WHAT HAVE WE LEARNED ABOUT INTELLIGENT TRANSPORTATION SYSTEMS?

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acknowledgements

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chapter 1

WHAT HAVE WE LEARNED
ABOUT ITS? A SYNTHESIS

INTRODUCTION

Intelligent transportation systems (ITS) apply well-established technologies in communications, control, electronics, and computer hardware and software to improve surface transportation system performance.

This simple definition underlies what has been a substantial change in surface transportation in the United States and around the world. Development of ITS was motivated by the increased difficulty—social, political, and economic—of expanding transportation capacity through conventional infrastructure-building. ITS represents an effort to harness the capabilities of advanced technologies to improve transportation on many levels. ITS is intended to reduce congestion, enhance safety, mitigate the environmental impacts of transportation systems, enhance energy performance, and improve productivity. Now, with the National ITS Program more than a decade old in the United States, it certainly is timely, appropriate, and necessary to ask these questions:

Have we succeeded in deploying ITS? Has that deployment had a positive effect on surface transportation? What have we learned from these ITS deployments that can guide us in the future?

In short, this study is concerned with what we have learned about ITS. But ITS is composed of many technologies and applications, some of which, it will be seen, are more successful than others. So, in a disaggregate manner, this study examines which ITS technologies and applications have been successful, which have not, and for which more information is needed to make a judgment. Of further interest are the characteristics that distinguish successful from unsuccessful applications in the ITS world. If they can be identified, then we can more effectively plan the future of the National ITS Program, building on that knowledge.

The National ITS Program is large and broad. Even in an evaluation as ambitious as this study, limits had to be set on which parts of ITS to include. The areas included within the scope of this study are as follows:

- Freeway, Incident, and Emergency Management, and Electronic Toll Collection (ETC)
- Arterial Management
- Traveler Information Systems
- Advanced Public Transportation Systems
- Commercial Vehicle Operations (CVO)
- Cross-Cutting Technical Issues
- Cross-Cutting Institutional Issues

While these areas represent a significant portion of ITS, some important areas were beyond the scope of this study. These include the Intelligent Vehicle Initiative (IVI), which is currently in the field testing stage. Also, a number of in-vehicle technologies and fleet management applications in commercial vehicles—outside the purview and control of the public sector—were not included. Highway-rail ITS applications had insufficient information for this report to comment on.

At the outset, it is important to establish a definition of what we mean by success. While many possible definitions exist, success in this study is tied to effectiveness—that is, whether an ITS application addresses major societal goals, such as enhanced safety and improved quality of life—and to deployment of each particular ITS technology or application. Implicit in this metric for success is the study team's belief in the test of the marketplace and the ITS community's ability to select those technologies and applications it sees as cost-effective and beneficial. While one could argue that other success metrics should be used, the study team's judgment was that ITS, now in its second decade of development, testing, and deployment in the United States, should be judged by its success in an increasingly sophisticated marketplace.

The ITS Joint Program Office (JPO) of the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (U.S. DOT) funds the development of several databases that were used to judge various ITS technologies and applications. Those include the following:

- Metropolitan ITS Deployment Tracking Database, maintained by the Oak Ridge National Laboratory.
- Commercial Vehicle Information Systems Network (CVISN) Deployment Tracking Database, maintained by the John A. Volpe National Transportation Systems Center (Volpe Center).
- 1998 Survey of Transit Agencies conducted by the Volpe Center.
- ITS Cost Database, maintained by Mitretek Systems.

Deployment levels for various technologies were defined as follows:

Deployed in fewer than 10 percent of possible sites = limited deployment

Deployed in between 10 percent and 30 percent of possible sites = moderate deployment

Deployed in more than 30 percent of possible sites = widespread deployment[1]

Deployment levels are based on the actual presence of particular technologies, not future plans to deploy, even if funding for the deployment has already been secured. If a metropolitan area or agency responded that they use some technology (e.g., a kiosk) at one location, then that metro area was included in the "count" for kiosks.

But simply identifying an ITS technology or application as unsuccessful (i.e., not adequately deployed) is not a sufficient base for understanding how to subsequently advance in that area. The study, therefore, included the reason for the lack of success, choosing among three fundamental causes for a technology or application not being deployed:

1. The technology simply did not function effectively in a real-world environment.

2. While the technology or application worked in a technical sense, it was too costly, meaning (a) it was simply too expensive to deploy compared with the potential

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[1] Specifically the "possible sites" on which these deployment levels are based are 78 of the largest metropolitan areas for Chapters 2, 3, 4 and 7; 525 transit agencies surveyed by the John A. Volpe National Transportation Systems Center for Chapter 5; and the 50 states plus the District of Columbia for Chapter 6.

benefits that accrued from its deployment; or (b) the absolute costs of acquisition, operations, and maintenance were considered too large by the deploying organization; or (c) the technology used was not suitable for a particular application.

3. Institutional barriers prevented the effective deployment of the technology or application.

Any of these reasons for lack of success could potentially be overcome in the future. Technologies can be enhanced, prices of various technologies can and do fall, often dramatically. And institutional barriers, while often tenacious, can be overcome with careful work over the long-term. Further, a particular technology or application may not have had time to develop a "following" in the marketplace, given development and deployment cycles.

Therefore, each technology was characterized as one of the following:

■ Successful.

■ Unsuccessful.

■ Holds Promise.

■ Jury Still Out.

Deployment level does not necessarily relate directly to success. For example, a technology that is only moderately deployed could be considered successful because it serves as an appropriate technological solution, though only for a small segment of the market.

While cost was considered in these analyses, detailed benefit/cost studies were not undertaken.

In short, what this study aims to do for the technologies described above is to identify why some succeeded and others failed, how some cannot yet be judged, and what the underlying reasons are in each case.

THE PROCESS

To answer these questions, the ITS JPO initiated the "What Have We Learned About ITS?" project. This project drew from experienced experts in the ITS field and the considerable literature developed in this area.

The first major project event took place on December 10, 1999, with a series of presentations in Washington, DC, delivered by various industry experts from Booz-Allen & Hamilton, the Volpe Center, Battelle, SAIC, Mitretek Systems, the Oak Ridge National Laboratory, and the Intelligent Transportation Society of America (ITS America) Benefits, Evaluation, and Costs (BEC) Committee. Experts from these organizations shared information intended to answer the following questions about the ITS technologies and applications listed earlier:

■ What ITS technology applications have been successful and why?

■ What ITS technology applications have not been successful and why?

■ For what ITS technologies is "the jury still out"?

- What institutional issues arose in ITS deployments and how were they overcome?
- What does the future hold?
- What next steps are needed?

Results of the meeting were captured in detailed minutes and in a "strawman" summary of findings.

The December 10, 1999, event produced valuable initial results; however, it was primarily internal to U.S. DOT, with participants mainly from consulting and research organizations drawing upon their experiences and previous work. There was no opportunity for commentary by the broader ITS community at that time, but meeting planners recognized the importance of eliciting this input—specifically, to seek the opinion of people in the ITS field with responsibilities for deployment of ITS technologies and applications, as well as other industry experts.

To that end, in April 2000, in conjunction with the Institute of Transportation Engineers (ITE) 2000 International Conference in Irvine, California, these initial results were presented to a broader community to validate or debunk them, and to document a national consensus, if one existed, of what we have learned. Breakout sessions addressed each of the seven ITS areas previously noted. Each breakout was 90 minutes long, with 30-45 minutes devoted to a presentation by the consultants on what we have learned about a particular area of ITS, and then 45-60 minutes devoted to active discussion of those results. The individual workshops were facilitated by the following experts:

- John Corbin, Wisconsin Department of Transportation (DOT)
- Lyle Berg, City of Bloomington, Minnesota
- Catherine Bradshaw, University of Washington

Table 1-1. ITS Roundtable Discussions at the ITE 2000 International Conference

Discussion Topic	Facilitator	Technical Presenter	Notetaker
Freeway & Incident Management	John Corbin, Wisconsin Department of Transportation	Vincent Pearce, Booz-Allen & Hamilton, Inc.	Ruth Duncan, Battelle
Arterial Management	Lyle Berg, City of Bloomington, Minnesota	Mark Carter, SAIC	Brandy Hicks, SAIC
Advanced Traveler Information Systems	Catherine Bradshaw, University of Washington	Jane Lappin, John A. Volpe National Transportation Systems Center	Cynthia Maloney, John A. Volpe National Transportation Systems Center
Advanced Public Transit Systems	Ginger Gherardi, Ventura County Transportation Commission	Robert Casey, John A. Volpe National Transportation Systems Center	Gary Ritter, John A. Volpe National Transportation Systems Center
Commercial Vehicle Operations	Gary Nishite, California Department of Motor Vehicles	John Kinateder, Battelle	Ruth Duncan, Battelle

Discussion Topic	Facilitator	Technical Presenter	Notetaker
Cross-Cutting Technical Issues	James Wright, Minnesota Department of Transportation	Michael McGurrin, Mitretrek Systems, Inc.	James Bunch, Mitretrek Systems, Inc.
Cross-Cutting Institutional Issues	Matt Edelman, TRANSCOM℠	Allan DeBlasio, John A. Volpe National Transportation Systems Center	David Jackson, John A. Volpe National Transportation Systems Center

- Ginger Gherardi, Ventura County Transportation Commission
- Gary Nishite, California Department of Motor Vehicles
- James Wright, Minnesota DOT
- Matthew Edelman, Transportation Operations Coordinating Committee (TRANSCOM℠)

The purpose of these workshops was to get reaction to earlier findings from additional informed professionals. The workshop process gave study teams a good deal of additional information—some supportive and some counter to previous findings. Also, in two of the areas—commercial vehicle operations and transit management—additional presentation venues were sought because of feelings that the ITE constituency might not totally represent informed opinion in those areas. These additional venues included the CVISN Project Managers Meeting, April 25, 2000, Tampa, Florida; the Great Lakes and Southeast Regional [CVISN] Mainstreaming Meeting, May 10-11, 2000, West Palm Beach, Florida; and the American Public Transportation Association Bus Operations Committee Meeting, May 7, 2000, Houston, Texas.

Consultants representing the seven areas then each produced an approximately 20-page white paper on what had been learned about each of the seven areas, integrating the workshop results. Those papers were reviewed by Professor Joseph Sussman of MIT, who also served as "master facilitator" at the ITE conference. Other reviewers included JPO staff, the Jet Propulsion Laboratory (JPL), and various public sector stakeholders. Professor Sussman produced this synthesis paper, which was reviewed by JPO, JPL, and the authors of the seven area papers. The synthesis is intended to capture overarching conclusions on what we have learned about ITS. The seven papers and this synthesis paper collectively represent a current report card on ITS deployment, the barriers it is encountering, and some views of the future.

To briefly preview the overall results of the study, while widespread deployment of many technologies and applications has occurred, a number lag behind for various reasons. It is fair to say that ITS has captured the "low hanging fruit" and that the clearly cost-effective technologies and applications have been deployed. Readers of the "glass is half-full" persuasion will be encouraged by this deployment. On the other hand, ITS deployments clearly suffer from a lack of overall integration, which some would argue prevents ITS from achieving its full impact. A more holistic approach to deployment will be necessary to achieve an integrated environment, often difficult because of institutional barriers.

The following is a brief discussion of what we have learned about ITS in each of the seven areas, continuing with overarching themes that cut across all of them.

SEVEN ITS AREAS

This section briefly summarizes some of the key concepts in the seven ITS areas studied in this program. As noted, the individual papers that comprise the following chapters describe each of the seven areas and include an executive summary, so no attempt will be made here to fully summarize those chapters. Rather, this section will touch upon major ideas as they support overarching project findings. No comparative or blanket assessments will be made of the seven areas.

Freeway, Incident, and Emergency Management, and Electronic Toll Collection (Chapter 2)
Author: Vincent Pearce, Booz-Allen & Hamilton

Chapter 2 is necessarily broad in its focus, as it includes a number of different, albeit related, technologies. Various technologies, including transportation management centers, ramp metering, dynamic message signs, roadside infrastructure, and dynamic lane and speed control, form the basis of these applications.

ETC is one of the fundamental and earliest deployed ITS technologies. It is also the most common example of the electronic linkage between vehicle and infrastructure that characterizes ITS. Freeways (i.e., limited access highways) represent a major and early ITS application area. Incident management on those facilities is of primary importance in reducing nonrecurrent congestion. Emergency management predates ITS as a concept, but is enhanced by the addition of ITS technologies.

While a number of systems have seen widespread deployment, much more can be accomplished. Institutional issues preventing truly integrated services are a major barrier. An important technical advance would be to upgrade such systems to be predictive (in the sense of predicting when congestion will occur in the future as a function of current traffic patterns and expectations about the future) as opposed to the responsive systems currently in place.

The author emphasizes the need to institutionalize operations budgets for these kinds of systems, along with the need to attract high-quality technical staff for deployment and operations support.

Arterial Management (Chapter 3)
Authors: Brandy Hicks and Mark Carter, SAIC

Arterials are high-capacity roadways controlled by traffic signals, with access via cross-streets and often abutting driveways. Arterial management predates ITS, with early deployments going back to the 1960s; it is a useful ITS application, with current deployment.

