Intelligent Transportation Systems
2005 Update

Benefits, Costs and Lessons Learned

U.S. Department of Transportation
Federal Highway Administration

Intelligent Transportation Systems Benefits, Costs, and Lessons Learned:

2005 Update

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16.Abstract

Intelligent Transportation Systems (ITS) technologies offer a clear opportunity to improve transportation safety, relieve congestion, and enhance productivity. This report is a continuation of a series of reports providing a synthesis of the information collected by the United States Department of Transportation's ITS Joint Program Office on the impact that ITS projects have on the operation of the surface transportation network, and the costs of ITS deployment and operations. New in the 2005 report is the inclusion of summaries of lessons learned from ITS planning, deployment, operations, and evaluation experience. Information in this report is drawn from the ITS Benefits and Costs Databases, regularly updated repositories of such information, available on the Internet at **www.benefitcost.its.dot.gov.** The report presents material from the databases that describes the impacts and costs of the intelligent transportation infrastructure as well as intelligent vehicle applications. More details of the lessons learned discussed in this report will be presented in the Internet-accessible ITS Lessons Learned Database planned to be available in the summer of 2005.

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Preface

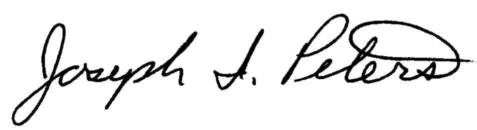
The U.S. Department of Transportation (USDOT) is pleased to present its 2005 snapshot of benefits and costs of Intelligent Transportation Systems (ITS) implementations, and to announce a valuable new database of lessons learned by those planning, deploying, and evaluating ITS.

Intelligent Transportation Systems Benefits, Costs, and Lessons Learned: 2005 Update is the sixth in a series of periodic publications that began in 1995. It is the next step toward a vision of one-stop shopping for qualitative and quantitative information about ITS.

As a public service, DOT sponsors regularly updated ITS Benefits and Costs Databases available online at www.benefitcost.its.dot.gov, which gives transportation professionals the information they need about ITS implementations and services. Companion websites documenting the amount and geographical deployment of ITS and the Lessons Learned Database, which is scheduled to be online in the summer of 2005, can be accessed online through the ITS Joint Program Office's homepage at www.its.dot.gov.

The printed version of this report (FHWA Report FHWA-JPO-05-002) can be ordered via e-mail to itspubs@fhwa.dot.gov. It can be viewed on DOT's ITS Electronic Document Library at www.its.dot.gov/itsweb/welcome.htm as document No. 14073.

Not all ITS efforts initiated by states, local governments, and private enterprises are documented in this 2005 Update report or in the databases. We encourage readers who are aware of ITS benefits, costs, or lessons learned to let us know about evaluation efforts or source documents that may be missing. To keep us up to date, readers may either use the "Contribute Data" feature of our online database, or send reference documents to:



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Executive Summary

U.S. highway deaths continue to climb (43,000 in 2003) and the ever increasing demand for travel by highway and public transit is causing the transportation system to reach the limits of its existing capacity, resulting in growing traffic congestion that robs Americans of time and money. Intelligent Transportation Systems (ITS) technologies offer a clear opportunity to improve transportation safety, relieve congestion, and enhance productivity.

The ITS vision includes a wide collection of applications that integrate surface transportation infrastructure with the vehicles that use it. Many existing applications of deployed ITS will contribute to the realization of this vision. This document focuses on the benefits, costs, and lessons learned through the deployment of the intelligent infrastructure and intelligent vehicles. Examples include: advanced traffic signal control systems; electronic transit fare payment systems; ramp meters; and collision avoidance systems. In order to apply ITS services most effectively, decision makers require benefits and cost information about the ITS they are considering as well as documented lessons learned from the experiences of others. To be most effective, these inputs should be supplemented with information that describes the context from which the data were derived.

This report is a continuation of a series of reports providing a snapshot of the information collected by the United States Department of Transportation (USDOT) ITS Joint Program Office (JPO) on the impact that ITS projects have on the operation of the surface transportation network. New in the 2005 report is the introduction of summaries of lessons learned from ITS planning, deployment, operation, maintenance, and evaluation experience; the previous report contained only benefits and costs information. The ITS JPO has just recently initiated the process of capturing these lessons and this report presents summaries of some of the first few collected. An ITS Lessons Learned Database is planned to be available in the summer of 2005, when it will be publicly accessible via the Internet. Because the Lessons Learned Database is just getting under way as this document is being written, this document focuses on providing an introductory overview.

Most of the information in this report is drawn from the ITS Benefits and Costs Databases, regularly updated repositories of such information, available on the Internet at www.benefitcost.its.dot.gov. The report presents material from the databases that describes the impacts of the intelligent transportation infrastructure as well as intelligent vehicle applications. The majority of published evaluations of ITS implementations document positive impacts on the transportation system, and the assessments provided in this report reflect this fact. However, every attempt has been made to incorporate positive, negative, and neutral findings. A small number of negative findings appear in this report, and this report also documents a few evaluations that found that an ITS implementation did not have an impact on a particular measure of effectiveness. Mixed results are also noted in the few instances where studies have found both positive and negative impacts in a given area. There is a continuing need for ongoing evaluation of ITS, as indicated by the large number of application areas within this report for which there are not enough evaluation data to make an assessment of the system's impact on many of the relevant performance measures.

The body of this report includes additional detail on the impacts and costs of applications within the wide variety represented by the major ITS technology application areas. Example lessons learned summaries are presented throughout the report.

The remainder of the Executive Summary contains brief descriptions of the 16 ITS technology application areas—13 infrastructure areas and 3 vehicle areas—as well as highlights of the benefits and costs information available for each.

The highlighted benefits and costs are reported from various ITS deployments. Project costs are not reported in a standard format; rather, cost data reflect the specific ITS project and vary in detail and content from project to project. Reported costs include: the total cost of the deployment, ITS equipment or component costs, and, less frequently, operations and maintenance (O&M) costs. This executive summary concludes with a discussion of lessons learned.

Infrastructure Technology Applications

Arterial Management Systems

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travelers.

Benefits		
Mobility	To improve air quality in downtown Syracuse and Onondaga County, the New York State Department of Transportation (NYSDOT) installed a computerized traffic signal system and optimized the signal timing of 145 intersections. The project resulted in a reduction of total delay experienced by vehicles during the a.m.-peak, mid-day, and p.m.-peak periods by 14–19%.[1]	
Costs		
System Cost	As discussed above, NYSDOT installed a computerized traffic signal system and optimized the signal timing of 145 intersections in Syracuse and Onondaga County.[1]	Total project cost: $8,316,000

Freeway Management Systems

Freeway management systems employ traffic detectors, surveillance cameras, and other means of monitoring traffic flow on freeways to support the implementation of traffic management strategies such as ramp meters, lane closures, and variable speed limits. These sensors can also be used to monitor critical transportation infrastructure for security purposes.

Benefits		
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 dynamic message signs throughout the state. A total of 221 questionnaires were returned and analyzed. The results indicated that 12% of respondents used the information more than five times per month to adjust travel routes during winter months, and 18% of respondents used the information more than five times per month to adjust travel routes during non-winter months.[2]	
Costs		
System Cost	The Utah DOT operates and maintains more than 69 permanently mounted variable message signs (VMS) on freeways and surface streets as part of the Utah Advanced Transportation Management System (ATMS). Portable message signs are also used along roadsides where there is no permanent VMS. Annual operating cost for the VMS is based on power consumption (electricity).[3]	Cost of VMS: $15.25 million Annual VMS operating cost: $21,960

Transit Management Systems

Transit ITS services include surveillance and communications, such as automated vehicle location (AVL) systems, computer-aided dispatch (CAD) systems, and remote vehicle and facility surveillance cameras, which enable transit agencies to improve the operational efficiency, safety, and security of the nation's public transportation systems. Public access to bus location data and schedule status information is increasingly popular on transit Internet websites and at bus stops.

Benefits	
Customer Satisfaction	At the Acadia National Park in Maine, electronic message signs were installed to inform visitors of updated bus arrival and departure times at three popular visitor destinations. A survey of park visitors who used the signage found that 90% indicated transit information signs made it easier to get around.[4]

Costs		
System Cost	Transit riders at Bellevue and Northgate Transit Centers (Seattle, Washington) are provided with bus arrival/departure times, bay number, and expected actual departure times for all bus routes using the transfer center. The system, Transit Watch, obtains actual times from an automatic vehicle identification (AVI) system and presents the information on monitors at the transit centers.[5]	Cost to deploy TransitWatch: $722,877 (1998) Annual operations & maintenance (O&M) cost: $179,652 (1998)

Incident Management Systems

Incident management systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, the time for responding vehicles to arrive, and the time required for traffic to return to normal conditions. Incident management systems make use of a variety of surveillance technologies, often shared with freeway and arterial management systems, as well as enhanced communications and other technologies that facilitate coordinated response to incidents.

Benefits	
Mobility	Delay savings identified in studies of freeway service patrols implemented in Minneapolis-St. Paul, Minnesota; Denver, Colorado; and Northwest Indiana documented annual benefits of $1.2 to $1.8 million, through reductions in the duration of incidents, and related congestion.[6, 7, 8]

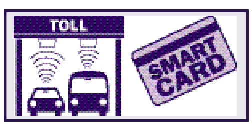
Costs		
System Cost	A freeway courtesy patrol (FCP) was implemented in the Detroit, Michigan, area in 1994. Michigan Department of Transportation (MDOT) administers the program as part of its larger freeway incident management program out of the Michigan Intelligent Transportation Systems Center (MITSC) in Detroit. In 2003, the program employed 32 drivers. The fleet includes 34 vehicles, of which 29 are vans and five are tow trucks. The standard hours of patrolling are from 6:00 a.m. to 11:00 p.m., Monday through Friday. The patrol also operates on special-event days (e.g., major community public events and sporting events).[9]	Cost to operate the FCP in 2003: $2.5 million Cost to operate the FCP in 2002: $2 million

Emergency Management Systems

ITS applications in emergency management include hazardous materials management, the deployment of emergency medical services, and large- and small-scale emergency response and evacuation operations.

Benefits		
Customer Satisfaction	The LifeLink project in San Antonio, Texas, enabled emergency room doctors to communicate with emergency medical technicians (EMTs) using two-way video, audio, and data communications. EMTs and doctors had mixed opinions about the system; however, it was expected that this technology would have more positive impacts in rural areas.[10]	
Costs		
System Cost	The Combined Transportation, Emergency & Communication Center (CTECC) is a multiagency partnership between the Texas Department of Transportation (TxDOT) Austin District, Travis County, City of Austin, and Capital Metropolitan Transportation Authority. The technological systems presently involved in the CTECC include 911 call handling, radio trunking, computer-aided dispatch (CAD), mobile data computer (MDC), including automatic vehicle location (AVL), and transportation and transit services. These integrated systems are essential to the delivery of emergency and transportation services in the Austin and Travis County region.[11]	CTECC equipment cost (approximately): **$5 million**

Electronic Payment Systems



Electronic payment systems employ various communication and electronic technologies to facilitate commerce between travelers and transportation agencies, typically for the purpose of paying tolls, transit fares, and parking fees.

Benefits		
Customer Satisfaction	Three projects in Europe demonstrated the coordinated use of a smart card as a payment system for public transit, shops, libraries, swimming pools, and other city services. User acceptance and satisfaction with these systems was very high, ranging from 71–87%.[12]	
Costs		
System Cost	The Washington Metropolitan Area Transit Authority (WMATA) is expanding the capability of their SmarTrip® contactless smart card system by linking it to multiple bus and rail fare collection systems throughout the Washington, D.C., area. A Regional Customer Service Center (RCSC) will be used to perform cross-jurisdictional management, distribution, and reconciliation tasks. The cost of the RCSC includes contracted services, central database, point of sale network and devices, and existing system software upgrades.[13]	Cost to deploy the RCSC: **$25.537 million** (2002–2003) Annual O&M cost (estimated): **$3.45 million** (2002–2003)

Traveler Information

Traveler information applications use a variety of technologies, including Internet websites, instant messaging, telephones, satellite radio, and local television and radio, to allow users to make more informed decisions regarding trip departures, routes, and mode of travel. Ongoing implementation of the designated 511 telephone number will improve access to traveler information across the country.

Benefits		
Customer Satisfaction	In Montana, 81% of survey respondents were satisfied or very satisfied with road conditions information available through a 511 telephone service provided by the Greater Yellowstone Regional Traveler and Weather Information System (GYRTWIS).[14] In Virginia, 90% of users who agreed to participate in a follow-up telephone survey found the 511 service deployed there useful, and nearly half of them indicated they had changed their travel plans on at least one occasion as a result of the information provided.[15]	
Costs		
System Cost	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 GYRTWIS project (see above). The GRYTWIS system cost includes system development, voice recognition, marketing, and a one-time improvement for the addition of regional reports, Amber Alerts, Homeland Security, and General Transportation Alerts. Annual operating cost includes contracted services and equipment lease, toll charges, marketing, and operating cost for the statewide alert system.[13]	Cost to deploy GYRTWIS: $188,000 Annual operating cost: $195,453

Information Management

ITS information management supports the archiving and retrieval of data generated by other ITS applications and assists in analysis functions that benefit transportation administration, policy evaluation, safety, planning, program assessment, operations research, and other applications. Data archiving systems are scalable to support a single agency's operations center and to support multiple agencies through regional data warehouses.

Benefits		
No data to report.		
Costs		
System Cost	The total cost of the Nevada DOT Freeway and Arterial System of Transportation (FAST) central system software design and development is approximately $4.225 million. The software will provide 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 the Archived Data Management System (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.[13]	Software design and development cost: $4.225 million (2000) ADMS design cost: $225,000 (1999)

Crash Prevention and Safety

Crash prevention and safety systems make use of sensor technology and active warning signs, including flashers, beacons, and dynamic message signs (DMS), to warn drivers of dangerous curves, excessive speed on downhill road segments, at-grade railroad crossings, and other dangerous conditions.

Benefits	
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% of vehicles crossing the tracks between the two trains. The number of drivers beginning to move their vehicles under the rising crossing gate before realizing a second train was approaching decreased by 86% after the system began operation. These benefits were determined by comparing data from a one-month evaluation period just before the system was installed and data from the two months immediately after installation.[16]

Costs		
System Cost	In Groton, Connecticut, a four-quadrant gate with automatic train stop system was deployed. The system included four-quadrant gates to deter vehicles from attempting to cross as trains approached, and six inductive loop vehicle detectors to detect vehicles blocking the tracks. In the event of an obstruction, the detector system was designed to notify train operators via an in-cab signaling system. If the engineer failed to slow the train, then an automated system would stop the train.[17]	The cost of the system included equipment installed at the crossing and the in-cab signaling system: **$977,000** (2001)

Roadway Operations and Maintenance

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. These applications monitor, analyze, and disseminate roadway and 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. This is often achieved through the temporary deployment of other ITS services, such as elements of traffic management and incident management programs.

Benefits	
Mobility	Average clearance times for incidents were reduced 44% with the implementation of motorist assistance patrols and a temporary traffic management center during a construction project at the "Big I" interchange in Albuquerque, New Mexico. During weekday operations, the Highway Department allocated two courtesy patrol units to patrol the construction zone between 5 a.m. and 8 p.m. and a wrecker was on-call from 6 a.m. to 6 p.m.[18]

Costs		
System Cost	The Michigan DOT (MDOT) used a temporary traffic management system (TTMS) during a construction project in downtown Lansing. The system was deployed from March 2001 to October 2001 and removed at the completion of the construction project. The project involved a complete closure of portions of I-496. The TTMS was used throughout the construction project. The system included 17 cameras, 12 DMS, six queue detectors (microwave sensors), and a commercial off-the-shelf (COTS) software package that ran on a server located at the construction traffic management center.[19]	Cost to lease the TTMS: **$2.4 million** (which is about 6% of the total project construction cost)

Road Weather Management

Road weather management activities include road weather information systems (RWIS), winter maintenance technologies, and coordination of operations within and between state DOTs. ITS applications assist with the monitoring and forecasting of roadway and atmospheric conditions, dissemination of weather-related information to travelers, weather-related traffic control measures such as variable speed limits, and both fixed and mobile winter maintenance activities.

Benefits	
Customer Satisfaction	The Washington State Department of Transportation (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. Ninety-four percent of surveyed users of a road weather information website covering roadways in Washington state agree that the weather information made travelers better prepared for their trips. More than half of the respondents (56 percent) agreed the information helped them avoid travel delays.[20]

Costs		
System Cost	As part of WSDOT system (see above), two environmental sensor stations (ESS) were installed at Sherman Pass and the town of Laurier, and two mobile highway advisory radio (HAR) systems were installed near the town of Republic and at the town of Kettle Falls. Broadcasts warn motorists of road construction, incidents, dangerous driving conditions and restrictions, and border crossing conditions and closures.[20]	Two ESS: $45,000 each HAR cost: $111,073 -Two mobile HARs: $52,000 -Signs, connectivity, clearing, and other associated costs: $59,073

Commercial Vehicle Operations

ITS applications for commercial vehicle operations are designed to enhance communication between motor carriers and regulatory agencies. Examples include electronic registration and permitting programs, electronic exchange of inspection data between regulating agencies for better inspection targeting, electronic screening systems, and several applications to assist operators with fleet operations and security.

Benefits	
Productivity	Three motor carriers surveyed during the Commercial Vehicle Information System and Network (CVISN) model deployment initiative indicated that electronic credentialing reduced paperwork and saved them 60 to 75% on credentialing costs. In addition, motor carriers were able to commission new vehicles 60% faster by printing their own credential paperwork and not waiting for conventional mail delivery.[21]

Costs		
System Cost	As part of the CVISN model deployment initiative, mentioned above, Kentucky and Maryland have implemented end-to-end International Registration Plan (IRP) electronic credentialing systems within their states. The costs to deploy these systems vary with the unique characteristics of each state. A significant impact on cost is whether commercial software is used or special software is developed and if third-party services will be used.[21]	Cost to implement end-to-end IRP in Kentucky: $935,906 Maryland: $464,802

Intermodal Freight

ITS can facilitate the safe, efficient, secure, and seamless movement of freight. Applications being deployed provide for tracking of freight and carrier assets such as containers and chassis, and improve the efficiency of freight terminal processes, drayage operations, and international border crossings.

Benefits		
Productivity	An electronic supply chain manifest system implemented biometric and smart-card devices to automate manual paper-based cargo data transfers between manufacturers, carriers, and airports in Chicago, Illinois, and New York, New York. Although participation was limited, the system was expected to improve efficiency. The time required for truckers to accept cargo from manufacturers decreased by about four minutes per shipment, and the time required for airports to accept the deliveries decreased by about three minutes per shipment.[22]	
Costs		
System Cost	A tracking device installed on fleet trailers can integrate Global Positioning System (GPS) technology with the Internet to provide a secure cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof-mounted solar panel.[23]	Cost: beginning at $800 per trailer (2000) Monthly service cost: $19 per subscriber with a three-year contract (2000)

Collision Avoidance Systems

To improve the ability of drivers to avoid accidents, vehicle-mounted collision avoidance systems continue to be tested and deployed. These applications use a variety of sensors to monitor the vehicle's surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, and road departure warning systems.

Benefits		
Safety	A National Highway Traffic Safety Administration (NHTSA) modeling study indicated collision warning systems would be effective in 42% of rear-end crash situations where the lead vehicle was decelerating, and effective in 75% of rear-end crashes where the lead vehicle was not moving. Overall, collision warning systems would be 51% effective.[24]	
Costs		
System Cost	The Federal Transit Administration (FTA), Port Authority of Allegheny County (Pittsburgh, Pennsylvania), and Carnegie Mellon University's Robotics Institute tested a collision avoidance system on 100 buses to warn bus drivers of obstacles in blind spots.[25]	Cost to equip each bus with 12 side-mounted ultrasonic sensors and an on-board computer: $2,600 (approx.) (2001)

Driver Assistance Systems

Numerous intelligent vehicle technologies exist to assist the driver in operating the vehicle safely. Systems are available to aid with navigation, while others, such as vision enhancement, adaptive cruise control, and speed control systems, are intended to facilitate safe driving during adverse conditions. Other systems assist with difficult driving tasks such as transit and commercial vehicle docking.

Benefits	
Safety	Ten vehicles were equipped with adaptive cruise control, including automatic throttle modulation and down shifting (but not braking) to maintain preset headways during a NHTSA field test. The performance of the system was compared to conventional cruise control and manually operated vehicles. Results indicated that vehicles equipped with adaptive cruise control made the fewest number of risky lane changes in response to slower traffic. Manually operated vehicles, however, had the quickest average response time to lead vehicle brake lights. Participants overwhelmingly ranked adaptive cruise control over the manual and conventional cruise control-equipped vehicles for convenience, comfort, and enjoyment, and indicated they would most likely use the system on freeways.[26]

Costs		
System Cost	In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio Metropolitan Model Deployment Initiative (MMDI). The units provided route guidance and real-time traffic conditions. The cost of the units (590 at approximately $2,800 each) was the most significant cost driver for the project. Most of the O&M cost is attributed to database updates.[10]	Total project cost: **$2,388,691** (1998) Annual O&M cost: **$102,330** (1998)

Collision Notification Systems

In an effort to improve response times and save lives, collision notification systems have been designed to 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 with automatic collision notification (ACN), and advanced systems may transmit information on the type of crash, number of passengers, and the likelihood of injuries.

Benefits	
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 one minute with some notification times as long as two minutes, and the average notification time for vehicles without ACN was about three minutes, with some notification times as long as 9, 12, 30, and 46 minutes.[27]

Costs		
System Cost	Numerous commercial Mayday/ACN products are available as factory-installed and after-market devices. Cost data are more prevalent for after-market devices than for factory-installed systems. Installation costs were not readily available. Annual service fees vary depending on the level of services offered.[28]	After market device cost range: **$400–$1,895** Monthly service fee: **$10–$27**

Lessons Learned Database–Coming Soon

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 JPO is in the process of developing an ITS Lessons Learned Database. Major objectives are:

- Capture experiences of stakeholders in their planning, deployment, operations, maintenance, and evaluation of ITS.
- Provide all ITS stakeholders with convenient access to the lessons learned knowledge so that they can make informed decisions in their future ITS actions.

The ITS Lessons Learned Database is planned to be available online in the summer of 2005. It will be accessible as a resource from the ITS JPO website, www.its.dot.gov.

ITS lessons will be classified by a number of attributes as summarized in Table ES.1. General lessons will be drawn from stakeholders' experience in such topic areas as management and partnerships, planning, design and deployment, procurement, technical integration, operations and maintenance, legal issues, and human resources. Technical lessons will be categorized under the current classification scheme of the ITS Benefits and Costs Databases, which organize information under 16 ITS application areas, including freeway management systems, arterial management systems, transit management systems, electronic payment systems, traveler information, collision warning systems, and driver assistance systems. In addition, lessons will also be grouped under ITS goal areas, and the ITS initiatives.

> 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.

Spread throughout the body of this report is a sampling of lessons learned in the planning, deployment, and evaluation of ITS, presented in the form of short summaries. These lessons depict experiences ranging from technical issues such as configuration management and arterial traffic detection systems upgrade, to general ITS issues such as legal issues in incident management. Examples of lessons learned included in this report are:

- **Regard 511 as an evolving service designed to attract and retain users.** The most successful 511 services track, respond to, and even try to predict user needs. One mechanism to capture user feedback is to incorporate a comment line on the 511 menu tree.[29] The target audience for this lesson is program managers, who should have flexibility in designing an evolving 511 service.
- **Execute thorough configuration management from the start of an ITS project.** At a minimum, the configuration management process needs to identify the naming conventions, interfaces, and required protocols. Agencies also need to be aware that every "new" innovation in off-the-shelf software comes with its own set of bugs, software licenses, languages, and interdependencies. The operating agency needs to determine its preferred software and integration design methodology and require the contractor to support that approach.[30] The target audience for this type of lesson is project managers.

Table ES.1
Lessons Learned Database–Categories, Audience, and Topic Areas

Lesson Categories	Major Target Audience	Lesson Topic Areas
General ITS	Program Managers	• Management and Partnerships • Planning • Design and Deployment • Procurement • Technical Integration • Operations and Maintenance • Legal Issues • Human Resources
ITS Applications	Project Managers, Planners, Designers	• Intelligent Infrastructure • Intelligent Vehicle
ITS Goal Areas	Executives, Researchers, Planners	• Safety • Mobility • Productivity • Efficiency (Capacity/Throughput) • Energy and Environment • Customer Satisfaction
ITS Initiatives	Initiative Program Managers and Support Teams	• Integrated Vehicle-Based-Safety Systems • Cooperative Intersection Collision Avoidance Systems • Next Generation 911 • Mobility Services for All Americans • Integrated Corridor Management Systems • Nationwide Surface Transportation Weather Observing and Forecasting System - Clarus • Emergency Transportation Operations • Universal Electronic Freight Manifest • Vehicle Infrastructure Integration (VII) • Intelligent Vehicle Initiative (IVI) • 511 Traveler Information • Wireless Enhanced 911 • Commercial Vehicle and Information Systems and Networks Deployment (CVISN) • ITS Architecture Consistency

The Lessons Learned Database is a relatively new venture for USDOT. Consequently, there may be few lessons available in each of the categories listed in Table ES.1. This scarcity of data makes it difficult to draw broad conclusions. The lessons contained both in the database and in this document should not be considered as official policy or guidance from USDOT. Instead, they describe the past experiences of others that readers may want to consider when making local decisions regarding the deployment of ITS.

In compiling the database, researchers have observed many lessons that appear repeatedly in multiple reference sources. To some, these lessons will appear obvious. Nevertheless, these lessons need to be told to a new generation of ITS professionals. As Peter F. Drucker once observed, "…(t)he obvious is precisely what needs to be pointed out—otherwise, it will be overlooked."[31] Detailed information on the above lessons, as well as new lessons, will be presented in a Lessons Learned Database planned to be made available to the public in the summer of 2005.

1.0 INTRODUCTION

U.S. highway deaths continue to climb (43,000 in 2003) and the ever-increasing demand for travel by highway and public transit is causing the transportation system to reach the limits of its existing capacity, resulting in growing traffic congestion that robs Americans of time and money. Intelligent Transportation Systems (ITS) technologies offer a clear opportunity to improve transportation safety, relieve congestion, and enhance productivity.

Since the mid 1990's, the U.S. Department of Transportation (USDOT) has been accumulating information regarding levels of ITS deployment in the United States, and associated benefits, costs, and lessons learned. With this publication, we are introducing the collection of lessons learned information as a new resource for ITS managers, executives, planners, designers, deployers, and researchers.

The ITS vision includes a wide collection of applications that integrate surface transportation infrastructure with the vehicles that use it. Many existing applications of deployed ITS will contribute to the realization of this vision. This document focuses on the benefits, costs, and lessons learned through the deployment of the intelligent infrastructure and intelligent vehicles. Examples include: advanced traffic signal control systems, electronic transit fare payment systems, ramp meters, and collision avoidance systems.

In order to apply ITS services most effectively, decision makers require benefits and costs information about the ITS they are considering as well as documented lessons learned from the experiences of others. To be most effective, these inputs should be supplemented with information that describes the context from which the data were derived. As technology evolves, the choices available change. Often, several technologies are combined in a single integrated system, providing a higher level of benefits than any single technology. The costs of these technology investments, not only the one-time, initial costs, but also the costs to operate and maintain them, are of interest to transportation agencies.

This report is a continuation of a series of reports providing a snapshot of the information collected by the USDOT ITS Joint Program Office (JPO) on the impact of ITS applications on the surface transportation network, and the cost of these applications. The last report, *ITS Benefits and Costs: 2003 Update*, was published in May 2003.[32] Benefit and cost information in the report is drawn from the ITS Benefits and Costs Databases, regularly updated repositories for this information, available on the Internet at www.benefitcost.its.dot.gov.

New in the 2005 report is the introduction of summaries of lessons learned from ITS planning, deployment, operation, maintenance, and evaluation experience; the previous report contained only benefits and costs information. The ITS JPO has just recently initiated the process of capturing these lessons, and this report presents summaries of some of the first few collected. An ITS Lessons Learned Database is under development and planned to be available in the summer of 2005, when it will be publicly accessible via the Internet. Because the Lessons Learned Database is just getting under way as this document is being written, this document focuses on providing an introductory overview.

NEW Signifies a new entry

The benefits and costs information contained in this 2005 report has been significantly updated since the previous report. The report includes 26 new benefits findings that did not appear in the prior report, representing 20 percent of the 128 findings documented in this edition. Forty-six new system cost examples are provided in this report (49 percent of the 93 examples in the document). Throughout the report, new costs and benefits data are highlighted with a NEW bar, as shown at left.

In documenting the benefits of ITS, this report provides an assessment of the effect of ITS applications on several important goal areas, such as safety and mobility, further described later in this report. These assessments are built from findings in the ITS Benefits Database, incorporating additions since the completion of the last report. While the assessments are based on the authors' review of all study findings, the examples provided in this document are only a portion of the total number of studies documented in the Benefits Database. The impact assessment for each ITS application area is presented through a rating system, as shown in Table 1.0.1. These ratings were developed through individual review of the database content by the authors, with additional discussion among the authors to establish the final ratings presented in this report. A particular rating was assigned if one or more of the reasons in the rationale column in Table 1.0.1 was evident in reviewing the evaluations of a given ITS application in the Benefits Database.

Table 1.0.1
Definition of Impact Ratings for Assessment of ITS Applications

Symbol	Impact Rating	Rationale
++	substantial positive impacts	• several studies with positive findings • documented impact of relatively large magnitude
+	positive impacts	• several studies documenting positive findings though the impact may be small or moderate • single, relatively rigorous study documented a positive impact
o	negligible impact	• studies performed found little significant impact
+/–	mixed results	• studies have found both positive and negative impacts on a given measure
?	not enough data	• usually, only a single study is available, and results cannot be taken to indicate a trend • studies in database have limited sample sizes, or study durations • studies in database are from a single location, and impacts are expected to vary in different locations
–	negative impacts	• several studies documenting negative findings • single, relatively rigorous study documenting a negative impact

The majority of published evaluations of ITS applications document positive impacts on the transportation system, and the assessments provided in this report reflect this fact. However, every attempt has been made to incorporate positive, negative, and neutral findings. A small number of negative findings appear in this report. For example, Section 2.6 documents increases in crashes at toll plazas with electronic toll collection, likely due to driver uncertainty regarding plaza configuration and the variations in the speeds of vehicles within the plazas. This report also documents a few evaluations that found that an ITS implementation did not have an impact on a particular measure of effectiveness, including two studies that found traveler information did not have a significant impact on throughput, while it did reduce traveler delay. Mixed results are also noted in the few instances where studies have found both positive and negative impacts in a given area. There is a continuing need for ongoing evaluation of ITS, as indicated by the large number of application areas within this report for which there are not enough evaluation data to make an assessment of the system's impact on one or more of the relevant performance measures.

This report is intended to be a reference report. The interested reader is encouraged to obtain source documents to appreciate the assumptions and constraints placed upon interpretation of the reported results.

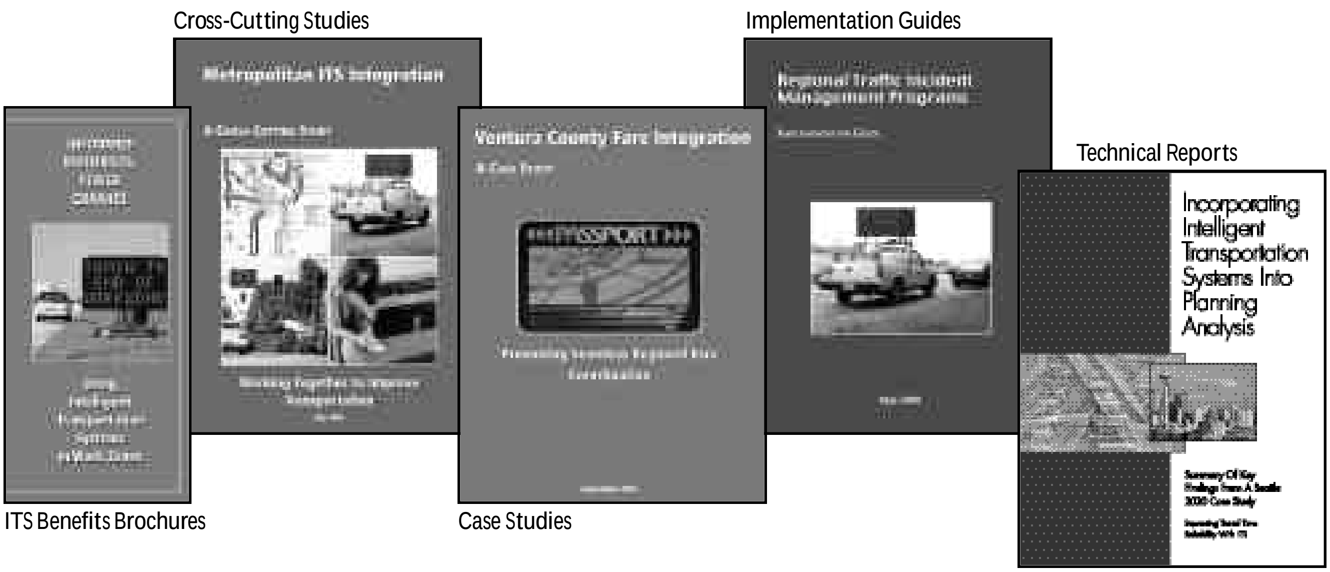
Interested readers are encouraged to check the databases from time to time for the latest findings on the benefits and costs of ITS. This report is intended to be a reference report; it highlights impacts, system cost data, and an initial set of lessons learned that have been identified by other authors. The interested reader is encouraged to obtain source documents to appreciate the assumptions and constraints placed upon interpretation of the reported results. An interactive version of this report will be available through the website in the near future, including links from sections of the report to relevant portions of the ITS Benefits, Costs, and Lesson Learned Databases. The databases include more detailed summaries of the evaluations cited in this report as well as links to source documents, when available online.

The ITS JPO website is another valuable resource for information on the various applications of ITS. The website, www.its.dot.gov, also includes links to many of the resources highlighted within this report, including an Electronic Document Library (EDL), which contains electronic copies of many of the reports made available by the JPO. The new ITS Technology Overview, being developed as part of the ITS JPO website, will provide online access to information on ITS integration. The ITS Technology Overview will provide an online definition of integration, both graphically and in text, for each element in the ITS classification scheme involved with a defined integration link. The ITS Technology Overview will also provide a summary of additional information for each element of the ITS classification scheme, including benefits, costs, lessons learned, deployment, and available documentation. The ITS JPO website is being updated and the revised site, including the ITS Technology Overview, will be unveiled in May 2005, coinciding with the release of this report.

1.0 Introduction

For those ITS technologies with a well-established track record, the JPO has developed a series of reports that help decision makers learn about how those ITS solutions can address local and regional transportation needs. There are several different types of reports in the series (many available at the website above), each designed to communicate with target audiences at various levels:

- **ITS Benefits Brochures** let experienced community leaders and transportation professionals explain in their own words how specific ITS technologies have benefited their areas.
- **Cross-Cutting Studies** examine various ITS approaches that can be taken to meet a community's goals.
- **Case Studies** provide in-depth coverage of specific approaches taken by communities across the United States.
- **Implementation Guides** serve as "how to" manuals to assist project staff in the technical details of implementing ITS.
- **Technical Reports** are easy-to-read excerpts from more detailed evaluation reports.



In addition to the variety of reports developed to assist transportation decision makers, information is available on how much and what types of ITS deployment have taken place. The ITS Metropolitan Deployment Tracking project began in 1996 with the goal of tracking the level of ITS deployment and integration in 75 of the nation's largest metropolitan areas. The number of metropolitan areas was later increased to 78. In 1997, and again in 1999, 2000, and 2002, data were collected based on a series of surveys targeted at 78 of the largest metropolitan areas. Beginning in 2002, the metropolitan target areas were expanded to include 30 medium-size, high-congestion areas, and 20 tourist areas. Additionally, in 2002, a new set of surveys was launched with the purpose of gathering data on rural/statewide ITS deployments targeted at each of the 50 states. In 2004, the metropolitan surveys of 78 large and 30 medium metropolitan areas and the statewide/rural surveys in each state were repeated. Results of the data collected for 2004 will be available at the ITS Deployment Tracking website, www.itsdeployment.its.dot.gov, in early summer 2005. This website also includes data online and in the form of reports from the earlier surveys and provides a view of deployment trends.

