did not encounter. New York is substantially larger and more geographically differentiated than any of the other states participating in the program, except Pennsylvania. New York has a border with Canada, so information related to Canadian provincial addresses is more important there than in other states. New York's large cities result in greater statewide complexity of routes and commercial traffic as well as a wider diversity of local and regional trucking companies. Its large geographic area also means that a large number of inspectors use the systems.⁴⁹⁵

Security Operations

ITS applications can be used to ensure the security and safety of motor carriers. Asset tracking technologies can monitor the location and condition of fleet assets (e.g., trailers, cabs, and trucks), and remote disabling systems can prevent the unauthorized use of fleet vehicles and assist in asset recovery.

Security Operations
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Commercial Vehicle subsystem: <ul style="list-style-type: none">• Driver and Vehicle Safety Sensors, Software: \$0.9K-\$1.7K• Cargo Monitoring Sensors and Gauges: \$0.13K-\$0.27K
Sample Costs of ITS Deployments
United States: The HAZMAT Transportation Safety and Security FOT was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. A digital cellular phone with pickup and delivery software with phone/on-board directions/mapping costs approximately \$250 per vehicle . This technology would also include on-site vehicle disabling with the wireless panic remote. Basic asset tracking units using satellite, terrestrial triangulation, and global positioning system-based locators cost \$139 to \$500 per unit ; mid-range units cost \$375 to \$450 per unit . ⁵⁰⁰

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INTERMODAL FREIGHT

THE HAZMAT TRANSPORTATION SAFETY AND SECURITY FIELD OPERATIONAL TEST FOUND THAT BASIC IN-VEHICLE TRACKING EQUIPMENT RANGED FROM \$429 TO \$995 PER VEHICLE.

FREIGHT

The dramatic growth in freight movement over the last several years has severely strained the transportation network. Landside access to U.S. ports, congestion on highways around major gateways, delays at border crossings, and congestion at major east-west rail interchanges have created major freight bottlenecks.

With increasing threats to productivity (i.e., shortage of drivers, high insurance rates, highway congestion, and increasing fuel and labor costs⁵⁰¹), ITS technologies that support efficient and reliable freight transportation along the supply chain and can help the freight industry benefit from just-in-time, lean-inventory business models.

Freight tracking applications can monitor, detect, and communicate freight status information to ensure containers remain sealed while en route. In addition, asset tracking technologies can monitor the location and identity of containers in real time. ITS freight terminal processes can improve operations at freight transfer stations, using information technology to expedite procedures often carried out using paper records. These technologies combined can provide an electronic freight manifest, reducing shipment processing time and increasing the productivity of freight carriers and the freight transportation system. Security can be augmented by tracking devices that confirm the location and condition of freight as it is sealed for transfer. ITS support for drayage operations can promote the efficient transfer of cargo by truck around major port facilities, using information technology to provide dispatchers and truck drivers with information on vessel traffic, container/cargo availability, on- and off-port traffic conditions, and delay times at terminal entrances. At international border crossings, automating revenue transactions and faster, more efficient confirmation of cargo manifest information can reduce delays associated with customs and tax collection processing. In addition, ITS applications that optimize traffic control and coordinate transfers near intermodal ports of entry can help reduce the strain of increased freight movement on the Nation's freight-highway connector system.

Related to intermodal freight technologies are technologies that facilitate safe and efficient motor carrier operations, which are discussed in the commercial vehicle operations chapter.

To support the U.S. DOT Congestion Initiative and reduce congestion at ports and terminals, the U.S. DOT developed the *Framework for a National Freight Policy* and implemented the Electronic Freight Management (EFM) initiative.

The EFM, a major ITS initiative being conducted by U.S. DOT, seeks to develop service-oriented Web-based technologies that have the potential to improve information exchange between multiple entities (both government and commercial) and increase the efficiency of cargo transfer.

The *Framework for a National Freight Policy* lays out a vision and objectives, then details strategies and tactics that the U.S. DOT and its partners in the public and private sectors can pursue to achieve these objectives. A draft was developed in 2006. Since that time, the U.S. DOT has been soliciting feedback on the policy, in order to building support among stakeholders.

For more information, visit the ITS JPO and *Framework for a National Freight Policy* Web sites: www.its.dot.gov and ostpxweb.dot.gov/freight_policy_framework.html.

INTERMODAL FREIGHT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Freight Tracking

Asset Tracking

Freight Terminal Processes

Drayage Operations

Freight-Highway Connector System

International Border Crossing Processes

ELECTRONIC SUPPLY CHAIN MANIFEST SYSTEMS CAN REDUCE DOCUMENT PROCESSING TIME FOR AIR CARGO SHIPMENTS BY OVER 50 PERCENT.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO INTERMODAL FREIGHT

Refer to other chapters in this document.

Commercial Vehicle Operations

- Credentials Administration
- Carrier Operations and Fleet Management
- Security Operations

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Findings

Benefits

Electronic supply chain manifest (ESCM) systems that automate the transfer of intelligent freight data between supply chain partners and government agencies have enabled freight operators to reduce administrative burdens, shorten processing times, and lower the cost of cargo movement. Initial field operational tests indicate that these automated tools, when applied to a domestic supply chain, can reduce the time it takes to accept and process cargo transfer documents by more than 50 percent.⁵⁰²

For international shipments, where multiple freight transactions and customs are required, ESCM systems can have even greater potential. An evaluation study conducted in Taiwan showed that approximately 70 percent of the paperwork required for international air cargo shipments included redundant data entry that could have been handled by automated ESCM systems.⁵⁰³

An evaluation of the potential impacts of a nationwide ESCM network estimated that there are about 0.17 billion air cargo shipments each year in the United States that could benefit from ESCM.⁵⁰⁴ With potential cost saving benefits ranging from \$11.77 to \$16.20 per air-freight shipment,⁵⁰⁵ ESCM could save the freight industry more than \$2 billion per year.⁵⁰⁶ Additional data on the cost to build a nationwide network should become available as the system develops.