However, adaptive control strategies, which make real-time adjustments to traffic signals based on sensing conditions (e.g., queues), for arterials are not in widespread use. While some argue that such control strategies have potential for substantial

benefits, only a handful are deployed nationally, of which four are federally funded field operational tests. The reasons for this deployment lag include cost issues as well as concerns that algorithms for adaptive traffic control simply do not perform well. In particular, when traffic volumes are heavy, the state-of-the-art algorithms appear to break down (although vendors claim otherwise). Also, system complexity drives the need for additional training.

Widespread deployment has not yet occurred for traveler information systems for arterials, even though studies suggest safety and delay reduction benefits. Hope is that with the addition of cellular phones, or cellular phone geolocation for traffic probes, and implementation of a national three-digit traveler information number (511), more deployment will occur.

Integration of various traffic management technologies with arterial management was viewed as an important next step. Integration of arterial management with emergency vehicle management, transit management, and freeway management would all be important and useful advances.

Traveler Information Systems (Chapter 4)
Author: Jane Lappin, EG&G Technical Services/John A. Volpe National Transportation Systems Center

Traveler information is one of the core concepts of ITS. This paper highlights what consumers value in traveler information. Among the valued items are high-quality information, easy and timely accessibility to that information, a high-quality user interface, and low prices, preferably free. Consumer demand for traveler information is a function of:

- The amount of congestion on the regional transportation network.
- The overall characteristics of that network.
- What is provided on the supply side in terms of information quality and user interface.
- Characteristics of individual trips.
- Driver and transit user characteristics.

Examples abound of various kinds of traveler information systems, with extensive deployment of various kinds of systems. While people value high-quality traveler information in the conceptual sense, they are not necessarily willing to pay for it. After all, free information—although often of lower quality—is universal (e.g., radio helicopter reports). So, whether traveler information systems can be a viable stand-alone commercial enterprise is likewise unclear. More likely, transportation information will be offered as part of some other package of information services. This study concludes that the Internet is likely to be a major basis of traveler information delivery in the future.

The analysis of traveler information systems brings home the fact that ITS operates within the environment of people's expectations for information: timeliness and quality of information are on a continually increasing slope in many non-ITS appli-

cations, with people's expectations heightened by the Internet and related concepts. Traveler information providers, whether public or private sector, need to be conscious of operating in the context of these changed expectations.

Further, the effective integration of traveler information with network management, or transportation management systems, of which freeway and arterial management are examples, is currently virtually nonexistent. Both network management and traveler information systems would benefit by more substantial integration, as would the ultimate customers—travelers and freight carriers—of these systems.

Advanced Public Transportation Systems (Chapter 5)
Robert Casey, John A. Volpe National Transportation Systems Center

That transit has difficulty attracting market share is a well-established fact. Reasons include the following:

- Land-use patterns incompatible with transit use.
- Lack of high-quality service, with travel times too long and unreliable.
- Lack of comfort.
- Security concerns.
- Incompatibility with the way people currently travel (for example, transit is often not suited for trip-chaining).

The hypothesis is that ITS transit technologies—including automatic vehicle location, passenger information systems, traffic signal priority, and electronic fare payment—can help ameliorate these difficulties, improving transit productivity and quality of service and real-time information for transit users.

Using ITS to upgrade transit clearly has potential. However, deployment has, for the most part, been modest, stymied by a number of constraints:

- Lack of funding to purchase ITS equipment.
- Difficulties in integrating ITS technologies into conventional transit operations.
- Lack of human resources needed to support and deploy such technologies.

Optimistically, there will be a steady but slow increase in the use of ITS technologies for transit management, as people with ITS expertise join transit agencies. But training is needed, and inertia must be overcome in deploying these technologies in a chronically capital-poor industry.

Integrating transit services with other ITS services is potentially a major intermodal benefit of ITS transit deployments; it is hoped that this integration, including highway and transit, multiprovider services, and intermodal transfers, will be feasible in the near-term.

Still the question remains, "How can we use ITS to fundamentally change transit operations and services?" The transit industry needs a boost, and can be vital in providing transportation services, especially in urban areas, and in supporting environmentally related programs. Can ITS be the mechanism by which the industry reinvents itself? The jury is certainly still out on that question.

Commercial Vehicle Operations (Chapter 6)
Author: John Orban, Battelle

This paper is limited to the public sector side of CVO systems, as states fulfill their obligation to ensure safety and enforce other regulations related to truck operations on their highways. These systems fall under the CVISN rubric and deal with roadway operations, including safety information exchange and electronic screening, as well as back-office applications like electronic credentialing.

While CVISN is experiencing some deployment successes, much remains to be done. Participation by carriers is voluntary in most programs, and requiring use of transponders by truckers may be difficult. Certainly these facts make universal deployment challenging. Also important as a barrier to deployment is consistency among states, particularly contiguous ones. Recognizing trucking as a regional or even national business, the interface between the trucking industry and the various states needs to be consistent for widespread deployment to occur. While each state has its own requirements for such systems, driven by its operating environment, states must work toward providing interstate interoperability. Expanded public-public partnerships are needed among states and between the Federal Government and states.

Some public and private sector tensions occur in the CVISN program as well. A good example is how truckers like the technologies that support weigh station bypass, whereby they are not required to stop at a weigh station if they have been previously checked. In such systems, the information is passed down the line from an adjoining station or even another state. At the same time, truckers are concerned about equity in tax collection and the privacy of their origin-destination data, because of competitive issues. Ironically, the same underlying CVISN system drives both applications. Public-private partnerships need to be developed in this application for public and private benefits to be effectively captured.

It is important to note that this study does not include fleet management—mechanisms by which private fleet operators can use ITS technologies to enhance the productivity of their fleets.

Cross-Cutting Technical and Programmatic Issues (Chapter 7)
Michael McGurrin, Mitretek Systems

Advanced technology is at the heart of ITS, so it is helpful to consider technical issues that affect ITS functions and applications. Technical issues include how one deals with rapidly changing technologies and how this aspect relates to the need for standards. Rapid obsolescence is a problem.

All in all, the author concludes that technology issues are not a substantial barrier to ITS deployment. Most technologies perform; the question is, are they priced within the budget of deploying organizations, and are those prices consistent with the benefits that can be achieved?

Two core technologies are those used for surveillance and communication:

1. Surveillance technologies have experienced some successes in cellular phone use for incident reports and in video use for incident verification, but the jury is still out on cellular phone geolocation for traffic probes. The lack of traffic flow sensors in many areas and on some roadway types continues to inhibit the growth of traveler information and improved transportation management systems.

2. Communications technologies have experienced some success with the Internet for pre-trip traveler information and credentials administration in CVO. Emerging technologies include wireless Internet and automated information exchange. The growth rate of these technologies is high. In particular, the numbers of Americans having access to the Internet is growing rapidly, portending increased use of ITS applications.[2]

Cross-Cutting Institutional Issues (Chapter 8)
Allan J. DeBlasio, John A. Volpe National Transportation Systems Center

Institutional issues are the key barrier to ITS deployment. This study identified the most important of the institutional issues, as well as approaches to dealing with them. The ten most prominent issues are as follows:

- Awareness and perception of ITS.
- Long-range operations and management.
- Regional deployment.
- Human resources.
- Partnering.
- Ownership and use of resources.
- Procurement.
- Intellectual property.
- Privacy.
- Liability.

Awareness and public and political appreciation of ITS as a system that can help deal with real and meaningful issues (e.g., safety, quality of life) are central to deployment success. Building a regional perspective to deployment using public-public and public-private partnerships is important. Recognizing that one must plan for sustained funding for operations in the long term is critical. Dealing with procurement questions is an important institutional concern, and public sector agencies are not accustomed to procuring high-technology components where intellectual property is at issue.

Fundamentally, ITS deployment requires cultural change in transportation deployment organizations that have traditionally focused on providing conventional infrastructure. No silver bullet exists for achieving this cultural change; rather, it is a continuing, ongoing, arduous process, and one that must be undertaken if ITS is to be successfully deployed.

[2] For an excellent treatment of public sector Internet use, see "A Survey of Government on Internet: The Next Revolution," *The Economist* (June 14, 2000).

CONCLUSIONS

This section summarizes overarching conclusions derived from the seven project areas, which comprise the chapters that follow. A useful typology for assessing ITS is to analyze it along the three major dimensions commonly used to characterize transportation issues: technology, system, and institutions (Sussman 2000):

Technology includes infrastructure, vehicles, and hardware and software that provide transportation functionality.

Systems are one step removed from the immediacy of technology and deal with how holistic sets of components perform. An example is transportation networks.

Institutions refer to organizations and interorganizational relationships that provide the basis for developing and deploying transportation programs.

TECHNOLOGY

Four technologies are central to most ITS applications:

Sensing—typically the position and velocity of vehicles on the infrastructure.

Communicating—from vehicle to vehicle, between vehicle and infrastructure, and between infrastructure and centralized transportation operations and management centers.

Computing—processing of the large amounts of data collected and communicated during transportation operations.

Algorithms—typically computerized methods for dynamically operating transportation systems.

One overarching conclusion of this study is that the quality of technology is not a major barrier to the deployment of ITS. Off-the-shelf technology exists, in most cases, to support ITS functionality.

An area where important questions about technology quality still remain is algorithms. For example, questions have been raised about the efficacy of software to perform adaptive traffic signal control. Also, the quality of collected information may be a technical issue in some applications.

That is not to say that issues do not remain on the technology side. In some cases, technology may simply be considered too costly for deployment, operations, and maintenance, particularly by public agencies that see ITS costs as not commensurate with the benefits to be gained by their deployment. Or, the technology may be too complex to be operated by current agency staff. Also, in some cases, technology falters because it is not easy to use, either by operators or transportation customers. Nonintuitive kiosks and displays for operators that are less than enlightening are two examples of the need to focus more on user interface in providing ITS technologies.

SYSTEMS

The overarching need at the ITS systems level is integration of ITS components. While exceptions can certainly be found, many ITS deployments are stand-alone applications (e.g., ETC). It is not hard to understand why. It is often cost-effective in the short run to deploy an individual application without worrying about all the interfaces and platforms required for an integrated system. In their zeal to make ITS operational, people often have opted for stand-alone applications—not necessarily an unreasonable approach for the first generation of ITS deployment.

However, for ITS to take the next steps forward, it will be important both for efficiency and effectiveness reasons to think in terms of system integration. For example, the integration of services for arterials, freeways, and public transit should be on the agenda for the next generation of ITS deployments. Further integration of services, such as incident management, emergency management, traveler information, and intermodal services, must be accomplished.

While this integration certainly adds complexity, it is also expected to provide economies of scale in system deployment and improvements in overall system effectiveness, resulting in better service for freight and traveling customers.

Another aspect of system integration is interoperability—ensuring that ITS components can function together. Possibly the best example of this function is interoperability of hardware and software in vehicles and on the infrastructure (e.g., ETC devices). The electronic linkage of vehicles and infrastructure must be designed using system architecture principles and open standards to achieve interoperability. It is quite reasonable for the public to ask whether their transponders will work with ETC systems across the country or even regionally. Unfortunately, the answer most often is no. And while it is important to make this technology operate properly on a broad geographic scale, it should also work for public transportation and parking applications.

Systems that need to work at a national scale, such as CVO, must provide interoperability among components. No doubt, institutional barriers to interoperability exist (e.g., different perspectives among political jurisdictions). But also without doubt, these barriers inhibit widespread deployment, which is ultimately in the best interest of those political jurisdictions.[3]

Another important example of needed integration is between advanced transportation management systems (ATMS) and advanced traveler information systems (ATIS). The former provides for operations of networks, the latter for traveler information, pre-trip and in-vehicle, to individual transportation customers. For the most part, these two technologies, while conceptually interlinked, have developed independently.

Currently, there are limited evaluative data on the technical, institutional, and societal issues related to integrating ATMS and ATIS, whereby ATMS, which

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[3] John Orban's paper (Chapter 6), "What Have We Learned About ITS for Commercial Vehicle Operations? Status, Challenges, and Benefits of CVISN Level 1 Deployment," contrasts technical interoperability, operations interoperability, and business model interoperability in the context of CVO and CVISN.

collect and process a variety of network status data and estimates of future demand patterns, provides travelers (via ATIS services) with dynamic route guidance. This integration, together with ATMS-derived effective operating strategies for the net- work—which account for customer response to ATIS-provided advice—can lead to better network performance and better individual routes.

Again, it is not surprising that these technologies developed independently in the first ITS generation, but in future generations, integration of these technologies and applications will be important. This integration is a complex and somewhat uncharted enterprise. But it should certainly be on the ITS agenda if full benefits of ATMS and ATIS deployment are to be realized.

Institutions

The final example in the previous section suggests another kind of integration that will be important for the future of ITS, namely institutional integration. The integration of public and private sector perspectives on ITS, as well as the integration of various levels of public sector organizations, are central to advancing the ITS agenda.

