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

2008 UPDATE

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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.

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TABLE OF CONTENTS

LIST OF FIGURES

OPERATIONS/ITS HELPLINE
1-866-367-7487

ITS APPLICATION OVERVIEW
www.itsoverview.its.dot.gov

LIST OF TABLES

PHOTO CREDITS

Cover

SunGuide transportation management center in Ft. Lauderdale, Florida. Florida Department of Transportation District IV.

Dynamic sign showing available parking in a garage at Baltimore Washington International (BWI) Airport. *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007, cover.

State patrol officer with laptop computer in his vehicle in Connecticut. CVISN *Safety Information Exchange for Commercial Vehicles in Connecticut: Increasing Inspection Efficiency Through Wireless Data Access at the Roadside*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-030, EDL No. 13981. September 2004, cover.

Executive Summary

Bus. iStockphoto International, Inc.

Cars queued up on a metered ramp in California. iStockphoto International, Inc.

Snowplow and cars on a snowy freeway. iStockphoto International, Inc.

Laptop computers lined up on a table. iStockphoto International, Inc.

State patrol officer inspecting a truck in Connecticut. CVISN *Safety Information Exchange for Commercial Vehicles in Connecticut: Increasing Inspection Efficiency Through Wireless Data Access at the Roadside*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-030, EDL No. 13981. September 2004, page 4-3.

Driver using windshield-mounted in-vehicle navigation device. iStockphoto International, Inc.

Aerial view of people gathered around a conference table. iStockphoto International, Inc.

Row of leather-bound law books. iStockphoto International, Inc.

Introduction

A major traffic jam in southern California. iStockphoto International, Inc.

Dynamic sign showing available parking near the Seattle Center in Seattle, Washington. *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007, cover.

Dynamic sign "Right Lane Closed Ahead" on I-80 in rural Wyoming. *National Evaluation of the FY 2003 Earmarked ITS Integration Project: Southern Wyoming, I-80 Dynamic Message Signs—Final Phase II Evaluation Report*, U.S. DOT, EDL No. 14377. January 2007, cover.

Intelligent Infrastructure

Cars traveling on a freeway with two dynamic signs. iStockphoto International, Inc.

Arterial Management

Traffic signal. iStockphoto International, Inc.

WALK/DON'T WALK sign showing the number of seconds left in the current phase. Virginia Department of Transportation.

Dynamic sign showing available parking in a garage at Baltimore Washington International (BWI) Airport. *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007, cover.

Static sign announcing the nearby presence of a red light camera. iStockphoto International, Inc.

Freeway Management

Static sign with flashing lights "I-80 West Closed When Flashing". *National Evaluation of the FY 2003 Earmarked ITS Integration Project: Southern Wyoming, I-80 Dynamic Message Signs—Final Phase II Evaluation Report*, U.S. DOT, EDL No. 14377. January 2007, cover.

Two surveillance cameras. iStockphoto International, Inc.

A truck entering a freeway on a metered ramp in Los Angeles, California. iStockphoto International, Inc.

Entrance to I-66 in northern Virginia with both static and dynamic signs. Virginia Department of Transportation.

Crash Prevention and Safety

Dynamic sign "2nd Train Coming" mounted on railroad crossing gantry. *Intelligent Transportation Systems at Highway-Rail Intersections: A Cross-Cutting Study*, U.S. DOT, EDL No. 13587. December 2001, cover.

A freight train traveling through a railroad crossing. iStockphoto International, Inc.

Bicyclists in San Francisco, California. iStockphoto International, Inc.

Road Weather Management

Snowplow. iStockphoto International, Inc.

An environmental sensor station. iStockphoto International, Inc.

Roadway Operations and Maintenance

A freeway work zone with a lane and directional shift. iStockphoto International, Inc.

An arterial street work zone with traffic cones and portable, dynamic arrow sign. iStockphoto International, Inc.

Portable, dynamic sign "Construction Ahead Expect Delay". iStockphoto International, Inc.

A freeway work zone with portable, dynamic arrow sign. iStockphoto International, Inc.

Transit Management

A transit dispatcher with computer-aided dispatching equipment in Ventura, California. *ITS Applications for Coordinating and Improving Human Services Transportation: A Cross-Cutting Study*, U.S. DOT, EDL No. 14140. August 2006, page 5-13.

Dynamic sign at Tri-Met bus stop in Portland, Oregon. *Oregon Regional Intelligent Transportation Systems (ITS) Integration Program Final Phase II Report: Transit Tracker Information Displays*, U.S. DOT Federal Highway Administration, EDL No. 13938. 14 November 2003, cover.

Chicago Transit Authority bus in Chicago, Illinois. iStockphoto International, Inc.

Transportation Management Centers

Traffic operations center in Salt Lake City, Utah. *Intelligent Transportation Systems at the 2002 Salt Lake City Winter Olympic Games: Event Study Traffic Management and Traveler Information*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-135, EDL No. 13850. 29 April 2003, cover.

SunGuide transportation management center in Ft. Lauderdale, Florida. Florida Department of Transportation District IV.

Transportation management center in Mesa, Arizona. City of Mesa, Arizona Department of Transportation.

Traffic Incident Management

Stranded motorist being helped by a service patrol driver. *Intelligent Transportation Systems at the 2002 Salt Lake City Winter Olympic Games: Event Study Traffic Management and Traveler Information*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-135, EDL No. 13850. 29 April 2003, page 54.

Dynamic sign "Congestion Ahead Reduce Speed." iStockphoto International, Inc.

Severe freeway crash. *Oregon Regional Intelligent Transportation Systems* (ITS) *Integration Program Final Phase III Report: I-5 Barbur Boulevard Parallel Corridor Traffic Management Demonstration Project*, U.S. DOT, EDL No. 14301. July 2005, cover.

Emergency Management

Crash with two firetrucks responding. iStockphoto International, Inc.

Ambulance in St. Paul, Minnesota. *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006, cover.

Crash on a rainy road with an ambulance and rescue vehicle responding. iStockphoto International, Inc.

Firetruck in Alexandria, Virginia. *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006, page 6 –1.

Electronic Payment and Pricing

Toll plaza with E-ZPass only lanes. *Electronic Toll Collection/Electronic Screening Interoperability Pilot Test Final Report Synthesis*, U.S. DOT Federal Highway Administration, EDL No. 14256. 29 July 2005, cover.

Fare payment for a transit bus in Ventura, California. ITS *Applications for Coordinating and Improving Human Services Transportation: A Cross-Cutting Study*, U.S. DOT, EDL No. 14140. August 2006, page 5-14.

"Smart Fare" smart card for regional fare payment in the Central Puget Sound area of Washington State. *Evaluation Strategy—Puget Sound Regional Fare Card: FY01 Earmark Evaluation*, U.S. DOT, EDL No. 13856. 24 June 2003, cover.

Traveler Information

511 Traffic and Road Conditions Web site www.511MN.org. Minnesota Department of Transportation.

Person using traveler information kiosk in Cape Cod, Massachusetts. Oak Ridge National Laboratory.

Stranded motorist talking on cell phone with static sign "511 Travel Info Call 511" in background. Virginia Department of Transportation.

Dynamic sign "Road Conditions Dial 511." *Model Deployment of a Regional, Multi-Modal 511 Traveler Information System: Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-013, EDL No. 14248. 30 September 2005, cover.

Information Management

Person using computer to analyze intersection traffic counts. *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005, cover.

Annotated map of the Los Angeles, California metropolitan area. *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005, cover.

Commercial Vehicle Operations

Truck on freeway. iStockphoto International, Inc.

Trucking company employee processing credentials paperwork for commercial vehicles in Washington State. CVISN *Electronic Credentialing for Commercial Vehicles in Washington State: Easier Licensing and Credentials Processing for the Motor Carrier Industry*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-029, EDL No. 13980. September 2004, cover.

State patrol officer with laptop computer in his vehicle in Connecticut. CVISN *Safety Information Exchange for Commercial Vehicles in Connecticut: Increasing Inspection Efficiency Through Wireless Data Access at the Roadside*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-030, EDL No. 13981. September 2004, cover.

Truck being screened at weigh station. *Washington State–British Columbia: International Mobility and Trade Corridor* (IMTC), U.S. DOT Federal Highway Administration, EDL No. 13952. October 2003, page 15.

Intermodal Freight

Aerial view of cargo ship. iStockphoto International, Inc.

Shipping containers suspended from overhead gantries at container terminal. iStockphoto International, Inc.

Truck crossing the U.S.-Canadian border. iStockphoto International, Inc.

Intelligent Vehicles

Driver using dashboard-mounted in-vehicle navigation device. iStockphoto International, Inc.

Collision Avoidance

Object detection device mounted in bus interior. *Evaluation Report: Driver Experience with the Enhanced Object Detection System for Transit Buses*, U.S. DOT, EDL No. 13781. January 2003, page 7.

Oncoming train detection device mounted on vehicle dashboard. *Intelligent Transportation Systems at Highway-Rail Intersections: A Cross-Cutting Study*, U.S. DOT, EDL No. 13587. December 2001, cover.

Driver Assistance

Interior of car with dashboard-mounted in-vehicle navigation device. iStockphoto International, Inc.

Bus driver pointing to a dashboard-mounted in-vehicle device in Cape Cod, Massachusetts. ITS *Applications for Coordinating and Improving Human Services Transportation: A Cross-Cutting Study*, U.S. DOT, EDL No. 14140. August 2006, page 5-7.

A state department of transportation employee using dashboard-mounted in-vehicle device. Virginia Department of Transportation.

Collision Notification

Fire truck responds to an intersection crash in Fairfax County, Virginia. *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006, cover.

Ambulance responding to freeway crash on a rainy road. iStockphoto International, Inc.

Lessons Learned

Close view of people gathered around conference table. iStockphoto International, Inc.

Management and Operations

A person in a wheelchair disembarking a paratransit van in Flint, Michigan. ITS *Applications for Coordinating and Improving Human Services Transportation: A Cross-Cutting Study*, U.S. DOT, EDL No. 14140. August 2006, cover.

Two workers examining the equipment inside a traffic signal cabinet. *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006, page 9-3.

511 Virginia Web site www.511Virginia.org. Virginia Department of Transportation.

Policy and Planning

Arizona Department of Transportation Intelligent Transportation Systems (ITS) Web site www.az511.com. Arizona Department of Transportation.

Cover. *Florida's ITS Integration Guidebook*, Prepared by the University of South Florida for the Florida DOT. Tampa, FL. 1 October 2002.

Design and Deployment

Truck being screened at a weigh station in Kentucky. Battelle.

Interior of truck cab with dashboard-mounted in-vehicle navigation device. *Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3: Final Report*, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007, cover.

State patrol officer getting out of vehicle. iStockphoto International, Inc.

Two ambulances traveling through an intersection in Fairfax County, Virginia. *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006, cover.

Leadership and Partnerships

Cover. *Simplified Guide to the Incident Command System for Transportation Professionals*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-004/FHWA-NHI-06-007. February 2006.

I-5 and I-405 in southern California with static signs for high-occupancy vehicle lanes. iStockphoto International, Inc.

Montana Department of Transportation. Montana Department of Transportation 511 Web site www.mdt511.com. Montana Department of Transportation.

Live-intercept survey being conducted. SAIC.

Funding

$100 bills. iStockphoto International, Inc.

California State Capital building in Sacramento, California. iStockphoto International, Inc.

Passenger boarding a paratransit bus in Cape Cod, Massachusetts. Oak Ridge National Laboratory.

Dynamic sign showing available parking spaces at Metra park-and-ride lots in the Chicago, Illinois metropolitan area. *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007, cover.

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ITS APPLICATION OVERVIEW
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Technical Integration

Interior of a Washington Metropolitan Area Transit Authority (WMATA) station in Washington, D.C. iStockphoto International, Inc.

Tri-Met bus in Portland, Oregon. *Oregon Regional Intelligent Transportation Systems (ITS) Integration Program Final Phase II Report: Transit Tracker Information Displays*, U.S. DOT Federal Highway Administration, EDL No. 13938. 14 November 2003, cover.

Procurement

Cover. Marshall, Kenneth and Philip Tarnoff. *Guide to Contracting ITS Projects*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 560. Washington, DC. 2006.

Contract papers and pen. iStockphoto International, Inc.

Legal Issues

Trucks queued up at a weigh station in Union, Connecticut. CVISN *Safety Information Exchange for Commercial Vehicles in Connecticut: Increasing Inspection Efficiency Through Wireless Data Access at the Roadside*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-030, EDL No. 13981. September 2004, page 1-1.

Toll plaza on the Golden Gate Bridge in the San Francisco, California metropolitan area. iStockphoto International, Inc.

Human Resources

"Help Wanted" section of a newspaper. iStockphoto International, Inc.

A technician in a bucket truck repairing a traffic signal. iStockphoto International, Inc.

Students taking an exam in a training class. iStockphoto International, Inc.

Maintenance Decision Support System (MDSS) logo. U.S. DOT Federal Highway Administration.

Conclusions

Cars queued up at toll plaza. iStockphoto International, Inc.

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ITS APPLICATION OVERVIEW

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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.

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 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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ITS APPLICATION OVERVIEW
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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.

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ITS APPLICATION OVERVIEW
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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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ITS APPLICATION OVERVIEW
www.itsoverview.its.dot.gov

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.*

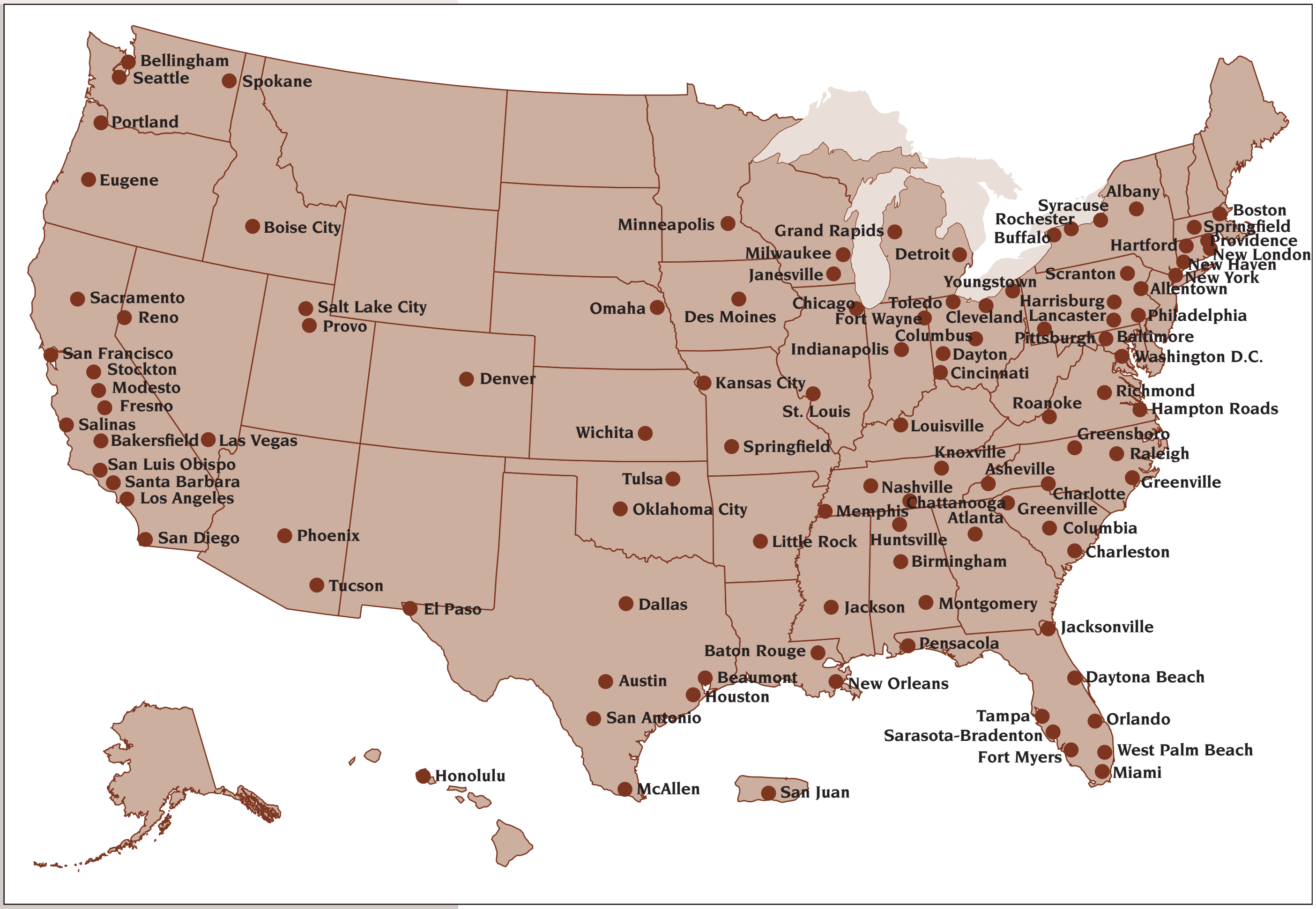

Figure 1 – Metropolitan Areas Surveyed Through the ITS Deployment Tracking Project

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ITS APPLICATION OVERVIEW

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INTELLIGENT INFRASTRUCTURE

A wide variety of infrastructure-based ITS applications improve the safety and mobility of the traveling public, while enabling organizations responsible for operating transportation facilities and providing services to do so more efficiently. The following 14 chapters of this report cover ITS applications that can be deployed on the transportation infrastructure to improve the operation of highway and public transportation systems, as well as freight movement. The first five chapters discuss applications on the roadway infrastructure. The transit management chapter describes applications for public transportation systems. Six chapters discuss ITS applications that support improved management and operations of transportation systems, utilizing both the roadway and transit infrastructure. Finally, two chapters describe ITS strategies for facilitating freight movement.

Many of the applications discussed in the following chapters, while presently facilitated by technology deployed entirely within the transportation infrastructure, can be improved through the deployment of vehicle infrastructure integration. Enhanced communication between the roadside and vehicles would enhance the capability of many of the applications discussed. For example, warnings of approaching vehicles or stopped traffic could be more readily communicated to drivers, without relying on the presence of dynamic message signs at the appropriate location.

INTELLIGENT INFRASTRUCTURE: ITS APPLICATIONS

Roadways

- Arterial Management
- Freeway Management
- Crash Prevention and Safety
- Road Weather Management
- Roadway Operations and Maintenance

Transit

- Transit Management

Management and Operations

- Transportation Management Centers
- Traffic Incident Management
- Emergency Management
- Electronic Payment and Pricing
- Traveler Information
- Information Management

Freight

- Commercial Vehicle Operations (Freight)
- Intermodal Freight

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ARTERIAL MANAGEMENT

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

ROADWAYS

Arterial management systems manage traffic along arterial roadways, employing vehicle detectors, traffic signals, and various means of communicating information to travelers. These systems make use of information collected by traffic surveillance devices to smooth the flow of traffic along travel corridors. They also disseminate important information about travel conditions to travelers via technologies such as dynamic message signs (DMS) or highway advisory radio (HAR).

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

Traffic signal control systems address a number of objectives, primarily improving traffic flow and safety. Adaptive signal control systems coordinate control of traffic signals along arterial corridors, adjusting the lengths of signal phases based on prevailing traffic conditions. Advanced signal systems include those that provide the ability for proactive management of signal systems by allowing traffic conditions to be actively monitored, provide the ability to archive traffic data, and may include some necessary technologies for the later development of adaptive signal control. Coordinated signal operations across neighboring jurisdictions may be facilitated by these advanced systems. Pedestrian detectors, specialized signal heads, and bicycle-actuated signals can improve the safety of all road users at signalized intersections. Arterial management systems can also apply unique operating schemes for traffic signals, portable or dedicated DMS, and other ITS components to smooth traffic flow during special events.

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

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

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

ARTERIAL MANAGEMENT CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Surveillance
- Traffic
- Infrastructure

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

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

Parking Management
- Data Collection
- Information Dissemination

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

Enforcement
- Speed Enforcement
- Traffic Signal Enforcement

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO ARTERIAL MANAGEMENT

Refer to other chapters in this document.

Transit Management

Operations and Fleet Management: Transit Signal Priority

Emergency Management

Response and Recovery: Emergency Vehicle Signal Preemption

Electronic Payment and Pricing

Pricing

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

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

Findings

Benefits

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

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

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

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

Table 1—Arterial Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Surveillance						
Traffic Control	✚	●	●		●	
Lane Management						
Parking Management		●	✚			●
Information Dissemination						
Enforcement	●					●

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

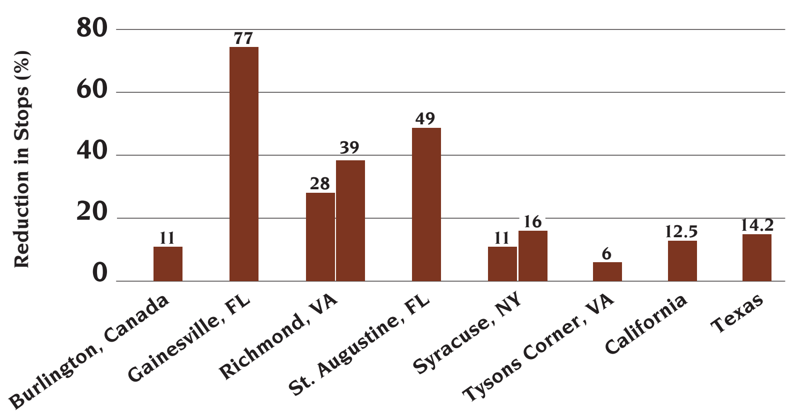

Figure 2 – Reduction of Number of Stops With Traffic Signal Coordination

Costs

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

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

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

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

Deployment

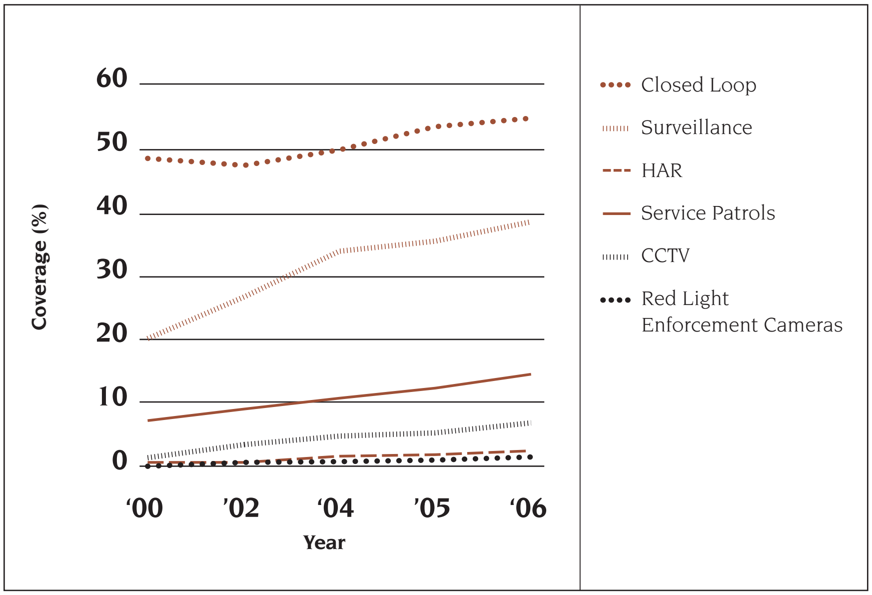

Figure 3 – Deployment Trends for Arterial ITS, 2000-2006

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

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

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Selected Highlights from the ITS Knowledge Resources on Arterial Management

Surveillance

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

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

LESSONS LEARNED

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

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

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

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

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Traffic Control: Adaptive Signal Control

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

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

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

Traffic Control: Advanced Signal Systems

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

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

LESSONS LEARNED

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

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

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

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

- Take advantage of facilitation by regional governmental organizations.

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

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

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Traffic Control: Bicycle and Pedestrian

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

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

LESSONS LEARNED

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

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

- Obtain access to telecommunication expertise.

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

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

(*Continued on next page.*)

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Traffic Control: Special Events

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

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

Lane Management

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

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

LESSONS LEARNED

(*Continued from previous page.*)

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

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

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

Parking Management

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

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

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

Information Dissemination

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

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

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Enforcement

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

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

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

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FREEWAY MANAGEMENT

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

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*.

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

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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.

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	●					●

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

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]

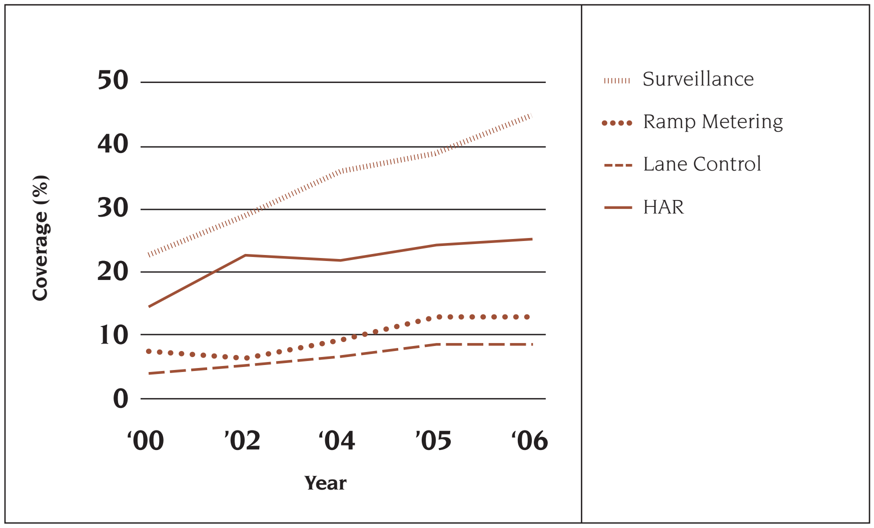

Figure 4 – Freeway Deployment Trends for 78 Major Metropolitan Areas

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.

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: • Inductive Loops on Corridor: $3K-$8K • Remote Traffic Microwave Sensor on Corridor: $9K-$13K • Closed Circuit Televsion (CCTV) Video Camera: $9K-$19K Transportation Management Center subsystem: • Hardware, Software for Traffic Surveillance: $131K-$160K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
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] **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]

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: • Ramp Meter: $24K-$49K 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
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] **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]
Benefit-Cost Studies
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]

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 • Dynamic Message Sign: $48K-$119K Toll Plaza subsystem: examples include • Electronic Toll Reader: $2K-$5K • High-Speed • Camera: $7K-$10K Toll Administration subsystem: examples include • Toll Administration Hardware: $5.4K-$8.1K • Toll Administration Software: $39K-$78K Roadside Telecommunications subsystem: examples include • 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]

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 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: • Software for Lane Control: \$24K-\$49K • Lane Control Gates: \$78K-\$117K Roadside Telecommunications subsystem: • 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: • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor • Environmental Sensor Station (Weather Station): $30K-$49K Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K • Highway Advisory Radio: $15K-$35K Transportation Management Center subsystem: • 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
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]

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: • Dynamic Message Sign: $48K-$119K • Dynamic Message Sign—Portable: $18.6K-$24K Roadside Detection subsystem: • Portable Traffic Management System: $78K-$97K 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)

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)	
Roadside Information subsystem: • Highway Advisory Radio: $15K-$35K • Highway Advisory Radio—Sign: $5K-$9K 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	
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] **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]	

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	●					

● Substantial positive impacts
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
blank 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]

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

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.

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.

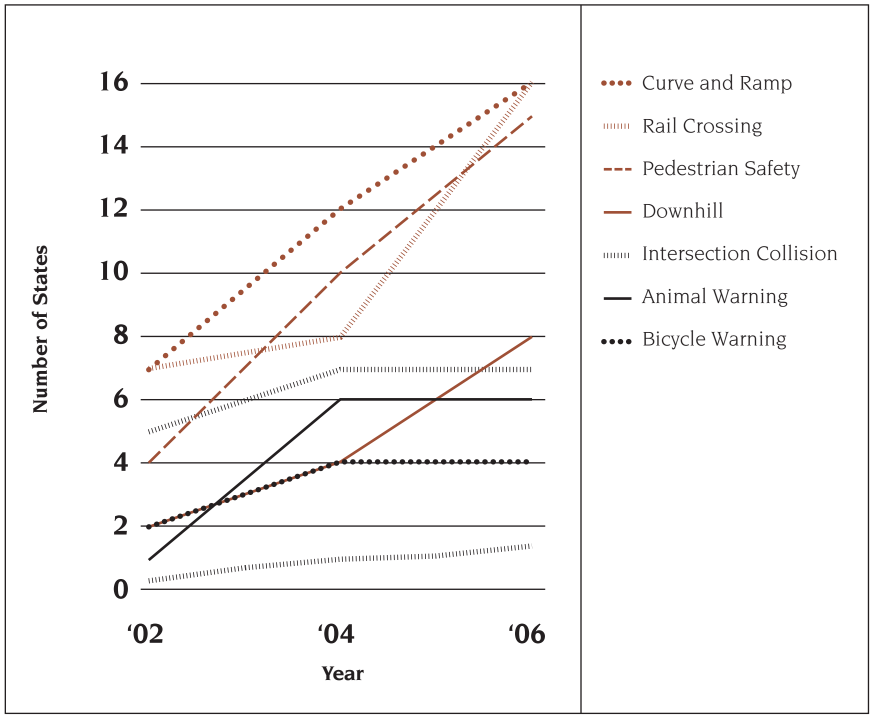

Figure 5 – Trends for Statewide/Rural Deployment of Crash Prevention and Safety Systems, 2002-2006

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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: • 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	
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: • 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)	

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	
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] **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]	

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: • Rail Crossing Four-Quad Gate, Signals: $90K-$101K • Rail Crossing Train Detector: $12K-$17K 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)

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	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] 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]

Intersection Collision 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 Control subsystem: • Signal Controller and Cabinet: \$8K-\$14K Roadside Information subsystem: • Dynamic Message Sign: \$48K 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
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 countdown 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: • Pedestrian Detection—Microwave: $0.6K • Pedestrian Detection—Infrared: $0.3K-$0.5K Roadside Information subsystem: • Light-Emitting Diode (LED) Countdown Signal: $0.306K-$0.424K • Pedestrian Crossing Illumination System: $26.8K-$41K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)	

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 breakaway 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]	

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

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In addition to the technologies profiled in this chapter, two major road weather programs—the C*larus* 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. C*larus* 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 C*larus* 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]

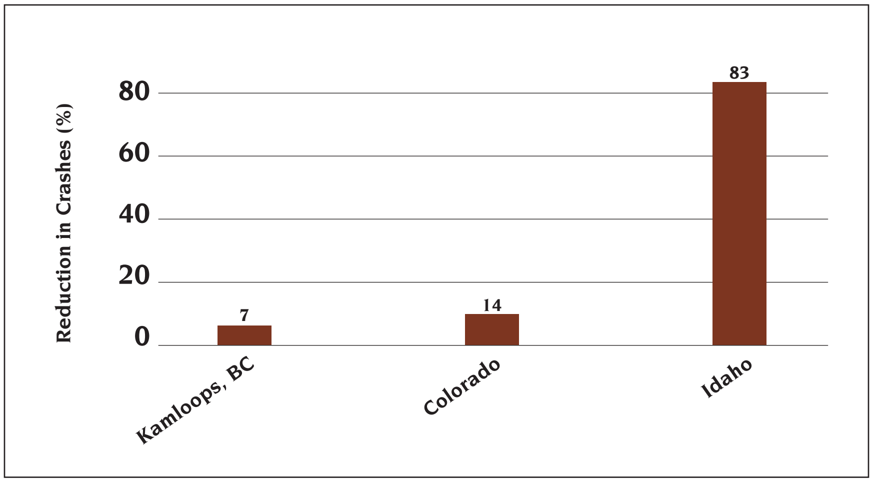

Figure 6 – Impact of Anti-Icing Programs on Weather Related Crashes

Table 5 presents qualitative ratings of the impact of road weather management ITS applications under each of the six ITS goals. All the strategies have been found effective in improving safety. Studies on the usage of surveillance technologies and treatment strategies have shown productivity improvements. Surveys have shown that both agency personnel and the general public are satisfied with road weather information dissemination.

Table 5—Road Weather Management Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Surveillance, Monitoring, and Prediction	●			●		✚
Information Dissemination (Advisory Strategies)	●					✚
Traffic Control (Control Strategies)	✚					
Response and Treatment (Treatment Strategies)	●			✚	✚	

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

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 policy (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.*)

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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]

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 Keysers 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)
Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K • Portable Dynamic Message Sign: $18.6K-$24K • Highway Advisory Radio: $15K-$35K 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
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]

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)
Roadside Control subsystem: • Fixed Lane Signal: \$5K-\$6K • Signal Controller and Cabinet: \$8K-\$14K Roadside Detection subsystem: • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor • Environmental Sensor Station (Weather Station): \$30K-\$49K Roadside Information subsystem: • Dynamic Message Sign: \$48K-\$119K • Highway Advisory Radio: \$15K-\$35K Transportation Management Center subsystem: • 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
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]
Benefit-Cost Studies
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]

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/ft^2 (CAD)**. Operating costs were **$15,000 (CAD)** or **\$0.70/ ft^2 (CAD)**.

For later FAST deployments in Ontario, the cost of the basic spray systems ranged from **\$90/ft^2 (CAD)** to **\$370/ft^2 (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]

ROADWAY OPERATIONS AND MAINTENANCE

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

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/h[237] 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

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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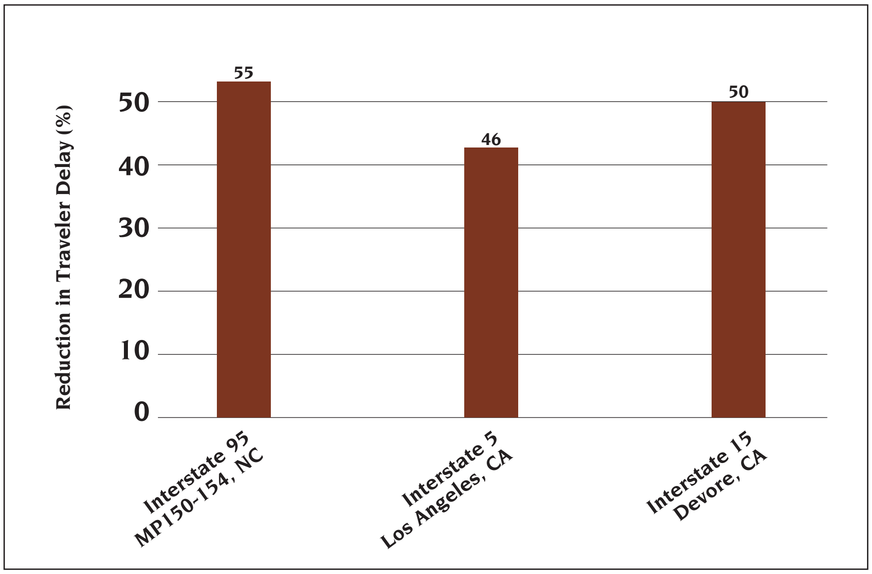

Figure 7 – Delay Reduction with AWIS

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: • Dynamic Message Sign: $48K-$119K • Dynamic Message Sign—Portable: $18.6K-$24K Roadside Detection subsystem: • Portable Traffic Management System: $78K-$97K 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)	

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Information Dissemination
Costs
Sample Costs of ITS Deployments
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] **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] **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]

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	
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.	
Benefits	
ITS Goals	**Selected Findings**
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 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]
Costs	
Sample Costs of ITS Deployments	
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]	

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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	
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.	
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.*)

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Work Zone Management
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor • Closed Circuit Television (CCTV) Video Camera: $9K-$19K Roadside Information subsystem: • Dynamic Message Sign—Portable: $18.6K-$24K • Highway Advisory Radio: $15K-$35K • Highway Advisory Radio Sign: $5K-$9K Roadside Detection subsystem: • Portable Traffic Management System: $78K-$97K • 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)

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

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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 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.

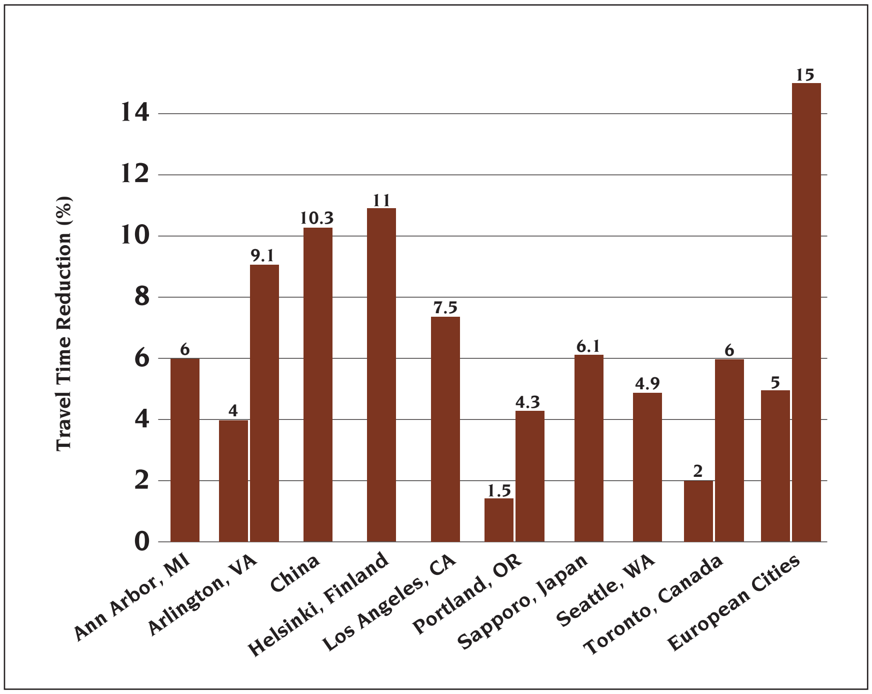

Figure 8 – Transit Travel Time Improvements with Transit Signal Priority

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]

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

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.

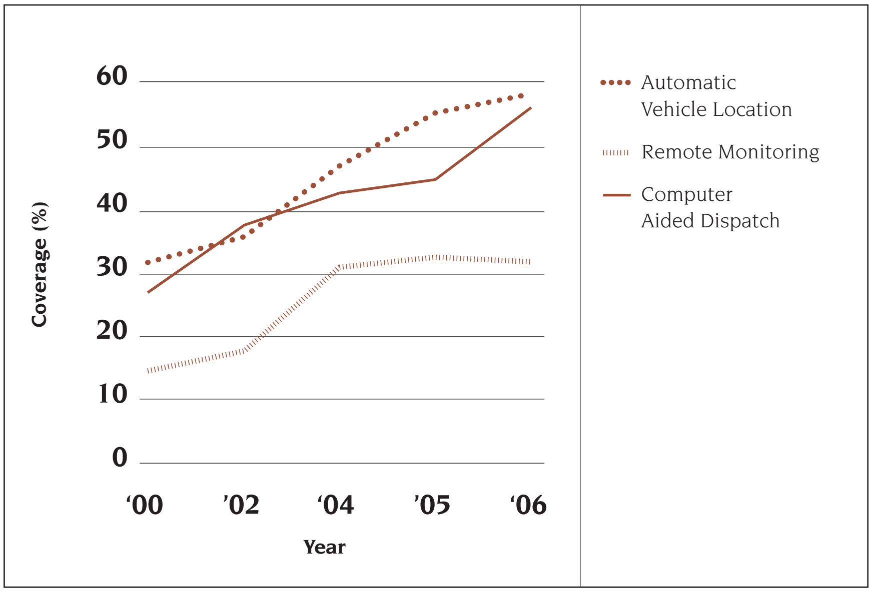

Figure 9 – Deployment Trends for Transit Management Technologies, 2000-2006

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	
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.	
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)	
Transit Management Center subsystem: • 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: • 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 Genessee 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	
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.	
Benefits	
ITS Goals	**Selected Findings**
Customer Satisfaction	***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]
Customer Satisfaction	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]

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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ITS APPLICATION OVERVIEW

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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	
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.	
Benefits	
ITS Goals	**Selected Findings**
Productivity	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] 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]
Customer Satisfaction	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]

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: • 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: • 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
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] **New Mexico:** Client Referral, Ridership, and Financial Tracking (CRRAFT), 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 CRRAFT are about **$95,000 annually**.[300] Building on the success of CRRAFT, 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 CRRAFT.[302]

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	
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.	
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]

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Safety and Security
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transit Management Center subsystem: • 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: • Security Package: $3.3K-$6K Remote Location subsystem: • Closed Circuit Television (CCTV) Camera: $2K-$5K • Transit Status Information Sign: $4K-$8K
Sample Costs of ITS Deployments
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 annunicators, and equipment health monitoring may only cost a few thousand dollars more.[306] **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]

TRANSPORTATION MANAGEMENT CENTERS

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

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 succesful 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.

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 coordination[310]

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]

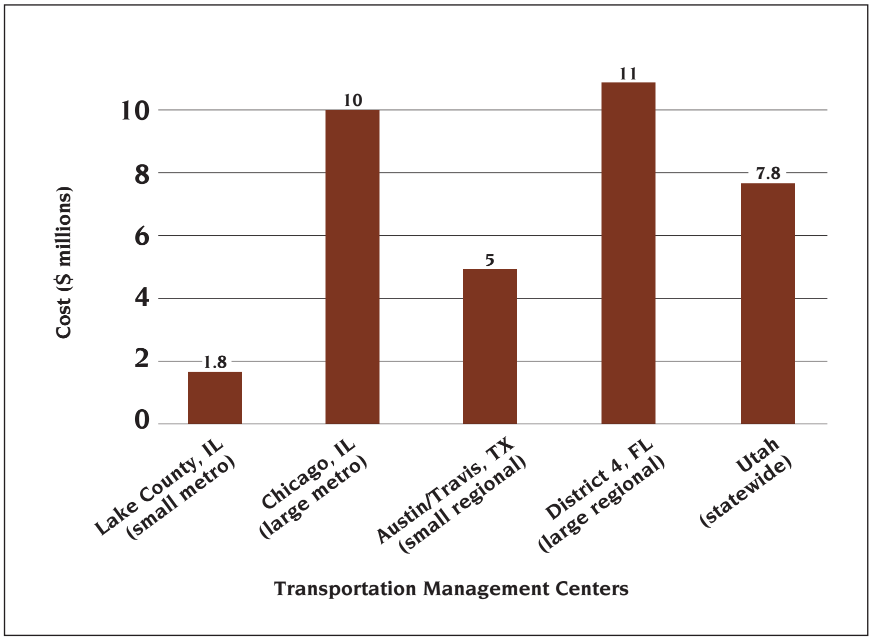

Figure 10 – TMC Initial Capital Costs

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 11 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.

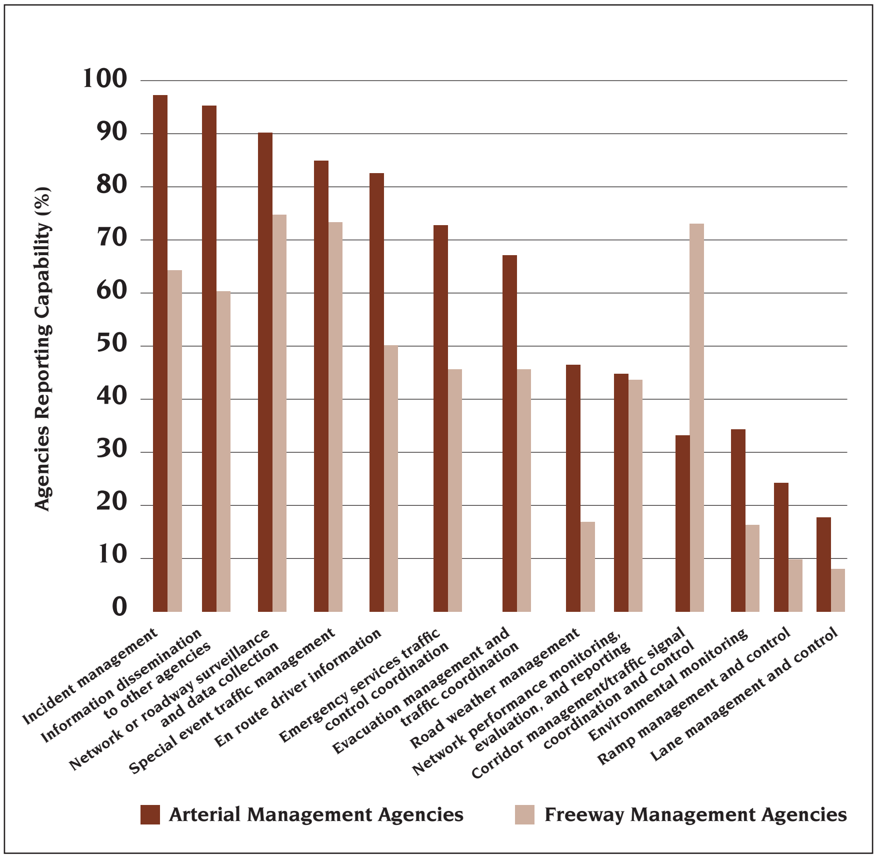

Figure 11 – Functional Capabilities of Transportation Management Centers

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: • 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 • **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

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

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.

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
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
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.

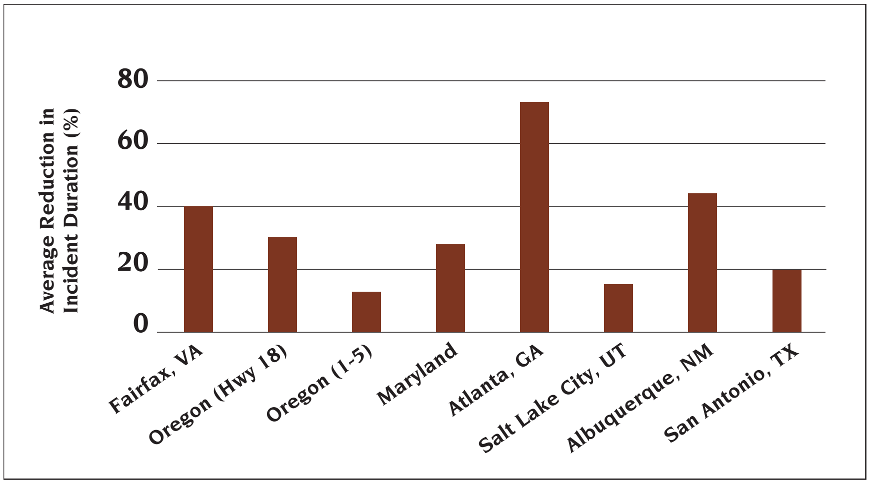

Figure 12 – Impact of Incident Management Programs on Incident Duration

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]

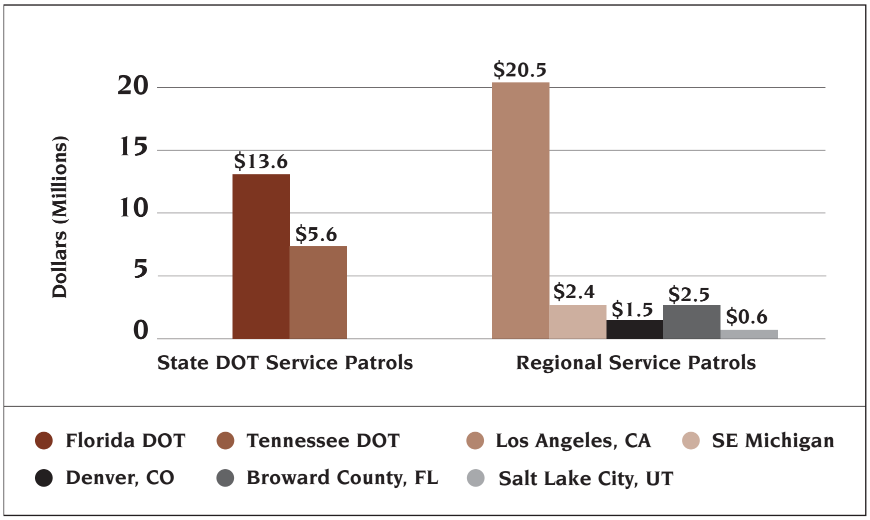

Figure 13 – Annual Cost Ranges of State DOT and Regional Service Patrols

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**

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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.

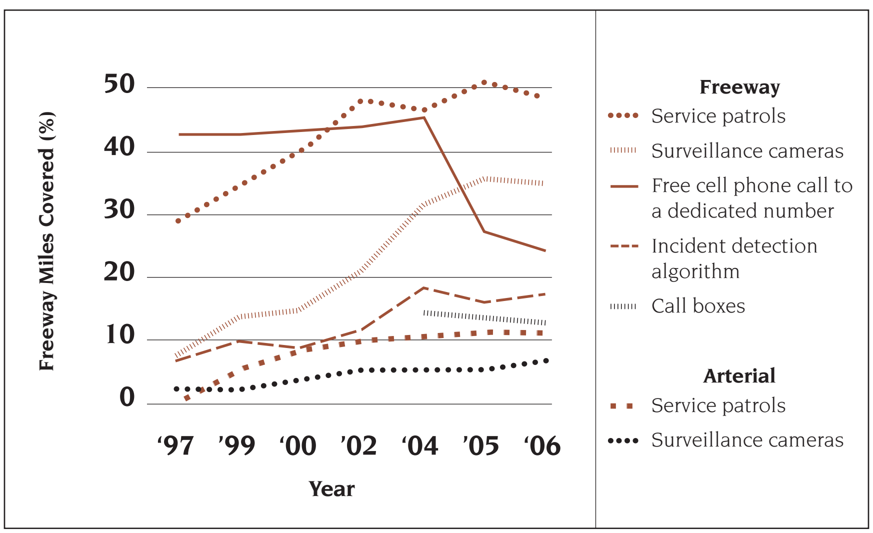

Figure 14 – Deployment Trends for ITS Technology on Freeways and Arterials Supporting Incident Management

Selected Highlights from the ITS Knowledge Resources on Traffic Incident Management

STUDIES OF TRAFFIC INCIDENT MANAGEMENT PROGRAMS HAVE FOUND INCIDENT DURATION REDUCTIONS OF 15 TO 65 PERCENT.

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: • 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: • Software for Incident Detection: $83K-$101K • Labor for Incident Detection: $751K-$917K for multiple staff (annually) Roadside Telecommunications subsystem: • 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
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]

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	
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. Service patrols cover nearly half (48 percent) of freeway miles and 11 percent of arterial miles in the country's 108 largest metropolitan areas.	
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: • Labor for Incident Response: $107K-$131K (annually)	
Sample Costs of ITS Deployments	
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]	
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] **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] **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]	

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
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] **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]

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
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.
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K • Portable Dynamic Message Sign: $18.6K-$24K • Highway Advisory Radio: $15K-$35K
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)

Information Dissemination
Costs
Sample Costs of ITS Deployments
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]

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 emergeny 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]

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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: • Automated Incident Investigation System: $14.1K
Sample Costs of ITS Deployments
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] **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]

EMERGENCY MANAGEMENT

EIGHTY (80) PERCENT OF EMERGENCY MANAGEMENT VEHICLES IN MAJOR METRO-POLITAN 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 of 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			●			

● Substantial positive impacts ✚ Positive impacts
❍ Negligible impacts ✱ Mixed results
✖ Negative impacts **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.

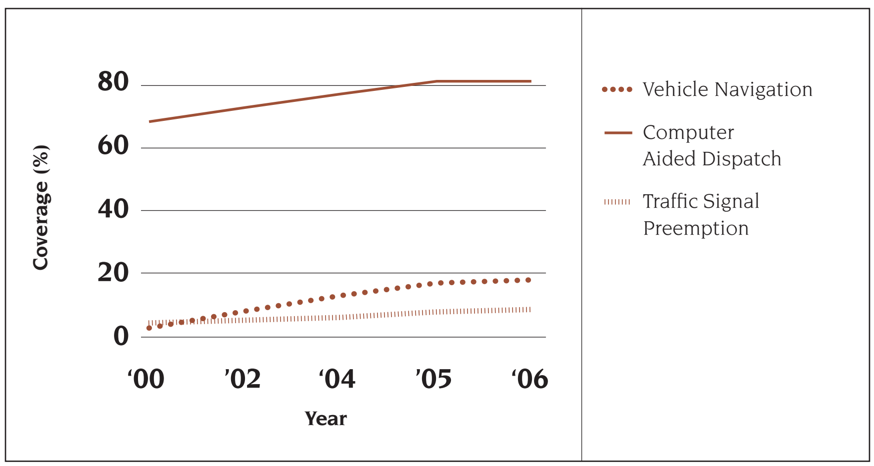

Figure 15 – Deployment Trends for Emergency Management Systems

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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	
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.	
Benefits	
ITS Goals	**Selected Findings**
Safety	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. The study also found that cosmbinations 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]

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]	

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: • 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
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]

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]

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.

<table>
<tr><th colspan="2">Response and Recovery—Response Management</th></tr>
<tr><th colspan="2">Benefits</th></tr>
<tr><td>ITS Goals</td><td>Selected Findings</td></tr>
<tr><td>Customer Satisfaction</td><td>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]
• Interoperable radio communications
• Dynamic message signs
• GPS and geographical information systems
• CCTV roadway surveillance
• Enhanced 9-1-1</td></tr>
<tr><th colspan="2">Costs</th></tr>
<tr><td colspan="2">Unit Costs Data Examples (See Appendix A for more detail)</td></tr>
<tr><td colspan="2">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)
Emergency Vehicle On-Board subsystem:
• Communications Interface: $0.3K-$2K
• Signal Preemption Emitter: $0.5K-$2.1K
Transportation Management Center subsystem:
• Integration for Traffic Information Dissemination: $83K-$101K
• Labor for Regional Control: $214K-$262K (annually)</td></tr>
<tr><td colspan="2">Sample Costs of ITS Deployments</td></tr>
<tr><td colspan="2">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]</td></tr>
</table>

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: • Signal Controller Upgrade for Signal Control: $2.4K-$6K • Roadside Signal Preemption/Priority: $5K-$6K Emergency Vehicle On-Board subsystem: • Signal Preemption/Priority Emitter: $0.5K-$2.1K 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	
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]	

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.)