Table 17 provides an overview of evaluation findings for a variety of ITS strategies for intermodal freight. Most results indicate improvements in the mobility and corresponding productivity benefits for freight transportation companies.

Table 17—Intermodal Freight Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Freight Tracking						
Asset Tracking				+		
Freight Terminal Processes		●		●	+	
Drayage Operations						
Intermodal Border Crossing Processes		●		●		
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + * blank 						
<ul style="list-style-type: none"> + * blank 						
<ul style="list-style-type: none"> + * blank 						
<ul style="list-style-type: none"> + * blank 						

Costs

The Hazardous Materials (HAZMAT) Transportation Safety and Security Field Operational Test (FOT) was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. Part of the assessment included collecting cost data for the different technologies. Of those technologies, many support efficient and reliable freight transportation. For instance, asset tracking technologies can monitor the location and identity of containers in real time. The study found that basic in-vehicle tracking equipment ranged from \$429 to \$995 per vehicle. Advanced in-vehicle tracking equipment (multiple sensors) ranged from \$1,290 to \$2,275 per vehicle. Basic costs for asset tracking—tracking of trailers whether tethered or untethered—ranged from \$139 to \$500 per unit. Mid-range costs ranged from \$375 to \$450 per unit.⁵⁰⁷

LESSONS LEARNED

Use an interoperable transponder to maximize benefits to both the private and public sector.

The Washington State-British Columbia International Trade and Mobility Corridor program deployed ITS technologies to improve border crossing operations on the U.S.-Canadian border between Washington and British Columbia.

Interoperable transponders provided a variety of benefits to both the private and public sectors, and alleviated motor carriers from having to buy multiple transponders. This benefit was especially important as transponder-based services were expanded in the corridor. Interoperability of transponders allowed participants to successfully administer the regional trucking fleets and improve truck safety by sharing credentialing information electronically.

- Encourage freight carriers to install electronic transponders that enable faster border crossing.

(Continued on next page.)

Selected Highlights from the ITS Knowledge Resources on Intermodal Freight

Freight Tracking

Freight tracking applications can monitor, detect, and communicate freight status information such as the condition and location of goods while ensuring that containerized cargo remains sealed within shipping containers while en route.

Freight Tracking	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	An air cargo security and logistics tracking system was evaluated from 2000 to 2002. The goal was to assess the potential security and efficiency benefits of a Web-based electronic manifest system compared to a traditional paper-based manifest system. Manufacturers, carriers, and airports that used the Web-based system felt it was easy to use and were very satisfied with the system's performance with respect to business functions. ⁵⁰⁸
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Commercial Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Electronic Cargo Seal Disposal: \$0.01K-\$0.024K • Electronic Cargo Seal Reusable: \$0.034K-\$0.42K Fleet Management Center subsystem: <ul style="list-style-type: none"> • Electronic Cargo Seal Reader: \$0.3K-\$1.4K 	

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Asset Tracking

Asset tracking technologies can monitor the location, identity, and status of mobile or stored freight containers, chassis, or other transportation assets in real time.

Asset Tracking
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Commercial Vehicle On-Board subsystem: <ul style="list-style-type: none"> • Autonomous Tracking Unit: \$0.34K-\$0.8K • Autonomous Tracking Unit: \$0.14K-\$0.4K (annual service charge) • Global Positioning System (GPS)/Differential GPS (DGPS): \$0.5K-\$1.8K
Sample Costs of ITS Deployments
<p>United States: The HAZMAT Transportation Safety and Security FOT was conducted to assess commercially-available, off-the-shelf technology that could be deployed in the near term to enhance the safety and security of HAZMAT transportation operations. Basic in-vehicle tracking equipment ranged from \$429 to \$995 per vehicle. Advanced in-vehicle tracking equipment (multiple sensors) ranged from \$1,290 to \$2,275 per vehicle. Basic costs for asset tracking, tracking of trailers (tethered and untethered) ranged from \$139 to \$500 per unit. Mid-range costs ranged from \$375 to \$450 per unit.⁵¹⁰</p>

LESSONS LEARNED

(Continued from previous page.)

The deployment proved that automatic vehicle identification transponders could be used to monitor the legal compliance of trucks. These transponders enabled eligible carriers to bypass weigh stations within the corridor. The cross-border bypass provided significant time savings for private motor carriers, as well as resource savings for regulatory personnel. As an added benefit, because transponder-equipped trucks bypassed border crossing queues, the border crossing times for non-transponder equipped trucks decreased.

- Be cognizant that the rate of return is dependent on the rate of participation.

Similar ITS deployments at regular roadside weigh stations may require a longer time period for payback of investment and are more sensitive to participation than border crossing deployments. Border crossing deployments could realize a return on investment the first year of deployment because of the high volume of transponder-equipped trucks.⁵⁰⁹

LESSONS LEARNED

Have a management-level champion to facilitate recruitment of participants and retain operational staff.

With the support of the Office of the Secretary of Transportation, the Federal Aviation Administration, the Federal Highway Administration Office of Freight Management and Operations, the American Trucking Associations Foundation led the formation of a public-private partnership to develop and test the electronic supply chain manifest (ESCM), the first operational electronic air cargo manifest and security system in the United States. This project demonstrated the improvements in efficiency and security of a Web-based electronic air cargo security system compared to traditional processes and paper-based manifest systems.

- Realize that lack of participation by enough supply chain partners will restrict use of an ESCM.

ESCM project participants reported that few of their transportation partners enrolled in the system. Without a larger number of participants, the benefits are difficult to quantify. Several participants stated that they did not have enough air freight shipments to adequately test the system.