Indeed, an important result of this study is that the major barriers to ITS deployment are institutional in nature. This conclusion should come as no surprise to observers of the ITS scene; the very definition of ITS speaks of applying "well-established technologies," so technological breakthroughs are not needed for ITS deployment. But looking at transportation from an intermodal, systemic point of view requires a shift in institutional focus that is not easy to achieve. Dealing with intra- and interjurisdictional questions, budgetary frameworks, and regional-level perspectives on transportation systems; shifting institutional foci to operations rather than construction and maintenance; and training, retaining, and compensating qualified staff are all institutional barriers to widespread deployment of ITS technologies.

Thinking through how to overcome various institutional barriers to ITS is the single most important activity we can undertake to enhance ITS deployment and develop successful implementations.

A Focus on Operations

Recent years have brought an increasing emphasis on transportation operations, as opposed to construction and maintenance of infrastructure, as a primary focus. Indeed, the entire ITE 2000 International Conference, at which workshops support- ing this study took place, was itself focused on operations as a critical factor in the future of the transportation field.

ITS is at the heart of this initiative, dealing as it does with technology-enhanced operations of complex transportation systems. The ITS community has argued that this focus on operations through advanced technology is the cost-effective way to go, given the extraordinary social, political, and economic costs of conventional infrastructure, particularly in urban areas. Through ITS, it is argued, one can avoid the high up-front costs of conventional infrastructure by investing more modestly in electronic infrastructure, then focusing attention on effectively operating that infrastructure and the transportation network at large.

While ITS can provide less expensive solutions, they are not free. There are up-front infrastructure costs (see section following on "Mainstreaming") and additional spending on operating and maintaining hardware and software. Training staff to support operations requires resources. Spending for ITS is of a different nature than spending for conventional infrastructure, with less up front and more in the out years. Therefore, planning for operations requires a long-term perspective by transportation agencies and the political sector.

For that reason, it is important to institutionalize operations within transportation agencies. Stable budgets need to be provided for operations and cannot be the subject of year-to-year fluctuation and negotiation, which is how maintenance has traditionally been, if system effectiveness and efficiency are to be maintained. Human resources needs must be considered as well (see section on "Human Resources").

To justify ITS capital costs as well as continuing costs, it is helpful to consider life cycle costing in the evaluation of such programs. The costs and benefits that accrue over the long term are the important metric for such projects. But organizations need to recognize that a lack of follow-through will cause those out-year benefits to disappear as unmaintained ITS infrastructure deteriorates and algorithms for traffic management are not recalibrated.

Mainstreaming

The term "mainstreaming" is used in different ways in the ITS setting.[4] Some argue that mainstreaming means integrating ITS components into conventional projects. Good examples are the Central Artery/Ted Williams Tunnel project in Boston, which includes important ITS elements, as well as conventional infrastructure. Another is the Woodrow Wilson Bridge on I-95, connecting Maryland and Virginia, currently undergoing a major redesign, which includes both conventional infrastructure and ITS technologies and applications. This approach has the advantage of serving as an opportunity for ITS deployment within construction or major reconstruction activities. Typically the ITS component is a modest fraction of total project cost.

Even so, ITS technologies and applications can sometimes come under close political scrutiny well beyond their financial impact on the project. For example, on the Woodrow Wilson Bridge, the decommitting of various ITS elements is being considered (*The Washington Post,* June 29, 2000, page A-15[5]).

Another definition of ITS mainstreaming suggests that ITS projects not be protected by special funds sealed for ITS applications, but that ITS should compete for funding with all other transportation projects. The advantage of this method is that ITS would compete for a much larger pool of money; the disadvantage is that ITS, in the current environment, might not compete particularly successfully for that larger

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[4] CVO has a specialized definition of "mainstreaming," implying multistate agency cooperation, but this is not a general use of the term.

[5] John Collins, President of ITS America, suggested that decommitting ITS technologies from the Woodrow Wilson Bridge "would be like constructing a house and deciding to save money by not buying lightbulbs."

pool. Those charged with spending public monies for transportation infrastructure have traditionally spent all, or virtually all, their money on conventional projects. Convincing these decision-makers that monies are better spent on ITS applications may be difficult.

This issue is clearly linked to human resource development. Professionals cannot be expected to select ITS unless they are knowledgeable about it, so education of the professional cadre is an essential precondition for success of mainstreaming—by either definition. Of course, the National ITS Program must also be prepared to demonstrate that the benefits of ITS deployments are consistent with the costs incurred.

Protected ITS funds—funds that can be spent only on ITS applications—may possibly be a good transition strategy as professional education continues and ITS benefits become clearer; but in the longer run, there are advantages to ITS being mainstreamed.

Human Resources

An important barrier to success in the deployment of new technologies and applications embodied in ITS is a lack of people to support such systems. The ITS environment requires skilled specialists representing new technologies. It also needs broad generalists with policy and management skills who can integrate advanced thinking about transportation services based on new technologies (Sussman 1995).

The ITS community has recognized these needs, and various organizations have established substantial programs for human resource development. FHWA's Professional Capacity Building program is a premier example, but hardly the only one. Universities, including the University of Michigan and the Virginia Polytechnic Institute, have developed programs, as has CITE (Consortium for Intelligent Transportation Education), housed at the University of Maryland. These programs, along with graduate transportation programs undergoing substantial ITS-related changes around the country, can provide a steady stream of talented and newly skilled people for the industry.

However, we must emphasize that institutional changes in transportation organizations are needed if these people are to be used effectively and retained, as people with high-technology skills can often demand much higher salaries than are provided by public sector transportation organizations. Cultural change along with appropriate rewards for operations staff, for example, will be necessary in organizations where the culture strongly favors conventional infrastructure construction and maintenance.

The need for political champions for ITS has long been understood in the ITS community. Here, though, we emphasize the need at all levels of implementing organizations for people with the ability to effectively deploy ITS.

The political realities may require public sector organizations to "contract in" staff to perform some of the high-technology functions inherent in ITS, as opposed to permanently hiring such individuals. Also, "contracting out"—having private sector

organizations handle various ITS functions on behalf of the public sector—is another option. In the short run, these options may both form useful strategies. In the long run, developing technical and policy skills directly in the public agency has important advantages for strategic ITS decision-making.

The Positioning of ITS

Almost from its earliest days, ITS has unfortunately been subject to over-expectations and over-selling. Advocates have often resorted to "hype" to promote the benefits of ITS technologies and applications and have minimized the difficulties in system integration during deployment. Often ITS has been seen by the public and politicians as a solution looking for a problem. Overtly pushing ITS can be counterproductive. Rather, ITS needs to be put to work in solving problems that the public and agencies feel truly exist.

Safety and quality of life are the two most critical areas that ITS can address. Characterizing ITS benefits along those dimensions when talking to the public or potential deploying agencies is a good strategy.

The media can also help to get the story out about ITS. Indeed, the most recent ITS America annual meeting in Boston in May 2000 had media relations as a major focus (Sussman 2000, spring).

Operator vs. Customer Perspective

Information is at the heart of ITS. The provision of information to operators to help them optimize vehicle flows on complex systems is one component. The flow of information to customers (drivers, transit users, etc.) so they can make effective choices about mode, route choice, etc., is another component.

There is a great deal of overlap in these two information sets, and yet sharing information between operators and customers is often problematic. Operators are usually public sector organizations. From their perspective, the needs of individual travelers should be subordinate to the need to make the overall network perform effectively. On the other hand, private sector information providers often create and deliver more tailored information focusing on the needs of particular travelers rather than overall system optimization.

It is not surprising that the agendas of the public sector agencies operating the infrastructure and those of the information-provider, private sector companies differ. And it is not unhealthy that they do. Nonetheless, it seems clear that the ultimate customer—the traveler—would benefit from a more effective integration of these two perspectives. This issue is both a technical and an institutional one, and is an important example of the need for service integration.

Regional Opportunities

A recurring theme in many of the papers in this document is the regional opportunity inherent in ITS. From a technological and functional point of view, ITS provides, for the first time, an opportunity to manage transportation at the scale of the metropolitan-based region. Along with state or even multistate geographic areas, metropolitan-based regions—the basic geographic unit for economic competition and growth (Porter 1998) and for environmental issues—can now be effectively managed from a transport point of view through ITS.

While a few regions have made progress, ITS technologies generally have not been translated into a regionally scaled capability. The institutional barriers are, of course, immense, but the prize from a regional viability perspective is immense as well. Thinking through the organizational changes that will allow subregional units some autonomy, but at the same time allow system management at the regional scale, is an ITS issue of the first order (Hardy 1996). Indeed, this approach could lead to new paradigms for strategic planning on a regional scale, supported by the information and organizational infrastructure developed in the context of ITS.

The strategic vision for ITS is as the integrator of transportation, communications, and intermodalism on a regional scale (Sussman 1999 and 2000 spring). Multistate regions with traffic coordination over very large geographic areas, as in the mountain states, is an important ITS application. Further, "corridors" such as I-95, monitored by the I-95 Corridor Coalition and stretching from Maine to Virginia, represent an ITS opportunity as well.

Surface Transportation as a Market

Surface transportation needs to be thought of as a market with customers with ever-rising and individual expectations. Modern markets provide choices. People demand choices in level of service and often are willing to pay for superior service quality; surface transportation customers will increasingly demand this service differentiation as well. While a market framework is not without controversy in publicly provided services, surface transportation operators can no longer think in terms of "one size fits all."

High-occupancy toll (HOT) lanes, where people driving a single-occupancy vehicle are permitted to use a high-occupancy vehicle (HOV) lane if they pay a toll, are an early example of this market concept in highway transportation. HOT lanes are enabled by ITS technologies. Other market opportunities building on ITS will doubtless emerge as well. Using ITS as a mechanism for thinking through how surface transportation should operate relative to markets, philosophically and conceptually, is an important line of endeavor.

Many other important and useful approaches to ITS implementation are contained within the chapters that follow, which analyze in more depth the seven ITS areas under study.

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chapter 2
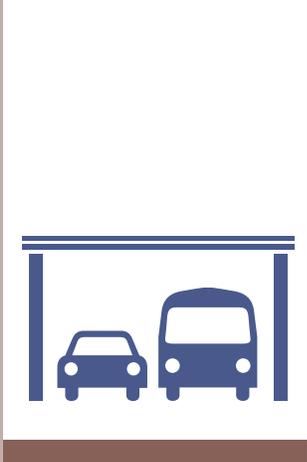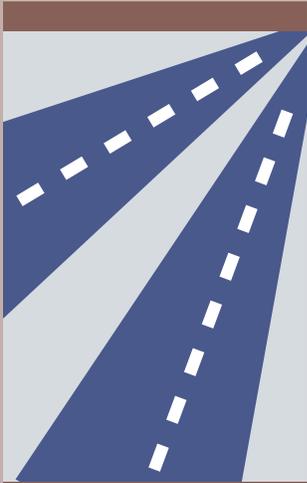
WHAT HAVE WE LEARNED
ABOUT FREEWAY, INCIDENT,
AND EMERGENCY MANAGEMENT
AND ELECTRONIC TOLL
COLLECTION?

EXECUTIVE SUMMARY

The intelligent infrastructure is often the most visible manifestation of intelligent transportation systems (ITS) along the roads, with freeway and incident management often among the first ITS elements implemented in a region or metropolitan area. They can significantly contribute to improving travel conditions by addressing delay caused by both recurring and nonrecurring congestion. Electronic toll collection (ETC) systems similarly aid in reducing congestion on toll roads. In a complementary way, emergency management systems can greatly aid in locating incidents and responding to them in the most rapid and effective manner possible.

Each of the ITS technologies discussed in this paper shows potential benefits; however, only a few of the technologies have reached widespread deployment. Reasons for the limited deployment vary for each technology, but include cost, institutional barriers, uncertainty of benefits, and technological incompatibilities. The following list summarizes the deployment levels of the ITS technologies presented for incident management, freeway management, emergency management, and electronic toll collection.

Widespread: Deployed in more than 30 percent of the largest 78 metropolitan areas.

Moderate: Deployed in 10 percent to 30 percent of the largest 78 metropolitan areas.

Limited: Deployed in less than 10 percent of the largest 78 metropolitan areas.

Incident management systems have proven to be highly successful, and are now found in many major urban areas around the United States. These programs are undergoing and benefiting from significant technological change, particularly that related to the advent of cellular geolocation. Incident management's greatest challenge has been in institutional integration (i.e., in integrating incident management into the mainstream transportation planning and programming processes and in integrating incident management programs across jurisdictional boundaries).

Table 2-1 summarizes the current deployment status for various approaches commonly used in incident management.

Table 2-1. Incident Management Summary Table

Technology*	Deployment Level	Limiting Factors	Comments
Service patrols	Widespread Deployment	Cost, staffing	**Successful**
Common communication frequencies	Limited Deployment[†]	Cost, institutional issues	**Successful**
Automated incident detection algorithms	Medium Deployment[†]	Technical performance	**Mixed**
Cellular communication for incident detection	Widespread Deployment	Availability, institutional issues	**Jury is still out**

Table 2-1. Continued

Technology*	Deployment Level	Limiting Factors	Comments
Motorist callboxes	Limited Deployment†	Being replaced by cell phone use	**Successful**
CCTV (ground, airborne, high magnification)	Widespread Deployment	Cost	**Successful**
Cellular geolocation (old generation)	Operational Testing†	Accuracy	**Unsuccessful**
Cellular geolocation (emerging generation)	Operational Testing†	Availability, institutional issues	**Jury is still out**
Regional incident management programs	Limited Deployment†	Institutional issues	**Holds promise**

Cross-cutting technologies, such as telecommunications, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issues?"

† Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Freeway management is becoming similarly common, and shares many resources with incident management. Freeway management systems are undergoing significant technological change, and often must accommodate such change in addition to increasing geographic coverage and incorporating additional agencies into the transportation management centers (TMCs), providing their operational foundations. Ramp metering, a major and highly effective component of freeway management, continues to be subject to negative local political pressure, and requires a careful balancing between arterial and freeway flows. Variable speed limits and dynamic lane controls continue to show promise, but are not yet widely deployed in the United States. Portable traffic management systems for use in work zones have proven quite successful. Deployment is now limited, but these systems are expected to become common in the future. Traditional procurement and contracting practices have created challenges in implementing the complex types of systems required.

Table 2-2 illustrates the current deployment status for different freeway management technologies:

Table 2-2. Freeway Management Summary Table

Technology/System*	Deployment Level	Limiting Factors	Comments
Transportation management centers (may incorporate multiple technologies)†	Widespread Deployment‡	Implementation cost, staffing	**Successful**
Portable transportation management centers (may incorporate multiple technologies)	Limited Deployment‡	Implementation cost, staffing	**Successful**
Road closure and restriction systems (may incorporate multiple technologies)	Limited Deployment‡	Institutional issues	**Successful**
Vehicle detection systems (may incorporate multiple technologies)	Widespread Deployment	Cost, maintenance	**Mixed—depends upon technology**
Vehicles as probes (may incorporate multiple technologies)	Limited Deployment	Cost, integration	**Jury is still out**
Ramp metering (includes multiple technologies)	Medium Deployment	Politics, user appearance	**Successful**
Dynamic message signs (includes multiple technologies)	Widespread Deployment	Cost, changing technology	**Mixed—due to operations quality**
Highway advisory radio (includes multiple technologies)	Medium Deployment	Staffing	**Mixed—due to operations quality**
Dynamic lane control	Medium Deployment	Not in MUTCD for mainlanes§	**Successful— especially on bridges and in tunnels**
Dynamic speed control/variable speed limit	Technical Testing‡	Not in MUTCD; may require local legislation to be enforceable	**Holds promise**
Downhill speed warning and rollover warning systems	Limited Deployment‡	Cost	**Successful**

Cross-cutting technologies, such as telecommunications and pavement sensors, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issues?"

† A transportation management center may control several of the systems listed further down the table, and will possibly utilize additional technologies, such as video display systems, local area networks, flow monitoring algorithms, geographic information systems, graphic user interfaces, and database management systems.

‡ Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

§ Mainlanes are freeway lanes that are not tunnels or bridges.

Mayday systems for emergency notification have become quite popular with motorists, although they are still primarily marketed to owners of premium vehicles. Often such systems are combined with supplementary services like driving directions, provided by a commercial call center. Use of computer aided dispatch (CAD) by emergency responders is quite common, although supplementing such systems with

vehicle location provided by automatic vehicle location systems has gone slowly because of institutional barriers.

Table 2-3 illustrates the current deployment status for different emergency management technologies.

Table 2-3. Emergency Management Summary Table

Technology	Deployment Level	Limiting Factors	Comments
GPS/Differential GPS on emergency management fleets	Widespread Deployment	Cost	**Successful**
Mayday systems	Widespread Deployment*	Cost, vehicle choice	**Successful**
Mayday processing centers/customer service centers	Widespread Deployment*	Cost	**Successful**
Public safety answering points	Widespread Deployment*	Cost, staffing	**Successful**
CDPD communication	Limited Deployment*	Availability	**Jury is still out**
Onboard display	Widespread Deployment	Cost, user acceptance	**Successful**
Preemption infra-red signal system	Widespread Deployment	Institutional issues, lack of standards	**Successful**
Computer-aided dispatch	Widespread Deployment	Cost, support staffing	**Successful**
Automatic vehicle location	Widespread Deployment	Cost	**Successful**
Networked systems among agencies	Limited Deployment*	Institutional issues, integration cost	**Holds promise**

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Electronic toll collection has repeatedly been shown to have positive impacts on both the toll facility's financial performance and on traffic flow. Although standards have been slow to develop due to competitive pressure, both standards and inter-operability are advancing. Marketing to potential users has proven to be at least as important as selecting the right system/technology in achieving overall system success. Advanced technologies, such as smart cards for use across applications, are showing increased adoption.

Table 2-4 illustrates the present levels of deployment of ETC technology.

Table 2-4. Electronic Toll Collection Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Dedicated short-range communication	Widespread Deployment	Need for standard	**Successful**
Smart cards	Limited Deployment	Commercial and user acceptance; need for standard	**Successful**
Transponders	Widespread Deployment	Privacy	**Successful**
Antennas	Widespread Deployment	Technical performance	**Successful**
License plate recognition	Limited Deployment*	Technical performance	**Jury is still out**

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

To be sustainable, processes for implementing and operating ITS-based programs need to be "mainstreamed," that is, they must be configured to fit within and benefit from the planning and programming processes through which other ongoing programs operate. Mainstreaming also implies broadening acceptance of and building support for ITS-based programs within many functions and at multiple levels of the participating agencies. It also means ensuring that ITS supports the core missions and goals of these agencies. For such support to be solid, the benefits of the programs must be clearly demonstrated, documented, and communicated broadly. Ongoing assessment of system performance is a growing trend.

Most ITS-based programs yield the greatest benefit if deployed on a regional basis; thus, they often cross jurisdictional boundaries. In incident management, for example, many agencies are also involved, even within a single jurisdiction. Success in this environment requires involvement by each stakeholder, achievement of consensus, and thorough understanding of roles and responsibilities by all participants. This approach requires recognizing and addressing the differences between stake-holders, as big differences may characterize what each can afford, staff, or justify. Partnerships between the public and private sectors require a clear understanding of the motivations and capabilities of each side, and of how to best leverage what each partner brings to the bargaining table.

Integration, both technically and institutionally, can yield benefits, but it is a complex undertaking that will eventually need to address linkages across systems, modes, and functions. Although standards and increased interoperability will significantly ease such integration, the standards development process itself is consensus-driven and requires an extended period to accomplish its goals.

The approaches to operations are also changing. Public agencies, traditionally seen as responsible for operating systems that support the public roadways, may experience great difficulty in hiring and retaining technical expertise, also in great demand from

the private sector. Thus, trends toward contract operation and maintenance and system privatization are emerging.

ITS project types from which this assessment was prepared range from technology demonstrations to full-scale implementations. They represent hundreds of millions of dollars of investment. Though not every lesson learned is universally applicable, many are relevant across project types. Some technical lessons, such as early problems with geolocation using cellular phones, have been overcome by technological advancement. The greatest impediments to ITS continue to be institutional, but they, too, will begin to diminish as new models of interagency and public-private partnerships are developed. Lessons from operations and management are just now becoming evident.

INCIDENT MANAGEMENT

Incident management provides an organized and functioning system for quickly identifying and clearing crashes, disabled vehicles, debris, and other nonrecurring flow impediments from area freeways and major arterials. Roadways are cleared and flow restored as rapidly as possible, minimizing frustration and delay to travelers while also meeting requirements and responsibilities of the involved agencies. Some jurisdictions and agencies responsible for operations and enforcement have worked together to develop a policy and operations agreement that defines specific incident management responsibilities. Such an agreement includes detection, verification, response, clearance, scene management, and traffic management and operations (ITS Deployment Tracking Database 2000).

Incident management programs can greatly benefit local travel conditions. Maryland's Coordinated Highways Action Response Team (CHART) program has documented a decrease of 2 million vehicle hours per year associated with nonrecurrent delay. Atlanta's NaviGAtor system, implemented in preparation for the 1996 summer Olympic Games, was estimated to have saved the state more than $44.6 million in 1997, its first year of operation. Pittsburgh's service patrol alone nearly reduced by half its response time to incidents, and is credited with a reduction of 547,000 hours of delay per year, valued at $6.5 million (ITS Benefits Database 2000).

Among these technologies, the most successful include service patrols and closed circuit television (CCTV). Service patrols, such as Illinois' Minutemen, Indiana's Hoosier Helpers, or Georgia's Highway Emergency Response Operators (HERO) program, have consistently generated high benefit/cost ratios for their sponsoring agencies, along with extremely positive public perception, documented through many letters received from motorists who have benefited from their assistance. Most of these programs are seen as both responsive and preventive incident management measures, as the situations they clear from shoulder lanes prevent "rubbernecking" delays. The Minuteman program pioneered the use of special service patrol vehicles able to move not only passenger but also commercial vehicles from traveled lanes. More recently, they have begun acquiring vehicles that allow "capture" and removal

of disabled vehicles from traveled lanes without the service patrol attendant needing to exit the vehicle—a major step forward in protecting agency employees.

CCTV is widely recognized as the key component that not only allows detailed determination of incident location, but also dispatch of the correct set of response resources, and possibly even the provision of important preparatory information to responders. Although intended primarily for use in managing incidents and freeway flow, CCTV has also proven to be of great value in observing and resolving basic flow problems on both freeways and adjacent arterials. An example of serious efforts being made to address citizen concerns about potential violation of privacy through CCTV systems is the development of a set of privacy principles by the Intelligent Transportation Society of America (ITS America). (The principles are currently in draft form, but are expected to be finalized and approved by the close of 2000.) CCTV images of traffic conditions have proven to be highly popular both with television traffic reporters and traveler information websites.

The broad acceptance of cellular telephones affects two incident management elements: (1) motorist access to cellular phones will likely reduce the need for motorist callboxes except in areas where cellular coverage is unreliable; and (2) as cellular phones, accessed through the emerging cellular geolocation technology, rapidly become the mainstay of incident location, they will replace the use of stationary vehicle detectors and incident detection algorithms. The latter have never been highly effective because of the need to balance false positive readings and slow incident detection.

Regionalization of incident management programs and implementation of common voice communications frequencies among incident responders is likely to increase over time, but, to become widespread, will require participating agencies to over-come many institutional and jurisdictional barriers. The U.S. Department of Transportation (U.S. DOT) has undertaken extensive effort to bring about this result, including sponsoring national workshops, training, and distribution of a broad variety of informative materials.

Incident Management Lessons Learned

Successful incident management programs must have a regional perspective. A good example is Maryland's CHART program, which addresses incidents and congestion both regionally and statewide. Such an approach assures the most effec-tive coordination of response and mitigation of nonrecurring congestion, regardless of incident location. Such programs should have a strategy based on stakeholder consensus, which contains formal agreements on respective roles and responsibilities, so that each participant has realistic expectations of other participants and a full understanding of its own obligations. One model for such a formal program is Milwaukee's Traffic Incident Management Enhancement (TIME) program. Comprehensive operating agreements are needed to achieve full, intermodal, interjurisdictional benefits. Finding the best way to work as a team has been challenging, but sharing information can have benefits well beyond those intended. Such was particularly the case in Atlanta during the 1996 Summer Olympic Games, where the responsible agencies overcame many institutional barriers to work

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together and successfully manage the tremendous travel demand created by the Games (U.S. DOT, Atlanta Navigator Study, Nov. 1998).

Law enforcement and other emergency services will likely realize measurable benefits from participation in a highly coordinated and formalized regional incident management program. In particular, the right types of partnerships can leverage individual investments, but participants must demonstrate and share benefits with decision-makers on a regular basis. One example of such a partnership is in Milwaukee, where the Wisconsin Department of Transportation (DOT) provided vehicles and the county sheriff provided personnel for a mutually desired freeway service patrol. Outreach to involved agencies and potential partners is key to ensuring program success (U.S. DOT, Regional Traffic Guide, 2000).

Incident management programs face difficulty in sustaining operations because they depend on scarce operations funding, which typically must be reallocated annually, and because they are susceptible to loss of the program champion. Sustainability is much more likely once the program is mainstreamed (i.e., it is part of the normal transportation planning and resource allocation process) (U.S. DOT, Regional Traffic Guide, 2000).

Incident management has been improved through extensive ITS infrastructure. But procurement and contracting issues have complicated acquiring and implementing this intelligent infrastructure. Problems occur when conventional procurement processes, which emphasize only price and offer little flexibility once the contract is signed, are used to obtain systems and software. Examples of such problems and potential solutions can be found in U.S. DOT's guides to innovative ITS procurement and procuring ITS software (U.S. DOT, FHWA Federal Aid ITS, Aug. 1997).

Nonintrusive detectors using technologies such as video image processors, radar, and passive acoustic sensing can provide excellent data when compared to the traditional inductive loop vehicle detector, while offering potential for portability, decreased damage during winter road maintenance, and avoidance of damage during road repair. This result was demonstrated in Detroit, Phoenix, and elsewhere.

Incident management software can significantly increase the speed, thoroughness, and consistency of responses to incidents, and can facilitate sharing of incident information across agency and jurisdictional boundaries. Incident detection algorithms, however, continue to suffer from the need to balance false positive readings with detection sensitivity. Efforts to use more advanced software techniques, such as artificial intelligence, expert systems, and neural networks, have yet to yield major gains in addressing this problem.