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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	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] 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]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
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) Emergency Vehicle On-Board subsystem: • Communications Interface: $0.3K-$2K • Signal Preemption Emitter: $0.5K-$2.1K Transportation Management Center subsystem: • 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]

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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: • 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: • 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: • 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]

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

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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.

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		●		●	●	✚

● Substantial positive impacts ✚ Positive impacts
❍ Negligible impacts ✱ Mixed results
✖ Negative impacts **blank** 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 charge[405].

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.

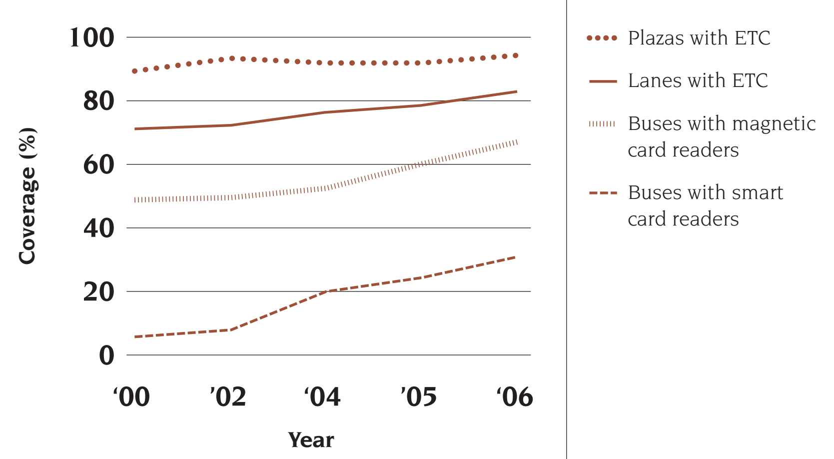

Figure 16 – Deployment Trends for Electronic Toll Collection and Fare Payment, 2000-2006

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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
Unit Costs Data Examples (See Appendix A for more detail)
Toll Plaza subsystem: • Electronic Toll Reader: $2K-$5K • High-Speed Camera: $7K-$10K Toll Administration subsystem: • Toll Administration Hardware: $5.9K-$8.8K • Toll Administration Software: $38K-$76K Roadside Telecommunication subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
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] **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]

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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]

Transit Fare Payment
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Transit Management subsystem: • 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 Transit Vehicle On-Board subsystem: • Electronic Farebox: $0.6K-$1.1K
Sample Costs of ITS Deployments
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] **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] **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] **New Mexico:** Building on the success of Client Referral, Ridership, and Financial Tracking (CRRAFT), 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 CRRAFT.[422]

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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: • Integration for Auto. Scheduling, Run Cutting, or Fare Payment: $219K-$486K Parking Management subsystem: • 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: • 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: • 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 emmisions of 8 percent in oxides of nitrogen, 7 percent in airborn 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
Sample Costs of ITS Deployments
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]   **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]

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

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

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 JPO's Web sites: *www.fightgridlocknow.gov* and *www.its.dot.gov/icms*.

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

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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.

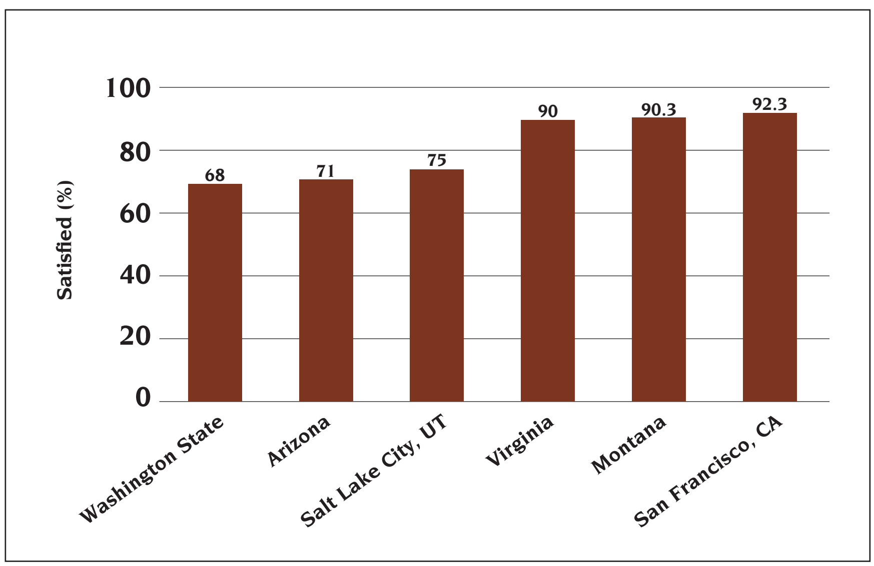

Figure 17 – Traveler Satisfaction with 511 Telephone Traveler Information Systems

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.[441]

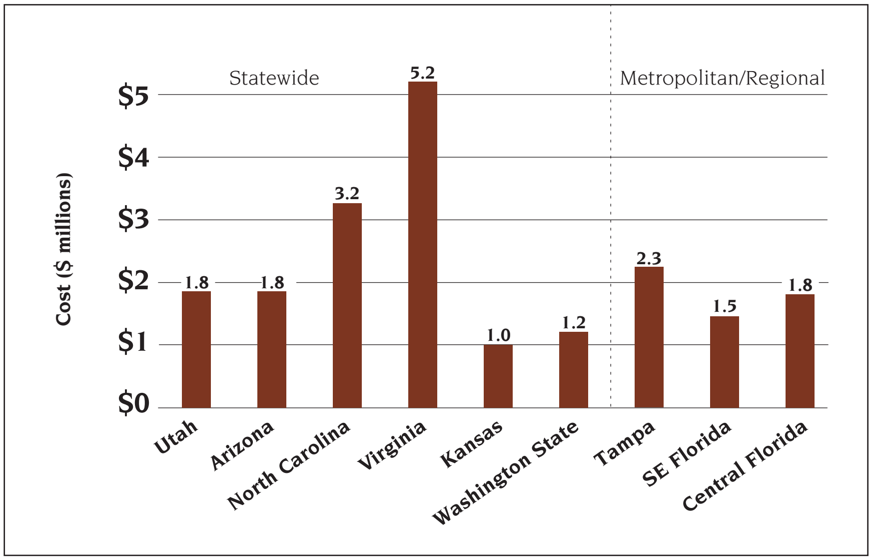

Figure 18 – Total Costs ($ millions) of Nine 511 Deployments

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.

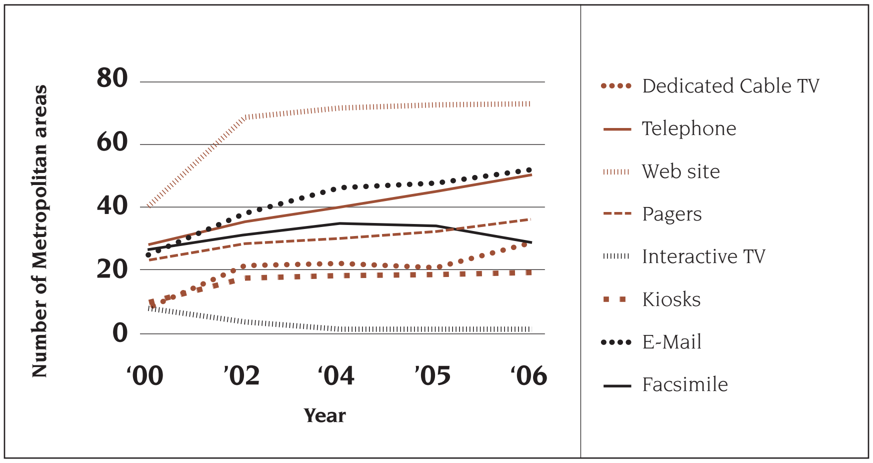

Figure 19 – Trends for Adoption of Traveler Information Media, 2000-2006

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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	
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.	
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.*)

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Pre-Trip Information
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Information Service Provider subsystem: • Information Service Provider Hardware: $23K-$34K • Information Service Provider Software: $267K-$535K • Information Service Provider Labor: $254K-$363K (annually) Remote Location subsystem: • Informational Kiosk: $11K-$24K Transportation Management subsystem: • 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
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] **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]

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	
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).	
Benefits	
ITS Goals	**Selected Findings**
Mobility	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]
Customer Satisfaction	***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. 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]

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 • Dynamic Message Sign: \$48K-\$119K Information Service Provider subsystem: • Information Service Provider Hardware: \$23K-\$34K • Information Service Provider Software: \$267K-\$535K • Information Service Provider Labor: \$254K-\$363K (annually) Remote Location subsystem: • Informational Kiosk: \$11K-\$24K Transportation Management subsystem: • 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
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]

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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	
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.	
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: • Dynamic Message Sign: $48K-$119K Information Service Provider subsystem: • Information Service Provider Labor: $254K-$363K (annually) Remote Location subsystem: • Informational Kiosk: $11K-$24K Transportation Management subsystem: • Software for Traffic Information Dissemination: $17K-$21K • Integration for Traffic Information Dissemination: $83K-$101K	
Sample Costs of ITS Deployments	
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]	

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 succesful 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
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
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.

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
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] **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 to1.5 full-time equivalent positions.[460] **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]
Benefit-Cost Studies
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]

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

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Table 15—CVISN Core Capability Requirements

Capability Area	State CVISN Core Capabilities
Safety Information Exchange	• 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 intrastate and interstate snapshots and connection to SAFER for exchange of interstate snapshots.
Credentials Administration	• 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	• 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]

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 tehnologies 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						

● Substantial positive impacts
❍ Negligible impacts
✖ Negative impacts
✚ Positive 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-TO-COST RATIOS RANGE FROM 2:1 TO 12:1 FOR ELECTRONIC SCREENING.

Benefit-Cost Studies

CVISN technologies are cost-effective, increasing safety; simplifing 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 credentialing[476], 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.

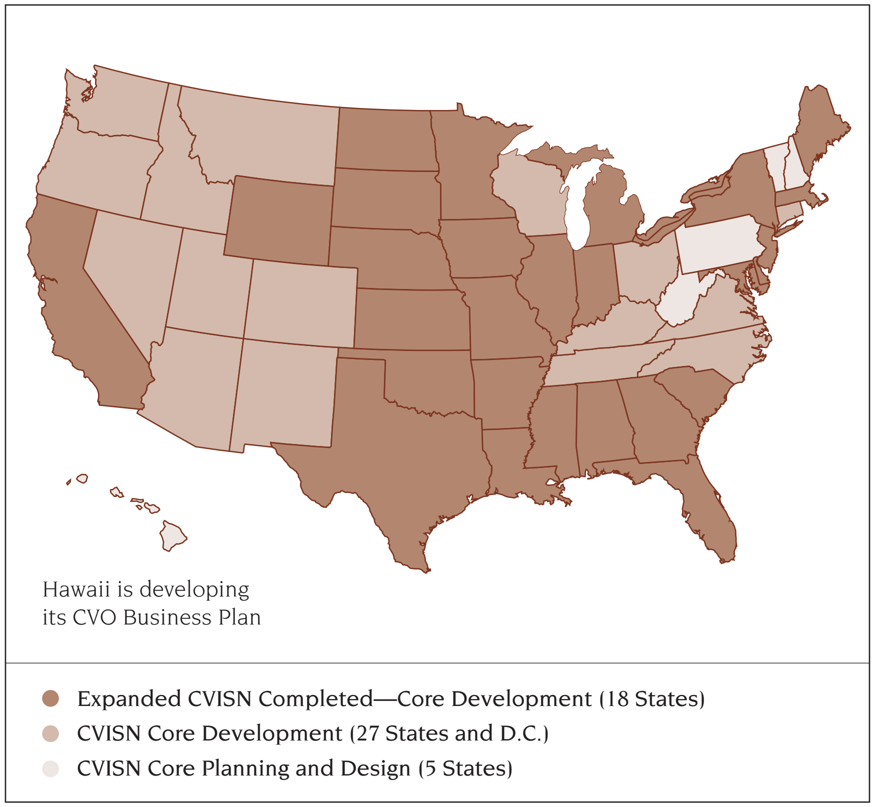

Figure 20 – Status of CVISN Deployment

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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: • 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)	

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: • 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)	

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.*)

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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: • Global Positioning System (GPS)/Differential GPS (DGPS): $0.5K-$1.8K • Cargo Monitoring Sensors and Gauges: $0.13K-$0.27K Fleet Management subsystem: • 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
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]

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: • 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 costs[501]), 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		●		●		

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

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: • Electronic Cargo Seal Disposal: $0.01K-$0.024K • Electronic Cargo Seal Reusable: $0.034K-$0.42K Fleet Management Center subsystem: • Electronic Cargo Seal Reader: $0.3K-$1.4K	

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: • 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
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]

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 Transportatioβn, 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: • 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

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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.

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]	

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]

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.)

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Forward Collision Warning
Costs
Sample Costs of ITS Deployments
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]
Benefit-Cost Studies
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]

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

ON-BOARD SAFETY SYSTEMS ARE OFFERED AS AN OPTION ON SOME VEHICLES, OFTEN PACKAGED WITH COMFORT, CONVENIENCE, AND ENTERTAINMENT SERVICES.

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*.

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

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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]

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						

● Substantial positive impacts
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
blank 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 provided 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
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]

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
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]

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	
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] **United States:** ACC is now available on most high-end automobiles. The cost to the consumer was estimated at **$3,000 per vehicl**e.[548]	
Benefit-Cost Studies	
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]	

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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ITS APPLICATION OVERVIEW

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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
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] **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]
Benefit-Cost Studies
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]

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
Sample Costs of ITS Deployments
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] **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]

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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/ng*911.

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

BASED ON A RECENT STUDY OF PRIVATE SECTOR DEPLOYMENT OF ITS, THE COST OF TELECOMMUNICATIONS- AND LOCATION-BASED SERVICES DESIGNED TO ASSIST MOTORISTS WAS ESTIMATED AT $350 PER UNIT.

OTHER ITS KNOWLEDGE RESOURCE CATEGORIES RELATED TO COLLISION NOTIFICATION

Refer to other chapters in this document.

Traffic Incident Management

Surveillance and Detection—Wireless Enhanced 911

Emergency Management

Emergency Medical Services—Advanced Automated Collision Notification

As shown in table 20, evaluations to date have documented strong customer satisfaction with ACN systems. These benefits include a heightened sense of safety, as reported by travelers testing an early deployment of the systems in Washington.[559] 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.[560]

Table 20—Collision Notification Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Mayday/Automated Collision Notification	●					●
Advanced Automated Collision Notification	●					

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

Costs

The Mayday Plus project was a six-month field operational test conducted in 1999 and 2000 that evaluated an automated crash location and collision severity notification system. The project report included the cost data for several Mayday commercial off-the-shelf products. At the time, car manufacturers installed some of these products as factory-installed options, while others were installed after market. The cost range for after-market products was from $400 to $1,895. Monthly service fees ranged from $10 to $27 depending on the level of service offered. At the time the report was written, the Mayday market was rapidly changing with an increase in the number of commercial products becoming available.[561] 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. Telematics services appear to be on the decline as several automakers in former agreements to offer such services have discontinued the service due to lack of consumer interest.[562]

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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	
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]	

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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ITS APPLICATION OVERVIEW

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LESSONS LEARNED

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. ITS lessons presented in this report are collected primarily from case studies, best practice compendiums, planning and design reviews, and evaluation studies. The ITS Electronic Document Library, Transportation Research Board's Transportation Research Information Services, international transportation literature databases (e.g., Transport), conference proceedings, and interviews are major sources for the documents that are reviewed for collection of lessons.

The lessons are based on experiences of ITS stakeholders from numerous ITS projects and programs in the country. A major focus for lessons presented in this section has been to gather evidence from which other stakeholders could benefit. This section presents a synthesis of lessons learned knowledge about key ITS areas of interest. More extensive details for the same and many other lessons can be found in the ITS Lesson Learned Knowledge Resource (LLKR).

The LLKR contained over 350 lessons as of the end of December 2007. The lessons learned relevant to each of the main lesson categories and topic areas were analyzed for themes and examples that support these lessons. Key lessons are presented by the subtopic areas that describe the types of lessons of the major category, shown in sidebars. (For example, the key lessons from the design and deployment category are broken into lessons relating to project management, requirements and design, standards and interoperability, implementation, quality assurance and testing, and design tools and models.) For selected lessons, noted in bold typeset, examples are presented that describe the experiences of agencies that did (or did not) take the action described in the lesson. Because these lessons presented are based on agencies' real-world experiences, they are offered as evidence-based lessons learned.

The information presented in this section follows this organizational approach:

- A description of the lesson category, including the types of lessons presented in subcategories
- A presentation of key lessons shown in sidebars
- A discussion of field evidence for selected key lessons, which are bolded
- Insight boxes that highlight points of major learning on a topic
- A short conclusion for the lesson category

LESSONS LEARNED: CATEGORIES

Management and Operations

Policy and Planning

Design and Deployment

Leadership and Partnerships

Funding

Technical Integration

Procurement

Legal Issues

Human Resources

The lessons learned information contained in this document is based on what has been captured through the efforts of developing the ITS Lessons Learned Knowledge Resource (*www.itslessons.its.dot.gov*), and should not be considered as official policy or guidance from the U.S. DOT.

The lessons learned presented in this section represent the experiences of many ITS practitioners across the country and can serve as a valuable resource for leaders in making informed decisions on future ITS projects and programs.

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MANAGEMENT AND OPERATIONS

ITS stakeholders use the phrase management and operations (M&O) to describe a decision-making approach 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.

Specific lesson topics on M&O include operations structure and strategy, M&O plans and programs, systems data and storage, performance measurement and evaluation, and M&O tools and models.

OPERATIONAL STRUCTURE LESSON

- Coordinate across jurisdictions, share resources, and create procedures that do not threaten individual agencies' roles.

Evidence-Based Lessons Learned

Operations

Lessons learned on managing and operating ITS overwhelmingly exemplify a key strategy: operate ITS as a regional endeavor. Operators understand the value of working together and realize the benefits of pursuing M&O strategies on a regional scale. However, historically, the perception has been that M&O is a local issue, not regional. Ultimately, a change in the institutional culture will be required to improve regional communications and coordination that will impact transportation decision making and benefit the traveling public. Operations focuses on two distinct categories: operational structure and operational strategies. The following discussion focuses on the experiences of many ITS professionals in establishing sound management and operations philosophies and strategies.

Operational Structure

Each agency needs to recognize that the traveling public is concerned, not about jurisdictional lines on the map, but about moving quickly, safely, and efficiently through the network. Therefore, regional transportation officials should focus on this end result. Key lessons on creating such an operational structure are presented below.

Coordinate across jurisdictions, share resources, and create procedures that do not threaten individual agencies' roles. Operational personnel at successful transportation management centers (TMCs) have found innovative ways to overcome institutional and technical limitations to maintain traffic incident management coordination. By developing small personal groups, trust is established that permeates throughout the corresponding organizations. The co-location of agencies in a building is often a means of effective operations structure, such as a TMC shared by traffic operators, transit staff, and public safety personnel. In this case, the planning, development, and operation of the facility are geared to effect regional coordination among practitioners. Evidence of such cooperation is provided below:

- In 2001, the Mid-Ohio Regional Planning Commission recognized the need for a multi-jurisdictional operations facility where transportation and emergency agencies could work side by side to manage traffic, transit, incidents, and emergencies. The Central Ohio Regional Transportation and Emergency Management Center (CORTRAN) evolved into a collaborative effort between State, county, and city transportation agencies; as well as emergency and public safety agencies. The commission continues to support the CORTRAN effort with State and local funds, and by guiding the partners in forming an intergovernmental agreement. The increased efficiency, productivity, and professional ties that can grow from such cooperative arrangements suggest that this should be a more conscious part of institutional consideration.[567]

- When Maryland's Coordinated Highways Action Response Team program began, it was a challenge to establish the relationships necessary among the participating agencies—Maryland State Highway Administration (MdSHA), Maryland State Police (MSP), and Maryland Transportation Authority. As the nucleus agency, MdSHA found it useful to build a relationship with other key agencies by cooperatively funding joint needs. For instance, MdSHA agreed to fund several necessary items for MSP including paint for outlining crash scenes, facilities improvements for the jointly-staffed transportation operations centers (TOCs), and fully-equipped motorcycles that could be used for reaching crash scenes during peak travel hours. In return, MSP has co-located full-time staff at the statewide operations center.[568]

There is usually a tradition of agency and jurisdictional independence, and some practitioners may have never considered options for sharing facilities, equipment, or other resources. However, these lessons indicate that multi-jurisdictional facilities save money, and enhance communication and collaboration among participants.

OPERATIONAL STRATEGIES LESSON

- Continually seek ways to make operations more effective when deploying ITS.

Operational Strategies

Continually seek ways to make operations more effective when deploying ITS. Critical to the ongoing success of ITS implementation is an effective operational strategy. These strategies are meant to combat congestion and unreliable travel.

- The Capital Area Rural Transportation System (CARTS) in Austin, Texas has an agreement with its vendor, but it also has a part-time staff person whose primary responsibility is technology support. Upon completion of the system deployment, this person will begin providing technical support on a full-time basis. CARTS management feels that this approach works better than relying solely on the software or hardware vendor because it enables problems to be resolved more quickly.
- An example of a different operational strategy occurred in Ottumwa, Iowa. The Transit Administrator in Ottumwa eventually had the automated vehicle location/mobile data terminal (AVL/MDT) software installed on her computer. She believes this has been beneficial since she now understands the problems that the dispatchers are having with the system and can help with solutions. To employ an effective system, it is important for managers to understand the problems that may occur. Installing software on the manager's computers allows them to get a better feel for the kinds of problems that are occurring and ways to mitigate them in the future.[569]

Maintenance

A successful ITS project is not solely dependent on how well the system was designed and deployed; ongoing success is dependent on how well the system is maintained and operated. A well-administered maintenance program is key to operating the system at peak efficiency. The experiences of several agencies pertaining to maintaining ITS applications are described below.

Evaluate and upgrade maintenance programs on an ongoing basis. A maintenance plan should be developed that addresses maintenance requirements, staffing and resource gaps, training programs for employees, a spare parts inventory, prioritization of maintenance needs, and preventive maintenance. A preventive maintenance plan should note all materials, equipment, and procedures that are needed to prevent problems with the element or system. A preventive maintenance program should reduce the overall demand for subsequent maintenance needs.[570]

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INSIGHT—OPERATIONS AND MAINTENANCE MANUAL

Several States and regions have developed operations manuals for their transportation management centers. Insights on such "best practices" commonly contained in these manuals include:

- Maintain complete as-built and as-modified drawings and specifications of all system equipment.
- Include maintenance and operations personnel in all phases of the project to ensure that their perspectives are included in all phases of the system life cycle.
- Perform an analysis of operations requirements of current ITS systems.
- Develop an operations manual for each system.
- Develop a program manual for each project or system.
- Monitor the amount of resources consumed.
- Maintain a detailed inventory of all system components.
- Give high priority to system maintenance to minimize liability risk.
- Obtain an annual maintenance contract on all computers and other hardware that is not easily supported by agency maintenance staff.
- Monitor contractor performance when contracting system operations and consider corrective action when necessary.[571]

MAINTENANCE LESSON

- Evaluate and upgrade maintenance programs on an ongoing basis.

In evaluating their maintenance program, New Jersey DOT personnel turned to several other agencies to study how they evaluated their programs. From this information, they identified some best practices, determined what would work in New Jersey, and developed recommendations for improving and upgrading their own maintenance program.[572]

- The California Department of Transportation (Caltrans) has developed a maintenance plan for the Los Angeles and San Francisco areas that, along with the descriptions of the maintenance activities, includes the staffing requirements and the associated costs of preventive and corrective maintenance.
- The State of Florida has developed a preventive maintenance plan that notes all the procedures, equipment, and materials required for preventive maintenance. In addition, the Utah DOT has developed an advanced transportation management system field maintenance manual that identifies and defines standards for unscheduled and preventive maintenance of all field devices. As part of its plan, the Utah DOT has developed a maintenance management system that tracks devices, monitors failure history, and recommends preventive maintenance schedules based on the recorded histories.[573]

Properly performed maintenance improves system performance and results in fewer equipment failures and lower life cycle costs. Evaluating the operations and maintenance (O&M) of ITS programs on a regular basis provides a foundation to gauge a system's operational efficiency and provides documentation for ITS professionals to plan and fund future system upgrades.

SYSTEM DATA AND STORAGE LESSON

- Strengthen interest in data archiving systems among traffic managers.

EVALUATION AND PERFORMANCE MEASUREMENT LESSON

- Provide an avenue for operators and customers to get involved in the planning process, incorporate operational performance measures in strategic and long-range plans.

System Data and Storage

Public agencies often struggle to collect credible data to evaluate the performance of a transportation system. Many agencies have inadequate resources to collect data other than speeds and travel times. Ironically, without the resources to properly evaluate the system and demonstrate improved performance, it becomes more difficult to justify additional resources to continue to operate and maintain the system. As the need to integrate performance measurement into the transportation decision-making process continues to grow, professionals look for ways to collect, archive, and disseminate high-quality data. The experiences of several transportation professionals on data collection and archiving are illustrated below.

Strengthen interest in data archiving systems among traffic managers.

- The University of Virginia and the Virginia Transportation Research Council (the research arm of the Virginia Department of Transportation (VDOT)) have developed a statewide data archive for VDOT managers. One of the many functions supported by the archive is performance measurement.

INSIGHT—THE ROLE OF TRAFFIC MANAGERS IN DATA COLLECTION

Traffic operations managers may be in the best position to champion and implement data archiving systems. These managers collect the data, maintain the equipment, and are most familiar with data collection devices and protocols. Greater awareness of the tangible benefits of developing and maintaining data archives would encourage traffic managers to champion such systems. Current trends and anecdotal evidence indicate that more traffic managers are beginning to take an interest in developing and maintaining data archives. The following are two major benefits of data archiving to traffic managers:

- Performance monitoring helps traffic managers preserve or expand funding for operations.
- Detector status reporting helps traffic managers diagnose and trouble-shoot extensive data collection systems.[574]
- The Ohio DOT Traffic Management Section studied several of the measures found in the Mobility Monitoring Program reports. The agency's goal was to use the archived data in combination with other, more widely available data to construct a method to evaluate operations on the entire roadway network.[575]

Evaluation and Performance Measurement

Performance measures help agencies to set standards, identify successful operational components, recognize areas that need improvement, and document accomplishments. Management can use the information to justify future resources for operating and maintaining existing systems and to propose new ITS projects for the region. The following lessons learned recognize experiences with performance measurement.

Provide an avenue for operators and customers to get involved in the planning process, incorporate operational performance measures in strategic and long-range plans. A long-range transportation plan (LRTP) can provide better information to customers and stakeholders on the progress being made toward desired goals and objectives and can serve to make long-range plans more real to the public. Moreover, incorporating

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performance measures helps to ensure that regional transportation system M&O programs receive adequate attention in prioritization of projects for funding.

- The Washington State Department of Transportation (WSDOT) found customer-oriented performance measures to be effective in drawing attention to the benefits associated with its transportation investments and in building credibility for the agency. As part of WSDOT's efforts to define performance measures for traffic congestion, the agency moved beyond using the traditional measure of average travel speeds. Instead, the agency added measures focused on travel reliability. These measures were developed through coordination between planners and operators, and involved ongoing coordination to track performance. Prior to this effort, non-recurring delay did not receive this systematic consideration. According to a WSDOT staff person, "The Secretary felt that by building the State DOT's accountability, the agency could attract more funding. The Secretary focused on making the case that WSDOT is on top of things. The best way to do that was through operations data because it gets at aspects of the system that the public cares about."
- WSDOT found that the benefits included helping planners focus on the day-to-day experiences of transportation system users. This collaboration between operations and planning personnel recognizes the significant impact that these measures have in improving the performance of the transportation system.[576]

Public agencies need to make decisions based on limited or less-than-ideal information. Performance monitoring and the associated decisions stemming from transportation system performance data should be viewed in this context. Some analysts believe that a wide gap remains between a multi-modal, system-wide performance measurement system and the available data to support it. Some agencies may be taking a "wait and see" attitude in regards to using archived data from TMCs. Other agencies may be hoping that probe vehicle data from cellular phones or vehicle monitoring systems will fill the data gap for performance monitoring. Some agencies may rely only on their own data and do not trust data collected by another agency. Yet, numerous practitioners around the country have been using available data resources to make informed decisions about system performance.[577]

Management and Operations Tools and Models

ITS can be viewed as a tool for addressing transportation management and operational needs. However, within the realm of ITS are tools and models that are potentially valuable for enhancing operational strategies and making the M&O process more efficient and cost-effective. Technologies such as Web sites, geographical information systems, AVL, and computer-aided dispatching (CAD) have given system operators new tools for improving planning, operations, and management of transportation systems. The following discussion and examples focus on the use of M&O tools and models by several agencies to further enhance the operations of their transportation systems.

Design Web sites with usability in mind and obtain feedback from customers. Traveler information Web site developers should focus on usability to create quality Web sites. To enhance the usability of the site, it is important to keep in mind a range of issues: from basic reliability and presenting information in a well-organized format to expanding ways that people can access the information. Thus, to ensure a successful and user-friendly traveler information Web site, it is imperative that designers conduct a thorough assessment of how their customers will utilize the Web site.

MANAGEMENT AND OPERATIONS TOOLS AND MODELS LESSONS

- Design Web sites with usability in mind and obtain feedback from customers.

- VDOT integrated information provided by various sources such that users could get to the information they needed as quickly as possible.
- Developers of the Louisville-Southern Indiana traveler information Web site—TRIMARC—view ease of use as very important. TRIMARC developers gather information and ideas from other traveler information Web sites and make TRIMARC as compliant with accessibility standards as possible, even providing interactive maps.
- Georgia Navigator—the Georgia DOT's intelligent transportation system—includes customized information on travel times, features "My Navigator" personalized home page, and automatically sends information to mobile devices such as personal digital assistants and cellular phones.[578]
- In an effort to continuously improve TranStar—the traveler information Web site for the Houston metropolitan area—the Texas DOT reviews the site on a monthly basis and implements new features every two or three months.
- The Denver Regional Transportation District, has developed beta-test groups of Web site users who try out new features and comment on redesigns.[579]

Identifying what users want from traveler information Web sites can be the first step in improving the quality of the sites. Developers of the best traveler information Web sites mentioned receiving feedback from users and using their comments to address technical issues or update the information provided. Thus, when designers are creating or updating traveler information Web sites, it is imperative that they include a thorough assessment of their customers' requirements to ensure a successful and user friendly site.

Management and Operations—Conclusions

ITS program managers and practitioners are continuously developing strategies to improve the efficiency and reliability of transportation systems and infrastructure. However, a successful ITS project is not solely dependent on how well the system was designed and deployed. Ongoing success depends on how well the system is managed, maintained, and operated. Using sound solutions and proven strategies can increase efficiency in developing successful M&O programs. Learning from others experiences can help develop better programs, make wiser use of available tools, and improve the performance of the system.

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POLICY AND PLANNING

Lessons in the policy and planning category discuss policies and approaches used to incorporate the consideration of ITS products and services in the transportation planning process. These approaches may include the development of policies used to elicit buy-in from regional stakeholders, as well as various planning documents (such as a regional ITS architecture, an ITS strategic plan, a concept of operations, a traffic analysis tool, or a long-range transportation improvement plan). Specific lesson learned topics discussed below include policy, planning, architecture and planning tools, and programming.

POLICY LESSONS

- Develop ITS stakeholder policies to ensure efficiency, consistency, and interoperability in deploying integrated systems.
- Develop a formal ITS data sharing policy.

Evidence-Based Lessons Learned

Policy

Develop ITS stakeholder policies to ensure efficiency, consistency, and interoperability in deploying integrated systems. A concerted approach to creating and enforcing statewide or regional ITS deployment policies will enhance regional interoperability, uniformity in implementation, efficiency improvements, and coordination with other transportation agencies.

- The New Jersey DOT experience with TOC planning, design, and operation suggests developing several policy and planning documents including: a concept of operations plan that summarizes what the system is supposed to accomplish and under what conditions it will be done, a TOC operations manual to help guide operators and engineers during the course of daily operations, and a policy document on fiber optic and wireless communications technologies for ITS deployments.[580]
- Experience from a project that combined freeway, arterial, and transit management technologies on State Route 17 and I-880 in Silicon Valley, California suggests developing policies on the following key issues:
  - The ability of one jurisdiction to assume control over equipment located in a neighboring jurisdiction
  - The use of maintenance staff from one jurisdiction to repair equipment in another jurisdiction
  - The rights of individual jurisdictions to use the deployed equipment for other purposes than defined by the group
  - The assignment of operational and maintenance responsibilities and funding
  - Liability concerns
  - Policies specifying the hierarchy of control over particular components

  These issues, among others, resulted in significant delays in approving an overall memorandum of understanding that subsequently defined system operations. (In 2002, all direct partners finally agreed upon the memorandum.)[581]
- The Colorado Department of Transportation (CDOT) has a policy on a wireless communications shared resource agreement with a local provider and has formed public-private partnership arrangements to address its wireless communications needs.
- In 2004, the City of New York issued a request for proposals from private ventures to implement a city-wide wireless network using a city-owned operating band frequency of 4.9 GHz for fire and police departments, traffic signal control systems, public safety, and emergency management applications. If successful, such arrangements with the private sector provide public agencies with access to the latest wireless communications technologies.[582]

Develop a formal ITS data sharing policy.

In a survey of transportation agencies regarding data sharing, more than half (18 out of 34 agencies) reported having a policy on data sharing in place and several others reported having plans to develop one. A formal policy aids data dissemination by providing a process for handling requests for data from other government agencies and private sector companies. This kind of formal process helps with ensuring fair treatment, as well as managing expectations and resources.[583]

INSIGHT—WHAT TO INCLUDE IN A DATA SHARING POLICY

Data sharing policies often include the following elements:

- Type of public data to which a private entity has access
- Fees or costs borne by the private sector associated with access and dissemination of public data
- Sharing of privately generated data with the public agency and protection of their value
- Dissemination of data by private entity to other parties (free or resale)
- Control over video images
- Requirements that the private entity use the public data to provide information to travelers
- Acknowledgement of public agency as source of data (e.g., logo)
- Technical requirements for access (e.g., communication system)
- Allowable advertising
- Personal identification and graphic images of serious injuries
- In-kind services provided by the private sector (e.g., airtime for public service announcements)
- Training on use of the public data
- Intellectual property rights
- Standardization of data format
- Monitoring usage of traveler information services
- Liability for data quality and availability
- Sharing of private entity revenue with public agency
- Placement of private equipment on public rights-of-way[584]

In the 1990s, the U.S. DOT chose four metropolitan areas (Phoenix, San Antonio, Seattle, and New York) to be models for regional ITS deployment. All four of these Model Deployment Initiative (MDI) sites have policies that primarily allow open access to the transportation information generated by the MDI equipment. But that information is shared through formalized agency policies, with each of the agencies addressing those policies in different ways. In particular, access and use of data by law enforcement agencies required extensive discussion and policy detail to ensure that the privacy of the general public was protected. (For instance, in Phoenix, Arizona DOT (ADOT) personnel feel that the agency's provision of feeds from traffic surveillance cameras to the public has been successful. In addition, agencies might find a written policy on camera use helpful. Furthermore, agencies must resolve if video surveillance tapes will be made, for what purpose, and who may gain access to them.[585]

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Planning

Learn the successful approaches to ITS planning.

- U.S. DOT analysts examined the institutional and other non-technical issues that public-sector participants encountered in deploying ITS. This led to the identification of nine approaches that were used successfully by the public-sector participants at the ITS MDI sites and other locations.
- Develop a regional perspective
- Make ITS visible
- Understand the nuances of partnering
- Plan for long-term operations and management
- Develop a regional management structure
- Facilitate ITS within your organization
- Identify appropriate procurement mechanisms
- Address intellectual property rights early
- Develop written policies[586]

INSIGHT—PLANNING A COMPLEX ITS PROJECT

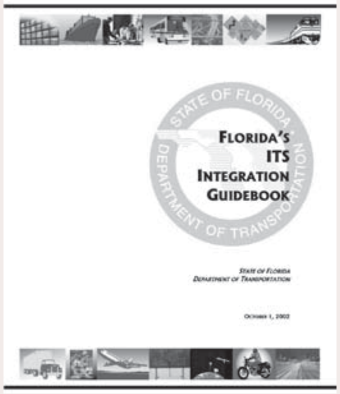
When planning a complex project, it is helpful to follow these "best practices":

- Assign a full-time Site Manager having the requisite project management and substantive skills and experience.
- Recognize in advance that an iterative, consensus-based process is time-consuming and plan accordingly.
- Anticipate the large amount of time that document review will take for all the parties involved in the project.
- Develop a realistic schedule and allow additional time as a safety factor to accommodate document review and related activities and to avoid schedule slippage.
- Provide for project management oversight and guidance to gain efficiency and coordination across all the tasks and work groups.
- Take account of the size and experience of each agency to help "level the playing field," and offer extra support where it is needed.
- Leverage the experience and resources of the larger partner agencies, and seek ways to support the staffing requirements of the smaller partner agencies.
- Be flexible and willing to make changes during the development, as it is impossible to anticipate all the issues and challenges that will arise.[587]

It is important to plan for greater time and project complexity than expected. The Puget Sound Regional Fare Card (RFC) project—which involved seven partner agencies from the Central Puget Sound region of Washington—is technically, procedurally, and organizationally very complex. This level of complexity places substantial demands in terms of time and effort on the agencies and their staff. One of the RFC Site Managers stated the challenge succinctly, "A regional fare card project will be more difficult and complex than you can imagine." [588]

PLANNING LESSONS

- Learn the successful approaches to ITS planning.
- Anticipate challenges in planning and deploying ITS in a rural environment.



ARCHITECTURE AND PLANNING TOOLS LESSON

- Use the National ITS Architecture and other tools for effective ITS planning.

Anticipate challenges in planning and deploying ITS in a rural environment.

- A deployment of smart card technology in a rural environment in New Mexico presented significant challenges. The New Mexico DOT anticipated the challenges, overcame the issues, and achieved a successful deployment of an Intelligent Coordinated Transit Card (ICTransit Card) system in a rural setting. Rural areas typically have limited local resources, so staffing needs for transit providers are difficult to fulfill and funding is at a minimum. Limited resources of a rural agency may require a contractor to provide operations support in addition to the technical deployment support. For the ICTransit Card project, the contractor staffed a help desk that proved to be invaluable. Agency staff could work out issues on a one-on-one basis and were often able to resolve issues the same day. In other instances, a trainer would do a "ride-along" with a transit driver in order to detect problems in the system.[589]
- As part of an effort to evaluate projects in the states that received Federal ITS Integration Program funds, the WSDOT Transportation Center evaluated five advanced traveler information system (ATIS) projects, three of which involved predominantly rural deployment. The study concluded that implementing ATIS in rural and remote areas offers challenges that do not exist in metropolitan areas. Some of these challenges include longer distances between needed ATIS resources and increased susceptibility of vandalism to ATIS devices. Traveler information for remote regions can involve issues that have a direct and often time-critical impact on traveler safety, such as severe weather conditions in potentially hazardous terrain. In these cases, ATIS notification must be highly reliable, accurate, and timely.[590]

Architecture and Planning Tools

Use the National ITS Architecture and other tools for effective ITS planning.

- Experience from 12 in-depth case studies suggests that, by using the National ITS Architecture's user services, planners can reduce their efforts and streamline the process of developing their ITS vision. It is recommended that workshops and focus groups be conducted to develop goals and objectives for the ITS program that map to the identified needs. It is also useful for the goals and objectives to be associated with short-, medium-, and long-term solutions and cross-referenced to individual user services and user service bundles (categorized by rural and urban categories). The ITS user service objectives should be defined on a regional basis. These objectives should address specific sub-objectives, meet customer needs, and target solutions to specific problems.[591]
- The Florida DOT District VII's ITS Integration Guidebook serves as an informational tool in defining the ITS integration context technically and institutionally and recommends an iterative process to achieve overall ITS integration that involves planning, institutional, and technical integration processes. At the core of the suggested approach is an iterative process of developing, using and maintaining a regional ITS architecture as part of an ITS strategic plan, considered the focal activity in planning and conducting ITS integration.[592]
- For public-sector investments, a transferable methodology was developed that facilitated quantitative evaluations of projected ITS costs and benefits in concert with various conventional improvements. Used in Seattle, the methodology is called the Process for Regional Understanding and Evaluation of Integrated ITS Networks (PRUEVIIN). PRUEVIIN enables planners to move beyond the constraints of the artificial "average" conditions now built into traditional planning models. This new methodology not only

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reveals important characteristics of proposed alternatives but also allows ITS to be considered directly and fairly in the planning process. The outcome of incorporating ITS into the planning process through an analytical methodology such as PRUEVIIN is a better understood, more robust, and more cost-effective transportation system for the future.[593]

Programming

Include ITS in the State's long-range transportation plan to take advantage of project synergies and stable funding.

- An independent evaluation of Delaware DOT's statewide integrated transportation management system—known as DelTrac—recommended including ITS projects in the department's long-range transportation plan (LRTP) in order to receive more stable and predictable funding. The 2002 Statewide Long-Range Transportation Plan stated, "… we will improve the management of Delaware's transportation system through the application of Intelligent Transportation System (ITS) technologies." This level of commitment to ITS was observed not just in the planning documents but also in comments made by Delaware DOT staff.[594]
- The metropolitan model deployment in Seattle—known as SmartTrek—was a partnership of 20 public and private organizations that implemented emerging technologies to help improve the performance of the Seattle region's existing transportation system. The team that evaluated SmartTrek recommended that all ITS deployments include planning for the future, including developing traveler information business plans and forecasting O&M costs. Although the diverse participants on the SmartTrek evaluation team faced several obstacles, none of them proved to be insurmountable or drastically affected the ITS deployments. Use of a long-range business plan and support for a long-term project vision contributed to the project's success.[595]
- The Washington State DOT suggested incorporating operational performance measures into its LRTP to provide an avenue for operators and customers to get involved in the planning process. The LRTP can provide better information to customers and stakeholders on the progress being made toward desired goals and objectives and can serve to make long-range plans more real to the public. Moreover, incorporating performance measures helps to ensure that regional transportation system management and operations programs receive adequate attention in prioritization of projects for funding.[596]

Policy and Planning—Conclusions

The policy and planning phase is the foundational step upon which the successful implementation of an ITS project hinges. Most ITS projects require cooperation among divisions within an agency (e.g., planning, operations, maintenance, etc.), as well as among regional agencies that are involved in managing some aspects of transportation systems (e.g., traffic, transit, goods movement, law enforcement, emergency response, etc.). ITS program managers and practitioners must strive to develop consistent policies acceptable to stakeholders, use the National ITS Architecture and other standard tools to prepare planning documents, and mainstream the ITS planning process by providing necessary input to the regional long-range transportation programming process. Learning from others' experiences can help develop better policies, make wiser use of available tools, and improve the efficiency and effectiveness of planning.

PROGRAMMING LESSON

- Include ITS in the State's long-range transportation plan to take advantage of project synergies and stable funding.

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DESIGN AND DEPLOYMENT

Lessons in the design and deployment category discuss the 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. Specific lesson topics on design and deployment include project management, requirements and design, standards and interoperability, implementation, quality assurance and testing, and design tools and models.

Evidence-Based Lessons Learned

Project Management

Make use of flexible methods and accepted techniques for successful project management. Use of project management techniques and methods helps designers deliver smarter ITS solutions on time and within budget. Many ITS projects have failed due to ineffective or poorly implemented project management activities.

- One of the key successes of the I-95 Corridor Coalition's test of the integration of electronic toll collection and electronic screening for commercial vehicles has been the flexible approach to project management adopted by the project team. This approach supported the mid-term project review that resulted in re-scoping of the project to eliminate the transponder subsidy for the motor carrier industry and to reallocate funds to support the development of online program enrollment capabilities. This flexible approach also enabled the project team to leverage the policy changes that enabled the creation of "super accounts," which facilitated the creation of Best Pass and PrePass™ Plus. The flexible structure also enabled extensive outreach efforts by the Maryland Motor Truck Association and the New York State Motor Truck Association to promote these super accounts.[597]
- During the Seattle Wide-area Information for Travelers (SWIFT) field operational test, confusion about responsibilities and roles affected the project development process. Early on, for instance, differences in how some organizations perceived their involvement in the SWIFT project caused some to view certain development activities as being a waste of time. Others did not understand and/or misinterpreted their roles in the project, which caused them to waste time. Some organizations viewed the SWIFT project as being a "research and development" project rather than a "demonstration" project that would involve actual implementation of new technologies. As a result, some organizations exhibited a greater sense of urgency in completing their assigned tasks, or in building the SWIFT system, than did others. Some team members eventually performed activities that were outside or in addition to their initial responsibilities. This problem produced some hard feelings among the team members, but it was generally acknowledged that some organizations and individuals "picked up the slack" for those who did not clearly understand their responsibilities and roles. One critical organizational element was the weekly teleconference. This simple, yet cost-effective method of managing and discussing the technical issues involved with the project was deemed by many of the SWIFT team members as a primary instrument of the project's success.[598]
- CDOT's I-25 Truck Safety Improvements Project (TSIP) was a large multi-jurisdictional project that utilized an integrator and manager. CDOT believed this was sound rationale even though this structure was not a complete success. The CDOT-manager partnership was a positive experience; however, the CDOT-integrator partnership was not as successful due to several unresolved issues. The fact that the overall TSIP project was a success despite CDOT's problems with its integrator shows the value of applying systems engineering principles.

PROJECT MANAGEMENT LESSON

- Make use of flexible methods and accepted techniques for successful project management.

REQUIREMENTS AND DESIGN LESSON

- Design and tailor system technology to deliver an ITS project that meets the needs of the users and customers.

- CDOT developed a five-tiered technical management structure that was implemented on a previous project and was maintained on the I-25 TSIP because of its proven effectiveness. The five-tiered structure is comprised of five levels of oversight ranging from the upper management level with less frequent meetings to the day-to-day participants that meet more frequently. Because of the deployment focus of this project, CDOT was able to eliminate two of the management levels that would typically be required for a normal software development project. The structure will be maintained and of even greater value on future projects to develop the CDOT core advanced traffic management system/advanced traveler information system.
- Due to successful application of the risk management principles that form a key part of systems management, CDOT was able to develop recovery plans to complete the intended work when the integrator's services were discontinued. Because of the systems engineering principles that were established, CDOT management was able to overcome adversities and complete the project successfully. By maintaining budgeted costs and schedules, CDOT was able to achieve the established goals for the region that included increased mobility and safety, improved productivity, and enhanced intermodal connectivity and inter-jurisdictional coordination.[599]

Requirements and Design

Design and tailor system technology to deliver an ITS project that meets the needs of the users and the customers. It is important to keep the design simple by only including necessary components. It is inefficient to design a system with high-end technologies that will not be used. The users' needs and abilities should always be kept in mind when deploying new systems.

- When implementing a pilot program for an AVL system in its snow removal truck fleet, VDOT learned that the system should not be so cumbersome to use that truck drivers are overwhelmed. Instead, the system should be tailored to deliver information of useful quality and quantity that the drivers can easily understand and absorb.
- Two-way messaging was included in the AVL system as a means of directing the contractor portion of the snow removal truck fleet that was not on the VDOT radio network. The intention was for supervisors at headquarters to send command messages ("Start plowing", "Return to base", etc.) to drivers via in-vehicle units (IVU)—in-vehicle global positioning systems (GPS) tracking receiver and communication devices) and that drivers would be able to send a limited set of preprogrammed messages back to headquarters ("I've finished plowing", "I'm lost", "Yes", "No", etc.). In practice, however, two-way messaging was of lesser value to the contractor fleet than to the VDOT state fleet, even though VDOT trucks also had radios. Although the same hired trucks were used during each storm event, the operators who drove the trucks were often different. The turnover in operators negated the value of the operator training that was undertaken prior to the winter season. Instead, staff responsible for the AVL system had to train the newly hired truck operators in the use of two-way messaging as they reported for duty at the start of the every storm. The burden of training a constant stream of new drivers led to the abandonment of the AVL system as the preferred form of communication.[600]
- Every State has a unique operating environment for commercial vehicles that will need to be considered when designing and deploying Commercial Vehicle Information Systems and Network technologies intended to be integrated with out-of-state systems. The use of the databases and human interfaces, developed as part of several field operational tests varies significantly. A survey of commercial vehicle inspectors in late

1999 found high use of various databases and systems in Connecticut and Rhode Island but lower use in New York, Massachusetts, and Maryland. Much of the variation could be attributed to the technological and institutional environment within each State. The evaluation strongly suggested these technologies could save time for roadside inspectors and improve the speed and accuracy of data reporting.

- During the design and deployment of the Safety and Fitness Electronic Record Data Mailbox system, which enables states to exchange safety data on commercial carriers, it became apparent that New York faced several significant challenges that other States did not encounter. New York is substantially larger and more geographically differentiated than the other states participating in the program, except Pennsylvania. New York has a border with Canada, meaning that information related to provincial addresses is more important there than in states such as Connecticut or Maryland. 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. Additionally, a significant percent of the carriers in the state operate on an intrastate basis only and are not represented in the U.S. DOT Inspection Selection System database.[601]
- Snow removal activities represent the worst-case environment for testing AVL technology, as VDOT learned when conducting its AVL pilot program. During snow events, temperature and climatic conditions are at their worst. GPS signals undergo serious electronic signal attenuation and noise effects because of snow on trees and emissions from vehicle radios and strobe lights. Vehicle-mounted units are subject to significant corrosion, mechanical shock, and fatigue conditions. Although all of these conditions affected the performance of the AVL system in Virginia, they did not preclude successful use of the technology over three winters of use.
- During its installation of IVUs on its snow removal fleet, VDOT also learned that IVUs should be permanently installed in vehicles when possible. Along with the harsh winter environment, the repetitive installation and removal of IVUs also resulted in a higher than expected failure rate (5 to 10 percent per storm) for wiring and sensor units. The unsecured units (i.e., those without a mounting board) moved around in vehicles during operations, resulting in the connecting plugs frequently being disconnected from the back of the IVUs, breaks in the wires, factures of the display screen, and separation of the antenna leads.[602]

Standards and Interoperability

ITS standards allow systems to talk to one another by supporting information exchange or data sharing. By developing a policy for ITS standardization, agencies can ensure that new ITS devices, systems, communications, and spare parts will all work as intended, in an interoperable manner.

Recognize interoperability as an important issue in achieving the vision of a nationwide 511 system. Deployers of 511 systems should recognize that interoperability is becoming an important issue in achieving the vision of a nationwide 511 system and should consider ways to achieve interoperability in their systems. Interoperability deals with how 511 services with adjacent operating borders provide seamless information to users. A growing number of 511 systems and major national travel corridors share boundaries and/or have significant travel between them. Callers in one metropolitan area may wish to dial 511 to find information not just for their local travels, but for their entire trip, which might include traveling through other metropolitan areas or regions and crossing

state borders. As the number of areas of the country offering 511 services increases, it is believed that users will have an expectation that information relating to areas outside their region will be available in a single call. For the vision to become a reality, callers need to be able to get information from areas outside the local 511 system, requiring interoperability of systems at the local level.

- Currently, interoperability is being approached in different ways by different deployers. This diversity of approaches will help provide the 511 services still in the planning stage with insight and lessons as to the best, most applicable solutions given a certain set of technical and financial circumstances. For example, since December 2002, the metropolitan Cincinnati system, the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS), has been successfully passing incident information into the Kentucky statewide Condition Acquisition Reporting System (CARS). This data sharing is accomplished using Traffic Management Data Dictionary (TMDD) ITS standards, implemented in Traveler Information Markup Language/eXtensible Markup Language. Kentucky traffic events reported in ARTIMIS are imported to the CARS-511 system in a fully-automated manner, without any manual data re-entry. Although the two 511 systems were developed independently, the standards are allowing seamless data exchange.
- In the San Francisco Bay area, the effort to deploy an interoperable system may have created some early implementation delays. However, the advantages of developing a region-wide 511 system that has been tested will reduce the implementation schedule for other agencies as they prepare to implement a 511 system and will help to more equally distribute the development costs among all the system implementers.[603]

STANDARDS AND INTEROPERABILITY LESSONS

- 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.

Cultivate commitment by the Federal Highway Administration and/or other appropriate agencies at the Federal level. While a contractual relationship existed between the Federal Highway Administration (FHWA) and VDOT for the integration of real-time data from the Virginia State Police (VSP) into VDOT's Smart Traffic Center, it became clear early on that FHWA was committed to the mission and success of the VDOT Richmond District during this project.