The ESCM operational test successfully demonstrated the use of technology to create a secure intermodal electronic manifest system and participants reported overall satisfaction with the ESCM system. However, staff turnover and the lack of participation by supply chain partners significantly limited the usefulness.⁵¹¹

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Freight Terminal Processes

ITS freight terminal processes can improve the efficiency of freight transfers or freight storage by activating transponder tags to track cargo containers within the terminal as they are processed and sealed for transfer or storage.

Freight Terminal Processes	
Benefits	
ITS Goals	Selected Findings
Productivity	The U.S. DOT evaluated a Web-based ESCM system and compared its performance with a traditional paper-based manifest system. ESCM delivered labor cost savings and time-on-task reductions in manifest preparation, paperwork handling, communications between partners, and actual load transfer times. Manufacturers reportedly saved more than 6 minutes per shipment, trucking companies saved more than 15 minutes per shipment, and airlines saved almost 12 minutes per shipment. The cost savings to air carriers was significant, considering the relatively small size of most air freight shipments compared to truckload highway shipments. ⁵¹²



Drayage Operations

ITS for drayage operations can promote the efficient loading, unloading, sorting, and transfer of cargo by implementing automated systems and robotics to optimize limited dock and port space.

Drayage Operations	
Benefits	
ITS Goals	Selected Findings
Mobility	An analytical demand model estimated the impacts of implementing an appointment system designed to expedite cargo handling at transfer stations by pre-registering truck arrival times at terminal gates. The model indicated that if all trucks used the appointment system, total in-terminal time across all vehicles would decrease by 48 percent. ⁵¹³
Productivity	Regional intelligent freight data networks and terminal gate scheduling systems reduce non-productive waiting time, emissions, and wasted fuel during idling. Evaluation data collected from the Freight Information Real-time System for Transport project estimated that savings per drayage trip to an ocean terminal would range from \$21.36 to \$247.57. ⁵¹⁴
Energy and Environment	In Chicago, a 2004 feasibility study indicated that automated truckway technologies (automatic truck steering, speed, and platoon spacing control) would save travel time and reduce fuel consumption. ⁵¹⁵



International Border Crossing Processes

At international border crossings, automating tax revenue transactions and faster, more efficient verification of cargo manifest information can reduce delays associated with multi-agency processes.

International Border Crossing Processes	
Benefits	
ITS Goals	Selected Findings
Mobility	Simulation models of traffic at the U.S.-Canadian border on the Ambassador Bridge connecting Detroit, Michigan with Windsor, Ontario showed that electronic border clearance could save equipped trucks 50 percent of the delay through customs. ⁵¹⁶
International Border Crossing Processes	
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Commercial Vehicle Electronic Credentialing/Administration subsystem: <ul style="list-style-type: none"> • State Employee Labor International Registration Plan (IRP) Credentialing: \$46K-\$163K (annually) • Contractor Labor for IRP Credentialing: \$6.4K-\$17K (annually) • State Employee Labor International Fuel Tax Agreement (IFTA) Credentialing: \$13.8K-\$111.8K (annually) • Vendor Labor for IFTA Credentialing: \$1K-\$19.2K (annually) 	
International Border Crossing Processes	
Benefit-Cost Studies	
United States: A study of electronic border clearance technologies in the mid-continent transportation corridor from Minnesota to Texas found that benefit-to-cost ratios for motor carriers range from 85:1 to 718:1. ⁵¹⁷	

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INTELLIGENT VEHICLES

In-vehicle applications of ITS use vehicle-mounted sensors and communications devices to assist with the safe operation of vehicles, prevent crashes, and mitigate the consequences of crashes that do occur. Collision avoidance systems monitor a vehicle's surroundings and provide warnings to the driver regarding dangerous conditions that may lead to a collision. Driver assistance systems provide information and, in some cases, assume partial control of the vehicle to assist with the safe operation of the vehicle. With the aim of speeding aid to victims after a crash occurs, collision notification systems alert responders when a crash occurs, with more advanced systems providing additional information on crash characteristics that can aid medical personnel.

Vehicle infrastructure integration represents an opportunity to improve a number of the vehicle-based ITS applications described in the following chapters. Updated information provided to vehicles through in-vehicle technologies could, for example, provide warnings of cross traffic at approaching intersections or enable navigation systems to avoid congested areas based on current traffic conditions.

INTELLIGENT VEHICLES: ITS APPLICATIONS

Collision Avoidance

Driver Assistance

Collision Notification

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COLLISION AVOIDANCE

AN INTEGRATED
COUNTERMEASURE SYSTEM
COULD PREVENT OVER 48 PERCENT
OF REAR-END, RUN-OFF-ROAD,
AND LANE CHANGE CRASHES.

VEHICLES

Collision avoidance systems use sensors and telecommunication networks to communicate with other vehicles as well as with the roadway infrastructure. In-vehicle warning systems are triggered, warning drivers when their vehicles are about to collide with another vehicle or with the roadside infrastructure. To improve the ability of drivers to take countermeasures, collision avoidance systems continue to be tested and deployed.

- Intersection collision warning systems (CWS) are designed to detect and warn drivers of approaching traffic and potential right-of-way violations at intersections.
- Obstacle detection systems use vehicle-mounted sensors to detect obstructions—such as other vehicles, road debris, or animals—in a vehicle's path or projected path and alert the driver.
- Lane change warning systems have been deployed to alert bus and truck drivers of vehicles, or other obstructions, in adjacent lanes when the driver prepares to change lanes.
- Lane departure warning (LDW) systems warn drivers that their vehicle is unintentionally drifting out of the lane.
- Rollover warning systems notify drivers when they are traveling too fast for an approaching curve, given their vehicles operating characteristics.
- Road departure warning systems warn drivers that their vehicle is about to leave the roadway, whether they are approaching a curve too fast, or about to drift off the road on a straight roadway segment.
- Forward collision warning (FCW) systems, also known as rear-end collision avoidance systems, warn drivers that they are in a conflict situation with a lead vehicle. These conflicts can arise when the lead vehicle is stopped, slowing, or traveling at a constant speed.
- Rear-impact warning systems warn the lead vehicle driver that they are in conflict with a following vehicle. The warning can be presented by the lead vehicle or transmitted from the following vehicle to an in-vehicle warning system in the leading vehicle.