Diversionary routing was confirmed in Minneapolis-St. Paul as an effective way to manage traffic congestion produced by an incident, as long as the capacity of the diversion routes is adequate and the traffic flow is controlled by dynamic signal timing adjustments to maintain service levels. Success also requires adequate time for system integration and testing (U.S. DOT, Incident Management, Sept. 1998).

Hazardous Material Incident Response

An estimated 700,000 hazardous material (HAZMAT) shipments occur each day in the United States. The vast majority are packaged properly, meet other stringent requirements, and arrive at their destination safely. The National Academy of Sciences, in its 1993 report, Hazardous Materials Shipment Information for Emergency Response, estimated that between 10,000 and 20,000 motor carrier incidents and approximately 1,000 to 1,500 rail incidents that occur annually involve or threaten release of hazardous materials and necessitate dispatch of emergency response professionals. To provide an appropriate level of safety for the public in the event of an incident, emergency response personnel need timely, accurate information about the contents of HAZMAT shipments. HAZMAT incident response systems improve the accuracy and availability of HAZMAT information provided to emergency response personnel (U.S. DOT, Hazardous Material Response, Sept. 1998).

The use of HAZMAT incident management systems appears to have the potential to reduce the time required to positively identify the hazardous material involved in the incident and to select the appropriate response. Simulations at two rail yards and a truck yard yielded 33 to 41 percent reductions in time required to identify HAZMAT cargoes and select a correct response to the incident situation. Participants in two HAZMAT system field operational tests indicated that this time savings could have several positive impacts. During the tests, users found both systems to be more effective than current systems in determining optimal emergency response and cleanup strategy. Primary implications are that less hazardous material will be leaked, and cleanup procedures can begin sooner. Participants also anticipated a reduction in resources expended to deal with the incident (e.g., by eliminating unnecessary equipment deployment) (U.S. DOT, Hazardous Material Response, Sept. 1998).

Implementation of HAZMAT incident management systems has continued to grow slowly, often supported by general advancement in constituent technologies and overall progress of commercial vehicle administrative ITS programs. Results to date are preliminary, based mainly on simulation and operational tests. Thus, there is limited experience in measuring actual costs and benefits, and in determining the full set of operational issues. In general, slow institutional change has been the main culprit, not faults in the technology.

HAZMAT Incident Response Lessons Learned

HAZMAT incident management systems decrease the time needed to identify the cargo and respond, increasing effectiveness of the response. First responders estimated a 34 percent reduction in time to recognize and identify a hazardous cargo. Operation Respond indicated similar results in Atlanta, Georgia, and in Tonawanda and Buffalo, New York. However, a study of the HAZMAT incident management field operational tests concluded that there must be broad, nearly universal enrollment of carriers for implementing agencies to realize full benefits of such systems. Obtaining participation of smaller or less sophisticated motor carriers is more difficult, as they are both more financially constrained and realize less total

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benefit from enrollment. Cost was not an obstacle to agencies' interest in participating in the Operation Respond system test, the initial software and training costs totaling less than $700 for the first year and $350 for succeeding years (U.S. DOT, Hazardous Material Response, Sept. 1998).

To date, response from agencies using the systems has been positive. The systems are perceived to be more effective, accessible, and accurate than the paper-focused processes agencies were using. User agencies in the Transit Xpress (TXS) field operational test found the TXS system would be better at maintaining safety and efficiency, tracking HAZMAT loads, accurately reflecting mixed loads, and helping to ensure that motor carriers comply with HAZMAT regulatory requirements. Users also report that they would add the tested systems to their operations (but would not dispose of current systems), and felt that the record-keeping ability of these systems would be an improvement (U.S. DOT, Hazardous Material Response, Sept. 1998).

Where is Incident Management Headed?

Incident management programs are moving more toward formalization, regionalization, and interagency coordination. While no growth was detected from 1998 to 1999 in the number of metropolitan areas with service patrols on freeways, dramatic growth was seen in service patrols on arterials. Metropolitan areas report decreased installation of loop detectors and increased use of nonintrusive detectors such as radar and video imaging detectors (ITS Deployment Tracking Database 2000).

Incident Management Issues

A number of issues must still be resolved in the field of incident management. Effective, long-term relationships among all key players need to be created and sustained, which often involves several agencies working jointly at multiple organizational levels. The challenge of establishing and continuing communications should not be underestimated, though notable successes are being achieved. The proliferation of new technologies, such as cellular 911, mayday systems, and cellular geolocation, may eliminate the need for conventional detection. Similarly, given the heavy cellular phone market penetration and wide E-911 accessibility, motorist aid call boxes and dedicated cellular incident reporting numbers may no longer be justified.

FREEWAY MANAGEMENT

Freeway management allows transportation operations personnel to monitor traffic conditions on the freeway system, identify recurring and nonrecurring flow impediments, implement appropriate traffic control and management strategies (e.g., ramp metering and lane control), and provide critical information to travelers through infrastructure-based dissemination methods (e.g., dynamic message signs [DMS] and highway advisory radio [HAR]) and in-vehicle information systems (ITS Deployment Tracking Database 2000).

Freeway management often includes a freeway management center (or multiple centers where regional responsibility for the freeway system is shared by more than

one operating entity) and links to other ITS components in the metropolitan area. Examples of such centers are found in Atlanta, Houston, Seattle, Minneapolis-St. Paul, and elsewhere (U.S. DOT, TMC Cross-Cutting Study, Oct. 1999). From these centers, personnel electronically monitor traffic conditions; activate response strategies; and initiate coordination with intra-agency and interagency resources, including emergency response and incident management providers. The growing presence and sophistication of freeway management centers has generated development of U.S. DOT concept of operations and human factors guides and a multistate pooled funds study of emerging management center issues.

Freeway management is a potent tool for combating recurrent congestion. The first 26-mile segment of San Antonio's TransGuide freeway management system is credited with reducing accidents by 15 percent and emergency response time by up to 20 percent. Studies of the INFORM freeway management system on Long Island in New York indicate that freeway speeds increased 13 percent, despite an increase of 5 percent in vehicle miles traveled during the evening peak period. Ramp metering, a major freeway management tool, was documented as increasing throughput by 30 percent in the Minneapolis-St. Paul metro area, with peak hour speeds increasing by 60 percent. Variable speed limits, a less common technique in the United States, were documented as decreasing traffic accidents by 28 percent during an initial 18 months of operation in the United Kingdom (ITS Benefits Database 2000).

TMCs have become a mainstay of coordinated freeway management in urban areas. California has eight and Texas has six urban TMCs. California also has five rural centers. These centers consistently employ freeway management systems using geographic information systems (GIS), graphic user interfaces, local area networks, and database management systems to control ramp meters, DMS, and HAR. Dynamic lane control is most common in tunnels and on bridges. Although not currently an accepted technique in the *Manual on Uniform Traffic Control Devices* (MUTCD), dynamic lane control has also proven successful over freeway mainlanes in San Antonio and Fort Worth, Texas. Dynamic speed control lacks enforceability in most state legal codes, and is therefore less common in the United States (its primary test having been in Washington State's Snoqualmie Pass); however, it is considerably more common in Europe.

Ramp metering continues to face political challenges (MN DOT, "RFP for Ramp Metering," June 2000) stemming from the complexity of balancing the interests of local (arterial) travelers and through (freeway) traffic, but has been widely proven to have significant benefits when implemented correctly and operated effectively (ITS Benefits Database 2000). Metering rates and algorithms, however, require judgments balancing the priorities of arterial flow against those of freeway flow. These judgments also have safety and infrastructure implications, such as assuring adequate storage capacity and coordinating availability of such storage with release of freeway-bound vehicles at signalized approaches. The Minnesota Legislature's decision to require the Minnesota DOT to evaluate the Twin Cities' ramp metering program by briefly turning off the metering exemplifies the extent of concern by high-level decision-makers.

Portable TMCs were formally studied and proven highly successful in Minnesota's Smart Work Zone field operational test and were later commercialized by that test's private sector partner (U.S. DOT, MN Smart Work Zone Study, June 1998). Almost all work zones now, at minimum, incorporate portable DMS, with increasing use of portable HAR.

Freeway management systems have traditionally relied on stationary detection devices, most commonly the inductive loop vehicle detector. The advent of electronic toll transponders and now of cellular geolocation increase the likelihood of stationary detectors being supplemented or replaced by vehicles serving as traffic probes—reducing the cost of implementation and maintenance and providing much broader coverage, including arterials. Vehicle probe data have been a mainstay in the Houston TranStar freeway management program for several years and were a successful component of San Antonio's TransGuide Metropolitan Model Deployment Initiative.

Road closure and restriction systems, such as the Highway Closure and Restriction System used by Arizona DOT, have proven to be quite popular with motorists and traveler information providers. These systems aggregate information on lane closures and make it widely available over a broad area and an extended time scale. Further integration of such systems is likely, allowing travelers to become aware of expected construction delays, regardless of jurisdictional boundaries.

Two vehicle operation warning technologies—downhill speed warning and rollover warning—have proven to be quite successful. These technologies are typically most applicable to commercial vehicle operation. Both typically use some form of radar to detect vehicle speed and likelihood of rollover through basic computer modeling of vehicle center of gravity. Because commercial vehicle incidents may occur in remote areas, may cause prolonged delay, often block multiple lanes, and can be among the most difficult to clear, the payback from these relatively inexpensive and simple applications can be significant. Results from the rollover prevention systems at the junctions of I-95 and I-495 (the Capital Beltway) in Washington, DC, have been impressive since their initial installation.

En route traveler information provided through DMS and HAR continues to be one of freeway management's most potent tools. HAR has experienced less than universal adoption, owing in part to early negative experiences caused by poor broadcast quality and delayed messages. Increasingly, flashing beacons are used to attract motorists' attention to HAR when critical messages are present.

Freeway Management Lessons Learned

The up-front effort needed for ITS program operation and technology selection is much greater than for traditional transportation infrastructure projects. This circumstance was particularly true in early freeway management implementations such as in Atlanta. Incorporating the experience and knowledge from other implementations increases likelihood of success.

Unfortunately, most early freeway management systems were implemented with little consideration for how they would operate. A U.S. DOT study found that essentially none of the early generation TMCs had prepared a concept of operations while planning or design was under way (U.S. DOT, TMC Implementation Guide, Dec. 1999). Because decisions made in the design/construction phase, such as degree of automation provided to operators and physical proximity of cooperating agencies, have a significant impact on operations and management, only now are operations-related design/construction lessons being fully captured.

Selecting an optimal mix of field devices, such as DMS, CCTV, HAR, and service patrols, requires careful consideration of budget, integration, and operations/management requirements. The system must be flexible as additional agencies/functions come into the TMC and are linked to its systems. For example, although the Texas DOT championed San Antonio's TransGuide transportation management program, local law enforcement, transit, and arterial traffic operations agencies also became interested in joining the program. In a comparable example, several years after the Houston TranStar transportation management program became operational, additional local agencies are joining in. Obtaining training and documentation along with the system is critical to the effectiveness of freeway management systems. Agency staffing policies are often not sufficiently flexible to create the needed positions. Such has been the experience at the California DOT (Caltrans), where an extensive study was undertaken in 1999 of TMC staffing needs.

One finding from the Atlanta experience was that systems engineering management plans are critical to proper integration. Most agencies lack the processes and resources necessary for configuration management, an element of a systems engineering approach. The Georgia DOT is only now undertaking implementation of a formal configuration management program, at considerable cost, over an extended period. A significant component of this cost is the investment in documenting the installed intelligent infrastructure equipment, information which could have been captured at the time of installation at considerably less expense. Atlanta also found that prototyping of key software systems and tools early and often throughout system design and development is critical to software development success. Traditional funding processes that facilitate initial capital investment but may complicate upgrades and system replacements create an attitude that promotes adoption of the latest technologies, encouraging changes to the system late in the implementation process (U.S. DOT, Atlanta Navigator Study, Nov. 1998).

The Minnesota Smart Work Zone project successfully addressed safety in work zones and their congestion impact. For example, it implemented a portable freeway management program that monitored congestion and provided traveler information on a localized basis. The freeway management system moved along the freeway with the construction crews. The Minnesota DOT felt that the system resulted in both increased safety and improved flow of traffic through the work zone (U.S. DOT, MN Smart Work Zone Study, June 1998).

Where is Freeway Management Headed?

Trends in freeway management include increased automation supporting all aspects of operator activity, greater integration of functions within the system and between freeway management centers, preventive action in addition to responsive action, and increased dependence on traveler information. For example, preventive freeway management is being demonstrated in an operational test on I-93 in Boston. Metropolitan areas report no increase in implementation of ramp metering, but show increased interest in active lane control. There is also evidence of increasing contractor operation/management of freeway management systems, such as for Long Island's INFORM system, Northern Virginia's Smart Travel system, and Michigan DOT's system in Detroit (U.S. DOT, TMC Cross-Cutting Study, Oct. 1999).

Freeway management systems will increasingly rely upon standards for communications between centers and between the center and its field equipment, using elements of the National Transportation Communications for ITS Protocol (NTCIP). Having identified a set of "critical" standards, U.S. DOT has had six standards development organizations at work for several years developing and balloting a broad range of ITS standards. U.S. DOT has also initiated a standards testing program whose objective is to document and share the experiences of early users of the emerging standards.