- For example, when issues were raised about the exact protocol to use for the exchange of information between VSP and VDOT, FHWA was willing to evaluate the available protocols. This evaluation is documented in "Final VSP Standards White Paper." After reviewing the candidate standards' stability, the current usage of the standards by others, the usability of the standards considering the fact that the VSP legacy CAD system would not be changed, and other issues with standards (e.g., TMDD and the IEEE-1512 family of standards) as they relate to the VSP CAD system, FHWA concurred with VDOT's recommendation to use the Common Alert Protocol. This one decision contributed significantly to the timely completion and success of this project.[604]

Implementation

Anticipating and preparing for the different institutional and organizational issues that arise during ITS projects will assist agencies in facilitating a smoother implementation process. Providing project stakeholders with a clear picture of the project goals and agencies' roles in accomplishing those goals will also help build a common understanding of the process and its ultimate performance. Maintaining flexibility throughout the process is crucial for agencies to be able to address any unforeseen changes that may occur. Finally, giving specific agency employees who will be users of the system an investment in its success is an important ingredient for implementing ITS technology.[605]

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Consider that advanced traveler information system deployment in rural and/or remote areas presents special challenges. Rural ATIS applications often involve remote locations that can result in additional deployment and maintenance needs. Rural ATIS device installation can involve locations that are not only remote relative to central maintenance facilities and regional management centers, but also are a significant distance from necessary power and communications systems. Terrain can affect communications transmission and coverage, making device placement, technology choices, and operational testing particularly important. These factors can also result in more difficulties with future maintenance access. While vandalism and theft are not unique to devices in rural locations, remote sites can pose additional concerns.

- One option is to deliberately place devices in secluded areas that are not conpiscuous and that are therefore less likely to be a target of vandalism or theft. However, as noted above, this can introduce additional inconvenience and cost to extend power and communications access, as well as affect maintenance access.
- The Washington State DOT reported that the seclusion of a device's site actually facilitated vandalism by making any intrusive activity less noticeable. Another option to discourage vandalism is to locate devices near occupied locations such as maintenance sheds when possible that would also have the added benefit of providing easier access for maintenance.[606]

Implement a limited-deployment fare pass system before implementing a region-wide fare card system. The Puget Sound RFC project has benefited from having first-hand experience with several transit fare pass systems over the past decade. While these fare pass systems were implemented to provide immediate benefits to transit riders, it was understood from the start that they were temporary systems—interim steps on the way to a comprehensive RFC system. These early fare systems provided invaluable experience that laid the foundation for the RFC project, giving passengers, system operators, and transit agencies a chance to learn about these systems and to identify and resolve some of their issues before committing to a full-scale, region-wide fare card system.

- Before implementing a region-wide electronic fare card system, it is important to consider the value of initially deploying a limited fare pass system, such as one for a university, in order to give transit riders a chance to get used to the new system. This also benefits the agencies by helping identify and resolve potential problems or obstacles to full implementation. Another successful practice is to examine the fare card implementation experiences and lessons from other locations and seek to apply those lessons to the local context and needs.
- Two precursor fare pass systems were implemented in the Puget Sound region in the early and mid-1990s: U-Pass and FlexPass. U-Pass was established in 1991 with the primary objective of reducing the number of students, staff, and faculty driving alone to the main campus of the University of Washington in Seattle. Riders were provided with a pass that offered a variety of benefits, including not having to pay cash for their rides and an unlimited number of rides on King County Metro, Community Transit, and Sound Transit buses. The success of this program led to the development of FlexPass, a similar system that is now in use by over 130 major employers in the Puget Sound region. FlexPass was the first employer-based program of its kind in the U.S. While these programs did not use electronic fare cards, they provided many travelers in the region with experience using a single fare pass valid on buses across multiple agencies.
- In September 1999, Sound Transit introduced a more advanced fare card system, called Puget Pass, under its Fare Integration Program. A region-wide agreement among five

IMPLEMENTATION LESSONS

- 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.

transit agencies provided transit riders a one-ticket fare system (though not a single regional fare structure) with seamless transfers on regional bus, commuter rail, and light rail services. Puget Pass represented Sound Transit's fulfillment of a commitment in its ballot initiative as well as a contractual obligation to the Washington State legislature to support regionalism in Puget Sound. This system ultimately benefited the RFC project because many of those who participated in negotiating the terms of the Puget Pass program also participated in the early deliberations and development of the RFC project.[607]

QUALITY ASSURANCE AND TESTING LESSON

- Conduct rigorous testing prior to deployment of an ITS project.

Quality Assurance and Testing

Being sure that the system has been debugged and field-tested before it is deployed system-wide will lessen the potential for a dangerous situation to occur and will improve the public's perception of how the system functions.

Conduct rigorous testing prior to deployment of an ITS project. Due to differences in traffic signal controllers and traffic signal systems, an emergency vehicle preemption (EVP) system is not simply a "plug and play" type system. Each EVP system needs to be tailored to fit the needs of the jurisdiction. During system installation, adjustments will need to be made prior to system-wide deployment. The system will need to be debugged using the parameters for that jurisdiction and, because of the nature of deploying this type of system and exposing the traveling public and the emergency vehicles to potential conflicts, a field test should be performed before system-wide deployment.

- Bench-testing can help prevent potential problems that may occur in the field when the system is deployed. Traffic controllers should be set up in the shop the same way as in the field to replicate any issues that may occur. In Fairfax County, Virginia, VDOT personnel found that their traffic signal controller software required an upgrade to allow dual use of the technology for both EVP and transit signal priority. If provided, transit signal priority should always be a secondary request to an EVP request. Prior to the software upgrade, VDOT found that the transit priority requests were granted the same level of precedence as an EVP request. If this situation had not been tested before deploying the system in the field, a serious situation may have occurred.[608]
- Staff at the Ottumwa Transit Authority in Ottumwa, Iowa felt that their project to install AVL and mobile data terminals on its transit fleet would have benefited from having a clear testing protocol and beta-testing early on in the process. In order to minimize installation costs, equipment was installed in vehicles all at once. Installation did not include any rigorous testing requirements. Revisions to the system have been made over time, but the de-bugging process negatively affects operations since the transit authority has to bring all 51 of its vehicles into the facility for modifications.

Contracts with vendors should include an acceptance testing phase as part of the implementation process for new technology. In this way, the agency is not left with a system that does not function properly once the vendor completes system development.

- In Williamsport, Pennsylvania, the vendor selected by River Valley Transit to supply its traveler information system provided an end-to-end solution, which included clear testing and acceptance procedures. This arrangement has resulted in a positive relationship between the agency and the vendor and has been key to the project's successful implementation.[609]

Using a beta-site can help improve system functionality in a limited environment and keeps implementation costs under control. A beta-test site provides software developers with the opportunity to analyze how the system works on a small scale before implementing the full-scale system. Developers can also learn from beta-test system users how best to train future users.

- During development of the ICTransit Card system, several factors lead to the selection of the Village of Los Lunas Public Transportation System in New Mexico to beta-test the system. The agency was chosen because it had a diverse clientele; it was reasonably close to the software development team (Alliance Transportation Research Institute (ATR Institute)) in Albuquerque; it had experienced users of the Client Referral, Ridership, and Financial Tracking system; and personnel were enthusiastic about deploying a smart card system. Using Los Lunas as a beta-test site allowed the ATR Institute to experience first-hand how the system would function on a daily basis and how to improve the system based on the knowledge and experience of the testing agency.[610]

Design Tools and Models

An effective needs assessment is an important step in the selection of an ITS deployment. In addition to a requirements analysis, a needs assessment also includes the use of a state or regional ITS architecture and the development of a telecommunications architecture. A regional ITS architecture is used to help define the telecommunications requirements of an ITS deployment. By identifying types, volumes, sources, and users of transportation information, a regional ITS architecture helps in understanding connectivity and bandwidth needs, as well as the nature of the communication flow (periodic, continuous, random). A regional ITS architecture progresses from defining the highest level of needs to the specifics of data elements and data flows and the standards which may be applicable.[611]

Conduct a requirements analysis to determine the most appropriate ITS telecommunications solution. Many factors must be considered in deciding upon the right telecommunications solution for an ITS Program, and a requirements analysis is an effective tool for outlining these factors. A requirements analysis is a hierarchical, iterative process for deriving and describing the full set of needs to be satisfied by a product, system, or service provider. The selection of the most appropriate telecommunications solution depends on the identification of the full set of requirements.

- In conducting a rigorous requirements definition process for the Chesapeake Highway Advisories Routing Traffic program, the MdSHA reasoned that it could not develop an efficient network for the program without knowledge of why it was needed, who would be served, and how it would be used. This information enabled MdSHA to identify the appropriate technical characteristics of the telecommunications system including data, video, and voice traffic.

DESIGN TOOLS AND MODELS LESSON

- Conduct a requirements analysis to determine the most appropriate ITS telecommunications solution.

INSIGHT—TECHNICAL REQUIREMENTS

Technical requirements must be written in terms that telecommunications engineers can use to derive technical architectures, including components (such as video, data, voice, and the local area network) and performance characteristics (such as reliability, maintainability and availability, and security). The requirements analysis should include the following three types of technical requirements:

- Functional requirements that identify what is to be done. For example, a functional requirement is that the network must carry incident information from the traffic management system to the traveler information system.
- Operational requirements that identify who or what performs the function, where the function is performed, how many perform the function, and when it is performed.
- Performance requirements that quantify performance measures such as how much, how often, or how fast.[612]
- In defining technical requirements, MdSHA was able to minimize two key risks: (1) that the agency would build a network that would not meet its needs, and (2) that the agency would build a network that would be costly to change or redesign in order to take advantage of technology improvements. By understanding and documenting its requirements, particularly by identifying who needed access to the information and how much bandwidth was required to provide acceptable access, MdSHA could build a network that adequately addressed its needs.[613]

There are a number of useful tools available for developing a regional ITS architecture. The National ITS Architecture provides a list of the elements at each step in the process, from which those appropriate to a region's architecture can be selected. The U.S. DOT also has produced a product, "Turbo Architecture," to assist agencies in the efficient development of regional architectures. U.S. DOT courses and training materials are also available.

- The Southern California ITS Showcase provides an example of a telecommunications ITS architecture. The showcase includes 17 projects distributed across four Caltrans districts. Systems from over a dozen agencies are included in or interconnected with the showcase. Each system converses with its peers through a "seed" which performs translation. Seeds are connected to a regional "kernel" which provides routing, network management, security, and other shared network services. Kernels are also interconnected via the showcase's primary network connections. Each district also contains a TMC co-owned and operated by Caltrans and the California Highway Patrol. The TMCs are also interconnected via the State's wide area network.

With a regional ITS architecture and a telecommunications architecture, agencies minimize the following risks:

- The network may be sized too small to meet the eventual demands.
- The network configuration may not match the user's needs.
- An approach is adopted that results in significant additional cost to be expanded to meet the full set of requirements.[614]

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Design and Deployment—Conclusions

Most agencies consider an ITS project successful if it meets the requirements of the agency, the needs of the customer, and is deployed within the budget and schedule constraints. Many agencies can benefit from the experiences of other agencies when designing and deploying an ITS project. Often there are numerous issues that should be addressed and resolved in the early stages of a project. Identifying other agencies with similar projects and discussing items that worked well and what they would or would not do again, can provide great benefits to an agency looking to deploy a project. The benefit of this approach is a less costly and more efficient system that meets expectations.

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LEADERSHIP AND PARTNERSHIPS

Lessons in the leadership and partnerships category 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 and accepting of ITS, and organizational structures that facilitate efficient planning and implementation of ITS. Specific lesson learned topics discussed below include leaders and champions, partnerships and agreements, awareness and outreach, and organizational management and structure.

LEADERS AND CHAMPIONS LESSON

- For regional ITS deployments involving multiple agencies, find an influential project champion for successful execution of the project.

Evidence-Based Lessons Learned

Leaders and Champion

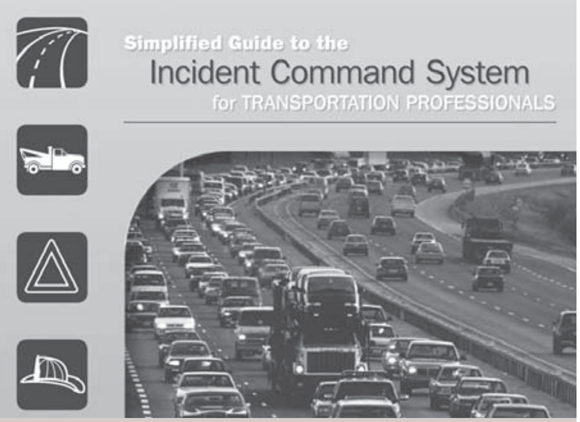
INSIGHT—ROLE OF AN ITS CHAMPION

An ITS champion can emerge in various forms including: a lead organization with strong commitment for regional collaboration; a decision maker (or a decision-making board) at a major agency in the region; a person who commands respect through the mastery of issues in transportation; an influential politician at the Federal, state, or local level; or an influential private citizen who is an adept builder of coalitions among various transportation agencies. An ITS champion can:

- Articulate the vision, goals, and objectives of the region
- Gain support from decision makers at the national, regional, and local levels
- Emphasize the need for a significant public education campaign
- Secure funding for program capital and operating costs
- Help develop strict system performance measures for participating agencies, system vendors, and integrators[615]

For regional ITS deployments involving multiple agencies, find an influential project champion for successful execution of the project.

- The Ventura County Transportation Commission (VCTC) and its board of directors successfully championed an automated transit fare collection demonstration project using smart card technology in Ventura County, California. Implemented between January 1996 and October 1999, the fare collection system, known as "Smart Passport," integrated several ITS technologies—including automatic passenger counters, AVL systems based on global positioning system technology, and contact-less smart card technology—and was applied to seven bus transit systems simultaneously. The VCTC lobbied transit operating agencies to participate in the demonstration by assuring the operators that their agencies would bear none of the costs, would receive adequate technical support to install and maintain the equipment, and would derive benefits from lower operating costs and improved service. As the participants accepted the new system, the VCTC moved from the role of champion to facilitator by establishing a working group that met monthly to address and resolve policy and technical issues. By the end of the project, the transit operators had overcome many challenges and reached a high level of institutional coordination under the leadership of the VCTC.[616]
- In addition to having a champion, establishing a clear leader and command structure is also important, especially for high-profile special events. In July 2004, the Democratic National Convention was held at the FleetCenter, a multipurpose sports facility located in downtown Boston, Massachusetts. The experience of the convention



highlights a valuable lesson—that there should be a clearly identified regional leader and a command structure that delineates the roles and responsibilities of each of the operation centers and how those operation centers will communicate with each other. The Boston region's transportation network is overseen by a myriad of local, regional, and State agencies. The planning process for the convention was complicated by the fact that there was no one clear leader for transportation issues. One of the ways that the participating agencies overcame this problem was examination of the Incident Command System—a structure developed by the Department of Homeland Security by which multiple jurisdictions coordinate their response to an event—to determine its applicability in managing travel during the convention. Clarifying the transportation leadership chain of command at the start, coupled with the use of the Incident Command System model, helped to ensure the successful planning and operation of future major public events.[617]

PARTNERSHIPS AND AGREEMENTS LESSON

- Forge regional partnership agreements capable of addressing the specific characteristics of individual partner agencies and their customers.

Partnership and Agreements

Forge regional partnership agreements capable of addressing the specific characteristics of individual partner agencies and their customers.

- The CDOT recognized the value of interagency partnership over the course of its I-25 Truck Safety Improvements Project. The partnership between CDOT, the Colorado Department of Revenue, Colorado Motor Carriers Association, and the electronic screening program PrePass™ was strengthened by the statewide automation of the commercial vehicle screening at ports-of-entry into the state. Commercial vehicle screening at three ports-of-entry were automated as part of the project, which has been highly successful. As of 2004, Colorado had the highest rate of automatic screening bypasses by commercial vehicles of any state.[618]

- A clear case needs to be made for the overriding value of regionalism. Seven public transportation agencies in the Central Puget Sound region formed a partnership to set up a regional fare card program. Factors that helped in the Puget Sound region included funding that was made available to motivate participation and defray the early costs of entry, an experience base with an early and limited fare card program called Puget Pass, visits by project partners to a fare card experiment in the San Francisco Bay area, and support from the Washington State Legislature.[619]

- A U.S. DOT survey of traffic management center staff across the country revealed that interagency agreements show management's commitment to establishing and continuously improving operational cooperation. The agreements may include common interpretation of operational goals, operational policies, organizational roles, and funding formulas. In the Texas metropolitan areas of Houston and Austin, formal agreements were established among local and State government agencies covering establishment, funding, management, and operations of the combined center. In Orlando, Florida, agencies developed a general memorandum of understanding establishing an organizational structure and documenting commitment for information sharing and implementation coordination.[620]

Consider public-private, partnership-based unique financing methods as ways to cover costs for transportation projects.

- E-470—a public toll highway in the Denver metropolitan area—is developed and operated by the E-470 Public Highway Authority, a public-private partnership comprised of eight members. Highway planning, design, and construction were financed with bonds. The 47-mile highway runs along the eastern perimeter of the Denver metropolitan area and services the Denver International Airport. The Authority experienced several ad-

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vantages to pursuing the design and construction of a facility with a public-private partnership agreement including cost savings, risk sharing, revenue growth, and efficient implementation. The Authority negotiated with outside businesses, such as insurance companies, to underwrite a portion of the highway's safety service patrol. The service is now called the State Farm Safety Patrol. This arrangement is another example of the types of relationships the authority can develop as a State enterprise that serves the public interest.[621]

- Managed-lane facilities employ various strategies—such as high-occupancy vehicle lanes, high-occupancy toll lanes, value pricing, and special use lanes—to improve traffic flow and maximize the efficiency of the freeway system. Guidance provided by the Texas Transportation Institute on funding and financing managed-lane projects suggests developing regional public partnerships to facilitate quicker financing. The State of Texas passed legislation that allows for more flexibility and control by local entities in developing transportation projects that meet the needs of the region. This legislation authorizes the formation of regional mobility authorities (RMAs) that can consist of one or more counties that have agreed to their formation. A single RMA is supposed to develop, finance, operate, and maintain each managed-lane facility. Additional proposed legislation, giving RMAs bonding authority and powers of eminent domain, would give RMAs the ability to issue bonds and finance projects. If the proposed legislation eventually passes, financing projects through an RMA would free up resources for the Texas DOT to devote funds to other needed projects that may not be as financially feasible as a toll project. Additionally, RMAs would provide for the leveraging of resources to enable a project to move forward by enhancing its financial viability.[622]

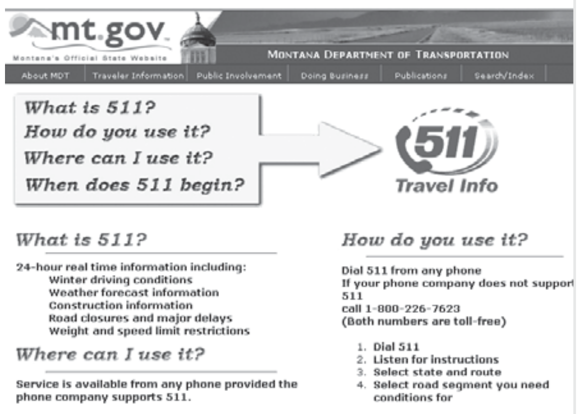
PARTNERSHIPS AND AGREEMENTS LESSON

- Consider public-private, partnership-based unique financing methods as ways to cover costs for transportation projects.

Awareness and Outreach

Consider several forms of customer outreach services, with a focus on customer convenience. For effective outreach to customers of ITS services such as 511, smart cards, or value pricing, agencies use various forms of communications including 800 telephone numbers, facsimile, e-mail, Web sites, dynamic message signs (DMS), roadside signs, and information booths at local community meetings or fairs. More traditional media—such as newspapers, radio, and TV—are also used, as a significant proportion of the general public relies on these media for traffic and transit information.

- The Orange County Transportation Authority in California 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.
- Operators of the I-15 Express Lanes project in San Diego, California maintain a Web site, a customer service center, and an 800 number to provide the public with information about the project and available services.[623]
- A model deployment of the 511 service in Arizona included an aggressive marketing campaign using statewide DMS. The early outreach efforts included posting the message, "Road Conditions, Dial 511," simultaneously on all of the ADOT's DMS located on Interstates and state highways 24 hours per day for a seven-day period. During the campaign, daily call volumes increased over 30-fold, from 500 to 1,000 calls per day before the campaign to 11,000 to 17,000 calls per day during the campaign. Call volumes dropped dramatically after the campaign but remained somewhat higher than before the campaign. The percentage of cellular phone calls also increased dramatically during this period, suggesting that many travelers who saw the message displayed on a DMS called 511 while still en route.[624]



AWARENESS AND OUTREACH LESSONS

- 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.

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INSIGHT—IMPORTANCE OF IN-REACH

While outreach outside the agency is important, in-reach is crucial to garner support for an ITS project that involves multiple departments within an agency. When planning for ITS projects, organizations must look within to resolve potential conflicts between departments. Often, new programs create divisions with regard to funding and chain of command that can jeopardize the success of a program.

The Washington State DOT piloted its modest but highly successful service patrol in Seattle under the leadership of its Engineering division, but decided to develop its full traffic incident management program under its Maintenance division. Placing the program under Maintenance was complicated by the maintenance staff's perception that an engineer had forced the implementation of an unnecessary program. Eventually, Seattle's incident management program was assigned to Traffic Operations with separate line item funding in the operations budget, and a new person was hired as part of the Maintenance division to the lead the program. The combination of removing incident management from Maintenance and hiring a Maintenance person to lead the program alleviated many of the problems that existed in the program's early years.[625]

- The Montana Department of Transportation (MDT) used a low-cost grassroots approach to raise awareness of the 511 telephone service. Under the direction of the MDT Public Information Office, marketing and outreach activities began in summer 2002, several months ahead of a ribbon-cutting event for the 511 service. Forms of outreach during the campaign included press releases, TV news interviews, newspaper articles, highway signs at select locations, and announcements on MDT's pre-511 telephone numbers. In addition, approximately 240 MDT employees who actively participate in the MDT Transportation Awareness Program raised public awareness of the 511 telephone service to state residents. The program allows time-off (with pay) to MDT employees who participate in approved public events to distribute information and educate the public about current MDT programs and initiatives. These public events are often informal settings such as manning booths at county fairs, trade shows, or local festivals.[626]
- A study examined the use of ITS in managing work zones by State DOTs was conducted at four sites: I-55 in Springfield, Illinois; I-496 in Lansing, Michigan; I-40/I-25 in Albuquerque, New Mexico; and I-40 in West Memphis, Arkansas. The results suggested use of proactive approaches in building public awareness of the work zone project status and traffic conditions. Successful techniques employed at these sites included holding press conferences, issuing news releases, and keeping local media (especially those the public turns to for traffic information) up-to-date.[627]

Conduct systematic surveys of and interviews with customers periodically to reliably assess customer satisfaction and to design strategies to improve satisfaction.

- An evaluation of the Utah DOT's 511 project recommended that consumer research be conducted at the planning stage, during early demonstration of a service or 6 months to 1 year after the service is implemented, and then every 12 to 18 months thereafter.[628]
- For its automated fare collection demonstration project, the VCTC conducted informal surveys of customers on each Ventura Intercity Service Transit Authority bus route and received positive anecdotal responses. The information gleaned from surveys and interviews helped the transit industry understand the positive attributes of smart cards for fare collection, such as their ease of replacement, their ability to collect data that can be used for budgeting, and the security of carrying less cash.[629]

- Use of live-intercept surveys was found to be effective in getting a higher response rate and a less biased sample of users than traditional mail-back surveys. For the model deployment of 511, ADOT used the live-intercept approach. Approximately 31 percent of the intercepted callers to 511 agreed to participate in a survey, of which approximately 71 percent followed through, yielding 411 surveys and an overall response rate of 22 percent. No complaints were received from intercepted callers regarding the method of recruitment of survey completion.[630]
- In Minnesota, a statewide traveler information survey was conducted to determine user awareness of its 511 service and the likelihood that people would use it. The Minnesota DOT received the following results to two key questions reflecting usage and customer satisfaction:
  - "Overall, how satisfied are you with the 511 service?" Very/Somewhat satisfied (93 percent), Not very/Not at all satisfied (7 percent); and
  - "How likely do you think you will be to use the 511 service in the future?" Very/Somewhat likely (93 percent), Not very/Not at all likely (7 percent).

  These results suggest a high degree of customer satisfaction for Minnesota's 511 service.[631]
- The New Mexico State Highway and Transportation Department administered over 1,000 surveys to assess the public's perception of the reconstruction of the "Big I" interchange in Albuquerque, which included many ITS elements. The survey found that 60 percent of respondents were pleased with the accuracy and timeliness of the public information provided.[632]

Organizational and Management Structure

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.

- The RFC project in the Central Puget Sound region of Washington State involved seven agencies (six transit operators and one ferry system) agreeing on a standard fare card medium, coordinating the associated business and operational processes, centralizing certain activities such as back office financial functions required for fare revenue reconciliation between agencies, and managing a contractor that is providing the system installation and support. The organizational approach used in the Puget Sound RFC project was based on a "consensus" model, in contrast to an "efficiency" model in which one agency manages the development process and makes key project decisions. The experience of a consensus model partnership for the Puget Sound RFC project exemplified a number of notable characteristics.
  - The structure of a consensus model requires that each agency take an active role in reviewing system design decisions and reaching agreement on vendor directives. This requirement multiplies the amount of work required to develop the project and makes the work more complicated because of the need to reach consensus among a variety of agencies with differing concerns.
  - The consensus model worked reasonably well throughout the initial stages of the project development process, during which high-level aspects of the system design were agreed upon between the partner agencies and with the system vendor. However, these stages of the process were characterized by schedule slippage and

ORGANIZATIONAL AND MANAGEMENT STRUCTURE LESSON

- 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.

by a heavy and unanticipated workload on the partner agency staff. As the project moved towards preparing and reviewing the detailed final design documents, these problems were exacerbated to a point where the continued viability of the initial organizational arrangement was questioned.[633]

INSIGHT—CONSENSUS PARTNERSHIP ORGANIZATIONAL MODEL

Detailed insights associated with a consensus model approach to partnership organization include the following:

- Allow each partner an equal say in decision making in the regional partnership to build trust, understanding, and buy-in by ensuring that no one agency will dominate the process.
- Build on past examples of sound institutional working relationships and emphasize the values associated with a philosophy of regionalism over individual agency self-interest.
- Be aware of trade-offs associated with the egalitarian structure of the consensus model. With each agency equally involved in decisions and policy, the consensus model almost certainly will entail more staff time and cost than a structure with one lead agency.
- Establish a formal agreement—endorsed by the highest levels of management in each agency—which specifies roles, responsibilities, and organizational structure in support of the consensus model.
- Adopt strong project management procedures that allow for clear goals, plans, and schedules to help keep the project on track, and provide adequate staffing and resources to a regional team to coordinate and lead a project of this magnitude.
- Seek a balance between attention to management of the vendor contract and to management of the project development process.[634]

While the consensus model is effective in forming partnerships, the implementation process is likely to be slower than in projects employing the efficiency model. TravInfo is a regional traveler information system in the San Francisco Bay area. Although TravInfo's organization was effective, the consensus-based partnership caused TravInfo to be slow at making critical decisions. While productive at some levels, the project approach during the field test was not flexible enough to quickly respond to obstacles that arose unexpectedly, such as the delays in Caltrans' responses to key questions, as well as the consultant's delivery of a system not fully compliant with design specifications.[635]

INSIGHT—ROLE OF AN ITS PROGRAM COORDINATOR

The role of an ITS Program Coordinator is to:

- Manage the overall ITS program planning and execution.
- Work with the functional areas to identify needs and to draft and carry out plans.
- Adhere to the policy directives set forth by the policy committee.
- Identify where coordination needs to take place across the functional areas and across other efforts on the transportation corridor.
- Keep the program on track—on budget and on schedule.

In carrying out these functions, the ITS Program Coordinator should have at least one staff person to provide administrative support.[636]

ORGANIZATIONAL AND MANAGEMENT STRUCTURE LESSON

- Clearly define the organizational structure and establish an ITS Program Coordinator to insure an effective ITS program.

Clearly define the organizational structure and establish an ITS Program Coordinator to insure an effective ITS program.

- A case study of the Virginia DOT's comprehensive deployment of ITS technologies along the I-81 corridor concluded that a strong program coordination function is vital to success. The case study recommended that the I-81 ITS Program Coordinator be a member of the VDOT Central Office ITS Division, so that he or she had the authority to make decisions for the program and was not vulnerable to funding delays and reductions.[637]

Leadership and Partnerships—Conclusions

ITS leaders and champions are pivotal decision makers who decide what is right for planning and implementing ITS so that project managers and practitioners, based on their leaders' guidance, can execute the ITS projects. Successful ITS planning and implementation requires championing of ITS by agency's high-level leadership, forging partnerships among entities involved in managing some aspects of the regional transportation system, performing awareness and outreach efforts within and outside agencies, and developing an efficient and effective organizational structure. Learning from others' experiences about leadership, partnerships, and management structure can help agencies make informed decisions about these fundamental aspects of ITS deployment.

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FUNDING

Lessons in the funding category discuss Federal, State, regional and local, and private funding, as well as a combination of funding sources, and innovative financing. Federal funding for highways and transit is established by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), a six-year surface transportation authorization bill passed in 2005. Within the highway program, there are six major funding categories: Interstate Maintenance, National Highway System, Congestion Mitigation/Air Quality (CMAQ) Improvement, Surface Transportation Program, Bridges, and Equity Bonus (known as Minimum Guarantee under the Transportation Efficiency Act for the 21st Century (TEA-21)). The transit program provides a mixture of formula and discretionary grants through the Urban Formula, Fixed Guideway Modernization, New Starts, and High Priority Bus categories.

The State and local agencies play the largest role in financing, owning, and operating highway and ITS systems and networks. Projects to be considered for funding—whether through Federal, State, or local sources—must be included in the Transportation Improvement Program for their State or region. Federal funds are available to manage, operate, and maintain ITS systems; however, the bulk of funds still typically come from States and localities.

Private financing refers to ways that State and local agencies can collaborate with the private sector to develop unique opportunities for funding ITS projects. Private sector involvement allows agencies to leverage private capital to implement projects in a shorter time frame.

Innovative financing for transportation is a broadly-defined term that encompasses a combination of specially-designed techniques that supplement traditional highway financing methods. While many of these techniques may not be new to other sectors, their application to transportation is innovative. There are numerous innovative techniques that can be combined with traditional funding programs. Several tools have been developed to assist agencies in determining the right financing situations for their projects.[638] The lessons in this subcategory include examples of how some jurisdictions have funded their ITS projects. Financing tools used by these jurisdictions include special assessments, impact fees, tax increment financing, and grants.

FEDERAL FUNDING LESSONS

- Clarify Federal funding regulations for projects that do not deliver tangible products.
- Distribute financial resources equitably according to agency capital cost shares.

Evidence Based Lessons Learned

The Intermodal Surface Transportation Efficiency Act of 1991 established a Federal program and authorized funds to research, develop, and operationally test ITS and to promote their implementation. TEA-21 extended this program and authorized funds through fiscal year 2003. TEA-21 also guaranteed a minimum level of spending for highway and transit programs. The next program established was SAFETEA-LU in 2005. SAFETEA-LU folded ITS planning, design, and deployment into mainstream highway programs and established eligibility for ITS projects using regular Federal Aid highway funding including funds from the National Highway System, State Transportation Planning, and CMAQ programs, as well as from other infrastructure programs.[639]

Clarify Federal funding regulations for projects that do not deliver tangible products. Procurement for an ITS project is not like procuring asphalt and concrete. Some ITS projects, when compared to traditional construction contracts, present challenges because they produce a service to customers and do not deliver a tangible product.

- The Hampton Roads ATIS project experienced multiple iterations of the contract between the VDOT and the prime contractor. There were several issues that became apparent as the public-private partnership evolved and there were numerous iterations within

VDOT, and between VDOT and FHWA. One significant challenge that VDOT encountered was a lack of Federal Aid regulations for transportation projects that do not deliver a tangible product, such as a new freeway lane or a reconstructed bridge. The Hampton Roads ATIS, in contrast, was proposing to deliver a service, not a product. In order to receive Federal Aid funding for the project, VDOT officials had to make this distinction clear to FHWA. Contract negotiations lasted over a year, due in part to the difficulty in negotiating with FHWA to receive Federal Aid funds.[640]

Distribute financial resources equitably according to agency capital cost shares. The development of a viable project finance plan in a multi-jurisdictional setting has proven difficult and at times required great flexibility on the part of the partner agencies.

- The Central Puget Sound Regional Fare Card project was awarded numerous Federal grants designed to assist the project. Rather than allocating individual grants to partner agencies, the RFC partners agreed to disburse grants proportional to the relative shares of equipment purchased by each agency. This equitable approach has encouraged agency participation. To the extent that a partner agency expands participation in the RFC project, both its responsibility for project costs as well as its share of total grant revenue would grow commensurate with its participation.[641]

STATE FUNDING LESSON

- Leverage State assistance in the procurement and funding of ITS technologies for rural transit.

State Funding

As transportation construction costs have increased, State and local budgets have become more constrained. Some transportation capacity projects move forward despite community, environmental, and space issues; but overcoming these constraints requires longer construction periods, frequent project mitigations, and more complex construction techniques. Consequently, each construction project consumes a larger share of available funds. As project costs increase, many States and localities face infrastructure deterioration from years of deferred maintenance. These funding challenges mean that few agencies can build all of the facilities that might be desired.[642]

Leverage State assistance in the procurement and funding of ITS technologies for rural transit. Partnerships between State and local agencies can be an effective tool in achieving the deployment of ITS in rural areas. In order to bring ITS to rural agencies, the programs are being funded at the State level. In one case, the State even set up the procurement for small agencies to buy into if they wanted. The following are selected benefits of an alliance between State DOTs and rural agencies.

- The price of equipment will drop and will become more affordable to rural agencies. If a State DOT becomes involved with the procurement and offers that procurement to all the rural agencies in the State, the procurement grows to a size that will then interest vendors.
- If the State DOT evaluates the offerings of ITS solutions, that information can be communicated to smaller agencies, eliminating the need for each agency to perform its own investigation.

Developing partnerships with State and neighboring agencies assists rural transit providers in procuring and successfully implementing ITS technologies. State agencies have the financial resources and subject matter experts that may not be available to rural and non-urban transit agencies, so it is best to consolidate efforts to eliminate redundancy and reduce funding expenditures.[643]

Regional and Local Funding

Increasingly, regional and local transportation plans include language supporting improved transportation systems management, promoting more efficient use of existing infrastructure, and adopting a more customer-oriented approach. Yet the funding and staff resources needed to support the implementation of such planning objectives are often lacking. For example, a plan might declare that regional coordination to maximize efficiency of the existing system is a top priority; but no funding is then allocated toward regional incident management programs, corridor management strategies, or regional traveler information systems.

Federal policies allow several funding sources to be used for regional systems M&O programs. Although there are greater Federal funding opportunities for M&O than many regions perceive, the bulk of funds typically must come from States and localities. State and local funding processes make it difficult to fully integrate planning and operations by creating separate categories of funds for capital and operations expenses.[644]

Consider partnering with neighboring agencies and non-traditional stakeholders. Non-traditional stakeholders, such as universities and law enforcement agencies, can provide additional resources and insight into solutions that may not have been considered.

- The Community Action Partnership of Mid-Nebraska has two partners in its implementation of ITS in rural transit, one of which is the Buffalo County Sheriff's Department. The Community Action Partnership sought out the Sheriff's Department because of the Sheriff's in-depth knowledge of geographical information systems and global positioning systems. Because the Community Action Partnership has limited resources, it seeks out subject matter experts in the local community whenever possible. The Sheriff's Department provides the expertise for the system and receives benefits because it can control the bus dispatch. This feature is important when emergencies occur because the Sheriff's Department can take control of the buses in times of natural disaster and for security reasons.[645]

REGIONAL AND LOCAL FUNDING LESSON

- Consider partnering with neighboring agencies and non-traditional stakeholders.

Private Funding

SAFETEA-LU makes it easier and more attractive for the private sector to participate in highway infrastructure and ITS projects, bringing new ideas and resources to the table. Innovative changes such as eligibility for private activity bonds, additional flexibility to use tolling to finance infrastructure improvements, and broader Transportation Infrastructure Finance and Innovation Act and State Infrastructure Bank loan policies, have the potential to stimulate needed private investment.[646] There is also greater need for public- and private-sector collaboration and for more cooperation among public agencies, partly in response to funding limitations and partly in response to the increasing system performance effects of non-recurring incidents.[647]

Consider public-private partnerships and unique financing methods as ways to cover costs for ITS projects. Public-private partnerships may be the most effective means of getting large, necessary projects implemented sooner. The ability to structure a project to obtain financing in the capital market will dictate the ultimate feasibility of a project.

A critical issue facing transportation officials today is the manner in which they fund and finance managed-lane facilities. Increasingly, governments are looking to the private sector

PRIVATE FUNDING LESSON

- Consider public-private partnerships and unique financing methods as ways to cover costs for ITS projects.

for participation in these large complex projects. Several Federal programs strive for inclusion of the private sector, not only as investors, but also as active participants in project development, construction, and operation. Additionally, the unique operating strategies used in managed-lane facilities create a demand for innovative financing techniques that are untried in the transportation arena. Typically, private investment backed by public debt assurance makes large ITS managed-lane projects more financially feasible. However, both public and private parties involved in these innovative financing arrangements need to be aware of the potential risks and plan accordingly.[648]

- In the case of an ATIS in Miami, public agency activities were geared towards traffic management with a corridor-based approach, while the private sector required a larger market with broader sources of information. When seeking private funds, these differences needed to be addressed to make projects attractive for private sector investment. The contract agreement established a framework for the private partner to establish non-traffic management business areas and revenue sources other than public funding.[649]

COMBINED FUNDING SOURCES LESSON

- Examine multiple funding sources and anticipate unforeseen costs associated with deploying ITS.

Combined Funding Sources

Examine multiple funding sources and anticipate unforeseen costs associated with deploying ITS. Combining funding from multiple sources can be an effective way of financing ITS projects. Transit agencies have brought forward a number of different funding and financial considerations important to rural transit agencies undertaking ITS deployments. Additionally, agencies need to realize ahead of time that costs may escalate throughout project deployment as well as during day-to-day operations. These rising costs make it important for agencies to explore all possible sources of funding to ensure budget constraints do not delay the installation process.

Funding for ITS deployments is available to rural transit agencies from a multitude of Federal, State, local, and even private sources. Rural transit agencies searching for funding need to be aware of the combinations of Federal, State, and local funding available to them and the ways in which match money can be obtained. Once the potential funding sources have been identified, it is important that agencies budget for the unexpected as well as the anticipated costs of a project. The following agencies have typically used an assortment of Federal, State, and local funding options.

- The Capital Area Rural Transportation System in Austin, Texas secured funding from the Federal Transit Administration (FTA) and the Texas DOT for the installation of AVL/MDT, scheduling and dispatch software, and enhancements to the radio system.
- In Florida, Community Transportation Coordinators are part of a statewide project undertaken by the Florida Commission for the Transportation Disadvantaged, an independent commission housed within the Florida DOT. The ITS project undertaken by these coordinators included two phases of installing new scheduling and dispatch software and AVL/MDT systems. The first phase was funded by an FTA demonstration grant. The second phase was funded with additional FTA money as well as a commission match, which required a 10 percent match from each participating coordinator.
- In New Mexico, the Client Referral, Ridership, and Financial Tracking system received funding for the implementation of new scheduling and dispatch software, and electronic fare card technology from the FTA, the New Mexico Human Services Department, the New Mexico Department of Labor, and the Alliance for Transportation Research Institute.[650]

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Innovative Financing

The primary objectives of innovative finance are to maximize the ability of states and other project sponsors to leverage Federal capital for needed investment in the Nation's transportation system, more effectively utilize existing funds, move projects into construction more quickly than under traditional financing mechanisms, and make possible major transportation investments that might not otherwise receive financing.[651]

To help close the gap between highway infrastructure investment needs and resources available from traditional sources, SAFETEA-LU includes provisions that, in addition to tolling options, will enhance innovative financing and encourage private sector investment.[652]

Consider development impact fees, special assessments, and other innovative mechanisms to help finance ITS projects, and management and operations strategies. Innovative financing can have a significant impact on a region trying to support its transportation facilities. Almost every transportation agency identifies inadequate funding as a major concern. At the same time, virtually every agency acknowledges that funding constraints are a major impetus for advancing M&O strategies. Planners often become champions for M&O strategies only when they recognize a serious discrepancy between available funds and the cost of new capital investments necessary to maintain regional mobility. However, planners should not wait for a budget crisis before offering regional leadership on M&O coordination, nor should practitioners choose between funding roadway construction and funding operational improvements.

- One innovative funding strategy is to use impact fees levied on land developers to fund operations equipment, such as traffic surveillance cameras and signal timing improvements. The practice of requiring developers to fund transportation improvements as a way to mitigate the transportation impacts of their projects is well established, but relying on this as a source of M&O improvements is relatively new. In Montgomery County, Maryland, an impact fee for large developments has replaced the use of some discretionary transportation funds. The county's public works department is using these impact fees to fund operations equipment, including DMS and vehicle detection equipment. In one instance, a major development funded a DMS that indicates when transit parking facilities at central rail stations are full, encouraging drivers to use parking lots at stations located further from the region's core. This new funding source has also helped to promote coordination between planning and operations.[653]
- The creation of a special assessment district provides State and local governments with another method for financing ITS projects. With special assessment districts, the recipient of the project pays for a proportional cost of the project. For example, a special assessment district might be created and a tax might be levied on district property owners if a project was of substantial and primary benefit to that particular district. This method is especially useful in projects that include a transit component. For instance, a bus rapid transit line and station could be part of a transportation network that influences land use resulting in a high density development. This development would receive a substantial benefit from being part of the network; therefore, businesses or residents in the district could be charged a special assessment.

INNOVATIVE FINANCING LESSON

- Consider development impact fees, special assessments, and other innovative mechanisms to help finance ITS projects, and management and operations strategies.

- Another method of financing is tax increment financing. Using this approach, a special district is created and improvements are made within the district, which stimulates private sector development. However, the tax rate is frozen before development begins or improvements are made. The taxes continue to be paid but the difference between the original assessed tax and the tax on assessed value after improvements is deposited into a special account that is used to pay off the bonds that were sold to finance the improvements. This money can also be leveraged for more improvements in the district.[654]

Funding—Conclusions

Funding and financing mechanisms available today reflect a shift from the traditional means of grant-based funding and address the realities of certain funding shortfalls. Federal and State Governments, as well as State DOTs, are working collaboratively with other regional and local entities as well as the private sector to maximize the effectiveness of every transportation improvement. Project stakeholders must work together to assemble a funding package that will result in a financially feasible project. The U.S. DOT has achieved tremendous advances in making large, complex projects more feasible and has developed numerous programs to capitalize on available resources. More effective financing of ITS projects will ultimately help to improve the mobility of the transportation system.

For transportation departments to implement ITS components, especially in remote locations, the costs to provide the power and communications infrastructure needed to make the data accessible can be substantial. Sharing capital, operations, and maintenance costs can be beneficial to all the agencies involved. Agencies can realize a significant impact by providing cost-effective solutions to deploying ITS components in remote locations.

Identifying potential funding sources for an ITS project can be a challenging task. For many agencies, the most useful initial contact for questions on fund availability is the ITS or transit office of the State DOT. In the absence of such an office, a good starting point may be to contact the Regional FTA or FHWA Office. The local program or project manager should determine the level and timing of funding available for ITS system development and the requirements for plans and other information in order to qualify for various sources of funding.

TECHNICAL INTEGRATION

Lessons in the technical integration category 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 and can be described in the subcategories of functional integration, jurisdictional considerations, and the integration of legacy systems.

There will almost always be technical issues encountered while integrating ITS components. A particular agency may not be able to anticipate all issues that might occur during a project deployment. However, agencies should anticipate that technical issues will occur and that these issues will most likely affect the cost and schedule of the project. The key to success is to plan accordingly and develop solutions prior to project deployment to minimize issues that may surface during the integration phase.

FUNCTIONAL INTEGRATION LESSON

- To develop usable systems that meet user needs, assess user needs and follow accepted usability engineering practices developing interactive systems.

Evidence-Based Lessons Learned

Functional Integration

Functional integration is a subset of the system integration process. During this process, system components are assembled into a working system and verified to ensure that they fulfill all of the system requirements. Assembling a puzzle is a helpful analogy for this step. The challenge in an ITS project puzzle is that not all of the pieces are available at the same time, some will not fit together particularly well at first, and there will be pressure to change some of the pieces after having already assembled them. Software and hardware integration are important components of functional integration, as the following discussion shows.

To develop usable systems that meet user needs, assess user needs and follow accepted usability engineering practices when developing interactive systems. The implementation of ITS software should actively involve a broad range of users during design, development, testing, and deployment to ensure the software investment results in a system that meets user needs and is accepted by the users. Several universities, state DOTs, and regional entities have demonstrated that developing requirements based on user needs, conducting surveys, performing usability testing, and obtaining feedback from users is critical to developing software that meets users' needs.

- Developers of several traveler information Web sites often cite receiving user feedback and acting on comments received as a key to success. In an effort to continuously improve TranStar—the traveler information Web site for the Houston metropolitan area—the Texas DOT reviews the site on a monthly basis and implements new features every two or three months. Others agencies, 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.
- Several state DOTs have used various usability engineering methods to assess user needs and test the interactive systems that were developed. The experience of the Georgia DOT demonstrates that conducting surveys enables developers to find out what potential users want before developing a site or updating an existing one. The Georgia DOT regularly seeks input from the public by surveying users about what features they use, how often and when, and whether they use the information to alter their route or mode of transportation. Virginia DOT personnel successfully performed usability testing after their Web site was developed to ensure that the site worked and that commuters received the information they expected.[655]

FUNCTIONAL INTEGRATION LESSON

- Use ITS standards when developing systems to maximize vendor flexibility and data exchange compatibility, and ensure comprehension by agencies.

Use ITS standards when developing systems to maximize vendor flexibility and data exchange compatibility, and ensure comprehension by agencies. Experience has demonstrated that following ITS standards and protocols increases vendor and system flexibility, and facilitates more efficient management and coordination of day-to-day traffic and emergency operations.

- Experiences from the Tri-County Metropolitan Transportation District of Oregon (TriMet) and the Utah DOT show that following ITS standards and protocols helped ensure that ITS components being integrated can function together. Additionally, following ITS standards and protocols helps provide vendor and system flexibility. In the case of the TriMet, at the time of its procurement of light-emitting diode (LED) signs, no Transmission Control Protocol/Internet Protocol (TCP/IP) standards for the LED sign interface had been developed. Consequently, the agency was forced to consider sign vendors that had proprietary protocols. Even though no standards were available, TriMet knew it wanted the LED signs to interface with TCP/IP-compliant devices, so TriMet provided specifications that required the sign vendors to interface with the protocols. TriMet staff believed that there was an advantage to using TCP/IP and standard protocols that would enable the agency to use different communication methods, yet retain the same applications. Complying with ITS standards and protocols helps to ensure a modular and compatible infrastructure.[656]
- In a study of TMCs in 10 different states, the FHWA determined that it was important to use multi-industry data interchange standards to integrate data, information, and systems. The use of standards allows better coordination of TMC efforts and more efficient management of day-to-day traffic and emergency operations. Incomplete or inaccessible information, however, often impedes the ability of TMCs and related agencies to coordinate and efficiently manage operations. The FHWA study concluded that the current application of information sharing and decision making at TMCs could be improved. Additional concepts of emergency integration were identified, including comprehensive coordination within and among TMCs, training and coordination among operations personnel, and integration of emergency information into TMC operations. The study concluded that these concepts could be implemented using existing technologies and that they offer the opportunity to move the current state-of-the-practice forward.[657]

Local ITS projects are typically required to be integrated with a statewide or regional ITS architecture. Integration and consistency is more easily achieved using open standards and established guidelines. When using standards and guidelines, it is important that they be easily understood by agencies developing systems under such guidance.

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Jurisdictional Integration

The intent of jurisdictional integration is to integrate the processes that allow seamless travel and coordination among jurisdictions, although the jurisdictions continue to operate as separate geographical and political entities. Technical integration issues relating to jurisdictional considerations involve both the design and implementation of ITS solutions, as well as coordination issues among regional entities. While jurisdictional issues often have organizational and coordination implications, these issues often interact with and affect technical system issues. Therefore, organization and coordination issues must be considered in concert with the technical integration system issues.

The following provides additional insight and evidence into jurisdictional considerations and improving coordination and cooperation among agencies.

Create systems and plans that allow information sharing and coordination among regional agencies and states. Experience has demonstrated that jurisdictional coordination is significantly improved by creating systems that allow management of implementations on a regional or statewide basis, as well as promoting the development of regional coordination plans. Experiences in Iowa and the Washington, D.C. metropolitan area demonstrate how information sharing and regional planning can help manage ITS implementation statewide and improve regional coordination and communication.

- When developing a statewide ITS architecture, the main goal of the Iowa DOT was to enable interoperability among all local transit operators. To achieve this goal, the Iowa DOT developed a template for ITS contracts. Transit agencies in the state must agree to the terms detailed in the template as a condition of participation in statewide ITS programs.[658]
- Transportation agencies in the Washington, D.C. metropolitan area discovered the negative consequences of a lack of communication and coordination during the terrorist attacks of September 11, 2001. Following the attack on the Pentagon, there was a rush of commuters fleeing the District of Columbia to the Maryland and Virginia suburbs just as the AM peak period was ending. There was no communication between the Virginia and Maryland DOTs and the agencies located within the city, such as the District of Columbia DOT and the National Park Service, which operates some of the city's key roadways located on national parkland. In addition, there was also no communication or coordination with the region's transit agency—Washington Metropolitan Area Transit Authority (WMATA). The Virginia and Maryland DOTs employed a variety of strategies to handle the unanticipated demand and get people out of the city, such as adjusting traffic signal timings for heavy traffic, displaying messages on dynamic message signs, and opening high-occupancy vehicle (HOV) lanes to all traffic. However, some emergency evacuation strategies could not be used due to the lack of communication and coordination among agencies. The Virginia DOT could not reach WMATA to notify the agency that it was permissible for its buses to use the opened HOV lanes. This limitation hampered those dependent on transit in their evacuation from the city. This experience illustrates why it is critical to create a system that allows the state to manage implementations as a whole and to tie in each transit agency.[659]

JURISDICTIONAL INTEGRATION LESSONS

- 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.

LEGACY SYSTEMS LESSON

- 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.

These experiences suggest that jurisdictional coordination and integration is best served by creating a system that allows the state or a region to manage implementations more holistically, across a larger geographical area, and by coordinating emergency management planning between different agencies and neighboring political jurisdictions. The experiences of the Iowa DOT demonstrate that regional coordination helps manage ITS implementation on a statewide basis, which facilitates more effective ITS deployments. With regard to emergency management planning, the experiences in the Washington, D.C. metropolitan area have led the regional agencies to work together to identify lines of authority among persons and agencies, strive to resolve different terminology, and develop systems to improve coordination and communication between agencies for future crises.

Legacy Systems

One of the largest and most common hurdles when developing ITS is to make them compatible with existing systems already deployed. There are several important factors that must be considered when integrating new systems with existing ones, and that can have significant impacts on the ITS system costs and deployment schedules. These issues include integrating with existing legacy systems to save costs associated with implementing a new system, as well as complying with standards whenever possible.

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. The experiences of TriMet and the experience of seven public transportation agency partners in the Central Puget Sound region of Washington State demonstrate that complying with standards and using commercial off-the-shelf technology can help save money, minimize risks, and make it easier to integrate existing systems with new ones.

- One successful strategy for procuring ITS technologies is to select commercial off-the-shelf technology (hardware and software) that is already proven. The experience of seven public transportation agencies in the Central Puget Sound region demonstrates that modifying or customizing a particular technology entails greater risks. A modified or customized system has the advantage of closely meeting the specified needs of the regional partnership, along with the disadvantage of needing more development and testing to be sure it does what it is supposed to do. (In the case of the Puget Sound system, only the on-board driver display unit was significantly customized to accommodate emerging smart bus initiatives.) Customized software may need to be developed in order to accommodate the partners' existing legacy systems.[660]
- Integrating with existing legacy systems can save money associated with implementing a new system. During procurement of a real-time bus arrival estimation system in the Portland, Oregon metropolitan area, the TriMet transit agency encountered several technical issues that were addressed successfully during project deployment. The Transit

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Tracker system was built upon the same platform as TriMet's existing automated vehicle location bus dispatch and rail central control systems, saving software development time and system costs. A few minor changes needed to be addressed because of the different requirements necessary for reporting information to customers as opposed to reporting information to the dispatchers. As an example, for the real-time Transit Tracker system, TriMet had to change the rate at which information was provided and expand the type of information provided by the system to respond to the needs of the customer.[661]

Agencies may not be able to eliminate all technical issues encountered with integrating ITS components that may occur; however, planning for issues and developing solutions prior to project deployment may help to minimize issues. Complying with standards and using off-the-shelf technology can help to keep the project within the projected budget and schedule, and make it easier to integrate new and 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.

- A field operational test of an electronic payment system that attempted to integrate transit fare payment, parking payment, and electronic toll collection in the Orlando, Florida metropolitan area illustrates the importance of including significant planning and development time in the overall project schedule when a regional system is being implemented. Given the large number of agencies involved in the Orlando integrated electronic payment project, extra time was needed to accommodate identification of and resolution of the various compatibility issues across existing legacy system equipment. This experience demonstrates that it is important to plan adequate development time to identify and resolve system integration issues with existing legacy equipment. The Orlando electronic payment system needed to integrate with existing field equipment, agency point-of-sale locations, existing revenue management systems at each agency, and a third-party clearinghouse system that settled prepaid funds to each agency based on the card payment and revalue transactions completed at each agency.[662]

Technical Integration—Conclusions

These experiences demonstrate that technical integration is a multi-faceted concept and involves more than simply assembling the pieces of a puzzle. This type of integration involves functional, jurisdictional, and legacy system issues that all must be considered and coordinated to successfully integrate the components of an ITS system. Following this guidance will help to keep project costs and schedules within projected ranges, and will help to foster ITS deployments that provide the anticipated transportation benefits and meet customer expectations.