The Integrated Vehicle-Based Safety System initiative, a major ITS initiative being conducted by U.S. DOT, will field test several collision avoidance technologies including forward collision warning. The initiative aims to accelerate deployment of advanced driver safety systems in all new light vehicles and heavy trucks. These safety systems have the potential to help drivers avoid the most common types of fatal collisions: rear-end, lane-change, and roadway departure. The U.S. DOT is partnering to field test the next generation of safety systems in 2008. For more information, visit the ITS JPO's Web site: www.its.dot.gov/ivbss.

COLLISION AVOIDANCE CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Intersection Collision Warning

Obstacle Detection

Lane Change Assistance

Lane Departure Warning

Rollover Warning

Road Departure Warning

Forward Collision Warning

Rear Impact Warning



Findings

Benefits

Table 18 summarizes the research to date on collision avoidance systems and documents the potential safety benefits for each type of warning system evaluated. Several of the studies project positive impacts based on the prevalence of the particular crash types addressed, and the likelihood that the deployed systems could address these crashes. Others evaluated the performance of the systems in field deployments on test vehicles.

Forward collision warning systems can reduce crashes and improve safety for commercial vehicles;⁵¹⁸ however, these technologies can have high initial costs making it difficult to deploy cost-effective solutions for fleets that experience few crashes.⁵¹⁹ For passenger vehicles, CWS can have much broader impacts. Working with industry, the U.S. DOT estimates that widespread deployment of integrated countermeasure systems could prevent over 48 percent of rear-end, run-off-road, and lane change crashes.⁵²⁰ This would represent 1.8 million target crashes.

Table 18—Collision Avoidance Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Intersection Collision Warning	●					
Obstacle Detection	●					
Lane Change Assistance	●					
Lane Departure Warning	●				●	
Rollover Warning	●					
Road Departure Warning	●					
Forward Collision Warning	●					
Rear Impact Warning						
● Substantial positive impacts		+		Positive impacts		
○ Negligible impacts		*		Mixed results		
✘ Negative impacts		blank		Not enough data		

Costs

CWS are still somewhat in the experimental stage and have had only limited application to date.⁵²¹ Rollover warning or roll stability control systems have limited commercial availability. Rear-impact warning or rear-end impact prevention systems are still in the research and development phase.⁵²² Some of the collision avoidance systems are available as factory-installed options, as standard items included in the base cost of a vehicle, or as a component of an upgrade package.

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Selected Highlights from the ITS Knowledge Resources on Collision Avoidance

Lane Departure Warning

Lane departure warning systems warn drivers that their vehicle is unintentionally drifting out of the lane.

Lane Departure Warning	
Benefits	
ITS Goals	Selected Findings
Safety	In the Netherlands, a five-month field operational test (FOT) of 20 cars equipped with LDW systems found that the number of unintentional lane crossings decreased by 35 percent on secondary roads and 30 percent on highways due to the use of LDW. Drivers also kept better course to prevent warnings. ⁵²³
Energy and Environment	In-vehicle computer visioning technology designed to detect and warn truck drivers of lane departure and driver drowsiness reduced fuel consumption by 15 percent, increased safety, and provided drivers with more comfortable working conditions. ⁵²⁴
Lane Departure Warning	
Costs	
Sample Costs of ITS Deployments	
United States: LDW systems were originally developed for heavy-duty trucks and are transitioning to passenger vehicles. These systems have been available in Japanese automobiles since 2002 and entered into the U.S. market beginning with certain 2005 model vehicles. The cost of LDW systems is difficult to quantify because they are often bundled with other option packages or require the purchase of an additional technology package. ⁵²⁵	

LESSONS LEARNED

Incorporate proven technologies and false alarm reduction strategies in the design of future automotive collision avoidance systems.

A field operational test of automotive collision avoidance systems (ACAS) was successful in building a production-intent, rear-end crash avoidance system in a passenger vehicle. This system integrated state-of-the-art technologies that performed forward collision warning and adaptive cruise control functions. In addition, this program produced a small, reliable fleet of ACAS-equipped vehicles that were used by lay people in an FOT as their own personal cars to experience ACAS functions under different naturalistic driving conditions.

- Consider state-of-the-art system design issues and technologies for ACAS.

The FCW function of ACAS incorporates state-of-the-art sensor technologies for short-term deployment plans. However, improved signal processing and threat assessment algorithms would enhance FCW alert efficacy by recognizing slower lead vehicles transitioning out of the path of the host vehicle. This scenario generated numerous unnecessary crash-imminent alerts during the FOT and even forced the ACC to automatically brake in response to lead vehicles exiting the freeway.

(Continued on next page.)

Rollover Warning

Rollover warning systems notify drivers when they are traveling too fast for an approaching curve, given their vehicle's operating characteristics. This has been primarily a focus of heavy trucks.

Rollover Warning	
Benefits	
ITS Goals	Selected Findings
Safety	Based on driving data collected during an operational test of several collision warning technologies installed on Freightliner trucks, in-vehicle rollover advisory control warning messages were expected to prevent 20 percent of rollover crashes caused by excessive speed in curves. For the national fleet of approximately 110,000 tanker trucks, the warning messages have the potential to prevent 34 crashes, 21 injuries, and 2 to 3 fatalities per year. ⁵²⁶

Forward Collision Warning

In the application area of forward collision warning systems, microwave radar and machine vision technology help detect and avert vehicle collisions. These systems typically use in-vehicle displays or audible alerts to warn drivers of unsafe following distances. If a driver does not apply brakes properly in a critical situation, some systems automatically assume control and apply the brakes in an attempt to avoid a collision.