1.1 BENEFITS DATABASE GOALS AND OVERVIEW

To expand the understanding of ITS benefits, the USDOT has been actively collecting information regarding the impact of ITS implementations for more than a decade. In support of this effort, the JPO sponsored the development of the ITS Benefits Database. The database is available to the public at www.benefitcost.its.dot.gov. The database contains the most recent data collected by the JPO. Its purpose is to transmit existing knowledge of ITS benefits to transportation professionals. The database also provides the research community with information on ITS areas where further analysis may be required.

The Benefits Database website contains detailed summaries of each of the ITS evaluation reports reviewed by the JPO that meet several acceptance criteria (see the "Criteria Document" under the "Available Documents" link at www.benefitcost.its.dot.gov). Summaries on the Web pages provide additional background on the context of the evaluations, the evaluation methodologies used, and links to the source documentation (when available online). While the JPO publishes summary reports such as this current document periodically, the online database is updated continuously, as reports are reviewed. Documents reviewed for inclusion in the database include the results of federal evaluation projects, as well as papers, journal articles, and state, local or international evaluation reports identified through review of conference proceedings and journals, or submitted through the database website. The collection of evaluation reports is an ongoing program, and readers are encouraged to submit relevant documents via the database website.

The collection of evaluation reports is an ongoing program, and readers are encouraged to submit relevant documents via the database website.

Table 1.1.1 provides an overview of the information available in the ITS Benefits Database, covering each goal area for each of the major ITS technology application areas. This report provides sample findings drawn from the larger body of data in the database. Table 1.1.1 demonstrates that a significant number of studies are accumulating in a number of areas, such as arterial and freeway management systems. However, there is much to be learned in many areas of ITS implementation.

Table 1.1.1
Documents Available in the ITS Benefits Database (as of September 30, 2004)

A Few Good Measures / Technology Application Area	Safety	Mobility	Capacity/ Throughput	Productivity	Customer Satisfaction	Energy and Environment
Arterial Management Systems	10+ References	10+ References	4 to 6 References	7 to 10 References	7 to 10 References	10+ References
Freeway Management Systems	10+ References	10+ References	7 to 10 References	1 to 3 References	7 to 10 References	4 to 6 References
Transit Management Systems	4 to 6 References	7 to 10 References	1 to 3 References	7 to 10 References	7 to 10 References	1 to 3 References
Incident Management Systems	7 to 10 References	10+ References	0 References	7 to 10 References	4 to 6 References	4 to 6 References
Emergency Management Systems	1 to 3 References	1 to 3 References	0 References	1 to 3 References	1 to 3 References	0 References
Electronic Payment Systems	1 to 3 References	4 to 6 References	1 to 3 References	4 to 6 References	4 to 6 References	4 to 6 References
Traveler Information	1 to 3 References	10+ References	1 to 3 References	0 References	10+ References	1 to 3 References
Information Management	0 References	0 References	0 References	1 to 3 References	0 References	0 References
Crash Prevention and Safety	10+ References	4 to 6 References	0 References	0 References	1 to 3 References	1 to 3 References
Roadway Operations and Maintenance	1 to 3 References	1 to 3 References	0 References	0 References	1 to 3 References	0 References
Road Weather Management	10+ References	1 to 3 References	1 to 3 References	7 to 10 References	1 to 3 References	1 to 3 References
Commercial Vehicle Operations	4 to 6 References	7 to 10 References	0 References	10+ References	4 to 6 References	1 to 3 References
Intermodal Freight	0 References	0 References	0 References	1 to 3 References	1 to 3 References	0 References
Collision Avoidance Systems	4 to 6 References	0 References	0 References	1 to 3 References	1 to 3 References	1 to 3 References
Driver Assistance Systems	4 to 6 References	10+ References	4 to 6 References	4 to 6 References	7 to 10 References	4 to 6 References
Collision Notification Systems	1 to 3 References	0 References	0 References	0 References	1 to 3 References	0 References

Number of References
- 0 References
- 1 to 3 References
- 4 to 6 References
- 7 to 10 References
- 10+ References

The online database also provides several capabilities to simplify access to information relevant to a researcher's interest. In addition to the technology application classification system used in this report (see Section 1.4), interested researchers can access document summaries classified by project location and the ITS goal areas addressed in the evaluations, or search the database for relevant keywords. Figures 1.1.1 and 1.1.2 show the distribution of project locations for evaluation studies included in the Benefits Database. These capabilities of the online database simplify access to the most recently available data on ITS benefits identified by the JPO. The website also contains a discussion of the criteria and sources used to determine whether or not a report should be added to the Benefits Database.

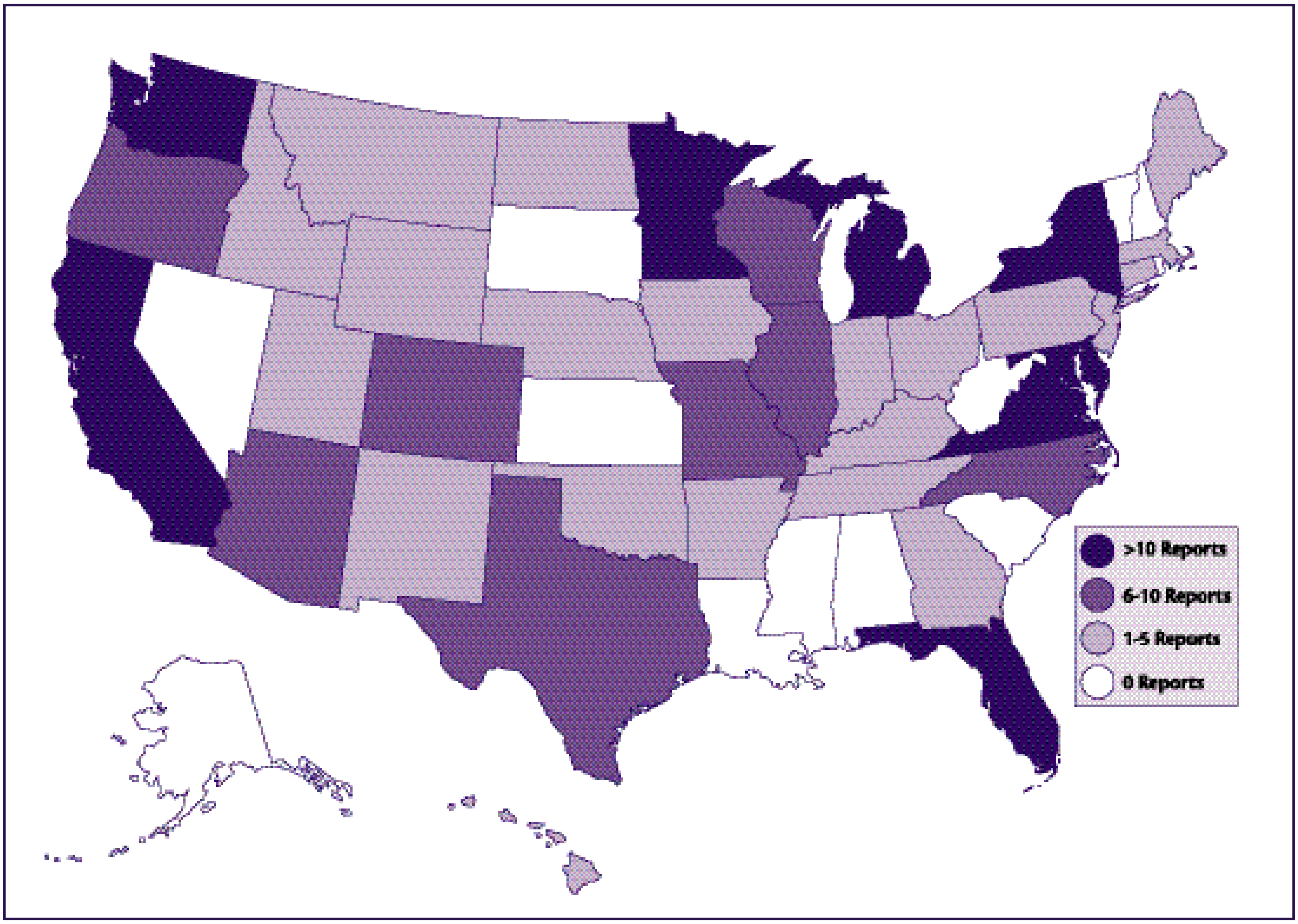


Figure 1.1.1

U.S. Map with Distribution of ITS Benefits Database Entries (as of September 30, 2004)

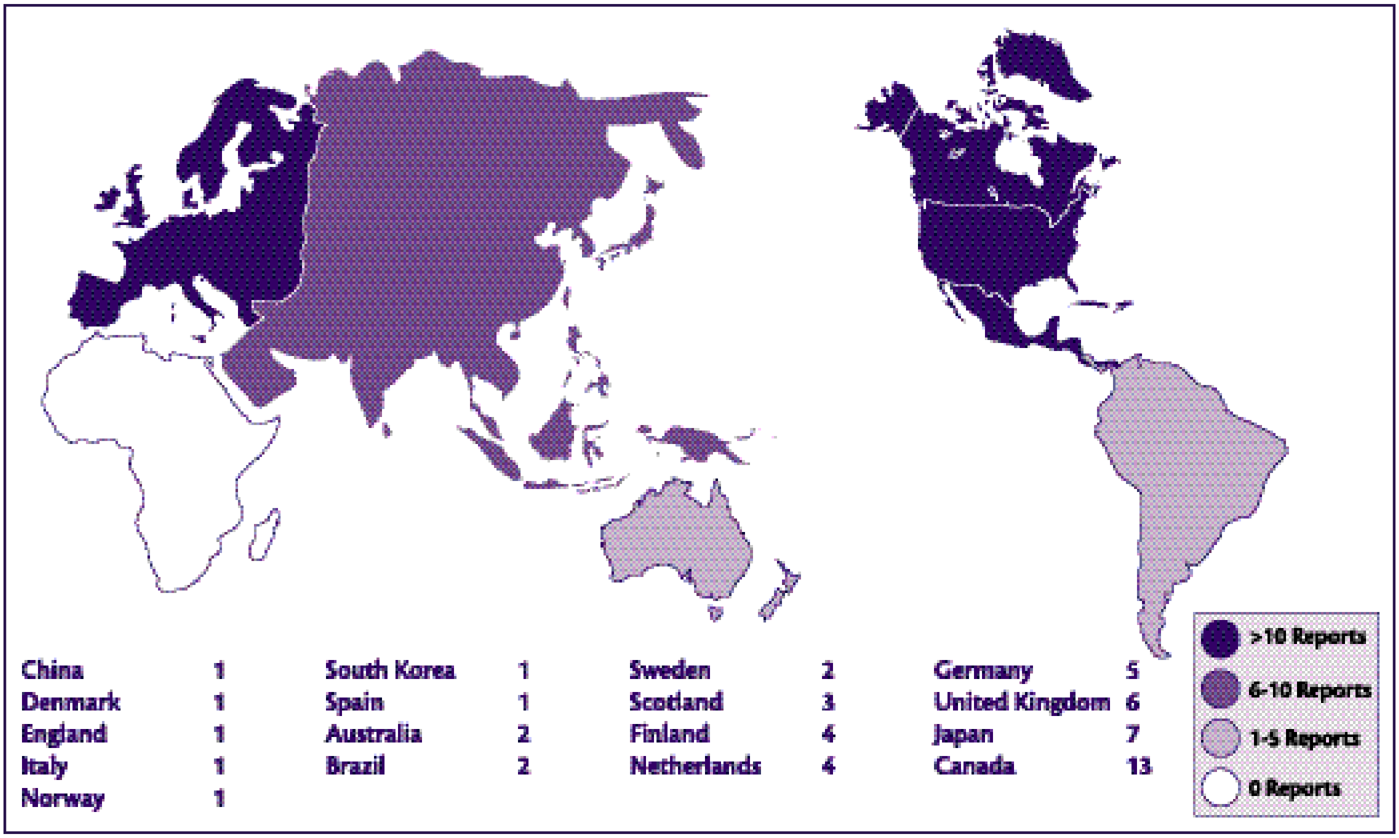


Figure 1.1.2.
World Map with Distribution of ITS Benefits Database Entries (as of September 30, 2004), not Including the United States

A FEW GOOD MEASURES

In the spring of 1996, the ITS JPO established a set of ITS program goal areas directly related to the ITS strategic plan.[33] The goal areas include improving traveler safety, improving traveler mobility, improving system efficiency, increasing the productivity of transportation providers, and conserving energy while protecting the environment. The JPO also identified several measures of effectiveness to evaluate the performance of ITS services in each goal area. The measures are known as the "Few Good Measures" and are intended to enable project managers to gauge the effects and impacts of ITS.

The USDOT has identified nine major initiatives that represent an important step in the continuing evolution of the ITS program and will contribute to strengthening the role of ITS in transportation safety, mobility, productivity, and global connectivity. Visit www.its.dot.gov for more information on these initiatives and their relationship with the safety, mobility, and productivity goals discussed below.

Safety

An explicit objective of the transportation system is to provide a safe environment for travel while continuing to strive to improve the performance of the system. Although undesirable, crashes and fatalities do occur. Several ITS services aim to minimize the risk of crash occurrence. This goal area focuses on reducing the number of crashes, and lessening the probability of a fatality should a crash occur. Typical measures of effectiveness used to quantify safety performance include the overall crash rate, fatality crash rate, and injury crash rate. Surrogate measures are also used, including vehicle speeds, speed variability, or changes in the number of violations of traffic safety laws.

Mobility

Improving mobility by reducing delay and travel time is a major goal of many ITS components. Measures of effectiveness typically used to evaluate mobility include the amount of delay time and the variability in travel time.

Delay can be measured in many different ways depending on the type of transportation system being analyzed. Delay of a system is typically measured in seconds or minutes of delay per vehicle. Also, delay for users of the system may be measured in person-hours. Delay for freight shipments could be measured in time past scheduled arrival time of the shipment. Delay can also be measured by observing the number of stops experienced by drivers before and after a project is implemented.

Travel time variability is an indicator of trip time reliability. It measures how stable or unpredictable the trip time is across numerous trips at different times of day. This measure of effectiveness can be readily applied to intermodal freight (goods) movement as well as personal travel. Reducing the variability of travel time improves the reliability of arrival time estimates that travelers or companies use to make planning and scheduling decisions. By improving operations, improving incident response, and providing information on delays, ITS services can reduce the variability of travel time in transportation networks. For example, traveler information products can be used in trip planning to help re-route commercial vehicle drivers around congested areas, resulting in less variability in travel time.

Productivity

ITS implementations can reduce operating costs and allow productivity improvements. Some applications may save time in completing business or regulatory processes, enabling businesses to increase their economic efficiency. For public agencies, ITS alternatives for transportation improvements may have lower acquisition costs and life-cycle costs when compared to traditional transportation improvements. Other ITS applications enable the collection and synthesis of data that can translate into cost savings and performance improvements. Operational efficiencies and cost savings made possible by ITS implementation can help both public and private entities make the most productive use of their resources. The measures of effectiveness for this goal area are improvements in efficiency, effectiveness, or cost savings as a result of implementing ITS.

Capacity/Throughput

Many ITS components seek to optimize the efficiency of existing facilities and use of rights-of-way so that mobility and commerce needs can be met while reducing the need to construct or expand facilities. This is accomplished by increasing the effective capacity of the transportation system. Effective capacity is the "maximum potential rate at which persons or vehicles may traverse a link, node, or network under a representative composite of roadway conditions," including "weather, incidents, and variation in traffic demand patterns."[34] Capacity, as defined by the Highway Capacity Manual, is the "maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a given point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions."[35] The major difference between effective capacity and capacity is that capacity is generally measured under typical conditions for the facility, such as good weather and pavement conditions, with no incidents affecting the system, while effective capacity can vary depending upon these conditions and the use of management and operational strategies. Throughput is defined as the number of persons, goods, or vehicles traversing a roadway section or network per unit time. Increases in throughput are sometimes realizations of increases in effective capacity. Under certain conditions, it may reflect the maximum number of travelers that can be accommodated by a transportation system. Throughput is more easily measured than effective capacity and therefore can be used as a surrogate measure when analyzing the performance of an ITS project.

Customer Satisfaction

Given that many ITS projects and programs are specifically developed to serve the public, it is important to ensure that traveler expectations are being met or surpassed. Customer satisfaction measures characterize the difference between users' expectations and experiences in relation to a service or product. The central question in a customer satisfaction evaluation is, "Does the product deliver sufficient value (or benefits) in exchange for the customer's investment, whether the investment is measured in money or time?" Typical results reported in evaluating the impacts of customer satisfaction with a product or service include product awareness, expectations of product benefit(s), product use, response (decision making or behavior change), realization of benefits, and assessment of value. Although satisfaction is difficult to measure directly, measures related to satisfaction can be observed, including amount of travel in various modes, mode choices, and the quality of service as well as the volume of complaints and/or compliments received by the service provider.

In addition to customer satisfaction, it is necessary to evaluate the satisfaction of the transportation system provider or manager. For example, many ITS projects are implemented to enhance coordination between various stakeholders in the transportation arena. In such projects, it is important to measure the satisfaction of the transportation providers to ensure the best use of limited funding. One way to measure the performance of such a project is to survey transportation providers before and after a project has been implemented to see if coordination was improved. It may also be possible to bring together providers from each of the stakeholder groups to evaluate their satisfaction with the system before and after the implementation of the ITS project.

Energy and Environment

The air quality and energy impacts of ITS services are very important considerations, particularly for communities striving to comply with federal air quality standards. In most cases, environmental benefits can be estimated only through the use of modeling and simulation. The problems related to regional measurement include the small impact of individual projects and large numbers of exogenous variables, including weather, contributions from nonmobile sources, air pollution drifting into an area from other regions, as well as the time-evolving nature of ozone pollution. Small-scale studies generally show positive impacts of ITS on the environment. These impacts result from smoother and more efficient flows in the transportation system. However, environmental impacts of travelers reacting to large-scale deployment of ITS in the long term are not well understood.

Decreases in emission levels and energy consumption have been identified as measures of effectiveness for this goal area. Specific measures of effectiveness for emission levels and fuel use include:

- Emission levels (kilograms or tons of pollutants including carbon monoxide (CO), oxides of nitrogen (NOx), hydrocarbons (HC), and volatile organic compounds)
- Fuel use (liters or gallons)
- Fuel economy (km/L or miles/gal)

1.2 COSTS DATABASE GOALS AND OVERVIEW

The ITS JPO also collects information on ITS costs and maintains this information in the ITS Costs Database. The database, a companion to the ITS Benefits Database, is available to the public at the same website, www.benefitcost.its.dot.gov. The database is a central site for ITS cost data and is based on the most recent data collected by the JPO. Its purpose is to make cost data available to public and private organizations. The database also provides data that the ITS JPO can use for programmatic and policy decisions and education of ITS stakeholders.

The costs database contains two types of cost information: unit costs and system costs. The difference in the two types of cost data is in the level of aggregation. Unit cost is the cost associated with an individual ITS element. System costs are associated with multiple ITS elements and typically represents the total cost of an ITS project or portion of an ITS project.

The unit costs database (presented in Appendix A) consists of a range of reported costs for a set of ITS elements. The cost data are organized by "subsystem" and generally follow the structure of the National ITS Architecture. The cost estimates are categorized as capital and operating and maintenance (O&M) costs. Capital costs are the costs expended for one-time, nonrecurring purchases. Operations and maintenance costs, often referred to as recurring costs, are the annual costs incurred on an ongoing basis. Costs are presented in a range to capture the lows and highs of the cost elements from the different data sources. A "Notes" field provides a brief narrative describing the particular unit cost element and its components. The cost data are useful in developing project cost estimates during the planning process. However, the user is encouraged to find local/regional data sources and current vendor data in order to perform a more detailed cost estimate.

The unit costs database is updated semiannually—in March and September. Beginning with the September 30, 2004 update, the dollar year of the cost data is provided for each ITS element. In addition, unit cost values are adjusted to 2003 year dollars. Information on indexes used in the adjustments is provided on the website.

The system costs portion of the database provides examples of systems that have been deployed and includes the cost of the implementation, in the form of detailed summaries. Summaries on the website provide additional background on the context of the ITS project, project cost data, and links to the source documentation (when available). Documents reviewed for inclusion in the database include the results of federal evaluation projects, as well as papers, journal articles, and state, local, or international evaluation reports identified through review of conference proceedings and journals, or through electronic submission via the website. The collection of cost sources is an ongoing effort, and readers are encouraged to submit relevant documents and cost data via the website.

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The online database also provides several capabilities to simplify access to information relevant to a researcher's interest. In addition to using the classification system used in this report, interested researchers can access document summaries classified by project location, or search the database for relevant keywords. Figure 1.2.1 is a map of the United States with distribution of system cost examples available in the ITS Costs Database. Although the majority of costs information in the system costs database is from U.S. deployments, a small number of summaries capture the costs of international deployments.

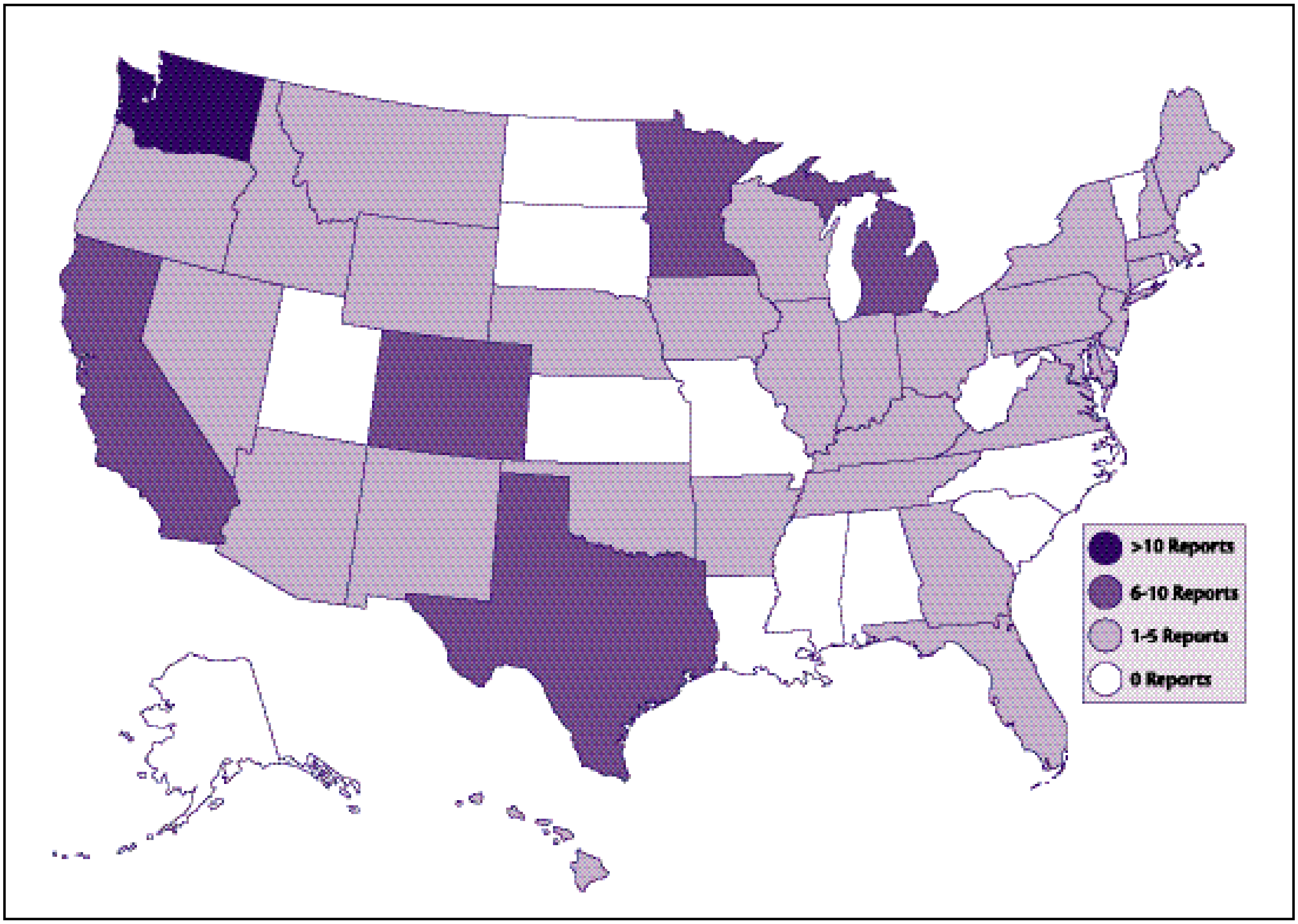


Figure 1.2.1

U.S. Map with Distribution of ITS System Costs Examples (Available in the ITS Costs Database as of September 30, 2004)

1.3 LESSONS LEARNED DATABASE GOALS AND OVERVIEW

Lessons Learned Database–Coming Soon

The ITS JPO is in the process of developing an ITS Lessons Learned Database. Major objectives are:

- Capture experiences of stakeholders in their planning, deployment, operations, maintenance, and evaluation of ITS.
- Provide all ITS stakeholders with convenient access to the lessons learned knowledge so that they can make informed decisions in their future ITS actions.

The ITS Lessons Learned Database is planned to be publicly available online in the summer of 2005, when it will be accessible as a resource from the ITS JPO website, www.its.dot.gov.

What is a Lesson Learned?

The lessons contained both in the database and in this document should not be considered as official policy or guidance from USDOT.

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. An ITS stakeholder experience of what worked and what did not work in the procurement of traffic management systems software is a valid candidate for the lessons learned database. Each lesson captured in the database will be described in a concise format. A lesson description will include items such as a lesson title in the form of a recommendation, a summary of major outcomes, context description, and identifying information such as date, location, source, and contact.

The lessons summarized in this document place the reader in the position of one who has experienced either a successful or unsuccessful practice. It then places the reader in the same position of the one who has learned a lesson and deduces a statement that says, "If I had the opportunity to turn back time, this is a possible rule that might be true or helpful to others." In other words the lesson is worded as a hypothetical action that may or may not be effective if re-tried by others in the present.

The Lessons Learned Database is a relatively new venture for USDOT. Consequently, there may be few lessons available in each of the categories listed in Table 1.3.1 below. This scarcity of data makes it difficult to draw broad conclusions. The lesson contained both in the database and in this document should not be considered as official policy or guidance from USDOT. Use discretion as to whether or not lessons reported in this document apply to your situation.

Lessons Learned Knowledge Sources

Lessons will be collected primarily from documented knowledge sources. ITS case studies, best practice compendiums, planning and design reviews, and evaluation studies are targeted as key resources. The ITS Electronic Document Library, Transportation Research Board's Transportation Research Information Services (TRIS), international transportation literature database (e.g., Transport), and conference proceedings are major sources of the documents that are currently being reviewed for collection of lessons.

Lesson Types

ITS lessons will be presented in a number of different categories and topic areas depending upon the intended audience and topic of interest. Table 1.3.1 provides a list of these classifications.

Table 1.3.1
Lessons Learned Database – Categories, Audience, and Topic Areas

Lesson Categories	Major Target Audience	Lesson Topic Areas
General ITS	Program Managers	• Management and Partnerships • Planning • Design and Deployment • Procurement • Technical Integration • Operations and Maintenance • Legal Issues • Human Resources
ITS Applications	Project Managers, Planners, Designers	• Intelligent Infrastructure • Intelligent Vehicle
ITS Goal Areas	Executives, Researchers, Planners	• Safety • Mobility • Productivity • Efficiency (Capacity/Throughput) • Energy and Environment • Customer Satisfaction
ITS Initiatives	Initiative Program Managers and Support Teams	• Integrated Vehicle Based Safety Systems • Cooperative Intersection Collision Avoidance Systems • Next Generation 911 • Mobility Services for All Americans • Integrated Corridor Management Systems • Nationwide Surface Transportation Weather Observing and Forecasting System–Clarus • Emergency Transportation Operations • Universal Electronic Freight Manifest • Vehicle Infrastructure Integration (VII) • Intelligent Vehicle Initiative (IVI) • 511 Traveler Information • Wireless Enhanced 911 • Commercial Vehicle and Information Systems and Networks Deployment (CVISN) • ITS Architecture Consistency

Lessons presented in the General ITS category will be targeted to program managers and provide insights into areas ranging from management and partnerships to human resources. For example, a reader may learn that ensuring team effort, political champion involvement, and consistent community outreach throughout the project is a critical element of any successful implementation of high-occupancy/toll lanes.

Lessons presented in the ITS applications category will be targeted to the project managers, planners, and designers responsible for a particular ITS application. These ITS applications lessons will be categorized according to the 16 technology application areas utilized in the benefits and costs databases. This will allow, for example, a designer planning a new transit management system to search for lessons gathered from the experiences of others deploying similar applications. Other application areas include freeway management systems, arterial management systems, electronic payment systems, traveler information, collision warning systems, and driver assistance systems.

Lessons presented in the ITS goals area category will be targeted to executives, researchers, and planners interested in learning more about successful approaches to maximizing benefits in key ITS goal areas ranging from safety to customer satisfaction.

Where appropriate, lessons will also be categorized according to the USDOT's ITS Initiatives. This categorization will aid program managers and others supporting the initiatives to quickly identify lessons that pertain to their particular initiative. It is expected that any given individual lesson may be appropriate to one or more different categories, audiences, and topic areas.

Figure 1.3.1 shows a schematic illustration of database access flow and the types of lesson information that are being collected for lessons within each topic area.

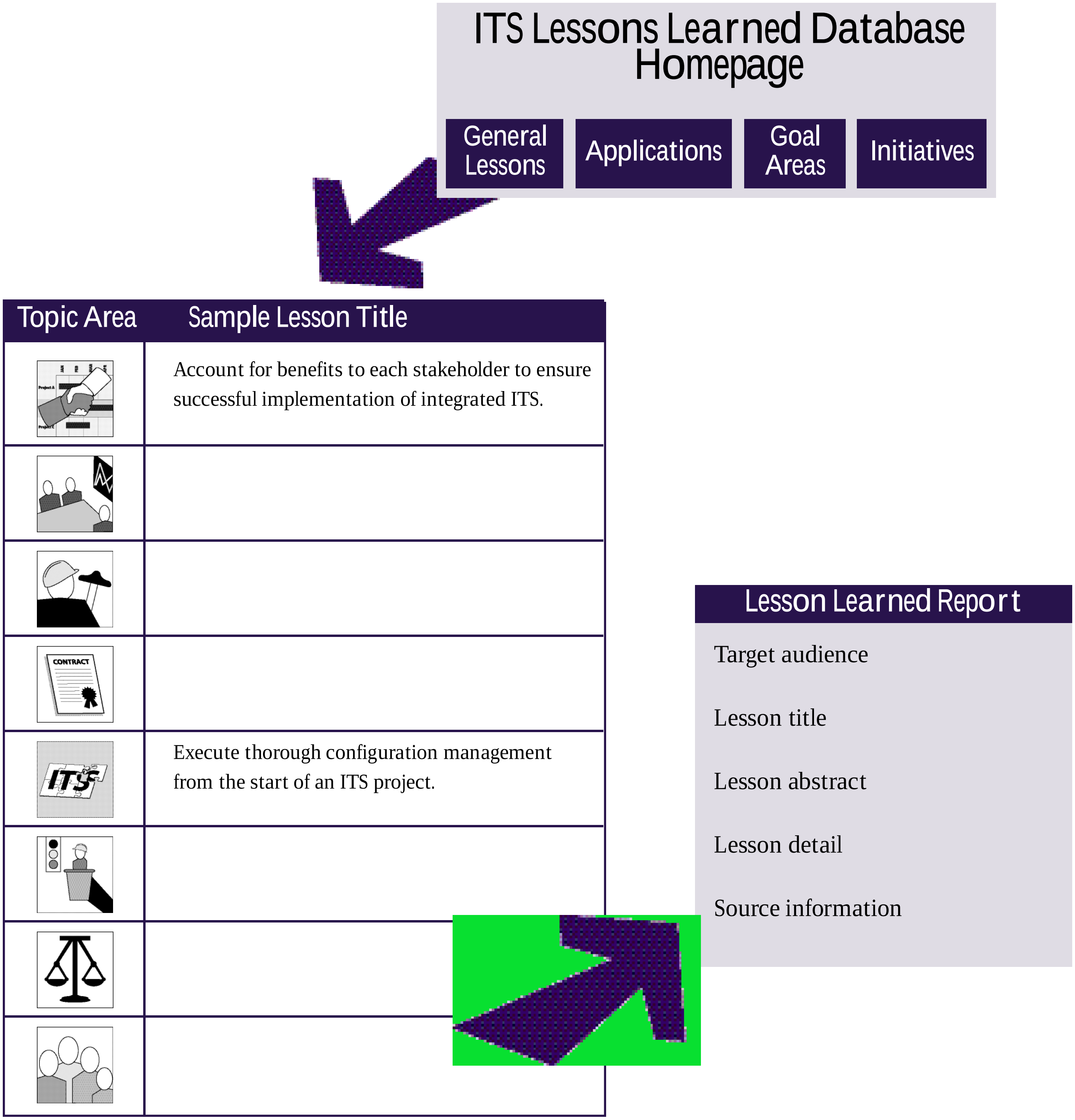


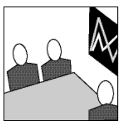
Figure 1.3.1
Lessons Learned Database Access and Output Concept

General Lessons

Management and Partnerships

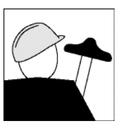
Management and partnerships lessons will capture: outreach and awareness efforts that made stakeholders knowledgeable and accepting of ITS; partnerships that facilitated collaboration and cooperation among multiple agencies in deploying ITS; approaches used to manage ITS programs, projects, and operations; and, policy decisions that impacted ITS. Examples of target groups for the awareness and outreach efforts are general public, elected and appointed officials, and technical staff. Key partnerships of interest include public-private partnerships, and public-public partnerships.

Planning



Planning lessons will capture the approaches used to incorporate the consideration of ITS products and services in the transportation planning process. These approaches may include the development of a regional ITS architecture, an ITS strategic plan, a concept of operations, a traffic analysis tool, or a transportation improvement plan (TIP—metropolitan, statewide).

Design and Deployment

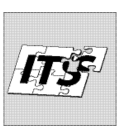


Design and deployment lessons will capture the approaches used in the design and completion of an ITS project, including the choice of appropriate ITS technologies, use of ITS standards and systems engineering, ITS software development issues, and the construction and implementation techniques on-site.

Procurement

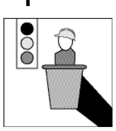
Procurement lessons will capture the approaches that facilitate the purchase of goods and services needed for an ITS project. They may include such items as procurement of ITS hardware and software and contracting methods.

Technical Integration



Technical integration will capture approaches that facilitated the technical connection of systems operated by different entities and the sharing of information from these systems. Such integration may occur among multiple systems, agencies, and regions.

Operations and Maintenance

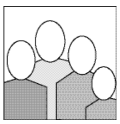


Operations and maintenance (O&M) will capture approaches that keep the ITS products and services functioning after a project has been implemented. O&M issues may include allocation of funds for O&M, outsourcing of specialized O&M services, and electronic and manual inspections that ensure ITS devices remain in operating condition. The operational strategies used to achieve high performance will also be covered.

Legal Issues

Lessons about handling legal issues will capture the approaches that facilitated resolution of potential disputes in areas such as liability, intellectual property rights, and privacy. Liability issues may include approaches that ensured that the legal responsibility for an act or failure to act within a project is properly assigned. Intellectual property rights lessons may capture approaches that equitably distributed the patents, copyrights, trademarks, and other documentation developed within a project among project participants. Privacy lessons may include technical approaches that were used that ensured the privacy of stakeholders is not violated and institutional approaches used that convinced stakeholders that ITS products and services do not infringe upon the privacy of an individual.

Human Resources



Human resources lessons will capture the approaches that ensured the right number of staff was assigned to plan, design, deploy, operate, and maintain an ITS project and that they had the right skills and training.

ITS Application Areas - Infrastructure and Vehicle

The ITS application areas are grouped in two categories—intelligent infrastructure and intelligent vehicle—which also form the structure for discussing the benefits and costs of ITS in this report, as discussed in Section 1.4. Most general lessons are likely to have been experienced through the planning and deployment efforts in one or more of the application areas. In the intelligent infrastructure category, lessons will be gathered in such areas as arterial management, freeway management, incident management, and transit management. In the intelligent vehicle category, lessons collected will fall under collision avoidance systems, driver assistance systems, and collision notification systems.