LEGACY SYSTEMS LESSON

- 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.

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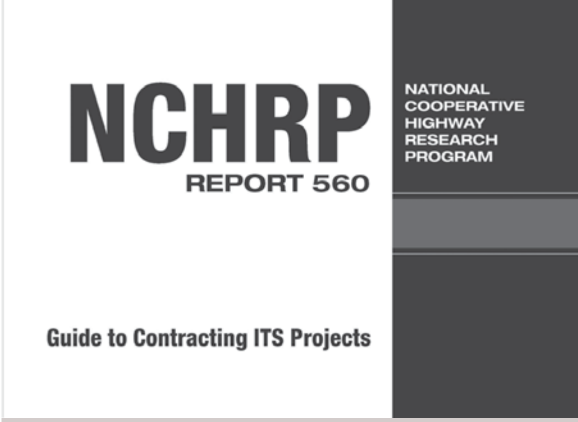
PROCUREMENT



Procurement is a critical step in the acquisition of an ITS project. The process of procuring ITS technologies has proven to be one of the most complicated and problematic of deployment phases for many agencies. Lessons in the procurement category of the Lessons Learned Knowledge Resources discuss work allocation, method of award, contract form, contract type, and terms and conditions. Many of the definitions and procurement guidelines provided in this section come from the National Cooperative Highway Research Program report, *Guide to Contracting ITS Projects*.[663]

Evidence Based Lessons Learned

Work Allocation

Work allocation, also called work distribution, determines whether contract work is best performed under one single contract or multiple contracts. The proper selection of contracts influences the overall success of the ITS deployment.

WORK ALLOCATION LESSONS

- 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.

Determine agency capability level when selecting the most appropriate ITS procurement package. Major ITS projects with significant software development, hardware integration, and long-term operations and maintenance support require sufficient agency capabilities; otherwise, the project risks not being successful. If an agency does not have the resources or organization for handling a major ITS project, it should consider reducing the scope of the project, seeking additional consultant services, or not doing the project. Agencies must assess the level of staff support dedicated to ITS projects as well as the staff's previous experience with ITS. Organizational experience should be based on an agency's experience with complex and risky projects. The agency must assess the extent to which it is organized to support ITS projects.[664]

- In the procurement of an automated vehicle location/computer aided dispatch system by two transit agencies in California—Riverside Transit Authority (RTA) and SunLine Transit Agency—the agencies jointly hired an independent consultant to act as a "system manager" to aid them in developing system requirements and a request for proposals, to oversee system acceptance testing, to review all documentation, and to oversee training. Based on this experience, the staff at the two agencies felt that it was in fact helpful to have an independent consultant in cases where the procuring agency does not have the technical expertise or resources in-house to manage the project. The agencies' staff also felt that the individual selected as the consultant should be truly independent and bring expert advice to the project team.[665]
- When confronted with the task of negotiating agreements with the region's telephone companies, the Montana DOT enlisted the help of a telecommunications expert within the Montana Department of Administration to negotiate an agreement with the local telephone companies for the Montana statewide 511 service. The person selected was experienced in dealing with telephone issues for the State. As a result, the terms of the final agreement were quite favorable to the MDT, with no per-call charges and minimal switching costs.[666]

METHOD OF AWARD LESSON

- Utilize flexible procurement methods that allow for thorough and detailed negotiations.

Maintain owner control and consistent oversight to keep a project on time and on budget. Agencies cannot simply "turn things over" to a contractor or systems manager. On transportation construction projects, it may be sufficient for the owning agency to take a more passive role, with activities often limited to conducting inspections. However, for ITS projects, agencies have to maintain an active role throughout the project. For software development, up to half the total requirements and design effort may actually be expended by the agency and end users, even after a software contract has been issued. Consequently, agencies must allocate sufficient resources, especially in terms of their own staff time, for software development.[667]

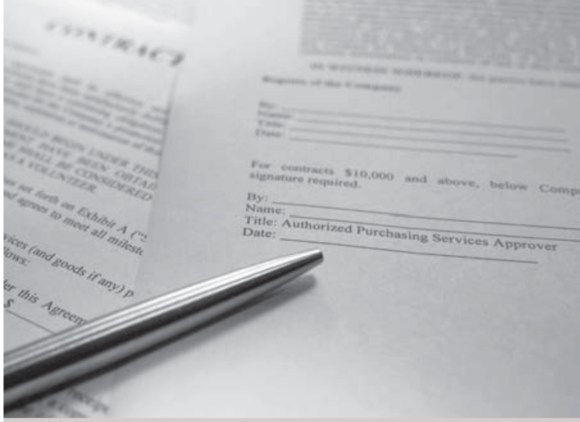
- During the I-25 Truck Safety Improvements Project, CDOT learned the importance of maintaining control and consistent oversight of the system integrator. The System Integrator retained for this project was also the integrator on another CDOT contract and the two contracts overlapped in schedule. Early in the project, difficulties emerged between CDOT management and the integrator. Eventually it was mutually agreed that the contract should be dissolved. CDOT was successfully able to recover the project by changing the I-25 TSIP implementation focus from the integrator to one using State employees. CDOT experienced a situation that is not uncommon and significantly impacts the cost, schedule, and performance of the project. It is essential that the project management team have enough expertise to be able to provide the consistent oversight as required for the scale and complexity of the project.
- During the procurement of the I-25 TSIP, many CDOT staff felt that smaller vendors provided better customer service than larger ones and tended to assign their best employees to the project.[668]
- There are actions that a procuring agency can take at the pre-bid phase that can help mitigate cost, schedule, and performance risks, such as interacting with potential vendors. RTA and SunLine had no interaction with potential vendors during the pre-bid phase. Staff felt that doing so would have helped them to better define the project scope and may have resulted in more responsive bids.[669]

Method of Award

Method of award is the process by which a contractor is selected during a competitive procurement. In most traditional transportation construction projects, price is the sole selection criteria. However, this approach may not be adequate for ITS projects, given the technical complexity often involved with ITS solutions. Rather, agencies should consider a range of factors, such as qualifications, experience, key personnel, and price.

Utilize flexible procurement methods that allow for thorough and detailed negotiations.

- Entering into negotiations with vendors when procuring ITS resources allows public agencies the most flexibility for evaluating different approaches to ITS deployments. When looking to obtain the services of a private partner, the Florida DOT used a procurement method known as an Invitation to Negotiate (ITN), permitted under Florida procurement laws. The ITN process is best suited when the scope of work for a project cannot be accurately and completely defined by the agency. The process occurs most often for acquisition of rapidly changing technology, outsourcing, and procurement of complex services. Under the ITN, a statement of work (SOW) is issued and vendors submit responses. The State then negotiates a final SOW and selects a vendor. Overall, the goal of using ITN to successfully procure an ITS project was achieved.



- When implementing ITS, relying on a single vendor and a limited number of public sector agencies does not adequately spread the potential risk and financial obligation among all involved parties. The Florida DOT (FDOT) recognized this shortcoming when implementing the ATIS in the Miami tri-county region. Due to the experience of implementing the Miami ATIS, FDOT has decided that future use of the ITN process will be based on a business model that expands the number of public and private partners, and includes both direct and indirect beneficiaries. For example, FDOT has considered using the ITN process for an ITS project along I-4 in the Orlando region. If used, the process would most likely seek participation from the tourism and hotel industries, as they would be potential indirect beneficiaries.[670]
- Because the Maricopa County DOT in Arizona had a flexible procurement process and was able to work with the local stakeholders, participants in the metropolitan model deployment in Phoenix—known as AZTech™—determined that it was more efficient to use the county as the official procurement agency than to use ADOT. Other agencies involved in the project, however, were given the flexibility to use the county as the procuring agency for their selected technologies or to procure products and services themselves through existing or new contracts and be reimbursed by the AZTech™ project.[671]
- A variable speed limit project in eastern Washington State—known as TravelAid—required the involvement of several Washington DOT offices, as well as different consultants and vendors. As the project progressed, contractual arrangements between the DOT and consultants shifted and were occasionally difficult. At times, negotiating these arrangements delayed the project and added to the cost, especially due to the use of non-standard equipment. However, the use of benchmarks may have helped reduce negotiating delays. After the contracts were developed, a partnership-like arrangement among the involved organizations was important to eventual completion of the system.[672]

Contract Form

Contract form defines the manner in which work is authorized during the contract period of performance. Typical forms of contracts include one large contract with multiple phases, task order contracts, and purchase orders.

Consider dividing a large ITS project into manageable task orders.

- The traditional approach of one large cost-plus-fixed-fee project is not necessarily the best mechanism to deploy a large multi-jurisdictional ITS project. Using this traditional format allows less flexibility to the implementing agency in terms of developing the scope, and managing performance, schedule, and budget. Another approach to consider is dividing the project into manageable task orders. Using this approach, project scopes of work, estimates, and schedules are developed for each task order and activated when the agency provides the contractor or system integrator with written notice to proceed. Breaking the project down into smaller task orders can prove to be a successful contracting method. When a large contract is difficult to manage, the impacts on schedule and costs can be significant. This approach improves the ability to manage the project's schedule and budget, creating an environment for a successful project deployment.[673] Task order contracts can also foster a team environment between the contractor and the client. Agencies may be better able to manage the project and ensure that they are fully aware of all facets of its design, deployment, and maintenance.[674]
- The task order contract configuration used for the I-25 TSIP in Colorado provided much better control of the contractor than the previous cost-plus-fixed-fee contract, which

CONTRACT FORM LESSON

- Consider dividing a large ITS project into manageable task orders.

CONTRACT TYPE LESSON

- Consider performance-based contracts, including incentives and penalties, during the procurement process.

essentially relieved the contractor of the responsibility to deliver finished products as well as removed CDOT's contractual clout. Although a task order contract configuration is not necessarily more efficient for the contractor, it provides a better mechanism for the agency to track progress and control schedules and costs. In the case of the I-25 TSIP using task orders allowed for better owner control. Based on the success of this project, CDOT continued to use the task order configuration on additional projects.[675]

- For their joint procurement of an AVL system, RTA and SunLine in Riverside, California included all project components in a single procurement. In retrospect, they felt that multiple smaller deployments might have helped mitigate risks and enabled them to incorporate lessons learned during the earlier phases of the deployment.[676]
- The design and deployment of traffic signal systems is viewed as a daunting task by many agencies. The design choices regarding the type of control system, the required communications, the type of signal timing schemes to be maintained by the system, and the type of software required to run the system are often overwhelming. In addition, the overall cost of designing, deploying, and maintaining a traffic signal system can be high. One method recommended to defuse some of the challenges faced is the use of task order contracts. An example application would be the use of a task order contract to purchase and deploy a closed-loop system under a fixed-price task order. Next, smaller tasks could then be issued to modify the system to accommodate special functions required in the system. Traffic signal systems tend to be composed of many complex components and tend to require significant time to deploy and test. Therefore, task order contracts can help overcome these challenges by providing agencies with a series of stop valves. With these check points an agency can assess a contractor's performance throughout the deployment of the system and determine the ability of the contractor to deliver the next task without making long-term, high-stake commitments.[677]

Contract Type

Contract types define the manner in which contractors are reimbursed for their services. There are a variety of contract types to be explored and managers must choose those best suited for their project requirements.

Consider performance-based contracts, including incentives and penalties, during the procurement process.

- One way of avoiding problems later in an ITS deployment is to develop performance-based contracts with vendors. An example might be building in project milestones with payment to vendors dependent on reaching these milestones. These incentives encourage vendors to meet expectations for performance and schedule.
- The Ottumwa Transit Authority, which provides bus service to Ottumwa, Iowa and the surrounding 10-county area, had problems during the implementation stage of its deployment of AVL and mobile data terminals, primarily stemming from difficulties with their contractors. Agency staff felt they should have written more performance-based contracts with the vendors in order to avoid the types of problems they encountered.[678]
- The use of incentive-driven contracting mechanisms and traffic incident management programs may reduce incident clearance times. The Florida Turnpike's Enterprise Roadway Incident Scene Clearance program uses incentives, providing qualified tow and clearance contractors the opportunity to earn bonuses for clearing major lane blockages within specific time limits. The program was activated 15 times in the first 9 months of

deployment. The success of the program was demonstrated by the ability of the towing contractors to clear each of these incidents within 90 minutes of the notice to proceed issued by the Florida Highway Patrol.[679]

Terms and Conditions

Terms and conditions are defined once a contract package has been determined. The *Guide to Contracting* ITS *Projects*[680] provides the terms and conditions required for various types of contracts, as well as the terms and conditions that are applicable to specific procurement packages. Agencies seeking guidance on specific terms and conditions of contracts should also consult the Federal Acquisition Regulations.[681]

Create policies to specifically address software and technologies including intellectual property rights that are brought into, enhanced, and developed during a project.

- There are many models to choose from in addressing intellectual property rights (IPR). The important lesson is to address these issues early. Addressing IPR issues early facilitates the relationship between public and private parties during contract negotiations, and throughout the project. This practice also helps to avoid the cost of delays when there are objections from the private parties involved.[682]
- The procurement, initial deployment, and ongoing operation of the Puget Sound Regional Fare Card program presented the partner agencies with new hardware and software technology and the need to address associated risks. One of the risks was associated to intellectual property, which was managed using a software escrow agreement. Under this agreement, the vendor's contract required the vendor to deposit the system source code and associated documentation with a software escrow company and to update and refresh these files at each milestone payment until full system acceptance. During the operating phase, the escrow had to be updated with each system upgrade. The contract stipulated that, if the vendor defaulted, the escrowed code would be released to the partner agencies and they would have the option to purchase the software outright.[683]
- In order to resolve IPR concerns between the public and private sector participants in AZTech™, the metropolitan model deployment in Phoenix, the parties requested that FHWA clarify the Federal Government's policy on proprietary information. As explained in a letter from FHWA's Associate Chief Counsel, use of the copyrightable or patentable products developed by the private sector is limited to FHWA projects with non-commercial purposes, i.e., whatever the private sector representatives bring to the project remains their property. Software brought to the project and enhanced throughout the course of the project is Federal property, although the private-sector representatives retain titles to the patents. Representatives from the AZTech™ project indicated that the letter from FHWA was essential to resolving IPR issues concerning software developed during the project.[684]
- When the Hampton Roads, Virginia area was implementing a traveler information system, both the public- and private-sector parties involved were concerned with legal problems relating to infringement of patents. An investigation into potential patent infringement was time-consuming and writing an infringement liability section for the contract was also found to be particularly difficult. With the assistance of the Office of the Virginia Attorney General, existing patent infringement sections from similar earlier Virginia DOT contracts were used instead. Contract negotiations lasted over a year, due in part to the difficulty in negotiating patent infringements.[685]

TERMS AND CONDITIONS LESSON

- Create policies to specifically address software and technologies including intellectual property rights that are brought into, enhanced, and developed during a project.

Procurement—Conclusions

Agencies must consider several procurement options for ITS in addition to the traditional acquisition procedures for construction projects. ITS project participants need to investigate their agencies' procurement options, look for innovative ways to build flexibility into their contracts, and identify ways to work within the given procurement system to meet their project needs. Early planning can save significant time and money in later phases of the project.

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LEGAL ISSUES

Lessons in the legal issues category discuss 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.[686] Privacy issues can present particular challenges in ITS projects, as new ITS technologies can often raise concerns about intrusive, "Big Brother" type surveillance.

Evidence-Based Lessons Learned

Intellectual Property

Intellectual property is a legal issue that concerns the ownership of ideas relating to innovations and technology. Ownership over patents, copyrights, and trademarks encourages advances in technology in ITS, as well as other areas. However, the involvement of Federal and State funding for ITS development can create barriers to ownership of ITS intellectual property.[687]

There is a continuing concern in the private sector that State or Federal laws will require firms participating in public-private partnerships to surrender valuable rights in intellectual property (such as computer programs, patentable inventions, and proprietary technical data) developed with public funds. On the other hand, the public sector strives to give the public the full benefit of public spending by acquiring the right to use such intellectual property for government purposes. Government officials also cite a concern about creating a monopoly for certain technologies. Although the issue of IPR has not been a showstopper to the ITS Program, it merits close scrutiny because it has caused delays in many ITS projects.

Address intellectual property rights early to develop a clear policy and increase efficiency. The assignment of IPR will always be an issue, and ITS practitioners must recognize this fact and address it. The section below discusses IPR issues and the importance of addressing these issues early and developing clear policies to handle such issues.

- The participants in several of the metropolitan Model Deployment Initiative sites were forced to resolve this issue before continuing with the MDI projects. Many of these participants had dealt with IPR issues in ITS work predating the MDI. As a starting point to resolving IPR concerns, administrators from both the AZTech™ (Phoenix) and the SmartTrek (Seattle) projects based their IPR policies on the Federal Government's policy on intellectual property. (The AZTech™ project even went so far as to include the Federal Government's policy in all contracts between the public and private sectors.) In both the SmartTrek and the AZTech™ projects, the use of this policy significantly improved the contract negotiation process and helped to resolve the concerns of the contracting parties. Before implementing this policy, public-sector participants in the AZTech™ project experienced a four-month delay in negotiating a contract with their first vendor. After implementing the policy, however, negotiations with other vendors took less time.[688]
- Resolving IPR questions early helps to increase efficiency. In both the AZTech™ and TransGuide (San Antonio) MDI projects, questions of intellectual property extended project negotiations. Only when these questions were answered were the project par-

INTELLECTUAL PROPERTY LESSON

- Address intellectual property rights early to develop a clear policy and increase efficiency.

INTELLECTUAL PROPERTY LESSON

- Understand the intellectual property rights issues concerning software development and technology and develop a clear policy to address these issues.

ticipants able to proceed with deploying their systems and only after resolution of these issues were project participants able to spend time on technical, rather than policy and procedural issues.[689]

Understand the IPR issues concerning software development and technology, and develop a clear policy to address these issues. Another set of important IPR issues are ones that relate to software development and software rights. The following examples discuss IPR issues associated with software development.

- Since the beginning of the ITS Program, the U.S. DOT has encouraged the participation of the private sector. However, Federal rules governing ownership and access to intellectual property have tended to discourage the private sector from investing in U.S. DOT-supported activities. To address this problem, the Transportation Efficiency Act for the 21st Century included new research and technology initiatives. These initiatives gave U.S. DOT operating agencies greater flexibility to negotiate terms and conditions for private-sector participation, such as those involving ownership and access to intellectual property, than was available under other research and capital programs. Agencies have found that they can reduce the impact that IPR issues have on project deployment schedules by taking creative approaches to resolving IPR issues. For example, the solicitation of Federal Government policy, development of licensing agreements, creation of an intellectual property manual, and the creation of more flexible programs illustrate that IPR issues do not represent insurmountable barriers to ITS deployment.

  The following examples discuss the importance of addressing IPR issues and questions of ownership of software and technology developed during the course of the project through a variety of approaches.

  - It is important to develop licensing agreements that clearly assign the intended intellectual property ownership and IPR to hardware and software technologies. For example, representatives from the AZTech™ project developed two licensing agreements: one for preexisting technologies and privately funded developments and another for hardware and software developed during the course of the AZTech™ project using public funds.
  - Developing formal procedures for addressing intellectual property issues is important for helping to define intellectual property ownership. For example, Texas DOT management established an Intellectual Property Committee that evaluated the Texas DOT's needs, made recommendations, and issued guidance to clarify the agency's policy on the ownership and use of intellectual property developed and used on projects funded by the agency.[690]

  These experiences illustrate both the importance of addressing IPR early to develop clear policies and the criticality of understanding the IPR issues associated with software development and technology.

Liability

The topic of legal liability is closely related to tort liability. Johnson [691] gives the following definition of tort liability:

A tort is an accidental or intentional harm to a person or thing. The legal concepts surrounding the assignment of fault, or liability, to a person or thing were first developed in England before the founding of the United States. In this country, most tort law is formed and enforced at the State level, with each State having a differing, but similar, set of laws

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and traditions. By seeking to find and assign fault, tort law is seeking to compensate the victim(s) for his or her injury in order to "make them whole."

The following examples provide guidance regarding ITS-related liability issues, and specially address developing written policies to address such issues early in the project development process.

Develop written policies to address liability issues early.

- Within the project development cycle, it is beneficial to stakeholders to develop written policies to address liability issues early. Policies developed for the AZTech™ metropolitan model deployment in Phoenix stressed that each partner should be legally responsible for the actions of its employees, including subcontractors. The contract between the Maricopa County DOT (the public sector contracting agency) and private sector participants included an indemnification clause and a limitation of liability. The indemnification clause stated that the private sector participant agrees to hold the county, State, and FHWA harmless in all suits arising from wanton, willful, or negligent acts and omissions on the part of the private sector contractor, its agents, or subcontractors. Liability under the contracts between public-sector and private-sector partners is limited to the amount of the contract and did not extend to indirect or consequential losses incurred by the Maricopa County DOT. The effect of the indemnification clause was to hold the private firms responsible for the actions of their employees and public agencies responsible for the actions of their employees.[692]
- In an effort in the Phoenix metropolitan area to facilitate traffic signal coordination among signals in many jurisdictions along a single corridor, engineers in the area established a Signals Working Group. These engineers established the following practices within the group to avoid potential liability issues.
  - Define and document a series of thresholds under which signal plans can be altered.
  - Establish written coordination policies and plans to cover signalized corridors bordering multiple jurisdictions.

The key to overcoming any constraint is to acknowledge its likelihood and address it early. Project participants should anticipate these obstacles and come to the table prepared to discuss them. This lesson illustrates how a metropolitan area can work together to circumvent any liability issues that may surface by establishing a discussion group and developing a set of plans and procedures to share traffic signal control among multiple jurisdictions. Cross-jurisdictional signal control can lead to significant benefits for a region having considerable impact on the performance of a corridor and contributing to the achievement of several ITS goals including safety, mobility, efficiency, and customer satisfaction. The group's actions were instrumental in reducing the liability associated with this multi-jurisdictional traffic signal control effort.[693]

Privacy

Privacy and data protection are important issues to the general public. In fact, one of the primary concerns people have about ITS is that these technologies will create a "Big Brother" that can track each vehicle's movements and access sensitive data, such as financial information.[694]

LIABILITY LESSON

- Develop written policies to address liability issues early.

The following lessons learned experiences provide evidence that the balance between data sharing and data security issues are central to stakeholder privacy concerns.

Carefully consider data sharing issues to effectively balance information sharing needs with data security and privacy measures for ITS applications.

- Ensuring data privacy was essential to the success of an international cross-border freight tracking system implemented in British Columbia, Canada and Washington State. The International Mobility and Trade Corridor (IMTC) Border Crossing Deployment Project's freight-tracking information system—the TransCorridor Operating System (TCOS)—linked shipping companies' information systems with the U.S. Customs Service's (USCS) Automated Manifest System. The TCOS provided data security by requiring commercial carriers, shippers, brokers, importers, exporters, and governmental regulatory agencies to register as trade corridor users. Users were then required to log in with a user name and password, which granted them access to specific pre-defined trade corridor information. Although certain stakeholders (USCS, the Washington State DOT, and the TCOS administrator) were allowed to view each company's freight information, private companies were not granted access to view their competitors' information. The deployment allowed the IMTC stakeholders to successfully demonstrate how freight data could be protected in this type of ITS deployment.

  The TCOS established data security measures to protect both private- and public-sector proprietary and sensitive information. Private-sector entities wanted to protect their proprietary and sensitive information. Public-sector stakeholders, such as USCS and the Canadian Customs and Revenue Agency, needed to access a wide range of shipment information related to the enforcement of national laws and regulation. The TCOS was designed to protect this delicate balance of information dissemination and protection.[695]

- Transportation agencies typically share data with other public agencies and private companies to improve transportation operations through better interagency coordination and to optimize the use of the transportation system by providing information to travelers. Although some agencies use contractual language or training and procedure manuals to handle data sharing, the preferred approach is a data sharing policy. In a U.S. DOT survey among public agencies about data sharing, more than half (18 of 34 agencies) reported having a policy on data sharing in place and several others reported having plans to develop one. A formal policy aids data dissemination by providing a process for handling requests for data from other government agencies and private sector companies. This kind of formal process helps with ensuring fair treatment as well as managing expectations and resources. When considering data sharing, it is helpful to recognize the following factors:
  - Use a data sharing policy to establish the general approach for your agency. The majority of public agencies take an open access approach to sharing traffic and transportation data that they collect.
  - Use an open access policy to enable and encourage a variety of ways of providing information to the public. In the right environment, free and open access to data will stimulate its creative use and dissemination by a significant number of participants.
  - Use an exclusive data sharing policy if restricted access may be necessary to stimulate interest and investment in data use and dissemination. Practical considerations for an exclusive arrangement include: wanting to avoid dealing with

PRIVACY LESSON

- Carefully consider data sharing issues to effectively balance information sharing needs with data security measures for ITS applications.

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too many private parties; having invested in infrastructure, but with no budget for information dissemination; or having no budget for either infrastructure or dissemination.

These lessons learned experiences show the importance of formalizing policies regarding data distribution for the public good, considering the needs of both the public and private sectors, and effectively balancing information sharing needs with data security measures for ITS applications.[696]

Rules and Regulations

Toll collection, managed-lane enforcement, and data sharing are often controversial issues that necessitate rules and regulations to manage their use. It is also important to ensure that an agency's rules are consistent with applicable laws.

Plan and create policies and rules that address electronic toll collection, enforcement, and data sharing issues. Electronic toll collection (ETC) combines installation of transponders on vehicles, the installation of technology that can "read" the transponder at toll plazas, and administration of accounts at a central office. When a user opens an account and a transponder is issued, information about the user is entered into a database, so that the appropriate charge on the account can be made. In some cases, the user may supply financial information, such as a credit or debit card number, so that the account can automatically be replenished when funds are running low.

ETC is critical to successful implementation of variable pricing, in which toll rates vary based on traffic conditions. Experiences from two toll facilities in California that employ variable pricing show the importance of obtaining legislative authorization for variable pricing, openly sharing toll policies with the public, and incorporating automated enforcement technologies. The success of a value pricing strategy depends on the ability to protect the integrity of the managed-lane facility, and automated toll collection and enforcement technologies are critical in this regard.

- I-15 in San Diego, California employs dynamic tolling, whereby toll rates vary during the day based on traffic conditions. Legislation passed at the State level authorized dynamic tolling on this facility. All users on the facility must be registered and must have a FastTrak account, including a transponder.
- State Route (SR) 91 in Orange County, California uses automated enforcement for toll collection. When a reader cannot detect a tag or detects an invalid tag, it triggers a camera that takes a photo of the vehicle's license plate. The license plate image is matched against the database records to determine if the motorist has a valid account. If there is no record of an account, state motor vehicle records are used to identify the driver, and then a citation is issued.

The planning, rules, and infrastructure make this ETC and enforcement much more feasible and manageable than previously possible. ETC provides the agency with a seamless system for collecting the tolls. At the same time, enforcement is required to protect the integrity of the facility. To the extent that enforcement can be automated, this will create a more efficient system for monitoring the facility.[697]

Develop a regional information sharing policy to help define information access and compensation arrangements. Developing a regional information policy helps to define information access and compensation agreements across project and jurisdictional boundaries.

RULES AND REGULATIONS LESSON

- Plan and create policies and rules that address electronic toll collection, enforcement, and data sharing issues.

RULES AND REGULATIONS LESSONS

- Develop a regional information sharing policy to help define information access and compensation arrangements.
- Consider legislative authority and institutional ar rangements.

- In the New York metropolitan area, Transportation Operations Coordinating Committee (TRANSCOM) staff developed a regional information policy that was later applied to several other projects, including the New York metropolitan model deployment (known as Trips 123) and an advanced traveler information system along the I-95 corridor. The policy defines what information was "TRANSCOM information," and therefore, the property of TRANSCOM and included under the rules of this policy. The policy also specified who would have access to the information, the level of compensation required for the information, and how compensation will be established.[698]

Consider legislative authority and institutional arrangements to help affect policy changes. Legislative authority and institutional arrangements are often needed to affect significant policy changes. For instance, using pricing as a lane management strategy may require legislative changes at both the State and Federal levels, as tolling is not explicitly allowed on the Interstate system. In addition, automated enforcement, a critical component of tolling, may require enabling legislation. Legislation also may facilitate cooperation between local agencies, State agencies, regional transportation authorities, and private developers. Since managed-lane projects may include a variety of operational strategies, numerous stakeholders may need to be involved, including transit authorities, toll authorities, and private interests. New institutional agreements may be necessary to define the scope and operation of a project.

- In an arrangement that was the first of its kind in the United States, construction and operation of the SR 91 Express Lanes was performed by a private company—California Private Transportation Company—which required new institutional arrangements. The California DOT (Caltrans) and local agencies worked with the company to develop a franchise agreement. The company designed and built the facility in the median of SR 91 on right-of-way owned by the State. However, the non-compete clause written into the agreement—Caltrans was prohibited from making other improvements in the corridor that might reduce traffic in the toll lanes—resulted in frustration amongst all the stakeholders, including the public.
- Planning for managed-lane projects requires input and coordinated planning from a number of stakeholders, including Federal agencies, the State DOT, the metropolitan planning organization, and local agencies, among others. During the planning process, some of the key issues that need to be addressed include institutional arrangements and legislative authority.[699]

Legal Issues—Conclusions

The legal issues discussed include a wide range of topics related to the application of ITS. These topics include intellectual property, liability, privacy, and rules and regulations. The legal issues associated with these areas must be handled in a proactive, thoughtful, and comprehensive manner since they impact a wide variety of important societal and transportation-related issues. Addressing these issues in such a manner will help to minimize legal problems associated with intellectual property issues, privacy concerns, and legislative authority arrangements.

HUMAN RESOURCES

The efficient operation of ITS depends on the effective management of human resources, i.e., ensuring that the right number of staff are assigned to plan, design, deploy, and operate an ITS project and that they have the right skills and training. Specific lesson topics on human resources include personnel management, recruiting and staffing, retention and turnover, and training.

PERSONNEL MANAGEMENT LESSONS

- Develop a staffing plan flexible enough to accommodate routine and emergency conditions.
- Consider different staffing arrangements to meet various scheduling demands at a transportation management center.

Evidence-Based Lessons Learned

Personnel Management

Develop a staffing plan flexible enough to accommodate both routine and emergency conditions. Staffing plans anticipate human resource needs and prescribe human resource activities, such as succession planning and training programs, to meeting those needs. Often, staffing plans meet the needs of day-to-day activities, but some ITS applications, such as transportation management centers, may need to plan for emergency situations.[700]

- A staffing plan provides a framework for human resource decisions and activities by outlining a systematic approach to human resource management. Human resource functions should be integrated to support one another. For example, performance evaluations should include an assessment of training that employees have completed, and training activities should enable employees to receive pay raises and promotions, possibly as part of a succession plan.
- Staffing plans are often driven by the strategy of the organization; however, a more appropriate conceptualization of strategy for a TMC may be in terms of the functions performed, the services offered, and the overall mission of the TMC. Staffing plans address the human resources needed to meet the goals of the organization.[701]
- Because TMCs provide a key public safety service that must remain operational during emergencies, TMCs must develop an emergency staffing plan. This staffing plan must ensure that all components of the TMC mitigate the emergency to the fullest extent possible under different operating conditions, even when components of the TMC are affected by the emergency. Although, by definition, the nature and timing of emergencies are not known in advance, TMCs can use many of the same techniques for staffing during planned special events as during emergencies. Furthermore, the nature, if not the timing, of emergencies can sometimes be predicted. For example, TMCs located along coastal cities of the Gulf of Mexico can develop an emergency staffing plan in the event of a hurricane.

INSIGHT—COMMON STRATEGIES FOR A FLEXIBLE STAFFING PLAN

The following are actions that agencies can take during an emergency or planned special event to increase staff levels. It is often helpful to include some of these actions in an emergency staffing plan.

- Access additional staff from a temporary agency or contractor
- Call in employees who have been promoted or moved to other sections of the organization
- Call in off-duty employees
- Call in retired employees
- Create a list of volunteers within the organization who can perform critical duties during a staff shortage
- Cross train staff to perform other critical duties (e.g., train technical staff or maintenance personnel to perform operations duties)
- Decrease the level of service or number of functions supported
- Have management, supervisors, or shift leaders perform the duties of their subordinates
- Place employees on-call in case of emergencies
- Redistribute workload among available staff
- Retain the current shift and/or call in the next shift early[702]

Consider different staffing arrangements to meet various scheduling demands at a transportation management center. Different staffing arrangements may be used to meet various scheduling demands. Typically, alternative staffing arrangements are used to increase the flexibility of using human resources to meet scheduling demands. For example, part-time employees may be used to meet the excess demand for services during anticipated periods of peak congestion. Different staffing arrangements may be appropriate depending on current staff levels and current and future needs.

- Part-time: Part-timers are typically less expensive and more flexible for TMC assignments. Although some part-time employees desire the reduction in hours per week, others accept part-time positions because of a lack of full-time positions. Part-time employees can require as much supervision and administrative support as full-time employees. Some part-time employees are not considered to be temporary employees and are referred to as permanent part-time. Although permanent part-time employees typically receive pro-rated benefits, often health insurance benefits are at the same rate as full-time employees.
- Job sharing: Job sharing is defined as two or more part-time employees covering the duties of one full-time position; job sharers are typically at the same performance level. Job sharing does not require that each employee works half time or that the number of hours add up to 40 per week. Often the decision to increase the number of hours beyond 40 per week will be made based on the preferences of the personnel at a TMC and available funding. By converting one full-time position into two or more part-time positions, employers gain flexibility in scheduling and a greater pool of knowledge, skills, and abilities. To succeed, job sharers must be willing to work as a team and able to perform the job as efficiently as one employee, which requires communication and cooperation. They must also have complementary knowledge, skills, abilities, and work styles. Otherwise splitting the job may be difficult and conflicts might arise.

- Temporary or contract employees: Although temporary employees hired from another agency usually cost more per hour, this option has a number of benefits. Temporary employees are not paid when there is no work for them to perform, are not provided benefits, and cannot file claims for unemployment compensation upon termination. Using temporary employees provides a layer of flexibility. TMCs may also choose to contract work to outside vendors. Typically, contractors are used on a per project basis or for the maintenance of field equipment. Because temporary employees and contractors are not employees of the TMC, the TMC is not responsible for hiring, disciplining, paying, or terminating them. Although TMCs require less human resources support for temporary or contracted employees, there may be a greater demand on management resources.
- Flexible utilization of existing employees: Internal actions, such as redeployment or reassignment, are often a more efficient option that maintains cost levels through the flexible utilization of existing employees. Redeployment or reassignment may be permanent or temporary, and may become necessary during an unexpected peak in demand or when an employee takes an extended vacation or sick leave. Overtime also enables employers to meet more demand without hiring additional employees. Employees are more willing to work overtime if they are satisfied with their jobs. However, excessive or involuntary overtime can reduce job satisfaction and morale. If overtime is necessary, the amount of overtime should be minimized and the number of hours should be limited to no more than 48 hours per week when possible.
- At the Arizona TMC, to cover the functions and hours of service, operations staffing levels include 13 full time employees—the operations supervisor, shift supervisors, and operators (certified and noncertified)—and 3 part-time students and interns. Each shift has a minimum of two operators, one of which is full-time. Interns must work with at least one full-time certified operator.[703]

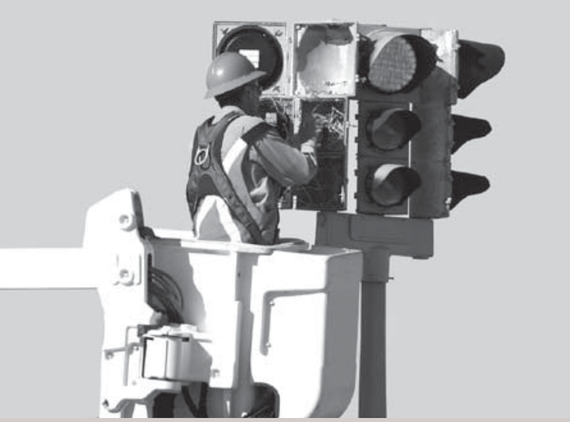
Although many alternative-staffing arrangements may be used to add flexibility in accommodating scheduling demands and meeting budgetary constraints, the staffing implications of the arrangements should be considered. For example, although voluntary part-time employees and job sharers may be satisfied with their working arrangements, involuntary part-time employees may resign as soon as they can find a full-time position. In addition, the option of hiring contractors provides staffing flexibility, but contractors may not show the same commitment to their jobs as full-time employees.[704]

Recruiting and Staffing

Organizations must determine what knowledge, skills, and abilities employees should possess, how many employees are currently required in each job, and how many might be required in the future. In addition, judgments must be made as to how a prospective employee's individual characteristics might make them better suited for certain positions. For example, the characteristics of an operator who will work the night shift may differ from those of a day-shift operator. The night shift may require an employee who can work independently and can handle more responsibility, in contrast to a day worker who may need more teamwork skills. Because an operator position requires an extensive amount of training, an applicant may need to be hired several months before the position is vacant so that there is sufficient time to complete their training and reach a minimum competency level in the position.[705]

RECRUITING AND STAFFING LESSONS

- Evaluate technical and support staffing needs to close gaps in ITS operational support.
- Involve staff in the ITS planning and deployment process.



Evaluate technical and support staffing needs to close gaps in ITS operational support. Complex ITS efforts, such as operating a traffic management center, require not only highly-skilled operators, but also highly-skilled technical and support staff, including systems administrators, purchasing agents, and network technicians.

- There are many benefits to providing qualified staff in key positions. Purchasing assistants who could manage equipment and warranties enable reduced costs and response times on field maintenance. Network systems technicians could help reduce costs and repair times by fixing glitches in-house. A systems administrator would allow for better functionality of the ITS system by supporting current and ongoing operational needs. TMC systems administrations, under the supervision of a TMC manager, have several key responsibilities, such as installing, revising, and maintaining ITS computer software systems and resolve related problems; managing computer equipment maintenance; and undertaking configuration management tasks.
- The City of Los Angeles has an in-house software team to operate and maintain its traffic signals. The team receives software maintenance support from three IT department staff members, whose role is to support the purchase of system parts and equipment, and to manage warranties. A dedicated staff member oversees in-house maintenance and coordinates the handling of materials with outside contractors. Purchasing assistants help with the operations and active procurement of spare parts, helping to cut response time on field maintenance and reduce procurement delays.[706]
- During the implementation of the I-25 Truck Safety Improvements Project, CDOT believed if it had the current levels of in-house expertise throughout the project, it may have had a better relationship with the system integrator. Acquiring these skill sets ultimately allowed CDOT to subdivide technical responsibilities for completion of multiple task orders between five or six capable and knowledgeable individuals, rather than two or three "thinly spread" individuals. CDOT believes that the acquisition of these needed skill sets was key to the success of the project.[707]

RETENTION AND TURNOVER LESSON

- Create meaningful career paths and adopt optimal workload conditions for successful operations staff hiring and retention.

Involve staff in the ITS planning and deployment process. Involving the staff is one strategy that can help provide smooth project integration into an agency's structure. When employees perceive that decisions are made without their involvement they may not be as willing to accept new technologies or develop new ways of doing business. They may also have concerns about job security.

- In the San Antonio MDI (TransGuide), employee involvement was sought out in several ways. The Ambulance Committee solicited feedback from emergency medical technicians and firefighters concerning the placement of video equipment in ambulances. The VIA Metropolitan Transit Authority asked its bus drivers to provide input on the placement of cameras within buses. Operators of the San Antonio TMC were involved in designing the upgrade and expanding the TransGuide center.[708]

Retention and Turnover

Create meaningful career paths and adopt optimal workload conditions for successful operations staff hiring and retention. Creating meaningful career paths and implementing safeguards against excessive workload are two key steps to take to minimize staffing problems.

- Meaningful career paths and other positive staffing policies make it easier to recruit and retain qualified employees. Negative staffing policies that can hinder recruitment and retention are unclear job descriptions, low pay rates, and stringent hiring qualifications. Agencies with such negative policies in place must work to change them.
- In transportation operations, it is often critical to not leave positions vacant for even a day. One technique for avoiding this situation is to hire appropriate staff as soon as the future vacany is identified, rather than waiting for the position to become vacant or waiting until a complex ITS project has been completed.
- Excessive workload can also lower job satisfaction and hinder recruitment and retention efforts. It is particularly important to guard against excessive workload at TMCs, where there is a tendency to assign multiple tasks to TMC operators, including tasks outside of traditional traffic management. ITS technologies can also be used to reduce operator workload at TMCs by automating selected tasks, such as automated video and voice logging of traffic incidents.[709]
- Organizations must anticipate future changes both from within the organization and from external sources. Staffing plans should be formulated in advance by anticipating future changes, instead of relying on reactionary decisions. Key positions within the organization can be tracked to determine when TMC employees plan to leave or retire. Lower-level employees can be groomed for promotion to fill key positions before the departure of higher-level employees. Economic growth or other factors such as an increase in gasoline prices may create a greater demand for services from TMCs. By anticipating the opportunity for growth, a TMC can request more money to hire more employees to expand operations and improve the services offered.[710]

Training

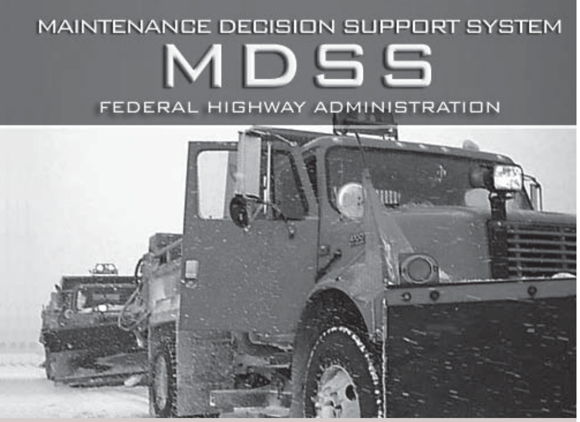
Training is the mechanism that develops in-house expertise and is, therefore, critical to the overall success of an ITS project. Management needs to be actively engaged and supportive of training efforts at the beginning of the project as well as throughout the life cycle of the program. Transportation staff will be more productive and efficient with proper and timely training. By providing ample amounts of initial and ongoing staff training, agencies have demonstrated ways in which training can be provided at a reasonable cost while developing in-house training capabilities.

Train staff throughout the deployment of a project to ensure successful implementation and use of ITS resources. Training staff in the use of ITS resources is necessary to ensure successful deployment and operations. Often smaller agencies cannot afford redundancy in staff capability and are more dependent on their employees to cover multiple roles. Along with the initial training as the deployment evolves, it is equally important to provide ongoing training as systems become operational. By providing sufficient staff training, agencies experience smoother ITS deployments and more efficient operations. The train-the-trainer approach has proven very popular with agencies. This approach can help cut down the costs associated with bringing in outside parties to train staff members, as well as building an in-house training capability.

- Employees of The Capital Area Rural Transportation System in Austin, Texas attend annual Trapeze (CARTS' software provider) user group meetings in Arizona. The trained staff then return to the agency and train other staff in use of the software, as needed.

TRAINING LESSONS

- 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.



- Trained employees from the Florida Commission for the Transportation Disadvantaged in St. Johns and Putnam Counties provide new participants with substantial amounts of peer-training and technical assistance with the RouteLogic software. The new participants found the training helpful from a technical aspect and the training facilitated co-operation between members of the various Community Transportation Coordinators.
- In New Mexico, the Alliance for Transportation Research Institute conducted regional training on the Client Referral, Ridership, and Financial Tracking system for transit system staff. A training session was held in four of the five New Mexico Human Services Department regions. Each transit agency sent two representatives, who returned to their organizations and trained other personnel.[711]
- Train-the-trainer programs not only train staff to work with new ITS technologies, but they can also alleviate staff concerns about organizational change. For example, in Indianapolis, deputies who participated in the mobile data terminal pilot project were able to train their fellow deputies on the equipment, thereby contributing to the system's acceptance and effective use.
- The training of San Antonio firefighters and emergency medical technicians on new ITS equipment occurred through a phased program in which small groups are selected and trained and, in turn, trained others. This system worked well for the San Antonio Fire Department because the units are geographically dispersed. Fire department management preferred to conduct in-house training, as outside trainers lacked familiarity with personnel concerns and with San Antonio Fire Department procedures.[712]

Provide training to maintenance crews before introducing a maintenance decision support system. In order to achieve the full benefits of a maintenance decision support system (MDSS), the 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. Training needs to occur before the tool is even introduced. DOTs need to build support for the tool by exerting strong leadership in support of the tool and by providing training to maintenance crews prior to the introduction to MDSS (as well as ongoing support while the MDSS is being used). DOTs should expect that it will take time for their management and crews to adopt and accept an MDSS into their standard operations. By addressing potential institutional barriers at the outset, DOTs will enable their maintenance crews to more effectively use an MDSS, and realize its benefits of increased safety, mobility and productivity.

INSIGHT—TECHNIQUES TO EFFECTIVELY IMPLEMENT TASK-TRANSFER ACTIVITIES

- The following are techniques that can be used to effectively implement task-transfer activities.
- Create rules or guidelines for transferring a task from one operator to another operator.
- Clearly document an operator's responsibilities and priorities when workload approaches or surpasses a peak level.
- Provide rules or guidance on which tasks are more critical and which tasks can remain incomplete.
- Ensure that the TMC system supports task-transfer.[713]

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The MDSS deployed by MaineDOT offered the DOT and the Scarborough crew a useful winter storm planning tool that supplemented other resources in some important ways. First, the MDSS added capabilities that they previously did not have from its other tools 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. However, an evaluation found that institutional issues hampered effective utilization of the tool.

- Once an MDSS is adopted, the MDSS vendor can offer active support to the maintenance crew that is using the tool to explain its capabilities, answer questions that arise, and suggest effective ways to take best advantage of its capabilities. The more active the relationship between the vendor and the state DOT users, the more effective the MDSS will be in supporting the DOT's maintenance operations. In Maine, the MDSS vendor worked closely with the DOT, offering MaineDOT the services of its meteorological staff and encouraging the Scarborough crew to call before every storm event to obtain further guidance and interpretation of the forecasts being provided.

- An MDSS is a very different and more complex technology compared with many of the systems used throughout Maine and other states. Maintenance personnel who are uncomfortable with computers and related technologies may be resistant to work with an MDSS initially. MaineDOT selected the Scarborough crew for an evaluation project based in part on its enthusiasm and willingness to work with the MDSS throughout the winter season. If more progressive crews adopt MDSS initially, they can serve as an example to other crews, and can also provide training to other crews.[714]

- It is important to develop and maintain an ongoing training program in order to provide well-trained staff for maintaining and operating systems. This will help ensure that staff can perform the maintenance and operations duties to which they have been assigned. California's plan for the Los Angeles area identifies training requirements for staff. Florida also recommends that a training program be developed and maintained.[715]

Implement cross-training mechanisms to allow task-transfer to handle variable loads of staffing needs. Cross training enables employees in different positions to offer assistance during peak workload conditions. For example, a manager may provide assistance to an operator on duty during an off-peak period if there is a major incident. An operator trained in handling the dynamic message sign system may also receive cross training in special event management to offer assistance during infrequent peaks in workload. One approach to ensuring task-transfer is to standardize the capabilities and interfaces of the equipment such as operation consoles. Another approach is to provide cross training for different positions.[716]

- In Cincinnati, ARTIMIS provides incident, congestion, and freeway management information for the Cincinnati-Northern Kentucky Region. The project staff began to provide training to Cincinnati Police Academy cadets on the services that ARTIMIS can provide to the academy to improve officers' experiences while on highway patrol duty. The early exposure of the cadets to the existing partnerships served to strengthen the strong bond between public safety officials and transportation professionals in the greater Cincinnati area.[717]

TRAINING LESSON

- Implement cross-training mechanisms to allow task-transfer to handle variable loads of staffing needs.

Human Resources—Conclusions

The human resource needs for ITS projects vary significantly from those of the traditional transportation engineering projects of facility construction and operations. Several best practices have been shown to be particularly helpful in ITS projects, including involving staff in the planning, design, and deployment process; developing a process for successful hiring and retention; and providing comprehensive initial and ongoing training.

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LESSONS LEARNED CONCLUSIONS

The lessons learned discussed in this report provide a synthesis of stakeholders' experience in their 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, whereas 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. Major conclusions are presented below.

Management and operations: ITS program managers and practitioners are continuously developing strategies to improve the efficiency and reliability of transportation systems and infrastructure. However, a successful ITS project is not solely dependent on how well the system was designed and deployed. Ongoing success depends on how well the system is managed, maintained, and operated.

Policy and planning: The policy and planning phase is the foundational step upon which the successful implementation of an ITS project hinges. Most ITS projects require cooperation among divisions within an agency, as well as among regional agencies that are involved in managing some aspects of transportation systems. ITS program managers and practitioners must strive to develop consistent policies acceptable to stakeholders, use the National ITS Architecture and other standard tools to prepare planning documents, and mainstream the ITS planning process by providing necessary input to the regional long-range transportation programming process.

Design and deployment: The design and deployment lessons include insights on project management, requirements and design, standards and interoperability, implementation, quality assurance and testing, and design tools and models. Most agencies consider an ITS project successful if it meets the requirements of the agency, the needs of the customer, and is deployed within the budget and schedule constraints. Issues associated with design and deployment are best dealt with in the early phases of a project. Identifying other agencies with similar projects and discussing items that worked well and what they would or would not do again, can provide great benefits to an agency looking to deploy a project.

Leadership and partnerships: ITS leaders and champions are pivotal decision makers who decide what is right for planning and implementing ITS so that project managers and practitioners, based on their leaders' guidance, can execute the ITS projects. Successful ITS planning and implementation requires championing of ITS by agency's high-level leadership, forging partnerships among entities involved in managing some aspects of the regional transportation system, performing awareness and outreach efforts within and outside agencies, and developing an efficient and effective organizational structure.

Funding: The funding lessons provide insights on types of funding sources used for ITS, including Federal, State, and local governments, as well as innovative financing mechanisms. Funding and financing mechanisms available today reflect a shift from the traditional means of grant-based funding and address the realities of certain funding shortfalls. Federal and State Governments, as well as State DOTs, are working collaboratively with other regional and local entities as well as the private sector to maximize the effectiveness of every transportation improvement. Project stakeholders must work together to assemble a funding package that will result in a financially feasible project.

Technical integration: Technical integration for ITS is a multi-faceted concept and involves more than simply assembling the pieces of a puzzle. This type of integration involves functional, jurisdictional, and legacy system issues that all must be considered and coordinated to integrate the components of an ITS system.

Procurement: Agencies must consider several procurement options for ITS, in addition to the traditional acquisition procedures for construction projects. ITS project participants need to investigate their agencies' procurement options, look for innovative ways to build flexibility into their contracts, and identify ways to work within the given procurement system to meet their project needs.

Legal issues: Several legal issues such as intellectual property, liability, privacy, and rules and regulations have particular impact on ITS deployment, and must be handled in a proactive, thoughtful, and comprehensive manner.

Human resources: The human resource needs for ITS projects vary significantly from those of the traditional transportation engineering projects of facility construction and operations. Several lessons learned have been shown to be particularly helpful in ITS projects, including involving staff in the planning, design, and deployment process; developing a process for successful hiring and retention; and providing comprehensive initial and ongoing training.

CONCLUSIONS

This report has presented many benefits based on evaluations of deployed of 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 Joint Program Office will be updated to provide convenient access to this information, enabling informed ITS decision making.

As documented in this report, significant amounts of information are available for many ITS services, but gaps in knowledge also exist. Refer to Appendix B for additional detail on the breadth of information available in the online knowledge resources on each of these subjects. Readers are encouraged to submit additional evaluation reports discussing system impacts, costs, or lessons learned via the online databases. Documented cost data for implemented ITS applications are also welcome and will help keep the unit and systems costs data up to date. The reader is reminded to check online for the most current information on deployment, benefits, costs, and lessons learned at *www.itsoverview.its.dot.gov.*

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APPENDIX A

UNIT COST DATA (2006 DOLLARS)

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
Roadside Telecommunications (RS-TC)										
1	DS0 Communication Line	TC001	20	0.5	0.9	**1995**	0.6	1.2	**2003**	56 Kbps capacity. Leased with typical distance from terminus to terminus is 8-15 miles, but most of the cost is not distance sensitive.
1	DS1 Communication Line	TC002	20	0.5	0.9	**1995**	4.8	9.6	**2005**	1.544 Mbps capacity (T1 line). Leased with typical distance from terminus to terminus is 8-15 miles, but most of the cost is not distance sensitive.
1	DS3 Communication Line	TC003	20	2.7	4.6	**1995**	22	67	**2001**	44.736 Mbps capacity (T3 line). Leased with typical distance from terminus to terminus is 8-15 miles, but most of the cost is not distance sensitive.
1	ISP Service Fee	TC007					0.17	0.6	**2004**	Monthly service fee ranges from $15 per month for regular dial-up service to $50 per month for DSL.
1	Conduit Design and Installation—Corridor		20	50	75	**2005**	3		**2005**	Cost is per mile. Includes boring, trenching, and conduit (3 or 4 inch). Cost would be significantly less for an aerial installation. In-ground installation would cost significantly less if implemented in conjunction with a construction project.
1	Twisted Pair Installation		20	11	15.7	**2004**	1.98		**2004**	Cost is per mile.
1	Fiber Optic Cable Installation		20	20	52	**2005**	1	2.5	**2005**	Cost is per mile for cable and in-ground installation. Cost would be significantly less for an aerial installation. In-ground installation would cost significantly less if implemented in conjunction with a construction project.
1	900 MHz Spread Spectrum Radio		10	8.2		**1999**	0.1	0.4	**2004**	Cost is per link.
1	Terrestrial Microwave		10	5	19.1	**2005**	0.5	1	**2005**	Cost is per link. Cost could be high-er depending on tower/antenna installation.
1	Wireless Communications, Low Usage	TC004					0.12	0.2	**2003**	125 Kbytes/month available usage (non-continuous use).
1	Wireless Communications, Medium Usage	TC005					0.5	0.6	**1995**	1,000 Kbytes/month available usage (non-continuous use).