Freeway Management Issues

Even with increased contracting for freeway management services, the extent to which freeway management should be privatized is still being debated. Meanwhile, there is continuing concern that public sector agencies have difficulty hiring and retaining the key technical specialists needed to operate and maintain their freeway management systems. Also unresolved is whether centralized or decentralized systems are superior and which type will come to dominate the field.   The density of intelligent transportation infrastructure needed for effective operation has yet to be answered, but is the subject of upcoming U.S. DOT studies.

Privacy continues to be an issue in freeway management. Initial privacy concerns stemmed from the ability of agencies to observe citizens through CCTV systems implemented to monitor traffic flow and incidents, or the mistaken perception that the purpose of these systems was to determine speeds of individual vehicles. Similar concerns arose in those areas where vehicles with electronic toll tags were monitored as traffic probes. In that case, measures were implemented to mask the identity of the vehicle owner from the traffic management agency and achieve anonymous probes. More recently, the ability of agencies and private sector firms to track cell phones in vehicles, allowing them to be used as "wireless data probes," has again raised privacy concerns. In most cases, agencies have implemented outreach programs to explain the safeguards against privacy violations and the procedures used to ensure they are working.

EMERGENCY MANAGEMENT

The purpose of emergency management services is to improve the response time of emergency services providers, thereby saving lives and reducing property damage. To reduce response time, it is necessary to reduce both the time it takes to notify providers and the time it takes for them to arrive at the scene. Emergency notification can be accomplished through cellular telephones, call boxes, and mayday devices (ITS Deployment Tracking Database 2000).

Emergency management systems can have important effects, both on accident survival and on motorist peace of mind. Of drivers testing the Puget Sound Help Me (PuSHMe) mayday system, 95 percent stated that they felt more secure operating a vehicle with the system installed.

Mayday systems have proven to be a significant commercial success for vehicle manufacturers, including General Motors' (GMs') OnStar™ system and the Ford/Lincoln RESCU system, as well as the American Automobile Association's more recent RESPONSE commercial mayday venture. Vehicle manufacturer-installed systems continue to be most common in more expensive vehicle models and in rental vehicles, and are often combined with well-liked, value-added services such as providing travel directions and yellow pages.

In the July 5, 2000, *LA Times,* GM states that its OnStar™ system has grown to a subscriber base of 250,000 in the United States and Canada since its introduction in 1996. The system logs 12,000 to 15,000 calls a day, about 5 percent of which involve emergencies. OnStar™ is available on 29 models of GM vehicles, and will become available on Honda's 2001 Acura models. GM predicts that the system will be available on 1 million vehicles by the end of 2000, and on 4 million by 2003 (*LA Times,* July 5, 2000).

On August 1, 2000, Ford and Qualcomm announced the creation of an alliance called Wingcast to compete directly with OnStar.™ The service will be available, starting with about 1 million vehicles in the 2002 model year. Nissan is also incorporating Wingcast into its Infiniti 2002 models, with Nissan brand cars to follow. Ford officials expect Wingcast to charge users between $9 and $29 per month. Price and level of service will vary by the Ford brand that sells it. OnStar™ charges its users $17 to $33 per month (*USA Today,* August 1, 2000).

In responding to events detected through mayday and other techniques, most emergency response agencies now use CAD systems to effectively manage their fleet resources. Agencies increasingly supplement this information by tracking vehicles with automated vehicle location (AVL) devices (*USA Today,* August 1, 2000). Integration of CAD data across jurisdictional boundaries is being facilitated by development of common location description standards, but will require resolution of institutional issues. Increased AVL implementation will require reducing system cost and successfully addressing organized labor's general dislike of such systems.

The Albuquerque Ambulance Company in New Mexico uses a map-based CAD system that allows the dispatcher to send ambulances to the exact location of an emergency, along with guidance on how to get there. Following installation of the system, the company's efficiency increased by 10 to 15 percent (ITS Benefits Database 2000).

Emergency Management Lessons Learned

The various emergency management systems implemented in field operational tests attained adequate positional accuracy in finding victims' vehicles. In the PuSHMe field operational test, the mean distance error was about 37 meters and the median distance error was about 31 meters from the actual vehicle location. The global positioning system (GPS) experienced difficulties in enclosed spaces or "urban canyons" (in between buildings), but was accurate with vehicles in forested or open terrain. With PuSHMe, the GPS-based systems experienced difficulties in accurately determining locations in enclosed spaces like parking garages. One vendor's product experienced a 37 percent failure rate and the other vendor's had a 29 percent failure rate in updating locations in between buildings. With elimination of "selective availability," announced in May 2000, and increasing presence of differential GPS, obtaining acceptable positional accuracy typically is not a difficult challenge to overcome.

Cellular communication has limitations in areas of marginal or poor cellular coverage. In Colorado's Mayday field operational test—in areas of marginal to nonexistent cellular coverage—the analog cellular system was unreliable in transmitting data (U.S. DOT, Emergency Notification Response, Sept. 1998). Since this test, not only has there been a dramatic increase in the size and density of cellular coverage, but digital cellular systems have made significant inroads on the initially analog-dominated marketplace.

The computer system and mapping database used by emergency call-takers must show and update the map quickly, displaying a wide range of geographic and political attributes in the area surrounding the location of the incident. In both the Colorado Mayday and PuSHMe field operational tests, the map display system and the map database used in the system were problematic. More specifically, in Colorado Mayday, the speed of the computer used for the map display system was adequate for the test but would likely be too slow under real world conditions of multiple, simultaneous mayday calls. The display system needed enhancement to automatically display streets in the vicinity of the incident. The display system also needed the capability to display more than one incident at a time. The map databases and display should have included all roads, road labels, geographic landmarks, and bodies of water, as well as city, county, state, and dispatch region boundaries (U.S. DOT, Emergency Notification Response, Sept. 1998).

Operators of vehicles with the mayday systems found them easy to use and felt more secure with the system available. Using one of the two systems tested in the PuSHMe operational test, 100 percent of users found the device easy to use. The auto redial feature was unanimously viewed as user-friendly. With respect to security and safety, 95.7 percent of users would feel more secure in their vehicle were the

system permanently available to them and other members of the family. In situations requiring police, medical, or roadside assistance, 95.6 percent of users thought the system would likely help authorities deliver assistance. In the area of reliability and consistency, 91 percent of respondents reported that only rarely or occasionally were they disconnected when speaking with the response center operator, and 100 percent reported that they were almost always or frequently automatically reconnected (U.S. DOT, Emergency Notification Response, Sept. 1998).

Tests validated the efficacy of using private service centers to screen calls. The PuSHMe operational test helped partners better understand the role of a private response center (PRC) in the deployment of an in-vehicle emergency response system. Private partners felt that a PRC would be a necessary component of any early deployment scenario and pointed to existing PRCs such as those serving the Ford Lincoln RESCU system. Public partners were less concerned, seeing the PRC as a viable and likely scenario but not the only one. Public partners are generally concerned, however, about the potential overload they experience from 911 calls made by motorists observing incidents.

Emergency Management—Computer Aided Dispatch

CAD systems, GIS, and AVL support real-time, traffic-sensitive route guidance for emergency vehicles and promote more efficient use of vehicle and personnel resources. Even though the technology is proven, it is still crucial to train dispatchers before they will embrace it. Packaged AVL systems are widely available, but the absence of standardized map locations remains an obstacle. Technology will enable public safety and traffic agencies to share data, but the agencies need to be aware of one another's resources, and must coordinate plans to address the public's privacy concerns. While integration among systems is feasible, it remains technologically challenging. Integration is time-consuming, costly, difficult to manage, and does not always produce easily quantifiable benefits, because CAD systems are typically proprietary, and no interface standards have been defined.

Emergency Management—Mayday

Mayday systems identify incidents through sensor data such as airbag deployment. They support increasingly accurate location data through improved cellular coverage, GPS formulas, and 10-second history of location prior to impact. Communication coverage and availability of crash data are expanding. Integration with E-911 will continue to develop as E-911 expands, but will lag for cellular 911 callers until auto-location of cellular 911 calls begins to become available. Interface requirements should be built to specific agency requirements.

Where is Emergency Management headed?

The capabilities of emergency response systems will continue to expand as more data on seatbelt use, airbag deployment, and other vehicle functions become available. In addition, cellular coverage will expand and become more accurate. E-911 calls will become integrated with and begin receiving information from data-rich Mayday cellular calls.

On July 19, 2000, U.S. Transportation Secretary Rodney Slater kicked off the National Mayday Readiness Initiative (NMRI). NMRI is a public-private partnership aimed at creating effective, efficient integration between Mayday service providers and the Nation's public emergency responders and incident managers. NMRI brings together all of the key stakeholders to discuss and work toward resolving issues. The initiative is co-sponsored by U.S. DOT and the ComCARE Alliance, with support by a grant from the General Motors Corporation. In a press release announcing NMRI, U.S. DOT said that it expected more than 11 million mayday units to be on the road by 2004 (U.S. DOT, press release, July 2000).

Emergency Management Issues

The primary issues with mayday systems relate to the ability to get location data from all cell phones. The Federal Communications Commission (FCC) has approved two technologies—network-based and GPS-based, leaving the decision on which technology to use for regional cellular geolocation to local authorities. A network-based solution, where location is determined according to triangulation by the cell phone network itself, may require access to information available only from the local carrier, complicating the ability of a privatized mayday center to obtain the information it needs. For GPS-based regions, the Mayday center will receive positional information directly from the calling phone.

The issues with CAD/AVL are both technical and institutional. Reconciling map location referencing problems will make the systems more robust, but it is unclear who will be responsible for carrying out this action. Expanding available resources depends on multiple agencies pooling their needs and funds.

ELECTRONIC TOLL COLLECTION

Electronic toll collection provides for automated collection of toll revenue through the application of in-vehicle, roadside, and communication technologies to process toll payment transactions (ITS Deployment Tracking Database 2000). Participating patrons (vehicles) are identified by the use of roadside hardware and software and an identifier or "tag." In areas with more than a single toll collection authority, compatible tag technologies enhance convenience to the patron and promote "seamless" transaction processing.

ETC systems can provide a number of major benefits. On the Tappan Zee Bridge in New York City, manual toll lanes were documented as having a capacity of 400 to 450 vehicles per hour, while those with ETC systems handled 1,000 vehicles per hour. Florida's Turnpike Authority calculated a 2.03:1 benefit/cost ratio if only 10 percent of the vehicles at a sample toll plaza used ETC, rising to well over 3:1 as the number of ETC-equipped vehicles increased (ITS Benefits Database 2000).

The technologies necessary for successful ETC emerged and matured rapidly, although the industry successfully resisted standardization for many years. Early problems with data errors were overcome, and ETC has repeatedly been shown to be both highly economical and widely popular, particularly with commuters. Major U.S. DOT efforts are improving standardization and interoperability. Further

success in this area is likely to result as smart cards are accepted for more than just transportation-related purposes, such as in Los Angeles where McDonalds™ is accepting them.

Electronic Toll Collection Lessons Learned

Poorly designed and poorly implemented ETC systems can be quite costly and can negatively impact traffic and the environment. Lee County reported that with tens of thousands of transactions per day, the problems created from a small percentage of incorrect transactions are significant (Burris 1998). Verifying the system's accuracy before making a selection was critical to the success of many early ETC programs.

Having a detailed marketing plan was key to the acceptance and rapid growth in use of Virginia's FasToll system (Harris and Choudhry 1998). Such outreach must identify and address the diverse audiences who may become enrolled in the program, speaking to the individual needs and motivations of each. In some cases, the majority of patrons are not regular commuters, as in Lee County, Florida (Burris 1998). Therefore, marketing campaigns targeted to the commuting population will miss a significant portion of potential ETC customers.

Public-private partnerships involving industry, financiers, and other private sector partners can reduce or eliminate the price of transponders as an impediment to widespread deployment, although most cases of such partnerships have been outside the United States.   The availability of automatic positive balances and exclusive lanes at toll booths are attractive to drivers and draw more ETC users (Harris and Choudhry 1998). The practice of confidential encryption should be promoted to reassure users who have confidentiality concerns, as the E-ZPass program has done (Ascher 1999).

Several toll facilities use license plate recognition technology to identify toll evaders. This technology continues to face challenges in achieving rapid startup, high productivity, and high accuracy owing, in many cases, to the wide variety of license plate placements, formats, and color schemes in the United States. In other applications, agencies still rely on staff to interpret the images captured photographically for enforcement purposes.

Electronic Payment Systems Lessons Learned

Existing proprietary revenue collection systems are limited in their ability to support an "open" architecture; therefore, a technology standard is needed to ensure compatibility. Electronic payment systems can reduce revenue collection and maintenance costs, increase security, allow for increased throughput, and provide more detailed customer information. One study indicated that ETC reduced the cost of staffing toll booths by 43.1 percent, money handling by 9.6 percent, and roadway maintenance by 14.4 percent (Philip and Schramm 1997). The case study for the ETC system at the Carquinez bridge suggests that, overall, the ETC project would realize most of its objectives, although expansion of the system beyond its initial pilot phase has experienced significant delays. The project would provide a higher level of service quality to toll patrons, improve quantity and quality of data collection, increase traffic flow on ETC toll lanes, and reduce vehicle emissions and fuel consumption.