ITS Program Goal Areas

Lessons will be categorized to reflect the progress being made in advancing the national ITS program goal areas such as improving safety, mobility, and productivity as well as capacity/throughput, customer satisfaction, energy, and environment. These goal areas were previously described in Section 1.1.

USDOT ITS Initiatives

The Lessons Learned Database will identify the potential linkage of a lesson with the USDOT's major ITS initiatives (see Table 1.3.1). The ITS initiatives represent an important step in the continuing evolution of the ITS program and will contribute to strengthening the role of ITS in transportation safety, mobility, productivity, and global connectivity. Additional information on these initiatives can be found on the ITS JPO website (www.its.dot.gov). The purpose of capturing ITS lessons associated with these initiatives is to leverage from the ITS stakeholders' experience in these areas. Lessons learned by the stakeholders could help guide the planning and programming efforts for these initiatives.

Lesson Samples

Spread throughout the remainder of this report is a sampling of the first few lessons gathered. Presented in short summaries, this sampling represents stakeholders' experience in such general areas as: management and partnerships; planning; design and deployment; technical integration; operations and maintenance; legal issues; human resources; and in technology application areas such as arterial management and freeway management.

> "…(t)he obvious is precisely what needs to be pointed out—otherwise, it will be overlooked."
>
> – Peter F. Drucker

In compiling the database, researchers have observed many lessons that appear over and over again in multiple reference sources. To some, these lessons will appear obvious. Nevertheless, these lessons need to be told to a new generation of ITS professionals. As Peter F. Drucker once observed, "…(t)he obvious is precisely what needs to be pointed out—otherwise, it will be overlooked."[31] As noted previously, the Lessons Learned Database is in the process of development, and this report presents only a sampling of ITS lessons in a summary format as an introductory overview. These lessons can be found at the beginning of Section 2 and in the sidebars embedded within the benefits/costs discussions in the subsequent sections. More details of these, as well as new lessons, will be presented in a Lessons Learned Database website planned to be made available to the public in the summer of 2005.

1.4 REPORT ORGANIZATION

In reporting the benefits, costs, and lessons learned in the deployment of ITS, this report follows a classification scheme for categorizing ITS applications. The ITS classification scheme used in this report groups ITS applications into two major components: intelligent infrastructure and intelligent vehicles. These components are then divided into technology application areas. Figures 1.4.1 through 1.4.3 present an overview of this classification scheme. Subsequent sections of this report provide additional detail within each of the major technology application areas.

Intelligent Transportation Systems

- Intelligent Infrastructure
- Intelligent Vehicles

Figure 1.4.1
Classification Scheme for ITS

The classification scheme cannot represent all aspects of ITS. For example, many of the technology application areas can be dependent on or heavily influenced by other areas. This dependency is not well shown in the classification scheme. Also note that many ITS technology application areas share information and operate in a cooperative manner that is difficult to capture in this format. For example, traveler information systems, especially those regional or multimodal in nature, must rely on surveillance data collected by other ITS applications such as freeway, arterial, and transit management systems. In addition, in-vehicle driver assistance systems, such as navigation, can be augmented by a cooperative infrastructure to provide routing and/or travel time information to vehicle systems. Within this report, in cases of integrated deployment of more than one application, system cost and impact data appear under the technology application area that the implementation most directly supports.

Sections 2 and 3 begin with a brief description of the ITS classification scheme components, intelligent infrastructure and intelligent vehicles, respectively. Subsequent subsections within these two sections include a brief description of each technology application area and specific ITS application area. The benefits and costs data are presented in tabular format based on the classification scheme structure for each technology application area. Example lessons learned are provided for many of the technology application areas (described in brief sidebars), throughout Section 2. The example lessons presented in this section have broad applicability across the various areas of ITS deployment. More comprehensive details of these and additional lessons will be presented in the forthcoming Lessons Learned Database, planned to be available in the summer of 2005. Within the benefit and cost tables, impact information is presented by goal area (e.g., safety, mobility, etc.), followed by a listing of relevant unit cost elements (refer to Appendix A), and concluding with available examples of system cost data.

Intelligent Infrastructure

Technology Application Areas

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Incident Management Systems
- Emergency Management Systems
- Electronic Payment Systems
- Traveler Information
- Information Management
- Crash Prevention and Safety
- Roadway Operations and Maintenance
- Road Weather Management
- Commercial Vehicle Operations
- Intermodal Freight

Figure 1.4.2
Classification Scheme for the Intelligent Infrastructure

Intelligent Vehicles

Technology Application Areas

- Collision Avoidance Systems
- Driver Assistance Systems
- Collision Notification Systems

Figure 1.4.3
Classification Scheme for Intelligent Vehicles

Figure 1.4.4 is an excerpt of Table 2.1.1 discussing the benefits and costs of arterial management systems; this portion presents the benefits and costs of ITS applications for bicyclists and pedestrians. Several pieces of information are provided in the benefits portion of the data table in each section of this report. The "Goal Area," one of the "Few Good Measures" discussed earlier in Section 1.1, is followed by the "Number of Studies" in the database identifying impacts within that goal area for a given application of ITS. The "Impact" rating in the third column represents an assessment of the application's impact on the performance goal area, considering the collection of reports in the database (a more complete discussion of these ratings is provided in Table 1.0.1). Impact ratings fall into one of the six categories defined in the Impact Legend below, which is also repeated in each subsection within Sections 2 and 3 of this report. Example impacts for each application are included in the final column of the table, drawn from representative studies within the database.

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

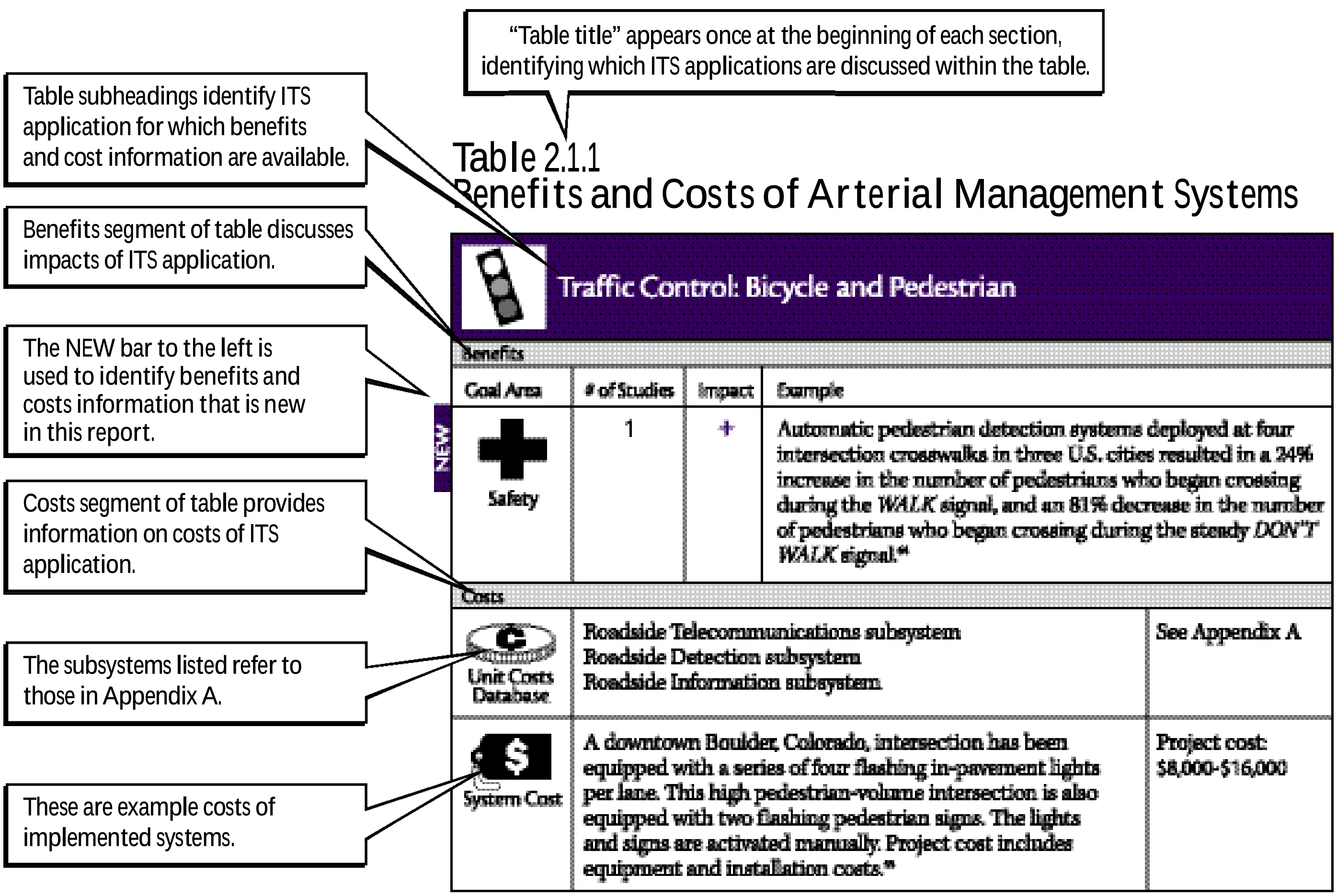
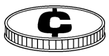


Figure 1.4.4

Excerpt of Table 2.1.1 (describing the benefits and costs of ITS applications for bicyclists and pedestrians)

Unit Costs Database



The costs portion of the data tables in each section include a listing of relevant unit cost subsystems for the application. The icon to the left identifies applicable unit cost subsystems in the Costs Database for the given application area, which can be used to refer to unit cost information in Appendix A. The Costs Database is regularly updated, with the most recent data available at www.benefitcost.its.dot.gov.

System Cost

Sample system cost information, along with a brief description of the implemented system, follows the unit cost information in each data table and is identified by the icon to the left. The purpose of presenting system cost information is to give the reader an example of systems that have been deployed along with the costs of each particular implementation. The reader is reminded that the costs presented are taken from the source documents. Project costs are not reported in a standard format; rather cost data reflect the specific ITS project and vary in detail and content from project to project. Reported costs include: the total cost of the deployment, ITS equipment or component costs, and, less frequently, operations and maintenance (O&M) costs. The parenthetical date following the system cost information represents the dollar year of the cost data, when known. New information on system costs is also added to the online costs database regularly.

Concluding remarks are presented in Section 4. A list of references and endnotes follows Section 4. Appendix A contains the unit cost data from the Costs Database in table format, as of September 30, 2004. Appendix B contains a summary of the data presented in this report. This summary tallies the references documenting ITS benefits and costs available in the online database. Appendix C contains a listing of acronyms and abbreviations used throughout the report.

2.0 BENEFITS, COSTS, AND LESSONS LEARNED OF THE INTELLIGENT INFRASTRUCTURE

The intelligent infrastructure consists of a wide variety of applications intended to improve the safety and mobility of the traveling public, while enabling organizations responsible for providing transportation facilities and services to do so more efficiently. Sections 2.1 to 2.13 of this report will discuss specific applications within the 13 technology application areas that make up the intelligent infrastructure listed in Figure 2.0. ITS can be deployed to improve the operation of both the highway and public transportation systems. Several applications can support critical transportation functions during emergency situations. Other applications facilitate convenient payment for highway tolls and transit fares. Traveler information programs synthesize information collected by ITS and disseminate it to travelers for their benefit in making travel decisions. Information management programs help transportation organizations manage and analyze the flow of data from deployed ITS and use it to improve transportation planning and operations. Crash prevention and safety applications provide a variety of countermeasures, often location-specific, to address transportation safety concerns. Road weather management implementations improve the ability of the highway transportation system to react to adverse weather conditions. Several applications can improve the daily operation and continuing maintenance of the highway system. ITS for commercial vehicle operations (ITS/CVO) and intermodal freight applications help facilitate the smooth and safe flow of freight throughout the country and at our borders.

Several metropolitan areas are implementing ITS services that are very highly integrated. Integration is accomplished by creating links between components, systems, services, or technology application areas. These links are used to share operational information and allow better use of infrastructure across jurisdictional boundaries. One example is sharing arterial traffic condition information originating from a traffic signal system with a freeway management system, allowing the freeway management system to provide expected travel times on alternate routes during congested periods. There are numerous other ways of integrating various implementations of ITS to achieve benefits greater than those of the individual system. The online Benefits Database contains a section presenting the evaluation reports that discuss integrated systems.

Intelligent Infrastructure

Technology Application Areas

- Arterial Management Systems
- Freeway Management Systems
- Transit Management Systems
- Incident Management Systems
- Emergency Management Systems
- Electronic Payment Systems
- Traveler Information
- Information Management
- Crash Prevention and Safety
- Roadway Operations and Maintenance
- Road Weather Management
- Commercial Vehicle Operations
- Intermodal Freight

Figure 2.0
Classification Scheme for the Intelligent Infrastructure

For a more complete understanding of the integration of ITS components, visit the ITS Technology Overview Web Site available through the ITS JPO website (www.its.dot.gov, click "ITS Overview", and follow the link to the ITS Technology Overview Web Site). The ITS Technology Overview Web Site provides a description of the types of information that can be shared between ITS applications to enable integrated operation.

Several documents have also been published which discuss the integration of ITS applications:

- *Metropolitan ITS Integration: A Cross-Cutting Study*. FHWA Report (FHWA-OP-02-083), FTA Report (FTA-TRI-11-02-05). Electronic Document Number 13672.
- *Tracking the Deployment of the Integrated Metropolitan Intelligent Transportation Systems Infrastructure in the USA: FY2002 Results*. FHWA Report. April 2004. (Available at www.itsdeployment.its.dot.gov.)

These documents are electronically available on the ITS Electronic Document Library at www.its.dot.gov/itsweb/welcome.htm.

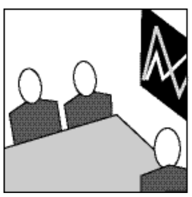
The USDOT has been actively tracking the deployment of ITS applications within the United States since 1997. In order to track progress toward fulfillment of deployment goals established by Secretary of the DOT in 1996, the USDOT ITS JPO developed the metropolitan ITS deployment tracking methodology. This methodology tracks deployment of many of the infrastructure-based ITS applications discussed in this chapter. Information is gathered through a set of surveys distributed to the state and local agencies involved with the various infrastructure components (such as arterial management, freeway management, and transit management systems). The surveys gather information on the extent of deployment of the infrastructure and on the extent of integration between the agencies that operate the infrastructure. Deployment is measured using a set of indicators tied to the major functions of each component. Integration is measured by assessing the extent to which agencies share information and cooperate in operations based on a set of defined links between the infrastructure components.[36]

Information collected during the ongoing series of surveys is available at the deployment tracking website, www.itsdeployment.its.dot.gov. This website contains updated information on the deployment of many infrastructure-based ITS applications discussed in this chapter.

ITS LESSON SAMPLES

A sample of six general ITS lessons is presented in this section. Often, an ITS lesson depicts a combination of experiences encompassing one or more of the ITS application areas (e.g., arterial management, freeway management) as well as nontechnical areas (e.g., human resource, legal issue). Broadly, these general lessons are classified in the following topic areas—management and partnerships; planning; design and deployment; procurement; technical integration; operations and maintenance; legal issues; and human resources. The lessons presented below are in a summary format, intended to be a prelude to the efforts currently under way by the ITS JPO to develop a publicly accessible ITS Lessons Learned Database. The database is expected to include lessons learned in all major ITS categories previously identified in **Table 1.3.1**.

1. A Delaware experience in ITS planning[37]



Lesson Learned–Include ITS in long-range plans.

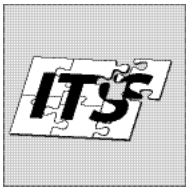
"Winning buy-in as part of the department's long-range plans is often easier in the long run than winning ongoing battles for approval for each project," noted a 2004 evaluation of the Delaware Department of Transportation's (DelDOT) statewide ITS program, DelTrac.

DelTrac was an integral part of the 2002 Statewide Long-Range Transportation Plan. Because the long-range plans at DelDOT called for radio broadcast of traveler information, DelDOT was able to take advantage of the available radio license to develop its traveler information services when a primary radio license became available in 2000, well before the DelTrac ITS infrastructure was actually in place to provide real-time traffic information.

The DelTrac evaluation provided a number of suggestions for inclusion of ITS in the department's long-range plan:

- Include ITS projects in the department's long-range plan in order to receive more stable and predictable funding.
- State the expected transportation benefits of an ITS project to increase its potential for inclusion in the long-range plan.
- Highlight ITS integration opportunities with other transportation projects to obtain support for ITS across divisions within the department.
- Gain management buy-in to the benefits of ITS in order to include ITS in the long-range plan.
- Take advantage of cost-effective deployment choices once ITS projects are in the long-range plan. For example, in Delaware, the long-range plan for ITS called for connecting many miles of road to a common telecommunication backbone. Actual installation of segments of this backbone was then linked, whenever possible, to existing buildings or maintenance projects, resulting in much more cost-effective fiber installation.

2. A Utah experience in technical integration[30]



Lesson Learned–Execute thorough configuration management from the start of an ITS project.

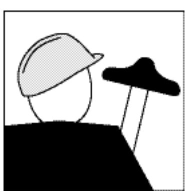
The Utah Department of Transportation's (UDOT) Salt Lake City ITS deployment, known as CommuterLink, is among the most comprehensive ITS operations in the nation. All ITS enabled functions and services are integrated, controlled, and monitored at the Traffic Operations Center (TOC).

In 2002, UDOT executed a series of case study evaluations that assessed the components of the CommuterLink deployment. Highlights of the lessons learned regarding technical integration of systems included:

- Execute thorough configuration management from the start of an ITS project.
- Be aware that "off-the-shelf" software comes with its own set of bugs, software licenses, languages, and interdependencies.
- Develop a preferred integration and software support approach for the agency and require the contractor to support that approach.

Maintaining accurate information about the current configuration was a challenge during the CommuterLink deployment. On a frequent basis, the contractor would add components and integrate new capabilities to the traffic operations center. There were also frequent changes in the communications channels as new backbone communications came online. A configuration management approach should have been in place from the start that identified the naming conventions, interfaces, and required protocols.

3. National experience in design and deployment with ITS standards[38]



Lesson Learned–Call out specific standards from the NTCIP group when procuring standards-based DMS.

The lessons cited were drawn from the experience of nine agencies that were among the first to use Dynamic Message Sign (DMS) built to the National Transportation Communications for ITS Protocol (NTCIP) specification. NTCIP is a group of ITS standards. ITS standards allow systems to talk to one another by supporting standard information exchange. Standards are designed to promote interchangeability and interoperability. DMS was one of the first systems to use elements of NTCIP and prove that the standard works.

The following are highlights of the lessons that past implementers offer on NTCIP-based DMS:

- Use NTCIP standards to enable the procuring agency to select from a larger pool of DMS vendors and avoid using proprietary software.
- Ask for and verify DMS vendor references, NTCIP specifications, and time to install.
- To reduce deployment risks, utilize vendors who have already (successfully) installed NTCIP-based DMS.
- When developing the Request for Proposals (RFP), specify more than just NTCIP compliance; call out the exact standards from the NTCIP group, and be specific about communications planned for the DMS and data exchange rates.

It is also reported that the lowest price is not always the best solution, and that incorporating standards into ITS design and deployment is an investment in the future.

4. A lesson in integrated ITS transit management and partnerships[39]

Lesson Learned–Account for benefits to each stakeholder to ensure successful implementation of integrated ITS.

An independent cross-cutting study looked into six ITS transit field operational tests to learn what made them successful or not. These field tests included: SmarTrip® (Washington, D.C.), SmartCard (Chicago, IL), Translink (San Francisco Bay Area, CA), Go Ventura (Ventura County, CA), Automated Dispatching (Santa Clara, CA), and Smart Shuttle (San Gabriel Valley, CA). The study included several lessons on the implementation of integrated ITS transit involving multiple organizations:

- Perform basic feasibility checks in planning that ask: "Will ITS solve the problem?" "Is it the best solution?"
- Develop clear goals and objectives that are agreed to by all parties, and verify that the technology solution is consistent with objectives.
- Implement formal institutional arrangements that provide for appropriate allocation of responsibility and risk.
- Provide for incremental deployment of technology to minimize the burden on participants; avoid potential costly mistakes; and allow learning during deployment.
- Presume the required ITS knowledge and skill levels may not exist within all participating organizations.
- Reflect the benefits of integration to all participants in the institutional agreements.

More details of these and additional lessons will be presented in a website planned to be available publicly in the summer of 2005.

2.1 Arterial Management Systems

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

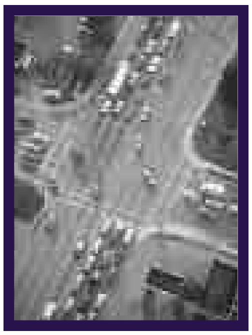
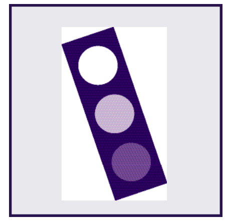


Figure 2.1.1, showing a portion of the ITS classification scheme, lists the variety of systems that may be employed as part of arterial management systems. Many of the services possible through arterial management systems are enabled by traffic surveillance technologies, such as sensors or cameras monitoring 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. Transit signal priority systems can ease the travel of buses or light-rail vehicles traveling arterial corridors and improve on-time performance. Signal preemption for emergency vehicles enhances the safety of emergency responders, reducing the likelihood of crashes while improving response times. Adaptive signal control systems coordinate control of traffic signals, across metropolitan areas, adjusting the lengths of signal phases based on prevailing traffic conditions. 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. 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 dynamic message signs, 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 (HOV) restrictions and the use of reversible flow lanes, allowing more lanes of travel in the peak direction of travel during rush hours. Parking management systems, most commonly deployed in

Intelligent Infrastructure



Arterial Management Systems

- Surveillance
  - Traffic
  - Infrastructure
- Traffic Control
  - Transit Signal Priority
  - Emergency Vehicle Preemption
  - Adaptive Signal Control
  - Advanced Signal Systems
  - Variable Speed Limits
  - Bicycle and Pedestrian
  - Special Events
- Lane Management
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
- Parking Management
  - Data Collection
  - Information Dissemination
- Information Dissemination
  - Dynamic Message Signs (DMS)
  - In-Vehicle Systems (IVS)
  - Highway Advisory Radio (HAR)
- Enforcement
  - Speed Enforcement
  - Stop/Yield Enforcement

Figure 2.1.1
Classification Scheme for Arterial Management Systems

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. Organizations operating ITS can share information collected by arterial management systems with road users through technologies within the arterial network, such as dynamic message signs or highway advisory radio. Arterial management systems may also include automated enforcement programs that increase compliance with speed limits, traffic signals, and other traffic control devices.

Sharing information with other components of the ITS infrastructure 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 roadway and public transit facilities.

Table 2.1.1 provides information on the benefits and costs of arterial management systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.1.1
Benefits and Costs of Arterial Management Systems

Surveillance

Benefits		
Supporting role, no benefits information.		
Costs		
Unit Costs Database	Roadside Telecommunication subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Utah Advanced Transportation Management System (ATMS) includes more than 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 includes the cameras and installation. The lifetime of the cameras is 10 years.[3]	Cameras and installation cost: $8.4 million Annual operating cost for cameras: $75,600 (NEW)
System Cost	In April 2001, the city of Colorado Springs, Colorado, began the process of replacing in-pavement loops with video detection at 420 intersections. Separate contracts were let for equipment and installation. The equipment included a two-year warranty and free upgrades. (Fine-tuning of the cameras was performed by city crews.) The cost per intersection varied based on the type of intersection (mast arm, span wire), number of cameras (one to eight), and additional work (lighting). The average cost per intersection does not include city crew staff time, but does include the cost of a custom-built video van, an additional bucket truck, and various test equipment. The relatively low cost per intersection is due in part to the large number of intersections involved in the project.[40]	Average cost per intersection: $13,000 Total project cost: $5.6 million (NEW)

Lessons Learned

Consider video detectors as an alternative to loops.[40]

The city of Colorado Springs experience in design and deployment

Colorado Springs, Colorado, has one of the largest video based arterial traffic detection systems in the United States. The city's signal system includes 420 actuated or semi-actuated signals that required 10,000 loop detectors. The annual loop failure rate was 20%; 2,000 out of 10,000. After an evaluation of available technologies in 2001, the city replaced the loop detectors with video detectors to enhance detection capabilities and reduce maintenance costs. Colorado Springs also utilized innovative contracting mechanisms to procure and install the video detection system.

Lessons Learned

Continued from page 35

The critical system design and deployment lessons learned include:

- Establish camera locations by a field trip to visualize what the camera will see.
- Never have the horizon in the picture or other large reflective surfaces.
- Instead of shooting across many lanes, install additional cameras to eliminate occlusion.

Since the video detection installation, there has been a significant reduction in service needs compared to loops. The total project, including the 420 intersections, cost approximately $5,600,000.

Traffic Control: Transit Signal Priority

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	15	++	Experience in 11 cities in the U.S. and abroad show 2–20% to 20% improvement in bus travel time.[12, 41, 42, 43, 44, 45, 46] Several studies show significant reduction in travel time variability, with a corresponding improvement in on-time performance.
Productivity	2	+	On a Toronto, Canada, light-rail transit line, signal priority allowed same level of service with less rolling stock.[47]
NEW Energy/ Environment	2	+	Simulation of a hypothetical transit signal priority system along a heavily traveled corridor in Arlington County, Virginia, found a 2–3% reduction in fuel consumed by buses across a number of priority scenarios.[42]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem Transportation Management Center subsystem	See Appendix A
NEW System Cost	A bus rapid transit (BRT) system was deployed to enhance bus operations and improve customer service in the Greater Vancouver area of British Columbia, Canada. In August 2001, BRT route #98 B-Line was introduced to connect the city of Richmond with Vancouver. The BRT service includes several ITS components, including automated vehicle location (AVL) technology, transit signal priority systems, on-board voice and digital announcements of next stop information, and real-time bus arrival time information using digital countdown signs at bus stops.[48]	Transit signal priority system: $1.6M (CAD) (2001)
System Cost	The Los Angeles DOT (LADOT) implemented a $10 million bus signal priority demonstration project along two corridors (Ventura Boulevard and the Santa Monica-Beverly Hills-Montebello route) in the City of Los Angeles, California. The initial deployment began in June 2000. The system consists of 331 loop detectors, 210 intersections equipped with automatic vehicle identification (AVI) sensors at the controller cabinet, and 150 transponder-equipped buses. Loop detection technology is used to detect the presence of a bus approaching the intersection. The bus identification is detected by the AVI sensor and sent to the transit management computer located at the LADOT transportation management center. The system checks the bus' schedule and headway to determine if it is early or on time. If the bus is behind schedule, one of four types of priority modes is granted.[46,49]	Total project cost: $10 Million Average cost: $13,500 per signalized intersection (2000) Transponder cost: Approximately $75 per bus (2000)
System Cost	The cost of transit signal priority systems varies based on many factors such as system design and functionality and type of equipment. Based on information reported in a recent ITS America report, the per-intersection cost of a transit priority system covers a wide range.[50]	Cost range: $8,000–$35,000 per intersection

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ! not enough data – negative impacts

Traffic Control: Emergency Vehicle Preemption

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	3	++	NEW A study in Houston, Texas, found signal preemption reduced average emergency vehicle response times by 16% in one fire district, 23% in another.[51] A simulation study in the Virginia suburbs of Washington, D.C., found emergency vehicle preemption caused minimal increases in average travel times (2.4%) for all traffic.[52]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Emergency Response Center subsystem Emergency Vehicle On-Board subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Several intersections in British Columbia, Canada, 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*. A visual verification system (set of blue and white lights) indicates that the intersection is controlled by an emergency vehicle preemption system and when the system has been activated.[53]	Cost: $4,000 per intersection (can be less if multiple intersections are equipped)

Traffic Control: Adaptive Signal Control

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	18	++	Studies from six cities in Canada, Brazil, Spain, and Scotland indicated delay reductions from 5–42% after installation of adaptive signal control.[54, 55, 56, 57, 58]
NEW Capacity/ Throughput	1	+	A study of the integrated deployment of freeway ramp metering and adaptive signal control on adjacent arterial routes in Glasgow, Scotland, found a 20% increase in vehicle throughput on the arterials and a 6% increase on freeways. Arterial traffic increased 13% after implementation of ramp metering and an additional 7% with the initiation of adaptive signal control.[58]
Energy/ Environment	3	+	Adaptive signal control in Toronto, Canada, has yielded emission reductions of 3–6% and fuel savings of 4–7%.[57]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Control subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Arlington County, Virginia, Department of Public Works, Traffic Engineering Division, recently brought 65 intersections (expandable to 235) under an adaptive signal control system. The cost included software, hardware, roadside equipment, cabling, mobilization and maintenance of traffic, installation, training, maintenance and test equipment, and system documentation.[59]	Total project cost: $2.43 million (2001)

Traffic Control: Advanced Signal Systems

Benefits

Goal Area	# of Studies	Impact	Example
Safety	3	+	Signal coordination along a Phoenix, Arizona, corridor resulted in a 6.7% reduction in crash risk, calculated based on improved travel speeds and a reduction in the average number of stops.[60]
Mobility	16	++	Signal coordination at 145 intersections in Syracuse, New York, reduced the total delay experienced by vehicles during the a.m.-peak, mid-day, and p.m.-peak periods by 14–19%.[1] NEW
Capacity/ Throughput	1	?	A simulation study of re-timed traffic signals along two major arterials north of Seattle, Washington, found a 7.0% annualized reduction in vehicle delay, accompanied by a 0.2% increase in vehicles traveling the corridor.[61] NEW
Productivity	3	+	Assigning a monetary value to reductions in delay, fuel use, and emissions achieved during a $4.7 million dollar upgrade of the Richmond, Virginia, signal system yielded benefits of $4.2 million annually.[62]
Energy/ Environment	9	+	Modeling studies of coordinated signal control in five U.S. localities found reductions in fuel use ranging from no significant change in Seattle, Washington, to a 13% decline in Syracuse, New York.[1, 60, 61, 62, 63]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Control subsystem Transportation Management Center subsystem	See Appendix A
System Cost	To improve air quality in downtown Syracuse and Onondaga County, the New York State Department of Transportation (NYSDOT) installed a computerized traffic signal system and optimized the signal timing of 145 intersections.[1]	Total project Cost: $8,316,000 NEW
System Cost	The Utah Advanced Transportation Management System (ATMS) includes a coordinated signal system. More than 600 of the 900 signals in the Salt Lake Valley are connected to the traffic operations center (TOC). With the installation of the communication system and central traffic control system, monitoring and adjusting the signal system is performed at the TOC rather than by site visit. Currently, more than 50 coordinated corridors have been implemented by Utah DOT. The cost of the signal system includes only the communication capability. The signals were already in place prior to the ATMS implementation.[3]	Signal communication capability: $2.2 million Annual maintenance cost: $15,000 NEW

Traffic Control: Bicycle and Pedestrian

Benefits

Goal Area	# of Studies	Impact	Example
NEW Safety	1	+	Automatic pedestrian detection systems deployed at four intersection crosswalks in three U.S. cities resulted in a 24% increase in the number of pedestrians who began crossing during the *WALK* signal, and an 81% decrease in the number of pedestrians who began crossing during the steady *DON'T WALK* signal.[64]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	A downtown Boulder, Colorado, 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. Project cost includes equipment and installation costs.[53]	Project cost: $8,000-$16,000

Traffic Control: Special Events

Benefits

No data to report.

Costs

NEW Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Control subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
NEW System Cost	The Utah ATMS includes a coordinated signal system. More than 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. The signals were already in place prior to the ATMS implementation.[3]	Signal communication capability: $2.2 million Annual maintenance cost: $15,000

Parking Management

Benefits			
Goal Area	# of Studies	Impact	Example
Capacity/ Throughput	1	?	Experience with parking management systems in Europe indicates a 25% reduction in downtown traffic volumes related to the search for parking.[65]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Parking Management subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Seattle Center Advanced Parking Information System in Seattle, Washington, provides information and routing directions to three major parking centers via variable message signs. This information is also available via the Internet, phone, and pagers to travelers prior to leaving for an event as well as travelers en route. Detection technology is used to monitor parking availability.[5]	Project cost: $925,265 (1998) Annual O&M cost: $50,523 (1998)

NEW

Information Dissemination: Dynamic Message Signs

TRAVEL ADVISORY TUNE TO 750AM

Benefits
No data to report (for applications on arterials).

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Utah DOT operates and maintains more than 69 permanently mounted variable message signs (VMS) on freeways and surface streets as part of the Utah Advanced Transportation Management System. Portable message signs are also used along roadsides where there is no permanent VMS. The annual operating cost is based on power consumption (electricity).[3]	Cost of VMS: $15.25 million Annual VMS operating cost: $21,960

NEW

Information Dissemination: In-Vehicle Systems (IVS)

Benefits

No data to report.

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Information Dissemination: Highway Advisory Radio

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Telecommunications susbsystem Roadside Information subsystem	See Appendix A
System Cost	No data to report (for applications on arterials).	

Enforcement: Speed Enforcement

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	5	+	A 1999 Institute of Transportation Engineers (ITE) synthesis study on automated enforcement lists two U.S. cities with automated speed limit enforcement programs, with documented crash reductions of 40% in Paradise Valley, Arizona, and 51% in National City, California.[66]
Customer Satisfaction	1	+	Fifteen months after extensive deployment of automated speed enforcement cameras in Great Britain, a nationwide survey found 70% of those surveyed thought that well-placed cameras were a useful way of reducing accidents and saving lives, while 21% thought that speed cameras were an infringement of civil liberties.[67] (NEW)

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	In April 2000, a cost recovery system for speed and red-light cameras was introduced in eight pilot areas in England, Wales, and Scotland. In Strathclyde, 28 fixed camera sites were established in mostly 30 mph 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, which may be due in part to not all of the sites being 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 partnership was one of the more experienced.[67]	First year cost: £204,330 Second year cost: £740,896 (NEW)

Enforcement: Stop/Yield Enforcement

Benefits

Goal Area	# of Studies	Impact	Example
Safety	12	?	Red light camera programs have resulted in reported violation reductions ranging from 20–75%; findings on crash impacts have been inconclusive.[68]
Customer Satisfaction	2	++	Public opinion surveys indicated 60–80% support for red light camera programs.[68]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem	See Appendix A
System Cost	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. 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).[69]	Costs per intersection: $67,000-$80,000
NEW System Cost	In April 2000, a cost recovery system for speed and red-light cameras was introduced in eight pilot areas in England, Wales, and Scotland. In Nottingham, two digital camera sites were implemented on its ring road. Mobile enforcement also took place at seven mobile sites and 19 red-light sites. Most enforcement took place in 30 mph 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, which may be due in part to not all of the sites being 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 partnership had comparatively less experience of camera enforcement.[67]	First year cost: £622,371 Second year cost: £778,536

2.2 Freeway Management Systems

There are six major ITS functions that make up freeway management systems, as shown in Figure 2.2.1. Traffic surveillance systems use detectors and video equipment to support the most advanced freeway management applications. These sensors can also be used to monitor critical transportation infrastructure for security purposes. 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), in-vehicle signing, or specialized information transmitted to individual vehicles. Other methods of providing traveler information, including those covering multiple modes or travel corridors, are discussed in Section 2.7–Traveler Information. Automated systems enforcing speed limits and aggressive driving laws can lead to safety benefits.

Table 2.1.1 provides information on the benefits and costs of freeway management systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure

Freeway Management Systems

- Surveillance
  - Traffic
  - Infrastructure
- Ramp Control
  - Ramp Metering
  - Ramp Closures
  - Priority Access
- Lane Management
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
- Special Event Trans. Mgmt.
  - Occasional Events
  - Frequent Events
  - Other Events
  - Temporary TMCs
- Information Dissemination
  - Dynamic Message Signs (DMS)
  - In-Vehicle Systems (IVS)
  - Highway Advisory Radio (HAR)
- Enforcement
  - Speed Enforcement
  - High Occupancy Vehicles (HOV)
  - Ramp Meter Enforcement

Figure 2.2.1
Classification Scheme for Freeway Management Systems

Table 2.2.1
Benefits and Costs of Freeway Management Systems

Traffic Surveillance

Benefits

Supporting role, no benefits information.