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
1	Wireless Communications, High Usage	TC006	20	0.5	0.9	**1995**	1.1	1.7	**2002**	3,000 Kbytes/month available usage (non-continuous use).
1	Call Box		10	4	6.7	**2004**	0.25	0.57	**2004**	Capital cost includes call box and installation. O&M is cost per unit (per year) for service maintenance contract and annual cellular service fee.
Roadside Detection (RS-D)										
2	Inductive Loop Surveillance on Corridor		5	3	8	**2001**	0.4	0.6	**2005**	Double set (4 loops) with controller, power, etc.
2	Inductive Loop Surveillance at Intersection		5	8.7	15.6	**2005**	0.9	1.4	**2005**	Four legs, 2 lanes/approach.
2	Machine Vision Sensor on Corridor		10	21.2	28	**2003**	0.2	0.4	**2003**	One sensor both directions of travel. Does not include installation.
2	Machine Vision Sensor at Intersection		10	16	25.9	**2005**	0.2	1	**2005**	Four-way intersection, one camera per approach. Does not include installation.
2	Passive Acoustic Sensor on Corridor			3.5	7.7	**2002**	0.2	0.4	**1998**	Cost range is for a single sensor covering up to 5 lanes. Low cost is for basic sensor, which consists of the sensor, mounting kit, junction box, & cabinet termination card. High cost includes basic sensor with solar and wireless option. This option consists of an antenna, solar charger, battery, & panel, and wireless base station, which will handle up to 8 sensors. Capital costs do not include installation or mounting structure.
2	Passive Acoustic Sensor at Intersection			5	14	**2001**	0.2	0.4	**2002**	Four sensors, 4-leg intersection.
2	Remote Traffic Microwave Sensor on Corridor		10	9	13	**2005**	0.1	0.59	**2005**	One sensor both directions of travel. Includes sensor, transceiver, cabinet, electrical service, and pole.
2	Remote Traffic Microwave Sensor at Intersection		10	17		**2001**	0.1		**2001**	Four sensors, 4 leg intersection. Includes installation.
2	Infrared Sensor Active			5.5	7	**2000**				Sensors detects movement in two directions and determines vehicle speed, classification, and lane position.
2	Infrared Sensor Passive			0.7	1.1	**2002**				Sensor covers one lane and detects vehicle count, volume, and classification.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	CCTV Video Camera	RS007	10	9	19	**2005**	1	2.3	**2004**	Cost includes color video camera with pan, tilt, and zoom (PTZ), cabinet, electrical services, encoder/decoder, and installation.
9	CCTV Video Camera Tower	RS008	20	4	13	**2005**				Low cost is for a 35 ft. tower. High cost is for 90 ft. tower. Includes foundation, pole, conduit, and labor. Camera lowering unit additional $3,500. Camera tower requires minimal maintenance.
2	Pedestrian Detection Microwave			0.6		**2001**				Cost is per device. Typical deployment consists of 2 devices per crosswalk for detection of pedestrian in crosswalk. Can be used for detection of pedestrian at the curbside.
2	Pedestrian Detection Infrared			0.3	0.5	**2002**				Cost is per device. Does not included installation. Typical deployment consists of 2 devices per crosswalk for detection of pedestrian at the sidewalk. Can be used for detection of pedestrian in the crosswalk.
2	Environmental Sensing Station (Weather Station)		25	30	49	**2005**	1.9	4	**2004**	Environmental Sensing Station (ESS), also known as a weather station, consists of pavement temperature sensor, subsurface temperature sensor, precipitation sensor (type & rate), wind sensor (speed & direction), air temperature and humidity sensors, visibility sensors, and remote processing unit (RPU). ESS provide condition data and are basic components of larger Road Weather Information Systems (see RWIS under TMC subsystem). RPU replaced every 5 years at approximately $6.4K. O&M includes calibration, equipment repairs, and replacement of damaged equipment. O&M costs could be higher if state provided maintenance.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	Traffic Camera for Red Light Running Enforcement			71	128	**2001**	57		**2001**	Low capital range is for a 35-mm wet film camera, which includes installation of the camera ($25K) and associated equipment (e.g., pole, loop detectors, cabinet foundation). High capital range is for digital camera, which includes a total of 2 cameras for a 3-lane approach. O&M cost is for one 35-mm wet film camera per year. Note, most jurisdictions contract with a vendor to install and maintain, and process the back office functions of the RLR system. The vendor receives compensation from fines charged to violators.
2	Portable Speed Monitoring System		15	4.8	14.4	**2002**				Trailer mounted two-digit dynamic message sign, radar gun, computer; powered by generator or operates off of solar power; and requires minimal operations and maintenance work. The system determines a vehicle's speed with the radar gun and displays the current speed, in real-time, and also stores the speeds in a computer for further analysis.
2	Portable Traffic Management System			78	97	**2003**				This portable unit collects traffic data, communicates with a central control facility, and displays real time traffic information to travelers. The system includes a trailer mounted dynamic message sign and mast equipped with a PTZ video camera, sensors, and wireless communications. Cost will vary depending on the type and number of traffic sensors installed.
Roadside Control (RS-C)										
2	Linked Signal System LAN	RS002	20	23	55	**2005**	0.3	0.6	**1995**	This element provides the connections to the linked signal system.
2	Signal Controller Upgrade for Signal Control	RS003	20	2.4	6	**2003**	0.2	0.4	**2005**	Local controller upgrade to provide advanced signal control.
2	Signal Controller and Cabinet			8	14	**2005**	0.2	0.5	**2005**	Includes installation of traffic signal controller and cabinet per intersection.
2	Traffic Signal			90	108	**2001**	2.2	2.7	**1999**	Includes installation for one signal (four-leg intersection), conduit, controller, and detection device. Cost ranges from traffic signal with inductive loop detection (low) to non-intrusive detection (high).

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	Signal Preemption Receiver	RS004	5	2	6	**2004**	0.04	0.2	**2004**	Two per intersection. Complement of IDAS elements RS005 and TV004.
2	Signal Controller Upgrade for Signal Preemption	RS005	10	2	4	**2005**				Add-on to base capability (per intersection). Complement of IDAS elements RS004 and TV004.
2	Roadside Signal Preemption/Priority		10	5	6	**2005**	0.2	1	**2005**	Includes infrared detector, detector cable, phase selector, system software, and installation. Capital costs range is for 2-directions. O&M cost estimate for operating, monitoring, and maintaining. Complement to transit (or emergency vehicle) on-board Signal Preemption/Priority Emitter. Capital costs can rise to $20K-$30K per intersection if traffic control equipment and/or systems need to be replaced.
2	Ramp Meter	RS006	5	24	49	**2003**	1.2	2.7	**2003**	Includes ramp meter assembly, signal displays, controller, cabinet, detection, and optimization.
3	Software for Lane Control	RS011	20	24	49	**1995**	2	5	**1995**	Software and hardware at site. Software is off-the-shelf technology and unit price does not reflect product development.
2	Lane Control Gates	RS012	20	78	117	**1995**	1.6	2	**1995**	Per location.
2	Fixed Lane Signal	RS009	20	5	6	**1995**	0.5	0.6	**1995**	Cost per signal.
2	Automatic Anti-icing System Short span		12	22		**1998**	1.8		**1998**	Typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every 5 years at cost of $3.5K. For a short span system ranging from 120 to 180 feet. O&M includes system maintenance, utilities, materials, and labor.
2	Automatic Anti-icing System Long Span		12	45	446	**1999**	1.4	26.6	**1999**	Typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every 5 years at cost of approximately $3.5K. For a long span system ranging from 320 feet to greater than 1/2 mile. O&M includes system maintenance, utilities, materials, and labor. The high O&M cost is for a much larger system; hence, the need for a greater amount of materials.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
Roadside Information (RS-I)										
2	Roadside Message Sign	RS010	20	39	58	**1995**	2	3	**1995**	Fixed message board for HOV and HOT lanes.
1	Wireline to Roadside Message Sign	RS013	20	5	8	**1995**				Wireline to VMS (0.5 mile upstation).
2	Variable Message Sign	RS015	10	48	119	**2005**	2.3	6	**2005**	Low capital cost is for smaller VMS installed along arterial. High capital cost is for full matrix, LED, 3-line, walk-in VMS installed on freeway. Cost does not include installation.
9	Variable Message Sign Tower	RS016	20	26	126	**2005**				Low capital cost is for a small structure for arterials. High capital cost is for a larger structure spanning 3-4 lanes. VMS tower structure requires minimal maintenance.
2	Variable Message Sign—Portable		14	18.6	24	**2005**	0.6	1.8	**2005**	Trailer mounted full matrix VMS (3-line, 8-inch character display); includes trailer, solar or diesel powered, and equipped with celluar modem for remote communication and control. Operating costs are for labor and replacement parts.
1	Highway Advisory Radio	RS017	20	15	35	**2005**	0.6	1	**2005**	Capital cost is for a 10-watt HAR. Includes processor, antenna, transmitters, battery back-up, cabinet, rack mounting, lighting, mounts, connectors, cable, and license fee. Super HAR costs an additional $9-10K (larger antenna). Primary use of the super HAR is to gain a stronger signal.
2	Highway Advisory Radio Sign		10	5	9	**2005**	0.25		**2005**	Cost is for a HAR sign with flashing beacons. Includes cost of the controller.
2	Roadside Probe Beacon	RS020	5	5	8	**2001**	0.5	0.8	**2001**	Two-way device (per location).
2	LED Count-down Signal		10	0.306	0.424	**2001**				Costs range from low (two 12x12-inch dual housing unit) to high (16X18-inch single housed unit). Signal indicates time remaining for pedestrian to cross, and a walk or don't walk icon. Count-down signals use low 8-watt LED bulbs, which require replacement approximately every 5-7 years.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	Pedestrian Crossing Illumination System		5	26.8	41	**2003**	2.6	4	**2001**	The capital cost range includes cost of equipment and installation. Equipment includes fixtures—4 lamps per lane—for a three lane crosswalk, controller, pole, and push button activator. Installation is estimated at 150—200% of the total equipment cost. Capital cost would be greater if the system included automated activation of the in-pavement lighting system. O&M is approximately 10% of the equipment cost.
2	Variable Speed Display Sign			3.5	4.7	**2001**				Low range is for a variable speed limit display system. High range includes static speed sign, speed detector (radar), and display system.
Roadside Rail Crossing (R-RC)										
2	Rail Crossing 4-Quad Gate, Signals	RS021	20	90	101	**1995**	3.3	3.8	**1995**	Gates and signals.
2	Rail Crossing Train Detector	RS022	20	12	17	**1995**	0.6	0.80	**1995**	Train detector circuitry and communication line from intelligent interface controller (IIC) to wayside interface equipment (WIE). Assume two track crossing with two 0.5 mile communication lines.
2	Rail Crossing Controller	RS023	10	6	8	**1995**	0.3	0.4	**1995**	Intelligent interface controller (IIC).
2	Rail Crossing Pedestrian Warning Signal, Gates	RS024	20	8	12	**1995**	0.2	0.2	**1995**	Pedestrian warning signal and gates.
2	Rail Crossing Trapped Vehicle Detector	RS025	10	19	23	**1995**	1	1.2	**1995**	Entrapped vehicle detection camera, with poles and controller.
Parking Management (PM)										
2	Entrance/Exit Ramp Meters		10	2	4	**1995**	0.2	0.4	**1995**	Ramp meters are used to detect and count vehicles entering/existing the parking facility. O&M costs based on annual service contract.
2	Tag Readers		10	2	4	**1995**	0.2	0.4	**1995**	Readers support electronic payment scheme. O&M costs based on annual service contract.
3	Database and Software for Billing & Pricing		10	10	15	**1995**	1	2	**1995**	Database system contains parking pricing structure and availability. O&M costs based on annual service contract.
2	Parking Monitoring System		10	19	41	**1998**				Includes installation, detectors, and controllers.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
Toll Plaza (TP)										
2	Electronic Toll Reader	TP001	10	2	5	**2001**	0.2	0.5	**2001**	Readers (per lane). O&M is estimated at 10% of capital cost.
2	High-Speed Camera	TP002	10	7	10	**2003**	0.4	0.8	**1995**	Cost includes 1 camera/2 lanes.
3	Electronic Toll Collection Software	TP003	10	5	10	**1995**				Includes COTS software and database.
4	Electronic Toll Collection Structure	TP004	20	13	20	**1995**				Mainline structure.
Remote Location (RM)										
2	CCTV Camera	RM001	7	2	5	**2005**	0.1	0.24	**2004**	Interior fixed mount camera for security. Low cost represents black & white pan/tilt/zoom (PTZ). High cost represents color PTZ. Does not include installation.
3	Integration of Camera with Existing Systems	RM002	10	2	2.4	**1995**				Per location.
2	Informational Kiosk	RM003	7	11	24	**2004**	1	4.4	**1998**	Includes hardware, enclosure, installation, modem server, and map software.
3	Integration of Kiosk with Existing Systems	RM004	7	2.1	26.7	**2005**				Software costs are for COTS (low) and developed/outdoor (high).
3	Kiosk Upgrade for Interactive Usage	RM005	5	5	8	**1995**	0.5	0.8	**1995**	Interactive information display interface (upgrade from existing interface).
3	Kiosk Software Upgrade for Interactive Usage	RM006	5	10	12	**1995**				Software is COTS.
2	Transit Status Information Sign		10	4	8	**2005**				A LED display installed at transit terminal that provides status information on transit arrival. Cost depends on quality, size, and controller capabilities.
2	Smart Card Vending Machine	RM007	5	29	31	**1995**	1.4	1.6	**1995**	Ticket vending machine for smart card.
3	Software, Integration for Smart Card Vending	RM008	20	3	5	**1995**				Software is COTS.
Emergency Response Center (ER)										
4	Basic Facilities, Comm for Large Area	EM006		5380		**1995**	538	807	**1995**	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
4	Basic Facilities, Comm for Medium Area	EM007		4304		**1995**	538	646	**1995**	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
4	Basic Facilities, Comm for Small Area	EM008		3766		**1995**	538	565	**1995**	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
5	Emergency Response Hardware	EM001	5	8	10	**2004**	0.15	0.20	**2004**	Includes 3 workstations. O&M is estimated at 2% of capital cost.
3	Emergency Response Software	EM002	10	68	146	**1995**	0.5	3.4	**1995**	Includes emergency response plans database, vehicle tracking software, and real time traffic coordination.
6	Emergency Response Labor	EM003					73	240	**1995**	Description is based on 1995 data: Two people. Salary costs are fully loaded including salary, overtime, overhead, benefits, etc.
3	Emergency Management Communications Software	EM004	20	5	10	**1995**	2.4	5	**1995**	Shared database between 4 sites. Cost is per site; software is COTS.
3	Hardware, Software Upgrade for E-911 and Mayday	EM005	10	102	175	**1995**	1.7	2.4	**1995**	Data communications translation software, E911 interface software, processor, and 3 workstations.
1	800 MHz 2-way Radio		5	0.7	1.6	**2001**	0.08	0.11	**2001**	Cost is per radio.
Emergency Vehicle On-Board (EV)										
1	Communications Interface	EV001	10	0.3	2	**2004**	0.02		**1995**	Emergency vehicle communications. Cost is per vehicle.
2	Signal Preemption/Priority Emitter		10	0.5	2.1	**2005**				Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/Priority (see Roadside Control subsystem).
Information Service Provider (ISP)										
4	Basic Facilities, Comm for Large Area	IS019		5380		**1995**	538	807	**1995**	For population >750,000. (standalone) Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
4	Basic Facilities, Comm for Medium Area	IS020		4304		**1995**	538	646	**1995**	For population <750,000 and >250,000. (stand-alone) Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
4	Basic Facilities, Comm for Small Area	IS021		3766		**1995**	538	565	**1995**	For population <250,000. (stand-alone) Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
5	Information Service Provider Hardware	IS001	5	23	34	**2004**	0.5	0.7	**2004**	Includes 2 servers and 5 workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Systems Integration	IS017	20	86	105	**1998**				Integration with other systems.
3	Information Service Provider Software	IS002	20	267	535	**1995**	13.4	26.7	**1995**	Includes database software (COTS) and traffic analysis software.
3	Map Database Software	IS003	2	10	29	**2005**				Software is COTS.
6	Information Service Provider Labor	IS004					254	363	**1995**	Description is based on 1995 data: 2 Staff @ 50K to 75K and 1 staff @ 75K to 100K. Salary cost are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
1	FM Subcarrier Lease	IS005					110	219	**1995**	Cost is per year.
5	Hardware Upgrade for Interactive Information	IS006	5	10	15	**2004**	0.20	0.30	**2004**	Includes 1 server and 2 workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Interactive Information	IS007	20	243	486	**1995**	12	24	**1995**	Trip planning software (includes some development costs).
6	Added Labor for Interactive Information	IS008					145	218	**1995**	Description is based on 1995 data: 1 Staff @ 50K to 75K for two shifts. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Software Upgrade for Route Guidance	IS009	20	243	486	**1995**	12	24	**1995**	Route selection software. Software is COTS.
3	Map Database Upgrade for Route Guidance	IS010	2	97	194	**1995**				Map database software upgrade.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
5	Hardware Upgrade for Emergency Route Planning	IS011	5	5	8	**2004**	0.10	0.2	**2004**	Includes 1 server. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Emergency Route Planning	IS012	20	49	97	**1995**	2.4	5	**1995**	Route guidance software. Software is COTS.
5	Hardware Upgrade for Dynamic Ridesharing	IS013	5	5	7	**2004**	0.10	0.14	**2004**	Includes 2 workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Dynamic Ridesharing	IS014	20	96	191	**1998**	5	10	**1995**	Software includes some development cost.
6	Added Labor for Dynamic Ridesharing	IS015					145	218	**1995**	Description is based on 1995 data: 1 Staff @ 50K to 75K for two shifts. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
7	Liability Insurance for Dynamic Ridesharing	IS016					66	132	**1995**	Description is based on 1995 data: 50K to 100K per year.
3	Software Upgrade for Probe Information Collection	IS018	20	243	486	**1995**	12	24	**1995**	Software includes COTS and some development cost.
Transportation Management Center (TM)										
4	Basic Facilities, Comm for Large Area	TM040		4314	9860	**2003**	431	1479	**2003**	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc. O&M is estimated at 10-15% of the capital cost.
4	Basic Facilities, Comm for Medium Area	TM041		4304		**1995**	538	646	**1995**	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc. O&M is estimated at 10-15% of the capital cost.
4	Basic Facilities, Comm for Small Area	TM042		3766		**1995**	538	565	**1995**	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc. O&M is estimated at 10-15% of the capital cost.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
5	Hardware for Signal Control	TM001	5	18	25	**2004**	7	8.2	**2003**	Includes I server and multiple workstations. O&M includes responsive and preventative maintenance.
3	Software, Integration for Signal Control	TM006	5	102	145	**2003**	145		**2003**	Software and integration for a large urban area. Cost would be lower (approx.$10,500) for a few arterial intersections. O&M includes software upgrades, revisions, and expansion of the system.
6	Labor for Signal Control	TM002					579	708	**2001**	Description is based on 2001 data: Costs include labor for operations (2 @ 50% of the time, at 100K), transportation engineer (1 at 50% of the time, at 100K), update timing plans (2K per system per month for every 10 systems), and signal maintenance technician (2 @ 75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Hardware, Software for Traffic Surveillance	TM003	20	131	160	**1995**	6.6	8.0	**1995**	Processor and software.
3	Integration for Traffic Surveillance	TM032	20	219	267	**1995**	10.9	13.4	**1995**	Integration with other systems.
5	Hardware for Freeway Control	TM004	5	8	10	**2004**	0.38	0.5	**2004**	Includes 3 workstations. O&M estimated at 5% of capital cost.
3	Software, Integration for Freeway Control	TM007	5	166	203	**2002**				Software and integration, installation and 1 year maintenance. Software is off-the-shelf technology and unit cost does not reflect product development.
6	Labor for Freeway Control	TM005					268	328	**2001**	Description is based on 2001 data: Labor for operations (2 @ 50% of 100K) and maintenance technicians (2 @ 75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
5	Hardware for Lane Control	TM008	5	3	3	**2004**	0.13	0.2	**2004**	Includes 1 workstation and 19-inch monitor. O&M estimated at 5% of capital cost.
3	Software, Integration for Lane Control	TM009	10	219	267	**1995**	11	13	**1995**	Software development and integration and software upgrade for controllers. Software development is fine tune adjustments for local installations. Otherwise, software is COTS.
6	Labor for Lane Control	TM010					107	131	**2001**	Description is based on 2001 data: Labor for 2 operators @ 50% of 100K.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
3	Software, Integration for Regional Control	TM011	10	287	383	**1998**				Software and integration, installation and 1 year maintenance. Integration with other TMC's. Software is COTS.
3	Real-time, Traffic Adaptive Signal Control System		10	110	137	**2001**	18		**2001**	The cost range is based on commercially available packages, which run on a centralized computer. The high capital cost includes software packages for graphical user interface and incident management. The cost range is representative of 65—235 intersections; cost would be lower for a smaller number of intersections.
6	Labor for Regional Control	TM012					214	262	**2001**	Description is based on 2001 data: Labor for operators (2 @ 50% of 100K), transportation engineer (1 @ 50% of 100K), and maintenance contract. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
5	Video Monitors, Wall for Incident Detection	TM013	10	44	80	**2003**	2	4	**2003**	Video wall and monitors. O&M estimated at 5% of capital cost.
5	Hardware for Incident Detection	TM014	5	33.6	52.0	**2004**	2	3	**2004**	Includes 4 servers, 5 workstations, and 2 laser printers. O&M estimated at 5% of capital cost; could be higher for responsive and preventative maintenance.
3	Integration for Incident Detection	TM025	20	87	107	**1995**	4.4	5.3	**1995**	Integration with other systems.
3	Software for Incident Detection	TM015	5	83	101	**2002**	4.1	5	**2002**	Software is COTS and includes development cost. O&M is estimated at 5% of capital.
6	Labor for Incident Detection	TM016					751	917	**2001**	Description is based on 2001 data: Labor for operators (4 @ 100K and 1 manager @ 150K) and 2 maintenance techs @ 75K.
5	Hardware for Incident Response	TM018	5	3	3	**2004**	0.13	0.2	**2004**	Includes 1 workstation and monitor. O&M estimated at 5% of capital cost.
3	Integration for Incident Response	TM026	20	175	214	**1995**				Integration with other systems.
3	Software for Incident Response	TM019	2	13	16	**1995**	0.656	0.802	**1995**	Software is COTS.
6	Labor for Incident Response	TM020					107	131	**2001**	Description is based on 2001 data: Labor for incident management coordinator (1 @ 100K).
2	Automated Incident Investigation System		5	14.1		**2001**				Includes workstation, tripod, monopole antenna, Auto Integration, and AutoCAD software.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
5	Hardware for Traffic Information Dissemination	TM021	5	3	3	**2004**	0.13	0.2	**2004**	Includes 1 workstation. O&M estimated at 5% of capital cost.
3	Software for Traffic Information Dissemination	TM022	5	17	21	**1995**	0.9	1	**1995**	Software is COTS.
3	Integration for Traffic Information Dissemination	TM023	20	83	101	**2000**	4.4	5.3	**1995**	Integration with other systems.
6	Labor for Traffic Information Dissemination	TM024					107	131	**2001**	Description is based on 2001 data: Labor for 1 operator @ 100K. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.
3	Software for Dynamic Electronic Tolls	TM027	5	22	27	**1995**	1.1	1.3	**1995**	Includes software installation and 1 year maintenance. Software is COTS.
3	Integration for Dynamic Electronic Tolls	TM028	20	87	107	**1995**	4.4	5.3	**1995**	Integration with other systems.
5	Hardware for Probe Information Collection	TM033	3	3	3	**2004**	0.13	0.2	**2004**	Includes 1 workstation. O&M estimated at 5% of capital cost.
3	Software for Probe Information Collection	TM034	5	17	21	**1995**	1.7	2.1	**1995**	Includes software installation and 1 year maintenance. Software is COTS.
3	Integration for Probe Information Collection	TM035	20	131	160	**1995**	13	16	**1995**	Integration with other systems.
6	Labor for Probe Information Collection	TM036					54	66	**2001**	Description is based on 2001 data: Labor for 1 operator (4 hours per day @ 100K/year). Salary costs are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
3	Software for Rail Crossing Monitor	TM037	5	17	21	**1995**	1.7	2.1	**1995**	Includes software installation and 1 year maintenance. Software is COTS.
3	Integration for Rail Crossing Monitor	TM038	20	87	107	**1995**				Integration with other systems.
6	Labor for Rail Crossing Monitor	TM039					54	66	**2001**	Description is based on 2001 data: Operators (1 @ 50% of 100K). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
5	Road Weather Information System (RWIS)		25	11		**1998**	0.2	2	**2001**	Description is based on unadjusted data values: A RWIS consists of several components: an environmental sensing station (ESS), CPU, workstation with RWIS software, and communications equipment. All components of the RWIS reside at the TMC with the exception of the ESS. See Roadside Detection subsystem for costs of ESS. Cost of the ESS ($29K-$48K) should be added to $12K listed here in order to cost out the entire system. CPU replaced every 5 years at a cost of approximately $4K. O&M costs range includes communication, and optional weather forecast/meteorological service.
Transit Management Center (TR)										
4	Basic Facilities, Comm for Large Area	TR014		5380		**1995**	538	807	**1995**	For population >750,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
4	Basic Facilities, Comm for Medium Area	TR015		4304		**1995**	538	646	**1995**	For population <750,000 and >250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
4	Basic Facilities, Comm for Small Area	TR016		3766		**1995**	538	565	**1995**	For population <250,000. Based on purchase of building rather than leasing space. Communications includes communications equipment internal to the facility such as equipment racks, multiplexers, modems, etc.
5	Transit Center Hardware	TR001	5	8	10	**2004**	0.15	0.20	**2004**	Includes 3 workstations. O&M estimated at 2% of capital cost.
3	Transit Center Software, Integration	TR002	20	792	1671	**2005**	6	12	**1995**	Includes vehicle tracking & scheduling, database & information storage, schedule adjustment software, real time travel information software, and integration. Software is COTS.
4	Transit Center Additional Building Space	TR003					8	12	**1995**	Description is based on 1995 data: Additional space required for ITS technology—$12-$18/sq. ft, 500 sq.ft..

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
6	Transit Center Labor	TR004					100	400	**2005**	Labor for 1 to 3 staff @ 125K. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Upgrade for Auto. Scheduling, Run Cutting, or Fare Payment	TR005	20	19	39	**1995**	0.4	0.8	**1995**	Processor/software upgrade, installation and 1 yr. maintenance (for processor). Software is COTS.
3	Integration for Auto. Scheduling, Run Cutting, or Fare Payment	TR012	20	219	486	**2005**				Integration with other systems.
3	Further Software Upgrade for E-Fare Payment	TR013	20	39	58	**1995**	0.8	1.2	**1995**	Software upgrade. Software is COTS. Automatic passenger counter processing software costs an additional $25K to several hundred thousand dollars depending on the system.
3	Vehicle Location Interface	TR007	20	10	15	**1995**				Vehicle location interface.
5	Video Monitors for Security System	TR008	5	2	5	**2003**	0.05	0.11	**2003**	Five per site. O&M estimated at 2% of capital cost.
5	Hardware for Security System	TR009	5	13	19	**2004**	0.3	0.4	**2004**	Includes 1 server and 3 workstations. O&M estimated at 2% of capital cost; could be higher for preventative and responsive maintenance.
3	Integration of Security System with Existing Systems	TR010	20	243	486	**1995**				Integration with other systems.
6	Labor for Security System	TR011					293	359	**1995**	Description is based on 1995 data: Labor for 3 staff @ 75K each. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Toll Administration (TA)										
5	Toll Administration Hardware	TA001	5	5.4	8.1	**2004**	0.27	0.41	**2004**	Includes 2 workstations, printer, and modem. O&M estimated at 5% of capital costs.
3	Toll Administration Software	TA002	10	39	78	**1995**	3.9	7.8	**1995**	Includes local database and national database coordination. Software is COTS.
Transit Vehicle On-Board (TV)										
2	Driver Interface and Schedule Processor	TV001	10	0.2	0.4	**1995**	0.005	0.01	**1995**	On-board schedule processor and database.
1	Cell Based Communication Equipment	TV002	10	0.14	0.23	**1995**	0.007	0.011	**1995**	Cell-based radio with data capacity.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	GPS/DGPS for Vehicle Location	TV003	10	0.5	2	**2002**	0.01	0.038	**2002**	AVL GPS/DGPS. Capital cost depends on features of unit. O&M cost (estimated at 2% of capital) is for unit maintenance and does not include annual telecom service fees.
2	Signal Preemption Processor	TV004	10	0.2	0.5	**1995**	0.005	0.008	**1995**	On-board schedule processor and database. Complement to IDAS elements RS004 and RS005.
2	Signal Preemption/Priority Emitter		10	0.5	2.1	**2005**	0.1		**2005**	Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/Priority (see Roadside Control subsystem). Estimated O&M.
2	Preemption/Priority Transponder			0.07		**2000**				Passive transponder mounted on underside of transit vehicle. Requires transit priority system at the Transit Management Center.
2	Trip Computer and Processor	TV005	10	0.1	0.12	**1995**	0.002	0.002	**1995**	On-board processor for trip reporting and data storage.
2	Security Package	TV006	10	3.3	6	**2005**	0.16	0.2	**1995**	On-board CCTV surveillance camera and hot button. The high capital cost represents a common installation of a digital event recorder system.
2	Electronic Farebox	TV007	10	0.6	1.2	**1995**	0.03	0.06	**1995**	On-board flex fare system DBX processor, on-board farebox, and smart card reader.
2	Automatic Passenger Counting System		10	0.98	9.8	**2005**				Low cost reflects the APC system as an add-on to an existing route scheduling or tracking system. High cost reflects the APC system as a stand alone installation. Cost is per vehicle and includes installation.
Commercial Vehicle Electronic Credentialing (EC)/Administration										
5	Computer network server for EC		4	6.3	46.4	**2004**				Each.
5	Personal computer (desktop or laptop) for EC administration		4	1.5	3	**2005**				Each.
8	Supplies and materials for EC outreach, internal and external publicity, training, other deployment support			1.1	23.7	**2003**				Per state, consumables for publicity, training, and other deployment support.
5	Bar code readers for law enforcement for EC			0.4	0.7	**2004**				Each.
3	EC software purchased for back-end admin		5	40.5	74.9	**2004**				Per state, for database management and data processing or reporting.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
3	EC software purchased for front-end interface		5	74	267	**2005**				Per state, for user interface and data entry. Depending on the functionality of the interface being developed, the cost could be much higher or much lower than the range shown.
6	State employee labor for new EC software development			74	257	**2005**				Per state. For states also reporting hours, FTEs ranged from about 0.2 to 2.6 FTE. Depending on the functionality of the system being developed, the dollar cost could be much higher or much lower than the range shown.
6	State employee labor for new EC hardware configuration			2.6	13.2	**2003**				Per state, after original hardware installation.
6	Contractor labor for new EC software development			166	996	**2003**				Per state. For states also reporting hours, FTEs ranged from about 1 to 3 FTE. Depending on the functionality of the system being developed, the cost could be much higher, or much lower than the range shown.
6	Contractor labor for new EC hardware configuration			3.5	6.8	**2004**				Per state, after original hardware installation.
6	Labor for existing (legacy) credentialing system interface and/or modification			12.8	42.6	**2004**				Per state, includes state employees, contractors, vendors. For states also reporting hours, FTEs ranged from about 0.1 to 0.4 FTE.
6	Labor for EC training			5.5	13.2	**2003**				Per state cost to state agency. Examples: Start-up workshops, training and publicity materials for administrators, law enforcement, and PRISM carriers.
6	Other start-up labor costs			11.0	44	**2003**				Per state, includes CVISN system architect, EC feasibility study; OS/OW permitting, program queries,IFTA/IRP program staff, maintenance, miscellaneous A&E, hardware, software, planning and facilitation, training and travel.
7	Membership fees paid to IRP Clearinghouse (annual)						8.5	16.0	**2004**	Per state, fees set by clearinghouse pro rata, based on registered power units per state.
7	Annual fees to IRP EC admin (back-end)						12.1	69.0	**2003**	Per thousand accounts, for third-party administrator (e.g., VISTA, Polk).
7	Annual fees to IRP EC admin (front-end)						5.3	31	**2004**	Per thousand accounts, for third-party administrator (e.g., VISTA, Polk).

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
8	Recurring costs for EC outreach ($/thousand accts.)						0.6	1.0	**2004**	Per thousand accounts. Outreach includes marketing, promotional, attendance at trade shows, advertising, booklets.
6	State employee annual labor IRP credentialing (legacy)						46	163	**2005**	Per thousand accounts, for legacy system (pre-CVISN) labor.
6	Contractor annual labor for IRP credentialing (legacy)						6.4	17.0	**2004**	Per thousand accounts, for legacy system (pre-CVISN) labor.
7	Membership fees paid to IFTA Clearinghouse (annual)						1		**2005**	Per state, fees set by clearinghouse.
7	Annual fees to IFTA EC admin (back-end)						11.7	35.2	**2004**	Per thousand accounts, for third-party administrator (e.g., VISTA, Polk).
7	Annual fees to IFTA EC admin (front-end)						7.5	12.8	**2004**	Per thousand accounts, for third-party administrator (e.g., VISTA, Polk).
6	State employee annual labor IFTA credentialing (legacy)						13.8	111.8	**2004**	Per thousand accounts, for legacy system (pre-CVISN) labor.
6	Vendor annual labor for IFTA credentialing (legacy)						1	19.2	**2004**	Per thousand accounts, for legacy system (pre-CVISN) labor.
Commercial Vehicle Safety Information Exchange (SIE)										
5	Computer network server for SIE		4	5	21.1	**2004**				Each, includes mobile servers used in roadside enforcement.
5	Desktop personal computer for SIE		4	1	1.7	**2004**				Each, includes computers used at roadside check stations.
5	Laptop personal computer for SIE		3	2.5	3.4	**2004**				Each.
5	Portable printer for mobile enforcement		4	0.3	0.3	**2004**				Each.
1	Wireless modem for vehicle and/or roadside use		3	0.5	0.9	**2003**				Each.
8	Supplies and materials for SIE outreach, training			5.6		**2004**				Per state, consumables for publicity and other deployment support.
5	Router for SIE		5	4.2	10	**2004**				Each.
1	T1 Lines for SIE		5	3	29.7	**2004**				Each line.
3	SIE software purchased off the shelf			6.1	20.2	**2004**				Per state.
6	State employee labor for new SIE software development			20	121	**2005**				Per state (e.g., CVIEW (Commercial Vehicle Information Exchange Window). For states also reporting hours, FTEs ranged from about 0.2 to 2 FTE).

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
6	State employee labor for new SIE hardware configuration			5	5.3	**2004**				Per state.
6	Contractor labor for new SIE software development			47.9	181.0	**2004**				Per state. Depending on the functionality of the system being developed, the cost could be much higher or much lower than the range shown.
6	Labor for existing (legacy) SIE system interface			74	257	**2005**				Per state, includes state employees, contractors, vendors.
6	Labor for training for SIE system deployment			4.3	7.6	**2004**				Per state.
1	Telephone and internet annual service charges for SIE						0.5	39.7	**2004**	Per state.
1	Wireless communication annual charges for SIE						25.8	61.5	**2004**	Per state.
6	State employee annual labor for SIE						20.2	67.1	**2004**	Per state.
6	Contractor annual labor for SIE						14.9	42.6	**2004**	Per state.
Commercial Vehicle Electronic Screening (ES) (Preclearance)										
5	Computer network server dedicated to ES		5	8.4	11.0	**2004**				Each.
5	Desktop PC dedicated to ES		5	2.3	3	**2005**				Each.
5	Laptop personal computer dedicated to ES		4	2.5		**2004**				Each.
2	Mainline (highway speed) WIM scale		10	59.8	249.2	**2004**				Each. Depending on the functionality of the equipment deployed, the cost could be much higher or much lower than the range shown. Some states reported equipment cost only; others reported installed cost, with accessories (e.g., signs, loop detectors, wiring, etc.).
2	Sorter lane (ramp speed) WIM scale		12	97.5	243.7	**2003**				Each.
2	ES transponder purchased by state for free distribution		5	0.01	0.05	**2004**				Each.
2	ES transponder purchased by state for resale		4	0.04	0.05	**2004**				Each.
2	Automated vehicle identification (AVI) equipment/system		10	50	99	**2004**				Each.
1	ES telecom. equipment (upstream to weigh station)		20	0.8	27.8	**2004**				Per state (e.g., fiber optic cable).

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	Electronic sign for weigh station		20	12.0	48	**2004**				Each (e.g., Open/Closed, directional arrows, or variable-message signs).
2	Loop detector for weigh station		20	1	6	**2005**				Each.
2	Upgrade of fixed-site weigh station for ES (excluding items listed above)			43.9	79.7	**2004**				Each. Some states reported building modifications, counters, cabinets, wiring, HVAC, structural changes to static scale building, highway poles and bases.
7	One-time start-up fees paid to ES admin			16.0		**2004**				Per state (e.g., PrePass or Norpass).
8	Supplies and materials for ES outreach and publicity			0.6	2.2	**2004**				Per state.
3	ES software purchased off the shelf			0.5	4	**2004**				Per state.
6	State employee labor for ES software development			12.8	31	**2004**				Per state.
6	State employee labor for new ES hardware configuration			5	5.3	**2004**				Per state.
6	Contractor labor for ES software development			196.9	200.1	**2004**				Per state.
6	Contractor labor for new ES hardware configuration			138.4	201.2	**2004**				Per state.
6	Labor for existing (legacy) system interface			31	31.9	**2004**				Per state, includes state employees, contractors, vendors.
6	Labor for training associated with ES system deployment			3.8	21.3	**2004**				Per state.
7	Annual payments made to ES admin						15		**2005**	Per state (e.g., PrePass or Norpass).
2	Annual maintenance cost for mainline WIM scale						51.8	127.6	**2004**	Each. Depending on the functionality of the equipment being maintained, the cost could be much higher or much lower than the range shown.
2	Annual maintenance cost for sorter-lane WIM scale for ES						10.0	35.9	**2004**	Each.
8	Annual costs for marketing, outreach, publicity, etc.						0.6	5.6	**2004**	Per state.
6	State employee annual labor for ES, higher-volume state						53.2	178	**2004**	Per state, volume based on relative numbers of carriers, vehicles, and inspections.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
6	State employee annual labor for ES, lower-volume state						5	6.4	**2004**	Per state, volume based on relative numbers of carriers, vehicles, and inspections.
Commercial Vehicle On-Board (CV)										
2	Electronic ID Tag	CV001	10	0.5	0.9	**1995**	0.01	0.017	**1995**	Includes ID tag, additional software & processing, and database storage. Software is COTS.
1	Communication Equipment	CV002	10	1.1	2.1	**1995**	0.007	0.011	**1995**	Commercial vehicle communication interface and communication device (cell-based radio).
2	Central Processor and Storage	CV003	10	0.2	0.4	**1995**	0.005	0.01	**1995**	Equipment on board for the processing and storage of cargo material.
2	GPS/DGPS	CV004	10	0.5	1.8	**2004**	0.12	0.6	**2004**	GPS for vehicle location. Capital cost depends on features of unit. O&M cost includes annual service fees.
2	Driver and Vehicle Safety Sensors, Software	CV005	10	0.9	1.7	**1995**	0.03	0.06	**1995**	Additional software and processor for warning indicator and audio system interface, and onboard sensors for engine/vehicle and driver. Software is COTS.
2	Cargo Monitoring Sensors and Gauges	CV006	10	0.13	0.27	**1995**	0.013	0.027	**1995**	Optional on-board sensors for measuring temperature, pressure, and load leveling.
2	Electronic Cargo Seal Disposable			0.010	0.024	**2003**				Cost for a disposable radio frequency identification (RFID) E-seal that provides a complete and accurate audit trail of seal status during transport. Low is for passive, and high is for active E-seal.
2	Electronic Cargo Seal Reusable			0.034	0.42	**2002**				Cost for a reusable radio frequency identification (RFID) E-seal that provides a complete and accurate audit trail of seal status during transport. Low is for passive, and high is for active E-seal. Depending on the vendor, some E-seals may incur a monthly service charge.
2	Autonomous Tracking Unit			0.34	0.8	**2003**	0.140	0.4	**2003**	Chassis or container mounted unit that tracks location and condition of assets (cost for on-board sensors not included). Higher priced units provide greater functionality, such as polling of location information and increased quantities of sensor data. Annual service charges include the communications link between unit and data center, and information services.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
Fleet Management Center (FM)										
5	Fleet Center Hardware	FM001	5	8	10	**2004**	0.15	0.20	**2004**	Costs include 3 workstations. O&M estimated at 2% of capital cost.
3	Fleet Center Software, Integration	FM002	20	209	486	**1995**				Includes processor and integration. Software is COTS.
6	Fleet Center Labor	FM003					489	598	**1995**	Description is based on 1995 data: Labor for 5 staff @ 75K. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Software for Electronic Credentialing, Clearance	FM004	20	78	175	**1995**				Includes electronic credential purchase software, database and management for trip reports, and database management for preclearance. Software is COTS.
3	Software for Tracking and Scheduling	FM005	20	10	33	**2004**	4	10	**1995**	Vehicle tracking and scheduling. Software is COTS.
3	Vehicle Location Interface	FM006	20	10	15	**1995**				Vehicle location interface from FMS to TMS.
3	Software Upgrade for Fleet Maintenance	FM007	20	19	39	**1995**	0.4	0.8	**1995**	Processor/software upgrade to add capability to automatically generate preventative maintenance schedules from vehicle mileage data. Software is COTS.
3	Integration for Fleet Maintenance	FM008	20	97	194	**1995**	2	4	**1995**	Integration with other systems.
3	Software Upgrade for HAZMAT Management	FM009	20	19	39	**1995**	0.4	0.8	**1995**	Vehicle tracking & scheduling enhancement. Software is COTS.
5	Hardware Upgrade for HAZMAT Management	FM010	5	3	3	**2004**	0.05	0.07	**2004**	Includes 1 workstation. O&M estimated at 2% of capital cost.
2	Electronic Cargo Seal Reader			0.3	1.4	**2002**				Unit cost depends on quantity purchased. Low cost is for handheld reader. High cost is for fixed reader. Cost will be significantly increased if reader is equipped with additional security features.
Vehicle On-Board (VS)										
1	Communication Equipment	VS001	7	0.2	0.4	**1995**	0.004	0.007	**1995**	Wireless data transceiver.
2	In-Vehicle Display	VS002	7	0.04	0.1	**1995**	0.001	0.002	**1995**	In-vehicle display/warning interface. Software is COTS.
2	In-Vehicle Signing System	VS003	7	0.12	0.31	**1995**	0.002	0.006	**1995**	Interface to active tag reader, processor for active tag decode, and display device for messages.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
2	GPS/DGPS	VS004	7	0.2	0.4	**1995**	0.004	0.01	**1995**	Global Positioning System/Differential Global Positioning Systems.
3	GIS Software	VS005	7	0.2	0.3	**1995**				Geographical Information System (GIS) software for performing route planning.
2	Route Guidance Processor	VS006	7	0.08	0.12	**1995**	0.002	0.002	**1995**	Limited processor for route guidance functionality.
2	Sensors for Lateral Control	VS007	7	0.6	0.9	**1995**	0.012	0.017	**1995**	Includes lane sensors in vehicle and lateral sensors MMW radar.
2	Electronic Toll Equipment	VS008	7	0.03	0.1	**1995**				Active tag interface and debit/credit card interface.
2	Mayday Sensor and Processor	VS009	7	0.12	0.5	**1995**	0.002	0.01	**1995**	Collision detector sensor and interface for Mayday processor. Software is COTS.
2	Sensors for Longitudinal Control	VS010	7	0.2	0.4	**1995**	0.005	0.01	**1995**	Longitudinal sensors MMW radar.
2	Advanced Steering Control	VS011	7	0.4	0.5	**1995**	0.008	0.01	**1995**	Advanced steering control ("hands off" driving). Software is COTS.
2	Advanced Cruise Control	VS012	7	0.12	0.23	**1995**	0.002	0.005	**1995**	Adaptive cruise control (automatic breaking and accelerating).
2	Intersection Collision Avoidance Processor, Software	VS013	7	0.22	0.43	**1995**	0.005	0.009	**1995**	Software/processor for infrastructure transmitted information, interface to in-vehicle signing and audio system, software and processor to link to longitudinal and lateral vehicle control modules based on input signal from vehicle intersection collision warning equipment package. Software is COTS.
2	Vision Enhancement System	VS014	7	2	2.4	**2003**	0.1	0.12	**2003**	In-vehicle camera, software & processor, heads-up display, and infra-red sensors (local sensor system). Software is COTS. O&M estimated at 5% of capital.
2	Driver and Vehicle Safety Monitoring System	VS015	7	0.51	1	**1995**	0.026	0.05	**1995**	Description is based on 1995 data: Safety collection processor and software, driver condition sensors, six vehicle condition sensors (@ $50 each), and vehicle data storage. Software is COTS.
2	Pre-Crash Safety System	VS016	7	0.9	1.7	**1995**	0.03	0.05	**1995**	Vehicle condition sensors, vehicle performance sensors, software/processor, interface, pre-crash safety systems deployment actuators. Software is COTS.

Index	Subsystem/ Unit Cost Element	IDAS No.^	Lifetime* (Years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Description
				Low	High		Low	High		
3	Software, Processor for Probe Vehicle	VS020	7	0.05	0.15	**1995**	0.001	0.003	**1995**	Software and processor for communication to roadside infrastructure, signal generator, message generator. Software is COTS.
2	Toll Tag/Transponder		5	0.025		**2004**				Most toll tags/transponders costs approx. $25. Some toll agencies require users to pay a refundable deposit in lieu of purchasing a tag. The user is charged the cost of the tag if the tag is lost.
2	In-Vehicle Navigation System		7	2.5		**1998**				COTS product that includes in-vehicle display and supporting software.
Personal Devices (PD)										
2	Basic PDA	PD001	7	0.1	0.3	**2004**				Personal digital assistant. O&M estimated at 2% of capital.
2	Advanced PDA for Route Guidance, Interactive Information	PD002	7	0.4	0.6	**2004**				Personal digital assistant with advanced capabilities (route guidance, interactive).
2	Modem Interface, Antenna for PDA	PD003	7	0.14	0.2	**1995**	0.003	0.004	**1995**	Modem interface and separate antenna for wireless capability.
2	PDA with Wireless Modem		2	0.2	0.6	**2003**	0.11	0.3	**2001**	Personal digital assistant with wireless modem. O&M based on monthly subscriber rate plans of 50 Kbytes (low) and 150 Kbytes (high).
2	GPS/DGPS	PD005	7	0.14	0.17	**2001**	0.003	0.004	**2001**	GPS/DGPS. O&M estimated at 2% of capital cost.
3	GIS Software	PD006	7	0.1	0.15	**1995**	0.005	0.008	**1995**	Additional GIS/GUI capability.

* Not available for all unit cost elements
^ Applicable only to unit cost elements used in IDAS.

The numbers shown in the far left column of the Unit Cost Data table correspond to the numbers listed below and identify the indexes used to adjust the cost data to 2006 dollars.

1 WPU1176: Applied to communications and related equipment.
2 WPU1178: Applied to elements that contain electronic components.
3 PCU5112105112105O2: Applied to software and integration elements.
4 PCU BBLD-BBLD: Applied to physical dwellings at Centers and Toll Plaza.
5 WPU115: Applied to computer hardware.
6 CIU101000000X000I: Applied to labor categories.
7 CUUR0000SA0: Applied to ISP Liability Insurance (IS016).
8 WPU09130124: Applied to elements related to outreach and publicity.
9 WPU10740512: Applied to towers and overhead structures.

The indexes are maintained by the Bureau of Labor Statistics (www.bls.gov). For additional information, visit the ITS Unit Costs Database online at www.itscosts.its.dot.gov.