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ETC systems also provide an opportunity to partner with other agencies and integrate with other ITS technologies (ITS Deployment Tracking Database 2000).

Earlier generation payment systems, such as bar code tags, have not completely disappeared and are still in use at some locations. Bar codes, however, were subject to degradation by dirt and grime, and were highly sensitive to correct placement on the vehicle.

Where is ETC Headed?

The future for ETC is regional, coordinated multi-use systems, especially as regional and national standards are developed. The potential for smart cards shared with other agencies and the private sector is real and must be pursued. Similarly, agreements between multiple agencies to pool or share "back office" toll processing activities hold potential for cost savings and increased automation. In such situations, multiple toll facilities using a common toll collection system, such as the E-ZPass system in the northeastern United States, can implement common processing facilities for processing transactions.

As usage expands, agencies will have to explore ways to increase conversion of lanes and create faster ETC lanes. Rapid payback supports system upgrading and replacement. Incorporation of vehicle identification technology into the vehicle during the manufacturing process may eliminate the need for add-on devices, should this technology become standard in the future.

Electronic Toll/Payment Issues

It will be important to determine the proper mix of ETC and manual lanes to allow for optimal road use and traffic flow. One key issue is the need for regional architecture standardization, but first the boundaries that constitute a "region" must be determined. The industry is debating the merits of discounting tolls for ETC users to encourage use, or charging them for the convenience of ETC.

CONCLUSION

Significant progress has been achieved in implementing freeway, incident, and emergency management and ETC systems, with many benefits realized from these investments. Some components, such as mayday systems, are being deployed at accelerated rates. Others, such as use of vehicles carrying cellular phones as wireless data probes, are only emerging, but show promise. Integration of technologies within each type of system and between the systems themselves is increasingly recognized as key to achieving full benefit from intelligent infrastructure, but is also known to present both technical and institutional challenges. As implementation expands, as new locations begin implementation, and as systems are updated or replaced, lessons and experiences like those documented in this paper will continue to have value in increasing the likelihood of rapid, successful, and cost-effective deployment, and in planning for generations of technologies yet to come (Pearce 1999).

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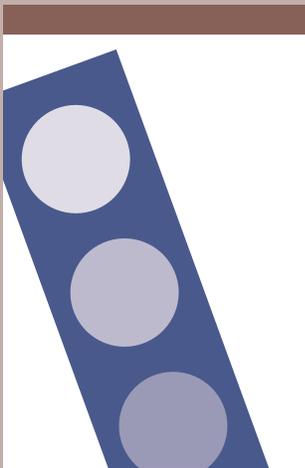
EXECUTIVE SUMMARY

This paper presents what has been learned in four principal areas of arterial management: (1) adaptive control strategies (ACS), (2) advanced traveler information systems (ATIS), (3) automated enforcement, and (4) integration. The levels of deployment, benefits, deployment challenges, and future steps are presented for each category.

ACS signifies traffic signal control systems that optimize timing plans in real time, based on current traffic conditions and demand. They have been shown to reduce delay and improve efficiency at intersections. Although the technology has been available for 20 years, ACS is not widely deployed in the United States. The systems are considered expensive and complicated, and U.S. traffic engineers do not seem convinced of the associated benefits. ACS seems to have potential for widespread use in the United States, but deployment has not yet reached that point.

ATIS for arterials provides information on arterial conditions (e.g., travel speeds, travel time, incidents) to motorists through such media as websites, radio, television, or personal devices. While surveys from the Metropolitan Model Deployment Initiative (MMDI) show that the public wants information on arterial conditions, only 67 out of 361 agencies (18 percent) in the largest 78 metropolitan areas reported providing this service. This limited dissemination is in part due to the lack of surveillance on arterial streets. Another challenge is the absence of a commonly understood method of describing conditions on arterial streets. For example, delays caused by traffic signals complicate travel time computations. The advent of new technologies, such as cell phones as probes, increases the likelihood that arterial information will make its way into traveler information systems.

Automated enforcement is a tool that can be used to encourage compliance with traffic laws and promote safety. This type of enforcement uses camera technology to photograph license plates of drivers who break traffic laws. Automated enforcement on arterial streets primarily involves red light running (RLR) and speed enforcement. Legislation has been passed or is being considered in 22 states to allow automated RLR enforcement. Deployment of systems is considered to be moderate. Intersections with RLR enforcement have seen a reduction in violations as high as 50 percent and a reduction in crashes as high as 70 percent. Deployment of automated speed enforcement is not as widespread as RLR enforcement. Privacy and fairness issues associated with automated enforcement make it somewhat controversial. Some automated speed enforcement programs have come under scrutiny by the public and motorist associations because they are perceived as being unfair, and the systems have been discontinued in some communities. However, the future for automated RLR enforcement appears strong as more cities implement this technology.

Integration of arterial management is broken down into three areas: integration across jurisdictions, integration with transit and emergency operations, and integration with freeway management. Integration across jurisdictions occurs in 54 percent of agencies in the largest 78 metropolitan areas. This type of integration consists of coordinating traffic signal timing plans and implementing similar cycle lengths across jurisdictional boundaries. Coordination across boundaries can improve efficiency and reduce delay.

Integration with transit and emergency operations takes the form of traffic signal controls that allow transit vehicle priority and emergency vehicle signal preemption. More than half the agencies in the largest 78 metropolitan areas have traffic signal technologies that allow for preemption by emergency vehicles, while only 12 percent allow some sort of priority for transit vehicles.

An integrated arterial freeway corridor is one that shares arterial travel times, speeds, and conditions with freeway management to adjust variable message signs (VMS), highway advisory radios (HARs), and freeway ramp meters. Freeway travel times, speeds, and conditions are shared with arterial management and used to optimize traffic signal timings. Nearly 20 percent of arterial and freeway management agencies report sharing information on traffic conditions with each other; however, it is unclear how this information is used or passed on to travelers. The number of truly integrated freeway arterial corridors appears to be limited.

Presently, only two arterial management intelligent transportation systems (ITS) technologies meet the deployment level requirements to be called "widespread." They are integration of time-of-day/fixed-time signal control across jurisdictions, and signal preemption for emergency vehicles.

Each of the arterial management ITS technologies discussed in this paper shows the potential for benefits; however, only a few of the technologies have reached wide-spread deployment.[1] Reasons for the limited deployments vary, but include cost, institutional barriers, uncertainty of benefits, and technological incompatibilities. Table 3-1 summarizes the deployment levels of the ITS technologies presented for arterial management.

Table 3-1. Arterial Management Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Adaptive control strategies	Limited Deployment	Cost, technology, perceived lack of benefits	**Jury is still out**—has shown benefits in some cases, cost still a prohibitive factor, some doubt among practitioners on its effectiveness
Arterial information for ATIS	Moderate Deployment	Limited deployment of appropriate surveillance, difficulty in accurately describing arterial congestion	**Holds promise**—new surveillance technology likely to increase the quality and quantity of arterial information
Automated red light running enforcement	Moderate Deployment*	Controversial, some concerns about privacy, legality	**Successful**—but must be deployed with sensitivity and education
Automated speed enforcement on arterial streets	Limited Deployment*	Controversial, some concerns about privacy, legality	**Jury is still out**—public acceptance lacking, very controversial

[1] The three different deployment levels are defined as follows: Deployed in fewer than 10 percent of the largest 78 metropolitan areas = Limited Deployment; Deployed in between 10 percent and 30 percent of the largest 78 metropolitan areas = Moderate Deployment; Deployed in more than 30 percent of the largest 78 metropolitan areas = Widespread Deployment

Table 3-1. Continued

Technology	Deployment Level	Limiting Factors	Comments
Integration of time-of-day and fixed-time signal control across jurisdictions	Widespread Deployment	Institutional issues still exist in many areas	**Successful**—encouraged by spread of closed-loop signal systems and improved communications
Integration of real-time or adaptive control strategies across jurisdictions (including special events)	Limited Deployment	Limited deployment of Adaptive Control Strategies, numerous institutional barriers	**Holds promise**—technology is becoming more available, institutional barriers falling
Integration with freeway (integrated management)	Limited Deployment	Institutional issues exist, lack of standards between systems preventing integration	**Holds promise**—benefits have been realized from integrated freeway arterial corridors
Integration with emergency (signal preemption)	Widespread Deployment	None	**Successful**
Integration with transit (signal priority)	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

INTRODUCTION

The purpose of this paper is to address what has been learned regarding arterial management, to identify trends in deployment levels of arterial management technologies, and to speculate on the future of arterial management. This paper addresses four principal areas of arterial management: adaptive control strategies, advanced traveler information systems for arterials, automated enforcement, and integration of arterial management.

Deployment levels of the various technologies primarily issue from the U.S. Department of Transportation's (U.S. DOT's) 1999 Metropolitan ITS Deployment Tracking Database (ITS Deployment Tracking Database 1999). Other deployment information was derived from a literature and website search. Opinions on the challenges and future of the technologies were gathered at the Institute of Transportation Engineers (ITE) 2000 International Conference, held in Irvine, California, in April 2000. More than 40 transportation professionals attended an ITE roundtable discussion on arterial management covering each of the four areas delineated in this paper.

ADAPTIVE CONTROL STRATEGIES

What are Adaptive Control Strategies?

Adaptive control strategies use algorithms that perform real-time optimization of traffic signals based on the current traffic conditions, demand, and system capacity. ACS includes software that adjusts a signal's split, offset, phase length, and phase

sequence to minimize delay and to reduce the number of stops. The systems require extensive surveillance, usually in the form of pavement loop detectors, and a communications infrastructure that allows for communication with the central and/or local controllers. ACS differs from other more traditional traffic-responsive systems in that new timing plans can be generated for every cycle, based on real-time information. Theoretically, ACS allows an infinite number of timing plans.

The traditional ACS technologies are Australia's SCATS (Sydney Coordinated Adaptive Traffic System) and the United Kingdom's SCOOT (Split, Cycle, Offset Optimization Technique) systems. Los Angeles developed and uses a system called ATSC (Automated Traffic Surveillance and Control) program. New adaptive control algorithms are being developed and tested in the United States under the ACS umbrella. OPAC (Optimized Policies for Adaptive Control) and RHODES (Real-Time Hierarchical Optimized Distributed Effective System) algorithms are deployed in field operational tests sponsored by the Federal Highway Administration (FHWA). Both algorithms are for use on arterial streets, with OPAC designed for over-saturated conditions and RHODES designed for under-saturated conditions. Another new adaptive system, RTACL (Real-Time Traffic Adaptive Control Logic), will be tested on a grid network in Chicago in late 2000. The RTACL algorithm is designed for a network of streets.

The jury is still out on whether ACS works well. Benefits have been demonstrated in several areas where traditional adaptive control technologies (e.g., SCOOT, SCATS) have been deployed. However, some argue that the systems are no better than good fixed-time/time-of-day plans. This observation may be true, especially in areas where traffic is predictable or there is little traffic growth. Other issues with adaptive control include detector maintenance and communications problems. Currently, little information exists on the benefits of newer adaptive control strategies like OPAC, RHODES, and RTACL, and the conclusions about ACS in this paper are taken mostly from experiences with SCOOT and SCATS.

Levels of Deployment

The ITS deployment tracking database currently reports eight ACS deployments in the United States. In addition to these eight, a literature search revealed the existence of two other sites: Broward County, Florida, and Newark/Wilmington, Delaware. One of the first and largest ACS deployments is in Oakland County, Michigan, as part of the FAST-TRAC project. The system became operational in 1992, and more than 350 intersections are now under SCATS control. Also, the ATSC system in Los Angeles includes 1,170 intersections and 4,509 detectors for signal timing optimization as of 1994 (Mitretek Systems 1999). Table 3 shows the deployment cities and levels of utilization. In addition to these deployed systems, there are currently field operation tests of OPAC and RHODES on Route 18 in New Jersey and in Tucson, Arizona, respectively. These two systems are not listed in Table 3-2, as they are field operational tests.

Table 3-2. Locations of Adaptive Control Strategies Deployments

City/County	System	Number of Intersections
Los Angeles, CA	ATSC	1170
Oakland County, MI	SCATS	350+
Hennepin County, MN	SCATS	71
Arlington, VA	SCOOT	65
Minneapolis, MN	SCOOT	60
Anaheim, CA	SCOOT	20
Durham, NC	SCATS	unknown

What are the benefits of ACS?

ACS has several advantages over traditional fixed-time/time-of-day plans. With ACS, timing plans are generated in real time and can more efficiently accommodate fluctuations in traffic demand. Ideally, ACS works best in areas with high levels of nonrecurring congestion, such as incidents and special events, and in areas with fluctuating traffic demand. Although ACS has been shown to provide benefits, it is difficult to give a generalized overview of the benefits for any of the systems, as each technology works differently, and each deployment site is unique and customized to that particular deployment. The extent of benefits depends on several factors, including number and spacing of intersections, size of study area, demand patterns, study base case, and type of adaptive control used.