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
NEW System Cost	The Florida Department of Transportation (FDOT), ITS Division, examined the design factors for closed-circuit television (CCTV) video camera sites and how the design and maintenance issues impact the life-cycle costs. FDOT reviewed studies on this subject and collected information from similar projects in other states. Pole height and effect on camera system performance, site placement and spacing, coverage area, environmental impacts, and use of camera-lowering devices are detailed in the report. The costs of several alternatives based on pole height and mounting with/without camera-lowering devices are compared in the report.[70]	Camera site, initial costs: **$16,550–$27,550** Camera system, life cycle costs: **$403,650–$835,000**
NEW System Cost	The Utah DOT employs traffic monitoring stations at approximately 1/2 mile intervals along Salt Lake Valley freeways as part of the Utah Advanced Transportation Management System (ATMS). The in-pavement congestion sensors allow CommuterLink operators to monitor traffic conditions. The sensors provide operators with information on traffic volume, speed, and congestion. Annual operational cost is based on power consumption (electricity).[3]	Congestion sensor cost: **$2.1 million** Annual maintenance cost: **$42,000** Annual operational cost: **$37,800**
NEW System Cost	The Illinois Department of Transportation (IDOT) District 8 will be deploying ITS field devices in conjunction with several multi million dollar construction projects. Technical and cost options were evaluated and presented to IDOT District 8 for a communication network connecting the ITS field devices to the transportation operations center. At the time of the study, a number of ITS devices were connected via leased telecommunication lines. IDOT desired to move away from the leased communication structure and associated recurring monthly costs. The major interstates in District 8 collectively encompass approximately 105 miles of centerline highway. The ITS devices that would be deployed along these interstates include CCTV cameras with pan/tilt/zoom, video detection stations, DMS, and HAR. Technical and non technical issues as well as initial and long-term costs were considered in the various communication alternatives. Initial capital cost, operations and maintenance (O&M) costs, and 15-year life-cycle costs are provided for four communication options.[71]	For the four options evaluated, capital costs range from **$18.1 million** to **$26 million**, and life cycle costs range from **$43 million** to **$52.5 million**

Ramp Control: Ramp Metering

Benefits

Goal Area	# of Studies	Impact	Example
Safety	5	+	A survey of traffic management centers in eight cities found that ramp metering reduced the accident rate by 24–50%.[72] NEW
Mobility	8	++	Two studies in Minneapolis-St. Paul, Minnesota, and one in Long Island, New York, place mainline speed increases on freeways with ramp metering between 8% and 26%.[73, 74, 75]
Capacity/ Throughput	3	++	The Minneapolis-St. Paul, Minnesota, shutdown study found that freeway volumes were 10% higher with ramp meters than they were during the shutdown.[73] A study in Glasgow, Scotland, found freeway volumes increased by 5% with ramp metering.[58]
Customer Satisfaction	3	++	Support for complete shutdown of the Minneapolis-St. Paul, Minnesota, ramp metering system dropped from 21% in 2000 to just 14% of survey respondents after implementation of a modified operating strategy in 2001.[73] Fifty-nine percent of survey respondents in Glasgow, Scotland, found ramp metering to be a helpful strategy.[58]
Energy/ Environment	1	?	A simulation study of the Minneapolis-St. Paul, Minnesota, system found 2–55% fuel savings for vehicles traveling along two modeled corridors under varying levels of travel demand.[74]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem	See Appendix A
System Cost	The Utah DOT employs 24 freeway ramp meters as part of the Utah ATMS. Ramp metering consists of sensors and traffic signals at freeway entrances to control the number and frequency of vehicles entering the freeway. The capital cost of ramp metering is the full cost to implement, including the design, equipment, and installation.[3, 76]	Cost of ramp metering is the full cost to implement, including the design, equipment, and installation: $5,750,000 Annual maintenance cost: $13,800 Annual Operational cost: $8,280 NEW

Lessons Learned

Ensure team effort, political champion involvement, and consistent community outreach throughout the project to successfully enable High Occupancy/Toll (HOT) lanes.[81]

A California management and partnerships experience

The HOT lanes on southern California's I-15 are operated under the FasTrak program of the San Diego Association of Governments (SANDAG). FasTrak HOT lanes opened in 1996 and evolved from underutilized high occupancy vehicle (HOV) lanes. To preserve the carpooling incentive, FasTrak HOT lanes remain free of charge for vehicles with two or more persons during the morning and afternoon peak periods in the direction of peak flow. Solo drivers can use HOT lanes for a toll paid through electronic toll collection technology. Actual tolls are based on real-time traffic levels on the I-15 Express Lanes. The tolls are posted on roadside FasTrak toll signs located before the entrance to the Express Lanes.

SANDAG made early and aggressive efforts to assess the public opinion and paid close

Lane Management: Lane Control

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	Traffic surveillance, lane control signs, variable speed limits, and dynamic message signs in Amsterdam, the Netherlands, have led to a 23% decline in the accident rate.[65]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Transportation Management Center subsystem	See Appendix A
System Cost	No data to report.	

Lane Management: Variable Speed Limits

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	In England, variable speed limits supplemented with automated speed enforcement have reduced rear-end accidents on approaches to freeway queues by 25–30%.[65]
Capacity/ Throughput	1	?	Combined with automated speed limit enforcement, an English variable speed limit system has increased freeway capacity by 5–10%.[65]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Roadside Detection subsystem Roadside Information subsystem	See Appendix A
System Cost	Washington State DOT (WSDOT) implemented Travel Aid, a variable speed limit system that changes as the weather does, along the Snoqualmie Pass (I-90) east of Seattle, Washington. Approximately 13 miles are operated as variable speed limit during the winter months. The system consists of radar detection, six environmental sensor stations (ESS), nine DMS, and radio and microwave transmission systems.[53, 77, 78]	Design and implementation cost: $5million (1997)

Special Event Transportation Management

EVENT PARKING NEXT EXIT

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Parking Management subsystem	See Appendix A
System Cost	No data to report.	

Information Dissemination: Dynamic Message Signs

TRAVEL ADVISORY TUNE TO 750AM

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	A San Antonio, Texas, deployment of DMS, combined with an incident management program resulted in a 2.8% decrease in crashes.[10]
Mobility	14	+	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%.[79]
Customer Satisfaction	7	+	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% of respondents used the information more than five times per month to adjust travel routes during winter months, and 18% of respondents used the information more than five times per month to adjust travel routes during non-winter months.[2]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Utah DOT operates and maintains more than 69 permanently mounted variable message signs (VMS) on freeways and surface streets as part of the Utah Advanced Transportation Management System. Portable message signs are also used along roadsides where there is no permanent VMS. Annual operating cost for the VMS is based on power consumption (electricity).[3]	Cost of VMS: $15.25 million Annual VMS operating cost: $21,960

NEW

Lessons Learned

Continued from page 48

attention to marketing issues throughout the project implementation. The following are highlights of the partnership and leadership lessons learned through project development and implementation:

- Encourage detailed project agreements that specify roles and responsibilities of participating agencies as early in the project process as possible, leaving adequate flexibility for unexpected issues.
- Ensure strong community outreach efforts throughout the project, and clearly communicate the goals, plans, progress and benefits.
- Consider local political buy-in as a key factor in HOT lane success.

An example of the FasTrak's continuing outreach was the execution of an 800-person telephone survey in 2001. The survey found that users support the FasTrak lanes, and data on the use of the facility supports this finding. Daily vehicle traffic on I-15 increased from 100,000 vehicles in 1992 to 250,000 in 2002.

Information Dissemination: Highway Advisory Radio

Benefits		
No data to report.		
Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
NEW System Cost	Washington State Department of Transportation (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 ESSs were installed at Sherman Pass and the town of Laurier, and two mobile HAR systems were installed near the town of Republic and at the town of Kettle Falls. Broadcasts warn motorists of road construction, incidents, dangerous driving conditions and restrictions, and border crossing conditions and closures.[20]	Two ESSs: $45,000 each HAR cost: $111,073 -Two mobile HAR: $52,000 -Signs, connectivity, clearing, and other associated costs: $59,073
System Cost	Washington State DOT deployed 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. Annual O&M costs are based on prior experience to operate and maintain.[13]	Average cost of the HAR (including installation): $20,000 (2001) Annual O&M cost: $1,000 (2001)

Enforcement: Speed Enforcement

Benefits

Goal Area	# of Studies	Impact	Example
Safety	10	++	A study of two years of crash data following deployment of speed cameras at study sites throughout Great Britain found a 35% reduction in the number of people killed or seriously injured at camera locations. There was a 14% decline in the number of personal injury accidents.[67] NEW
Customer Satisfaction	3	+	Eighty-two percent of survey respondents in the Washington, D.C., area favored video technology used to enforce aggressive driving laws such as not speeding and not following too closely.[80]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem	See Appendix A
System Cost	In April 2000, a cost recovery system for speed and red-light cameras was introduced in eight pilot areas in England, Wales, and Scotland. The Northamptonshire pilot consisted of five 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 1 km). Enforcement took place at 10 sites where the speed limit was 60–70 mph. 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.[67]	First year cost: £1,702,404 Second year cost: £2,247,838 NEW

2.3 Transit Management Systems

Transit ITS services include a number of ITS applications that can help transit agencies increase safety and improve 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 now monitor in-vehicle and in-terminal surveillance systems to improve quality of service and improve the safety and security of passengers and operators.

Transportation demand management services increase public access to transit resources where coverage is limited. Fleet management systems improve transit reliability through implementation of automated vehicle location (AVL) and computer-aided dispatch (CAD) systems which can reduce passenger wait times. These systems have sometimes been implemented with in-vehicle self-diagnostic equipment to automatically alert maintenance personnel of potential problems.

Public access to bus location data and schedule status information is increasingly popular on transit Internet websites. 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 time, and on-board systems such as next-stop audio annunciators help passengers in unfamiliar areas reach their destinations.

Figure 2.3.1 shows the classification of benefits and costs information for transit management systems. Transit signal priority and electronic payment systems, discussed in Sections 2.1 and 2.6, respectively, also provide significant benefits to transit operations.

Table 2.3.1 provides information on the benefits and costs of transit management systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure

Transit Management Systems

- Safety and Security
  - In-Vehicle Surveillance
  - Facility Surveillance
  - Employee Credentialing
  - Remote Disabling Systems
- Transportation Demand Management
  - Ride Sharing/Matching
  - Dynamic Routing/Scheduling
  - Service Coordination
- Fleet Management
  - AVL/CAD
  - Maintenance
  - Planning
- Information Dissemination
  - In-Vehicle Systems (IVS)
  - In-Terminal/Wayside
  - Internet/Wireless/Phone

Figure 2.3.1
Classification Scheme for Transit Management Systems

Table 2.3.1
Benefits and Costs of Transit Management Systems

Safety and Security: In-Vehicle Surveillance

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The Ann Arbor, Michigan, transit on-board camera systems were often noticed by passengers, but the system only provided a significant feeling of additional security when respondents were traveling at night.[82]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
NEW System Cost	CCTV cameras are one of the primary surveillance systems used on transit vehicles. The cost of CCTV camera systems have decreased in recent years and now come as options on new transit vehicles. In Chicago, Illinois, on-board transit surveillance systems were installed on 322 buses. Multiple cameras were installed on the interior of each bus to ensure complete coverage, and digital event recorders were used to securely capture video, audio, and sensor data. In 1998, the Chicago Transit Authority (CTA) reported the total cost of installation was $3.1 million. The cost per vehicle depends on the technology deployed, complexity, and size of the system. Typically, analog CCTV systems are least expensive and digital CCTV systems are more expensive. Digital event recorders are capable of recording visual images as well as signals from other on-board systems.[83]	CTA on-board system surveillance cost: $3.1 million (1998) CCTV system median cost per vehicle: $6,500 Digital event recorder systems per vehicle: $5,000–$7,000

Safety and Security: Facility Surveillance

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	When respondents in Ann Arbor, Michigan, rated the degree to which improvements increased their sense of security, police presence showed the greatest influence, followed closely by increased lighting. Emergency phones and video cameras had less influence.[82]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem Remote Location subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

Transportation Demand Management: Dynamic Routing/Scheduling

FOR RIDE SHARING INFO CALL 511

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	In Eindhoven, the Netherlands, onboard computers recorded daily transit performance. This information was used to plan minimum transit route times and increase schedule reliability.[84]
Customer Satisfaction	1	?	In San Jose, California, the Outreach paratransit program installed AVL on 40 vehicles, as part of an automated scheduling and routing system. A paratransit driver commented that she was satisfied with the system. In particular, she cited its usefulness in settling driver-passenger disputes concerning on-time performance.[85]
Productivity	4	+	The automated scheduling and routing system installed in San Jose, California, enabled shared rides to increase from 38 to 55%, allowing the fleet size to decrease from 200 to 130 vehicles.[85]

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	The cost of demand-responsive operational software and computer-aided dispatching systems varies depending on the transit mode, application, and system functionality. Low-end systems can facilitate scheduling, accounting, and report generation activities. High-end systems generally have more advanced transit demand management features and can automate passenger registration, schedule trips in real time, interface with GIS and AVL systems, and communicate with digital mobile messaging systems.[86]	Cost range: $10,000–$50,000+ per system implementation

Lessons Learned

To ensure successful Automatic Vehicle Location and Computer Aided Dispatch (AVL/CAD) integration that involves legacy systems, perform thorough configuration management starting early in the planning process.[97]

A small transit agency's experience with AVL/CAD integration

Montachusett Area Regional Transit Authority (MART) is a small transit operator in rural Massachusetts. It operates fixed route and paratransit service. In 2000, MART instituted a pilot program to integrate a new AVL system with its existing reservation and CAD systems. Challenges included legacy systems from different vendors that were proprietary and poorly documented, limited radio coverage and bandwidth, and existing contractual agreements with the third-party operators.

Specific lessons learned from overcoming these challenges include:

- Carefully consider the impact of deploying new technologies on an agency's existing operating procedures.

Transportation Demand Management: Service Coordination

FOR RIDE SHARING INFO CALL 511

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	3	+	Travel dispatch centers in Europe used service coordination systems to decrease paratransit operations costs 2–3%. This compared favorably to the previous 15% annual increase.[12]

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
NEW System Cost	In 2002, the Utah Transit Authority (UTA) in Salt Lake City, Utah, implemented connection protection for passengers transferring from the TRAX (light rail) to buses. The connection protection system uses the real-time information from the TRAX and the bus schedule data along with specific rules that determine when to hold a bus and how long a specific bus can wait for a train without serious impact to the bus schedule. The system uses rules to hold buses based on the frequency and market type of the bus service. Mobile data terminals (MDTs) on-board the buses receive and display the instructions to the driver.[87]	Connection Protection software cost: $305,000

Fleet Management: AVL/CAD

Benefits

Goal Area	# of Studies	Impact	Example
NEW Mobility	8	++	The Denver, Colorado, Regional Transportation District (RTD) implemented its AVL system to improve bus service, and succeeded in decreasing passenger late arrivals by 21%.[88] The AVL/CAD systems deployed in Baltimore, Portland, and Milwaukee improved on-time bus performance 9–23%.[89, 90, 91]
Customer Satisfaction	4	+	The Global Positioning System (GPS)-based vehicle location system in Denver, Colorado,rated very well with Regional transportation District (RTD) dispatchers. Operators and dispatchers were able to communicate more quickly and efficiently. Approximately 80% of dispatchers found the system "easy" or "very easy" to use, and about 50% of operators and street supervisors thought likewise.[92]
NEW Productivity	6	++	AVL capability was added to the Tri-Met bus dispatch system without requiring a significant change to existing service design and delivery practices. The new system reduced passenger wait time and in-vehicle travel time, providing savings valued at about $3.5 million annually.[89]

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	According to a literature search and survey of transit agencies in the United States and abroad on the state of the practice in real-time bus arrival information, the majority of AVL systems use GPS technology; other technologies used include signpost and transponders. Bus arrival time is disseminated to riders via dynamic message signs or liquid crystal displays at stops. The same information also may be disseminated via the Internet, cellular phones, and personal digital assistants. The most common information displayed at the stops includes current date and time, route number and final destination of the bus, wait time (presented as count-down or time range), and service disruptions or other service/security messages. The communications technologies frequently used to disseminate information from the central system to each stop are cellular and conventional telephone lines.[93]	The total capital cost for the AVL and real-time information systems ranged from a low of $60,000 for the Fairfax (Virginia) CUE with 12 AVL-equipped vehicles to more than $70 million for the London Buses with an AVL-equipped fleet of 5,700. NEW

Fleet Management: Maintenance

Benefits			
Goal Area	# of Studies	Impact	Example
Productivity	2	+	A demonstration project in Valencia, Spain, incorporated remote maintenance bus monitoring with dynamic scheduling. The system decreased non-revenue service time through a 20–30% reduction in the time to detect and correct vehicle faults.[12]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	The Ottumwa Transit Authority (OTA) is a department of the City of Ottumwa, Iowa. The agency provides bus service to Ottumwa, Iowa, and the surrounding 10-county area, which covers 5,000 square miles. OTA operates 51 vehicles. The heart of the rural transit ITS project is a two-way radio system which offers improved voice communication and increased bandwidth for the AVL/MDT system. Vehicle condition is transmitted to the central dispatch facility as part of the log-on/pre-trip procedure. Major maintenance and servicing of remote vehicles is scheduled at the facility when conditions are warranted.[94]	Total project cost for 51 vehicles: $628,000 NEW

ITS Lessons Learned

Continued from page 56

- Review existing contracts with all third party service providers to ensure that changes in operating procedures are allowable.
- Involve operators and third party service providers early in the system planning and design process.
- Plan for developing proficiency in the operation of new systems and equipment through documentation and staff training.
- Carefully analyze and test the new systems on existing equipment, like servers, as early as possible.
- Test communication coverage specified by wireless service providers during the design phase.
- Implement a formal configuration management process for all existing and new systems.

Challenges faced and lessons learned by the MART in its AVL/CAD implementation are useful guidance to any agency undergoing an integration initiative, especially small and rural transit providers with third-party service providers.

Fleet Management: Planning

Benefits

No data to report.

Costs

Unit Costs Database	Transit Management Center subsystem	See Appendix A
NEW System Cost	The River Valley Transit, operated by the Williamsport Bureau of Transport, a city department, provides fixed route and demand responsive services in the greater Williamsport, Pennsylvania area. The rural transit ITS system, traveler information system (TIS), provides real-time customer information on routes operating out of a new intermodal facility. TIS informs riders audibly and visually as to which of 10 bays buses will arrive at and depart from; provides a 20-second notification before buses depart the center; notifies drivers when they have pulled into the wrong bay; and allows the agency to create reports for operational and planning purposes. The project cost included signs, in-vehicle equipment, computer equipment, software, installation, integration, and warranty.[94]	Total project cost: $200,000

Information Dissemination: In-Vehicle Systems

Benefits

Goal Area	# of Studies	Impact	Example
NEW Customer Satisfaction	1	?	At the Acadia National Park in Maine, 84% of surveyed visitors indicated the on-board next-stop announcement systems installed on shuttle buses made it easier for them to get around.[4]

Costs

Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
NEW System Cost	A bus rapid transit (BRT) system was deployed to enhance bus operations and improve customer service in the Greater Vancouver area of British Columbia, Canada. In August 2001, BRT route #98 B-Line was introduced to connect the city of Richmond with Vancouver. The BRT service includes several ITS components, including AVL technology, transit signal priority systems, on-board voice and digital announcements of next stop information, and real-time bus arrival time information using digital countdown signs at bus stops.[48]	AVL and real-time information system: $4.2 million (CAD) (2001)

NEXT BUS 5 MINUTES Information Dissemination: In-Terminal/Wayside

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	3	++	At the Acadia National Park in Maine, electronic message signs were installed to inform visitors of updated bus arrival and departure times at three popular visitor destinations. Ninety percent of surveyed visitors who used the information indicated the technology made it easier to get around.[4]

NEW

Costs

Unit Costs Database	Roadside Telecommunications subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
System Cost	Transit riders at Bellevue and Northgate Transit Centers (Seattle, Washington) are provided with bus arrival/departure times, bay number, and expected actual departure times for all bus routes using the transfer center. The system, TransitWatch, obtains actual times from an AVI system and presents the information on monitors at the transit centers. Approximately 12% of the capital cost and 25% of the operations and maintenance (O&M) cost listed represent the TransitWatch project's portion of costs shared with other projects in the Seattle Smart Trek Metropolitan Model Deployment Initiative (MMDI).[5]	Cost to deploy TransitWatch: $722,877 (1998) Annual O&M cost: $179,652 (1998)

Information Dissemination: Internet/Wireless/Phone

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The ROUTES (Rail, Omnibus, Underground, Travel Enquiry System) computerized travel enquiry system used by the London Transport in London, England, helped 13% of travelers change their travel modes to transit, which generated an estimated 1.3 million pounds sterling (approximately $2 million USD) of additional revenue for bus companies, 1.2 million pounds (approximately $1.9 million USD) for the underground, and 1 million pounds (approximately $1.6 million USD) for railways.[95]

Costs		
Unit Costs Database	Transit Management Center subsystem Transit Vehicle On-Board subsystem Personal Devices subsystem	See Appendix A
System Cost	BusView is a component of Metro Online, the King County, Washington, transit website. BusView displays bus progress and routes on a map. Roughly 25% of the capital cost and 25% of the O&M cost were shared with other Seattle Smart Trek MMDI projects.[5]	Capital cost: $333,118 (1998) Annual O&M cost: $175,552 (1998)
System Cost	The Regional Transportation District in Denver, Colorado, has implemented a voice recognition call-in system called Talk-n-Ride, which enables transit riders to call a toll-free number and check if their bus or train is on time and the scheduled arrivals of the next three buses. The cost to implement the system does not include the cost for tracking bus location.[96]	Cost to implement Talk-n-Ride: $40,000 (2001)

2.4 Incident Management Systems

Incident management systems can reduce the effects of incident-related congestion by decreasing the time to detect incidents, reducing the time for responding vehicles to arrive, and decreasing the time required for traffic to return to normal conditions. The classification of benefit and cost data for incident management systems is summarized in Figure 2.4.1.

A variety of surveillance and detection technologies can help detect incidents quickly, including inductive loop or acoustic roadway detectors, and camera systems providing frequent still images or full-motion video. Information from wireless enhanced 911 systems, mayday, and automated collision notification systems, as well as roadside call boxes can also help incident management system personnel identify incidents quickly. Mobilization and response may include automated vehicle location and computer-aided dispatch systems, as well as response routing systems, to help incident response teams arrive swiftly. Motorist assistance patrols, occasionally initiated prior to the emergence of ITS technologies, are now frequently incorporated into traffic management systems. These patrols significantly reduce the time to clear incidents, especially minor ones.

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 (TMC)-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 websites. 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.

Intelligent Infrastructure

Incident Management Systems

- Surveillance and Detection
  - Detectors
  - Imaging/Video
  - Wireless E911
  - Mayday/ACN
  - Call Boxes
  - Traveler Reported
- Mobilization and Response
  - AVL/CAD
  - Response Routing
  - Motorist Assistance Patrols
- Information Dissemination
  - Dynamic Message Signs (DMS)
  - Highway Advisory Radio (HAR)
- Clearance and Recovery
  - Investigation
  - Video
  - Temporary Traffic Control

Figure 2.4.1
Classification Scheme for Incident Management Systems

It is generally understood that incident management systems are 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, particularly in areas with well-established programs.

Table 2.4.1 provides information on the benefits and costs of incident management systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.4.1
Benefits and Costs of Incident Management Systems

Surveillance and Detection

Benefits

Goal Area	# of Studies	Impact	Example
NEW Customer Satisfaction	2	+	TMC staff in Pittsburgh, Pennsylvania, indicated a real-time traffic information system used to monitor traffic density and congestion was useful and helped improve coverage for incident management.[98]

Costs

Unit Costs Database	Roadside Telecommunication subsystem Roadside Detection subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Georgia DOT installed 147 call boxes along a 39-mile rural section of I-185 as part of a pilot project. The total project cost included 147 call boxes, three computer systems at the answer center, and one computer at the maintenance center.[99]	Total project cost: $911,873 Average cost per-call box, including construction: $5,590 (1999) Annual O&M breakdown: Maintenance cost for one year: $51,450 (1999) Cellular service cost for one year: $38,808 (1999)

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

Mobilization and Response

Benefits

Goal Area	# of Studies	Impact	Example
Safety	6	+	In San Antonio, Texas, combined incident management and freeway management systems along the Medical Center corridor reduced crashes by 2.8%.[10]
Mobility	9	++	A study of the Coordinated Highways Action Response Team (CHART) in Maryland found that the system reduced average incident duration by 57% in 2000 and 55% in 1999.[100]
Customer Satisfaction	1	+	Motorist assistance patrols are well-received by the public. The Virginia Department of Transportation has published hundreds of "thank you" letters received regarding their Safety Service Patrol.[101]
Productivity	5	+	Delay savings identfied in studies of freeway service patrols implemented in Minneapolis-St. Paul, Minnesota, Denver, Colorado, and Northwest Indiana documented annual benefits of $1.2 to $1.8 million through reductions in the duration of incidents and related congestion.[6]
Energy/ Environment	5	+	Reductions in incident-related delay also lead to fuel savings and related emissions reductions. A simulation study of the San Antonio, Texas, TransGuide system of freeway and incident management found the system saved an average 2,600 gallons of fuel during major incidents.[102]

Costs

Unit Costs Database	Transportation Management Center subsystem	See Appendix A
System Cost	In San Antonio, Texas, an integrated freeway/incident management system was developed as part of a freeway expansion project. The project covered a 28.9-mile stretch of I-10, I-410, and US 281 in the northern region of San Antonio. The majority of the cost was for surveillance, detection, and information equipment and communications hardware. Detection technologies such as acoustic sensors, loops, and digital detectors, CCTV cameras, dynamic message signs and lane control systems, and supporting fiber optic communications infrastructure were deployed. The cost of mobilization (e.g., keeping traffic moving during deployment) during the expansion was approximately $2 million (1998). This cost was kept low based on the planning decision to deploy the ITS components as part of the highway reconstruction.[10]	Cost of the freeway and incident management expansion project: approximately **$26.6 million** (1998) Estimated annual O&M cost: **$852,000** (1998)

NEW

Lessons Learned

Enhance incident management programs with quick clearance legislation.[103]

National experience with legal issues

In 2003, the National Cooperative Highway Research Program (NCHRP) published the Synthesis of Highway Practice #318. This study presents detailed classifications of laws, policies, and agreements that facilitate institutional support of quick clearance strategies.

Quick clearance laws must address the following criteria for incident clearance: Who is authorized to initially move the vehicle and cargo; Where to move; and, By what means can the incident be cleared?

The following are highlights of the legislation and policy-related lessons learned and presented in the synthesis:

- Evaluate the scope of existing legislation authorizing the removal or tow of driver attended disabled or wrecked vehicles off of travel lanes.

Costs *(continued)*

NEW – System Cost	A freeway courtesy patrol (FCP) was implemented in the Detroit, Michigan, area in 1994. Michigan Department of Transportation (MDOT) administers the program as part of its larger freeway incident management program out of the Michigan Intelligent Transportation Systems Center (MITSC) in Detroit. In 2003, the program employed 32 drivers. The fleet includes 34 vehicles, of which 29 are vans and 5 are tow trucks. The standard hours of patrolling are from 6:00 a.m. to 11:00 p.m., Monday through Friday. The patrol also operates on special-event days (e.g., major community public events and sporting events).[9]	Cost to operate the FCP in 2003: **$2.5 million** Cost to operate the FCP in 2002: **$2 million**
System Cost	Dane County, Wisconsin, implemented an interagency dispatch and reporting coordination system to improve response to incidents and emergencies. Police vehicles are equipped with on-board computers used to transmit incident data to a central dispatching database.[53]	Cost per vehicle: **$8,000–$10,000**

Information Dissemination

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
NEW – System Cost	For the San Antonio, Texas, integrated freeway/incident management system mentioned earlier in this section, a total of 77 variable message signs (VMS) were deployed: 23 large and 54 small. The signs were deployed as part of a freeway expansion project. The project covered a 28.9-mile stretch of I-10, I-410, and US 281 in the northern region of San Antonio.[10]	Costs of 23 large VMS: **$2,035,257** (1998) Costs of 54 small VMS: **$2,340,763** (1998)

Clearance and Recovery: Investigation

Benefits

No data to report.

Costs

Unit Costs Database	Transportation Management subsystem	See Appendix A
System Cost	Computer-aided incident investigation equipment was purchased as part of the Phoenix, Arizona, Metropolitan Model Deployment Intiative (MMDI) to reduce incident clearance time and improve the quality of accident investigations. The initial cost of the project included hardware, software, and training.[60]	Total start-up cost: $147,000 (1998) Annual O&M costs: $4,305 (not including labor) (1998)
System Cost	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.[53]	Cost per vehicle: $8,000–$10,000

Lessons Learned

Continued from page 64

- Develop a traffic fatality certification law to permit the removal of the body of a crash victim from a highway traveled way, thus increasing scene safety.
- Involve medical examiners in the planning of incident clearance policies, procedures, and legislation.
- Establish a driver removal law (with guidance to when a driver must remove his/her vehicle off travels lanes) for involving the motoring public in a quick clearance practice.
- Develop authority and tow laws to permit public agency removal of driver attended vehicles and/or spilled cargo obstructing traffic.
- Develop quick clearance initiatives and policies for handling traffic incidents on arterials.

Without the proper quick clearance legislation in place, even the most comprehensive incident management programs will not reach their ultimate potential and may put responders at legal risk.

2.5 Emergency Management Systems

Benefits of emergency management include improved notification, dispatch, and guidance of emergency responders to the scene of an incident. Figure 2.5.1 shows the current classification of benefits and costs for emergency management systems. ITS applications in emergency management cover hazardous materials management, the deployment of emergency medical systems, and large- and small-scale emergency response and evacuation operations. Each of these systems can improve public safety by decreasing response times and increasing the operational efficiency of safety professionals during emergency situations, such as hurricane evacuations.

Across the United States, federal, state, and local governments are working to support first responders, secure our borders, and improve technology for national security. As these programs come to fruition, additional information will become available on the benefits of ITS for emergency management activities.

ITS applications associated with hazardous materials (HAZMAT) shipment can accomplish four major functions intended to provide for the safe and secure transport of hazardous materials by road. 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.[104]

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 automated collision notification

Intelligent Infrastructure

Emergency Management Systems

- Hazardous Materials Management
  - Tracking
  - Detection
  - Driver Authentication
  - Route Planning
- Emergency Medical Services
  - Advanced ACN
  - Telemedicine
- Response and Recovery
  - Early Warning System
  - Response Management
  - Evacuation and Re-Entry Management
  - Emergency Traveler Information

Figure 2.5.1
Classification Scheme for Emergency Management Systems

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.

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, winter storms, 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). 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. 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.

Table 2.5.1 provides information on the benefits and costs of emergency management systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.5.1
Benefits and Costs of Emergency Management Systems

Hazardous Materials Management		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Emergency Response Center subsystem Emergency Vehicle On-Board subsystem Fleet Management Center subsystem	See Appendix A
System Cost	No data to report.	

Emergency Medical Services: Advanced ACN		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Emergency Response Center subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Emergency Medical Services: Telemedicine

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	+/–	The LifeLink project in San Antonio, Texas, enabled emergency room doctors to communicate with emergency medical technicians (EMTs) using two-way video, audio, and data communications. EMTs and doctors had mixed opinions about the system; however, it was expected that this technology would have more positive impacts in rural areas.[10]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Emergency Response Center subsystem Emergency Vehicle On-Board subsystem	See Appendix A
System Cost	The LifeLink project (San Antonio, Texas) was deployed to provide improved emergency services. The system supports voice and video teleconferencing between University Hospital and 10 of the ambulances in the San Antonio Fire Department. Much of the cost of the project is attributed to research and development.[10]	Project cost: $3.25 million (1998) Annual O&M cost: $25,325 (1998)

Response and Recovery: Response Management

Benefits		
No data to report.		
Costs		
Unit Costs Database	Emergency Response Center subsystem Emergency Vehicle On-Board subsystem	See Appendix A
System Cost	The Combined Transportation, Emergency & Communication Center (CTECC) is a multiagency partnership between the Texas Department of Transportation (TxDOT) Austin District, Travis County, City of Austin, and Capital Metropolitan Transportation Authority. The technological systems presently involved in the CTECC include 911 call handling, radio trunking, computer aided dispatch (CAD), mobile data computer (MDC) including AVL, and transportation and transit services. These integrated systems are essential to the delivery of emergency and transportation services in the Austin and Travis County region.[11]	PBX telephone equipment: $677,125 Client/server LAN/WAN equipment: $727,537 Video wall equipment: $2.16 million Audio/video distribution equipment: $706,427 Structured wiring and cabling: $500,340 Miscellaneous computer equipment: $209,000
System Cost	To overcome the lack of shared communication among emergency operations centers (EOCs) in the Seattle, Washington, metropolitan area, the Smart Trek project purchased and distributed to each EOC communications equipment that operated on the same frequency. The project cost included the purchase of sixteen 800 MHz radios, three repeater station upgrades, other equipment, and planning and development labor costs.[5]	Project cost: $151,700 (1998) Annual O&M cost: $2,860 (1998)

NEW

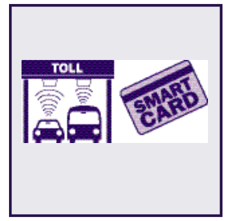
2.6 Electronic Payment Systems

Electronic payment systems are used by transportation agencies for the collection of highway tolls, transit fares, and parking fees. Some public agencies in Europe have also demonstrated systems that go beyond transportation. For the purpose of presenting the benefits and costs of electronic payment systems, see Figure 2.6.1, modal applications are presented separately (i.e., electronic toll collection [ETC], transit fare payment, and parking fee payment) and multi-use payment is reserved for systems containing two or more applications of a different nature.

Electronic payment is currently characterized by the use of cards or transponders carried by the user that electronically communicate with devices maintained by the transportation agency, to conduct and record payment transactions. The transaction and transaction data are used in different ways, depending on how the payment system stores and tracks value. The transaction can deduct value from the user's prepaid system account (typical for ETC), or change the stored value amount held on the user's card (typical for transit). For single-agency systems, transaction data are used to reconcile internal agency accounts. For regional systems, they are also used to reconcile accounts with other agencies at a regional clearinghouse.

ETC supports the collection of payment at toll plazas using automated systems to increase the operational efficiency and convenience of toll collection. ETC systems operate as either integrated, multistate systems such as the E-Z Pass system, or single-state or single toll authority systems such as the Oklahoma Turnpike System. A great deal of coordination and upgrades is required for a single-state or agency toll authority to become integrated with other toll systems. ETC is one of the most successful ITS applications with numerous benefits related to delay reductions, improved throughput, and reduced fuel consumption and vehicle emissions at toll plazas. Studies have also documented increases in crashes at toll plazas with ETC, likely due to driver uncertainty regarding plaza configuration and speed variability between vehicles with and without ETC transponders. The most advanced ETC technologies can identify and process vehicles traveling at high speeds. This enables cars to travel on the mainline without having to slow

Intelligent Infrastructure



Electronic Payment Systems

- Toll Collection
- Transit Fare Payment
- Parking Fee Payment
- Multi-use Payment

Figure 2.6.1
Classification Scheme for Electronic Payment Systems

down and negotiate tollbooths. Benefits of integrated systems are expected to be greater than those of non-integrated systems.

Transit fare payment systems 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. Regional processing centers can consolidate financial information and streamline fare transaction management for multiple transit agencies. A transit fare payment system can be part of a closed system operated by a single transit agency, or after much coordination and upgrading, it can be integrated across multiple transit agencies, becoming part of a regional fare payment system. As with toll collection systems, benefits of integrated transit fare payment systems are expected to be greater than those of non-integrated systems.

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

Multi-use payment is a category for integrated payment systems that can be used in two or more of the four following ways: transit, toll collection, parking, and participating merchants. Most examples of multi-use payment systems in the United States provide the capability to pay for some combination of transit fare, highway tolls, and parking fees. The E-Z Pass tag that is used for electronic toll payment in the E-Z Pass system can also be used for parking payment at New York City area airports. Other systems, most notably in Europe, may provide for purchases at nearby participating vendors or merchants. Multi-use payment capabilities can make transit, toll payment, and parking more convenient. Payment for bus, rail, parking, and potentially other public or private sector goods and services can be simplified by using electronic devices such as smart cards and transponder tags. Fare transaction processors access information on these devices and communicate account activity to a regional database. Centralized systems can track the location and activity of smart cards to help with highway, transit, and/or parking planning and operations, and limit unauthorized use of individual accounts.