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1-866-367-7487

ITS APPLICATION OVERVIEW

www.itsoverview.its.dot.gov

APPENDIX B

AVAILABLE DATA IN THE ITS KNOWLEDGE RESOURCES

Number of Benefits, Costs, and Lessons Learned Database Entries by ITS Application Area (as of 01/01/08)

Application Area		**Number of Entries**		
		Benefits	**Costs**	**Lessons**
Roadway	Arterial Management	121	30	22
	Freeway Management	71	15	52
	Crash Prevention and Safety	16	8	5
	Road Weather Management	33	18	25
	Roadway Operations and Maintenance	46	16	21
Transit	Transit Management	30	16	22
Management and Operations	Transportation Management Centers	N/A*	N/A*	N/A*
	Traffic Incident Management	53	21	48
	Emergency Management	7	6	20
	Electronic Payment and Pricing	21	6	44
	Traveler Information	53	16	49
	Information Management	1	1	16
Freight	Commercial Vehicle Operations	36	7	13
	Intermodal Freight	4	2	8
Intelligent Vehicles	Collision Avoidance	9	2	1
	Driver Assistance	34	5	9
	Collision Notification	2	1	1

* *While this report was in publication, data in the online ITS Knowledge Resources resources was categorized to highlight information related to TMCs. Consult the Web sites for current information on the number of entries available discussing TMCs.*

Number of Lessons by Lesson Category	
Lesson Category	**Number of Database Entries**
Management and Operations	143
Design and Deployment	167
Human Resources	46
Technical Integration	71
Policy and Planning	117
Funding	21
Procurement	41
Legal Issues	18
Leadership and Partnerships	109

Number of Lessons by Systems Engineering Activity	
Systems Engineering Activity	**Number of Database Entries**
Retirement/Replacement	4
System Requirements	88
Operations and Maintenance	72
Regional Architecture(s)	70
Unit / Device Testing	16
Detailed Design	40
High-Level Design	40
System Validation	5
System Verification and Deployment	15
Subsystem Verification	9
Changes and Upgrades	16
Feasibility Study / Concept Exploration	92
Software / Hardware Development Field Installation	47
Concept of Operations	91
Systems Engineering Project/Technical Management	86
Systems Engineering Program Management	44

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LIST OF ACRONYMS

ACAS	Automotive Collision Avoidance System
ACC	Adaptive Cruise Control
ACN	Automated Collision Notification
ADMS	Archived Data Management System
AMBER	America's Missing: Broadcast Emergency Response
ARTIMIS	Advanced Regional Traffic Interactive Management and Information Systems
ATIS	Advanced Traveler Information System
ATMS	Advanced Transportation Management System
AVL	Automated Vehicle Location
AWIS	Automated Work Zone Information Systems
BART	Bay Area Rapid Transit (California)
BRT	Bus Rapid Transit
BWI	Baltimore/Washington International Thurgood Marshall Airport
CA	Commercial Vehicle Administration (Unit Cost Subsystem)
CAD	Computer-Aided Dispatch
CAD	Canadian Dollars
Caltrans	California Department of Transportation
CARS	Condition Acquisition and Reporting System
CARTS	Capital Area Rural Transportation System (Austin, Texas)
CC	Commercial Vehicle Check Station (Unit Cost Subsystem)
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CICAS	Cooperative Intersection Collision Avoidance Systems
CMAQ	Congestion Mitigation/Air Quality
CORTRAN	Central Ohio Regional Transportation and Emergency Management Center
COTS	Commercial Off-The-Shelf
CRRAFT	Client Referral, Ridership, and Financial Tracking (New Mexico)
CV	Commercial Vehicle On-Board (Unit Cost Subsystem)

CVISN	Commercial Vehicle Information Systems and Network
CVO	Commercial Vehicle Operations
CWS	Collision Warning System
DGPS	Differential Global Positioning System
DMS	Dynamic Message Signs
DOT	Department of Transportation
EFM	Electronic Freight Management
EMS	Emergency Medical Services
ER	Emergency Response Center (Unit Cost Subsystem)
ESCM	Electronic Supply Chain Manifest
ESS	Environmental Sensor Station
ETC	Electronic Toll Collection
EV	Emergency Vehicle On-Board (Unit Cost Subsystem)
EVP	Emergency Vehicle Preemption
FAST	Fixed Automated Spray Technology (Road Weather Management)
FAST	Freeway and Arterial System of Transportation (Nevada DOT)
FAQ	Frequently Asked Questions
FCW	Forward Collision Warning
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FM	Fleet Management (Unit Cost Subsystem)
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
FTA	Federal Transit Administration
FY	Fiscal Year
GIS	Geographical Information Systems
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials

HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
ICM	Integrated Corridor Management
ICTransit	Intelligent Coordinated Transit
IDOT	Illinois Department of Transportation
IFTA	International Fuel Tax Agreement
IMTC	International Mobility and Trade Corridor
IPR	Intellectual Property Rights
IRP	International Registration Plan
ISP	Information Service Provider (Unit Cost Subsystem)
ITN	Invitation to Negotiate
ITS	Intelligent Transportation Systems
IVU	In-Vehicle Unit
JPO	Joint Program Office
LAN	Local Area Network
LDW	Lane Departure Warning
LED	Light Emitting Diode
LLKR	Lessons Learned Knowledge Resource
LRTP	Long Range Transportation Plan
M&O	Management and Operations
MDI	Model Deployment Initiative
MdSHA	Maryland State Highway Administration
MDSS	Maintenance Decision Support System
MDT	Mobile Data Terminal
MDT	Montana Department of Transportation
Mn/DOT	Minnesota Department of Transportation
MSAA	Mobility Services for All Americans
MSP	Maryland State Police

MTA	Mass Transportation Authority (Flint, Michigan)
NCHRP	National Cooperative Highway Research Program
NG9-1-1	Next Generation 9-1-1
NHTSA	National Highway Traffic Safety Administration
NORPASS	North American Pre-clearance and Safety System
O&M	Operations and Maintenance
ODOT	Ohio Department of Transportation
ORT	Open Road Tolling
PD	Personal Devices (Unit Cost Subsystem)
PennDOT	Pennsylvania Department of Transportation
PM	Parking Management (Unit Cost Subsystem)
PRUEVIIN	Process for Regional Understanding and Evaluation of Integrated ITS Networks
PSAP	Public Safety Answering Point
RFC	Regional Fare Card
RM	Remote Location (Unit Cost Subsystem)
RMA	Regional Mobility Authorities
R-RC	Roadside Rail Crossing (Unit Cost Subsystem)
RS-C	Roadside Control (Unit Cost Subsystem)
RS-D	Roadside Detection (Unit Cost Subsystem)
RS-I	Roadside Information (Unit Cost Subsystem)
R-RC	Roadside Rail Crossing (Unit Cost Subsystem)
RS-TC	Roadside Telecommunications (Unit Cost Subsystem)
RTA	Riverside Transit Authority (California)
RWIS	Road Weather Information System
SAFER	Safety and Fitness Electronic Record
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: a Legacy for Users
SIE	Safety Information Exchange

SIRV	Severe Incident Response Vehicle (Florida DOT, District IV)
SOV	Single-Occupancy Vehicle
SOW	Statement of Work
SR	State Route
STC	Smart Traffic Center
SUV	Sport Utility Vehicle
SWIFT	Seattle Wide-area Information for Travelers (Washington State)
TA	Toll Administration (Unit Cost Subsystem)
TCOS	TransCorridor Operating System
TCP/IP	Transmission Control Protocol/Internet Protocol
TEA-21	Transportation Efficiency Act for the 21st Century
TM	Transportation Management Center (Unit Cost Subsystem)
TMC	Transportation Management Center
TMDD	Traffic Management Data Dictionary
TOC	Traffic Operations Center
TP	Toll Plaza (Unit Cost Subsystem)
TR	Transit Management Center (Unit Cost Subsystem)
TRANSCOM	Transportation Operations Coordinating Committee
TriMet	Tri-County Metropolitan Transportation District of Oregon
TSIP	Truck Safety Improvements Project (I-25 in Colorado)
TV	Transit Vehicle On-Board (Unit Cost Subsystem)
TxDOT	Texas Department of Transportation
UK	United Kingdom
U.S.	United States
U.S. DOT	United States Department of Transportation
USCS	United States Customs Service
USGS	United States Geological Survey
VCTC	Ventura County Transportation Commission (California)

VDOT	Virginia Department of Transportation
VII	Vehicle Infrastructure Integration
VS	Vehicle On-Board (Unit Cost Subsystem)
VSL	Variable Speed Limit
VSP	Virginia State Police
WIM	Weigh In Motion
WMATA	Washington Metropolitan Area Transit Authority
WSDOT	Washington State Department of Transportation

ENDNOTES

1 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

The National Traffic Signal Report Card: Technical Report, National Transportation Operations Coalition. Washington, DC. 2005. Costs ID: 2007-00114

2 Sources that support these findings:

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

Smith, S. and C. Perez. "Evaluation of INFORM—Lessons Learned and Applications to Other Systems," Paper Presented at the 71st Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 1992. Benefits ID: 2000-00098

3 Sources that support these findings:

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, TN. 6–10 August 2000. Benefits ID: 2007-00335

Detroit Freeway Corridor ITS *Evaluation*, U.S. DOT Federal Highway Administration, EDL No. 13586. July 2001. Benefits ID: 2007-00472

Innovative Traffic Control Technology and Practice in Europe, U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00355

ITS *Impacts Assessment for Seattle* MMDI *Evaluation: Modeling Methodology and Results*, U.S. DOT Federal Highway Administration. EDL No. 11323. September 1999. Benefits ID: 2007-00359

Jeannotte, Krista. "Evaluation of the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS)," Paper Presented at the 11th Annual ITS America Meeting. Miami, FL. June 2001. Benefits ID: 2007-00347

Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft), U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2000-00134

Smith, S. and C. Perez. "Evaluation of INFORM—Lessons Learned and Applications to Other Systems," Paper Presented at the 71st Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 1992. Benefits ID: 2000-00098

4 *Twin Cities Ramp Meter Evaluation: Final Report*. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00416

5 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

6 Drakopoulos, Alexander. "CVO/Freight and ITS Session," Presentation at the 12th annual ITS Forum, Wisconsin Chapter of ITS America—Smartways, Marquette University. Milwaukee, WI. 31 October 2006. Benefits ID: 2008-00513

7 Pento, Robert J. "Evaluation of PennDOT ITS Deployments," PennDOT, Bureau of Highway Safety and Traffic Engineering, Presentation to the 2005 Transportation Engineering and Safety Conference. 7 December 2005. Costs ID: 2008-00136

8 Sources that support these findings:

Evaluation of Rural ITS Information Systems along U.S. 395, *Spokane, Washington*, U.S. DOT Federal Highway Administration, EDL No. 13955. 8 January 2004. Benefits ID: 2004-00274

Final Evaluation Report: Evaluation of the Idaho Transportation Department Integrated Road-Weather Information System, U.S. DOT Federal Highway Administration, EDL No. 14267. 2 February 2006. Benefits ID: 2008-00522

9 Sources that support these findings:

Breen, Bryon D. *Anti-Icing Success Fuels Expansion of the Program in Idaho*, Idaho Transportation Department, Snow and Ice Pooled Fund Cooperative Program, Web page URL www.sicop.net/US-12%20Anti%20Icing%20Success.pdf. Last Accessed 5 October 2001. Benefits ID: 2001-00214

Breen, Bryon D. *Anti-Icing Success Fuels Expansion of the Program in Idaho*, Idaho Transportation Department, Snow and Ice Pooled Fund Cooperative Program, Web page URL www.sicop.net/US-12%20Anti%20Icing%20Success.pdf. Last Accessed 5 October 2001. Benefits ID: 2007-00336

Case Study #6: Winter Maintenance Innovations Reduce Accidents and Costs—City of Kamloops, Prepared by the McCormick Rankin Corporation and Ecoplans Limited for the Insurance Corporation of British Columbia and Environment. Canada. 2004. Benefits ID: 2008-00526

O'Keefe, Katie and Xianming Shi. *Synthesis of Information on Anti-icing and Pre-wetting for Winter Highway Maintenance Practices in North America: Final Report*, Prepared by the Montana State University for the Pacific Northwest Snowfighters Association and the Washington State DOT. 19 August 2005. Benefits ID: 2008-00525

10 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice—Final Report*, Transportation Research Board, NCHRP, Project 20-7/Task 200. Washington, DC. September 2006. Costs ID: 2008-00142

11 Sources that support these findings:

Bushman, R. and C. Berthelot. "Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones," Presentation at the 83rd Annual Transportation Research Board Meeting. Washington, DC. 11–15 January 2004. Benefits ID: 2007-00326

Chu, L., H. Kim, H. Liu, and W. Recker. „Evaluation of Traffic Delay Reduction from Automatic Workzone Information Systems Using Micro-Simulation," Paper Presented at the 84th Annual Transportation Research Board Meeting. Washington, DC. 9–13 January 2005. Benefits ID: 2007-00400

12 Sources that support these findings:

Fontaine, M.D., P. Carlson, and G. Hawkins, *Use of Innovative Traffic Control Devices to Improve Safety at Short-Term Rural Work Zones*, Texas Transportation Institute, Report No. 1879-S. College Station, TX. 2000. Benefits ID: 2007-00331

Garber, N. and S. Patel. *Effectiveness of Changeable Message Signs with Radar in Controlling Vehicle Speeds in Work Zones*, Virginia Transportation Research Council, Report No. VTRC-95-R4. Charlottesville, VA. 1994. Benefits ID: 2007-00332

Garber, N. and S. Srinivasan, *Effectiveness of Changeable Message Signs with Radar in Controlling Vehicle Speeds in Work Zones*, Virginia Transportation Research Council, Report No. VTRC-98-R10. Charlottesville, VA. 1998. Benefits ID: 2007-00330

McCoy, P. J., J. Bonneson, and J. Kollbaum. *Speed Reduction Effects of Speed Monitoring Displays with Radar in Work Zones on Interstate Highways*, Transportation Research Board, Report No. TRR 1509. Washington, DC. 1995. Benefits ID: 2007-00329

13 Sources that support these findings:

Fontaine, M., P. Carlson, and G. Hawkins. *Use of Innovative Traffic Control Devices to Improve Safety at Short-Term Rural Work Zones*, Prepared by the Texas Transportation Institute for the Texas DOT. 2000. Benefits ID: 2007-00331

Fontaine, Michael D. and Steven D. Schrock. "Feasibility of Real-Time Remote Speed .Enforcement in Work Zones," Paper Presented at the 81st Annual Transportation Research Board Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00490

Garber, N. and Surbhi T. Patel, *Effectiveness of Changeable Message Signs in Controlling Vehicle Speeds in Work Zones: Final Report*, Virginia Transportation Research Council, Report No. VTRC 95-R4. Charlottesville, VA. August 1994. Benefits ID: 2007-00332

McCoy, P. J., J. Bonneson, and J. Kollbaum. *Speed Reduction Effects of Speed Monitoring Displays with Radar in Work Zones on Interstate Highways*, Transportation Research Board, Report No. TRR 1509. Washington, DC. 1995. Benefits ID: 2007-00329

14 Fontaine, Mike. "Operational and Safety Benefits of Work Zone ITS," Presentation to "ITS in Work Zones" Workshop/Peer Exchange. September 2005. Costs ID: 2006-00109

15 "Transit Impact Matrix," U.S. DOT Web site URL itsweb.mitretek.org/its/aptsmatrix.nsf/viewbyEfficiency?OpenView. Last Accessed 12 December 2007.

16 Sources that support these findings:

APTS *Benefits*, U.S. DOT Federal Transit Administration. November 1995. Benefits ID: 2000-00028

Strathman, J., et al. "Evaluation of Transit Operations: Data Applications of Tri-Met's Automated Bus Dispatching System," *Transportation*, Vol. 29, No. 3. August 2002. Cited in Furth, Peter G., et al. *Uses of Archived* AVL-APC *Data to Improve Transit Performance and Management: Review and Potential*, Transit Cooperative Research Program Web Document No. 23. June 2003. Benefits ID: 2000-00151

Milwaukee County Transit System, Status Report, Milwaukee County. Milwaukee, WI. July 1995. Benefits ID: 2000-00110

17 Harman, Lawrence J. and Uma Shama. TCRP Synthesis 70: Mobile Data Terminals—A Synthesis of Transit Practice, Transportation Research Board, Transit Cooperative Research Program. Washington, DC. 2007. Costs ID: 2008-00147

18 Sources and supporting information:

Integration of Emergency and Weather Elements into Transportation Management Centers, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-090, EDL No. 14247. 28 February 2006.

Guidelines for Transportation Management Systems Maintenance Concept and Plans, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-04-011, EDL No. 13882. 31 December 2002.

19 *Transportation Management Center Concepts of Operation: Implementation Guide*, .U.S. DOT Federal Highway Administration, Report No. FHWA-OP-99-029, EDL No. 11494. December 1999.

20 Sources supporting this range include:

2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Costs ID: 2007-00120

Burk, Brian D. "Combined Transportation, Emergency and Communications Center: A Partnership of Performance," Presented at 14th ITS America Annual Meeting. San Antonio, TX. May 2004. Costs ID: 2005-00093

Krueger, C., et al. *The Chicago Traffic Management Center Preliminary Design Study Planning Effort*, Chicago DOT. 2003. Costs ID: 2008-00157

Lake County TMC *Study: Implementation Phasing Plan—Version* 2.0, Prepared by the National Engineering Technology Corporation. Report No. DCN 2020IIPPR2.0. Arlington Heights, IL. September 2003. Costs ID: 2008-00158

Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

21 Sources supporting this range include:

2005 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2006. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. 28 March 2006. Costs ID: 2006-00097

2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

MAG *Regional Concept of Transportation Operations, Technical Memorandum No.* 5/6, Prepared by Kimley-Horn for the Maricopa Associated of Governments (MAG). Phoenix, AZ. 7 January 2004. Costs ID: 2008-00159

Transportation Management Center: Business Planning and Plans Handbook, U.S. DOT Federal Highway Administration, TMC Pooled Fund Study. December 2005. Costs ID: 2008-00160

Transportation Management Center Staffing and Scheduling for Day-to-Day Operations, U.S. DOT Federal Highway Administration. January 2006. Costs ID: 2008-00161

22 Sources that support these findings:

"1996 ITS Tour Report: Eastern North America," Institute of Transportation Engineers 1996 ITS World Congress, Vol. 1, Pages 4–5. 1997. Benefits ID: 2000-00123

Bertini, R., et al. *Evaluation of Region 2 Incident Response Program Using Archived Data*, Portland State University Report No. PSU-CE-TRG-01-01. Portland, OR. June 2001. Benefits ID: 2007-00483

Performance Evaluation of CHART—Coordinated Highways Action Response Team—Year 2002, University of Maryland, College Park and Maryland State Highway Administration. College Park, MD. November 2003. Benefits ID: 2007-00425

Petrov, A., et al. "Evaluation of the Benefits of a Real-Time Incident Response System," Paper Presented at the 9th World Congress on Intelligent Transport Systems. Chicago, IL. 14–17 October 2002. Benefits ID: 2007-00485

"1996 ITS Tour Report: Eastern North America," Institute of Transportation Engineers 1996 ITS World Congress, Vol. 1, Pages 4–5. 1997. Benefits ID: 2000-00123

23 Sources that support these findings:

"CDOT Launches Courtesy Patrol on I-70 West," Colorado DOT. Denver, CO. 4 March 2005. Costs ID: 2006-00101

"Freeway Service Patrol: 'About FSP'' and 'Facts at a Glance' Web Site," Los Angeles Metropolitan Transportation Authority. 22 June 2006. Web site URL www.metro.net/news_info/facts.htm. Last Accessed 12 December 2007. Costs ID: 2006-00102

Hagen, Larry, Huaguo Zhou, and Harkanwal Singh. *Road Ranger Benefit—Cost Analysis*, Prepared by the University of South Florida for the Florida DOT. November 2005. Correspondence with the report authors (Larry Hagen and Huaguo Zhou). 2006. Costs ID: 2006-00103

HELP *Annual Operating Report, July* 1, 2004–*June* 30, 2005, Tennessee DOT. Nashville, TN. October 2005. Costs ID: 2006-00096

MDOT *Freeway Courtesy Patrol in Southeast Michigan*: 2004 *Evaluation Report*, Southeast Michigan Council of Governments. Detroit, MI. May 2005. Costs ID: 2006-00104

24 Sources that support these findings:

Cuciti, P. and B. Janson. "Incident Management via Courtesy Patrol: Evaluation of a Pilot Project in Colorado," Paper Presented at the 74th Annual Meeting of the Transportation Research Board. Washington, DC. January 1995. Benefits ID: 2000-00068

Fenno, D. and M. Ogden. "Freeway Service Patrols: A State of the Practice," Paper Presented at the 77th Annual Meeting of the Transportation Research Board. Washington, DC. January 1998. Benefits ID: 2000-00130

Highway Helper Summary Report—Twin Cities Metro Area, Minnesota DOT. St. Paul, MN. July 1994. Benefits ID: 2000-00009

Latoski, S., et al. "Cost-Effectiveness Evaluation of Hoosier Helper Freeway Service Patrol," *Journal of Transportation Engineering*, Vol. 125, No. 5. September/October 1999. Benefits ID: 2000-00002

25 *Managing Demand Through Travel Information Services*, Prepared for the U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-005, EDL No. 14072. 2005. Benefits ID: 2007-00409

26 *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

27 Sources that support these findings:

2005 *Regional Value Pricing Corridor Evaluation and Feasibility Study: Dallas/Fort Worth—Value Pricing History and Experience*, North Central Texas Council of Governments. Arlington, TX. June 2005. Benefits ID: 2008-00549

Douma, Frank, Johanna Zmud, and Tyler Patterson. "Pricing Comes to Minnesota: Baseline Attitudinal Evaluation of the I-394 HOT Lane Project," Paper Presented at the 85th Transportation Research Board Annual Meeting. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00550

28 2005 *Regional Value Pricing Corridor Evaluation and Feasibility Study: Dallas/Fort Worth—Value Pricing History and Experience*, North Central Texas Council of Governments. Arlington, TX. June 2005. Benefits ID: 2008-00549

29 Sources that support these findings:

Benefits and Costs of Full Operations and ITS Deployment: A 2003 *Simulation for Cincinnati*, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-031, EDL No. 13979. May 2005. Costs ID: 2008-00164

Benefits and Costs of Full Operations and ITS Deployment: A 2003 *Simulation for Seattle*, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-033, EDL No. 13977. May 2005. Costs ID: 2008-00165

Benefits and Costs of Full Operations and ITS Deployment: A 2025 *Forecast for Tucson*, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-032, EDL No. 13978. May 2005. Costs ID: 2008-00166

30 Vasudevan, Meenakshy, Karl Wunderlich, James Larkin, and Alan Toppen. "A Comparison of Mobility Impacts on Urban Commuting Between Broadcast Advisories and Advanced Traveler Information Services," Paper Presented at the 84th Annual Transportation Research Board Meeting. Washington, DC. 9–13 January 2005. Benefits ID: 2005-00285

31 *America's Travel Information Number: Implementation and Operational Guidelines for 511 Services Version 3.0*, 511 Deployment Coalition. September 2005. Benefits ID: 2007-00301

32 *511 Deployment Costs: A Case Study*, 511 Deployment Coalition. November 2006. Costs ID: 2007-00125

33 Stephens, Jerry, et al. *An Evaluation of Montana's State Truck Activities Reporting System*, Prepared by the Montana State University for the Montana DOT. 11 August 2003. Benefits ID: 2003-00268

34 Liu, Henry X., et al. *A Literature and Best Practices Scan: ITS Data Management and Archiving*, University of Wisconsin. Madison, WI. May 2002. Benefits ID: 2008-00559

35 Sources that support these findings:

National Evaluation of the TMC Applications of Archived Data Operational Test—ADMS Virginia, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-014, EDL No. 14250. August 2005. Benefits ID: 2008-00560

Smith, Brian L. and Ramkumar Venkatanarayana. "Usage Analysis of a First Generation ITS Data Archive: Lessons Learned in the Development of a Novel Information Technology Application," Paper Presented at the 85th Annual Transportation Research Board Meeting. Washington, DC. 22–26 January 2006.

36 *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005. Costs ID: 2008-00173

37 *Evaluation of the Commercial Vehicle Information Systems and Networks (CVISN) Model Deployment Initiative: Volume I—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2002-00241

38 The national survey regarding electronic clearance is discussed in *Driver Acceptance of Commercial Vehicle Operations (CVO) Technology in the Motor Carrier Environment*, 1997. Benefits ID: 2000-00141. The Maryland survey is detailed in Bapna and Zaveri, 2000. Benefits ID: 2000-00165

39 *Description of Costs Data from State Self-Evaluations of Commercial Vehicle Information Systems and Networks (CVISN) Deployments (October 2003 to October 2005)*, U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14347. 20 February 2006.

40 Sources that support these findings:

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: 2007-00456

Maze, T. and C. Monsere. "Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2007-00447

41 Sources that support these findings:

A Report to the Maryland General Assembly Senate Budget and Taxation Committee and House Appropriations Committee regarding Commercial Vehicle Information Systems and Network, Prepared by the Maryland DOT for the Maryland General Assembly. November 1998. Benefits ID: 2000-00142

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: 2007-00455

Evaluation of the Commercial Vehicle Information Systems and Networks (CVISN) Model Deployment Initiative: Volume I—Final Report, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00486

Maze, T. and C. Monsere. *Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations*, Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2001-00181

42 Sources that support these findings:

A Report to the Maryland General Assembly Senate Budget and Taxation Committee and House Appropriations Committee regarding Commercial Vehicle Information Systems and Network, Prepared by the Maryland DOT for the Maryland General Assembly. November 1998. Benefits ID: 2000-00142

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

The National Traffic Signal Report Card: Technical Report, National Transportation Operations Coalition. Washington, DC. 2005. Costs ID: 2007-00114

68 *The National Traffic Signal Report Card: Technical Report*, National Transportation Operations Coalition. Washington, DC. 2005. Costs ID: 2007-00114

69 Shaheen, Susan A. and Caroline Rodier. "Research Pays Off—Smart Parking Management to Boost Transit, Ease Congestion: Oakland, California, Field Test Shows Promise," *TR News*, No. 251, Transportation Research Board. Washington, DC. July–August 2007. Costs ID: 2008-00134

70 Peterman, Josh, Rafat Raie, and Garland Wong. "Real-time Video Over Copper Networks: A Tale of Two Cities," Paper Presented at the 14th ITS America Meeting. San Antonio, TX. 26–28 April 2004. Costs ID: 2005-00094

71 "WSDOT Adds Cameras to Fight Congestion on State Route 522 through Lake Forest Park and Kenmore," Washington State DOT. 4 December 2002. Costs ID: 2003-00003

72 Sources that support these findings:

Banerjee, Frances T. *Preliminary Evaluation Study of Adaptive Traffic Control System* (ATCS), City of Los Angeles DOT. July 2001. Benefits ID: 2007-00316

Peck, C., et al. "Learning from the User: Next Steps for ITACA's adaptive control," *Traffic Technology International*, Annual Review, Pages 155–158. 1999. Benefits ID: 2007-00363

"SCOOT in Toronto," *Traffic Technology*. Spring 1995. Benefits ID: 2007-00385

What Have We Learned About ITS?, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-006, EDL No. 13316. December 2000. Benefits ID: 2007-00431

73 Sources that support these findings:

Abdel-Rahim, Ahmed, et al. "The Impact of SCATS on Travel Time and Delay," Paper Presented at the 8th Annual ITS America Meeting. Detroit, MI. 4–6 May 1998. Benefits ID: 2000-00138

Adaptive Control Software, Turner-Fairbank Highway Research Center, Office of Operations R&D, Report No. HRTS-04-037, HRDO-03/12-03(500)E). 2 February 2005. Web page URL ops.fhwa.dot.gov/publications/adaptivecontrol. Last Accessed 6 December 2007. Benefits ID: 2008-00509

Diakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 9–13 January 2000. Benefits ID: 2007-00337

Greenough and Kelman. "ITS Technology Meeting Municipal Needs—The Toronto Experience," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8 November 1999. Benefits ID: 2007-00362

Peck, C., et al. "Learning from the User: Next Steps for ITACA's Adaptive Control," Traffic Technology International, Annual Review, Pages 155–158. 1999. Benefits ID: 2007-00363

Siemens Automotive, USA. "SCOOT in Toronto," *Traffic Technology International*. Spring 1995. Benefits ID: 2007-00385

Zhou, Wei-Wu, et al. "Fuzzy Flows," ITS: *Intelligent Transportation Systems*. May/June 1997. Benefits ID: 2000-00086

74 Diakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 9–13 January 2000. Benefits ID: 2002-00243

75 Greenough and Kelman. "ITS Technology Meeting Municipal Needs—The Toronto Experience," Paper Presented at the 6th World Congress Conference on ITS. 8 November 1999. Benefits ID: 2007-00361

76 Correspondence with Mr. Kirk Houser, PE, Traffic Engineer, City of Tyler, Texas. February 2008. Costs ID: 2008-00179

77 Correspondence with Mr. Daniel Worke, Arlington County Department of Public Works, and contractor estimate. February 2001. Costs ID: 2003-00002

78 Sources that support these findings:

Hetrick, Stephen and Curtis B. McCollough. "How to save $4.2 Million a Year," ITS *International Newsletter*. 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

79 Sources that support these findings:

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. Benefits ID: 2008-00506

Sunkari, Srinivasa. "The Benefits of Retiming Traffic Signals," ITE *Journal*. April 2004. Benefits ID: 2007-00311

80 *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: 2007-00398

81 ITS *Impacts Assessment for Seattle* MMDI *Evaluation: Modeling Methodology and Results*, U.S DOT, EDL No. 11323. September 1999. Benefits ID: 2001-00199

82 Sources supporting this range:

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

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

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

83 The estimate of $2,500 to $3,100 is based on information from the following resources:

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," 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

The National Traffic Signal Report Card: Technical Report, National Transportation Operations Coalition. Washington, DC. 2005. Costs ID: 2007-00114

84 *The National Traffic Signal Report Card: Technical Report*, National Transportation Operations Coalition. Washington, DC. 2005. Costs ID: 2007-00114

85 Sources that support these findings:

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. Benefits ID: 2008-00507

Sunkari, Srinivasa. "The Benefits of Retiming Traffic Signals," ITE *Journal*. April 2004. Benefits ID: 2007-00311

86 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

87 *Evaluation of Automated Pedestrian Detection at Signalized Intersections*, U.S. DOT, Report No. FHWA-RD-00-097. August 2001. Benefits ID: 2004-00276

88 *Rural ITS Toolbox*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Costs ID: 2003-00006

89 Logi, F. and S. G. Ritchie. "Development and Evaluation of a Knowledge-Based System for Traffic Congestion Management and Control," *Transportation Research*, Vol. 9C, No. 6, Pages 443–459. December 2001. Benefits ID: 2002-00247

90 Perrin, Joseph, et al. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for Utah DOT. March 2004. Costs ID: 2004-00086

91 Litman, Todd. *London Congestion Pricing: Implications for Other Cities*, Victoria Transport Policy Institute. January 2006. Costs ID: 2007-00127

92 *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007. Benefits ID: 2008-00508

93 Rodier, Caroline J. and Susan A. Shaheen. *Transit-Based Smart Parking in the U.S.: Behavioral Analysis of San Francisco Bay Area Field Test*, Institute of Transportation Studies, University of California, Report No. UCD-ITS-RR-06-19. Davis, CA. December 2006. Benefits ID: 2008-00510

94 *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007. Benefits ID: 2008-00511

95 *Advanced Parking Management Systems: A Cross-Cutting Study—Taking the Stress out of Parking*, U.S. DOT, Report No. FHWA-JPO-07-011, EDL No. 14318. January 2007. Costs ID: 2008-00131

96 Shaheen, Susan A. and Caroline Rodier. "Research Pays Off—Smart Parking Management to Boost Transit, Ease Congestion: Oakland, California, Field Test Shows Promise," TR News, No. 251, Transportation Research Board. Washington, DC. July–August 2007. Costs ID: 2008-00134

97 *Downtown Bellingham Parking Management Strategy*, The Transpo Group. September 2004. Correspondence with Mr. Bruce Haldors, The Transpo Group, June 2007. Costs ID: 2007-00130

98 Perrin, Joseph, et al. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for Utah DOT. March 2004. Costs ID: 2004-00086

99 Decina, Lawrence E., et al. *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

100 Washington, Simon and Kangwon Shin. *The Impact of Red Light Cameras (Automated Enforcement) on Safety in Arizona*, Arizona DOT, Report No. 550. June 2005. Benefits ID: 2008-00512

101 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. 11 February 2003. Benefits ID: 2003-00264

102 *Automated Enforcement of Traffic Signals: A Literature Review*, U.S. DOT, EDL No. 13603. 13 August 2001. Benefits ID: 2002-00242

103 Sisiopiku, et al. "Assessment of Red Light Running Camera Enforcement Technologies," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Costs ID: 2003-00011

104 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. 11 February 2003. Costs ID: 2004-00085

105 "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.

106 Sources that support these findings:

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

Smith, S. and C. Perez. "Evaluation of INFORM—Lessons Learned and Applications to Other Systems," Paper Presented at the 71st Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 1992. Benefits ID: 2000-00098

107 Sources that support these findings:

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, TN. 6–10 August 2000. Benefits ID: 2007-00335

Detroit Freeway Corridor ITS *Evaluation*, U.S. DOT Federal Highway Administration, EDL No. 13586. July 2001. Benefits ID: 2007-00472

Innovative Traffic Control Technology and Practice in Europe, U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00355

ITS *Impacts Assessment for Seattle* MMDI *Evaluation: Modeling Methodology and Results*, U.S. DOT Federal Highway Administration. EDL No. 11323. September 1999. Benefits ID: 2007-00359

Jeannotte, Krista. "Evaluation of the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS)," Paper Presented at the 11th Annual ITS America Meeting. Miami, FL. June 2001. Benefits ID: 2007-00347

Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft), U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2000-00134

Smith, S. and C. Perez. "Evaluation of INFORM—Lessons Learned and Applications to Other Systems," Paper Presented at the 71st Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 1992. Benefits ID: 2000-00098

108 Sources that support these findings:

Dakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 9–13 January 2000. Benefits ID: 2007-00337

Hourdakis, John and Panos Michalopoulos. "Evaluation of Ramp Meter Control Effectiveness in Two Twin Cities Freeways," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00482

Smith, S. and C. Perez. "Evaluation of INFORM—Lessons Learned and Applications to Other Systems," Paper Presented at the 71st Annual Meeting of the Transportation Research Board. Washington, DC. January 1992. Benefits ID: 2000-00098

109 Sources that support these findings:

Dakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 12–16 January 2000. Benefits ID: 2002-00243

Detroit Freeway Corridor ITS *Evaluation*, U.S. DOT Federal Highway Administration, EDL No. 13586. July 2001. Benefits ID: 2001-00213

"Ramp up the Volume," ITS *International*. November 1997. Benefits ID: 2000-00049

"Telematics Applications Programme, 4th Framework Programme," RTD&D 1994–1998, Web site URL www.cordis.lu/telematics/tap_transport/research/10.html. Last Accessed 29 October 2004. Benefits ID: 2007-00387

Twin Cities Ramp Meter Evaluation: Final Report. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00417

110 Sources that support these findings:

Allsopp, Richard, et al. "Safety Evaluation of Ramp Metering in Glasgow Using the Asset Image Processing System," Paper Presented at the 5th World Congress Conference on ITS. Seoul, Korea. 12–16 October 1998. Benefits ID: 2000-00152

Cleavenger, Daniel K. and J. Upchurch. "Effect of Freeway Ramp Metering on Accidents: The Arizona Experience," ITE *Journal*, Vol. 69, No. 8, Page 12. August 1999. Benefits ID: 2000-00032

Estimation of Benefits of Houston TranStar, Prepared by the Parsons Transportation Group for the Texas Transportation Institute. 7 February 1997. Benefits ID: 2000-00014

Ramp Metering Status in North America, 1995 Update, U.S. DOT, Report No. DOT-T-95-17. June 1995. Benefits ID: 2000-00077

Twin Cities Ramp Meter Evaluation: Final Report. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00420

111 Sources that support these findings:

Diakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 12–16 January 2000. Benefits ID: 2007-00338

Travel Time Messaging on Dynamic Message Signs—Houston, TX, Texas DOT and the U.S. DOT Federal Highway Administration. May 2005. Benefits ID: 2007-00304

112 Innovative Traffic Control Technology and Practice in Europe, U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00331

113 Sources that support these findings:

Fontaine, Michael D. and Steven D. Schrock. "Feasibility of Real-Time Remote Speed Enforcement in Work Zones," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00490

Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. February 2003. Benefits ID: 2007-00344

114 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. February 2003. Benefits ID: 2007-00344

115 *Working Paper: Estimating the Federal Proportion of Funds Expended on ITS Infrastructure for Fiscal Year 2000*, U.S. DOT Federal Highway Administration. EDL No. 13596. May 2001. Costs ID: 2003-00013

116 2006 *Annual Report SMART SunGuide Transportation Management Center* (TMC), Florida DOT District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

117 "Cost Estimates for Blewett/Stevens Pass Highway Advisory Radios," U.S. DOT Federal Highway Administration, ITS Joint Program Office. Washington, DC. July 2001. Costs ID: 2003-00016

118 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. February 2003. Costs ID: 2004-00085

119 *Twin Cities Ramp Meter Evaluation: Final Report*. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00416

120 2006 *Annual Report SMART SunGuide Transportation Management Center* (TMC), Florida DOT District IV. January 2007. Costs ID: 2007-00120

121 *Design Criteria: Pole Heights and Location for Video Surveillance Systems—Version 1*, Florida DOT, ITS Office. Tallahassee, FL. 25 November 2003. Costs ID: 2004-00077

122 *Twin Cities Ramp Meter Evaluation: Final Report*. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00420

123 Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and U.S. DOT Federal Highway Administration. March 2004. Benefits ID: 2005-00286

124 *Twin Cities Ramp Meter Evaluation: Final Report*. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00417

125 Diakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 9–13 January 2000. Benefits ID: 2002-00243

126 Hourdakis, John and Panos Michalopoulos. "Evaluation of Ramp Meter Control Effectiveness in Two Twin Cities Freeways," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Benefits ID: 2002-00237

127 *Twin Cities Ramp Meter Evaluation: Final Report*, Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00419

128 Diakaki, Christina, et al. "Application and Evaluation of the Integrated Traffic-Responsive Urban Corridor Control Strategy (IN-TUC) in Glasgow," Paper Presented at the 79th Transportation Research Board Annual Meeting. Washington, DC. 9–13 January 2000. Benefits ID: 2007-00339

129 *Working Paper: Estimating the Federal Proportion of Funds Expended on ITS Infrastructure for Fiscal Year 2000*, U.S. DOT Federal Highway Administration. EDL No. 13596. May 2001. Costs ID: 2003-00013

130 *Cost Estimates for ITS Devices of the T-REX Project*, Colorado DOT and Transportation Expansion (T-REX) Project Fact Book. Winter 2002. Costs ID: 2003-00014

131 *Twin Cities Ramp Meter Evaluation: Final Report*. Prepared by Cambridge Systematics for the Minnesota DOT, EDL No. 13425. St. Paul, MN. 1 February 2001. Benefits ID: 2007-00416

132 Pool, Robert W. Jr. and C. Kenneth Orski. *HOT Lanes: A Better Way to Attack Urban Highway Congestion*, CATO Institute, Regulation, Vol. 23. No. 1. Washington, DC. (2000). Costs ID: 2008-00135

133 *Managed Lanes: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Office of Transportation Management, Report No. FHWA-HOP-05-037. November 2004. Lesson ID: 2007-00380

134 *Innovative Traffic Control Technology and Practice in Europe*. U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00355

135 Wendelboe, Jens Toft. *Traffic management applications on the Køge Bugt Motorway, Denmark*, European Commission Directorate General Energy and Transport. April 2003. Benefits ID: 2007-00501

136 *Innovative Traffic Control Technology and Practice in Europe*. U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00355

137 *Innovative Traffic Control Technology and Practice in Europe*. U.S. DOT Federal Highway Administration, Office of International Programs, Report No. FHWA-PL-99-021. August 1999. Benefits ID: 2007-00353

138 Wendelboe, Jens Toft. *Traffic management applications on the Køge Bugt Motorway, Denmark*, European Commission Directorate General Energy and Transport. April 2003. Benefits ID: 2007-00501

139 Sources that support these findings:

Robinson, Mark. "Examples of Variable Speed Limit Applications," Presentation given at the Speed Management Workshop held in conjunction with the 79th Annual Meeting of the Transportation Research Board. Washington, DC. 9–13 January 2000.

Rural ITS Toolbox. U.S. DOT, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Costs ID: 2003-00015

"Smart Trek," Puget Sound Regional Council, Web page URL www.smarttrek.org/html/new2.html. Last Accessed 2 November 2004.

140 *Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft)*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2007-00375

141 *Detroit Freeway Corridor ITS Evaluation*, U.S. DOT Federal Highway Administration, EDL No. 13586. July 2001. Benefits ID: 2007-00472

142 Ran, Bin, et al. *Evaluation of Variable Message Signs in Wisconsin: Driver Survey*, University of Wisconsin. Madison, WI. May 2002. Benefits ID: 2004-00279

143 *2006 Annual Report SMART SunGuide Transportation Management Center* (TMC), Florida DOT District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

144 Perrin, Joseph, et al. *Advanced Transportation Management System Elemental Cost Benefit Assessment*. Prepared by the University of Utah for the Utah DOT and U.S DOT Federal Highway Administration. Salt Lake City, UT. March 2004. Costs ID: 2004-00086

145 Paniati, Jeffrey and Jeffrey Lindley. *Dynamic Message Sign (DMS) Recommended Practice and Guidance*, U.S. DOT Federal Highway Administration. July 2004. Lesson ID: 2007-00337

146 *Changeable Message Sign Operation and Messaging Handbook*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-070. August 2004. Lesson ID: 2007-00336

147 Paniati, Jeffrey and Jeffrey Lindley, *Dynamic Message Sign (DMS) Recommended Practice and Guidance*, U.S. DOT Federal Highway Administration. July 2004. Lesson ID: 2007-00337

148 *Evaluation of Rural ITS Information Systems along* U.S. 395, *Spokane, Washington*, U.S. DOT, EDL No. 13955. 8 January 2004. Benefits ID: 2007-00484

149 *Evaluation of Rural ITS Information Systems along* U.S. 395, *Spokane, Washington*, U.S. DOT, EDL No. 13955. 8 January 2004. Costs ID: 2004-00079

150 "Cost Estimates for Blewett/Stevens Pass Highway Advisory Radios," U.S. DOT Federal Highway Administration, ITS Joint Program Office. Washington, DC. July 2001. Costs ID: 2003-00016

151 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. 11 February 2003. Benefits ID: 2007-00344

152 Gaines, Adrian, et al. *Transport: A cost recovery system for speed and red-light cameras—Two year pilot evaluation*, Prepared by the Great PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. 11 February 2003. Benefits ID: 2003-00264

153 Gaines, Adrian, et al. *Department for Transport: A cost recovery system for speed and red-light cameras—two year pilot evaluation*, Prepared by the PA Consulting Group and University College London for the Department for Transport, Road Safety Division. London, England. 11 February 2003. Costs ID: 2004-00085

154 Sources that support these findings:

"FHWA Safety," U.S. DOT Federal Highway Administration, Web site URL safety.fhwa.dot.gov/intersections/index.htm. Last Accessed 12 December 2007.

Torbic, Darren J., et al. *Guidance for Implementation of the* AASHTO *Strategic Highway Safety Plan, Volume 7: A Guide for Reducing Collisions on Horizontal Curves*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 500. Washington, DC. 2004.

Pedestrian and Bicyclist Intersection Safety Indices: Final Report, U.S. DOT Highway Safety Research Center for the Turner-Fairbank Highway Research Center, Report No. FHWA-HRT-06-125. November 2006.

155 Drakopoulos, Alexander. "CVO/Freight and ITS Session," Presentation at the 12th annual ITS Forum, Wisconsin Chapter of ITS America—Smartways, Marquette University. Milwaukee, WI. 31 October 2006. Benefits ID: 2008-00513

156 Mattingly, Stephen P. "Mitigating Overheight Vehicle Crashes Into Infrastructure: A State of the Practice," Paper Presented at the 82nd Annual Transportation Research Board Meeting. Washington, DC. 12–16 January 2003. Benefits ID: 2008-00514

157 Inman, Vaughan W., et al. "Field and Driving Simulator Validations of System for Warning Potential Victims of Red-Light Violators," Paper Presented at the 85th Annual Transportation Research Board Meeting, Washington, DC. 22–26 January 2006. Benefits ID: 2008-00515

158 Pento, Robert J. "Evaluation of PennDOT ITS Deployments," PennDOT, Bureau of Highway Safety and Traffic Engineering, Presentation to the 2005 Transportation Engineering and Safety Conference. 7 December 2005. Costs ID: 2008-00136

159 Mattingly, Stephen P. "Mitigating Overheight Vehicle Crashes Into Infrastructure: A State of the Practice," Paper Presented at the 82nd Annual Transportation Research Board Meeting. Washington, DC. 12–16 January 2003. Costs ID: 2008-00137

160 *Intersection Collision Avoidance Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-030, EDL No. 14105. September 2003. Costs ID: 2008-00138

161 Cortelazzi, Lou, et al. *Pennsylvania Turnpike Commission's Advanced Traveler Information System* (ATIS) *Phase* III *Project*, Prepared by DMJM Harris for the Pennsylvania Turnpike Commission, EDL No. 14308. Philadelphia, PA. April 2006. Benefits ID: 2008-00516

162 Strickland, Rodney and Hugh McGee. "Evaluation Results of Three Prototype Automatic Truck Rollover Warning Systems," Paper Presented at the 77th Annual Transportation Research Board Meeting. Washington, DC. 11–15 January 1998. Benefits ID: 2000-00131

163 Drakopoulos, Alexander. "CVO/Freight and ITS Session," Presentation at the 12th Annual ITS Forum, Wisconsin Chapter of ITS America—Smartways, Marquette University. Milwaukee, WI. 31 October 2006. "Design Guidelines for Including ITS in Projects," Colorado DOT CoTrip, Web site URL www.cotrip.org/its/ITS%20Guidelines%20Web%20New%20Format%202-05/Web%20Solutions%20Packages/Truck%20Overturn%20Speed%20Advisory%20System.xls. Last Accessed 10 February 2008. Costs ID: 2008-00178

164 Sources that support these findings:

Field Evaluation of the Myrtle Creek Advanced Curve Warning System, Oregon DOT and the U.S. DOT Federal Highway Administration, Report No. FHWA-OR-RD-06-13. June 2006. Benefits ID: 2008-00517

Tribbett, Lani, et al. *An Evaluation of Dynamic Curve Warning Systems in the Sacramento River Canyon: Final Report*, Western Transportation Institute, Montana State University. Bozeman, MT. April 2000. Benefits ID: 2007-00415

165 Pento, Robert J. "Evaluation of PennDOT ITS Deployments," PennDOT Bureau of Highway Safety and Traffic Engineering, Presentation to the 2005 Transportation Engineering and Safety Conference. 7 December 2005. Costs ID: 2008-00136

166 *Rural ITS Toolbox*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Lesson ID: 2005-00075

167 "IRD Uses WIM Info in Suite of Truck Safety Advisory Systems," *Inside ITS*, Pages 8–9. December 1997. Benefits ID: 2000-00055

168 *Rural ITS Toolbox*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Benefits ID: 2008-00518

169 Janson, Bruce N. *Evaluation of Downhill Truck Speed Warning System on I–70 West of Eisenhower Tunnel*, Prepared by the University of Colorado for the Colorado DOT, EDL No. 11963. Denver, CO. December 1999. Benefits ID: 2001-00212

170 Drakopoulos, Alexander. "CVO/Freight and ITS Session," Presentation at the 12th Annual ITS Forum, Wisconsin Chapter of ITS America—Smartways, Marquette University. Milwaukee, WI. 31 October 2006. Benefits ID: 2008-00519

171 Mattingly, Stephen P. "Mitigating Overheight Vehicle Crashes Into Infrastructure: A State of the Practice," Paper Presented at the 82nd Annual Transportation Research Board Meeting. Washington, DC. 12–16 January 2003. Costs ID: 2008-00137

172 Cawley, Patrick, M. "Evaluation of Overheight Vehicle Detection/Warning Systems," Paper Presented at the 2002 ITE Spring Conference and Exhibit. Palm Harbor, FL. 24–27 March 2002. Costs ID: 2008-00139

173 "Second Train Coming Warning Sign Demonstration Projects," *Research Results Digest*, U.S. DOT Federal Transit Administration, Transit Cooperative Research Program, TCRP RRD No. 51. November 2002. Benefits ID: 2005-00282

174 "Second Train Coming Warning Sign Demonstration Projects," *Research Results Digest*, U.S. DOT Federal Transit Administration, Transit Cooperative Research Program, TCRP RRD No. 51. November 2002. Benefits ID: 2005-00282

175 *Metropolitan Model Deployment Initiative: San Antonio Evaluation Report—Final Draft*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2000-00134

176 Gent, Steve, J., et al. *Evaluation of an Automated Horn Warning System at Three Highway-Railroad Grade Crossings in Ames, Iowa*, Iowa DOT. Ames, IA. 1998 (date estimated). Benefits ID: 2007-00477

177 "Second Train Coming Warning Sign Demonstration Projects," *Research Results Digest*, U.S. DOT Federal Transit Administration, Transit Cooperative Research Program, TCRP RRD No. 51. November 2002. Benefits ID: 2008-00520

178 Hanscom, Fred R. "Rural Stop-Sign Controlled Intersection Accident Countermeasure System Device Vehicle-Behavioral Evaluation," Paper Presented at the 10th ITS America Annual Meeting. Boston, MA. 1–4 May 2000. Benefits ID: 2000-00167

179 *Intersection Collision Avoidance Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-030, EDL No. 14105. September 2003. Benefits ID: 2008-00573

180 *Intersection Collision Avoidance Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-030, EDL No. 14105. September 2003. Costs ID: 2008-00138

181 Hughes, Ronald, et al. "ITS and Pedestrian Safety at Signalized Intersections," *ITS Quarterly*, Vol. 7, No.2. Spring/Summer 1999. Benefits ID: 2000-00018

182 *Evaluation of Automated Pedestrian Detection at Signalized Intersections*, U.S. DOT Federal Highway Administration, Report No. FHWA-RD-00-097. August 2001. Benefits ID: 2004-00276

183 *Animal Vehicle Crash Mitigation Using Advanced Technology Phase I: Review, Design and Implementation—Final Report*, Prepared by the Montana State University for the Oregon DOT, Alaska DOT, and U.S. DOT, Report No. SPR-3(076). Bozeman, MT. August 2006. Benefits ID: 2008-00521

184 *Animal Vehicle Crash Mitigation Using Advanced Technology Phase I: Review, Design and Implementation—Final Report*, Prepared by the Montana State University for the Oregon DOT, Alaska DOT, and U.S. DOT, Report No. SPR-3(076). Bozeman, MT. August 2006. Costs ID: 2008-00140

185 *Animal Vehicle Crash Mitigation Using Advanced Technology Phase I: Review, Design and Implementation—Final Report*, Prepared by the Montana State

University for the Oregon DOT, Alaska DOT, and U.S. DOT, Report No. SPR-3(076). Bozeman, MT. August 2006. Lesson ID: 2007-00409

186 *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services*, The National Academy of Sciences, National Research Council. Washington, DC. April 2004.

187 "Road Weather Management Program," U.S. DOT Federal Highway Administration, Web site URL www.ops.fhwa.dot.gov/Weather/q1_roadimpact.htm. Last Accessed 20 February 2008.

188 Sources with supporting information:

Pisano, Paul, et al. "U.S. Highway Crashes in Adverse Road Weather Conditions," Paper Presented at the American Meteorological Society Annual Meeting, New Orleans, LA, 20–24 January 2008.

Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services, The National Academy of Sciences, National Research Council. Washington, DC. April 2004.

189 Goodwin, L. *Weather Impacts on Arterial Traffic Flow*, Mitretek Systems. Falls Church, VA. December 2002.

190 Sources with supporting information:

"Clarus Initiative," U.S. DOT Federal Highway Administration, Web site URL www.clarusinitiative.org. Last Accessed 14 December 2007.

"Road Weather Management Program," U.S DOT Federal Highway Administration, Web site URL ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#3. Last Accessed 14 December 2007.