Forward Collision Warning	
Benefits	
ITS Goals	Selected Findings
Safety	Based on data collected from a FOT involving 10 vehicles and 66 drivers, an integrated system of forward collision warning and adaptive cruise control (ACC) functions was projected to prevent about 10 percent of all rear-end crashes, and 10 to 20 percent of severe near-crashes (with a minimum time-to-collision of less than 3 seconds with a peak deceleration level by the host vehicle of over 0.3g). ⁵²⁷

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Forward Collision Warning	
Costs	
Sample Costs of ITS Deployments	
<p>United States: The U.S. DOT sponsored an independent evaluation of an FOT of three advanced intelligent vehicle safety systems: CWS, ACC, and advanced braking systems. The three systems were in or nearing commercial production at the time of the FOT and were designed for use in commercial trucks. The CWS is based on forward radar sensors. If the system detects a potential crash, a warning system notifies the driver to take corrective action through in-cab visual displays and audible alarms. For the installed costs, the CWS was assumed to range from \$2,000 to \$3,000 per tractor. The costs were estimated based on consultation with manufacturers and suppliers, and engineering analysis of similar systems.⁵²⁸</p>	
Benefit-Cost Studies	
<p>United States: The cost-effectiveness of CWS was evaluated for large trucks and tractor-trailers. The results indicated that there was little or no economic justification for deploying these systems on all large trucks. With respect to tractor-trailers, however, future deployments were economically justified if relative deployment costs were lower.⁵²⁹</p>	

LESSONS LEARNED

(Continued from previous page.)

- Conduct additional research to reduce false alarm rates.

Additional research may be necessary to reduce the rates of false and nuisance alerts of FCW and to enhance the timing of crash-imminent alerts for mid-term deployment plans. Proceeding with further FCW enhancement activities may depend on successful results from short-term deployments and sufficient market penetration levels.⁵³⁰

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DRIVER ASSISTANCE

VEHICLES

Driver assistance refers to a collection of capabilities and associated technologies to help augment key driving tasks, such as navigation, speed control, and parking. These technologies continue to gain interest in the marketplace.

- In-vehicle navigation and route guidance systems with global positioning system (GPS) technology may reduce driver error, increase safety, and save time by improving driver decisions in unfamiliar areas.
- Integrated communication systems that enable drivers and dispatchers to coordinate re-routing decisions on-the-fly can also save time and money, and improve productivity.
- In-vehicle vision enhancement improves visibility for driving conditions involving reduced sight distance due to night driving, inadequate lighting, fog, drifting snow, or other inclement weather conditions.
- Object detection systems, such as parking aids for passenger vehicles, warn the driver of an object (front, side, or back) that is in the path of or adjacent to the path of the vehicle.
- Adaptive cruise control (ACC), intelligent speed control, and lane-keeping assistance assist drivers with safe vehicle operation.
- Roll stability control systems take corrective action, such as throttle control or braking, when sensors detect that a vehicle is in a potential rollover situation.
- Drowsy driver warning systems alert the driver that he or she is fatigued which may lead to lane departure or road departure.
- Precision docking systems automate precise positioning of vehicles at loading/unloading areas.
- Coupling/decoupling systems help vehicle operators link multiple vehicles, such as buses or trucks, into platoons.
- On-board monitoring systems track and report cargo condition, safety and security status, and the mechanical condition of vehicles equipped with in-vehicle diagnostics. This information can be presented to the driver immediately, transmitted off-board, or stored. In the event of a crash or near-crash, in-vehicle event data recorders can record vehicle performance data and other input from video cameras or radar sensors to improve the post-processing of crash data.

Many of these driver assistance systems have begun to emerge in production automobiles.

Several other chapters in this report discuss ITS applications related to driver assistance technologies. Many of the technologies that enable the warning systems discussed in the Collision Avoidance chapter also support the driver assistance capabilities discussed in this chapter. Traveler information programs can provide important data to in-vehicle navigation systems, improving the performance of these devices. Data recorded by in-vehicle devices can be archived and monitored over time to improve vehicle performance and facilitate vehicle safety studies for future enhancements to vehicle technology.

The Vehicle Infrastructure Integration (VII) initiative, which seeks to enhance communication between vehicles and the roadside infrastructure, will have an impact on the deployment of ITS applications for driver assistance in the coming years. The availability of enhanced information on traffic conditions has the potential to improve the performance of in-vehicle navigation systems. For example, information transmitted from the roadside also has the potential to enhance lane keeping assistance. VII has the potential to impact many other aspects of ITS deployment discussed throughout this report. Additional information on the VII initiative is available at the ITS JPO's Web site: www.its.dot.gov/vii.

ON-BOARD SAFETY SYSTEMS ARE OFFERED AS AN OPTION ON SOME VEHICLES, OFTEN PACKAGED WITH COMFORT, CONVENIENCE, AND ENTERTAINMENT SERVICES.

DRIVER ASSISTANCE CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Navigation/Route Guidance

Driver Communication

With Other Drivers

With Carrier/Dispatch

Vision Enhancement

Object Detection

Adaptive Cruise Control

Intelligent Speed Control

Lane Keeping Assistance

Roll Stability Control

Drowsy Driver Warning Systems

Precision Docking

Coupling/Decoupling

On-Board Monitoring

Cargo Condition

Safety and Security

Vehicle Diagnostics

Event Data Recorders

ELECTRONIC STABILITY CONTROL REDUCES THE RISK OF FATAL SINGLE-VEHICLE CRASHES BY 59 PERCENT FOR SUVs AND 53 PERCENT FOR CARS.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO DRIVER ASSISTANCE

Refer to other chapters in this document.

Traveler Information

Pre-Trip Information

En Route Information

Information Management

Data Archiving

Collision Avoidance

Obstacle Detection

Lane Change Assistance

Lane Departure Warning

Road Departure Warning

Forward Collision Warning

Rear Impact Warning

Findings

Benefits

As shown in table 19, evaluations have documented the performance of in-vehicle navigation systems, driver communication systems, ACC, and roll stability control.