Table 2.6.1 provides information on the benefits and costs of electronic payment systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.6.1
Benefits and Costs of Electronic Payment Systems

Toll Collection

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	–	In Florida, driver uncertainty about congestion at Express Pass (E-PASS) toll stations contributed to a 48% increase in accidents.[105]
Mobility	4	++	Implementation of the E-ZPass system by the New Jersey Turnpike Authority (NJTA) reduced delay for all vehicles at toll plazas by 85%.[106]
Capacity/ Throughput	1	+	A study of ETC on the Tappan Zee Bridge in New York City showed an ETC lane could process 1,000 vehicles/hour (vph), while a manual lane could handle only 400–450 vph.[107]
Customer Satisfaction	1	?	Twenty percent of travelers on two bridges in Lee County, Florida, adjusted their departure times as a result of value pricing and electronic tolls.[108]
Productivity	3	+	Based on changes in traffic conditions after deployment of E-ZPass, passenger cars on the New Jersey turnpike saved an estimated $19 million in delay costs and $1.5 million in fuel costs each year.[106]
Energy/ Environment	4	+/–	Model calculations of emissions using the EPA Mobile-5a model and traffic field data indicated ETC decreased CO by 7.3%, decreased hydrocarbons by 7.2%, and increased NOx by 33.8% at the Holland East Toll Plaza in Florida. NOx increased as a result of higher engine speeds.[109]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Toll Plaza subsystem Toll Administration subsystem	See Appendix A
System Cost	The cost for the Oklahoma Turnpike Authority to operate an electronic toll collection lane is approximately 91% less than to staff and operate a traditional toll lane.[110]	Annual O&M cost: $16,000 per lane

Lessons Learned

To successfully deploy regional fare systems: (1) carefully plan and negotiate agreements on technical requirements; and (2) incorporate customer acceptance techniques.[116]

A Ventura County, California, experience in implementing a regional smart card system

An integrated electronic fare collection system was field tested in Ventura County, California, between 1996 and 1999. The smart card was planned to be used by six transit agencies for fare payment. Also, a university was expected to use the smart card for an identification card, a universal semester bus pass, and parking access.

The initial deployment of the smart card system faced "numerous operational and data processing problems resulting in inconsistent data and infrequent reports," and had implementation problems for some of the agencies. Ventura County learned from the initial attempts and the problems were overcome. A successful system is in operation today.

Transit Fare Payment

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	3	+	Chicago, Illinois, transit riders participating in a pilot program rated convenience, rail use, and speed the most preferred features of the SmartCard electronic fare payment system.[111]
Productivity	3	+	The smart card electronic payment system in Ventura, California, saved an estimated \$9.5 million per year in reduced fare evasion, \$5 million in reduced data collection costs, and \$990,000 by eliminating transfer slips.[112]

Costs

Unit Costs Database	Roadside Telecommunications Subsystem Transit Management Center subsystem Transit Vehicle On-Board subsystem	See Appendix A
NEW System Cost	The Central Puget Sound Regional Fare Coordination (RFC) Project features smart card technology that will support and link the fare collection systems of the major transit agencies operating in the Central Puget Sound region of Washington State. The cost of the RFC Project will be paid out during the 2003–2007 timeframe. The cost includes all vendor contract cost components, including equipment, equipment installation, fare cards, integration, and project management as well as other RFC Project administration costs, including sales tax, contingency fund, and project management team costs.[113, 114, 115]	Total project cost: **\$42.1 million** (nominal) Average annual O&M costs: **\$3.28 million** over first 10 years of project operation (nominal)
NEW System Cost	The Washington Metropolitan Area Transit Authority (WMATA) is expanding the capability of their SmarTrip® contactless smart card system by linking it to multiple bus and rail fare collection systems throughout the Washington, D.C., area. A Regional Customer Service Center (RCSC) will perform cross-jurisdictional management, distribution, and reconciliation tasks. The cost of the RCSC includes contracted services, central database, point-of-sale network and devices, and existing system software upgrades.[13]	Cost to deploy the RCSC: **\$25.537 million** (2002–2003) Annual O&M cost (estimated): **\$3.45 million** (2002–2003)

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

Multi-use Payment Systems

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	+	Three projects in Europe demonstrated the coordinated use of a smart card as a payment system for public transit, shops, libraries, swimming pools, and/or other city services. User acceptance and satisfaction with these systems was very high, ranging from 71–87%.[12]

Costs

Unit Costs Database	Transit Vehicle On-Board subsystem Transit Management Center subsystem	See Appendix A
System Cost	No data to report.	

Lessons Learned

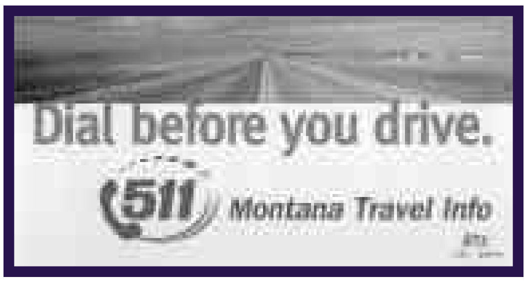
Continued from page 76

Initial technical difficulties and data processing problems led to these technical lessons learned:

- Ensure that the system integrator is on site throughout the project.
- During the planning phase of the program, obtain agreement between all participating operators for: system performance requirements; minimum requirements for data collection processes; reporting requirements that define report formats and the reporting schedule; and designation of clearinghouse and settlement responsibilities.
- Carry out verification and monitoring of these requirements continuously during the project design and implementation.
- Apply customer acceptance techniques, including extensive marketing; customer usage incentives such as free transfers, fare discounts, and automatic replenishment; and frequent customer satisfaction surveys and interviews.

2.7 Traveler Information

Providing traveler information on several modes of travel can be beneficial to both the traveler and service providers. Many transit agencies use traveler information websites to provide schedules, expected arrival times, expected trip times, and route planning services to patrons. See www.transitweb.its.dot.gov for a listing of such sites. Also, many state DOT and local transportation agencies are providing current traffic conditions and expected travel times using similar approaches. Ongoing implementations of the 511 telephone number will improve access to traveler information. Each of these services allows users to make a more informed decision for trip departures, routes, and mode of travel, especially in bad weather. They have been shown to increase transit usage, and may help to reduce congestion when travelers choose to defer or postpone trips, or select alternate routes. Information on impacts and costs of traveler information systems are separated into those that provide pre-trip information, and those that provide en-route information, as shown in Figure 2.7.1.



Note that the traveler information programs discussed in this section of the report, and documented in the corresponding portions of the database, are generally regional, and occasionally multimodal in nature. Roadside or transit facility-based traveler information components such as dynamic message signs (DMS), highway advisory radio (HAR), and in-terminal displays are most often deployed, operated, and controlled by arterial, freeway, transit, or incident management systems. Earlier sections of this report discuss evaluations of these information dissemination technologies.

Evaluation of implemented traveler information systems reveals that the systems are well-received by those who make use of them. The number of travelers using the information generally represents a small portion of the total travelers in a region. Consequently, evaluations of traveler information systems show that such systems demonstrate a modest impact on travel times across the regional transportation network. Nevertheless, individual users of the systems do perceive significant personal benefit in the form of improved on-time reliability, reducing the number of excessively early and late arrivals through better trip-planning made possible by traveler information services.

Intelligent Infrastructure

Traveler Information

- Pre-trip Information
  - Internet/Wireless
  - 511
  - Other Telephone
  - TV/Radio
  - Kiosks
- En-Route Information
  - Wireless
  - 511
  - Other Telephone
  - Radio
  - In-Vehicle Systems (IVS)
- Tourism and Events
  - Travel Services
  - Advanced Parking
  - Electronic Payment

Figure 2.7.1
Classification Scheme for Traveler Information

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, transit, and parking availability. The systems may also provide mobility services such as pre-trip route planning or en-route navigation.

Table 2.7.1 provides information on the benefits and costs of traveler information. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.7.1
Benefits and Costs of Traveler Information

Pre-Trip Information

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	8	+	A simulation study of the Washington, D.C., metropolitan area found that individuals using traveler information services could improve their on-time reliability while reducing the risk of running late. Overall, regular users of the pre-trip traveler information benefited significantly by reducing the frequency of early and late arrivals by 56% and 52% respectively.[117]
Capacity/ Throughput	4	o	Modeling studies in Detroit, Michigan, and Seattle, Washington, have shown slight improvements in corridor capacity with the provision of traveler information.[61, 79]
NEW Customer Satisfaction	21	++	An Internet survey of users of traveler information websites in Philadelphia and Pittsburgh, Pennsylvania, found that 86% of users in Philadelphia and 68% of users in Pittsburgh had changed their original travel route for at least one of their trips based on information received.[98] In Montana, 81% of survey respondents were satisfied or very satisfied with road conditions information available through a 511 telephone service provided by the Greater Yellowstone Regional Traveler and Weather Information System.[14]
Energy/ Environment	3	?	A 1993 prospective study of traveler information in Boston, Massachusetts, found that the system would reduce vehicle emissions from participating travelers. The study estimated a 25% reduction in volatile organic compounds, a 1.5% reduction in oxides of nitrogen, and a 33% reduction in carbon monoxide.[118]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Information Service Provider subsystem Remote Location subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Arizona DOT's (ADOT) traveler information system has been operational since 1998, and was converted to 511 in March 2002. The system is currently being enhanced. Costs for the existing system are available; costs for the enhanced system will be available in the future. The system provides information on Interstates, U.S. Highways, and State Routes throughout Arizona. In addition, Phoenix and Tucson transit options are supported by transferring callers to the respective transit agency. Information is obtained using touchtone (keypad) menu selections. The implementation cost includes the cost to develop the original (pre-enhanced) interactive voice response (IVR) phone system, "VRAS" (voice response activated system); the cost of the original IVR hardware, software, and engineering; and the cost to convert the VRAS system from the 10-digit number to 511. The primary driver for the annual operating cost is the phone charges (e.g., toll-free number, transfers). Annual operational costs are kept low because the ADOT 511 system is highly automated and integrated with Highway Condition and Reporting System (HCRS), the primary source of information.[119]	Pre-enhanced 511 system implementation cost: $355,020 Annual operating costs: $136,734 NEW
System Cost	The Arizona DOT enhanced its traveler information system, Trailmaster, as part of the AZTech Metropolitan Model Deployment Initiative (MMDI) project. The cost of the enhancement included hardware and software upgrades, and web page redesign. The project team estimated that the original Trailmaster website cost was approximately 10 times as much as that of the redesign.[60]	Cost to enhance Trailmaster: $135,782 (1998) Annual O&M cost: $116,551 (1998)
System Cost	Real-time traffic condition information similar to the information provided on the Trailmaster website (see above) is available at kiosks located at selected public and commercial sites. Approximately 28 kiosks are deployed in the Phoenix, Arizona, region.[60]	Cost for Trailmaster kiosk project: $459,732 (1998) Annual O&M cost: $153,519 (1998)

Lessons Learned

511 should be thought of as an evolving service designed to attract users.[29]

National experience in 511 management and partnerships

In early 2001, the 511 Deployment Coalition was established. Since then, the Coalition has developed guidance, tracked national 511 status, and documented lessons learned to assist 511 implementers. Lessons tracked range from cost estimates for implementing the service to recommendations on how to enhance and track the usage of the service.

En-Route Information

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	4	+	Enhancements to the traveler information system in San Antonio, Texas, during the MMDI included improvements to the Internet website, and the installation of in-vehicle navigation (IVN) devices in vehicles operated by public agencies in the area. Modeling results indicate significant potential benefits for individuals using the devices. Over a one-year period, a traveler using an IVN device could experience an 8.1% reduction in delay.[10]
NEW Customer Satisfaction	13	++	In Virginia, an automated telephone 511 traveler information service was deployed. In order to evaluate the impacts of the system on customer satisfaction, survey data were collected from 400 participants who used the system, and later agreed to participate in a follow-up telephone survey. Overall, 90% of respondents found the service useful, and nearly half of them indicated they had changed their travel plans on at least one occasion as a result of the information provided.[15]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Transportation Management Center subsystem Vehicle On-Board subsystem Personal Devices subsystem	See Appendix A
NEW System Cost	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 Traveler and Weather Information Systems (GYRTWIS) project. The system cost includes system development, voice recognition, marketing, and one-time improvement for the addition of regional reports, AMBER (America's Missing: Broadcast Emergency Response) Alerts, Homeland Security, and General Transportation Alerts. Annual operating cost includes contracted services and equipment lease, toll charges, marketing, and operating cost for the statewide alert system.[13]	Cost to deploy GYRTWIS 511: $188,000 Annual operating cost: $195,453
NEW System Cost	511 traveler information is available in a growing number of locations throughout the U.S. Many of the 511 systems are statewide, a few provide metropolitan area coverage, and one provides coverage for a rural corridor. The 511 Coalition collected cost data representative of actual 511 deployments from around the U.S. Costs are broken down by five general categories applicable to the development phase and the operations and maintenance phases. Deploying agencies do not necessarily use these same accounting categories; however, example costs that fall within these general categories are presented so the reader has insight into some costs that may be encountered. The five cost categories presented are: labor, equipment, telecommunications, 511 content upgrades, and marketing.[120]	Sample costs- Text-to-speech and voice recognition software: $179,000 Switch programming for carriers throughout one state: $84,000 511 advertisement in 350,000 travel guides: $3,400

Tourism and Events

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	2	+	In Acadia National Park, 90% of visitors who used real-time transit departure signs, 84% of visitors who experienced automated on-board next-stop message announcements, and 74% of visitors who experienced real-time parking information reported these technologies made it easier to get around.[4] NEW

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Parking Management subsystem	See Appendix A
System Cost	The Seattle Center Advanced Parking Information System in Seattle, Washington, provides information and routing directions to three major parking centers via dynamic message signs. This information is also available via the Internet, phone, and pagers to travelers prior to leaving for an event as well as travelers en route.[5]	System cost: $925,265 (1998) Annual O&M cost: $50,523 (1998)

Lessons Learned

Continued from page 82

The following are highlights of lessons on awareness and outreach culled from various states with operational 511 systems:

- Market and brand 511 service sufficiently, correctly, and consistently across regions, states, and the nation. For greater return on 511 investments, clearly relay to users what the service is and how it should be used.
- Think of 511 as an evolving service designed to attract and retain users.
- Track, respond to, and even try to predict 511 user needs.
- Capture user feedback by incorporating a comment line on the 511 menu tree.

The Coalition website (www.deploy511.org) offers 511 marketing and awareness guidance and tools that have been successfully employed by implementers.

2.8 Information Management

Data generated for immediate use in ITS applications can be archived and used for multiple purposes. Archived ITS data can be used to improve planning and operations and supplement government reporting systems by providing more comprehensive measures of performance analysis. Stored ITS data are typically referred to as an ITS data archive. Typical examples include bus journey times generated by transit automatic vehicle location (AVL) systems or traffic volume data monitored by freeway loop detectors.

The data stored in ITS data archives can be processed and organized using an archived data management system (ADMS) to facilitate subsequent analysis by end users. The inclusion of the Archived Data User Service (ADUS) in the National ITS Architecture underscores the value of archived data management systems and the need to collect, manage, and distribute ITS data to end users at the federal, state, and local level. The National ITS Architecture highlights a broad range of end users, including policymakers, planners, system operators, and the general public.

ADMS generally are scalable, allowing expansion of the scope of archived data to cover many functional items by finding relations among new sources and sets of data. Several large ADMS have been deployed in the United States over the past several years. The level of complexity of each system has been dependent on the end user needs. Small-scale systems have been tailored to meet the needs of a single agency or operations center, while larger systems have been deployed to collect data generated by multiple agencies, and to incorporate this data into regional ITS data warehouses.

Figure 2.8.1 shows how data archiving applications fit into the ITS classification scheme. Operating agencies around the country are in various stages of planning, implementing, and operating archived data management systems. As more advanced data analysis techniques develop, and the efficiency of data reporting systems is improved, additional examples of the effectiveness of information management systems will become available.[121]

Table 2.8.1 provides information on the costs of information management. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Figure 2.8.1
Classification Scheme for Information Management

Table 2.8.1
Costs of Information Management

Data Archiving		
Benefits		
No data to report.		
Costs		
Unit Costs Database	Transportation Managaement subsystem	See Appendix A
System Cost	The total cost of the Nevada DOT Freeway and Arterial System of Transportation (FAST) central system software design and development is approximately $4.225 million. The software will provide 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 the Archived Data Management System (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.[122]	Software design and development cost: $4.225 million (2000) ADMS design cost: $225,000 (1999)

2.9 Crash Prevention and Safety

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. Figure 2.9.1 depicts the current classification for collecting crash prevention and safety systems benefits and costs information. Road geometry warning systems warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous conditions that may cause rollovers or other crashes on ramps, curves, or downgrades. Highway-rail crossing systems can reduce the potential for collisions at railroad crossing, including catastrophic accidents involving school buses or hazardous materials carriers. The goal of the Highway-Rail Intersection (HRI) User Service in the National ITS Architecture is to further improve safety at these crossings and improve coordination between rail operations and traffic management functions.

Intersection detection systems can reduce approach speeds at rural intersections by advising drivers of the presence and direction of approaching traffic. Pedestrian safety systems can help protect pedestrians by automatically activating in-pavement lighting to alert drivers as pedestrians enter crosswalks. Bicycle warning systems can notify drivers when a cyclist is in an upcoming stretch of roadway to improve safety on narrow bridges and tunnels. Animal warning systems can alert travelers when wildlife is in the vicinity of the roadway, or attempt to deter animals from crossing the roadway while traffic is present.

Table 2.9.1 provides information on the benefits and costs of crash prevention and safety. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure

Crash Prevention and Safety

- Road Geometry Warning Systems
  - Ramp Rollover Warning
  - Curve Speed Warning
  - Downhill Speed Warning
  - Overheight/Overwidth Warning
- Highway-Rail Crossing Systems
- Intersection Collision Warning
- Pedestrian Safety
- Bicycle Warning Systems
- Animal Warning Systems

Figure 2.9.1
Classification Scheme for Crash Prevention and Safety

Table 2.9.1
Benefits and Costs of Crash Prevention and Safety

Road Geometry Warning Systems: Ramp Rollover Warning

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	3	+	A ramp rollover warning system was installed at three curved exit ramps on the beltway around Washington, D.C. in 1993. On-site sensors and computers detected truck speeds, weight, and height classification, and then calculated the probability a truck would roll over as it approached. If a truck was at risk, a roadside warning sign was activated to alert drivers to slow down. Prior to deployment there were 10 truck rollover accidents at these sites between 1985 and 1990. After deployment, no accidents were recorded between 1993 and 1997.[123]

Costs		
Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	As mentioned in the benefits example above, three automatic ramp rollover warning systems have been deployed around the Washington, D.C., Capital Beltway. The costs of this system for software, construction, calibration, commissioning, testing, and design were $166,462 for a one-lane ramp and $268,507 for a two-lane ramp. These costs were for a prototype rollover warning system.[124]	Single lane ramp cost: $166,462 (1994) Dual lane ramp cost: $268,507 (1994)

Road Geometry Warning Systems: Curve Speed Warning

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	An advanced curve warning system was installed on five curves along I-5 in a mountainous portion of rural northern California. A before-and-after evaluation at two sites showed a significant reduction in truck speeds on downgrades greater than 5%.[125]
Customer Satisfaction	1	?	In a survey completed 10 months after installation of the northern California curve warning system described above, 70% of commercial vehicle drivers and 85% of passenger car drivers indicated the signs were useful. Sixty-nine percent of both types of drivers indicated they reduced their speed through the curves in response to the signs.[125]

NEW

Costs

Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	No data to report.	

Road Geometry Warning Systems: Downhill Speed Warning

Benefits

Goal Area	# of Studies	Impact	Example
Safety	3	+	A dynamic truck downhill speed warning system installed on I-70 in Colorado decreased truck accidents by 13% and reduced the use of run away truck ramps by 24%.[123]
Customer Satisfaction	1	?	A small-scale study of truck drivers who experienced the dynamic truck downhill speed warning system in Colorado indicated that most drivers thought it was helpful.[126]

Costs

Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	A truck speed warning system was deployed on a downgrade curve along I-70 in Glenwood Canyon, Colorado. If a truck is detected (via radar) exceeding the posted speed, then the truck's speed is posted on a dynamic message sign (DMS).[53]	Estimated cost range for a single site: $25,000–$30,000 (1996)

Highway Rail Crossing Systems

NEW

Benefits

Goal Area	# of Studies	Impact	Example
Safety	4	+	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% of vehicles crossing the tracks between the two trains. The number of drivers beginning to move their vehicles under the rising crossing gate before realizing a second train was approaching decreased by 86% after the system began operation. These benefits were determined by comparing data from a one-month evaluation period just before the system was installed and data from the two months immediately after installation.[16]
Mobility	2	?	The San Antonio, Texas, simulations of increased traffic volumes indicated DMS with railroad crossing delay information may decrease system delay by 7%.[10]
Customer Satisfaction	1	?	Before implementation of an automated warning system, 77% of surveyed residents in Ames, Iowa, indicated that train horns had a "negative" or "very negative" impact on their quality of life. After deployment, 82% of residents responded that the automated horn was "no problem."[127]
Energy/ Environment	2	?	Noise levels were measured at a highway-rail intersection before and after installation of the automated horn system in Ames, Iowa. Results indicated that areas impacted by noise levels greater than 80 decibels decreased by 97%.[127]

Costs

Unit Costs Database	Roadside Rail Crossing subsystem Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	The Advanced Warning for Railroad Delays (AWARD) project was implemented as part of the San Antonio, Texas, Metropolitan Model Deployment (MMDI). The project consisted of Doppler radar and acoustic sensors deployed at selected locations of railroad tracks to detect the presence, speed, and length of oncoming trains as they approach grade crossings. Data are transmitted to the TransGuide Operations Center, where the data are analyzed and railroad delay information is communicated to travelers on existing dynamic message signs.[10]	AWARD project cost: $350,800 (1998) Annual O&M cost: $34,000 (1998)

Costs *(continued)*			
System Cost	In Groton, Connecticut, a four-quadrant gate with automatic train stop system was deployed. The system included four-quadrant gates to deter vehicles from attempting to cross as trains approached, and six inductive loop vehicle detectors to detect vehicles blocking the tracks. In the event of an obstruction, the detector system was designed to notify train operators via an in-cab signaling system. If the engineer failed to slow the train, then an automated system would stop the train.[17]	The cost of the system included equipment installed at the crossing and the in-cab signaling system: $977,000 (2001)	NEW
System Cost	In northern Chicago, Illinois, an in-vehicle railroad crossing warning system was designed and deployed. When a train was detected by the track circuitry that activates the bells, signals, and gates, a transmitter would also broadcast a signal intended or any vehicle equipped with the special warning system receiver. In-vehicle receivers within a certain distance would activate and operate in one of three modes: audio, visual, or combination audio/visual. The in-vehicle receiver device was installed in 300 vehicles, including school buses, emergency vehicles (i.e., fire, police, and ambulance), and commercial vehicles that normally traveled through the study area.[17]	Total project cost including 300 in-vehicle units and train detection equipment at five crossings: $679,000 (2001)	NEW

Intersection Collision Warning

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	A collision countermeasure system (CCS) was installed at an unsignalized, two-way, stop-controlled intersection in a rural area of Aden, Virginia. Before-and-after field data indicated the system lowered approach speeds. Safer projected-times-to-collision (PTCs) were observed after system implementation.[128]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

Pedestrian Safety

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Detection subsystem Roadside Information subsystem Roadside Telecommunications subsystem	See Appendix A
System Cost	A downtown Boulder, Colorado, 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.[53]	Project cost including equipment and installation: $8,000–$16,000

Bicycle Warning Systems

Benefits

No data to report.

Costs

Unit Costs Database	No data to report.	
System Cost	A Bicycle in Tunnel Warning System was deployed at a tunnel on Highway 971 near Chelan, Washington. Flashing beacons on a fixed message sign are activated when a cyclist presses a push-button, and deactivate after a preset time interval has passed. The fixed message sign reads, *PEDS/BICYCLES IN TUNNEL WHEN FLASHING.* The cost to implement the system was kept low due to the existing power source at the tunnel entrance.[53]	Cost to implement the system: $5,000 (1979)

Animal Warning Systems

Benefits

No data to report.

Costs

Unit Costs Database	No data to report.		
System Cost	An Animal Warning System has been deployed in the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) corridor. A transmitter is installed along the road where a high number of animal-vehicle incidents have occurred. The cost per site includes transmitter, solar pack, and installation (estimated). The cost does not include off-the-shelf in-vehicle radar detectors required to receive the signal from the transmitter.[53]	Cost per site includes transmitter, solar pack, and installation (estimated): $3,800	
System Cost	On the Olympic penninsula in Washington state, an animal warning system was deployed. The system was designed to alert motorists of the presence of elk by triggering a solar-powered radio activated flashing *ELK X-ING* warning sign when an animal equipped with a radio collar was within a quarter mile of the roadway. A federal grant was used to pay for the cost of collaring 12 lead elk (10% of herd), building and installing the radio-activated signs, and purchasing the equipment necessary to monitor the elk herd.[129]	Warning system: $75,000 (2001)	NEW
System Cost	In Saskatchewan, Canada, a new technology was deployed to alert wildlife of freeway traffic and scare animals away from the road. Twenty-five wildlife warning units were placed on both sides of the road approximately every 1,000 feet along a 3.1-mile section of Highway 7. Units at each end of the array were equipped with sensors and transmitters to detect approaching vehicles and send signals to other warning units downstream, enabling them to activate warning lights and sounds to repel animals away from the roadway and oncoming traffic. The cost of the system did not include installation and maintenance costs during the two-year project.[129]	Wildlife deterrent system: $100,000 CAD (2001)	NEW

2.10 Roadway Operations and Maintenance

Operating and maintaining transportation systems is costly. Many state DOTs are implementing ITS to better manage roadway maintenance efforts and to enhance safety 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.

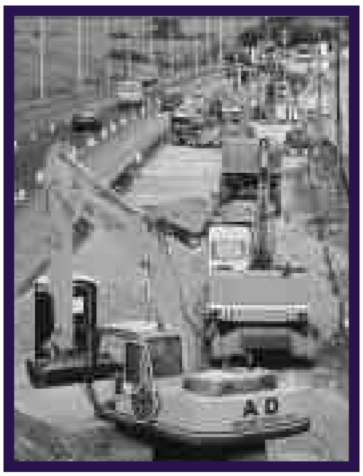


Figure 2.10.1 summarizes the classification scheme for collecting benefits and costs information for roadway operation and maintenance. Information dissemination technologies can be deployed temporarily, or existing systems can be updated periodically to provide information on work zones or other highway maintenance activities. Several 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.

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. ITS may also be used to manage traffic along detour routes during full road closures to facilitate rapid and safe reconstruction projects.

Table 2.10.1 provides information on the benefits and costs of roadway operations and maintenance. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure

Roadway Operations and Maintenance

- Information Dissemination
  - Portable DMS
  - Highway Advisory Radio (HAR)
  - 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

Figure 2.10.1
Classification Scheme for Roadway Operations and Maintenance

Table 2.10.1
Benefits and Costs of Roadway Operations and Maintenance

Information Dissemination

Benefits

Goal Area	# of Studies	Impact	Example
NEW Safety	2	+	In Arkansas, automated work zone information systems (AWIS) were installed and tested at construction sites in two cities. Each AWIS was primarily a queue detection system designed to calculate and report delay times to travelers via roadside changeable message signs. Analysis of the impacts of the system indicated rear-end crashes and fatalities were less frequent in areas where AWIS was deployed, however, the observation period for this study was limited, so the results may not be representative. The results may be further confounded by a statewide work zone safety information campaign conducted at the time of the study.[130]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Information Service Provider subsystem Personal Devices subsystem Transportation Management Center subsystem	See Appendix A
NEW System Cost	In 2000, the Arkansas State Highway and Transportation Department (AHTD) began the Interstate Rehabilitation Project, a five-year construction project including the rebuilding of 60% of Arkansas's total Interstate miles. Two work zones were equipped with two different types of AWIS in an attempt to mitigate traffic congestion and automobile incidents at the work zone site. Both systems were provided by a contractor. The first site was a 6.3-mile segment of I-40 located in Lonoke County. This AWIS included a central system controller, two highway advisory radios (HAR), five traffic radar sensors measuring vehicle speed, five dynamic message signs (DMS) and two supplemental speed stations. The second site was an 8.6-mile segment of I-40 located in Pulaski County. This AWIS included a central system controller, a host computer in the engineer's office, two DMS, queue detection sensors, and five HAR. Both systems utilize traffic sensors and DMS that are equipped to communicate with a central controller via radio (Federal Communications Commission (FCC) or FHWA band). The DMS were automated to display one of the various preset messages available. The display corresponded to the scenario monitored by the traffic sensors.[131]	Lonoke County AWIS: $322,500 Pulaski County AWIS: $490,000

Costs *(continued)*		
System Cost	The New Mexico State Highway and Transportation Department (NMSHTD) used ITS in a two-year construction project of "The Big I" interchange where I-40 and I-25 intersect. The system included eight fixed CCTV cameras, eight modular (expandable) DMS, four arrow dynamic signs, four portable DMS, four portable traffic management systems (a single integrated platform for camera and DMS), and four HAR units. Components were linked to base station computers via wireline and wireless communications. Information on traffic conditions were provided via the HAR and DMS, and via other outlets to include website, radio, fax, and e-mail distribution lists. NMSHTD purchased the ITS with the intent of incorporating much of the system into a freeway management system once construction was completed. Other components would be used in future work zone projects.[19]	Work zone ITS cost: **$1.5 million** NEW

Asset Management: Fleet Management

Benefits		
No data to report.		
Costs		
Unit Costs Database	Fleet Management subsystem	See Appendix A
System Cost	The purpose of the Advanced Rural Transportation Information and Coordination (ARTIC) project in Minnesota was to share application of ITS across various public agencies such as transportation, public safety, and transit utilizing a central communications and dispatching center. Automated vehicle location (AVL)/Global Positioning System (GPS) equipment was installed on fleet vehicles for ease of location, identification, and dispatching. Mobile data terminals (MDT) were also installed allowing for data transmission between the vehicles and the dispatch center. AVL and MDT were installed on 15 Mn/DOT vehicles, four Minnesota State Police (MSP) vehicles, and 15 transit buses. To demonstrate the capability of transmitting data from fleet vehicles to the center, an interface was developed between the MDT and the sand spreader control on the snow plows.[53]	Project cost for AVL and MDT installation: **$1.574 million**

Asset Management: Infrastructure Management

NEW

Benefits			
Goal Area	# of Studies	Impact	Example
Productivity	1	?	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% lower on Interstate roadways and 26% on non-Interstate primary roadways.[132]

Costs		
Unit Costs Database	Fleet Management subsystem	See Appendix A
System Cost	No data to report.	

Work Zone Management

Benefits

Goal Area	# of Studies	Impact	Example
Safety	4	+	NEW Iowa evaluated the effectiveness of a citizens band (CB) radio alert system used to warn approaching truckers of slow-moving maintenance vehicles on I-35. The test was conducted using a roadway paint crew of four to five vehicles traveling at 25 miles per hour (mph) spread out over one mile. The trailing vehicle in the crew was equipped with a CB transmitter to automatically broadcast warning message up to a distance of four miles. A survey found that 39 of 59 truckers who saw the paint crew indicated the alert system was effective at warning them of workers in the roadway.[133]
Mobility	2	+	Average clearance times for incidents were reduced by 44% with the implementation of motorist assistance patrols and a temporary traffic management center during a construction project at the "Big I" interchange in Albuquerque, New Mexico. During weekday operations, the Highway Department allocated two courtesy patrol units to patrol the construction zone between 5 a.m. and 8 p.m. on weekdays, and a wrecker was an on-call from 6 a.m. to 6 p.m.[18]
Customer Satisfaction	3	+	An investigation into remote speed enforcement in work zones in Texas drew mixed results from project participants. While officers felt the system had the potential to allow safe enforcement of speed limits in work zones, by relaying images of offending drivers to officers downstream, some had concerns regarding the proper identification of speeding vehicles.[134]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Detection subsystem Roadside Control subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Michigan DOT (MDOT) used a temporary traffic management system (TTMS) during a construction project in downtown Lansing. The system was deployed from March 2001 to October 2001 and removed at the completion of the construction project. The project involved a complete closure of portions of I-496. The TTMS was used throughout the construction project. The system included 17 cameras, 12 DMS, six queue detectors (microwave sensors), and a commercial off-the-shelf (COTS) software package that ran on a server located at the construction traffic management center.[19]	NEW Cost to lease the TTMS: $2.4 million (which is about 6% of the total project construction cost)

Costs *(continued)*		
System Cost	Ohio DOT installed Web cameras in its I-70 work zone to assist in traffic management. The cost of installation was kept very low due to the use of temporary structures. Although the installations were temporary and would not meet environmental standards for permanent structures, the video images of traffic in the construction areas were beneficial to Ohio DOT.[135]	System cost: $17,000 for eight cameras
System Cost	Michigan DOT teamed up with FHWA and Michigan State University for an 18-month study to test the use of variable speed limits (VSL) in work zones. The equipment, seven VSL trailers, was rented for the study. The project cost includes the equipment, technical support, and transport of the VSL trailers.[136]	Project cost: $400,900 (2002)

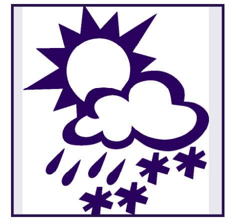
2.11 Road Weather Management

Adverse weather conditions pose a significant threat to the infrastructure and operation of our nation's roads. The Road Weather Management Program, within the FHWA Office of Operations, seeks to better understand the impacts of weather on roadways, and promote strategies, tools, and technologies to mitigate those impacts. The program is working to promote a national road weather observing system, enhance decision support for winter maintenance personnel, and advance weather-responsive traffic management. Figure 2.11.1 depicts the classification of benefits and costs data associated with Road Weather Management.

ITS applications that assist road weather management support four major types of activities. Surveillance, monitoring, and prediction of weather and roadway conditions enable the appropriate management actions to mitigate the impacts of any adverse conditions. Information dissemination technologies help road weather managers notify travelers of adverse conditions they may face on their trips. Traffic control measures may be enacted to 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. 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 automatic vehicle location on snow plows supporting a computer-aided dispatch system.

