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

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16. Abstract

Intelligent transportation systems (ITS) provide a proven set of strategies for addressing the challenges of assuring safety and reducing congestion, while accommodating the growth in transit ridership and freight movement. This report presents information on the performance of deployed ITS under each of these goal areas, as well as information on the costs, deployment levels, and lessons learned regarding ITS deployment and operations. The report, and the collection of four Web-based resources upon which it is based, have been developed by the U.S. DOT's ITS Joint Program Office (JPO) to support informed decision making regarding ITS deployment. This report discusses 17 different areas of ITS application. These chapters are divided into two sections discussing technologies deployed on the transportation infrastructure and those deployed within vehicles. The 14 different infrastructure applications discussed can be grouped into ITS strategies applied to roadways, transit, management and operations of transportation systems, and freight movement. Lessons learned during ITS planning implementation and deployment, are highlighted throughout the report and in a chapter following the review of ITS applications.

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EXECUTIVE SUMMARY

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

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

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

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

Intelligent Infrastructure

ROADWAYS

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

Arterial Management

Studies demonstrate the ability of traffic control ITS applications to enhance mobility, increase efficiency of the transportation systems, and reduce the impact of automobile travel on energy consumption and air quality. The ability of both adaptive signal control and coordinated signal timing to smooth traffic can lead to corresponding safety improvements through reduced rear-end crashes. Optimizing signal timing is considered a low-cost approach to reducing congestion. Based on data from six separate studies, the costs range from $2,500 to $3,100 per signal per update.[1] Based on a series of surveys of arterial management agencies in 78 of the largest U.S. metropolitan areas, half of traffic signals in these metropolitan areas were under centralized control through closed-loop or computer control in 2006.

Freeway Management

There are numerous ITS strategies to improve freeway operations. Metropolitan areas that deploy ITS infrastructure including dynamic message signs (DMS) to manage freeway and arterial traffic, and integrate traveler information with incident management systems can increase peak period freeway speeds by 8 to 13 percent,[2] improve travel time, and according to simulation studies, reduce crash rates and improve trip time reliability with delay reductions ranging from 1 to 22 percent.[3] In Minneapolis-St. Paul, the benefit-to-cost ratio for a ramp metering system was estimated at 15:1.[4]

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

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

Crash Prevention and Safety

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

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

Road Weather Management

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

Roadway Operations and Maintenance

ITS technologies deployed for roadway operations and maintenance activities can have system-wide impacts. Network simulation models estimate that smart work zones can reduce total delay by 41 to 75 percent.[11] In addition to improving mobility, work zone ITS can improve safety. Evaluation data show that areas equipped with speed monitoring displays can decrease vehicle speeds by 4 to 6 mi/h,[12] and reduce the number of speeding vehicles by 25 to 78 percent.[13] Work zone ITS deployment costs ranged from $100,000 to $2.5 million with the majority of systems ranging from $150,000 to $500,000.[14]

TRANSIT

Several applications of ITS for transit management have been deployed.

Transit Management

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

Mobile data terminals (MDTs) are an important component of transit fleet management systems. MDTs are multifunctional on-board devices that support two-way communication between the vehicle and the control center. Capital costs for MDTs typically range between $1,000 and $4,000 per unit with installation costs frequently between $500 and $1,000.[17]

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

MANAGEMENT AND OPERATIONS

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

Transportation Management Centers

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

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

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

Traffic Incident Management

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

One component of successful traffic incident management programs are service patrols for which State DOTs can spend from $5.6 million to $13.6 million per year.[23] Service patrols have also been the subject of numerous benefit-to-cost analyses over the course of their deployment, with 26 studies of the programs completed in 23 U.S. cities between 1994 and 2005. These studies document benefit-to-cost ratios ranging from 2:1 to 36:1.[24]

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

Emergency Management

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

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Electronic Payment and Pricing

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

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

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

Traveler Information

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

Information Management

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

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

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

FREIGHT

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

Commercial Vehicle Operations

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

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

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

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

Intermodal Freight

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

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

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

Intelligent Vehicles

VEHICLES

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

Collision Avoidance

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

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

Driver Assistance

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

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

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

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

Collision Notification

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

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

Lessons Learned

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

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

Management and Operations

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

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

Policy and Planning

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

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

Design and Deployment

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

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

Leadership and Partnerships

The lessons learned on leadership and partnerships discuss the role of an ITS champion, partnerships that promote collaboration and cooperation among multiple agencies in deploying ITS, outreach and awareness efforts that make stakeholders knowledgeable and accepting of ITS, and organizational structures that facilitate efficient planning and implementation of ITS. Key lessons learned are summarized below:

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

Funding

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

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

Technical Integration

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

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

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

Procurement

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

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

Legal Issues

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

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

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

Human Resources

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

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

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

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

ENDNOTES

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

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