In-vehicle navigation and route guidance systems have gained mainstream acceptance and are widely available in private vehicles. Studies of the systems from the mid-to-late 1990s identified the ability of the devices to provide mobility benefits and improve safety by routing travelers to limited-access freeways and major arterials. When linked to sources of current traffic congestion information to provide dynamic routing, one study found that the devices could reduce traffic congestion and thereby provide additional network capacity. These studies also found travelers had favorable impressions of the devices.

Several studies have been completed assessing the potential of ACC, which is now available in some private vehicles. The most recent studies have found that the systems are most effective at improving safety when bundled with collision warning systems. With widespread deployment, ACC has the ability to reduce vehicle emissions and increase the capacity of roadways. Drivers have demonstrated an acceptance of ACC.

While both cars and sport utility vehicles (SUVs) benefit from electronic stability control systems, the reduction in the risk of single-vehicle crashes was significantly greater for SUVs (49 to 67 percent) than for cars (33 to 44 percent).⁵³¹ With respect to fatal single-vehicle crashes, however, the impacts were similar (59 percent reduction for SUVs and 53 percent reduction for cars).⁵³²

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Table 19—Driver Assistance Benefits Summary						
	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Navigation/Route Guidance	+	●	●			●
Driver Communication				●		
Vision Enhancement						
Object Detection						
Adaptive Cruise Control	●		+		+	●
Intelligent Speed Control						
Lane Keeping Assistance						
Roll Stability Control	●					
Drowsy Driver Warning Systems						
Precision Docking						
Coupling/Decoupling						
On-Board Monitoring						
<ul style="list-style-type: none"> ● Substantial positive impacts ○ Negligible impacts ✘ Negative impacts + ✱ blank Positive impacts Mixed results Not enough data 						

Costs

On-board safety systems are offered as an option on some vehicles, but more often than not these systems are being packaged with comfort, convenience, and entertainment services. A consumer willing to pay for ACC, for example, may forgo the purchase if required to buy a more expensive package that includes unrelated and unwanted features such as climate-controlled front seats and a rear-view monitor. As a result, this bundling approach is deterring consumers from purchasing safety systems. Another side effect of bundling is the difficulty in determining the cost of each individual ITS technology.⁵³³



Selected Highlights from the ITS Knowledge Resources on Driver Assistance

Navigation/Route Guidance

In-vehicle navigation systems with GPS technology may reduce driver error, increase safety, and save time by improving driver decisions in unfamiliar areas. The systems may be linked to traveler information services to provide updated routing instructions that account for current traffic conditions.

Navigation/Route Guidance	
Benefits	
ITS Goals	Selected Findings
Safety	In Orlando, Florida, a simulation study of navigation devices found that drivers using the devices reduced their crash risk by four percent as a result of improved wrong turn performance and the tendency of the system to select routes with improved (normally safer) facilities. ⁵³⁴
Mobility	Summary Finding: In-vehicle navigation/route guidance devices can reduce travel times by 4 to 10 percent under normal traffic conditions or recurring traffic congestion. ⁵³⁵
Efficiency	A simulation study of roadways in Orlando, Florida found that, assuming a market penetration of 30 percent, dynamic route guidance would allow the road network to handle a 10 percent increase in vehicle volumes. ⁵³⁶
Customer Satisfaction	In San Antonio, Texas, 60 percent of drivers of paratransit vehicles equipped with in-vehicle navigation devices reported that they saved time and felt safer than using paper maps. ⁵³⁷
Costs	
Sample Costs of ITS Deployments	
United States: Navigation units are available as optional or standard equipment on many vehicle models. Based on available market data, increased sales in both types of purchases are likely. Navigation units are often integrated with other top-selling, on-board electronics. Several after-market products are also available, with prices around \$1,300 to \$1,500 for equipment plus about \$15 per month for subscription to a satellite service. ⁵³⁸	

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Driver Communication

Integrated driver communication systems enable drivers and dispatchers to coordinate re-routing decisions on-the-fly and can also save time and money, and improve productivity.

Driver Communication	
Benefits	
ITS Goals	Selected Findings
Productivity	An advanced routing and decision-making software communications program for commercial vehicles helped dispatchers organize and route time-sensitive delivery orders. The system increased the number of deliveries per driver-hour by 24 percent. ⁵³⁹
Driver Communication	
Costs	
Sample Costs of ITS Deployments	
<p>Michigan: The Flint Mass Transportation Authority (MTA) developed a plan to deploy ITS technologies to improve the effectiveness and efficiency of transit service in Genesee County. To provide communication between the driver and the dispatch center, the plan included the deployment of mobile data terminals on 250 vehicles. Costs are estimated at \$4,000 per unit, or \$1 million for the fleet. Operations and maintenance (O&M) costs are estimated at \$100,000 per year.⁵⁴⁰</p>	

Vision Enhancement

In-vehicle vision enhancement improves visibility during night driving, inadequate lighting, fog, drifting snow, or other inclement weather conditions. These systems may also monitor vehicle blind spots to assist the driver in making safe lane changes.

Vision Enhancement	
Costs	
Sample Costs of ITS Deployments	
<p>United States: Blind spot monitoring provides warnings to drivers that another vehicle is in one of the “blind” spots to the side and rear of the car. One such system available on the U.S. market utilizes digital camera-based sensors mounted on the exterior side mirrors and provides a visual warning when another vehicle is in the blind spot. This system is available as an option and is priced at approximately \$500 per vehicle. Other mirror-mounted blind spot detection systems are in development, but will utilize 24 GHz radar. Production costs for these systems, installed on both side mirrors, are estimated at \$400 to \$500 per vehicle.⁵⁴¹</p>	

Adaptive Cruise Control

ACC systems maintain a driver-set speed without a lead vehicle or a specified following time if there is a lead vehicle and it is traveling slower than the set speed.