Table 2.11.1 provides information on the benefits and costs of road weather management. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure



Road Weather Management

- Surveillance, Monitoring, and Prediction
  - Pavement Conditions
  - Atmospheric Conditions
  - Water Level
- Information Dissemination
  - Dynamic Message Signs (DMS)
  - Internet/Wireless/Phone
  - Highway Advisory Radio (HAR)
- Traffic Control
  - Variable Speed Limits
  - Traffic signal Control
  - Lane Use/Road Closures
  - Vehicle Restrictions
- Response and Treatment
  - Fixed Winter Maintenance
  - Mobile Winter Maintenance

Figure 2.11.1
Classification Scheme for Road Weather Management

Table 2.11.1
Benefits and Costs of Road Weather Management

Surveillance, Monitoring, and Prediction

Benefits

Goal Area	# of Studies	Impact	Example
NEW Customer Satisfaction	2	+	In interviews following the deployment of two new environmental sensor stations (ESS) equipped with pole-mounted CCTV cameras and sensors to measure an array of environmental conditions, the Washington State DOT road maintenance crews ranked pavement conditions data as the most useful ITS technology deployed, 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 minimize unnecessary trips.[20]

Costs

Unit Costs Database	Roadside Detection subsystem Transportation Management subsystem Roadside Telecommunications subsystem	See Appendix A
NEW System Cost	In 2003, the Ohio Department of Transportation (ODOT) expanded its Roadway Weather Information System (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 in the U.S. Eighty-six ESS have been installed with two more sites going operational in the following construction season. Information from the ESS is processed by a central server located in Columbus. The data are used by ODOT garages for treatment of roads during snow and ice conditions. The deployment was contracted as a product purchase wherein the vendor was responsible for equipment installation. ODOT required that the ESS be compliant with National Transportation Communications for ITS Protocol (NTCIP) and support wireless communication. The contract also includes a two-year service agreement (recurring costs over two years) for maintenance support 365 days a year, 24 hours a day, and 7 days a week, with penalties imposed for down sites.[137]	Cost of 88 additional ESS including training and warranty/ service agreement: **$3.699 million** (2003)
NEW System Cost	A fog detection system is being planned in response to a serious multivehicle accident 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 RWISs 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 RWIS and warning signs.[138]	Costs to modify Big Savage and Keyser sites: **$75,000** per location Cost of new infrastructure at Friendsville: **$125,000**

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

Costs *(continued)*		
System Cost	In order to better manage hurricane-related evacuations, the Louisiana Department of Transportation and Development (LA DOTD) worked with the United States Geological Survey (USGS) to deploy Information Stations. Information Stations are USGS Hydrowatch stations that are fitted with traffic count detectors. Information Stations gather and transmit in real time data on traffic and water level conditions along evacuation routes. The costs of these systems vary depending on factors such as retrofitting existing equipment, leveraging joint agency deployments, and sharing operating costs.[139]	Information Station deployment cost: $26,000 (approx.) Information Station annual operations cost: $14,000 (approx.) NEW

ICE AHEAD Information Dissemination

Benefits

Goal Area	# of Studies	Impact	Example
Safety	6	+	An Idaho DOT study found significant speed reductions when weather-related warnings were posted on dynamic message signs. During periods of high winds and snow-covered pavement, vehicle speeds dropped by 35% to 35 mph when warning messages were displayed, compared to a 9% drop to 44 mph without the dynamic message signs.[140]
Customer Satisfaction	1	+	Ninety-four percent of surveyed users of a road weather information website covering roadways in Washington state agree that the weather information made travelers better prepared for their trips. More than half of the respondents (56%) agreed the information helped them avoid travel delays.[20] NEW

Costs

Unit Costs Database	Roadside Telecommunications subsystem Roadside Information subsystem Remote Location subsystem Personal Devices subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Washington State Department of Transportation (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 ESS were installed at Sherman Pass and the town of Laurier, and two mobile HAR systems were installed near the town of Republic and at the town of Kettle Falls. Broadcasts warn motorists of road construction, incidents, dangerous driving conditions and restrictions, and border crossing conditions and closures.[20]	Two ESS: $45,000 each HAR cost: $111,073 -Two mobile HAR: $52,000 -Signs, connectivity, clearing and other associated costs: $59,073 NEW

Lessons Learned

To develop accurate forecasts, ensure careful quality control, and calibration to local conditions for data integration within Road Weather Information Systems (RWIS).[147]

Lessons on weather data analysis for transportation operations

This is a summary of cross-cutting experiences on weather data analysis from five projects. Projects occurred in Pennsylvania, Iowa, Nevada, New York, and Utah. The experiences highlight the approaches to better utilize weather data in transportation operations. Significant lessons learned include:

- Ensure data integration overcomes problems with different data formats; instrument siting and maintenance issues; and communication.
- Increase polling frequency and transmission reliability by using wireless communication technology for RWIS.

Traffic Control

Goal Area	# of Studies	Impact	Example
Benefits			
Safety	5	+	A variable speed limit system implemented along Interstate 75 in Tennessee to control traffic during foggy conditions, and close the freeway if necessary, has dramatically reduced crashes. While there had been more than 200 crashes, 130 injuries, and 18 fatalities on this highway section since the interstate opened in 1973, a 2003 report notes that only one fog-related crash has occurred on the freeway since installation of the system in 1994.[141]
Mobility	1	o	An investigative study sponsored by the Minnesota Department of Transportation (Mn/DOT) found that optimizing traffic signals along an arterial corridor to accommodate adverse winter weather conditions yielded an 8% 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.[142]
Customer Satisfaction	1	?	Survey results in Finland indicate that 90% of drivers found weather-controlled variable speed limit signs to be useful.[143]
Productivity	2	+	The Mn/DOT uses mainline and ramp closure gates to close segments of freeways during severe weather. During a 1998 storm, closure allowed Interstate 90 to be cleared 4 hours earlier than nearby Highway 75, with I-90 clearance costs 18% lower than those for Highway 75.[144]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Roadside Control subsystem Roadside Detection subsystem Roadside Information subsystem Transportation Management Center subsystem	See Appendix A
System Cost	Washington State DOT implemented Travel Aid, a variable speed limit (VSL) system that changes as the weather does, along the Snoqualmie Pass (I-90) east of Seattle. Approximately 13 miles are operated as VSL during the winter months. The system consists of radar detection, six weather stations, nine dynamic message signs, and radio and microwave transmission systems.[53, 77, 78]	Design and implementation cost: $5 million (1997)

Response and Treatment

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	3	?	In Minnesota, the Mn/DOT installed an automated anti-icing system on a 1,950-foot (594-meter), eight-lane bridge near downtown Minneapolis on I-35. In the first year of operation, the system significantly improved roadway safety through a 68% decline in winter crashes, when compared to prior winters with comparable weather.[141]
Productivity	6	+	The Wisconsin DOT has found that a snow forecasting model combined with ice detection systems help improve planning for work schedules, reducing labor-hours up to four hours per person during a significant storm.[145]

Costs		
Unit Costs Database	Roadside Detection subsystem Roadside Control subsystem Roadside Telecommunicatons subsystem Transportation Management Center subsystem	See Appendix A
System Cost	The Southeast Michigan Snow and Ice Management (SEMSIM) project is a multiagency automatic vehicle location (AVL) system that will use 500 highway maintenance vehicles equipped with Global Positioning System (GPS) receivers and sensors to monitor snow plow use, rate of application for de-icing materials, and air and road temperatures. In 2002, the system cost approxiamtely $1.862 million to equip 292 vehicles. The system included the development, manufacturing, testing, and integration of software and hardware components (vehicle logic unit, mobile data terminal, sensors, bracket and wiring harness), and communications. 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. As of November 2003, 375 vehicles were operational.[13]	AVL/GPS system cost: $1.862 million (2002)
System Cost	To address weather-related accidents on a section of I-90 near Vantage, Washington, the Washington State DOT assessed the benefits and costs of deploying an automated anti-icing system to prevent the formation of pavement frost and black ice and to reduce the impact of freezing rain. The proposed installation consists of a liquid chemical storage tank, a pump, a dispensing system with spray nozzles, an ESS, a computerized control system, and a CCTV camera for remote viewing. The system monitors weather and road condition data from the ESS, and automatically activates the dispensing system when predetermined conditions exist. The system also alerts dispatchers and the maintenance supervisor when the anti-icing system is activated.[146]	Initial cost estimate: $599,500 (1999) Annual O&M costs (estimated): $32,800 (1999)

Lessons Learned

Continued from page 104

- Ensure quality control to best utilize environmental data.
- Include metadata in the RWIS data set (e.g., wind speed, precipitation rate, roadway surface conditions, etc.).
- Calibrate data in mesonets to account for differences in station siting.
- Aspirate sensors to account for high bias in temperature readings at RWIS sites during certain conditions.
- Improve mesoscale forecasts in complex terrain by using RWIS data.
- Work to continuously improve predictions of air temperature, precipitation, and cloud cover in order to increase pavement condition forecasting accuracy.

2.12 Commercial Vehicle Operations

ITS applications for commercial vehicle operations are designed to enhance communication between motor carriers and regulatory agencies, particularly during interstate freight movements. 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. Figure 2.12.1 shows the components of the ITS classification scheme for commercial vehicle operations.

Commercial Vehicle Information System and Networks (CVISN) 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.

Electronic screening promotes safety and efficiency for commercial vehicle operators. Carriers that equip their fleets with low-cost in-vehicle transponders can communicate with check stations and automatically transfer regulatory data to authorities as trucks approach check stations. These and other technologies such as weigh-in-motion (WIM) scales improve efficiency and reduce congestion at check stations by allowing safe and legal carriers to bypass inspections and return to the mainline without stopping.

Several ITS technologies have been implemented to support motor carriers with their day-to-day operations: automated vehicle location (AVL)/computer-aided design (CAD) technologies assist with scheduling and tracking of vehicle loads; on-board monitoring of cargo can alert drivers and carriers of potentially unsafe load conditions; and traveler information can help carriers choose alternate routes and departure times, avoid traffic, bypass inclement weather, and arrive on time.

Intelligent Infrastructure

Commercial Vehicle Operations

- 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
  - AVL/CAD
  - On-Board Monitoring
  - Traveler Information
- Security Operations
  - Asset Tracking
  - Remote Disabling Systems

Figure 2.12.1
Classification Scheme for Commercial Vehicle Operations

ITS can also 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.

Table 2.12.1 provides information on the benefits and costs of commercial vehicle operations. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 2.12.1
Benefits and Costs of ITS for Commercial Vehicle Operations

Credentials Administration: Electronic Funds

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	A survey of members of the Maryland Motor Truck Association (MMTA) and the Independent Truckers and Drivers Association (ITDA) indicated the potential value of Electronic Data Interchange (EDI) and the Internet for conducting business with Maryland state agencies rated 1.85 and 2.04 on a scale of one to three.[148]
Productivity	1	?	A two-year study by the American Trucking Association Foundation (ATAF) found that the commercial vehicle administrative processes (CVAP) reduced carriers' costs by an estimated 9–18% when EDI was used.[149]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle Administration subsystem Fleet Management Center subsystem	See Appendix A
System Cost	New York developed an Internet-based One-Stop-Credentialing and Registration system (OSCAR) to provide a cost-effective method to implement commercial vehicle registration and data exchange between states. As a proof-of-concept demonstration, OSCAR provided the following functions: • Internet-accessible credential application forms • International Registration Plan (IRP) credentialing • International Fuel Tax Agreement (IFTA) credentialing • Highway User Tax (HUT) credentialing • Single State Registration System (SSRS) credentialing[150]	Cost for the Internet-based electronic credentialing system: $577,910 (1999)

Credentials Administration: Electronic Registration/Permits

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	2	+	In Europe, several projects investigated management systems designed to improve the operating efficiency of carriers. Benefits included a 30% reduction in order processing time and fewer processing errors.[12]
Customer Satisfaction	2	?	In a survey of Maryland Motor Truck Association members, 33% thought electronic registration was valuable, 13% were neutral, and 11% thought it had little or no value; 43% were unable to comment.[148]
Productivity	5	++	Three motor carriers surveyed during the CVISN model deployment initiative indicated that electronic credentialing reduced paperwork and saved them 60–75% on credentialing costs. In addition, motor carriers were able to commission new vehicles 60% faster by printing their own credential paperwork and not waiting for conventional mail delivery.[21]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle Administration subsystem Fleet Management Center subsystem	See Appendix A
System Cost	As part of the CVISN model deployment initiative, Kentucky and Maryland have implemented end-to-end IRP electronic credentialing systems within their states. The costs to deploy these systems vary with the unique characteristics of each state. A significant impact on cost is whether commercial software is used or special software is developed and if third-party services will be used.[21]	Cost to implement end-to-end IRP in Kentucky: $935,906 Maryland: $464,802

Safety Assurance: Safety Information Exchange

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	1	?	The results of field testing in Connecticut indicate that Inspection Selection Systems (ISS) supplemented with electronic sharing of safety inspection data increased out-of-service order rates by 2%. Modeling efforts estimated that ISS could prevent 84 commercial vehicle accidents per year nationwide.[21]

Costs		
Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle Administration subsystem Commercial Vehicle Check Station subsystem	See Appendix A
System Cost	Using cost data based on full CVISN deployment of Safety Information Exchange (SIE) systems in Kentucky and Connecticut, an estimate can be calculated for other states. Initial SIE systems include wireless telecommunications, Safety and Fitness Electronic Record (SAFER) Data Mailbox, and Commercial Vehicle Information Exchange Window (CVIEW). System cost assumes a state has 50 mobile enforcement units.[21]	Estimated cost for SIE: $650,000 Estimated annual O&M cost: $161,000

Safety Assurance: Automated Inspection

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	1	+	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. The percentage of commercial vehicles placed out of service because of brake problems increased by a factor of 2.5 as a result of infrared screening at these stations.[151]
Customer Satisfaction	1	?	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 inspection than motorcoach drivers.[152]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

Electronic Screening: Safety Screening

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	Most truck drivers and CVO inspectors surveyed during the CVISN Model Deployment Initiative (MDI) felt electronic screening saved them time.[21]
Customer Satisfaction	1	+/–	Motor carriers surveyed during the CVISN MDI 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.[21]
Productivity	2	?	The CVISN MDI analysis 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 B/C ratio of 2:1.[21]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle Check Station subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Electronic Screening: Border Clearance

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	3	+	Simulation models of traffic on the Ambassador Bridge Border Crossing System (ABBCS) showed that electronic border clearance could save equipped trucks 50% of the delay through customs.[153]

Costs

Unit Costs Database	No data to report.
System Cost	No data to report.

Electronic Screening: Weight Screening

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	The Westa (weigh station) simulation model evaluated weigh station throughput in Seymour, Indiana, based on variations in entrance ramp length, deployment of screening transponders, and use of weigh-in-motion (WIM) scales. The model showed that WIM scales can be very effective at reducing the number of trucks in queue at weigh stations.[154]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle Administration subsystem Commercial Vehicle Check Station subsystem Commercial Vehicle On-Board subsystem	See Appendix A
NEW System Cost	Electronic screening infrastructure typically includes automatic vehicle identification, WIM scales, signage, workstations, and telecommunications at the roadside, and transponders installed in commercial vehicles. The majority of the cost for electronic screening is borne by state agencies. Electronic screening costs can range broadly depending on the level of infrastructure.[21, 155, 156]	Roadside equipment cost range: $150,000–$780,000 (1997) In-vehicle transponder cost: $50

Electronic Screening: Credential Checking

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	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.[152]
Productivity	2	?	A survey of the mid-continent transportation corridor along Interstate Highway (IH) 35 from Duluth, Minnesota, to Laredo, Texas, showed that except for the most conservative growth and high-cost estimates, benefits of electronic credential checking exceed costs for most motor carriers. State agencies, however, were able to realize positive B/C ratios only when very aggressive growth scenarios were paired with low-cost estimates.[155]

Costs		
Unit Costs Database	Roadside Telecommunications Subsystem Commercial Vehicle Check Station subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	States interested in converting existing static weigh stations to participate in CVISN electronic screening would not incur some of the one-time start-up costs for the initial site such as software development.[21]	Cost for first site: $522,252 Cost for additional site: $303,450

Lessons Learned

Ensure that the impacts of commercial vehicle technologies are examined from the perspective of both the public and private sectors and understand that these two sectors may have very different priorities and goals. Furthermore, be aware that any movement toward deployment of these technologies must address significant institutional issues.[157]

Lessons on deploying Commercial Vehicle Operations technologies

The USDOT conducted a field operational test and independent assessment in 2004 to investigate the efficacy of commercial vehicle technologies to improve the safety, security, and efficiency of hazardous materials shipments. The test involved 100 vehicles deployed and operating throughout the nation and a variety of technologies from GPS tracking and communications to biometric access. Significant lessons learned from the test include the following:

- Deploy technologies that flexibly address the needs of motor carriers. The motor carrier industry is a diverse universe of businesses, each business with

Carrier Operations and Fleet Management: AVL/CAD

Benefits

Goal Area	# of Studies	Impact	Example
Mobility	1	?	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% and decreased travel time 14%.[12]
NEW Productivity	3	+	Analysis of fleet operations conducted as part of the Hazardous Materials Safety and Security Technology field operational test evaluation demonstrated the potential of tracking technologies to: • Increase driver productivity (increased pick-ups and deliveries) in local operations by 3.5% (less than truck load(LTL)-parcel delivery) and 11% (bulk fuel deliveries). • Reduce overall fleet operating costs per truck $1,560 to $10,968 per year for long-haul truckload operations.[157]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Fleet Management Center subsystem Commercial Vehicle On-Board subsystem	See Appendix A
NEW System Cost	Global Positioning System (GPS) positioning incorporated with terrestrial or satellite-based mobile communication systems, reporting location of power units at predetermined intervals, on-demand by dispatcher or as a result of driver/dispatcher messaging or change in engine ignition status.[157]	Cost: $1,200 (terrestrial) to $2,200 (satellite) per power unit, including installation. Monthly costs approximately $60 per unit.
System Cost	A tracking device installed on fleet trailers can integrate GPS technology with the Internet to provide a secure cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof-mounted solar panel.[23]	Cost: beginning at $800 per trailer (2000) Monthly service cost: $19 per subscriber with a three-year contract (2000)

Carrier Operations and Fleet Management: On-Board Monitoring

Benefits			
Goal Area	# of Studies	Impact	Example
Productivity	2	–	The American Trucking Association Foundation (ATAF) conducted an extensive B/C analysis of the effects of CVO user services on regulatory compliance cost of motor carriers. The B/C ratio for on-board safety monitoring ranged from 0.49:1 to 0.02:1.[158]

Costs		
Unit Costs Database	Fleet Management Center subsystem Commercial Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Carrier Operations and Fleet Management: Traveler Information

Benefits			
Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The FleetForward operational test conducted by the ATAF 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% of motor carriers felt traffic information was a valuable tool for identifying congestion.[159]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

Lessons Learned

Continued from page 114

unique operational characteristics, customer base, business goals, and constraints.

- Demonstrate technology efficacy and return on investment in order to penetrate into the commercial motor carrier market successfully. Motor carrier confidence in technology and the ability of technologies to pay for themselves are key to carrier adoption of technology.
- Consider that commercial vehicle technologies cannot be successful if they are deployed in a vacuum. Such technology must be accompanied by supporting changes in policy and procedures. For example, the addition of a GPS system to high-value cargo offers little security benefit unless methods are put in place to actually allow the cargo to be tracked or monitored.
- Address issues of data privacy early in the design and formulation of potential commercial vehicle technology solutions. Put simply, the private sector will not voluntarily embrace technologies that cannot guarantee the safeguarding of their critical business information.

2.13 Intermodal Freight

ITS can facilitate the safe, efficient, secure, and seamless movement of freight. Figure 2.13.1 shows how intermodal freight applications fit into the ITS classification scheme. 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.

Table 2.13.1 provides information on the benefits and costs of intermodal freight. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Intelligent Infrastructure

Intermodal Freight

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

Figure 2.13.1
Classification Scheme for Intermodal Freight

Table 2.13.1
Benefits and Costs of ITS Applications for Intermodal Freight

Freight Tracking

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	During the Electronic Intermodal Supply Chain Manifest field operational test in Chicago, Illinois, and New York, New York, participants thought access to real-time cargo shipment information over the Internet was beneficial. Manufacturers, carriers, and airports that used the system thought it was easy to use, and were very satisfied with the system's capability of duplicating necessary business functions. The system was expected to improve operational efficiency if more fully deployed.[22]

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle On-Board subsystem Fleet Management Center subsystem	See Appendix A
System Cost	No data to report.	

Asset Tracking

Benefits

No data to report.

Costs

Unit Costs Database	Roadside Telecommunications subsystem Commercial Vehicle On-Board subsystem Fleet Management Center subsystem	See Appendix A
System Cost	A tracking device installed on fleet trailers can integrate Global Positioning System (GPS) technology with the Internet to provide a secure cost-effective method for remote and accurate management of trailers. The self-powered unit has a rechargeable battery pack, a roof-mounted combination GPS and wireless antenna, and a roof- mounted solar panel.[23]	Cost: beginning at $800 per trailer (2000) Monthly service cost: $19 per subscriber with a three-year contract (2000)

Freight Terminal Processes

Benefits			
Goal Area	# of Studies	Impact	Example
Productivity	1	?	An electronic supply chain manifest system implemented biometric and smart-card devices to automate manual paper-based cargo data transfers between manufacturers, carriers, and airports in Chicago, Illinois, and New York, New York. Although participation was limited, the system was expected to improve efficiency. The time required for truckers to accept cargo from manufacturers decreased by about four minutes per shipment, and the time required for airports to accept the deliveries decreased by about three minutes per shipment.[22]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

Dryage Operations

Benefits			
Goal Area	# of Studies	Impact	Example
Mobility	1	?	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 48%.[160]

Costs	
Unit Costs Database	No data to report.
System Cost	No data to report.

3.0 BENEFITS AND COSTS OF INTELLIGENT VEHICLES

Intelligent Vehicles

Program Areas

- Collision Avoidance Systems
- Driver Assistance Systems
- Collision Notification Systems

Figure 3.0.1
Classification Scheme for Intelligent Vehicles

In-vehicle applications of ITS, known as intelligent vehicle technologies, use vehicle-mounted sensors and communications devices to assist with the safe operation of vehicles and mitigate the consequences of crashes that do occur. The many intelligent vehicle applications under various levels of development, testing, and deployment fall into three technology application areas as depicted in Figure 3.0.1. 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 an accident occurs, with more advanced systems providing additional information on crash characteristics that can aid medical personnel.

Sections 3.1 through 3.3 discuss each of these intelligent vehicle technology application areas in greater detail.

3.1 Collision Avoidance Systems

To improve the ability of drivers to avoid accidents, collision avoidance systems continue to be tested and deployed. A number of different vehicle-based technologies are under development:

- Intersection collision warning systems 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 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 systems, often 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 following vehicle driver that they are in conflict with the lead vehicle. The warning can be presented by the lead vehicle or transmitted to an in-vehicle warning system in the following vehicle.

Table 3.1.1 summarizes the classification of benefits and costs under collision avoidance systems.

While most collision avoidance systems are still in the research, prototype, and testing phases, some (e.g., forward collision warning and lane control) have begun to emerge in mainstream markets. Cost data are not readily available for collision warning systems in the early development stages or even for those systems in the commercial market. Much of the collision avoidance system cost data in reports and studies is based on estimates and/or market analysis of the public's willingness to pay for a specific in-vehicle feature. Also, some of

Intelligent Vehicles

Collision Avoidance Systems

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

Figure 3.1.1
Classification Scheme for Collision Avoidance Systems

these features 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. Hence, this section contains few examples of system cost data.

Table 3.1.1 provides information on the benefits and costs of collision avoidance systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 3.1.1
Benefits and Costs of Collision Avoidance Systems

Intersection Collision Warning

Benefits		
No data to report.		
Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Obstacle Detection

Goal Area	# of Studies	Impact	Example
Safety	1	?	A transport company in St. Nicholas, Quebec, Canada, was able to reduce at-fault accidents by 33.8% in the first year after the installation of a radar-based collision warning system. The system included a forward-looking sensor and a side sensor to warn drivers of obstacles in blind spots.[161]

Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	The Federal Transit Administration (FTA), Port Authority of Allegheny County (Pittsburgh, Pennsylvania), and Carnegie Mellon University's Robotics Institute tested a collision avoidance system on 100 buses to warn bus drivers of obstacles in blind spots.[25]	Cost to equip each bus with 12 side-mounted ultrasonic sensors and an on-board computer: $2,600 (approx.) (2001)

Lane Change Assistance

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	2	?	A study conducted by NHTSA indicated a lane change/merge crash avoidance system would be effective in 37% of crashes.[24]

Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	A collision warning system that uses radar technology can reduce sideswipes during lane changes and right turns.[162]	Average cost for a collision warning system with forward-looking and side sensor: $2,500

Road Departure Warning

Benefits			
Goal Area	# of Studies	Impact	Example
Safety	2	?	A study conducted by NHTSA indicated a road-departure countermeasure system would be effective in 24% of crashes.[24]

Costs		
Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Forward Collision Warning

Benefits

Goal Area	# of Studies	Impact	Example
Safety	3	?	A NHTSA modeling study indicated collision warning systems would be effective in 42% of rear-end crash situations where the lead vehicle was decelerating, and effective in 75% of rear-end crashes where the lead vehicle was not moving. Overall, collision warning systems would be 51% effective.[24]

Costs

Unit Costs Database	Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	A Florida-based trucking company has installed a collision warning system to reduce the number of rear-end incidents. Adaptive cruise control can be added to further reduce rear-end collisions.[162, 163]	Average cost for a collision warning system with forward-looking and sidesensor: $2,500 Adaptive cruise control: $350–$400 extra

3.2 Driver Assistance Systems

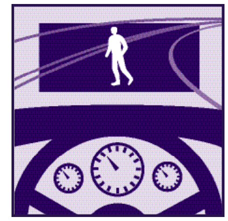
ITS technologies that assist driving tasks continue to gain interest in the marketplace. Several applications are currently available, while others are in various phases of operational tests:

- 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, 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 or adjacent to the path of the vehicle.
- Adaptive cruise control, 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 alerts 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.

Recently, real-time on-board monitoring applications have been developed to 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 the post-accident processing of data.

Figure 3.2.1 summarizes the classification of benefits and costs data for driver assistance systems.

Intelligent Vehicles



Driver Assistance Systems

- 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

Figure 3.2.1
Classification Scheme for Driver Assistance Systems

Many of the driver assistance systems discussed above have begun to emerge in mainstream markets. While system performance and safety testing has been performed by vehicle manufacturers, the impacts of deployment of these technologies on the operation of the transportation system will continue to be evaluated as deployment becomes more widespread. Cost data are not readily available for systems that remain in development stages or even for those systems in the commercial market. Furthermore, many reports and studies on driver assistance systems contain little or no cost data, or are based on estimates and/or market analysis of the public's willingness to pay for a specific in-vehicle feature. Also, some of these features 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. Hence, this section contains few examples of system cost data.

Table 3.2.1 provides information on the benefits and costs of driver assistance systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 3.2.1
Benefits and Costs of Driver Assistance Systems

Navigation/Route Guidance

Benefits

Goal Area	# of Studies	Impact	Example
Safety	2	?	Safety impacts of in-vehicle navigation systems were estimated using simulation models and field data collected from the TravTek project. Results indicated users could decrease their crash risk by up to 4%.[164]
Mobility	4	+	The City Laboratories Enabling Organization of Particularly Advanced Telematics Research and Assessments (CLEOPATRA) project in Turin, Italy, demonstrated a time savings of more than 10% for cars equipped with in-vehicle navigation devices.[12]
Capacity/ Throughput	2	?	Capacity improvements from in-vehicle navigation systems were estimated using simulation models and field data from the TravTek project. Using a market penetration rate of 30%, and overall average trip duration as a surrogate for a given level of service, dynamic route guidance enabled the system to handle a 10% increase in demand.[164]
Customer Satisfaction	3	+	In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio Metropolitan Model Deployment Initiative (MMDI). Focus groups composing drivers of vehicles equipped with the units indicated that the drivers most satisfied with the system were those who frequently drove different routes each day, particularly paratransit drivers and police investigators.[10]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	In-vehicle navigation units were distributed to public agencies in the San Antonio, Texas, area as part of the San Antonio MMDI. The units provided route guidance and real-time traffic conditions. The cost of the units (590 at approximately $2,800 each) was the most significant cost driver for the project. Most of the operations and maintenance (O&M) cost is attributed to database updates.[10]	Total project cost: $2,388,691 (1998) Annual O&M cost: $102,330 (1998)

Driver Communication with Carrier/Dispatch

Benefits

Goal Area	# of Studies	Impact	Example
Productivity	2	+	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%.[165]

Costs

Unit Costs Database	Emergency Vehicle On-Board subsystem Transit Vehicle On-Board subsystem Commercial Vehicle On-Board subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	The automated vehicle location (AVL) system installed by the Regional Transit District (RTD) in Denver, Colorado, included the capability for voice and data communication between fleet vehicles and the dispatch center. The GPS/in-vehicle logic unit/transit control head was approximately $3,517 per bus.[92]	AVL system cost: $10.4 million

Adaptive Cruise Control

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	+/–	Ten vehicles were equipped with adaptive cruise control, including automatic throttle modulation and down shifting (but not braking) to maintain preset headways during a NHTSA field test. The performance of the system was compared to conventional cruise control and manually operated vehicles. Results indicated that vehicles equipped with adaptive cruise control made the fewest number of risky lane changes in response to slower traffic. Manually operated vehicles, however, had the quickest average response time to lead vehicle brake lights.[26]
Capacity/ Throughput	3	+	In the Netherlands, a simulation model investigated the impact of an automated braking system capable of automatically resetting itself after activation in the operational speed range of 30 to 150 km/hr. With a market penetration of 20%, and a headway setting of 0.8 seconds, the system increased capacity by 3.2%. However, if headway was set at 1.2 seconds, capacity increased by only 1.0%.[166]
Customer Satisfaction	2	+	The adaptive cruise control system deployed in the NHTSA field test generally had a very high level of acceptance by the participants. Participants overwhelmingly ranked adaptive cruise control over the manual and conventional cruise control-equipped vehicles for convenience, comfort, and enjoyment. Participants indicated they would most likely use the system on freeways.[26]
Energy/ Environment	3	+	Driver response and vehicle dynamics were recorded for one adaptive cruise control vehicle and two manually operated vehicles in a single lane of freeway traffic. The adaptive cruise control 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% during scenarios with frequent acceleration and deceleration.[167]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	A Florida-based trucking company has installed a collision warning system to reduce the number of rear-end incidents. The company installed the collision warning system on 1,682 tractors with plans to outfit the entire fleet of about 4,000. Adaptive cruise control, at an additional cost of $350–$400, can be added to further reduce rear-end collisions.[162, 163]	Average cost for a collision warning system with forward-looking and side sensor: $2,500

Intelligent Speed Control

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	In the southern Swedish town of Eslov, 25 personal vehicles were equipped with governors activated by wireless beacons at city points-of-entry to limit inner city vehicle speeds to 50 km/hr. The vast majority of participants preferred this adaptive speed control over other physical countermeasures such as speed humps, chicanes, or mini-roundabouts.[168]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Coupling/Decoupling

Benefits

Goal Area	# of Studies	Impact	Example
Energy/ Environment	1	?	An electronic towbar system coupled two heavy-duty trucks without the aid of a mechanical towbar. The system enabled a trailing truck to autonomously follow a lead truck by a distance of approximately 10 meters. Track testing showed the lead truck and the trailing truck reduced fuel consumption by about 7% and 15–21%, respectively, when traveling at 80 km/hr.[169]

Costs

Unit Costs Database	Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

3.3 Collision Notification Systems

Collision notification systems have been designed to 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 (ACN)), and typically establish wireless data and voice communications with call centers that then relay the information to emergency response services. Data transmitted include vehicle location and description and the 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 an accident, 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.

Figure 3.3.1
Classification Scheme for Collision Notification Systems

Figure 3.3.1 summarizes the classification of benefits and costs data under collision notification.

More than 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.

Table 3.3.1 provides information on the benefits and costs of collision notification systems. An assessment of the impact of these systems is indicated by using the symbols in the Impact Legend at the bottom of each page.

Table 3.3.1
Benefits and Costs of Collision Notification Systems

Mayday/ACN

Benefits

Goal Area	# of Studies	Impact	Example
Customer Satisfaction	1	?	The Puget Sound Help Me (PuSHMe) Mayday System allowed a driver to immediately contact a response center, transmit GPS coordinates, and request assistance. Survey responses were collected from 23 participants equipped with Mayday voice communication systems, and 54 participants equipped with Mayday text messaging. The surveys indicated 95% of drivers felt more secure if equipped with Mayday voice communications, and 70% of drivers felt more secure if equipped with Mayday text messaging.[170]

Costs

Unit Costs Database	Roadside Telecommunication subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	Numerous commercial Mayday/ACN products are available as factory-installed and after-market devices. Cost data are more prevalent for after-market devices than for factory-installed systems. Installation costs were not readily available. Annual service fees vary depending on the level of services offered.[28]	After-market device cost range: \$400–\$1,895 Monthly service fee: \$10–\$27

Advanced ACN

Benefits

Goal Area	# of Studies	Impact	Example
Safety	1	?	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.[27]

Costs

Unit Costs Database	Roadside Telecommunication subsystem Vehicle On-Board subsystem	See Appendix A
System Cost	No data to report.	

Impact Legend ++ substantial positive impacts + positive impacts o negligible impacts +/– mixed results ? not enough data – negative impacts

4.0 Conclusion

This report has presented many of the findings on the benefits and costs of ITS accumulated in the ITS Benefits and Costs Databases. New in this 2005 report is the inclusion of summaries of lessons learned during ITS planning, deployment, and evaluation. Significant amounts of information are available for many ITS services, but many gaps in knowledge also exist. Refer to Appendix B for additional detail on available benefits and cost data. In general, ITS services have shown positive benefit, but the authors have identified a number of areas with mixed results, not enough information, or negligible impacts. While reported negative impacts are usually outweighed by other positive impacts, a few evaluations have identified opportunities for improvement in future deployments. The reader should note that reported results are highly sensitive to the deployment environment.

Interested 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 cost data up to date. The reader is reminded to check online for the most current information on benefits, costs, and lessons learned at www.benefitcost.its.dot.gov.

The level of ITS deployment in the United States and worldwide continues to increase (see www.itsdeployment.its.dot.gov). As experience with additional applications increases, additional impacts will become apparent, and further information on the costs of ITS implementation will become available. Implementing agencies will also learn valuable lessons regarding appropriate implementation and operational strategies. The ITS JPO will continue to make this information available via the JPO website at www.its.dot.gov, the ITS Benefits and Costs Databases at www.benefitcost.its.dot.gov, the forthcoming ITS Lessons Learned Database (available in the summer of 2005), and other publications.

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Appendix A: ITS Unit Cost Data

(as of September 30, 2004)

ITS unit costs are available in two formats: unadjusted (see Section A.1 on the following page) and adjusted (see Section A.2). The unadjusted format presents costs data in its original value along with the dollar year of the capital and operating and maintenance (O&M) costs. The adjusted format presents capital and O&M unit costs in 2003 dollars. The dollar year the cost data were adjusted from is provided along with the index used to adjust the cost data. If the cost data are 2003 values, then no adjustment was made. The unit costs presented in this appendix represent data collected through September 30, 2004.

Information on indexes used to adjust the costs is provided in Table A. The indexes used in the adjustments are maintained by the Bureau of Labor Statistics (www.bls.gov). The year-by-year index series from 1995 to 2003 can be accessed at this website. Index information is also available in the ITS Costs Database (www.benefitcost.its.dot.gov).

Table A
Indexes Used to Adjust ITS Unit Costs Data

Index	Index Series Identifier	Application to ITS Unit Costs Database Elements
1	WPU1176	Communications and related equipment
2	WPU1178	Elements that contain electronic components
3	PCU5112105112102	Software and integration elements
4	PCU BBLD-BBLD	Physical dwellings at Centers and Toll Plaza
5	WPU115	Computer hardware
6	ECI11061I	Labor categories
7	CUUR0000SA0	ISP Liability Insurance (IS016)

The index number in Section A.2 (far left column) corresponds to the index used to adjust the cost data. The index is representative of the ITS element. For example, the first element in Roadside Telecommunications, DS0 Communication Line, is tagged with Index 1. Index 1 is the WPU1176 index and is applied to communications and related equipment. The capital cost range is an adjusted value and was adjusted from a 1995 value (see date directly to the right of the capital cost range). The O&M costs are 2003 values obtained in Mitretek's analysis (as such, no adjustment needed).

Appendix A.1
Unadjusted Unit Costs

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Roadside Telecommunications (RS-TC)									
DS0 Communication Line	TC001	20	0.5	1	1995	0.6	1.2	2003	56Kbps capacity. Leased with typical distance from terminus to terminus of 8–15 miles, but most of the cost is not distance sensitive.
DS1 Communication Line	TC002	20	0.5	1	1995	4.8	8.4	2002	1.544Mbps capacity (T1 line). Leased with typical distance from terminus to terminus of 8–15 miles, but most of the cost is not distance sensitive.
DS3 Communication Line	TC003	20	3	5	1995	24	72	2001	44.736 Mbps capacity (T3 line). Leased with typical distance from terminus to terminus of 8–15 miles, but most of the cost is not distance sensitive.
ISP Service Fee	TC007					0.18	0.6	2002	Monthly service fee ranges from $15 per month for regular dial-up service to $50 per month for DSL.
Direct Bury Armor Encased Fiber Cable			60		1999	0.02		1999	Cost is per mile. Includes cable and installation.
Conduit Design and Installation - Corridoring		20	50	65	2003	0.02		1999	Cost is per mile. Includes boring, trench, 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.
Twisted Pair Installation		20	12		1999	0.02		1999	Cost is per mile.
Fiber Optic Cable Installation		20	20	50	2003	0.02		1999	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.
Cellular Communication			0.5		1999	0.3	0.4	1999	Cost is for one unit.
900 MHz Spread Spectrum Radio		10	9		1999	0.15	0.4	1999	Cost is per link.
Microwave Communication		10	10	20	2002	0.5	1	2002	Cost is per link. Cost could be higher depending on tower/antenna installation.
Wireless Communications, Low Usage	TC004					0.12	0.2	2003	125 Kbytes/month available usage (non-continuous use).
Wireless Communications, Medium Usage	TC005					0.6	0.7	1995	1,000 Kbytes/month available usage (non-continuous use).
Wireless Communications, High Usage		20	0.5	1	1995	1.2	1.8	2002	3,000 Kbytes/month available usage (non-continuous use).
Call Box		10	4	5.9	2002	0.714		1999	Capital cost includes call box and installation. O&M is cost per unit (per year) for service maintenance contract and annual cellular service fee.