191 Sources that support these findings:

Evaluation of Rural ITS *Information Systems along* U.S. 395, Spokane, Washington, U.S. DOT Federal Highway Administration, EDL No. 13955. 8 January 2004. Benefits ID: 2004-00274

Final Evaluation Report: Evaluation of the Idaho Transportation Department Integrated Road-Weather Information System, U.S. DOT Federal Highway Administration, EDL No. 14267. 2 February 2006. Benefits ID: 2008-00522

192 Sources that support these findings:

Cooper, B.R. and Helen E. Sawyer. *Assessment Of* M25 *Automatic Fog-Warning System—Final Report*, Safety Resource Centre, Transportation Research Laboratory. Crowthorne, Berkshire, United Kingdom. 1993. Benefits ID: 2005-00283

Fog Project on I–75 *between Chattanooga and Knoxville*, Tennessee ITS State Status Report. October 2000. U.S. DOT Web site URL www.its.dot.gov/staterpt/tn.htm. Last Accessed 7 November 2001. Benefits ID: 2001-00219

Hogema, Jeroen and Richard van der Horst. *Evaluation of* A16 *Motorway Fog-Signaling System with Respect to Driving Behavior*, Transportation Research Board, Report No. TRR 1573. Washington, DC. 1995. Benefits ID: 2000-00022

Kumar, Manjunathan and Christopher Strong. *Comparative Evaluation of Automated Wind Warning Systems*, Prepared by the Montana State of University for the California DOT, Oregon DOT, and U.S. DOT. February 2006. Benefits ID: 2008-00523

Perrrin, Joseph and Brad Coleman. *Adverse Visibility Information System Evaluation* (ADVISE): *Interstate* 215 *Fog Warning System—Final Report*, Prepared by the University of Utah for the Utah DOT, Report No. UT-02.12. Salt Lake City, UT. June 2003. Benefits ID: 2005-00281

Ulfarsson, Gudmundur F., et al. TRAVELAID, Prepared by the University of Washington for the Washington State Transportation Commission and the U.S. DOT. December 2001. Benefits ID: 2002-00240

193 Sources that support these findings:

Cooper, B.R. and Helen E. Sawyer. *Assessment of* M25 *Automatic Fog-Warning System: Final Report*, Safety Resource Centre, Transportation Research Laboratory. Crowthorne, Berkshire, United Kingdom. 1993. Benefits ID: 2005-00283

Fog Project on I–75 *between Chattanooga and Knoxville*, Tennessee ITS State Status Report. October 2000. U.S. DOT Web site URL www.its.dot.gov/staterpt/tn.htm. Last Accessed 7 November 2001. Benefits ID: 2001-00219

Hogema, Jeroen and Richard van der Horst. *Evaluation of* A16 *Motorway Fog-Signaling System with Respect to Driving Behavior*, Transportation Research Board, Report No. TRR 1573. Washington, DC. 1995. Benefits ID: 2000-00022

Kumar, Manjunathan and Christopher Strong. *Comparative Evaluation of Automated Wind Warning Systems*, Prepared by the Montana State of University for the California DOT, Oregon DOT, and U.S. DOT. February 2006. Benefits ID: 2008-00523

Perrrin, Joseph and Brad Coleman. *Adverse Visibility Information System Evaluation* (ADVISE): *Interstate* 215 *Fog Warning System—Final Report*, Prepared by the University of Utah for the Utah DOT, Report No. UT-02.12. Salt Lake City, UT. June 2003. Benefits ID: 2005-00281

194 O'Keefe, Katie and Xianming Shi. *Synthesis of Information on Anti-icing and Pre-wetting for Winter Highway Maintenance Practices in North America: Final Report*, Prepared by the Montana State University for the Pacific Northwest Snowfighters Association and the Washington State DOT. 19 August 2005. Benefits ID: 2008-00524

195 Sources that support these findings:

Breen, Bryon D. *Anti-Icing Success Fuels Expansion of the Program in Idaho*, Idaho Transportation Department, Snow and Ice Pooled Fund Cooperative Program, Web page URL www.sicop.net/US–12%20Anti%20Icing%20Success.pdf. Last Accessed 5 October 2001. Benefits ID: 2001-00214

Breen, Bryon D. *Anti-Icing Success Fuels Expansion of the Program in Idaho*, Idaho Transportation Department, Snow and Ice Pooled Fund Cooperative Program, Web page URL www.sicop.net/US–12%20Anti%20Icing%20Success.pdf. Last Accessed 5 October 2001. Benefits ID: 2007-00336

Case Study #6: Winter Maintenance Innovations Reduce Accidents and Costs—City of Kamloops, Prepared by the McCormick Rankin Corporation and Ecoplans Limited for the Insurance Corporation of British Columbia and Environment. Canada. 2004. Benefits ID: 2008-00526

O'Keefe, Katie and Xianming Shi. *Synthesis of Information on Anti-icing and Pre-wetting for Winter Highway Maintenance Practices in North America: Final Report*, Prepared by the Montana State University for the Pacific Northwest Snowfighters Association and the Washington State DOT. 19 August 2005. Benefits ID: 2008-00525

196 Kumar, Manjunathan and Christopher Strong. *Comparative Evaluation of Automated Wind Warning Systems*, Prepared by the Montana State of University for the California DOT, Oregon DOT, and U.S. DOT. February 2006. Costs ID: 2008-00141

197 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice—Final Report*, Transportation Research Board, NCHRP, Project 20-7/Task 200. Washington, DC. September 2006. Costs ID: 2008-00142

198 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice—Final Report*, Transportation Research Board, NCHRP, Project 20-7/Task 200. Washington, DC. September 2006. Costs ID: 2008-00142

199 Sources that support these findings:

Andrle, Stephen J., et al. *Highway Maintenance Concept Vehicle—Final Report: Phase Four*, Iowa State University, Center for Transportation Research and Education. Ames, IA. June 2002. Costs ID: 2008-00143

Kack, David and Eli Cuelho. *Needs Assessment and Cost-Benefit Analysis of RoadView™ Advanced Snowplow Technology System*, Sixth International Symposium on Snow Removal and Ice Control Technology, Transportation Research Circular, Number E-C063. Washington, DC. June 2004. Costs ID: 2008-00144

200 "Greater Yellowstone Regional Traveler and Weather Information Systems (GYRTWIS) 511 Implementation," U.S.DOT Federal Highway Administration, ITS Joint Program Office. Washington, DC. July 2004 and July 2006. Costs ID: 2005-00089

201 Shi, X., et al. *Evaluation of Utah Department of Transportation's Weather Operations/RWIS Program: Phase I*, Prepared by the Montana State of University for the Utah DOT. February 2007. Benefits ID: 2008-00527

202 Schirokoff, A., P. Rama, and A. Tuomainen. "Country-Wide Variable Speed Limits?," Paper Presented at the XIII International Road Weather Conference (SIRWEC). Torino, Italy. 25–27 March 2006. Benefits ID: 2008-00528

203 Sources that support these findings:

Pilli-Sihvola, Yrjo, et al. *Road Weather Service System in Finland and Savings in Driving Costs*, Transportation Research Board, Report No. TRR 1387. Washington, DC. 1993. Benefits ID: 2007-00499

Stowe, Robert. "A Benefit/Cost Analysis of Intelligent Transportation System Applications for Winter Maintenance," Paper Presented at the 80th Transportation Research Board Annual Meeting. Washington, DC. 7–11 January 2001. Benefits ID: 2001-00178

204 Stowe, Robert. "Benefit/Cost Analysis of Intelligent Transportation System Applications for Winter Maintenance," Paper Presented at the 80th Annual Transportation Research Board Meeting. Washington, DC. 7–11 January 2001. Benefits ID: 2007-00437

205 Shi, X., et al. *Evaluation of Utah Department of Transportation's Weather Operations/RWIS Program: Phase I*, Prepared by the Montana State University for the Utah DOT. February 2007. Benefits ID: 2008-00527

206 *Evaluation of Rural ITS Information Systems along U.S. 395, Spokane, Washington*, U.S. DOT Federal Highway Administration, EDL No. 13955. 8 January 2004. Benefits ID: 2007-00484

207 Kumar, Manjunathan and Christopher Strong. *Comparative Evaluation of Automated Wind Warning Systems*, Prepared by the Montana State of University for the California DOT, Oregon DOT, and U.S. DOT. February 2006. Costs ID: 2008-00141

208 *Ohio DOT Roadway Weather Information System (RWIS) Expansion*, Ohio DOT. Columbus, OH. 2003. Costs ID: 2004-00071

209 *I-68 Fog Detection System Planning Report*, Sabra, Wang, and Associates. Baltimore, MD. 7 November 2003. Costs ID: 2005-00092

210 Shi, X., et al. *Evaluation of Utah Department of Transportation's Weather Operations/RWIS Program: Phase I*, Prepared by the Montana State of University for the Utah DOT. February 2007. Benefits ID: 2008-00527

211 Kumar, Manjunathan and Christopher Strong. *Comparative Evaluation of Automated Wind Warning Systems*, Prepared by the Montana State of University for the California DOT, Oregon DOT, and U.S. DOT. February 2006. Benefits ID: 2008-00529

212 *A Case Study of the Maintenance Decision Support System (MDSS) in Maine*, U.S. DOT Federal Highway Administration. September 2007. Lesson ID: 2007-00405

213 Lowry, Stephen D. *Traffic Safety Effects of a Wet Pavement Detection System Installed on a North Carolina Interstate: A Statistical Summary of Crash Data for a Temporary On-Site Detour inside an I-485 Construction Zone in Mecklenburg County*. North Carolina DOT. August 2004. Benefits ID: 2008-00530

214 *Evaluation of Rural ITS Information Systems along U.S. 395, Spokane, Washington*, U.S. DOT Federal Highway Administration, EDL No. 13955. 8 January 2004. Benefits ID: 2004-00274

215 "Greater Yellowstone Regional Traveler and Weather Information Systems (GYRTWIS) 511 Implementation," U.S.DOT Federal Highway Administration, ITS Joint Program Office. Washington, DC. July 2004 and July 2006. Costs ID: 2005-00089

216 *Integration of Emergency and Weather Elements into Transportation Management Centers*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-090, EDL No. 14247. 28 February 2006. Lesson ID: 2007-00353

217 *Best Practices for Road Weather Management: Version 2.0*, U.S. DOT Federal Highway Administration, Road Weather Management Program, Report No. FHWA-OP-03-081. 2003. Benefits ID: 2008-00531

218 Maki, Pamela J. *Adverse Weather Traffic Signal Timing*, Prepared by Short Elliott Hendrickson for the Minnesota DOT, Web page URL trafficware.infopop.cc/downloads/00005.pdf. 2002. Last Accessed 14 December 2007. Benefits ID: 2001-00216

219 *Documentation and Assessment of Mn/DOT Gate Operations*, Prepared by BRW for the Minnesota DOT. St. Paul, MN. October 1999. Benefits ID: 2001-00215

220 Pilli-Sihvola, Yrjo and Lahesmaa Jukka. *Weather-Controlled Road and Investment Calculations*, Finnish National Road Administration. Southeastern Region, Kouvola. December 1995. Benefits ID: 2007-00503

221 Schirokoff, A., P. Rama, and A. Tuomainen. "Country-Wide Variable Speed Limits?," Paper Presented at the XIII International Road Weather Conference (SIRWEC). Torino, Italy. 25–27 March 2006. Costs ID: 2008-00145

222 Schirokoff, A., P. Rama, and A. Tuomainen. "Country-Wide Variable Speed Limits?," Paper Presented at the XIII International Road Weather Conference (SIRWEC). Torino, Italy. 25–27 March 2006. Benefits ID: 2008-00528

223 Khattak, A. P. and Geza Pesti. *Bridge Prioritization for Installation of Automatic Anti-Icing Systems in Nebraska*, Proceedings of the 2003 Mid-Continent Transportation Research Symposium. Ames, IA. 21–22 August 2003. Benefits ID: 2008-00534

224 Pilli-Sihvola, Yrjo, et al. *Road Weather Service System in Finland and Savings in Driving Costs*, Transportation Research Board, Report No. TRR 1387. Washington, DC. 1993. Benefits ID: 2000-00085

225 Boselly, Edward S. *Benefit/Cost Study of RWIS and Anti-icing Technologies: Final Report*, Transportation Research Board, NCHRP, Report No. 20-7(117). Washington, DC. March 2001. Benefits ID: 2007-00469

226 Boselly, Edward S. *Benefit/Cost Study of RWIS and Anti-icing Technologies: Final Report*, Transportation Research Board, NCHRP, Report No. 20-7(117). Washington, DC. March 2001. Benefits ID: 2007-00470

227 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice—Final Report*, Transportation Research Board, NCHRP, Project 20-7/Task 200. Washington, DC. September 2006. Costs ID: 2008-00142

228 Meyer, Eric, I. Ahmed. "Benefits-Cost Assessment of Automatic Vehicle Location (AVL) in Highway Maintenance," Paper Presented at the 83rd Transportation Research Board Annual Meeting. Washington, DC. 11–15 January 2004. Costs ID: 2008-00146

229 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice—Final Report*, Transportation Research Board, NCHRP, Project 20-7/Task 200. Washington, DC. September 2006. Costs ID: 2008-00142

230 Sources that support these findings:

Andrle, Stephen J., et al. *Highway Maintenance Concept Vehicle—Final Report: Phase Four*, Iowa State University, Center for Transportation Research and Education. Ames, IA. June 2002. Costs ID: 2008-00143

Kack, David and Eli Cuelho. *Needs Assessment and Cost-Benefit Analysis of RoadView™ Advanced Snowplow Technology System*, Sixth International Symposium on Snow Removal and Ice Control Technology, Transportation Research Circular, Number E-C063. Washington, DC. June 2004. Costs ID: 2008-00144

231 Khattak, A. P. and Geza Pesti. *Bridge Prioritization for Installation of Automatic Anti-Icing Systems in Nebraska*, Proceedings of the 2003 Mid-Continent Transportation Research Symposium. Ames, IA. 21–22 August 2003. Benefits ID: 2008-00534

232 Meyer, Eric and I. Ahmed. "Benefit-Cost Assessment of Automatic Vehicle Location (AVL) in Highway Maintenance," Paper Presented at the 83rd Transportation Research Board Annual Meeting. Washington, DC. 11–15 January 2004. Benefits ID: 2008-00536

233 Sources that support these findings:

Pilli-Sihvola, Yrjo, et al. *Road Weather Service System in Finland and Savings in Driving Costs*, Transportation Research Board, Report No. TRR 1387. Washington, DC. 1993. Benefits ID: 2007-00499

Stowe, Robert. "A Benefit/Cost Analysis of Intelligent Transportation System Applications for Winter Maintenance," Paper Presented at the 80th Transportation Research Board Annual Meeting. Washington, DC. 7–11 January 2001. Benefits ID: 2001-00178

234 *National Strategy to Reduce Congestion on America's Transportation Network*, U.S DOT. May 2006.

235 Sources that support these findings:

Bushman, R. and C. Berthelot. "Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones," Presentation at the 83rd Annual Transportation Research Board Meeting. Washington, DC. 11–15 January 2004. Benefits ID: 2007-00326

Chu, L., H. Kim, H. Liu, and W. Recker. "Evaluation of Traffic Delay Reduction from Automatic Workzone Information Systems Using Micro-Simulation," Paper Presented at the 84th Annual Transportation Research Board Meeting. Washington, DC. 9–13 January 2005. Benefits ID: 2007-00400

236 Sources that support these findings:

Bushman, R. and C. Berthelot. "Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones," Presentation at the 83rd Annual Transportation Research Board Meeting. Washington, DC. 11–15 January 2004. Benefits ID: 2007-00326

Scriba, Tracy. "Knowing Ahead of Time," Transportation Management and Engineering. May 2005. Benefits ID: 2007-00327

237 Sources that support these findings:

Fontaine, M.D., P. Carlson, and G. Hawkins, *Use of Innovative Traffic Control Devices to Improve Safety at Short-Term Rural Work Zones*, Texas Transportation Institute, Report No. 1879-S. College Station, TX. 2000. Benefits ID: 2007-00331

Garber, N. and S. Patel. *Effectiveness of Changeable Message Signs with Radar in Controlling Vehicle Speeds in Work Zones*, Virginia Transportation Research Council, Report No. VTRC-95-R4. Charlottesville, VA. 1994. Benefits ID: 2007-00332

Garber, N. and S. Srinivasan, *Effectiveness of Changeable Message Signs with Radar in Controlling Vehicle Speeds in Work Zones*, Virginia Transportation Research Council, Report No. VTRC-98-R10. Charlottesville, VA. 1998. Benefits ID: 2007-00330

McCoy, P. J., J. Bonneson, and J. Kollbaum. *Speed Reduction Effects of Speed Monitoring Displays with Radar in Work Zones on Interstate Highways*, Transportation Research Board, Report No. TRR 1509. Washington, DC. 1995. Benefits ID: 2007-00329

238 Sources that support these findings:

Fontaine, M., P. Carlson, and G. Hawkins. *Use of Innovative Traffic Control Devices to Improve Safety at Short-Term Rural Work Zones*, Prepared by the Texas Transportation Institute for the Texas DOT. 2000. Benefits ID: 2007-00331

Fontaine, Michael D. and Steven D. Schrock. "Feasibility of Real-Time Remote Speed .Enforcement in Work Zones," Paper Presented at the 81st Annual Transportation Research Board Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00490

Garber, N. and Surbhi T. Patel, *Effectiveness of Changeable Message Signs in Controlling Vehicle Speeds in Work Zones: Final Report*, Virginia Transportation Research Council, Report No. VTRC 95-R4. Charlottesville, VA. August 1994. Benefits ID: 2007-00332

McCoy, P. J., J. Bonneson, and J. Kollbaum. *Speed Reduction Effects of Speed Monitoring Displays with Radar in Work Zones on Interstate Highways*, Transportation Research Board, Report No. TRR 1509. Washington, DC. 1995. Benefits ID: 2007-00329

239 Sources that support these findings:

Evaluation of 2004 Dynamic Late Merge System, Prepared by URS for the Minnesota DOT. St. Paul, MN. 28 December 2004. Benefits ID: 2007-00318

Intelligent Transportation Systems in Work Zones: A Case Study—Dynamic Lane Merge System, U.S. DOT Federal Highway Administration, EDL No. 14011. October 2004. Benefits ID: 2007-00403

240 ATIS *Evaluation Framework*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-066, EDL No. 14313. April 2005. Benefits ID: 2008-00537

241 Sources that support these findings:

Bushman, R. and C. Berthelot. "Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones," Presentation at the 83rd Annual Transportation Research Board Meeting. Washington, DC. 11–15 January 2004. Benefits ID: 2007-00326

Chu, L., H. Kim, H. Liu, and W. Recker. "Evaluation of Traffic Delay Reduction from Automatic Workzone Information Systems Using Micro-simulation," Presentation to the Transportation Research Board 84th Annual Meeting. Washington, DC. 9–13 January 2005. Benefits ID: 2007-00400

Lee, Eul-Bum and Changmo Kim. "Automated Work Zone Information System (AWIS) on Urban Freeway Rehabilitation: California Implementation," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2006-00293

242 Fontaine, Mike. "Operational and Safety Benefits of Work Zone ITS," Presentation to "ITS in Work Zones" Workshop/Peer Exchange. September 2005. Costs ID: 2006-00109

243 Sources that support these findings:

Bushman, R. and C. Berthelot. "Estimating the Benefits of Deploying Intelligent Transportation Systems in Work Zones," Presentation at the 83rd Annual Transportation Research Board Meeting. Washington DC. 11–15 January 2004. Benefits ID: 2007-00326

Lee, Eul-Bum and Changmo Kim. "Automated Work Zone Information System (AWIS) on Urban Freeway Rehabilitation: California Implementation," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2006-00293

244 Lee, Eul-Bum and Changmo Kim. "Automated Work Zone Information System (AWIS) on Urban Freeway Rehabilitation: California Implementation," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2006-00293

245 Bushman, R. and C. Berthelot. *Effect of Intelligent Transportation Systems in Work Zones: Evaluation of North Carolina Smart Work Zones—Final Report*, North Carolina DOT. September 2004. Benefits ID: 2008-00533

246 Groth, Sue. "Mn/DOT Work Zone ITS Contracts and Specification," Presentation to "ITS in Work Zones" Workshop/Peer Exchange. September 2005. Costs ID: 2006-00109

247 Sneed, Brian. "I-64 Add-lane Traffic Monitoring System," Presentation to "ITS in Work Zones" Workshop/Peer Exchange. September 2005. Correspondence with Mr. Brian Sneed, Illinois DOT ITS Engineer. 22 June 2007. Costs ID: 2007-00126

248 *Intelligent Transportation Systems in Work Zones: A Case Study—Real Time Work Zone Traffic Control System*, Prepared for the U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-04-018, EDL No. 13984. Washington, DC. October 2004. Costs ID: 2006-00107

249 Stephens, Jerry, et al. *An Evaluation of Montana's State Truck Activities Reporting System*. Prepared by the Montana State University for the Montana DOT. Bozeman, MN. 11 August 2003. Benefits ID: 2003-00268

250 Shi, Xianming, et al. *Vehicle-Based Technologies for Winter Maintenance: The State of the Practice*, Transportation Research Board, NCHRP, Project 20-7/Task 200. September 2006. Costs ID: 2008-00142

251 Sources that support these findings:

Scriba, Tracy. "Knowing Ahead of Time," *Transportation Management and Engineering*. May 2005. Correspondence with Mr. Steve Kite, North Carolina DOT. 13 February 2007. Benefits ID: 2007-00407

Tudor, Lorie, et al. "Deployment of Smart Work Zone Technology in Arkansas," Paper Presented at the 82nd Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 2003. Benefits ID: 2004-00271

252 *Intelligent Transportation Systems in Work Zones: A Case Study—Dynamic Lane Merge System*, U.S. DOT Federal Highway Administration, EDL No. 14011. October 2004. Benefits ID: 2007-00317

253 *Portable Traffic Management System Smart Work Zone Application: Operational Test Evaluation Report*, Report Prepared by SRF Consulting Group for the Minnesota DOT, Report No. 0942089.7/11. May 1997. Benefits ID: 2007-00325

254 *Intelligent Transportation Systems in Work Zones: A Case Study—Real Time Work Zone Traffic Control System*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-04-018, EDL No. 13984. October 2004. Benefits ID: 2007-00404

255 *Intelligent Transportation Systems in Work Zones: A Case Study—Real Time Work Zone Traffic Control System*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-04-018, EDL No. 13984. October 2004. Benefits ID: 2007-00405

256 *Intelligent Transportation Systems in Work Zones: A Case Study—Dynamic Lane Merge System*, U.S. DOT Federal Highway Administration, EDL No. 14011. October 2004. Correspondence with Mr. Jeff Grossklaus, Michigan DOT, November 2006 and January 2007. Costs ID: 2007-00110

257 Kratofil, Joseph, A. Jr. "A Benefit-Cost Analysis for the Use of Intelligent Transportation Systems Technology for Temporary Construction Zone Management on the I-496 Reconstruction in Lansing, Michigan," Prepared for Louis A. Reibling, Ph.D. in Partial Completion of the Degree of Master of Science in Administration, Central Michigan University, EDL No. 13591. Mt. Pleasant, MI. 14 March 2001. Benefits ID: 2007-00111

258 Kite, Steve. "SMART Work Zones: Technology for Work Zone Management—Making Work Zones Work Better Through Innovations in Technologies, Practices, and Products," North Carolina DOT Presentation, Web page URL www.ncdot.org/doh/preconstruct/traffic/conference/reports/tc2.pdf. Last Accessed 12 December 2007. Costs ID: 2006-00106

259 Fontaine, Mike. "Operational and Safety Benefits of Work Zone ITS," Presentation to "ITS in Work Zones" Workshop/Peer Exchange. September 2005. Costs ID: 2006-00109

260 Kratofil, Joseph, A. Jr. "A Benefit-Cost Analysis for the Use of Intelligent Transportation Systems Technology for Temporary Construction Zone Management on the I-496 Reconstruction in Lansing, Michigan," Prepared for Louis A. Reibling, Ph.D. in Partial Completion of the Degree of Master of Science in Administration, Central Michigan University, EDL No. 13591. Mt. Pleasant, MI. 14 March 2001. Costs ID: 2007-00111

261 "National Transit Database," U.S. DOT Federal Transit Administration, Web site URL www.ntdprogram.gov/ntdprogram/ntd.htm. Last Accessed 9 August 2007.

262 Furth, Peter G., et al. TCRP *Report 113: Using Archived AVL-APC Data to Improve Transit Performance and Management*, Transportation Research Board, Transit Cooperative Research Program. Washington, DC. 2006.

263 "Mobility Services for All Americans," U.S. DOT ITS Joint Program Office Web site URL www.its.dot.gov/msaa/index.htm. Last Accessed 13 November 2007.

264 "Integrated Corridor Management (ICM) Quarterly Newsletter—Spring 2007," U.S. DOT Web site URL www.its.dot.gov/icms/index.htm. Last Accessed 13 November 2007.

265 "Transit Impact Matrix," U.S. DOT Web site URL itsweb.mitretek.org/its/aptsmatrix.nsf/viewbyEfficiency?OpenView. Last Accessed 12 December 2007.

266 Bruun, Eric C. "Technological Maturity of ITS and Scheduling and Integrated Service Options to Transit Planners," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007.

267 Sources that support these findings:

APTS *Benefits*, U.S. DOT Federal Transit Administration. November 1995. Benefits ID: 2000-00028

Strathman, J., et al. "Evaluation of Transit Operations: Data Applications of Tri-Met's Automated Bus Dispatching System,"

Transportation, Vol. 29, No. 3. August 2002. Cited in Furth, Peter G., et al. *Uses of Archived AVL—APC Data to Improve Transit Performance and Management: Review and Potential*, Transit Cooperative Research Program Web Document No. 23. June 2003. Benefits ID: 2000-00151

Milwaukee County Transit System, Status Report, Milwaukee County. Milwaukee, WI. July 1995. Benefits ID: 2000-00110

268 Sources with results used to construct this range of impacts include (listed alphabetically by study location per figure 8):

Chada, Shireen and Robert Newland. *Effectiveness of Bus Signal Priority: Final Report*, Prepared by the University of South Florida for the Florida DOT and U.S. DOT, Report No. NCTR-416-04, EDL No. 13651. Tallahassee, FL. January 2002. Benefits ID: 2007-00345

Crout, David. "Transit Signal Priority Evaluation," Paper Presented at the ITS America 13th Annual Meeting and Exposition, Minneapolis, MN. May 2003. Benefits ID: 2003-00265

Dion, Francois, et al. "Evaluation of Transit Signal Priority Benefits along a Fixed-Time Signalized Arterial," Paper Presented at the 81st Annual Meeting of the Transportation Research Board, Washington, DC. 13–17 January 2002. Benefits ID: 2007-00348

Greenough and Kelman. "ITS Technology Meeting Municipal Needs—The Toronto Experience," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2007-00362

"ITS developed by Japanese Police," Japan Traffic Management Technology Association, Institute of Urban Traffic Research. (Undated) Benefits ID: 2000-00073

Lehtonen, Mikko and Risto Kulmala. "The Benefits of a Pilot Implementation of Public Transport Signal Priorities and Real-Time Passenger Information," Paper Presented at the 81st Annual Transportation Research Board Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00392

Los Angeles Metro Rapid Demonstration Program: Final Report, Prepared by Transportation Management and Design, Inc. for the Los Angeles County Metropolitan Transportation Authority and the Los Angeles DOT. March 2002. Benefits ID: 2008-00544

"Telematics Applications Programme, 4th Framework Programme," RTD&D 1994–1998, Web site URL www.cordis.lu/telematics/tap_transport/research/10.html. Last Accessed 15 November 2004. Benefits ID: 2000-00135

Wang, Yinhai, et al. *Comprehensive Evaluation on Transit Signal Priority System Impacts Using Field Observed Traffic Data*, TransNow Report (TNW2007-06), University of Washington. Seattle, WA. 15 June 2007. Benefits ID: 2008-00538

269 Harman, Lawrence J. and Uma Shama. TCRP *Synthesis 70: Mobile Data Terminals—A Synthesis of Transit Practice*, Transportation Research Board, Transit Cooperative Research Program. Washington, DC. 2007. Costs ID: 2008-00147

270 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

271 Sources that support these findings:

APTS *Benefits*, Report Prepared by the U.S. DOT Federal Transit Administration. November 1995.

Milwaukee County Transit System, Status Report, Milwaukee County. July 1995. Benefits ID: 2000-00110

Strathman, J., et al. "Evaluation of Transit Operations: Data Applications of Tri-Met's Automated Bus Dispatching System,"

Transportation, Vol. 29, No. 3. August 2002. Cited in Furth, Peter G., et al. *Uses of Archived AVL—APC Data to Improve Transit Performance and Management: Review and Potential*, Transit Cooperative Research Program Web Document No. 23. June 2003. Benefits ID: 2000-00151

272 Furth, Peter G. and Theo H. J. Muller. "Integrating Bus Service Planning with Analysis, Operational Control, and Performance Monitoring," Paper Presented at the ITS America 10th Annual Meeting. Boston, MA. 1–4 May 2000. Benefits ID: 2000-00163

273 Strathman, James G., et.al. "Service Reliability Impacts of Computer-Aided Dispatching and Automatic Vehicle Location Technology: A Tri-Met Case Study," *Transportation Quarterly*, Vol. 54, No. 3. Summer 2000. Benefits ID: 2000-00151

274 Strathman, J., et al. "Evaluation of Transit Operations: Data Applications of Tri-Met's Automated Bus Dispatching System," *Transportation*, Vol. 29, No. 3. August 2002. Cited in Furth, Peter G., et al. *Uses of Archived AVL—APC Data to Improve Transit Performance and Management: Review and Potential*, Transit Cooperative Research Program Web Document No. 23. June 2003. Benefits ID: 2000-00151

275 *Evaluation of Utah Transit Authority's Connection Protection System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-005, EDL No. 14074. 12 May 2004. Benefits ID: 2008-00539

276 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

277 Kack, David and Deepu Philip. *An Evaluation of RouteMatch Software in the Billings MET Special Transit System*, Montana State University. Bozeman, MT. 2 May 2007. Costs ID: 2008-00149

278 *Evaluation of the Cape Cod Advanced Public Transit System Phases I and II—Final Report*, U.S. DOT, EDL No. 14096. Washington, DC. January 2003. Costs ID: 2008-00150

279 ITS *Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, MI. June 2005. Costs ID: 2008-00151

280 Sources with results used to construct this range of impacts include (listed alphabetically by study location per figure 8):

Chada, Shireen, and Robert Newland. *Effectiveness of Bus Signal Priority: Final Report*, Prepared by the University of South Florida for the Florida DOT and the U.S. DOT, Report No. NCTR-416-04, EDL No. 13651. Tallahassee, FL. January 2002. Benefits ID: 2007-00345

Crout, David. "Transit Signal Priority Evaluation," Paper Presented at the ITS America 13th Annual Meeting and Exposition, Minneapolis, MN. 19–22 May 2003. Benefits ID: 2003-00265

Dion, Francois, et al. "Evaluation of Transit Signal Priority Benefits along a Fixed-Time Signalized Arterial," Paper Presented at the 81st Annual Meeting of the Transportation Research Board., Washington, DC. 13–17 January 2002. Benefits ID: 2007-00348

Greenough and Kelman. "ITS Technology Meeting Municipal Needs—The Toronto Experience," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2007-00362

"ITS developed by Japanese Police," Japan Traffic Management Technology Association, Institute of Urban Traffic Research, . (Undated.) Benefits ID: 2000-00073

Lehtonen, Mikko and Risto Kulmala. "The Benefits of a Pilot Implementation of Public Transport Signal Priorities and Real-Time Passenger Information," Paper Presented at the 81st Annual Transportation Research Board Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00392

Los Angeles Metro Rapid Demonstration Program: Final Report, Prepared by Transportation Management and Design, Inc. for the Los Angeles County Metropolitan Transportation Authority and the Los Angeles DOT. Los Angeles, CA. March 2002. Benefits ID: 2008-00544

"Telematics Applications Programme, 4th Framework Programme," RTD&D 1994–1998, Web site URL www.cordis.lu/telematics/tap_transport/research/10.html. Last Accessed 15 November 2004. Benefits ID: 2000-00135

Wang, Yinhai, et al. *Comprehensive Evaluation on Transit Signal Priority System Impacts Using Field Observed Traffic Data*, TransNow Report (TNW2007-06), University of Washington. Seattle, WA. 15 June 2007. Benefits ID: 2008-00538

281 *Los Angeles Metro Rapid Demonstration Program: Final Report*, Prepared by Transportation Management and Design Inc., for the Los Angeles County Metropolitan Transportation Authority and the Los Angeles DOT. Los Angeles, CA. March 2002. Benefits ID: 2008-00544

282 Shladover, Steven E., et al. *Assessment of the Applicability of Cooperative Vehicle—Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*, Report No. UCB-ITS-PRR-2004-26, University of California, PATH Program. Berkeley, CA. 19 August 2004. Benefits ID: 2007-00460

283 Dion, Francois, et al. "Evaluation of Transit Signal Priority Benefits along a Fixed-Time Signalized Arterial," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Benefits ID: 2003-00256

284 98 *B-line Bus Rapid Transit Evaluation Study*, Prepared by the IBI Group for Transport Canada. 29 September 2003. Benefits ID: 2008-00545

285 *Transit Signal Priority* (TSP): *A Planning and Implementation Handbook*, Prepared by ITS America. May 2005. Costs ID: 2008-00155

286 Maas, Doug and Marc Porter. "Watt Avenue—Deployment of an ITS Corridor," Paper Presented at the 13th ITS America Annual Meeting. 19–22 May 2003. Costs ID: 2004-00083

287 *Metro Rapid Demonstration Program Evaluation Report*, U.S DOT Federal Transit Administration. July 2001. Costs ID: 2008-00156

288 *Acadia National Park Field Operational Test: Visitor Survey*, U.S. DOT Federal Highway Administration, EDL No. 13806. February 2003. Benefits ID: 2007-00438

289 Lehtonen, Mikko and Risto Kulmala. "The Benefits of a Pilot Implementation of Public Transport Signal Priorities and Real-Time Passenger Information," Paper Presented at the 81st Annual Transportation Research Board Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2007-00391

290 "Survey Finds London Transit Info Changes Behavior, Creates Revenue," Inside ITS, Page 8. 9 March 1998. Benefits ID: 2000-00060

291 *Real-time Bus Arrival Information Systems Return-on-Investment Study*, U.S. DOT Federal Transit Administration. Washington, DC. August 2006. Costs ID: 2008-00152

292 ITS *Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, MI. June 2005. Costs ID: 2008-00151

293 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

294 Kack, David and Deepu Philip. *An Evaluation of RouteMatch Software in the Billings MET Special Transit System*, Montana State University. Bozeman, MT. 2 May 2007. Benefits ID: 2008-00540

295 *Northeast Florida Rural Transit Intelligent Transit System*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-124, EDL No. 13848. February 2003. Benefits ID: 2008-00541

296 Bruun and Marx. *OmniLink—A Case Study of a Successful Flex-Route Capable ITS Implementation*, Transportation Research Board, Report No. TRR 1971. Washington, DC. 2006. Cited in Eric C. Bruun. "Technological Maturity of ITS and Scheduling and Integrated Service Options to Transit Planners," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007. Benefits ID: 2008-00542

297 *Evaluation of the South Lake Tahoe Coordinated Transit System (CTS) Project: Phase III Evaluation* U.S. DOT, EDL No. 14316. 14 April 2006. Benefits ID: 2008-00543

298 Kack, David and Deepu Philip. *An Evaluation of RouteMatch Software in the Billings MET Special Transit System*, Montana State University. Bozeman, MT. 2 May 2007. Costs ID: 2008-00149

299 *Rural Transit ITS Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Costs ID: 2004-00074

300 Correspondence with Mr. Eric F. Holm, Program Manager, Alliance for Transportation Research Institute. 23 March 2005. Costs ID: 2008-00153

301 *Intelligent, Coordinated Transit Smart Card Technology (ICTransit Card)*, University of New Mexico, Alliance for Transportation Research (ATR) Institute. Albuquerque, NM. September 2005. Costs ID: 2008-00154

302 Correspondence with Mr. Eric F. Holm, Program Manager, Alliance for Transportation Research Institute. 23 March 2005. Costs ID: 2008-00153

303 *Evaluation of Utah Transit Authority's Connection Protection System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-005, EDL No. 14074. 12 May 2004. Lesson ID: 2006-00229

304 *Denver Regional Transportation District Automatic Vehicle Location System*, U.S. DOT Federal Transit Administration, Report No. DOT-VNTSC-FTA-00-04, EDL No. 13589. August 2000. Benefits ID: 2007-00463

305 Wallace, Richard, R., et al. "Passenger Reactions to Transit Safety Measures," Transportation Research Board, Report No. TRR 1666, EDL No. 13148. 1999. Benefits ID: 2007-00422

306 *Advanced Public Transportation Systems: State of the Art—Update 2006*, U.S. DOT Federal Transit Administration, Report No. FTA-NJ-26-7062-06.1. 30 March 2006. Costs ID: 2008-00133

307 *ITS Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, MI. June 2005. Costs ID: 2008-00151

308 *Advanced Public Transportation Systems: State of the Art—Update 2006*, U.S. DOT Federal Transit Administration, Report No. FTA-NJ-26-7062-06.1. 30 March 2006. Lesson ID: 2008-00430

309 "TMS Performance Monitoring, Evaluation, and Reporting," Presentation by the University of Virginia and SAIC. March 2006.

310 Sources and supporting information:

Integration of Emergency and Weather Elements into Transportation Management Centers, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-090, EDL No. 14247. 28 February 2006.

Guidelines for Transportation Management Systems Maintenance Concept and Plans, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-04-011, EDL No. 13882. 31 December 2002.

311 *Transportation Management Center Concepts of Operation: Implementation Guide*, .U.S. DOT Federal Highway Administration, Report No. FHWA-OP-99-029, EDL No. 11494. December 1999.

312 Sources supporting this range include:

2006 *Annual Report SMART SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Costs ID: 2007-00120

Burk, Brian D. "Combined Transportation, Emergency and Communications Center: A Partnership of Performance," Presented at 14th ITS America Annual Meeting. San Antonio, TX. May 2004. Costs ID: 2005-00093

Krueger, C., et al. *The Chicago Traffic Management Center Preliminary Design Study Planning Effort*, Chicago DOT. 2003. Costs ID: 2008-00157

Lake County TMC Study: Implementation Phasing Plan—Version 2.0, Prepared by the National Engineering Technology Corporation. Report No. DCN 2020IIPPR2.0. Arlington Heights, IL. September 2003. Costs ID: 2008-00158

Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

313 Sources supporting this range include:

2005 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2006. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. 28 March 2006. Costs ID: 2006-00097

2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

MAG *Regional Concept of Transportation Operations, Technical Memorandum No. 5/6*, Prepared by Kimley-Horn for the Maricopa Associated of Governments (MAG). Phoenix, AZ. 7 January 2004. Costs ID: 2008-00159

Transportation Management Center: Business Planning and Plans Handbook, U.S. DOT Federal Highway Administration, TMC Pooled Fund Study. December 2005. Costs ID: 2008-00160

Transportation Management Center Staffing and Scheduling for Day-to-Day Operations, U.S. DOT Federal Highway Administration. January 2006. Costs ID: 2008-00161

314 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

315 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

316 Sources supporting this range include:

Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

Robison, David, Matt Sargent, and Steve Beckwith. *Challenges Faced and Tactics Used to Integrate Real-Time State Police* CAD *Data with the* VDOT *Richmond District Smart Traffic Center: Lessons Learned Document*, Virginia DOT. January 2005. Correspondence with Mr. Robb Alexander on 6 April 2006. Costs ID: 2006-00095

317 *Guidelines for Transportation Management Systems Maintenance Concept and Plans*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-04-011, EDL No. 13882. 31 December 2002. Costs ID: 2008-00163

318 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

319 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

320 MAG *Regional Concept of Transportation Operations*, Technical Memorandum No. 5/6, Prepared by Kimley-Horn for the Maricopa Associated of Governments (MAG). Phoenix, AZ. 7 January 2004. Costs ID: 2008-00159

321 Sources supporting this range include:

Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

Transportation Management Center: Business Planning and Plans Handbook, U.S. DOT Federal Highway Administration, TMC Pooled Fund Study. December 2005. Costs ID: 2008-00160

322 Sources supporting this range include:

Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

Lake County TMC Study: Implementation Phasing Plan—Version 2.0, Prepared by the National Engineering Technology Corporation. Report No. DCN 2020IIPPR2.0. Arlington Heights, IL. September 2003. Costs ID: 2008-00158

323 *Lake County TMC Study: Implementation Phasing Plan—Version 2.0*, Prepared by the National Engineering Technology Corporation. Report No. DCN 2020IIPPR2.0. Arlington Heights, IL. September 2003. Costs ID: 2008-00158

324 *Guidelines for Transportation Management Systems Maintenance Concept and Plans*, Prepared by PB Farradyne for the U.S. DOT Federal Highway Administration, Report No. FHWA-OP-04-011. 31 December 2002. Costs ID: 2008-00163

325 *Lake County TMC Study: Implementation Phasing Plan—Version 2.0*, Prepared by the National Engineering Technology Corporation. Report No. DCN 2020IIPPR2.0. Arlington Heights, IL. September 2003. Costs ID: 2008-00158

326 Burk, Brian D. "Combined Transportation, Emergency and Communications Center: A Partnership of Performance," Presented at 14th ITS America Annual Meeting. San Antonio, TX. May 2004. Costs ID: 2005-00093

327 *Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

328 Krueger, C., et al. *The Chicago Traffic Management Center Preliminary Design Study Planning Effort*, Chicago DOT. 2003. Costs ID: 2008-00157

329 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

330 Robison, David, Matt Sargent, and Steve Beckwith. *Challenges Faced and Tactics Used to Integrate Real-Time State Police* CAD *Data with the* VDOT *Richmond District Smart Traffic Center: Lessons Learned Document*, Virginia DOT. January 2005. Correspondence with Mr. Robb Alexander on 6 April 2006. Costs ID: 2006-00095

331 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007. Costs ID: 2007-00120

332 Krueger, C., et al. *The Chicago Traffic Management Center Preliminary Design Study Planning Effort*, Chicago DOT. 2003. Costs ID: 2008-00157

333 Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

334 Siesel, Douglas E. and Brian A. Sneed. "Traffic Operations Center/ITS Field Components Communication Study," Paper Presented to the 13th ITS America Annual Meeting. Minneapolis, MN. 19–22 May 2003. Costs ID: 2004-00070

335 Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

336 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

337 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

338 Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT Federal Highway Administration. March 2004. Costs ID: 2004-00086

339 *Intelligent Transportation System Deployment Analysis System Customization: Technical Memorandum No. 4—Florida-Specific Intelligent Transportation System Deployment Costs Version 2*, Prepared by the Florida DOT. Tallahassee, FL. August 2004. Costs ID: 2008-00162

340 *Transportation Management Center: Business Planning and Plans Handbook*, U.S. DOT Federal Highway Administration, TMC Pooled Fund Study. December 2005. Costs ID: 2008-00160

341 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Costs ID: 2008-00161

342 *Transportation Management Center: Business Planning and Plans Handbook*, U.S. DOT Federal Highway Administration, TMC Pooled Fund Study. December 2005. Costs ID: 2008-00160

343 MAG *Regional Concept of Transportation Operations, Technical Memorandum No. 5/6*, Prepared by Kimley-Horn for the Maricopa Associated of Governments (MAG). Phoenix, AZ. 7 January 2004. Costs ID: 2008-00159

344 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Costs ID: 2008-00161

345 Sources supporting this range include:

2005 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2006. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. 28 March 2006. Costs ID: 2006-00097

2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007 Costs ID: 2007-00120

346 *National Strategy to Reduce Congestion on America's Transportation Network*, Prepared by the U.S. DOT. May 2006.

347 "ITS Deployment Statistics Knowledge Resource," U.S. DOT, Web site URL www.itsdeployment.its.dot.gov. Last Accessed 12 December 2007.

348 "Next Generation 9-1-1 Overview," U.S. DOT Web site URL www.its.dot.gov/ng911/ng911_overview.htm. Last Accessed 31 December 2007.

349 Sources that support these findings:

"1996 ITS Tour Report: Eastern North America," Institute of Transportation Engineers 1996 ITS World Congress, Vol. 1, Pages 4–5. 1997. Benefits ID: 2000-00123

Bertini, R., et al. *Evaluation of Region 2 Incident Response Program Using Archived Data*, Portland State University Report No. PSU-CE-TRG-01-01. Portland, OR. June 2001. Benefits ID: 2007-00483

Performance Evaluation of CHART—*Coordinated Highways Action Response Team—Year* 2002, University of Maryland, College Park and Maryland State Highway Administration. College Park, MD. November 2003. Benefits ID: 2007-00425

Petrov, A., et al. "Evaluation of the Benefits of a Real-Time Incident Response System," Paper Presented at the 9th World Congress on Intelligent Transport Systems. Chicago, IL. 14–17 October 2002. Benefits ID: 2007-00485

"1996 ITS Tour Report: Eastern North America," Institute of Transportation Engineers 1996 ITS World Congress, Vol. 1, Pages 4–5. 1997. Benefits ID: 2000-00123

350 Sources that support these findings:

"CDOT Launches Courtesy Patrol on I-70 West," Colorado DOT. Denver, CO. 4 March 2005. Costs ID: 2006-00101

"Freeway Service Patrol: 'About FSP'' and 'Facts at a Glance' Web Site," Los Angeles Metropolitan Transportation Authority. 22 June 2006. Web site URL www.metro.net/news_info/facts.htm. Last Accessed 12 December 2007. Costs ID: 2006-00102

Hagen, Larry, Huaguo Zhou, and Harkanwal Singh. *Road Ranger Benefit-Cost Analysis*, Prepared by the University of South Florida for the Florida DOT. November 2005. Correspondence with the report authors (Larry Hagen and Huaguo Zhou). 2006. Costs ID: 2006-00103

HELP *Annual Operating Report*, *July* 1, 2004–*June* 30, 2005, Tennessee DOT. Nashville, TN. October 2005. Costs ID: 2006-00096

MDOT *Freeway Courtesy Patrol in Southeast Michigan*: 2004 *Evaluation Report*, Southeast Michigan Council of Governments. Detroit, MI. May 2005. Costs ID: 2006-00104

351 Sources that support these findings:

Cuciti, P. and B. Janson. "Incident Management via Courtesy Patrol: Evaluation of a Pilot Project in Colorado," Paper Presented at the 74th Annual Meeting of the Transportation Research Board. Washington, DC. January 1995. Benefits ID: 2000-00068

Fenno, D. and M. Ogden. "Freeway Service Patrols: A State of the Practice," Paper Presented at the 77th Annual Meeting of the Transportation Research Board. Washington, DC. January 1998. Benefits ID: 2000-00130

Highway Helper Summary Report—Twin Cities Metro Area, Minnesota DOT. St. Paul, MN. July 1994. Benefits ID: 2000-00009

Latoski, S., et al. "Cost-Effectiveness Evaluation of Hoosier Helper Freeway Service Patrol," *Journal of Transportation Engineering*, Vol. 125, No. 5. September/October 1999. Benefits ID: 2000-00002

352 *Evaluation of Intelligent Transportation Infrastructure Program* (ITIP) *in Pittsburgh and Philadelphia*, Pennsylvania, U.S. DOT, EDL No. 13777. 5 September 2002. Benefits ID: 2003-00257

353 Perrin, Joseph, Rodrigo Disegni, and Bhargava Rama. *Advanced Transportation Management System Elemental Cost Benefit Assessment*, Prepared by the University of Utah for the Utah DOT and the U.S. DOT. March 2004. Costs ID: 2004-00086

354 *Performance Evaluation of* CHART—*Coordinated Highways Action Response Team—Year* 2002, University of Maryland, College Park and Maryland State Highway Administration. College Park, MD. November 2003. Benefits ID: 2007-00425

355 Sources that support these findings:

Bertini, R., et al. *Evaluation of Region 2 Incident Response Program Using Archived Data*, Portland State University, Report No. PSU-CE-TRG-01-01. Portland, OR. June 2001. Benefits ID: 2007-00483

Performance Evaluation of CHART—*Coordinated Highways Action Response Team—Year* 2002, University of Maryland, College Park and Maryland State Highway Administration. College Park, MD. November 2003. Benefits ID: 2007-00425

Petrov, A., et al. "Evaluation of the Benefits of a Real-Time Incident Response System," Paper Presented at the 9th World Congress on Intelligent Transport Systems. Chicago, IL. 14–17 October 2002. Benefits ID: 2007-00485

1996 ITS Tour Report: Eastern North America, Institute of Transportation Engineers, 1996 ITS World Congress, Vol. 1. Pages 4–5. 1997. Benefits ID: 2000-00123

356 Sources that support these findings:

Bertini, Robert L. et al. *Evaluation of Region 2 Incident Response Program Using Archived Data*, Prepared by the Portland State University for the Oregon DOT, Report No. PSU-CE-TRG-01-01. 30 June 2001. Benefits ID: 2006-00298

Cuciti, P. and B. Janson. "Incident Management via Courtesy Patrol: Evaluation of a Pilot Program in Colorado," Paper Presented at the 74th Annual Meeting of the Transportation Research Board. Washington, DC. January 1995. Benefits ID: 2000-00068

Highway Helper Summary Report—Twin Cities Metro Area, Minnesota DOT Report No. TMC 07450-0394. St. Paul, MN. July 1994. Benefits ID: 2000-00009

Latoski, S., et al. "Cost-Effectiveness Evaluation of Hoosier Helper Freeway Service Patrol," *Journal of Transportation Engineering*, Vol. 125, No. 5. September/October 1999. Benefits ID: 2000-00002

357 Hagen, Larry, Huaguo Zhou, and Harkanwal Singh. *Road Ranger Benefit Cost Analysis*, Prepared by the Center for Urban Transportation Research, University of South Florida for the Florida DOT. Report No. BD544-14. November 2005. Benefits ID: 2007-00314.

358 Sources that support these findings:

HELP *Annual Operating Report: July* 1, 2004—*June* 30, 2005, Published by the Office of Highway Incident Management, Tennessee DOT. October 2005. Benefits ID: 2007-00309

Todd, P. N. 1997 "What the customer had to say," Virginia DOT Safety Service Patrol Report. 1997. Benefits ID: 2000-00029

359 HELP *Annual Operating Report: July* 1, 2005—*June* 30, 2006, Published by the Office of Highway Incident Management, Tennessee DOT. September 2006. Costs ID: 2007-00119

360 HELP *Annual Operating Report: July* 1, 2004—*June* 30, 2005, Published by the Office of Highway Incident Management, Tennessee DOT. October 2005. Costs ID: 2006-00096

361 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007 Costs ID: 2007-00120

362 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007 Costs ID: 2007-00120

363 Robison, David, Matt Sargent, and Steve Beckwith. *Challenges Faced and Tactics Used to Integrate Real-Time State Police* CAD *Data with the* VDOT *Richmond District Smart Traffic Center: Lessons Learned Document*, Virginia DOT. January 2005. Correspondence with Mr. Robb Alexander on 6 April 2006. Costs ID: 2006-00095

364 Guin, Angshuman, et al. *Benefits Analysis for the Georgia Department of Transportation NaviGAtor Program: Final Report*, Prepared by URS Corporation for the Georgia DOT. August 2006. Benefits ID: 2007-00466

365 Latoski, S., et al. "Cost-Effectiveness Evaluation of Hoosier Helper Freeway Service Patrol," *Journal of Transportation Engineering*, Vol. 125, No. 5. September/October 1999. Benefits ID: 2000-00002

366 *Incident Management Successful Practices: A Cross-Cutting Study*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FHWA-JPO-99-018/FTA-TRI-11-99-09, EDL No. 11484. April 2000. Lesson ID: 2006-00263

367 2006 *Annual Report* SMART *SunGuide Transportation Management Center* (TMC), Florida DOT, District IV. January 2007. Correspondence with Mr. Steve Corbin, FDOT District IV, ITS Operations Manager. February 2007 Costs ID: 2007-00120

368 *Phoenix Metropolitan Model Deployment Initiative Evaluation Report (Final Draft)*. U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-015, EDL No. 12743. April 2000. Costs ID: 2003-00027

369 *Rural ITS Toolbox*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Costs ID: 2003-00029

370 *Incident Management Successful Practices: A Cross-Cutting Study*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FHWA-JPO-99-018/FTA-TRI-11-99-09, EDL No. 11484. April 2000. Lesson ID: 2006-00264

371 *Incident Management Successful Practices: A Cross-Cutting Study*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FHWA-JPO-99-018/FTA-TRI-11-99-09, EDL No. 11484. April 2000. Lesson ID: 2006-00265

372 *National ITS Architecture Documents: Security*, U.S. DOT, EDL No. 14063. October 2003.

373 "Emergency Transportation Operations Overview," U.S. DOT, ITS Joint Program Office, Web site URL www.its.dot.gov/eto/eto_overview.htm. Last Accessed 31 December 2007.

374 *Hazardous Materials Safety and Security Technology Field Operational Test Volume II: Evaluation Final Report Synthesis*, U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14095. 11 November 2004. Benefits ID: 2007-00491

375 *Common Issues in Emergency Transportation Operations Preparedness and Response: Results of the FHWA Workshop Series*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-07-090. February 2007.

376 "GIS-based Disaster Management Systems: a Cogent Data Framework," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006.

377 *Managing Demand Through Travel Information Services*, Prepared for the U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-005, EDL No. 14072. 2005. Benefits ID: 2007-00409

378 *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

379 Sources that support these findings:

Benefits and Costs of Full Operations and ITS Deployment: A 2003 Simulation for Cincinnati, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-031, EDL No. 13979. May 2005. Costs ID: 2008-00164

Benefits and Costs of Full Operations and ITS Deployment: A 2003 Simulation for Seattle, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-033, EDL No. 13977. May 2005. Costs ID: 2008-00165

Benefits and Costs of Full Operations and ITS Deployment: A 2025 Forecast for Tucson, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-032, EDL No. 13978. May 2005. Costs ID: 2008-00166

380 *Hazardous Materials Safety and Security Technology Field Operational Test Volume II: Evaluation Final Report Synthesis*, U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14095. 11 November 2004. Benefits ID: 2007-00491

381 *Hazardous Materials Safety and Security Technology Field Operational Test Volume II: Evaluation Final Report Synthesis*, U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14095. 11 November 2004. Benefits ID: 2006-00291

382 *Hazardous Material Transportation Safety and Security Field Operational Test (FOT) Final Report—Deployment Team*, U.S. DOT Federal Motor Carrier Safety Administration. 31 August 2004. Costs ID: 2006-00100

383 *Hazardous Materials Safety and Security Technology Field Operational Test Volume II: Evaluation Final Report Synthesis*, U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14095. 11 November 2004. Benefits ID: 2006-00291

384 *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. Costs ID: 2008-00167

385 *Metropolitan Model Deployment Initiative: San Antonio Evaluation Report (Final Draft)*. U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2007-00375

386 *A Study of the Impact of Nine Transportation Management Projects on Hurricane Evacuation Preparedness*, U.S. DOT Federal Highway Administration, EDL No. 13940. November 2003. Costs ID: 2005-00091

387 "Transportation and Emergency Services: Identifying Critical Interfaces, Obstacles, and Opportunities," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00546

388 *ITS Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, MI. June 2005. Costs ID: 2008-00151

389 *Emergency Response Management System Study*, Prepared by Traffic Engineers, Inc. for the Houston Metropolitan Transit Authority. Houston, TX. April 1991. Benefits ID: 2002-00227

390 *Evaluation of Emergency Vehicle Signal Preemption on the Route 7 Virginia Corridor*. U.S. DOT Federal Highway Administration, Report No. FHWA-RD-99-070. July 1999. Benefits ID: 2000-00125

391 *Rural ITS Toolbox*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-030, EDL No. 13477. November 2001. Costs ID: 2003-00018

392 *Managing Demand Through Travel Information Services*, Prepared for the U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-005, EDL No. 14072. 2005. Benefits ID: 2007-00409

393 "An Operational Analysis of the Hampton Roads Hurricane Evacuation Traffic Control Plan," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007. Benefits ID: 2008-00547

394 *A Study of the Impact of Nine Transportation Management Projects on Hurricane Evacuation Preparedness*, U.S. DOT Federal Highway Administration, EDL No. 13940. November 2003. Lesson ID: 2005-00138

395 Cortelazzi, Lou, et al. *Pennsylvania Turnpike Commission's Advanced Traveler Information System (ATIS) Phase III Project*, Pennsylvania Turnpike Commission, EDL No. 14308. April 2006. Costs ID: 2008-00168

396 David Lively, M.A. David and Osama Elhamshary. *Lessons Learned From Advanced Traveler Information Systems: Applications for Emergency Management and Long Term Disaster Recovery*, California DOT. April 2004. Lesson ID: 2006-00316

397 *Advanced Public Transportation Systems: State of the Art Update 2006*, U.S. DOT Federal Transit Administration, Report No. FTA-NJ-26-7062-06.1. 30 March 2006.

398 *Congestion Pricing—A Primer Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-07-074. December 2006.

399 "National Strategy to Reduce Congestion," U.S. DOT Web site URL www.fightgridlocknow.gov. Last Accessed 29 February 2008.