Adaptive Cruise Control	
Benefits	
ITS Goals	Selected Findings
Safety	A field evaluation in Michigan tested ACC combined with forward collision warning to form an automotive collision avoidance system (ACAS). The study found that ACAS could reduce exposure to driving conflicts leading to rear-end crashes by 8 to 23 percent and estimated that the combined system could eliminate about 10 percent of all rear-end crashes. ⁵⁴² An earlier study of stand-alone ACC found that the technology was effective at reducing risky lane changes in response to slower traffic, but drivers of these vehicles took 0.3 seconds longer than manually-controlled vehicles to respond to lead vehicle brake lights. ⁵⁴³
Efficiency	In Michigan, an evaluation of ACC indicated that the technology would improve roadway capacity under conditions of high velocity and short time-headway settings (one second), and reduce road capacity if longer time-headway settings (two seconds) were used. ⁵⁴⁴

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Adaptive Cruise Control	
Benefits	
Energy and Environment	Driver response and vehicle dynamics were recorded for one ACC vehicle and two manually-operated vehicles in a single lane of freeway traffic. The ACC vehicle attempted to smooth traffic flow by minimizing the variance between acceleration and deceleration extremes. Simulation models based on collected field data estimated a fuel savings of 3.6 percent during scenarios with frequent acceleration and deceleration. ⁵⁴⁵
Customer Satisfaction	Survey data collected from tractor-trailer drivers with one to three years of experience driving with intelligent vehicle safety systems—including radar-based collision warning systems (CWS), ACC systems, and advanced electronic braking systems—indicated that in-vehicle safety systems lowered their perceived workload by 14 to 21 percent over a range of driving conditions (good conditions, heavy traffic, and low visibility). ⁵⁴⁶
Costs	
Sample Costs of ITS Deployments	
<p>United States: The U.S. DOT sponsored an independent evaluation of a field operational test (FOT) of three advanced in-vehicle safety systems: CWS, ACC, and advanced braking systems. The three systems were in or nearing commercial production at the time of the FOT and were designed for use in commercial trucks. The cost of adding ACC to a vehicle already equipped with CWS was estimated at \$300 per truck. ACC can be bundled with CWS as an integrated complementary package. Bundled packages of CWS and ACC cost approximately \$2,300; the cost is approximately \$6,300 if an advanced braking system is added.⁵⁴⁷</p> <p>United States: ACC is now available on most high-end automobiles. The cost to the consumer was estimated at \$3,000 per vehicle.⁵⁴⁸</p>	
Benefit-Cost Studies	
<p>United States: A 2007 societal benefit-cost analysis of the installation of a bundle of ACC, a CWS, and an advanced braking system on tractor-trailer commercial vehicles found the installation of the systems to be economically justified in two of six modeled scenarios (with benefit-to-cost ratios ranging from 1.1:1 to 1.3:1). None of the six evaluated scenarios for deployment of the technologies on all types of commercial vehicles yielded a benefit-to-cost ratio greater than 1:1.⁵⁴⁹</p>	

Intelligent Speed Control

Intelligent speed control systems limit maximum vehicle speed via a signal from the infrastructure to an equipped vehicle.

Intelligent Speed Control	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	In the southern Swedish town of Eslov, 25 personal vehicles were equipped with governors (speed controllers) activated by wireless beacons at city points-of-entry to limit inner city vehicle speeds to 50 km/h. The vast majority of participants preferred this adaptive speed control over other physical countermeasures such as speed humps, chicanes, or mini-roundabouts. ⁵⁵⁰
Benefit-Cost Studies	
Illinois: In the central area of Chicago, a feasibility study for proposed dedicated truck facilities indicated that driver assistance technologies including speed control, steering control, and fully automated driving would help to make the proposed network cost-effective by lowering construction costs, improving truck travel times, and increasing capacity on the proposed roadways. ⁵⁵¹	

Roll Stability Control

Roll stability control systems take corrective action, such as throttle control or braking, when sensors detect that a vehicle is in a potential rollover situation.

Roll Stability Control	
Benefits	
ITS Goals	Selected Findings
Safety	An analysis of the effectiveness of electronic stability control in reducing single-vehicle crashes in passenger cars and SUVs (using 1997-2002 crash data from five states) suggested that single-vehicle crashes were reduced by 35 percent for passenger cars and by 67 percent for SUVs. ⁵⁵²

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Precision Docking

Precision docking systems automate precise positioning of vehicles, typically transit vehicles, at loading/unloading areas.

Precision Docking
Costs
Sample Costs of ITS Deployments
<p>Worldwide: Costs data were obtained from various bus rapid transit (BRT) projects either underway or planned and made available to transit professionals and policy makers in planning and decision making related to implementing different components of BRT systems. The data are representative of BRT development costs. Hardware integration for on-board precision docking systems costs approximately \$50,000 per vehicle. Optical/magnetic sensors cost approximately \$4,000 per station.⁵⁵³</p> <p>Illinois: Precision docking technologies, used for easy boarding and alighting of transit passengers, were one of several technologies evaluated in a case study of transportation problems facing the central area of Chicago. The costs of the in-vehicle components were approximately \$14,000 when only several hundred units would be produced. The costs dropped significantly to \$2,700 when production levels would be closer to 10,000.⁵⁵⁴</p>
Benefit-Cost Studies
<p>Illinois: In the central area of Chicago, an economic feasibility assessment of precision docking technologies for cross-town routes found that deployment of the technologies would be economically justifiable if they provided reductions in dwell time of 2.5 seconds per stop.⁵⁵⁵</p>



On-Board Monitoring

On-board monitoring applications track and report cargo condition, safety and security, and the mechanical condition of vehicles equipped with in-vehicle diagnostics. This information can be presented to the driver immediately, transmitted off-board, or stored. In the event of a crash or near-crash, in-vehicle event data recorders can record vehicle performance data and other input from video cameras or radar sensors to improve post-crash processing of data.