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

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Roadside Detection (RS-D)									
Inductive Loop Surveillance on Corridor		5	3	8	2001	0.5	0.8	1995	Double set (four loops) with controller, power, etc.
Inductive Loop Surveillance at Intersection		5	9	16	2003	1	1.6	1999	Four legs, two lanes/approach.
Machine Vision Sensor on Corridor		10	21.7	29	2003	0.2	0.4	2003	One sensor both directions of travel. Does not include installation.
Machine Vision Sensor at Intersection		10	20	25.7	2003	0.2	0.5	2003	Four-way intersection, one camera per approach. Does not include installation.
Passive Acoustic Sensor on Corridor			3.7	8	2002	0.2	0.4	1998	Cost range is for a single sensor covering up to five lanes. Low cost is for basic sensor, which consists of the sensor, mounting kit, junction box, and cabinet termination card. High cost includes basic sensor with solar and wireless option. This option consists of an antenna, solar charger, battery, and panel, and wireless base station, which will handle up to eight sensors. Capital costs do not include installation or mounting structure.
Passive Acoustic Sensor at Intersection			5	15	2001	0.2	0.4	2002	Four sensors, four leg intersection.
Remote Traffic Microwave Sensor on Corridor		10	3.3	6	2002	0.1		2001	One sensor both directions of travel. Includes installation.
Remote Traffic Microwave Sensor at Intersection		10	18		2001	0.1		2001	Four sensors, four leg intersection. Includes installation.
Infrared Sensor Active			6	7.5	2000				Sensor detects movement in two directions and determines vehicle speed, classification, and lane position.
Infrared Sensor Passive			0.7	1.2	2002				Sensor covers one lane and detects vehicle count, volume, and classification.
CCTV Video Camera	RS007	10	7.5	17	2003	1.5	2.4	2001	Cost includes color video camera with pan, tilt, and zoom (PTZ). Includes installation.
CCTV Video Camera Tower	RS008	20	4	12	2003				Low cost is for a 35 ft. tower. High cost is for 90 ft. tower. Includes foundation, pole, conduit, and labor.
Pedestrian Detection Microwave			0.6		2001				Cost is per device. Typical deployment consists of two devices per crosswalk for detection of pedestrian in crosswalk. Can be used for detection of pedestrian at the curbside.
Pedestrian Detection Infrared			0.3	0.5	2002				Cost is per device. Does not included installation. Typical deployment consists of two devices per crosswalk for detection of pedestrian at the sidewalk. Can be used for detection of pedestrian in the crosswalk.

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

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Environmental Sensing Station (Weather Station)		25	30	50	2003	1.9	4.1	2003	Environmental Sensing Station (ESS), also known as a weather station, consists of pavement temperature sensor, subsurface temperature sensor, precipitation sensor (type and rate), wind sensor (speed and 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 five years at $6.4K. O&M includes calibration, equipment repairs, and replacement of damaged equipment. O&M costs could be higher if state provided maintenance.
Traffic Camera for Red Light Running Enforcement			75	136	2001	60		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 two cameras for a three-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.
Lowering System		20	8	10.5	2003				Cost includes the lowering system and the pole (pole height ranging 40 ft. to 70 ft.). Installation costs not included. The lowering system is mechanically operated; requires routine lubrication.
Portable Speed Monitoring System		15	5	15	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.
Portable Traffic Management System			80	100	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)									
Linked Signal System LAN	RS002	20	40	70	1995	0.4	0.8	1995	This element provides the connections to the linked signal system.
Signal Controller Upgrade for Signal Control	RS003	20	2.5	6	2003	0.2	0.5	1995	Local controller upgrade to provide advanced signal control.
Signal Controller and Cabinet			8	15	2003	0.2	0.5	2001	Includes installation of traffic signal controller and cabinet per intersection.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Traffic Signal			95	115	2001	2.4	3	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).
Signal Preemption Receiver	RS004	5	2	8	1995	0.05	0.2	1995	Two per intersection. Complement of IDAS elements RS005 and TV004.
Signal Controller Upgrade for Signal Preemption	RS005	10	2	5	1995				Add-on to base capability (per intersection). Complement of IDAS elements RS004 and TV004.
Roadside Signal Preemption/Priority			2.5	5.5	2003				Includes infrared detector, detector cable, phase selector, and system software. Capital costs range is for two directions (low) and four directions (high). Does not include installation costs. Complement to transit (or emergency vehicle) on-board Signal Preemption/Priority Emitter.
Ramp Meter	RS006	5	25	50	2003	1.2	2.8	2003	Includes ramp meter assembly, signal displays, controller, cabinet, detection, and optimization.
Software for Lane Control	RS011	20	25	50	1995	2.5	5	1995	Software and hardware at site. Software is off-the-shelf technology and unit price does not reflect product development.
Lane Control Gates	RS012	20	100	150	1995	2	3	1995	Per location.
Fixed Lane Signal	RS009	20	6	8	1995	0.6	0.8	1995	Cost per signal.
Automatic Anti-Icing System Short Span		12	25		1998	2		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 five 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.
Automatic Anti-Icing System Long Span		12	50	495	1999	1.5	29.5	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 five years at cost of $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.
Roadside Information (RS-I)									
Roadside Message Sign	RS010	20	50	75	1995	2.5	3.75	1995	Fixed message board for HOV and HOT lanes.
Wireline to Roadside Message Sign	RS013	20	6	9	1995				Wireline to VMS (0.5 mile upstation).
Variable Message Sign	RS015	20	48	120	2003	2.4	6	2003	Low capital cost is for smaller VMS installed along arterial. High capital cost is for full matrix, LED, three-line, walk-in VMS installed on freeway. Cost does not include installation.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Variable Message Sign Tower	RS016	20	25	120	2003				Low capital cost is for a small structure for arterials. High capital cost is for a larger structure spanning three to four lanes. VMS tower structure requires minimal maintenance.
Variable Message Sign–Portable		14	21.5	25.5	2002	1.2	2	2000	Trailer mounted VMS (three-line, 8” character display); includes trailer, solar or diesel powered.
Highway Advisory Radio	RS017	20	16	32	2001	0.6	1	2001	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.
Highway Advisory Radio Sign		10	5	9	2003	0.25		2003	Cost is for a HAR sign with flashing beacons. Includes cost of the controller.
Roadside Probe Beacon	RS020	5	5	8	2001	0.5	0.8	2001	Two-way device (per location).
LED Countdown Signal		10	0.325	0.45	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. Countdown signals use low eight-watt LED bulbs, which require replacement approximately every five to seven years.
Pedestrian Crossing Illumination System		5	27.5	42	2003	2.75	4.2	2001	The capital cost range includes cost of equipment and installation. Equipment includes fixtures—four 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.
Variable Speed Display Sign			3.7	5	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)									
Rail Crossing Four-Quad Gate, Signals	RS021	20	115	130	1995	4.25	4.85	1995	Gates and signals.
Rail Crossing Train Detector	RS022	20	16	21.5	1995	0.77	1.03	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.
Rail Crossing Controller	RS023	10	8	10	1995	0.4	0.5	1995	Intelligent interface controller (IIC).
Rail Crossing Pedestrian Warning Signal, Gates	RS024	20	10	15	1995	0.2	0.3	1995	Pedestrian warning signal and gates.
Rail Crossing Trapped Vehicle Detector	RS025	10	25	30	1995	1.25	1.5	1995	Entrapped vehicle detection camera with poles and controller.

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			Low	High		Low	High		
Parking Management (PM)									
Entrance/Exit Ramp Meters		10	2	5	1995	0.2	0.5	1995	Ramp meters are used to detect and count vehicles entering/exiting the parking facility. O&M costs based on annual service contract.
Tag Readers		10	2	5	1995	0.2	0.5	1995	Readers support electronic payment scheme. O&M costs based on annual service contract.
Database and Software for Billing and Pricing		10	10	15	1995	1	2	1995	Database system contains parking pricing structure and availability. O&M costs based on annual service contract.
Parking Monitoring System		10	21	46	1998				Includes installation, detectors, and controllers.
Toll Plaza (TP)									
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.
High-Speed Camera	TP002	10	7	10	2003	0.5	1	1995	Cost includes one camera/two lanes.
Electronic Toll Collection Software	TP003	10	5	10	1995				Includes COTS software and database.
Electronic Toll Collection Structure	TP004	20	10	15	1995				Mainline structure.
Remote Location (RM)									
CCTV Camera	RM001	7	2.1	5	2003	0.1	0.25	2003	Interior fixed mount camera for security. Low cost represents black and white pan/tilt/zoom (PTZ). High cost represents color PTZ. Does not include installation.
Integration of Camera with Existing Systems	RM002	10	2	2.5	1995				Per location.
Informational Kiosk	RM003	7	12	25	2001	1.2	5	1998	Includes hardware, enclosure, installation, modem server, and map software.
Integration of Kiosk with Existing Systems	RM004	7	2.2	27.4	1995				Software costs are for COTS (low) and developed/outdoor (high).
Kiosk Upgrade for Interactive Usage	RM005	5	5	8	1995	0.5	0.8	1995	Interactive information display interface (upgrade from existing interface).
Kiosk Software Upgrade for Interactive Usage	RM006	5	10	12	1995				Software is COTS.
Transit Status Information Sign		10	4	8	2002				A LED display installed at transit terminal that provides status information on transit arrival. Cost depends on quality, size, and controller capabilities.
Smart Card Vending Machine	RM007	5	37	40	1995	1.85	2	1995	Ticket vending machine for smart card.
Software, Integration for Smart Card Vending	RM008	20	3	5	1995				Software is COTS.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Emergency Response Center (ER)									
Basic Facilities, Comm for Large Area	EM006		4,000		1995	400	600	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.
Basic Facilities, Comm for Medium Area	EM007		3,200		1995	400	480	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.
Basic Facilities, Comm for Small Area	EM008		2,800		1995	400	420	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
Emergency Response Hardware	EM001	5	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M is estimated at 2% of capital cost.
Emergency Response Software	EM002	10	70	150	1995	0.5	3.5	1995	Includes emergency response plans database, vehicle tracking software, and real-time traffic coordination.
Emergency Response Labor	EM003					50	165	1995	Two people. Salary costs are fully loaded including salary, overtime, overhead, benefits, etc.
Emergency Management Communications Software	EM004	20	5	10	1995	2.5	5	1995	Shared database between four sites. Cost is per site; software is COTS.
Hardware, Software Upgrade for E-911 and Mayday	EM005	10	105	180	1995	1.7	2.5	1995	Data communications translation software, E911 interface software, processor, and three workstations.
800 MHz. Two-way Radio		5	0.8	1.7	2001	0.09	0.12	2001	Cost is per radio.
Emergency Vehicle On-Board (EV)									
Communications Interface	EV001	10	0.3	2	1995	0.02		1995	Emergency vehicle communications. Cost is per vehicle.
Signal Preemption/Priority Emitter			0.5	2.1	2003				Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/Priority (see Roadside Control subsystem).
Information Service Provider (ISP)									
Basic Facilities, Comm for Large Area	IS019		4,000		1995	400	600	1995	For population >750,000 (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.
Basic Facilities, Comm for Medium Area	IS020		3,200		1995	400	480	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.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Basic Facilities, Comm for Small Area	IS021		2,800		1995	400	420	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
Information Service Provider Hardware	IS001	5	26	35	2003	0.5	0.7	2003	Includes two servers and five workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Systems Integration	IS017	20	90	110	1998				Integration with other systems.
Information Service Provider Software	IS002	20	275	550	1995	13.75	27.5	1995	Includes database software (COTS) and traffic analysis software.
Map Database Software	IS003	2	15	30	2003				Software is COTS.
Information Service Provider Labor	IS004					175	250	1995	Two staff at $50K to $75K and one staff at $75K to $100K. Salary cost are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
FM Subcarrier Lease	IS005					120	240	1995	Cost is per year.
Hardware Upgrade for Interactive Information	IS006	5	12	16	2003	0.24	0.32	2003	Includes one server and two workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Software Upgrade for Interactive Information	IS007	20	250	500	1995	12.5	25	1995	Trip planning software (includes some development costs).
Added Labor for Interactive Information	IS008					100	150	1995	One staff at $50K to $75K for two shifts. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software Upgrade for Route Guidance	IS009	20	250	500	1995	12.5	25	1995	Route selection software. Software is COTS.
Map Database Upgrade for Route Guidance	IS010	2	100	200	1995				Map database software upgrade.
Hardware Upgrade for Emergency Route Planning	IS011	5	8	10	2003	0.16	0.2	2003	Includes one server. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Software Upgrade for Emergency Route Planning	IS012	20	50	100	1995	2.5	5	1995	Route guidance software. Software is COTS.
Hardware Upgrade for Dynamic Ridesharing	IS013	5	4	6	2003	0.08	0.12	2003	Includes two workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
Software Upgrade for Dynamic Ridesharing	IS014	20	100	200	1998	5	10	1995	Software includes some development cost.
Added Labor for Dynamic Ridesharing	IS015					100	150	1995	One staff at $50K to $75K for two shifts. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Liability Insurance for Dynamic Ridesharing	IS016					50	100	1995	$50K to $100K per year.
Software Upgrade for Probe Information Collection	IS018	20	250	500	1995	12.5	25	1995	Software includes COTS and some development cost.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Transportation Management Center (TM)									
Basic Facilities, Comm for Large Area	TM040		3,500	8,000	2003	350	1,200	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.
Basic Facilities, Comm for Medium Area	TM041		3,200	3,200	1995	400	480	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.
Basic Facilities, Comm for Small Area	TM042		2,800	2,800	1995	400	420	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.
Hardware for Signal Control	TM001	5	18.5	28.5	2003	9	10.5	2003	Includes one server and multiple workstations. O&M includes responsive and preventative maintenance.
Software, Integration for Signal Control	TM006	5	105	150	2003	150		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.
Labor for Signal Control	TM002					486	594	2001	Costs include labor for operations (two at 50% of the time, at $100K), transportation engineer (one at 50% of the time, at $100K), update timing plans ($2K per system per month for every 10 systems), and signal maintenance technician (two at $75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Hardware, Software for Traffic Surveillance	TM003	20	135	165	1995	6.75	8.25	1995	Processor and software.
Integration for Traffic Surveillance	TM032	20	225	275	1995	11.25	13.75	1995	Integration with other systems.
Hardware for Freeway Control	TM004	5	6	9	2003	0.3	0.45	2003	Includes three workstations. O&M estimated at 5% of capital cost.
Software, Integration for Freeway Control	TM007	5	180	220	2002				Software and integration, installation and one year maintenance. Software is off-the-shelf technology and unit cost does not reflect product development.
Labor for Freeway Control	TM005					225	275	2001	Labor for operations (two at 50% of $100K) and maintenance technicians (two at $75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Hardware for Lane Control	TM008	5	2	3	2003	0.1	0.15	2003	Includes one workstation and 19” monitor. O&M estimated at 5% of capital cost.

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			Low	High		Low	High		
Software, Integration for Lane Control	TM009	10	225	275	1995	11.25	13.75	1995	Software development and integration and software upgrade for controllers. Software development is fine tune adjustments for local installations. Otherwise, software is COTS.
Labor for Lane Control	TM010					90	110	2001	Labor for two operators at 50% of $100K.
Software, Integration for Regional Control	TM011	10	300	400	1998				Software and integration, installation and one year maintenance. Integration with other TMC's. Software is COTS.
Real-time, Traffic Adaptive Signal Control System		10	120	150	2001	20		2001	The costs 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.
Labor for Regional Control	TM012					180	220	2001	Labor for operators (two at 50% of $100K), transportation engineer (one at 50% of $100K), and maintenance contract. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Video Monitors, Wall for Incident Detection	TM013	15	57	103	2003	3	5	2003	Video wall and monitors. O&M estimated at 5% of capital cost
Hardware for Incident Detection	TM014	5	43	57	2003	2.15	2.85	2003	Includes four servers, five workstations, and two laser printers. O&M estimated at 5% of capital cost; could be higher for responsive and preventative maintenance.
Integration for Incident Detection	TM025	20	90	110	1995	4.5	5.5	1995	Integration with other systems.
Software for Incident Detection	TM015	5	90	110	2002	4.5	5.5	2002	Software is COTS and includes development cost. O&M is estimated at 5% of capital.
Labor for Incident Detection	TM016					630	770	2001	Labor for operators (four at $100K and one manager at $150K) and two maintenance techs at $75K.
Video Monitor for Incident Response	TM017	5	0.6	1.5	2003				Includes one 19" monitor.
Hardware for Incident Response	TM018	5	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
Integration for Incident Response	TM026	20	180	220	1995				Integration with other systems.
Software for Incident Response	TM019	2	13.5	16.5	1995	0.675	0.825	1995	Software is COTS.
Labor for Incident Response	TM020					90	110	2001	Labor for incident management coordinator (one at $100K).
Automated Incident Investigation System		5	15		2001				Includes workstation, tripod, monopole antenna, Auto Integration, and AutoCAD software.
Hardware for Traffic Information Dissemination	TM021	5	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
Software for Traffic Information Dissemination	TM022	5	18	22	1995	0.9	1.1	1995	Software is COTS.
Integration for Traffic Information Dissemination	TM023	20	90	110	2000	4.5	5.5	1995	Integration with other systems.
Labor for Traffic Information Dissemination	TM024					90	110	2001	Labor for one operator at $100K. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.
Software for Dynamic Electronic Tolls	TM027	5	22.5	27.5	1995	1.125	1.375	1995	Includes software installation and one year maintenance. Software is COTS.

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			Low	High		Low	High		
Integration for Dynamic Electronic Tolls	TM028	20	90	110	1995	4.5	5.5	1995	Integration with other systems.
Hardware for Probe Information Collection	TM033	3	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
Software for Probe Information Collection	TM034	5	18	22	1995	1.8	2.2	1995	Includes software installation and one year maintenance. Software is COTS.
Integration for Probe Information Collection	TM035	20	135	165	1995	13.5	16.5	1995	Integration with other systems.
Labor for Probe Information Collection	TM036					45	55	2001	Labor for one operator (four hours per day at $100K/year). Salary costs are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
Software for Rail Crossing Monitor	TM037	5	18	22	1995	1.8	2.2	1995	Includes software installation and one year maintenance. Software is COTS.
Integration for Rail Crossing Monitor	TM038	20	90	110	1995				Integration with other systems.
Labor for Rail Crossing Monitor	TM039					45	55	2001	Operators (one at 50% of $100K). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Road Weather Information System (RWIS)		25	25		1998	0.4	2.5	2001	An 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 ($10K–$50K) should be added to $25K listed here in order to cost out the entire system. CPU replaced every 5 years at a cost of $4K. O&M costs range includes communication, and optional weather forecast/meteorological service.
Tansit Management Center (TR)									
Basic Facilities, Comm for Large Area	TR014		4,000	4,000	1995	400	600	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.
Basic Facilities, Comm for Medium Area	TR015		3,200	3,200	1995	400	480	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.
Basic Facilities, Comm for Small Area	TR016		2,800	2,800	1995	400	420	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.
Transit Center Hardware	TR001	5	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M estimated at 2% of capital cost.
Transit Center Software, Integration	TR002	20	815	1,720	1995	6	12	1995	Includes vehicle tracking and scheduling, database and information storage, schedule adjustment software, real-time travel information software, and integration. Software is COTS.

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			Low	High		Low	High		
Transit Center Additional Building Space	TR003					6	9	1995	Additional space required for ITS technology - $12–$18/sq.ft., 500 sq.ft.
Transit Center Labor	TR004					50	250	1995	Labor for three staff at $75K. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Upgrade for Auto. Scheduling, Run Cutting, or Fare Payment	TR005	20	20	40	1995	0.4	0.8	1995	Processor/software upgrade, installation and one year maintenance (for processor). Software is COTS.
Integration for Auto. Scheduling, Run Cutting, or Fare Payment	TR012	20	225	500	1995				Integration with other systems.
Further Software Upgrade for E-Fare Payment	TR013	20	40	60	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.
Vehicle Location Interface	TR007	20	10	15	1995				Vehicle location interface.
Video Monitors for Security System	TR008	5	3	7	2003	0.06	0.14	2003	Five per site. O&M estimated at 2% of capital cost.
Hardware for Security System	TR009	5	14	19	2003	0.28	0.38	2003	Includes one server and three workstations. O&M estimated at 2% of capital cost; could be higher for preventative and responsive maintenance.
Integration of Security System with Existing Systems	TR010	20	250	500	1995				Integration with other systems.
Labor for Security System	TR011					202	247	1995	Labor for three staff at $75K each. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Toll Administration (TA)									
Toll Administration Hardware	TA001	5	4	6	2003	0.2	0.3	2003	Includes two workstations, printer, and modem. O&M estimated at 5% of capital costs.
Toll Administration Software	TA002	10	40	80	1995	4	8	1995	Includes local database and national database coordination. Software is COTS.
Transit Vehicle On-Board (TV)									
Driver Interface and Schedule Processor	TV001	10	0.3	0.5	1995	0.006	0.01	1995	On-board schedule processor and database.
Cell-Based Communication Equipment	TV002	10	0.15	0.25	1995	0.0075	0.0125	1995	Cell-based radio with data capacity.
GPS/DGPS for Vehicle Location	TV003	10	0.5	2	2002	0.01	0.04	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.
Signal Preemption Processor	TV004	10	0.3	0.6	1995	0.006	0.01	1995	On-board schedule processor and database. Complement to IDAS elements RS004 and RS005.
Signal Preemption/Priority Emitter			0.5	2.1	2003				Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/Priority (see Roadside Control subsystem).
Preemption/Priority Transponder			0.075		2000				Passive transponder mounted on underside of transit vehicle. Requires transit priority system at the Transit Management Center.

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

Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Trip Computer and Processor	TV005	10	0.1	0.15	1995	0.002	0.003	1995	On-board processor for trip reporting and data storage.
Security Package	TV006	10	4.2	7	1995	0.21	0.265	1995	On-board CCTV surveillance camera and hot button. The high capital cost represents a common installation of a digital event recorder system.
Electronic Farebox	TV007	10	0.8	1.5	1995	0.04	0.075	1995	On-board flex fare system DBX processor, on-board farebox, and smart card reader.
Automatic Passenger Counting System		10	1	10	2003				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 Administration (CA)									
Commercial Vehicle Admin Hardware	CA001	5	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M estimated at 2% of capital cost.
Commercial Vehicle Admin Software, Integration	CA002	20	200	220	1995	4	4.4	1995	Includes processor and integration. Software is COTS.
Commercial Vehicle Admin Labor	CA003					270	330	2003	Labor for four staff at $75K (average). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software Upgrade for Electronic Credential Purchasing	CA004	20	60	140	1995	1.2	2.8	1995	Electronic credentials purchase software, database and management for post-trip processing and E-credentials.
Software Upgrade for Inter-Agency Info Exchange	CA005	20	20	40	1995	0.4	0.8	1995	Processor and integration add-on. Software is COTS.
Added Labor for Inter-Agency Info Exchange	CA006					67	82	1995	Labor for one staff at $75K (average). Salary cost are fully loaded prices including base salary, overtime, benefits, etc.
Software Upgrade for Safety Administration	CA007	20	40	80	1995	0.8	1.6	1995	Database add-on, software, and integration. Software is COTS.
Commercial Vehicle Check Station (CC)									
Check Station Structure	CC001	20	50	75	1995				Roadside structure–mainline w/ lane indicator signals.
Signal Board	CC002	10	10	15	1995	1	1.5	1995	Roadside signal board.
Signal Indicator	CC003	20	5	10	1995	0.25	0.5	1995	Signal indicator system.
Roadside Beacon	CC004	10	5	8	1995	0.5	0.8	1995	Roadside beacon used for electronic screening (not included in roadside subsystem). Beacon repair/replacement.
Wireline to Roadside Beacon	CC005	20	10	20	1995				Dedicated wireline communication from beacon to roadside (one mile upstream).
Check Station Software, Integration	CC006	20	180	215	1995				Software, processor and integration.
Check Station Hardware	CC007	5	2	3	2003	0.04	0.06	2003	Includes one workstation. O&M estimated at 2% of capital cost.
Safety and Fitness Electronic Records (SAFER) Data Mailbox			7.5	9.2	1999	0.44	0.66	1999	Includes portable computer with printer and wireless Internet modem to download, record, and upload carrier safety database records at field locations or check stations.
Detection System	CC008	10	50	75	1995	2.5	3.75	1995	Commercial vehicle communication interface and communication device (cell based radio).

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Software Upgrade for Safety Inspection	CC009	20	40	80	1995	0.8	1.6	1995	Safety database add-on and result writing to vehicle tag processor add-on. Software is COTS.
Handheld Safety Devices	CC010	5	3	5	1995	0.3	0.5	1995	For commercial vehicle inspection. The devices either measure data themselves or read data from the vehicle. Three per location.
Software Upgrade for Citation and Accident Recording	CC011	20	20	40	1995	1	2	1995	Software add-on for recording of citation and accident information to the commercial vehicle.
Weigh-In-Motion Facility	CC012	10	14	21	1995	1.4	2.1	1995	Includes WIM fixed load cell and interface to roadside facility. Software is COTS.
Wireline to Weigh-In-Motion Facility	CC013	10	1	2	1995	0.1	0.2	1995	Wireline communication (local line).
Commercial Vehicle On-Board (CV)									
Electronic ID Tag	CV001	10	0.65	1.1	1995	0.013	0.022	1995	Includes ID tag, additional software and processing, and database storage. Software is COTS.
Communication Equipment	CV002	10	1.15	2.25	1995	0.0075	0.0125	1995	Commercial vehicle communication interface and communication device (cell-based radio).
Central Processor and Storage	CV003	10	0.3	0.5	1995	0.006	0.01	1995	Equipment on board for the processing and storage of cargo material.
GPS/DGPS	CV004	10	0.5	1.8	2002	0.01	0.036	2002	GPS for vehicle location. 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.
Driver and Vehicle Safety Sensors, Software	CV005	10	1.1	2.2	1995	0.04	0.08	1995	Additional software and processor for warning indicator and audio system interface, and onboard sensors for engine/vehicle and driver. Software is COTS.
Cargo Monitoring Sensors and Gauges	CV006	10	0.17	0.35	1995	0.017	0.035	1995	Optional on-board sensors for measuring temperature, pressure, and load leveling.
Electronic Cargo Seal Disposable			0.01	0.025	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.
Electronic Cargo Seal Reusable			0.035	0.44	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.
Autonomous Tracking Unit			0.35	0.8	2003	0.144	0.42	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.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Fleet Management Center (FM)									
Fleet Center Hardware	FM001	5	6	9	2003	0.12	0.18	2003	Costs include three workstations. O&M estimated at 2% of capital cost.
Fleet Center Software, Integration	FM002	20	215	500	1995				Includes processor and integration. Software is COTS.
Fleet Center Labor	FM003					337	412	1995	Labor for five staff at $75K. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
Software for Electronic Credentialing, Clearance	FM004	20	80	180	1995				Includes electronic credential purchase software, database and management for trip reports, and database management for pre-clearance. Software is COTS.
Software for Tracking and Scheduling	FM005	20	40	100	1995	4	10	1995	Vehicle tracking and scheduling. Software is COTS.
Vehicle Location Interface	FM006	20	10	15	1995				Vehicle location interface from FMS to TMS.
Software Upgrade for Fleet Maintenance	FM007	20	20	40	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.
Integration for Fleet Maintenance	FM008	20	100	200	1995	2	4	1995	Integration with other systems.
Software Upgrade for HAZMAT Management	FM009	20	20	40	1995	0.4	0.8	1995	Vehicle tracking and scheduling enhancement. Software is COTS.
Hardware Upgrade for HAZMAT Management	FM010	5	2	3	2003	0.04	0.06	2003	Includes one workstation. O&M estimated at 2% of capital cost.
Electronic Cargo Seal Reader			0.3	1.5	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)									
Communication Equipment	VS001	7	0.2	0.4	1995	0.004	0.008	1995	Wireless data transceiver.
In-Vehicle Display	VS002	7	0.05	0.1	1995	0.001	0.002	1995	In-vehicle display/warning interface. Software is COTS.
In-Vehicle Signing System	VS003	7	0.16	0.4	1995	0.003	0.008	1995	Interface to active tag reader, processor for active tag decode, and display device for messages.
GPS/DGPS	VS004	7	0.25	0.5	1995	0.005	0.01	1995	Global Positioning System/Differential Global Positioning Systems.
GIS Software	VS005	7	0.2	0.3	1995				Geographical Information System (GIS) software for performing route planning.
Route Guidance Processor	VS006	7	0.1	0.15	1995	0.002	0.003	1995	Limited processor for route guidance functionality.
Sensors for Lateral Control	VS007	7	0.8	1.1	1995	0.016	0.022	1995	Includes lane sensors in vehicle and lateral sensors MMW radar.
Electronic Toll Equipment	VS008	7	0.04	0.1	1995				Active tag interface and debit/credit card interface.
Mayday Sensor and Processor	VS009	7	0.15	0.65	1995	0.003	0.013	1995	Collision detector sensor and interface for Mayday processor. Software is COTS.
Sensors for Longitudinal Control	VS010	7	0.3	0.5	1995	0.006	0.01	1995	Longitudinal sensors MMW radar.
Advanced Steering Control	VS011	7	0.5	0.6	1995	0.01	0.012	1995	Advanced steering control ("hands off" driving). Software is COTS.

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Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Cost Date	O&M Cost ($K/year)		Cost Date	Notes
			Low	High		Low	High		
Advanced Cruise Control	VS012	7	0.15	0.3	1995	0.003	0.006	1995	Adaptive cruise control (automatic breaking and accelerating).
Intersection Collision Avoidance Processor, Software	VS013	7	0.28	0.55	1995	0.006	0.011	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.
Vision Enhancement System	VS014	7	2	2.5	2003	0.1	0.125	2003	In-vehicle camera, software and processor, head-up display, and infra-red sensors (local sensor system). Software is COTS. O&M estimated at 5% of capital.
Driver and Vehicle Safety Monitoring System	VS015	7	0.66	1.25	1995	0.033	0.063	1995	Safety collection processor and software, driver condition sensors, six vehicle condition sensors (at $50 each), and vehicle data storage. Software is COTS.
Pre-Crash Safety System	VS016	7	1.1	2.15	1995	0.037	0.067	1995	Vehicle condition sensors, vehicle performance sensors, software/processor, interface, pre-crash safety systems deployment actuators. Software is COTS.
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.
Toll Tag/Transponder		5	0.025		2003				Most toll tags/transponders cost 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.
In-Vehicle Navigation System		7	2.8		1998				COTS product that includes in-vehicle display and supporting software.
Personal Devices (PD)									
Basic PDA	PD001	7	0.2	0.4	2001	0.004	0.008	2001	Personal digital assistant. O&M estimated at 2% of capital.
Advanced PDA for Route Guidance, Interactive Info	PD002	7	0.5	0.75	1995	0.01	0.015	1995	Personal digital assistant with advanced capabilities (route guidance, interactive).
Modem Interface, Antenna for PDA	PD003	7	0.18	0.25	1995	0.004	0.005	1995	Modem interface and separate antenna for wireless capability.
PDA with Wireless Modem		2	0.2	0.6	2003	0.12	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).
GPS/DGPS	PD005	7	0.15	0.18	2001	0.003	0.004	2001	GPS/DGPS. O&M estimated at 2% of capital cost.
GIS Software	PD006	7	0.1	0.15	1995	0.005	0.008	1995	Additional GIS/GUI capability.