400 Burris, Mark and Ashley Yelds. "Using ETC to Provide Variable Tolling: Some Real-World Results," Paper Presented at the 10th ITS America Annual Meeting, Boston, MA. 1–4 May 2000. Benefits ID: 2000-00168

401 *Pennsylvania Turnpike Value Pricing Study*, Prepared by Wilbur Smith Associates for the Pennsylvania Turnpike Commission, Executive Summary, Pages ES-5 and ES-6. March 2004. Benefits ID: 2008-00548

402 Sources that support these findings:

2005 Regional Value Pricing Corridor Evaluation and Feasibility Study: Dallas/Fort Worth—Value Pricing History and Experience, North Central Texas Council of Governments. Arlington, TX. June 2005. Benefits ID: 2008-00549

Douma, Frank, Johanna Zmud, and Tyler Patterson. "Pricing Comes to Minnesota: Baseline Attitudinal Evaluation of the I-394 HOT Lane Project," Paper Presented at the 85th Transportation Research Board Annual Meeting. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00550

403 *2005 Regional Value Pricing Corridor Evaluation and Feasibility Study: Dallas/Fort Worth—Value Pricing History and Experience*, North Central Texas Council of Governments. Arlington, TX. June 2005. Benefits ID: 2008-00549

404 Sources that support these findings:

Benefits and Costs of Full Operations and ITS Deployment: A 2003 Simulation for Cincinnati, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-031, EDL No. 13979. May 2005. Costs ID: 2008-00164

Benefits and Costs of Full Operations and ITS Deployment: A 2003 Simulation for Seattle, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-033, EDL No. 13977. May 2005. Costs ID: 2008-00165

Benefits and Costs of Full Operations and ITS Deployment: A 2025 Forecast for Tucson, Prepared for the U.S. DOT, Report No. FHWA-JPO-04-032, EDL No. 13978. May 2005. Costs ID: 2008-00166

405 *Central London Congestion Charging: Impacts Monitoring—Fifth Annual Report*, Transport for London. July 2007. Benefits ID: 2008-00551

406 Klodzinski, Jack, Eric Gordin, and Haitham M. Al-Deek. "Evaluation of Impacts from Deployment of an Open Road Tolling Concept for a Mainline Toll Plaza," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007. Benefits ID: 2008-00552

407 Ayman, Mohamed, et al. "Safety Considerations in Designing Electronic Toll Plazas: Case Study," *ITE Journal*, Page 20. March 2001. Benefits ID: 2001-00179

408 Klodzinski, Jack, Eric Gordin, and Haitham M. Al-Deek. "Evaluation of Impacts from Deployment of an Open Road Tolling Concept for a Mainline Toll Plaza," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007. Benefits ID: 2008-00553

409 Lennon, L. "Tappan Zee Bridge E-Z Pass System Traffic and Environmental Studies," Paper Presented at the Institute of Transportation Engineers 64th Annual Meeting. Washington, DC. 1994. Benefits ID: 2000-00099

410 "Innovative Toll Collection System Pays Off for Motorists and Agencies," U.S. DOT Federal Highway Administration, Report No. FHWA-SA-97-088. Washington, DC. 1997. Costs ID: 2003-00036

411 Saka, Anthony and Dennis Agboh. "Assessment of the Impact of Electronic Toll Collection on Mobile Emissions in the Baltimore Metropolitan Area," Paper Presented at the 81st Transportation Research Board Annual Meeting. Washington, DC. 13–17 January 2002. Benefits ID: 2005-00284

412 *Miami-Dade Expressway Authority: Open Road Tolling Master Plan—2007–2011*, Prepared by Dade Transportation Consultants for the Miami-Dade Expressway Authority. March 2006. Costs ID: 2008-00169

413 *I-5 North Coast Managed Lanes Value Pricing Study Concept Plan—Volume I*, Prepared by PB Consult for the San Diego Association of Governments (SANDAG). April 2006. Costs ID: 2008-00170

414 *Washington State Comprehensive Tolling Study: Final Report—Volume 2: Background Paper #8: Toll Technology Considerations, Opportunities, and Risks*, Prepared by the IBI Group and Cambridge Systematics for the Washington State DOT. 20 September 2006. Lesson ID: 2007-00390

415 *Characteristics of Bus Rapid Transit for Decision Making*, Prepared by the U.S. DOT Federal Transit Administration, Report No. FTA-VA-26-7222-2004.1. August 2004. Benefits ID: 2008-00554

416 Miller, Mark A., et al. *Transit Service Integration Practices: An Assessment of U.S. Experiences*, Prepared by the University of California, Partners for Advanced Transit and Highways (PATH), Report No. UCB-ITS-PRR-2005-7. Berkeley, CA. 25 March 2005. Benefits ID: 2008-00555

417 Foote, Peter J. and Darwin G. Stuart. "Testing Customer Acceptance of SmartCards at the Chicago Transit Authority," Paper Presented at the 81st Annual Meeting of the Transportation Research Board. Washington, DC. 13–17 January 2002. Benefits ID: 2002-00244

418 *Silver Line Waterfront Bus Rapid Transit (BRT) Project 2007 Evaluation*, U.S. DOT Federal Transit Administration. Report No. FTA-DC-26-7248-2007.02. 1 June 2007. Costs ID: 2008-00171

419 "Project Report SmarTrip Regional Rollout," Prepared by the Northern Virginia Transportation Commission for the U.S. DOT Federal Transit Administration. 6 February 2007. Costs ID: 2008-00132

420 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

421 *Intelligent, Coordinated Transit Smart Card Technology (ICTransit Card)*, University of New Mexico, Alliance for Transportation Research (ATR) Institute. Albuquerque, NM. September 2005. Costs ID: 2008-00154

422 Correspondence with Mr. Eric Holm, Program Manager, Alliance for Transportation Research Institute. 23 March 2005. Costs ID: 2008-00153

423 Miller, Mark A., et al. *Transit Service Integration Practices: An Assessment of U.S. Experiences*, Prepared by the University of California, Partners for Advanced Transit and Highways (PATH), Report No. UCB-ITS-PRR-2005-7. Berkeley, CA. 25 March 2005. Benefits ID: 2008-00556

424 Miller, Mark A., et al. *Transit Service Integration Practices: An Assessment of U.S. Experiences*, Prepared by the University of California, Partners for Advanced Transit and Highways (PATH), Report No. UCB-ITS-PRR-2005-7. Berkeley, CA. 25 March 2005. Benefits ID: 2008-00557

425 "Washington Metropolitan Area Transit Authority's (WMATA) SmarTrip® Regional Customer Service Center," U.S. DOT Federal Highway Administration, ITS Joint Program Office. Washington DC. February 2004. Costs ID: 2004-00073

426 *Orlando Regional Alliance for Next Generation Electronic Payment Systems (ORANGES) Evaluation Final Report: Electronic Payment Systems Field Operational Test*, U.S. DOT Federal Transit Administration, EDL No. 14268. 6 December 2004. Benefits ID: 2008-00558

427 *Pennsylvania Turnpike Value Pricing Study*, Prepared by Wilbur Smith Associates for the Pennsylvania Turnpike Commission, Executive Summary, Pages ES-5 and ES-6. March 2004. Benefits ID: 2008-00548

428 Todd Litman. *London Congestion Pricing: Implications for Other Cities*, Victoria Transport Policy Institute. British Columbia, Canada. 10 January 2006. Benefits ID: 2007-00333

429 Todd Litman. *London Congestion Pricing: Implications for Other Cities*, Victoria Transport Policy Institute. British Columbia, Canada. 10 January 2006. Benefits ID: 2008-00585

430 *Central London Congestion Charging: Impacts monitoring—Fifth Annual Report*, Transport for London. London, England. July 2007. Benefits ID: 2008-00584

431 Douma, Frank, Johanna Zmud, and Tyler Patterson. "Pricing Comes to Minnesota: Baseline Attitudinal Evaluation of the I-394 HOT Lane Project," Paper Presented at the 85th Transportation Research Board Annual Meeting. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00550

432 *Value Pricing on the I-75 HOV/BRT Project*, Prepared by HNTB for the Georgia State Road and Tollway Authority. Atlanta, GA. April 2006. Costs ID: 2007-00128

433 Todd Litman. *London Congestion Pricing: Implications for Other Cities*, Victoria Transport Policy Institute. British Columbia, Canada. 10 January 2006. Costs ID: 2007-00127

434 *Washington State Comprehensive Tolling Study: Final Report—Volume 2: Background Paper #8: Toll Technology Considerations, Opportunities, and Risks*, Prepared by the IBI Group and Cambridge Systematics for the Washington State DOT. 20 September 2006. Lesson ID: 2007-00394

435 *Washington State Comprehensive Tolling Study: Final Report—Volume 2: Background Paper #8: Toll Technology Considerations, Opportunities, and Risks*, Prepared by the IBI Group and Cambridge Systematics for the Washington State DOT. 20 September 2006. Lesson ID: 2007-00394

436 *National Strategy to Reduce Congestion on America's Transportation Network*, U.S. DOT. May 2006.

437 "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.

438 Vasudevan, Meenakshy, Karl Wunderlich, James Larkin, and Alan Toppen. "A Comparison of Mobility Impacts on Urban Commuting Between Broadcast Advisories and Advanced Traveler Information Services," Paper Presented at the 84th Annual Transportation Research Board Meeting. Washington, DC. 9–13 January 2005. Benefits ID: 2005-00285

439 "ATIS U.S. Business Models Review," U.S. DOT Federal Highway Administration, Web page URL ops.fhwa.dot.gov/travelinfo/resources/atis_bm.htm. Last Accessed 2 October 2007.

440 *America's Travel Information Number: Implementation and Operational Guidelines for 511 Services Version 3.0*, 511 Deployment Coalition. September 2005. Benefits ID: 2007-00301

441 *511 Deployment Costs: A Case Study*, 511 Deployment Coalition. November 2006. Costs ID: 2007-00125

442 Shah, Vaishali, et al. "An Assessment of the Potential of ATIS to Reduce Travel Disutility in the Washington, DC Region," Paper Presented at the 82nd Annual Meeting of the Transportation Research Board. Washington, DC. 12–16 January 2003. Benefits ID: 2003-00266

443 Sources that support these findings:

Detroit Freeway Corridor ITS Evaluation, U.S. DOT Federal Highway Administration, EDL No. 13586. July 2001. Benefits ID: 2001-00213

ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results, U.S. DOT Federal Highway Administration, EDL No. 11323. September 1999. Benefits ID: 2001-00199

444 *Air Quality Study of the SmarTraveler Advanced Traveler Information Service*, Tech Environmental. Waltham, MA. July 1993. Benefits ID: 2000-00004

445 *Intelligent Transportation Systems at the 2002 Salt Lake City Winter Olympic Games: Event Study Traffic Management and Traveler Information*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-135, EDL No. 13850. 29 April 2003. Benefits ID: 2006-00290

446 "Costs for the Alaska Traveler Information System," U.S. DOT Federal Highway Administration, ITS Joint Program Office. Washington, DC. 24 July 2006. Correspondence with Ms. Jill Sullivan, ITS/Iways Coordinator, Division of Program Development ADOT&PF. July 2007. Costs ID: 2007-00129

447 *Model Deployment of a Regional, Multi-Modal 511 Traveler Information System: Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-013, EDL No. 14248. 30 September 2005. Costs ID: 2006-00099

448 *Best Practices for Traveler Information Websites: Lessons Learned From Top Traffic and Transit Website Winners*, U.S. DOT Federal Highway Administration. June 2006. Lesson ID: 2006-00317

449 *Travel Time Messaging on Dynamic Message Signs—Houston*, TX, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-051. May 2005. Benefits ID: 2007-00304

450 *America's Travel Information Number: Implementation and Operational Guidelines for 511 Services Version 3.0*, 511 Deployment Coalition. September 2005. Benefits ID: 2007-00301

451 511 *Deployment Costs: A Case Study*, 511 Deployment Coalition. November 2006. Costs ID: 2007-00125

452 *Model Deployment of a Regional, Multi-Modal 511 Traveler Information System: Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-013, EDL No. 14248. 30 September 2005. Lesson ID: 2006-00241

453 Yusuf, Juita-Elena (Wie), Candice Wallace, and Steven Kreis. *Evaluation of the Eastern Kentucky Rural Highway Information Project 511 Tourism Service*, University of Kentucky, Kentucky Transportation Center, Report No. KTC-06-10/RS-F2-03-1F, EDL No. 14307. May 2006. Benefits ID: 2007-00306

454 Yusuf, Juita-Elena (Wie), Candice Wallace, and Steven Kreis. *Evaluation of the Eastern Kentucky Rural Highway Information Project 511 Tourism Service*, University of Kentucky, Kentucky Transportation Center, Report No. KTC-06-10/RS-F2-03-1F, EDL No. 14307. May 2006. Correspondence with Mr. Wayne Bates, Kentucky Transportation Cabinet. 10 March 2006. Costs ID: 2007-00124

455 *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005. Costs ID: 2008-00173

456 Furth, Peter G., et al. *Uses of Archived AVL-APC Data to Improve Transit Performance and Management: Review and Potential*, Transportation Research Board, Transit Cooperative Research Program, Web Document No. 23, Appendix A. Washington DC. June 2003. Benefits ID: 2008-00587

457 Stephens, Jerry, et al. *An Evaluation of Montana's State Truck Activities Reporting System*, Prepared by the Montana State University for the Montana DOT. 11 August 2003. Benefits ID: 2003-00268

458 Sources that support these findings:

National Evaluation of the TMC Applications of Archived Data Operational Test—ADMS Virginia, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-014, EDL No. 14250. August 2005. Benefits ID: 2008-00560

Smith, Brian L. and Ramkumar Venkatanarayana. "Usage Analysis of a First Generation ITS Data Archive: Lessons Learned in the Development of a Novel Information Technology Application," Paper Presented at the 85th Annual Transportation Research Board Meeting. Washington, DC. 22–26 January 2006.

459 *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005. Costs ID: 2008-00173

460 *National Evaluation of the TMC Applications of Archived Data Operational Test—ADMS Virginia*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-014, EDL No. 14250. August 2005. Costs ID: 2008-00174

461 "Cost Estimate for Nevada Archived Data User Service (ADUS)," U.S. DOT Federal Highway Administration, ITS Joint Program Office. Washington DC. May 2001. Costs ID: 2003-00038

462 Liu, Henry X., et al. *A Literature and Best Practices Scan: ITS Data Management and Archiving*, University of Wisconsin. Madison, WI. May 2002. Benefits ID: 2008-00559

463 *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005. Lesson ID: 2007-00385

464 *Archived Data Management Systems: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-044, EDL No. 14128. Washington, DC. December 2005. Lesson ID: 2007-00385

465 Sources that support these findings:

Jones, Crystal. "Perspective on Freight Congestion," Public Roads, Vol. 71, No. 1. July/August 2007.

Wilson, Rosalyn. "Embracing Security as a Core Business Function," 17th Annual State of Logistics Report, Sponsored by the Council of Supply Chain Management Professionals. Washington, DC. 19 June 2006.

466 Richeson, Kim E. *Introductory Guide to CVISN*, Johns Hopkins University Applied Physics Laboratory, Report No. POR-99-7186, Preliminary Version P.2. Laurel, MD. February 2000.

467 Rodier, Caroline J., et al. "Virtual Commercial Vehicle Compliance Stations: A Review of Legal and Institutional Issues," Paper Presented at 85th Annual Transportation Research Board Meeting. Washington, DC. 22–26 January 2006.

468 PrePass statistics from: "PrePass," PrePass, Web site URL www.prepass.com/Pages/Home.aspx . Last Accessed 14 March 2008.

NORPASS statistics from: "NORPASS," NORPASS—North American Preclearance and Safety System, Web site URL www.norpass.net/index.html.Last Accessed 14 March 2008.

469 "Oregon.gov—Motor Carrier Transportation," Oregon DOT, Web site URL www.oregon.gov/ODOT/MCT/GREEN.shtml. Last Accessed 14 March 2008.

470 *The Electronic Freight Management Initiative*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-085, EDL No. 14246. April 2006.

471 *Evaluation of the Commercial Vehicle Information Systems and Networks* (CVISN) *Model Deployment Initiative: Volume I—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2002-00241

472 The national survey regarding electronic clearance is discussed in *Driver Acceptance of Commercial Vehicle Operations* (CVO) *Technology in the Motor Carrier Environment*, 1997, Benefits ID: 2000-00141 and the Maryland survey is detailed in Bapna and Zaveri, 2000, Benefits ID: 2000-00165.

473 *Description of Costs Data from State Self-Evaluations of Commercial Vehicle Information Systems and Networks* (CVISN) *Deployments* (*October* 2003 *to October* 2005), U.S. DOT Federal Motor Carrier Safety Administration, EDL No. 14347. 20 February 2006.

474 Sources that support these findings:

Benefits and Costs of Full Operations and ITS *Deployment*: A 2003 *Simulation for Cincinnati*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-031, EDL No. 13979. May 2005. Costs ID: 2008-00164

Benefits and Costs of Full Operations and ITS *Deployment*: A 2003 *Simulation for Seattle*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-033, EDL No. 13977. May 2005. Costs ID: 2008-00165

Benefits and Costs of Full Operations and ITS *Deployment*: A 2025 *Forecast for Tucson*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-032, EDL No. 13978. May 2005. Costs ID: 2008-00166

475 Sources that support these findings:

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: 2007-00456

Maze, T. and C. Monsere. "Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2007-00447

476 Sources that support these findings:

A *Report to the Maryland General Assembly Senate Budget and Taxation Committee and House Appropriations Committee regarding Commercial Vehicle Information Systems and Network*, Prepared by the Maryland DOT for the Maryland General Assembly. November 1998. Benefits ID: 2000-00142

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: 2007-00455

Evaluation of the Commercial Vehicle Information Systems and Networks (CVISN) *Model Deployment Initiative: Volume I—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00486

Maze, T. and C. Monsere. *Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations*, Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2001-00181

477 Sources that support these findings:

A *Report to the Maryland General Assembly Senate Budget and Taxation Committee and House Appropriations Committee regarding Commercial Vehicle Information Systems and Network*, Prepared by the Maryland DOT for the Maryland General Assembly. November 1998. Benefits ID: 2000-00142

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

478 *Evaluation of the Commercial Vehicle Information Systems and Networks* (CVISN) *Model Deployment Initiative: Volume I—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2002-00241

479 *Description of Benefits and Lessons Learned from State Self-Evaluations of Commercial Vehicle Information Systems and Networks* (CVISN) *Deployments: Draft* (*October* 2003 *to August* 2006), U.S. DOT Federal Highway Administration, Draft. 28 February 2007. Benefits ID: 2008-00561

480 *Evaluation of the Commercial Vehicle Information Systems Networks* (CVISN) *Model Deployment Initiative* (*Volume* 1: *Final Report*), U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00489

481 Bapna, Sanjay and Jigish Zaveri. *Perceived Benefits and Utilization of Technology: A Comprehensive Survey of the Maryland Motor Carrier Industry*, Morgan State University. Baltimore, MD. 14 November 2000. Benefits ID: 2000-00165

482 CVISN *Safety Information Exchange for Commercial Vehicles in Connecticut: Increasing Inspection Efficiency Through Wireless Data Access at the Roadside*, U.S.DOT Federal Highway Administration, Report No. FHWA-JPO-04-030, EDL No. 13981. September 2004. Lesson ID: 2006-00232

483 *Evaluation of Infrared Brake Screening Technology: Final Report*, U.S. DOT, Report No. DOT-MC-01-007, EDL No. 13339. December 2000. Benefits ID: 2001-00203

484 *Driver Acceptance of Commercial Vehicle Operations* (CVO) *Technology in the Motor Carrier Environment*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-97-00-10, EDL No. 714. 1997. Benefits ID: 2000-00141

485 *Evaluation of the Commercial Vehicle Information Systems Networks* (CVISN) *Model Deployment Initiative* (*Volume* 1: *Final Report*), U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00488

486 *Evaluation of the Commercial Vehicle Information Systems Networks* (CVISN) *Model Deployment Initiative* (*Volume* 1: *Final Report*), U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00487

487 *Evaluation of the Commercial Vehicle Information Systems Networks* (CVISN) *Model Deployment Initiative* (*Volume* 1: *Final Report*), U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-04-082, EDL No. 13677. March 2002. Benefits ID: 2007-00488

488 *Final Evaluation Report: Ambassador Bridge Border Crossing System* (ABBCS) *Field Operational Test*, Prepared by Booz Allen Hamilton for the ABBCS FOT Partners, EDL No. 13072. Detroit, MI. May 2000. Benefits ID: 2000-00129

489 Maze, T. and C. Monsere. "Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2007-00448

490 Glassco, R. "Simulation Analysis of Congestion-Reduction Strategies at an Overloaded Weigh Station," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 November 1999. Benefits ID: 2001-00180

491 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Benefits ID: 2008-00562

492 *Electronic Toll Collection/Electronic Screening Interoperability Pilot Test Final Report Synthesis*, U.S. DOT Federal Highway Administration, EDL No. 14256. 29 July 2005. Benefits ID: 2008-00563

493 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Benefits ID: 2008-00564

494 *Driver Acceptance of Commercial Vehicle Operations* (CVO) *Technology in the Motor Carrier Environment*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-97-00-10, EDL No. 714. 1997. Benefits ID: 2000-00141

495 *Evaluation of the* I-95 *Commercial Vehicle Operations Roadside Safety and Safer Data Mailbox Field Operational Tests*, U.S. DOT Federal Highway Administration, EDL No. 13787. 29 March 2002. Lesson ID: 2006-00236

496 "Telematics Applications Programme, 4th Framework Programme," RTD&D 1994–1998, Web site URL www.cordis.lu/telematics/tap_transport/research/10.html. Last Accessed 14 December 2007. Benefits ID: 2008-00565

497 A *Survey of the Use of Six Computing and Communications Technologies in Urban Trucking Operations*, American Trucking Associations Foundation. Alexandria, VA. 1992. Benefits ID: 2000-00090

498 *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

499 *FleetForward Evaluation: Final Report*, I-95 Corridor Coalition, EDL No. 13283. Rockville, MD. October 2000. Benefits ID: 2001-00189

500 *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

501 *Evaluation of U.S. Commercial Motor Carrier Industry Challenges and Opportunities: Final Report*, ICF Consulting, Fairfax, VA. 31 March 2003.

502 *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

503 Shon, Zhengyi, Jinn-Tsai Wong, and Teng-Wei Wang. "Measuring the Cost Savings of Applying Electronic Supply Chain Manifest in Air Cargo," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00566

504 *Electronic Supply Chain Manifest Benefit Calculations—Revised* 2005, U.S. DOT Federal Aviation Administration and Federal Highway Administration. December 2005.

505 Sources that support these findings:

Electronic Supply Chain Manifest Benefit Calculations—Revised 2005, U.S. DOT Federal Aviation Administration and Federal Highway Administration. December 2005. Benefits ID: 2008-00567

The Freight Technology Story: Intelligent Freight Technologies and Their Benefits, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-030, EDL No. 14118. June 2005. Benefits ID: 2008-00568

506 *Electronic Supply Chain Manifest Benefit Calculations—Revised* 2005, U.S. DOT Federal Aviation Administration and Federal Highway Administration. December 2005. Benefits ID: 2008-00567

507 *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

508 *Electronic Supply Chain Manifest Benefit Calculations—Revised* 2005, U.S. DOT Federal Aviation Administration and Federal Highway Administration. December 2005. Benefits ID: 2008-00569

509 *Washington State—British Columbia: International Mobility and Trade Corridor* (IMTC), U.S. DOT Federal Highway Administration, EDL No. 13952. October 2003. Lesson ID: 2006-00211

510 *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

511 *Electronic Intermodal Supply Chain Manifest Field Operational Test Evaluation Final Report*, U.S. DOT Federal Highway Administration, EDL No. 13769. December 2002. Lesson ID: 2006-00202

512 Sources that support these findings:

Electronic Supply Chain Manifest Benefit Calculations—Revised 2005, U.S. DOT Federal Aviation Administration and Federal Highway Administration. December 2005. Benefits ID: 2008-00567

Sedor, Joanne and Michael Onder. "A High-Tech Route for Freight Efficiency," *Public Roads*, Vol. 69, No. 6. May/June 2006.

513 *Freight Information Real-Time System for Transport* (FIRST): *Evaluation Final Report*, U.S. DOT, EDL No. 13951. October 2003. Benefits ID: 2004-00275

514 *The Freight Technology Story: Intelligent Freight Technologies and Their Benefits*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-030, EDL No. 14118. June 2005. Benefits ID: 2008-00568

515 Shladover, Steven E., et al. *Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*, University of California PATH Program, Report No. UCB-ITS-PRR-2004-26. Berkeley, CA. 19 August 2004. Benefits ID: 2007-00461

516 *Final Evaluation Report: Ambassador Bridge Border Crossing System* (ABBCS) *Field Operational Test*, Prepared by Booz Allen Hamilton for the ABBCS FOT Partners, EDL No. 13072. Detroit, MI. May 2000. Benefits ID: 2000-00129

517 Maze, T. and C. Monsere. "Analysis of a Multi-State Corridor Deployment of Intelligent Transportation Systems for Commercial Vehicle Operations," Paper Presented at the 6th World Congress Conference on ITS. Toronto, Canada. 8–12 January 1999. Benefits ID: 2007-00448

518 Sources that support these findings:

Carnell, Robert C. and Nancy J. McMillan. "Conditional Analysis of Safety Benefits of a Collision Warning System and Adaptive Cruise Control in Commercial Trucks," Paper Presented at the 86th Annual Meeting of the Transportation Research Board. Washington, DC. 21–25 January 2007. Benefits ID: 2008-00570

Ference, Jack. "The Integrated Vehicle-Based Safety Systems Initiative," Paper Presented at the 13th World Congress Conference on ITS. London, U.K. 8–12 October 2006.

Kanianthra, Joseph N. and Allen A. Mertig. *Opportunities for Collision Countermeasures Using Intelligent Technologies*, U.S. DOT National Highway Traffic Safety Administration. 1997. Benefits ID: 2007-00496

519 Sources that support these findings:

Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3: Final Report, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007. Benefits ID: 2008-00571

Shladover, Steven E., et al. *Assessment of the Applicability of Cooperative Vehicle-Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*, University of California, PATH Program, Report No. UCB-ITS-PRR-2004-26. Berkeley, CA. 19 August 2004. Benefits ID: 2007-00459

520 *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

521 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

522 *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

523 Alkim, Bootsma, and Hoogendoorn. "Dutch Field Operational Test Experience with the Assisted Driver," Paper Presented at the 14th World Congress Conference on ITS. Beijing, China. 9–13 October 2007. Benefits ID: 2008-00574

524 "Electronic Devices in Transportation," *Promote Chauffeur*, Hahn and FT3/AB Daimler Chrysler, Report No. Brief-7/20/1999-1. 20 July 1999. Benefits ID: 2000-00008

525 *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

526 *Evaluation of the Freightliner Intelligent Vehicle Initiative Field Operational Test Final Report*, U.S. DOT, Report No. FHWA-OP-03-179, EDL No. 13871. September 2003. Benefits ID: 2008-00575

527 *Evaluation of an Automotive Rear-End Collision Avoidance System*, U.S. DOT, Report No. DOT HS 810 569, EDL No. 14303. April 2006. Benefits ID: 2008-00576

528 *Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3: Final Report*, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007. Costs ID: 2008-00176

529 *Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version 1.3: Final Report*, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007. Benefits ID: 2008-00571

530 *Evaluation of an Automotive Rear-End Collision Avoidance System*, U.S. DOT, Report No. DOT HS 810 569, EDL No. 14303. April 2006. Lesson ID: 2007-00328

531 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

532 "Update on Electronic Stability Control," *Insurance Institute for Highway Safety*, Status Report, Vol. 41, No. 5. 13 June 2006. Benefits ID: 2008-00580

533 *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

534 *TravTek Evaluation Modeling Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-RD-95-090, EDL No. 4403. January 1996. Benefits ID: 2000-00053

535 Sources that support these findings:

ADVANCE Project: Formal Evaluation of the Targeted Deployment (*Vol.* II, *Appendix* J), U.S. DOT Federal Highway Administration, EDL No. 3324. July 1996. Benefits ID: 2000-00093

Metropolitan Model Deployment Initiative: San Antonio Evaluation Report—Final Draft, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2007-00374

"Telematics Applications Programme, 4th Framework Programme," RTD&D 1994–1998, Web site URL www.cordis.lu/telematics/tap_transport/research/10.html. Last Accessed 29 October 2004. Benefits ID: 2007-00389

536 *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

537 *Metropolitan Model Deployment Initiative: San Antonio Evaluation Report* (*Final Draft*). U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-017, EDL No. 12883. May 2000. Benefits ID: 2007-00374

538 *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

539 Doyle, Elly, et al. *Final Report: Commercial Fleet Management Project*, George Mason University, Transportation Policy Program. Fairfax, VA. January 1998. Benefits ID: 2000-00007

540 ITS *Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, IL. June 2005. Costs ID: 2008-00151

541 *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

542 *Evaluation of an Automotive Rear-End Collision Avoidance System*, U.S. DOT National Highway Traffic Safety Administration Report, Report No. DOT HS 810 569, EDL No. 14303. April 2006. Benefits ID: 2008-00576

543 *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

544 *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: 2001-00207

545 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

546 *Phase* II *Driver Survey Report: Volvo Intelligent Vehicle Initiative Field Operational Test—Final Report*, U.S. DOT, EDL No. 14122. 28 October 2004. Benefits ID: 2008-00583

547 *Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version* 1.3*—Final Report*, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007. Costs ID: 2008-00176

548 *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

549 *Evaluation of the Volvo Intelligent Vehicle Initiative Field Operational Test Version* 1.3*—Final Report*, U.S. DOT, Report No. FHWA-JPO-07-016, EDL No. 14352. 5 January 2007. Benefits ID: 2008-00581

550 Almqvist, Sverker. "Speed Adaptation: A Field Trial of Driver Acceptance, Behavior, and Safety," Paper Presented at the 5th World Congress Conference on ITS. Seoul, Korea. 12–16 October 1998. Benefits ID: 2000-00157

551 Shladover, et al. *Assessment of the Applicability of Cooperative Vehicle—Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*. University of California, PATH Program, Report No. UCB-ITS-PRR-2004-26. Berkeley, CA. 19 August 2004. Benefits ID: 2006-00299

552 *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

553 Kittelson and Associates, et al. TCRP *Report 118: Bus Rapid Transit Practitioner's Guide*, Transit Cooperative Research Program, Transportation Research Board. Washington, DC. 2007. Costs ID: 2008-00148

554 Shladover, et al. *Assessment of the Applicability of Cooperative Vehicle—Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*. University of California, PATH Program, Report No. UCB-ITS-PRR-2004-26. Berkeley, CA. 19 August 2004. Costs ID: 2008-00177

555 Shladover, et al. *Assessment of the Applicability of Cooperative Vehicle—Highway Automation Systems to Bus Transit and Intermodal Freight: Case Study Feasibility Analyses in the Metropolitan Chicago Region*. University of California, PATH Program, Report No. UCB-ITS-PRR-2004-26. Berkeley, CA. 19 August 2004. Benefits ID: 2007-00460

556 *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

557 ITS *Implementation Plan*, Prepared by the IBI Group for the Flint Mass Transportation Authority. Flint, IL. June 2005. Costs ID: 2008-00151

558 *Evaluation of the Mayday/9–1–1 Field Operational Test: Final Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-049, EDL No. 14297. 19 July 2006.

559 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

560 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

561 To, Hau, and Omar Choudhry. *Mayday Plus Operational Test: Evaluation Report*, Prepared by Castle Rock Consultants for the Minnesota DOT. St. Paul, MN. April 2000. Costs ID: 2004-00064

562 *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

563 Dick, Virginia, Daniel Murray, and Amy Houser. "A Synthesis of Commercial Motor Vehicle Safety Technology Surveys: What Have We Learned?," Paper Presented at the 85th Annual Meeting of the Transportation Research Board. Washington, DC. 22–26 January 2006. Benefits ID: 2008-00582

564 *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

565 *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

566 *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

567 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004. Lesson ID: 2005-00037

568 *Regional Traffic Incident Management Programs: Implementation Guide*, U.S. DOT, Report No. FHWA-OP-01-002/FTA-TRI-11-00-03, EDL No. 13149. May 2001. Lesson ID: 2006-00178

569 *Rural Transit ITS Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00349

570 Walton, Jennifer. *Maintenance and Operations Plan for Intelligent Transportation Systems in Kentucky*, University of Kentucky. Lexington, KY. June 2004. Lesson ID: 2007-00308.

571 Walton, Jennifer. *Maintenance and Operations Plan for Intelligent Transportation Systems in Kentucky*, University of Kentucky. Lexington, KY. June 2004. Lesson ID: 2007-00308.

572 *Intelligent Transportation Systems* (ITS)—*Operational Support Contracts—Implementation Plan—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-NJ-2005-010. 31 January 2005. Lesson ID: 2007-00359.

573 Walton, Jennifer. *Maintenance and Operations Plan for Intelligent Transportation Systems in Kentucky*, University of Kentucky. Lexington, KY. June 2004. Lesson ID: 2007-00308.

574 *Lessons Learned: Monitoring Highway Congestion and Reliability Using Archived Traffic Detector Data*, Report No. FHWA-HOP-05-003, EDL No. 14059. October 2004. Lesson ID: 2006-00272.

575 *Lessons Learned: Monitoring Highway Congestion and Reliability Using Archived Traffic Detector Data*, Report No. FHWA-HOP-05-003, EDL No. 14059. October 2004. Lesson ID: 2006-00272

576 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016. 2004, EDL No. 14071. 2004. Lesson ID: 2005-00019

577 *Lessons Learned: Monitoring Highway Congestion and Reliability Using Archived Traffic Detector Data*, Report No. FHWA-HOP-05-003, EDL No. 14059. October 2004. Lesson ID: 2006-00267

578 *Best Practices for Traveler Information Websites: Lessons Learned From Top Traffic and Transit Website Winners*, U.S. DOT Federal Highway Administration. June 2006. Lesson ID: 2007-00320

579 *Best Practices for Traveler Information Websites: Lessons Learned From Top Traffic and Transit Website Winners*, U.S. DOT Federal Highway Administration. June 2006. Lesson ID: 2007-00317

580 *Intelligent Transportation Systems (ITS): Operational Support Contracts—Implementation Plan—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-NJ-2005-010. 31 January 2005. Lesson ID: 2007-00356

581 *Silicon Valley Smart Corridor: Final Evaluation Report*, U.S. DOT Federal Highway Administration, EDL No. 13897. 24 September 2003. Lesson ID: 2006-00208

582 *Intelligent Transportation Systems (ITS): Operational Support Contracts—Implementation Plan—Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-NJ-2005-010. 31 January 2005. Lesson ID: 2007-00356

583 *Sharing Data for Traveler Information: Practices and Policies of Public Agencies*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-001, EDL No. 13592. January 2002. Lesson ID: 2005-00134

584 *Sharing Data for Traveler Information: Practices and Policies of Public Agencies*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-001, EDL No. 13592. January 2002. Lesson ID: 2005-00134

585 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00123

586 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00122

587 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00223

588 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00223

589 *Intelligent, Coordinated Transit Smart Card Technology (ICTransit Card)*, University of New Mexico, Alliance for Transportation Research (ATR) Institute. Albuquerque, NM. September 2005. Lesson ID: 2005-00137

590 ATIS *Evaluation Framework*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-066, EDL No. 14313. April 2005. Lesson ID: 2006-00247

591 *Best Practices of Rural and Statewide ITS Strategic Planning*, U.S. DOT Federal Highway Administration, EDL No. 13608, Report No. FHWA-OP-02-037. July 2002. Lesson ID: 2005-00088

592 *Florida's ITS Integration Guidebook*, Prepared by the University of South Florida for the Flordia DOT. Tampa, FL. 1 October 2002. Lesson ID: 2006-00196

593 *Incorporating Intelligent Transportation Systems Into Planning Analysis: Improving Travel Time Reliability With ITS. Summary Of Key Findings From A Seattle 2020 Case Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02–031, EDL No. 13605. May 2002. Lesson ID: 2005-00031

594 *An Evaluation of Delaware's DelTrac Program—Building an Integrated Transportation Management System*, U.S. DOT Federal Highway Administration, EDL No. 14019. May 2004. Lesson ID: 2005-00023

595 *Metropolitan Model Deployment Initiative: Seattle Evaluation Report—Final Draft*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-00-019, EDL No. 13071. 30 May 2000. Lesson ID: 2005-00120

596 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004. Lesson ID: 2005-00019

597 *Electronic Toll Collection/Electronic Screening Interoperability Pilot Test Final Report Synthesis*, U.S. DOT Federal Highway Administration, EDL No. 14256. 29 July 2005. Lesson ID: 2006-00262

598 *Seattle Wide-area Information For Travelers: Institutional Issues Study*, Prepared by SAIC for the Washington State DOT. Seattle, WA. 19 October 1998. Lesson ID: 2005-00114

599 *I-25 Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00105

600 Roosevelt, Daniel, Robert Hanson, and William Campenni. *Lessons Learned From a Pilot Project of an Automatic Vehicle Location System in an Urban Winter Maintenance Operations Setting*, Prepared by the University of Virginia for the Virginia DOT, Report No. VTRC02-R11. April 2002. Lesson ID: 2006-00258

601 *Evaluation of the I-95 Commercial Vehicle Operations Roadside Safety and Safer Data Mailbox Field Operational Tests*, U.S. DOT Federal Highway Administration, EDL No. 13787. 29 March 2002. Lesson ID: 2006-00236

602 Roosevelt, Daniel, Robert Hanson, and William Campenni. *Lessons Learned From a Pilot Project of an Automatic Vehicle Location System in an Urban Winter Maintenance Operations Setting*, Prepared by the University of Virginia for the Virginia DOT, Report No. VTRC02-R11. April 2002. Lesson ID: 2006-00258

603 *Implementation and Operational Guidelines for 511 Services, Version 2.0*, 511 Deployment Coalition. September 2003. Lesson ID: 2005-00091

604 Robison, David, Matt Sargent, and Steve Beckwith. *Challenges Faced and Tactics Used to Integrate Real-Time State Police CAD Data with the VDOT Richmond District Smart Traffic Center: Lessons Learned Document*, Virginia DOT. January 2005. Lesson ID: 2005-00056

605 *Rural Transit ITS Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00343

606 *ATIS Evaluation Framework*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-066, EDL No. 14313. April 2005. Lesson ID: 2006-00247

607 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00221

608 *Traffic Signal Preemption for Emergency Vehicles: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-010, EDL No. 14097. January 2006. Lesson ID: 2006-00230

609 *Rural Transit ITS Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00348

610 *Intelligent, Coordinated Transit Smart Card Technology (ICTransit Card)*, University of New Mexico, Alliance for Transportation Research (ATR) Institute. Albuquerque, NM. September 2005. Lesson ID: 2005-00136

611 *Communications for Intelligent Transportation Systems—Successful Practices: A Cross-Cutting Study*, U.S. DOT, Federal Highway Administration and Federal Transit Administration, Report No. FHWA-JPO-99-023/FTA-TRI-11-99-02, EDL No. 11488. 2000. Lesson ID: 2007-00362

612 *Communications for Intelligent Transportation Systems—Successful Practices: A Cross-Cutting Study*, U.S. DOT, Federal Highway Administration and Federal Transit Administration, Report No. FHWA-JPO-99-023/FTA-TRI-11-99-02, EDL No. 11488. 2000. Lesson ID: 2007-00360

613 *Communications for Intelligent Transportation Systems—Successful Practices: A Cross-Cutting Study*, U.S. DOT, Federal Highway Administration and Federal Transit Administration, Report No. FHWA-JPO-99-023/FTA-TRI-11-99-02, EDL No. 11488. 2000. Lesson ID: 2007-00360

614 *Communications for Intelligent Transportation Systems—Successful Practices: A Cross-Cutting Study*, U.S. DOT, Federal Highway Administration and Federal Transit Administration, Report No. FHWA-JPO-99-023/FTA-TRI-11-99-02, EDL No. 11488. 2000. Lesson ID: 2007-00362

615 *Ventura County Fare Integration: A Case Study*, U.S. DOT *Federal Transit Administration and Federal Highway Administration*, Report No. FTA-TRI-11-01-01/FHWA-OP-01-033, EDL No. 13479. September 2001. Lesson ID: 2005-00039

616 *Ventura County Fare Integration: A Case Study*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FTA-TRI-11-01-01/FHWA-OP-01-033, EDL No. 13479. September 2001. Lesson ID: 2005-00039

617 *Transportation Management and Security During the 2004 Democratic National Convention*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-040, EDL No. 14120. 2005. Lesson ID: 2006-00197

618 *I-25 Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00106

619 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00219

620 *Integration of Emergency and Weather Elements into Transportation Management Centers*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-090, EDL No. 14247. 28 February 2006. Lesson ID: 2007-00350

621 Interview with Dave Kristick, Director of Operations, E-470 Public Highway Authority. Aurora, CO. August 2006. Lesson ID: 2006-00307

622 Collier, Tina and Ginger Daniels Goodin. *Managed Lanes: The Funding and Financing of Managed Lanes*, Texas Transportation Institute. College Station, TX. 2005. Lesson ID: 2007-00382

623 *Managed Lanes: A Cross-cutting Study*, U.S. DOT Federal Highway Administration, Office of Transportation Management, Report No. FHWA-HOP-05-037. November 2004. Lesson ID: 2007-00380

624 *Model Deployment of a Regional, Multi-Modal 511 Traveler Information System: Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-013, EDL No. 14248. 30 September 2005. Lesson ID: 2006-00241

625 *Regional Traffic Incident Management Programs: Implementation Guide*, U.S. DOT, Report No. FHWA-OP-01-002/FTA-TRI-11-00-03, EDL No. 13149. May 2001. Lesson ID: 2006-00178

626 *Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System* (GYRTWIS), U.S. DOT Federal Highway Administration, EDL No. 13958. 30 December 2003. Lesson ID: 2006-00204

627 *Intelligent Transportation Systems in Work Zones: A Cross-Cutting Study—Integrated Work Zone Systems for Improving Travel Conditions and Safety*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-025, EDL No. 13600. November 2002. Lesson ID: 2006-00286

628 *Implementation and Operational Guidelines for 511 Services, Version 2.0*, 511 Deployment Coalition. September 2003. Lesson ID: 2005-00097

629 *Ventura County Fare Integration: A Case Study*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FTA-TRI-11-01-01/FHWA-OP-01-033, EDL No. 13479. September 2001. Lesson ID: 2005-00038

630 *Model Deployment of a Regional, Multi-Modal 511 Traveler Information System: Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-06-013, EDL No. 14248. 30 September 2005. Lesson ID: 2006-00242

631 *Implementation and Operational Guidelines for 511 Services, Version 2.0*, 511 Deployment Coalition. September 2003. Lesson ID: 2005-00097

632 *Intelligent Transportation Systems in Work Zones: A Case Study—Work Zone Traffic and Incident Management System—Keeping Traffic Moving During Reconstruction of the Big I, a Major Interstate—Interstate Interchange in Albuquerque*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-04-072, EDL No. 13941. Janaury 2004. Lesson ID: 2005-00062

633 Evaluation of the Central Puget Sound Regional Fare Coordination Project, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00218

634 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00218

635 Yim, Youngbin and Elizabeth Deakin. *TravInfo Field Operational Test Institutional Evaluation Final Results*, Universtiy of California, PATH Program, Report No. UCB-ITS-PWP-2000-2. Berkeley, CA. December 1999. Lesson ID: 2006-00281

636 Baker, Stephanie. *Case Study Evaluation of the Virginia Department of Transportation's I–81 ITS Program*, Virginia Tech Transportation Institute, EDL No. 13659. Blacksburg, VA. 15 March 2002. Lesson ID: 2007-00355

637 Baker, Stephanie. *Case Study Evaluation of the Virginia Department of Transportation's I–81 ITS Program*, Virginia Tech Transportation Institute, EDL No. 13659. Blacksburg, VA. 15 March 2002. Lesson ID: 2007-00355

638 *Innovative Finance Primer*, U.S DOT Federal Highway Administration, Report No. FHWA-AD-02-004. April 2002.

639 "About Us," U.S. DOT Research and Innovative Technology Administration (RITA), Web site URL www.its.dot.gov/its_overview.htm. Last Accessed 15 February 2008.

640 Demetsky, Michael, Brian Park, and Ramkumar Venkatanarayana. *Hampton Roads Advanced Traveler Information System* (HRATIS) *First Year Evaluation Report*, University of Virginia, Report No. UVA-CE-ITS-03-1, EDL No. 13634. Charlottesville, VA. October 2001. Lesson ID: 2005-00144

641 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00225

642 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004. Lesson ID: 2005-00033

643 Acumen Building Enterprise. *e-Transit: Electronic Business Strategies for Public Transportation—Volume 6, Strategies to Expand and Improve Deployment of ITS in Rural Transit Systems*, Transportation Research Board, Transit Cooperative Research Program (TCRP). Report No. 84. Washington, DC. 2005. Lesson ID: 2007-00369

644 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004. Lesson ID: 2005-00032

645 Acumen Building Enterprise. *e-Transit: Electronic Business Strategies for Public Transportation—Volume 6, Strategies to Expand and Improve Deployment of ITS in Rural Transit Systems*, Transportation Research Board, Transit Cooperative Research Program (TCRP). Report No. 84. Washington, DC. 2005. Lesson ID: 2007-00369

646 *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users—A Summary of Highway Provisions*, U.S DOT Federal Highway Administration. 25 August 2005.

647 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004.

648 Collier, Tina and Ginger Daniels Goodin. *Managed Lanes: The Funding and Financing of Managed Lanes*, Texas Transportation Institute. College Station, TX. 2005. Lesson ID: 2007-00382

649 *Miami Regional Advanced Traveler Information System: Final Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-086, EDL No. 13678. April 2002. Lesson ID: 2007-00372

650 *Rural Transit ITS Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00345

651 *Innovative Finance Primer*, U.S DOT Federal Highway Administration, Report No. FHWA-AD-02-004. April 2002.

652 "Innovative Finance for Surface Transportation," American Association of State Highway and Transportation Officials, Web site URL www.innovativefinance.org. Last Accessed 15 February 2008.

653 *Getting More by Working Together—Opportunities for Linking Planning and Operations*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-05-016, EDL No. 14071. 2004. Lesson ID: 2005-00033

654 Collier, Tina and Ginger Daniels Goodin. *Managed Lanes: The Funding and Financing of Managed Lanes*, Texas Transportation Institute. College Station, TX. 2005. Lesson ID: 2007-00382

655 *Best Practices for Traveler Information Websites: Lessons Learned From Top Traffic and Transit Website Winners*, U.S. DOT Federal Highway Administration. June 2006. Lesson ID: 2007-00317

656 OR0206—*Transit Tracker (Regional Intermodal Transit Traveler Information and Security System) Lessons Learned Report*, Prepared by David Evans and Associates for the Oregon DOT and Tri-Met. Portland, OR. April 2004. Lesson ID: 2005-00129

657 *Integration of Emergency and Weather Elements into Transportation Management Centers*, U.S. DOT Federal Highway Administration, Report No. FHWA-HOP-06-090, EDL No. 14247. 28 February 2006. Lesson ID: 2007-00351

658 Acumen Building Enterprise. *e-Transit: Electronic Business Strategies for Public Transportation—Volume 6, Strategies to Expand and Improve Deployment of ITS in Rural Transit Systems*, Transportation Research Board, Transit Cooperative Research Program (TCRP). Report No. 84. Washington, DC. 2005. Lesson ID: 2007-00371

659 *Effects of Catastrophic Events on Transportation System Management and Operations: The Pentagon and the National Capitol Region—September* 11, 2001, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-042, EDL No. 14119. March 2002. Lesson ID: 2006-00216

660 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00226

661 OR0206—*Transit Tracker (Regional Intermodal Transit Traveler Information and Security System) Lessons Learned Report*, Prepared by David Evans and Associates for the Oregon DOT and Tri-Met. Portland, OR. April 2004. Lesson ID: 2005-00129

662 *Orlando Regional Alliance for Next Generation Electronic Payment Systems* (ORANGES) *Evaluation Final Report: Electronic Payment Systems Field Operational Test*, U.S. DOT Federal Transit Administration, EDL No. 14268. 6 December 2004. Lesson ID: 2006-00188

663 Marshall, Kenneth and Philip Tarnoff. *Guide to Contracting* ITS *Projects*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 560. Washington, DC. 2006.

664 Marshall, Kenneth and Philip Tarnoff. *Guide to Contracting* ITS *Projects*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 560. Washington, DC. 2006. Lesson ID: 2007-00324

665 *Riverside County Transit Project Final Evaluation Report*, U.S. DOT. January 2006. Lesson ID: 2005-00173

666 *Final Evaluation Report for the Greater Yellowstone Regional Traveler and Weather Information System* (GYRTWIS), U.S. DOT Federal Highway Administration, EDL No. 13958. 30 December 2003. Lesson ID: 2006-00206

667 *The Road to Successful* ITS *Software Acquisition: Executive Summary, Volume I—Overview and Themes, and Volume II—Software Acquisition Process Reference Guide*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-98-035, EDL No. 4130. July 1998. Lesson ID: 2006-00274

668 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00103

669 *Riverside County Transit Project Final Evaluation Report*, U.S. DOT. January 2006. Lesson ID: 2005-00173

670 *Miami Regional Advanced Traveler Information System: Final Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-086, EDL No. 13678. April 2002. Lesson ID: 2007-00374

671 *What Have We Learned About* ITS?, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-006, EDL No. 13316. December 2000. Lesson ID: 2006-00298

672 *Travel Aid: Lessons Learned and Recommendations*, U.S. DOT Federal Highway Administration, Highway and Vehicle Technology Group. March 1999. Lesson ID: 2005-00084

673 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00104

674 *Successful Traffic Signal System Procurement Techniques*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-032, EDL No. 13611. 31 January 2002. Lesson ID: 2005-00076

675 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00103

676 *Riverside County Transit Project Final Evaluation Report*, U.S. DOT. January 2006. Lesson ID: 2005-00173

677 *Successful Traffic Signal System Procurement Techniques*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-032, EDL No. 13611. 31 January 2002. Lesson ID: 2005-00076

678 *Rural Transit* ITS *Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00347

679 "*The SunGuide Disseminator: Florida's Turnpike Enterprise Takes Proactive* RISC *in Incident Management*," Florida DOT Web site URL www.floridaits.com/Newsletters/2005/May/05–2005.htm#RISC. Last Accessed 15 February 2008. Lesson ID: 2005-00051

680 Marshall, Kenneth and Philip Tarnoff. *Guide to Contracting* ITS *Projects*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 560. Washington, DC. 2006.

681 Marshall, Kenneth and Philip Tarnoff. *Guide to Contracting* ITS *Projects*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 560. Washington, DC. 2006. Lesson ID: 2007-00324

682 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00108

683 *Evaluation of the Central Puget Sound Regional Fare Coordination Project*, U.S. DOT Federal Highway Administration, EDL No. 14000. 13 April 2006. Lesson ID: 2006-00226

684 *What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues: Facilitating Private Sector Participation and Expediting Performance*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FTA-TRI-11-99-11/FHWA-JPO-99-021, EDL No. 11486. August 2000. Lesson ID: 2005-00101

685 Demetsky, Michael, Brian Park, and Ramkumar Venkatanarayana. *Hampton Roads Advanced Traveler Information System* (HRATIS) *First Year Evaluation Report*, University of Virginia, Report No. UVA-CE-ITS-03-1, EDL No. 13634. Charlottesville, VA. October 2001. Lesson ID: 2005-00144

686 Johnson, M. "ITS and Legal Issues—A Primer," *Intelligent Transportation Primer*, Institute for Transportation Engineers, Pages 23-1 to 23-13. 2001.

687 Johnson, M. "ITS and Legal Issues—A Primer," *Intelligent Transportation Primer*, Institute for Transportation Engineers, Pages 23-1 to 23-13. 2001.

688 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00108

689 *What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues: Facilitating Private Sector Participation and Expediting Performance*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FTA-TRI-11-99-11/FHWA-JPO-99-021, EDL No. 11486. August 2000. Lesson ID: 2005-00101

690 *What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues: Facilitating Private Sector Participation and Expediting Performance*, U.S. DOT Federal Transit Administration and Federal Highway Administration, Report No. FTA-TRI-11-99-11/FHWA-JPO-99-021, EDL No. 11486. August 2000. Lesson ID: 2005-00101

691 Johnson, M. "ITS and Legal Issues—A Primer," *Intelligent Transportation Primer*, Institute for Transportation Engineers, Pages 23-1 to 23-13. 2001.

692 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00122

693 *What Have We Learned About* ITS?, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-006, EDL No. 13316. December 2000. Lesson ID: 2006-00299

694 Johnson, M. "ITS and Legal Issues—A Primer," *Intelligent Transportation Primer*, Institute for Transportation Engineers, Pages 23-1 to 23-13. 2001.

695 *Washington State—British Columbia: International Mobility and Trade Corridor* (IMTC), U.S. DOT Federal Highway Administration, EDL No. 13952. October 2003. Lesson ID: 2006-00210

696 *Sharing Data for Traveler Information: Practices and Policies of Public Agencies*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-02-001, EDL No. 13592. January 2002. Lesson ID: 2005-00134

697 *Managed Lanes: A Cross-Cutting Study*, U.S. DOT *Federal Highway Administration*, Office of Transportation Management, Report No. FHWA-HOP-05-037. November 2004. Lesson ID: 2007-00378

698 *Successful Approaches to Deploying a Metropolitan Intelligent Transportation System*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-99-032, EDL No. 8483. March 1999. Lesson ID: 2005-00123

699 *Managed Lanes: A Cross-Cutting Study*, U.S. DOT Federal Highway Administration, Office of Transportation Management, Report No. FHWA-HOP-05-037. November 2004. Lesson ID: 2007-00376

700 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00309

701 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00310

702 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00312

703 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00304

704 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00304

705 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00310

706 *Intelligent Transportation Systems* (ITS)—*Operational Support Contracts*—*Implementation Plan*—*Final Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-NJ-2005-010. 31 January 2005. Lesson ID: 2007-00357

707 I-25 *Truck Safety Improvements Project: Local Evaluation Report*, U.S. DOT Federal Highway Administration, Report No. FHWA-JPO-05-039, EDL No. 14121. 29 December 2004. Lesson ID: 2005-00103

708 *What Have We Learned About* ITS?, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-006, EDL No. 13316. December 2000. Lesson ID: 2005-00102

709 *Metropolitan Transportation Management Center Concepts of Operation*: A *Cross-Cutting Study*—*Improving Transportation Network Efficiency*, U.S. DOT Federal Highway Administration and Federal Transit Administration, Report No. FHWA-JPO-99-020/FTA-TRI-11-99-10, EDL No. 10923. October 1999. Lesson ID: 2006-00290

710 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00310

711 *Rural Transit* ITS *Best Practices*, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-03-077, EDL No. 13784. March 2003. Lesson ID: 2007-00342

712 *What Have We Learned About* ITS?, U.S. DOT Federal Highway Administration, Report No. FHWA-OP-01-006, EDL No. 13316. December 2000. Lesson ID: 2005-00102

713 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00304

714 A *Case Study of the Maintenance Decision Support System* (MDSS) *in Maine*, U.S. DOT Federal Highway Administration. September 2007. Lesson ID: 2007-00405

715 Walton, Jennifer. *Maintenance and Operations Plan for Intelligent Transportation Systems in Kentucky*, University of Kentucky. Lexington, KY. June 2004. Lesson ID: 2006-00308

716 *Transportation Management Center Staffing and Scheduling for Day-to-Day Operations*, U.S. DOT Federal Highway Administration. January 2006. Lesson ID: 2006-00304

717 Brooke, Ken, Kevin Dopart, Ted Smith, and Aimee Flannery. *Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management*, Transportation Research Board, National Cooperative Highway Research Program (NCHRP), Report No. 520. Washington, DC. 2004. Lesson ID: 2005-00077