On-Board Monitoring
Costs
<p>Sample Costs of ITS Deployments</p> <p>United States: Concierge services widely available through systems provided by ATX® and OnStar® assist motorists by connecting the vehicle to a remote operator who can then contact and dispatch emergency personnel to the scene of a crash. Typically, the hardware (estimated at \$350 per unit) and the first year's subscription costs are included in the retail price of the vehicle with subsequent subscriptions sold on an annual basis. The basic safety-related OnStar® service is \$199 per year which also includes a remote diagnostics system that is linked to sensors monitoring the condition of the engine and electronic systems.⁵⁵⁶</p> <p>Michigan: The Flint MTA developed a plan to deploy ITS technologies to improve effectiveness and efficiency of transit service in Genessee County. The plan includes on-board diagnostics for 100 vehicles to support more efficient maintenance operations and on-road trouble-shooting. The capital costs were estimated to be \$200,000; the O&M costs were estimated to be \$20,000 annually.⁵⁵⁷</p>

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COLLISION NOTIFICATION

REPORTS FROM THE PRIVATE SECTOR INDICATE BASIC IN-VEHICLE SAFETY AND SECURITY PACKAGES NOW INCLUDE ADVANCED SAFETY FEATURES SUCH AS ADVANCED ACN.

VEHICLES

Collision notification systems detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions. These systems can be activated manually (Mayday) or automatically (automated collision notification or ACN), and typically establish wireless data and voice communications with call centers who then relay the information to emergency response services. Data transmitted include vehicle location and the description and nature of the emergency. More advanced ACN systems use in-vehicle crash sensors, global positioning system (GPS) technology, and wireless communications systems to automatically determine the severity, location, condition, and orientation of vehicles in a crash, and communicate this information to emergency responders. Advanced ACN data can assist responders in determining the type of equipment needed in an emergency (basic or advanced life support emergency medical services), mode of transport (air or ground), and the location of the nearest trauma center.

Over a dozen commercial Mayday/ACN products are available. Many of these products are available as factory-installed options on high-end luxury cars; others are installed as after-market products. The typical Mayday/ACN product utilizes location technology, wireless communication, and a third-party response center to notify the closest public safety answering point (PSAP) for emergency response.

The emergency management chapter also discusses automated collision notification systems. In addition, the traffic incident management chapter discusses enhanced 9-1-1 service as a means of detecting incidents.

In addition to the ITS technologies profiled in this chapter, the Next Generation 9-1-1 (NG9-1-1) initiative, a major ITS initiative currently being conducted by U.S. DOT, will improve emergency communication, which would, in turn, improve notification of traffic incidents. The Next Generation 9-1-1 initiative will establish the foundation for public emergency services in this wireless environment and enable an enhanced 9-1-1 system to be compatible with any communications device. The goal of the NG9-1-1 initiative is to enable the transmission of voice, data, or video from different types of communication devices to PSAPs and on to emergency responder networks. For more information, visit the ITS JPO's Web site: www.its.dot.gov/ng911.

Findings

Benefits

The U.S. DOT tested the feasibility of a Mayday system designed to deliver telematics-based emergency calls to a PSAP as if they were conventional telephone calls to 9-1-1. While initial acceptance testing indicated that the system was a viable concept, researchers indicated that the cost of implementing and operating such a nationwide system would be disproportionately high considering the small representation of telematics-initiated 9-1-1 calls.⁵⁵⁸ Currently, telematics service providers continue to use emergency advisory personnel to receive Mayday calls and manually interface with 9-1-1 call takers.

COLLISION NOTIFICATION CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Mayday/Automated Collision Notification

Advanced Automated Collision Notification



Selected Highlights from the ITS Knowledge Resources on Collision Notification

Mayday/Automated Collision Notification

The typical Mayday/ACN product utilizes location technology, wireless communication, and a third-party response center to notify the closest PSAP for emergency response.

Mayday/Automatic Collision Notification	
Benefits	
ITS Goals	Selected Findings
Customer Satisfaction	Several surveys of motor carriers asked them to indicate which, if any, technologies they planned to install in some or all of their fleet vehicles in the future. The most commonly selected technologies were Mayday/ACN systems (26 percent), remote diagnostic systems (23 percent), and rollover stability systems (23 percent). ⁵⁶³
Costs	
Sample Costs of ITS Deployments	
<p>United States: Concierge services widely available through systems provided by ATX® and OnStar® assist motorists by connecting the vehicle to a remote operator who can then contact and dispatch emergency personnel to the scene of a crash. Typically, the hardware (estimated at \$350 per unit) and the first year's subscription are included in the retail price of the vehicle with subsequent subscriptions sold on an annual basis. The basic safety-related OnStar® service is \$199 per year with other packages costing \$399 to \$799 per year.⁵⁶⁴</p>	



Advanced Automated Collision Notification

Advanced ACN systems use in-vehicle crash sensors, GPS technology, and wireless communications systems to supply public/private call centers with crash location information, and in some cases, the number of injured passengers and the nature of their injuries.

Advanced Automated Collision Notification	
Benefits	
ITS Goals	Selected Findings
Safety	Between July 1997 and August 2000, the impacts of advanced ACN on incident notification were tracked for vehicles with and without ACN systems in urban and suburban areas of Erie County, New York. Based on a limited number of crash events, the average notification time for vehicles equipped with ACN was less than 1 minute with some notification times as long as 2 minutes, and the average notification time for vehicles without ACN was about 3 minutes with some notification times as long as 9, 12, 30, and 46 minutes. ⁵⁶⁵
Costs	
Sample Costs of ITS Deployments	
United States: An ACN system that detects not only airbag deployment, but also determines the severity of a crash, direction of impact, multiple impacts, and rollover (if equipped with the appropriate sensors) is available in a basic safety and security subscription service package for \$199 per year , as of 2003. ⁵⁶⁶	

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