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Appendix A.2
Adjusted Unit Costs (2003 Dollars)

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K) Low	Capital Cost ($K) High	Adjusted From Date	O&M Cost ($K/year) Low	O&M Cost ($K/year) High	Adjusted From Date	Notes
	Roadside Telecommunications (RS-TC)									
1	DS0 Communication Line	TC001	10	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	4.7	8.2	2002	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	2.8	4.7	1995	23	69	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					0.18	0.6	2002	Monthly service fee ranges from $15 per month for regular dial-up service to $50 per month for DSL.
1	Direct Bury Armor Encased Fiber Cable			56		1999	0.02		1999	Cost is per mile. Includes cable and installation.
1	Conduit Design and Installation - Corridor		20	50	65	2003	0.02		1999	Cost is per mile. Includes boring, trenching, and conduit (three or four 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		1999	0.02		1999	Cost is per mile.
1	Fiber Optic Cable Installation		20	20	50	2003	0.02		1999	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	Cellular Communication			0.5		1999	0.3	0.4	1999	Cost is for one unit.
1	900 MHz Spread Spectrum Radio		10	8.4		1999	0.14	0.4	1999	Cost is per link.
1	Microwave Communication		10	9.8	19.6	2002	0.5	1	2002	Cost is per link. Cost could be higher 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					0.6	0.7	1995	1,000 Kbytes/month available usage (non-continuous use).
1	Wireless Communications, High Usage	TC006	20	0.5	0.9	1995	1.2	1.8	2002	3,000 Kbytes/month available usage (non-continuous use).
1	Call Box		10	4	5.8	2002	0.67		1999	Capital cost includes call box and installation. O&M is cost per unit (per year) for service maintenance contract and annual cellular service fee.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
	Roadside Detection (RS-D)									
2	Inductive Loop Surveillance on Corridor		5	3	8	2001	0.4	0.6	1995	Double set (four loops) with controller, power, etc.
2	Inductive Loop Surveillance at Intersection		5	9	16	2003	0.9	1.5	1999	Four legs, two lanes/approach.
2	Machine Vision Sensor on Corridor		10	21.7	29	2003	0.2	0.4	2003	One sensor both directions of travel. Does not include installation.
2	Machine Vision Sensor at Intersection		10	20	25.7	2003	0.2	0.5	2003	Four-way intersection, one camera per approach. Does not include installation.
2	Passive Acoustic Sensor on Corridor			3.6	7.9	2002	0.2	0.4	1998	Cost range is for a single sensor covering up to five lanes. Low cost is for basic sensor, which consists of the sensor, mounting kit, junction box, and cabinet termination card. High cost includes basic sensor with solar and wireless option. This option consists of an antenna, solar charger, battery, and panel, and wireless base station, which will handle up to eight 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, four-leg intersection.
2	Remote Traffic Microwave Sensor on Corridor		10	3.2	5.9	2002	0.1		2001	One sensor both directions of travel. Includes installation.
2	Remote Traffic Microwave Sensor at Intersection		10	17		2001	0.1		2001	Four sensors, four-leg intersection. Includes installation.
2	Infrared Sensor Active			5.6	7	2000				Sensors detect movement in two directions and determine vehicle speed, classification, and lane position.
2	Infrared Sensor Passive			0.7	1.2	2002				Sensor covers one lane and detects vehicle count, volume, and classification.
2	CCTV Video Camera	RS007	10	7.5	17	2003	1.4	2.3	2001	Cost includes color video camera with pan, tilt, and zoom (PTZ), and installation.
	CCTV Video Camera Tower	RS008	20	4	12	2003				Low cost is for a 35 ft. tower. High cost is for 90 ft. tower. Includes foundation, pole, conduit, and labor.
2	Pedestrian Detection Microwave			0.6		2001				Cost is per device. Typical deployment consists of two 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 two devices per crosswalk for detection of pedestrian at the sidewalk. Can be used for detection of pedestrian in the crosswalk.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
	Roadside Detection (RS-D)									
2	Environmental Sensing Station (Weather Station)		25	30	50	2003	1.9	4.1	2003	Environmental Sensing Station (ESS), also known as a weather station, consists of pavement temperature sensor, subsurface temperature sensor, precipitation sensor (type and rate), wind sensor (speed and 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 five years at $6.4K. O&M includes calibration, equipment repairs, and replacement of damaged equipment. O&M costs could be higher if state provided maintenance.
2	Traffic Camera for Red Light Running Enforcement			71	128	2001	57		2001	Description is based on 2001 data: 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 two cameras for a three-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.
	Lowering System		20	8	10.5	2003				Cost includes the lowering system and the pole (pole height ranging 40 feet to 70 feet). Installation costs not included. The lowering system is mechanically operated; requires routine lubrication.
2	Portable Speed Monitoring System		15	4.9	14.7	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			80	100	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.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K) Low	Capital Cost ($K) High	Adjusted From Date	O&M Cost ($K/year) Low	O&M Cost ($K/year) High	Adjusted From Date	Notes
	Roadside Control (RS-C)									
2	Linked Signal System LAN	RS002	20	32	56	1995	0.3	0.6	1995	This element provides the connections to the linked signal system.
2	Signal Controller Upgrade for Signal Control	RS003	20	2.5	6	2003	0.2	0.4	1995	Local controller upgrade to provide advanced signal control.
2	Signal Controller and Cabinet			8	15	2003	0.2	0.5	2001	Includes installation of traffic signal controller and cabinet per intersection.
2	Traffic Signal			90	108	2001	2.2	2.8	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).
2	Signal Preemption Receiver	RS004	5	2	6	1995	0.04	0.2	1995	Two per intersection. Complement of IDAS elements RS005 and TV004.
2	Signal Controller Upgrade for Signal Preemption	RS005	10	2	4	1995				Add-on to base capability (per-intersection). Complement of IDAS elements RS004 and TV004.
2	Roadside Signal Preemption/ Priority			2.5	5.5	2003				Includes infrared detector, detector cable, phase selector, and system software. Capital costs range is for two-directions (low) and four-directions (high). Does not include installation costs. Complement to transit (or emergency vehicle) on-board Signal Preemption/Priority Emitter.
2	Ramp Meter	RS006	5	25	50	2003	1.2	2.8	2003	Includes ramp meter assembly, signal displays, controller, cabinet, detection, and optimization.
3	Software for Lane Control	RS011	20	25	50	1995	3	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	80	120	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	23		1998	1.8		1998	Description is based on unadjusted data values: typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every five 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	46	458	1999	1.4	27.3	1999	Description is based on unadjusted data values: typical automatic anti-icing system consists of a control system, chemical storage tank, distribution lines, pump, and nozzles. Pump and control hardware replaced every five years at cost of $3.5K. For a long span system ranging from 320 feet to greater than a 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.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
	Roadside Information (RS-I)									
2	Roadside Message Sign	RS010	20	40	60	1995	2	3	1995	Fixed message board for HOV and HOT lanes.
1	Wireline to Roadside Message Sign	RS013	20	6	8	1995				Wireline to VMS (0.5 mile upstation).
2	Variable Message Sign	RS015	20	48	120	2003	2.4	6	2003	Low capital cost is for smaller VMS installed along arterial. High capital cost is for full matrix, LED, three-line, walk-in VMS installed on freeway. Cost does not include installation.
	Variable Message Sign Tower	RS016	20	25	120	2003				Low capital cost is for a small structure for arterials. High capital cost is for a larger structure spanning three to four lanes. VMS tower structure requires minimal maintenance.
2	Variable Message Sign–Portable		14	21	25	2002	1.1	1.9	2000	Trailer mounted VMS (three-line, 8" character display); includes trailer, solar or diesel powered.
1	Highway Advisory Radio	RS017	20	15	31	2001	0.6	1	2001	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	2003	0.25		2003	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 Countdown 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. Countdown signals use low eight-watt LED bulbs, which require replacement approximately every five to seven years.
2	Pedestrian Crossing Illumination System		5	27.5	42	2003	2.6	4	2001	The capital cost range includes cost of equipment and installation. Equipment includes fixtures–four 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.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
	Roadside Rail Crossing (R-RC)									
2	Rail Crossing Four-Quad Gate, Signals	RS021	20	92	104	1995	3.4	3.9	1995	Gates and signals.
2	Rail Crossing Train Detector	RS022	20	13	17	1995	0.62	0.82	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	20	24	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/exiting 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 and 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	42	1998				Includes installation, detectors, and controllers.
	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 one camera/two lanes.
3	Electronic Toll Collection Software	TP003	10	5	10	1995				Includes COTS software and database.
4	Electronic Toll Collection Structure	TP004	20	11	16	1995				Mainline structure.
	Remote Location (RM)									
2	CCTV Camera	RM001	7	2.1	5	2003	0.1	0.25	2003	Interior fixed mount camera for security. Low cost represents black and white pan/tilt/zoom (PTZ). High cost represents color PTZ. Does not include installation.
3	Integration of Camera with Existing Systems	RM002	10	2	2.5	1995				Per location.
2	Informational Kiosk	RM003	7	11	24	2001	1.1	4.5	1998	Includes hardware, enclosure, installation, modem server, and map software.
3	Integration of Kiosk with Existing Systems	RM004	7	2.2	27.5	1995				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	2002				A LED display installed at transit terminal that provides status information on transit arrival. Cost depends on quality, size, and controller capabilities.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K) Low	Capital Cost ($K) High	Adjusted From Date	O&M Cost ($K/year) Low	O&M Cost ($K/year) High	Adjusted From Date	Notes
2	Smart Card Vending Machine	RM007	5	30	32	1995	1.5	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		4,365		1995	436	655	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	EM007		3,492		1995	436	524	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		3,055		1995	436	458	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	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M is estimated at 2% of capital cost.
3	Emergency Response Software	EM002	10	70	150	1995	0.5	3.5	1995	Includes emergency response plans database, vehicle tracking software, and real-time traffic coordination.
6	Emergency Response Labor	EM003					66	217	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	2.5	5	1995	Shared database between four sites. Cost is per site; software is COTS.
3	Hardware, Software Upgrade for E-911 and Mayday	EM005	10	105	180	1995	1.7	2.5	1995	Data communications translation software, E911 interface software, processor, and three workstations.
1	800 MHz. Two-way Radio		5	0.8	1.6	2001	0.09	0.12	2001	Cost is per radio.
	Emergency Vehicle On-Board (EV)									
1	Communications Interface for E-911 and Mayday	EV001	10	0.3	2	1995	0.02		1995	Emergency vehicle communications. Cost is per vehicle.
2	Signal Preemption/Priority Emitter			0.5	2.1	2003				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		4,365		1995	436	655	1995	For population >750,000 (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.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
4	Basic Facilities, Comm for Medium Area	IS020		3,492		1995	436	524	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		3,055		1995	436	458	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	26	35	2003	0.5	0.7	2003	Includes two servers and five workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Systems Integration	IS017	20	89	109	1998				Integration with other systems.
3	Information Service Provider Software	IS002	20	276	551	1995	13.8	27.6	1995	Includes database software (COTS) and traffic analysis software.
3	Map Database Software	IS003	2	15	30	2003				Software is COTS.
6	Information Service Provider Labor	IS004					230	329	1995	Description is based on 1995 data: two staff at $50K–$75K and one staff at $75K–$100K. Salary cost are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
1	FM Subcarrier Lease	IS005					113	226	1995	Cost is per year.
5	Hardware Upgrade for Interactive Information	IS006	5	12	16	2003	0.24	0.32	2003	Includes one server and two workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Interactive Information	IS007	20	251	501	1995	13	25	1995	Trip planning software (includes some development costs).
6	Added Labor for Interactive Information	IS008					131	197	1995	Description is based on 1995 data: one staff at $50K–$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	251	501	1995	13	25	1995	Route selection software. Software is COTS.
3	Map Database Upgrade for Route Guidance	IS010	2	100	201	1995				Map database software upgrade.
5	Hardware Upgrade for Emergency Route Planning	IS011	5	8	10	2003	0.16	0.2	2003	Includes one server. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Emergency Route Planning	IS012	20	50	100	1995	2.5	5	1995	Route guidance software. Software is COTS.
5	Hardware Upgrade for Dynamic Ridesharing	IS013	5	4	6	2003	0.08	0.12	2003	Includes two workstations. O&M is estimated at 2%; could be higher for responsive and preventative maintenance.
3	Software Upgrade for Dynamic Ridesharing	IS014	20	99	197	1998	5	10	1995	Software includes some development cost.
6	Added Labor for Dynamic Ridesharing	IS015					131	197	1995	Description is based on 1995 data: one staff at $50K–$75K for two shifts. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
7	Liability Insurance for Dynamic Ridesharing	IS016					60	121	1995	Description is based on 1995 data: $50K to $100K per year.
3	Software Upgrade for Probe Information Collection	IS018	20	251	501	1995	13	25	1995	Software includes COTS and some development cost
	Transportation Management Center (TM)									
4	Basic Facilities, Comm for Large Area	TM040		3,500	8,000	2003	350	1,200	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		3,492		1995	436	524	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		3,055		1995	436	458	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.
5	Hardware for Signal Control	TM001	5	18.5	28.5	2003	9	10.5	2003	Includes one server and multiple workstations. O&M includes responsive and preventative maintenance.
3	Software, Integration for Signal Control	TM006	5	105	150	2003	150		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					525	641	2001	Description is based on 2001 data: costs include labor for operations (two at 50% of the time, at $100K), transportation engineer (one at 50% of the time, at $100K), update timing plans ($2K per system per month for every 10 systems), and signal maintenance technician (two at $75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Hardware, Software for Traffic Surveillance	TM003	20	135	165	1995	6.8	8.3	1995	Processor and software.
3	Integration for Traffic Surveillance	TM032	20	226	276	1995	11.3	13.8	1995	Integration with other systems.
5	Hardware for Freeway Control	TM004	5	6	9	2003	0.3	0.45	2003	Includes three workstations. O&M estimated at 5% of capital cost.
3	Software, Integration for Freeway Control	TM007	5	171	209	2002				Software and integration, installation and one year maintenance. Software is off-the-shelf technology and unit cost does not reflect product development.

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6	Labor for Freeway Control	TM005					243	297	2001	Description is based on 2001 data: labor for operations (two at 50% of $100K) and maintenance technicians (two at $75K). Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
5	Hardware for Lane Control	TM008	5	2	3	2003	0.1	0.15	2003	Includes one workstation and 19" monitor. O&M estimated at 5% of capital cost.
3	Software, Integration for Lane Control	TM009	10	226	276	1995	11	14	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					97	119	2001	Description is based on 2001 data: labor for two operators at 50% of $100K.
3	Software, Integration for Regional Control	TM011	10	296	395	1998				Software and integration, installation and one year maintenance. Integration with other TMC's. Software is COTS.
3	Real-time, Traffic Adaptive Signal Control System		10	113	141	2001	19		2001	The costs 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.
6	Labor for Regional Control	TM012					194	237	2001	Description is based on 2001 data: labor for operators (two at 50% of $100K), transportation engineer (one at 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	15	57	103	2003	3	5	2003	Video wall and monitors. O&M estimated at 5% of capital cost.
5	Hardware for Incident Detection	TM014	5	43	57	2003	2.15	2.85	2003	Includes four servers, five workstations, and two 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	90	110	1995	4.5	5.5	1995	Integration with other systems.
3	Software for Incident Detection	TM015	5	86	105	2002	4.3	5.2	2002	Software is COTS and includes development cost. O&M is estimated at 5% of capital.
6	Labor for Incident Detection	TM016					680	831	2001	Description is based on 2001 data: labor for operators (four at $100K and one manager at $150K) and two maintenance techs at $75K.
5	Video Monitor for Incident Response	TM017	5	0.6	1.5	2003				Includes one 19" monitor.
5	Hardware for Incident Response	TM018	5	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
3	Integration for Incident Response	TM026	20	180	221	1995				Integration with other systems.
3	Software for Incident Response	TM019	2	14	17	1995	0.677	0.827	1995	Software is COTS.
6	Labor for Incident Response	TM020					97	119	2001	Description is based on 2001 data: labor for incident management coordinator (one at $100K).
2	Automated Incident Investigation System		5	14.1		2001				Includes workstation, tripod, monopole antenna, Auto Integration, and AutoCAD software.

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				Low	High		Low	High		
5	Hardware for Traffic Information Dissemination	TM021	5	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
3	Software for Traffic Information Dissemination	TM022	5	18	22	1995	0.9	1.1	1995	Software is COTS.
3	Integration for Traffic Information Dissemination	TM023	20	85	104	2000	4.5	5.5	1995	Integration with other systems.
6	Labor for Traffic Information Dissemination	TM024					97	119	2001	Description is based on 2001 data: labor for one operator at $100K. Salary costs are fully loaded and include base salary, overtime, overhead, benefits, etc.
3	Software for Dynamic Electronic Tolls	TM027	5	23	28	1995	1.1	1.4	1995	Includes software installation and one year maintenance. Software is COTS.
3	Integration for Dynamic Electronic Tolls	TM028	20	90	110	1995	4.5	5.5	1995	Integration with other systems.
5	Hardware for Probe Information Collection	TM033	3	2	3	2003	0.1	0.15	2003	Includes one workstation. O&M estimated at 5% of capital cost.
3	Software for Probe Information Collection	TM034	5	18	22	1995	1.8	2.2	1995	Includes software installation and one year maintenance. Software is COTS.
3	Integration for Probe Information Collection	TM035	20	135	165	1995	14	17	1995	Integration with other systems.
6	Labor for Probe Information Collection	TM036					49	59	2001	Description is based on 2001 data: labor for one operator (four hours per day at $100K/year). Salary costs are fully loaded prices and include base salary, overtime, overhead, benefits, etc.
3	Software for Rail Crossing Monitor	TM037	5	18	22	1995	1.8	2.2	1995	Includes software installation and one year maintenance. Software is COTS.
3	Integration for Rail Crossing Monitor	TM038	20	90	110	1995				Integration with other systems.
6	Labor for Rail Crossing Monitor	TM039					49	59	2001	Description is based on 2001 data: operators (one at 50% of $100K). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
5	Road Weather Information System (RWIS)		25	14		1998	0.3	2	2001	Description is based on unadjusted data values: an 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 ($10K–$50K) should be added to $25K listed here in order to cost out the entire system. CPU replaced every five years at a cost of $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		4,365		1995	436	655	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.

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				Low	High		Low	High		
4	Basic Facilities, Comm for Medium Area	TR015		3,492		1995	436	524	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		3,055		1995	436	458	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	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M estimated at 2% of capital cost.
3	Transit Center Software Integration	TR002	20	817	1,725	1995	6	12	1995	Includes vehicle tracking and scheduling, database and information storage, schedule adjustment software, real-time travel information software, and integration. Software is COTS.
4	Transit Center Additional Building Space	TR003					7	10	1995	Description is based on 1995 data: additional space required for ITS technology—$12–$18/sq.ft., 500 sq.ft.
6	Transit Center Labor	TR004					66	329	1995	Description is based on 1995 data: labor for three staff at $75K. 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	20	40	1995	0.4	0.8	1995	Processor/software upgrade, installation and one year maintenance (for processor). Software is COTS.
3	Integration for Auto. Scheduling, Run Cutting, or Fare Payment	TR012	20	226	501	1995				Integration with other systems.
3	Further Software Upgrade for E-Fare Payment	TR013	20	40	60	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	3	7	2003	0.06	0.14	2003	Five per site. O&M estimated at 2% of capital cost.
5	Hardware for Security System	TR009	5	14	19	2003	0.28	0.38	2003	Includes one server and three 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	251	501	1995				Integration with other systems.
6	Labor for Security System	TR011					266	325	1995	Description is based on 1995 data: labor for three staff at $75K each. Salary cost are fully loaded prices including base salary, overtime, overhead, benefits, etc.
	Toll Administration (TA)									
5	Toll Administration Hardware	TA001	5	4	6	2003	0.2	0.3	2003	Includes two workstations, printer, and modem. O&M estimated at 5% of capital costs.
3	Toll Administration Software	TA002	10	40	80	1995	4.0	8.0	1995	Includes local database and national database coordination. Software is COTS.

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				Low	High		Low	High		
	Transit Vehicle On-Board (TV)									
2	Driver Interface and Schedule Processor	TV001	10	0.2	0.4	1995	0.005	.01	1995	On-board schedule processor and database.
1	Cell-Based Communication Equipment	TV002	10	0.14	0.24	1995	0.0071	0.0118	1995	Cell-based radio with data capacity.
2	GPS/DGPS for Vehicle Location	TV003	10	0.5	2	2002	0.01	0.039	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			0.5	2.1	2003				Data-encoded emitter; manually initiated. Complement to Roadside Signal Preemption/Priority (see Roadside Control subsystem).
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	3.4	6	1995	0.17	0.21	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	1	10	2003				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 Administration (CA)									
5	Commercial Vehicle Admin Hardware	CA001	5	6	9	2003	0.12	0.18	2003	Includes three workstations. O&M estimated at 2% of capital cost.
3	Commercial Vehicle Admin Software, Integration	CA002	20	201	221	1995	4	4.4	1995	Includes processor and integration. Software is COTS .
6	Commercial Vehicle Admin Labor	CA003					270	330	2003	Description is based on 1995 data: labor for four staff at $75K (average). Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Software Upgrade for Electronic Credential Purchasing	CA004	20	60	140	1995	1.2	2.8	1995	Electronic credentials purchase software, database and management for post-trip processing and E-credentials.
3	Software Upgrade for Inter-Agency Info Exchange	CA005	20	20	40	1995	0.4	0.8	1995	Processor and integration add-on. Software is COTS.
6	Added Labor for Inter-Agency Info Exchange	CA006					88	108	1995	Description is based on 1995 data: labor for one staff at $75K (average). Salary cost are fully loaded prices including base salary, overtime, benefits, etc.
3	Software Upgrade for Safety Administration	CA007	20	40	80	1995	0.8	1.6	1995	Database add-on, software, and integration. Software is COTS.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K) Low	Capital Cost ($K) High	Adjusted From Date	O&M Cost ($K/year) Low	O&M Cost ($K/year) High	Adjusted From Date	Notes
	Commercial Vehicle Check Station (CC)									
4	Check Station Structure	CC001	20	55	82	1995				Roadside structure–mainline w/ lane indicator signals.
2	Signal Board	CC002	10	8	12	1995	0.8	1.2	1995	Roadside signal board.
2	Signal Indicator	CC003	20	4	8	1995	0.2	0.4	1995	Signal indicator system.
2	Roadside Beacon	CC004	10	4	6	1995	0.4	0.6	1995	Roadside beacon used for electronic screening (not included in roadside subsystem). Beacon repair/replacement.
1	Wireline to Roadside Beacon	CC005	20	9	19	1995				Dedicated wireline communication from beacon to roadside (one mile upstream).
3	Check Station Software, Integration	CC006	20	180	216	1995				Software, processor and integration.
5	Check Station Hardware	CC007	5	2	3	2003	0.04	0.06	2003	Includes one workstation. O&M estimated at 2% of capital cost.
5	Safety and Fitness Electronic Records (SAFER) Data Mailbox			4.9	6.1	1999	0.29	0.43	1999	Includes portable computer with printer and wireless Internet modem to download, record, and upload carrier safety database records at field locations or check stations.
1	Detection System	CC008	10	47	71	1995	2.4	3.5	1995	Commercial vehicle communication interface and communication device (cell-based radio).
3	Software Upgrade for Safety Inspection	CC009	20	40	80	1995	0.8	1.6	1995	Safety database add-on, and result writing to vehicle tag processor add-on. Software is COTS.
2	Handheld Safety Devices	CC010	5	2	4	1995	0.2	0.4	1995	For commercial vehicle inspection. The devices either measure data themselves or read data from the vehicle. Three per location.
3	Software Upgrade for Citation and Accident Recording	CC011	20	20	40	1995	1	2	1995	Software add-on for recording of citation and accident information to the commercial vehicle.
3	Weigh-In-Motion Facility	CC012	10	14	21	1995	1.4	2.1	1995	Includes WIM fixed load cell and interface to roadside facility. Software is COTS.
1	Wireline to Weigh-In-Motion Facility	CC013	10	1	2	1995	0.1	0.2	1995	Wireline communication (local line).
	Commercial Vehicle On-Board (CV)									
2	Electronic ID Tag	CV001	10	0.52	0.9	1995	0.01	0.018	1995	Includes ID tag, additional software and processing, and database storage. Software is COTS.
1	Communication Equipment	CV002	10	1.1	2.1	1995	0.0071	0.0118	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	2002	0.01	0.035	2002	GPS for vehicle location. 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.

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

Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
2	Driver and Vehicle Safety Sensors, Software	CV005	10	0.9	1.8	1995	0.03	0.06	1995	Additional software and processor for warning indicator and audio system interface, and on-board sensors for engine/ vehicle and driver. Software is COTS.
2	Cargo Monitoring Sensors and Gauges	CV006	10	0.14	0.28	1995	0.014	0.028	1995	Optional on-board sensors for measuring temperature, pressure, and load leveling.
2	Electronic Cargo Seal Disposable			0.01	0.025	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	0.43	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			0.35	0.8	2003	0.144	0.42	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
	Fleet Management Center (FM)									
5	Fleet Center Hardware	FM001	5	6	9	2003	0.12	0.18	2003	Costs include three workstations. O&M estimated at 2% of capital cost.
3	Fleet Center Software, Integration	FM002	20	216	501	1995				Includes processor and integration. Software is COTS.
6	Fleet Center Labor	FM003					443	542	1995	Description is based on 1995 data: labor for five staff at $75K. Salary costs are fully loaded prices including base salary, overtime, overhead, benefits, etc.
3	Software for Electronic Credentialing, Clearance	FM004	20	80	180	1995				Includes electronic credential purchase software, database and management for trip reports, and database management for pre-clearance. Software is COTS.
3	Software for Tracking and Scheduling	FM005	20	40	100	1995	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	20	40	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	100	201	1995	2	4	1995	Integration with other systems.
3	Software Upgrade for HAZMAT Management	FM009	20	20	40	1995	0.4	0.8	1995	Vehicle tracking and scheduling enhancement. Software is COTS.
5	Hardware Upgrade for HAZMAT Management	FM010	5	2	3	2003	0.04	0.06	2003	Includes one workstation. O&M estimated at 2% of capital cost.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
2	Electronic Cargo Seal Reader			0.3	1.5	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	0.008	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	0.13	0.32	1995	0.002	0.006	1995	Interface to active tag reader, processor for active tag decode, and display device for messages.
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	0.013	0.018	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	0.24	1995	0.002	0.005	1995	Adaptive cruise control (automatic breaking and accelerating).
2	Intersection Collision Avoidance Processor, Software	VS013	7	0.22	0.44	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	2.5	2003	0.1	0.125	2003	In-vehicle camera, software and processor, head-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	0.53	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 (at $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.
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, and message generator. Software is COTS.

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Index	Subsystem/Unit Cost Element	IDAS No.^	Lifetime* (years)	Capital Cost ($K)		Adjusted From Date	O&M Cost ($K/year)		Adjusted From Date	Notes
				Low	High		Low	High		
2	Toll Tag/Transponder		5	0.025		2003				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	0.2	0.4	2001	0.004	0.008	2001	Personal digital assistant. O&M estimated at 2% of capital.
2	Advanced PDA for Route Guidance, Interactive	PD002	7	0.4	0.6	1995	0.01	0.012	1995	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.

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Appendix B: Available Benefit and Cost Data

The table below presents the number of benefits references and system costs examples currently available in the ITS Benefits and Costs Databases for each of the technology application areas discussed in this report. The table demonstrates that there is still a need for further research into the effects of many of the various types of applications within these categories. For example, while there are numerous evaluation reports in the database covering arterial management systems, parking management and traffic control techniques for special events are two areas that would benefit from further study. Totals by category presented in this table do not always equal the sum of those reported in the body of this report. A number of reports in the database discuss evaluations of larger systems, which include several ITS applications, appearing several times in the totals. However, the evaluation findings appear in the body of the report within the application area most directly responsible for the impact cited. For example, an evaluation of an arterial management system providing data to a traveler information system would appear in both categories below, but only within the traveler information section in the body of the report.

As indicated in the table, examples of system cost data are available in each of the intelligent infrastructure application areas. However, system cost data are still needed for a few of the ITS application areas such as lane management strategies, transit security, emergency management, and intermodal freight. Examples of system cost data are not prevalent in the intelligent vehicle application areas. This lack of cost data can be attributed to the fact that many intelligent vehicle applications are still in the research and prototype phases. Cost data in many cases, if available, are based on estimates and/or market analysis of the public's willingness to pay for a specific feature. Also, some of these features 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.

Summary of Benefits References and System Cost Data

(as of September 30, 2004)

Technology Application Areas	Number of Benefits References	System Cost Data Available
Intelligent Infrastructure		
Arterial Management Systems		
Traffic Surveillance	3	✓
Traffic Control: Transit Signal Priority	16	✓
Traffic Control: Emergency Vehicle Preemption	4	✓
Traffic Control: Adaptive Signal Control	17	✓
Traffic Control: Advanced Signal Systems	17	✓
Traffic Control: Variable Speed Limits	0	
Traffic Control: Bicycle and Pedestrian	2	✓
Traffic Control: Special Events	1	
Lane Management	0	
Parking Management	1	✓
Information Dissemination: Dynamic Message Signs	4	✓
Information Dissemination: In-Vehicle Systems	0	
Information Dissemination: Highway Advisory Radio	1	✓
Enforcement: Speed Enforcement	5	✓
Enforcement: Stop/Yield Enforcement	12	✓
Freeway Management Systems		
Traffic Surveillance	9	✓
Ramp Control	14	✓
Lane Management	4	✓
Special Event Transportation Management	0	
Information Dissemination: Dynamic Message Signs	19	✓
Information Dissemination: In-Vehicle Systems	0	
Information Dissemination: Highway Advisory Radio	5	✓
Enforcement	10	✓
Transit Management Systems		
Safety and Security	1	✓
Transportation Demand Management: Ride Sharing/Matching	0	
Transportation Demand Management: Dynamic Routing/Scheduling	4	✓
Transportation Demand Management: Service Coordination	1	✓

Technology Application Areas	Number of Benefits References	System Cost Data Available
Intelligent Infrastructure		
Transit Management Systems *continued*		
Fleet Management: AVL/CAD	13	✓
Fleet Management: Maintenance	1	✓
Fleet Management: Planning	0	✓
Information Dissemination: In-Vehicle Systems	2	✓
Information Dissemination: In-Terminal/Wayside	4	✓
Information Dissemination: Internet/Wireless/Phone	2	✓
Incident Management Systems		
Surveillance and Detection	17	✓
Mobilization and Response	14	✓
Information Dissemination	8	✓
Clearance and Recovery	1	✓
Emergency Management Systems		
Hazardous Materials Management	2	
Emergency Medical Services: Advanced ACN	1	
Emergency Medical Services: Telemedicine	1	✓
Response and Recovery	1	✓
Electronic Payment Systems		
Toll Collection	10	✓
Transit Fare Payment	6	✓
Parking Fee Payment	0	
Multi-use Payment	1	
Traveler Information		
Pre-Trip Information	33	✓
En-Route Information	11	✓
Tourism and Events	3	✓
Information Management		
Data Archiving	1	✓
Crash Prevention and Safety		
Road Geometry Warning Systems: Ramp Rollover	3	✓
Road Geometry Warning Systems: Curve Speed Warning	1	✓
Road Geometry Warning Systems: Downhill Speed Warning	3	✓
Road Geometry Warning Systems: Overheight/Overwidth Warning	0	
Highway–Rail Crossing Systems	4	✓

Technology Application Areas	Number of Benefits References	System Cost Data Available
Intelligent Infrastructure		
Crash Prevention and Safety *continued*		
Intersection Collision Warning	1	
Pedestrian Safety	0	✓
Bicycle Warning Systems	0	✓
Animal Warning Systems	0	✓
Roadway Operations and Maintenance		
Information Dissemination	3	✓
Asset Management	1	✓
Work Zone Management	7	✓
Road Weather Management		
Surveillance, Monitoring, and Prediction	10	✓
Information Dissemination	8	✓
Traffic Control	7	✓
Response and Treatment	6	✓
Commercial Vehicle Operations		
Credentials Administration: Electronic Funds	2	✓
Credentials Administration: Electronic Registration/Permitting	10	✓
Safety Assurance: Safety Information Exchange	4	✓
Safety Assurance: Automated Inspection	2	
Electronic Screening: Safety Screening	4	
Electronic Screening: Border Clearance	4	
Electronic Screening: Weight Screening	6	✓
Electronic Screening: Credential Checking	4	✓
Carrier Operations and Fleet Management: AVL/CAD	4	✓
Carrier Operations and Fleet Management: On-Board Monitoring	3	
Carrier Operations and Fleet Management: Traveler Information	3	
Security Operations	0	✓
Intermodal Freight		
Freight Tracking	1	
Asset Tracking	1	✓
Freight Terminal Processes	1	
Drayage Operations	1	
Freight Highway Connector System	0	
International Border Crossing Process	0	

Technology Application Areas	Number of Benefits References	System Cost Data Available
Intelligent Vehicles		
Collision Avoidance Systems		
Intersection Collision Warning	0	
Obstacle Detection	2	✓
Lane Change Assistance	2	✓
Lane Departure Warning	0	
Rollover Warning	0	
Road Departure Warning	2	
Forward Collision Warning	3	✓
Rear Impact Warning	0	
Driver Assistance Systems		
Navigation/Route Guidance	9	✓
Driver Communication	2	✓
Vision Enhancement	0	
Object Detection	0	
Adaptive Cruise Control	5	✓
Intelligent Speed Control	2	
Lane-Keeping Assistance	1	
Roll Stability Control	0	
Drowsy Driver Warning System	0	
Precision Docking	0	
Coupling/Decoupling	1	
On-Board Monitoring	2	
Collision Notification Systems		
Mayday/ACN	1	✓
Advanced ACN	1	

Appendix C: List of Acronyms and Abbreviations

AAR	After Action Review
ABBCS	Ambassador Bridge Border Crossing System
ACN	Automated Collision Notification
ADMS	Archived Data Management System
ADOT	Arizona Department of Transportation
ADUS	Archived Data User Service
AHTD	Arkansas State Highway and Transportation Department
AMBER	America's Missing: Broadcast Emergency Response
APC	Automatic Passenger Counter
APTS	Advanced Public Transportation System
ARTIC	Advanced Rural Transportation Information and Coordination
ARTIMIS	Advanced Regional Traffic Interactive Management and Information Systems
ATAF	American Trucking Association Foundation
ATIS	Advanced Traveler Information System
ATMS	Advanced Transportation Management System
AVI	Automatic Vehicle Identification
AVL	Automated Vehicle Location
AWARD	Advanced Warning for Railroad Delays
AWIS	Automated Work Zone Information Systems
B/C	Benefit/Cost
BRT	Bus Rapid Transit
CA	Commercial Vehicle Administration (Unit Cost Subsystem)
CAD	Computer Aided Dispatch
CAD	Canadian Dollars
CB	Citizens Band
CC	Commercial Vehicle Check Station (Unit Cost Subsystem)
CCS	Collision Countermeasure System
CCTV	Closed Circuit Television
CHART	Coordinated Highways Action Response Team
CLEOPATRA	City Laboratories Enabling Organization of Particularly Advanced Telematics Research and Assessments
CO	Carbon Monoxide
COTS	Commercial Off-The-Shelf
CTECC	Combined Transportation, Emergency, and Communication Center
CUE	City-University-Energysaver
CV	Commercial Vehicle On-Board (Unit Cost Subsystem)
CVAP	Commercial Vehicle Administrative Processes
CVIEW	Commercial Vehicle Information Exchange Window
CVISN	Commercial Vehicle Information Systems and Network
CVO	Commercial Vehicle Operations
DelDOT	Delaware Department of Transportation
DMS	Dynamic Message Signs
DOT	Department of Transportation
DSL	Digital Subscriber Line
EDI	Electronic Data Interchange
EDL	Electronic Document Library
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
E-PASS	Express Pass
ER	Emergency Response Center (Unit Cost Subsystem)
ESS	Environmental Sensor Station

ETC	Electronic Toll Collection
EV	Emergency Vehicle On-Board (Unit Cost Subsystem)
FAST	Freeway and Arterial System of Transportation
FCC	Federal Communications Commission
FCP	Freeway Courtesy Patrol
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FM	Fleet Management (Unit Cost Subsystem)
FOT	Field Operational Test
FY	Fiscal Year
GIS	Geographical Information Systems
GPS	Global Positioning System
GUI	Graphic User Interface
GYRITS	Greater Yellowstone Rural Intelligent Transportation Systems
GYRTWIS	Greater Yellowstone Regional Travel and Weather Information System
HAR	Highway Advisory Radio
HAZMAT	Hazardous Materials
HC	Hydrocarbons
HCRS	Highway Condition and Reporting System
HOT	High Occupancy/Toll
HOV	High Occupancy Vehicle
HRI	Highway–Rail Intersections
HUT	Highway User Tax
ICC	Intelligent Cruise Control
IDAS	ITS Deployment Analysis System
IDOT	Illinois Department of Transportation
IFTA	International Fuel Tax Agreement
IIC	Intelligent Interface Controller
IRP	International Registration Plan
ISP	Information Service Provider (Unit Cost Subsystem)
ISS	Inspection Selection Systems
ITDA	Independent Truckers and Drivers Association
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS/CVO	ITS For Commercial Vehicles Operations
IVN	In-Vehicle Navigation
IVR	Interactive Voice Response
IVS	In-Vehicle Systems
JPO	Joint Program Office
LADOT	Los Angeles Department of Transportation
LA DOTD	Louisiana Department of Transportation and Development
LAN/WAN	Local Area Network/Wide Area Network
LED	Light Emitting Diode
LTL	Less Than Truck Load
MART	Montachusett Area Regional Transit Authority
MDC	Mobile Data Computer
MDI	Model Deployment Initiative
MDOT	Michigan Department of Transportation
MDT	Mobile Data Terminal
MITSC	Michigan Intelligent Transportation Systems Center
MMDI	Metropolitan Model Deployment Initiative
MMTA	Maryland Motor Transportation Authority
MMW	Millimeter Wave Radar
Mn/DOT	Minnesota Department of Transportation
MSP	Minnesota State Police
N/A	Not Applicable

NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NJTA	New Jersey Turnpike Authority
NMSHTD	New Mexico State Highway and Transportation Department
NOx	Oxides of Nitrogen
NTCIP	National Transportation Communications for ITS Protocol
NYSDOT	New York State Department of Transportation
O&M	Operations & Maintenance
ODOT	Ohio Department of Transportation
OSCAR	One-Stop-Credentialing and Registration
OTA	Ottumwa Transit Authority
PBX	Private Branch Exchange
PC	Personal Computer
PD	Personal Devices (Unit Cost Subsystem)
PDA	Personal Digital Assistant
PM	Parking Management (Unit Cost Subsystem)
PSAP	Public Safety Answering Point
PTC	Projected-Times-to-Collision
PuSHMe	Puget Sound Help Me
RCSC	Regional Customer Service Center
RFC	Regional Fare Coordination
RFID	Radio Frequency Identification
RFP	Request for Proposal
RM	Remote Location (Unit Cost Subsystem)
ROUTES	Rail, Omnibus, Underground, Travel Enquiry System
RPU	Remote Processing Unit
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)
RTD	Regional Transportation District
RWIS	Road Weather Information System
SAFER	Safety and Fitness Electronic Record
SANDAG	San Diego Association of Governments
SCOOT	Split Cycle Offset Optimization Techniques
SEMSIM	Southeast Michigan Snow and Ice Management
SIE	Safety Information Exchange
SSRS	Single State Registration System
TA	Toll Administration (Unit Cost Subsystem)
TIP	Transportation Improvement Plan
TIS	Traveler Information System
TM	Transportation Management Center (Unit Cost Subsystem)
TOC	Traffic Operations Center
TP	Toll Plaza (Unit Cost Subsystem)
TR	Transit Management Center (Unit Cost Subsystem)
TRIS	Transportation Research Information Services
TTMS	Temporary Traffic Management System
TV	Transit Vehicle On-Board (Unit Cost Subsystem)
TxDOT	Texas Department of Transportation
UDOT	Utah Department of Transportation
U.S.	United States
USDOT	United States Department of Transportation

USD	United States Dollars
USGS	United States Geological Survey
UTA	Utah Transit Authority
VII	Vehicle Infrastructure Integration
VMS	Variable Message Sign
VRAS	Voice Response Activated System
VS	Vehicle On-Board (Unit Cost Subsystem)
WESTA	Weigh Station Model
WIE	Wayside Interface Equipment
WIM	Weigh In Motion
WMATA	Washington Metropolitan Area Transit Authority
WSDOT	Washington State Department of Transportation

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