Three functional areas have shown improvement, or potential for improvement, due to ACS over fixed-time plans. They are delay reduction, safety, and operations and maintenance.

Delay Reduction

In responding to demand variations in real time, ACS adjusts the timing plan to minimize delay and number of stops, a basic goal of an ACS system. Each system performs this optimization in a similar fashion. Delay reductions were reported from five of the deployments. The benefits ranged from 19 to 42 percent. The range in delay may be attributed to differing definitions of delay (e.g., time stopped at an intersection or corridor travel time over a free-flow travel time) and the base case study condition.

The largest delay reduction was experienced in Broward County, Florida, where a SCATS test system was installed at five intersections. A Florida Department of Transportation (DOT) evaluation showed that SCATS reduced delay by up to 42 percent and travel time by up to 20 percent (TransCore 2000). Before-and-after studies of the Oakland County, Michigan, SCATS deployment showed significant

delay improvements. Corridor travel time was reduced from 7 percent to 32 percent over optimized fixed-time signal control. The average travel time reduction for traffic during peak periods was 8 percent (average speed increased from 25 mph to 27 mph) (Abdel-Rahim et al. 1998). A preliminary study of the SCOOT installation in 56 intersections in Minneapolis shows a 19 percent reduction in delay during special events. Table 3-3 provides more delay reduction information.

Table 3-3. ACS Travel Time and Delay Benefits Realized in the United States

Location	System	Benefits Realized
Broward County, FL*	SCATS	Delay reduced by up to 42%, travel time reduced by up to 20%
Oakland County, MI	SCATS	Delay reduced by 6.6% to 32%, with an average of 7.8%
Newark, DE area	SCATS	Travel time reduced by up to 25%
Los Angeles, CA	ATSC	Delay reduced by 44%, travel time reduced by 13%
Minneapolis, MN	SCOOT	Delay reduced by up to 19% during special events

*The system in Broward County was installed as a demonstration and has since been turned off due to lack of funds.

Safety

A reduction in number of stops leads to reduced chance of rear-end collisions. ACS has the ability to reduce the number of stops through a corridor by improving coordination. When compared to fully optimized fixed-time systems, SCATS has been shown to reduce stops by up to 40 percent (TransCore 2000). Following implementation of a SCATS system in Broward County, Florida, the number of stops decreased by 28 percent (TransCore 2000). Floating car studies in Oakland County, Michigan, showed a 33 percent reduction of stops, and the ATSC system in Los Angeles reduced stops by an estimated 41 percent (Mitretek Systems 1999).

Operations and Maintenance

High-growth areas benefit from adaptive control's ability to continually generate timing plans. While there are no guidelines specifying the optimal length of time between traffic signal optimization, the ITS deployment tracking database shows that only 27 percent of agencies in the 78 largest metropolitan areas re-time their signals each year, as shown in Table 3-4. Slightly fewer than a third report re-timing their signals on an as-needed basis. However, practitioners participating in the roundtable discussion held at the ITE 2000 International Conference reported that re-timing most likely occurs when funding and staff resources are available. In fact, ITE estimates that nearly 75 percent of all signals in the United States need to be re-timed (Meyer 1997). In areas of high growth, signal timing plans quickly become out-of-date. The ability of ACS to respond in real time addresses the shortcomings of signal timing in responding to changes in demand.

Table 3-4. Signal Re-Timing Schedule

	As Needed	1 year or less	2 years	3-5 years	5+ years
# of agencies	62	53	21	41	18
% of agencies	31.8%	27.2%	10.8%	21%	9.2%

Source: Metropolitan ITS Deployment Tracking Database, Oak Ridge National Laboratory (1999).

ACS may reduce operational and maintenance costs associated with signal re-timing. The Minnesota DOT reported that technicians were pleased with the ease of operations of the SCOOT system in Minneapolis. Technicians found the system easy to operate, requiring a minimum amount of maintenance once installed (Remer 2000).

What are the deployment challenges to ACS?

ACS has limited deployment in the United States. Several factors have limited its use, including cost, system complexity, and uncertainty in the benefits of adaptive systems.

Current adaptive control system benefits do not appear to be proven to traffic engineers. Several participants in the ITE roundtable discussion mentioned they are not convinced or even aware of ACS benefits. ACS is particularly sensitive to installation. For example, a limited SCOOT installation in Anaheim, California, produced little improvement and, in some cases, actually increased delay. During peak traffic periods, the system experienced delays that were 10 percent greater than baseline conditions. However, during nonpeak periods, the delay was decreased by 5 percent. According to a U.S. Department of Transportation-sponsored evaluation of the system, the reason for sub-optimal performance was most likely in placement of the detectors.

Also, the benefits of ACS depend on the base case condition. In areas characterized by fluctuations in traffic demand and low growth, ACS offers few benefits over well-maintained fixed-time/time-of-day signals. The consensus of engineers in the ITE roundtable discussion was that the benefits of traditional ACS over well-maintained fixed-time plans are unproven (although, as was demonstrated previously, such well-maintained fixed-time plans are the exception, not the rule).

Participants also expressed concern about the complexity of adaptive control systems. Additional training is normally required to operate such systems, which are not considered user-friendly. Different terminology causes problems for U.S. traffic engineers. In the Hennepin County, Minnesota, deployment, system operators found the SCATS system difficult to learn, even though extensive training was provided. Operators had difficulty working with the complex user interface.

In a similar fashion, ACS systems are highly dependent on the communications network, as well as the traffic detectors. If problems arise with communications, the system does not work efficiently, as occurred in Hennepin County, Minnesota, where

the communications system was unreliable, and arterial traffic signals experienced ongoing communications failures (Booz-Allen & Hamilton 1999).

Finally, cost appears to be a major obstacle to widespread ACS deployment, even for those who appear convinced of its benefits. This concern extends to both the capital and the operations and maintenance costs of ACS. For example, one of the biggest selling points offered by ACS proponents is that over the long term, the systems are more cost-effective than traditional signal timing approaches. They argue that the operations and maintenance costs associated with ACS are much lower than those associated with signal re-timing. However, as Table 3-5 illustrates, the equation is not that simple, for while signal re-timing costs decrease, other costs such as loop maintenance increase.

Table 3-5. Operations and Maintenance Costs for SCOOT Compared to Standard Traffic Control Devices

Equipment/Task	Costs of SCOOT vs. Standard
Controllers	Same
Detectors	Increases
Loop siting, validation, and fine tuning	No O&M costs (one-time cost)
Signal plans/updates	Decreases
Central equipment and communications	Same as any computer system

Source: Reissnecker, A., "Equipment Requirements for Adaptive Traffic Control," TRB Workshop (January 9, 2000).

Furthermore, even if the operations and maintenance costs were lower, practitioners have expressed concern about the large capital costs associated with ACS. While these costs vary widely depending on the size of deployment, they can (as Table 3-6 indicates) be quite significant. Even some of the practitioners who feel the benefits of ACS justify and outweigh these costs have difficulty in securing the large amounts of capital funding necessary to deploy ACS. Many municipal budgets are not structured to support such large, one-time costs for their arterial network.

WHAT HAVE WE LEARNED ABOUT INTELLIGENT TRANSPORTATION SYSTEMS?

Table 3-6. Estimated Costs of ACS Components

System	Central Hardware ($)	Central Software ($)	Local Controllers* ($)	Detectors* ($)
SCATS[†]	30,000	40,000 - 70,000	4,000 - 6,000	5,000 - 7,000
SCOOT	30,000	unknown	unknown	5,000 - 7,000
OPAC	20,000 - 50,000	100,000 - 200,000	4,000 - 6,000	unknown
RHODES	50,000	500	unknown	unknown
ATCS	40,000 - 50,000	1,000 + license	8,000 - 10,000	5,000 -10,000

*per intersection

† requires regional hardware and software

What does the future hold for ACS?

According to the ITS deployment tracking database, only five other sites expect to use an adaptive control system by the year 2005—a rather dismal outlook for ACS. However, most participants in the ITE roundtable discussion believed ACS had the potential to provide significant benefits. These benefits have not yet been convincing or made well-known. Participants agreed that a database of ACS benefits may be helpful in choosing between a traditional traffic signal system and adaptive control.

Furthermore, despite the rather low level of domestic deployment, ACS has enjoyed relatively widespread use outside the United States. For example, SCOOT has been deployed at more than 100 sites worldwide, while SCATS has been deployed in nine countries. While the reasons for this discrepancy are not fully understood, it has been suggested that off-shore development of these systems may be the factor limiting their adoption here. To illustrate, some practitioners have argued that these traditional, foreign-designed systems are insensitive to a number of unique, yet critical, aspects of U.S. signal control, such as pedestrian clearance times.

Finally, this issue may be addressed in part by the adaptive control systems now being developed in the United States. These systems, which are currently being field tested, include RHODES, OPAC, and RTACL, and may show significant benefits and be easier to use than traditional systems. Because cost is one of the main prohibitive factors, the Federal Highway Administration is also considering such solutions as a scaled-down, lower cost ACS that could also be used in small and medium-sized cities and would not require total replacement of current traffic control devices.

ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS) FOR ARTERIALS

What is ATIS for arterials?

ATIS for arterials is used to collect and/or disseminate information on roadway conditions to travelers so they can make more informed decisions.

In addition to traditional radio and television broadcasts, arterial information is disseminated primarily through three ITS media: VMS, websites, and HAR. In addition, U.S. DOT recently announced the creation of a national three-digit traveler information number (511). Both static and dynamic information is provided over these media. Static information includes lane closures and construction, while dynamic information includes real-time travel times and congestion.

Levels of deployment

According to the ITS deployment tracking database, 67 of 361 agencies (nearly 19 percent) report providing some type of arterial information to travelers, with few providing real-time or dynamic information such as travel speeds. This moderate deployment level and lack of real-time data stem from a combination of limited surveillance on arterial roadways and from difficulties in conveying meaningful arterial travel conditions. For example, spot speeds collected through loop detectors are fairly common and useful on freeway facilities. However, even if such detectors were present on an arterial network (which they rarely are), the resulting spot speeds may be misleading, given the confounding influence of traffic signals.

The most widely used ITS method to provide arterial travel information is the Internet, with 28 agencies operating websites. Table 3-7 depicts the deployment levels of other common technologies for providing arterial information. Information provided includes data on arterial speeds, incidents, road closures, and queue lengths.

Table 3-7. Arterial ATIS Deployment Levels

Technology*	1999 Level of Deployment (Number of Sites)
Dedicated cable TV	5.0% (18)
Telephone system	5.8% (21)
Internet websites	7.8% (28)
Pagers/personal data assistants	2.8% (10)
Interactive TV	0.3% (1)
Kiosks	3.0% (11)
E-mail or other direct PC communication	4.4% (16)

Table 3-7. Continued

Technology*	1999 Level of Deployment (Number of Sites)
In-vehicle navigation systems	0.3% (1)
Cell phone/voice	1.1% (4)
Cell phone/data	0.6% (2)
Facsimile	5.0% (18)
Other	1.9% (7)

Broadcast media is the primary method currently used to disseminate arterial information. Television and radio broadcast arterial information in virtually every major metropolitan area. However, these traditional media are not considered ITS.

Source: Reissnecker, A., "Equipment Requirements for Adaptive Traffic Control," TRB Workshop (January 9, 2000).

What are the benefits of ATIS for arterials?

ATIS that provides information on arterial roadway conditions offers benefits in customer satisfaction and improved efficiency. In addition to freeway information, travelers seem to want information on arterial roadways so they can make more informed decisions. More than half (57 percent) of respondents in a survey of web-site users in Seattle suggested adding arterials to traveler information. Similar results were found from surveys in Phoenix and San Antonio during MMDI evaluations. Providing information on arterial conditions may also lead to slight reductions in delay. Results from the Seattle MMDI evaluation show that adding arterial information can bring about a 3.4 percent reduction in delay, up from 1.5 percent, and lead to significant reductions in variability (Jensen et al. 2000).

What are the deployment challenges?

Providing accurate and reliable traveler information continues to be a deployment challenge for ATIS. In most cases, the infrastructure does not exist for arterial data collection. Traveler information systems often have to rely on data collected to serve other needs, such as data from traffic management functions. Agencies are still seeking the best method of surveillance to collect arterial information. ITE round-table participants agreed that the biggest impediment to providing ATIS with arterial information is providing accurate and reliable travel times.

Another issue concerning arterial ATIS is that currently no common method exists to describe arterial conditions. Users do not always understand the performance metrics used by traffic engineers (e.g., intersection level of service, saturation) for arterial roadways. In addition, as previously mentioned, traditional measures like spot speeds may be misleading on facilities dominated by traffic signal control.

What does the future hold?

Although the current situation does not lend itself to adequate data collection methods, the future does seem hopeful with the emergence of new technologies. As part of the MMDI, San Antonio, Texas, used automated vehicle identification tags and readers to determine travel times/speeds on arterial streets. The system was found to be technically sound; however, the tags never reached a sufficient level of market penetration to consistently measure travel times/speeds throughout all times of the day. Nevertheless, this method can be successful for collecting data on arterials if the appropriate level of market penetration is reached.

In another example, Farmer's Branch, Texas, took advantage of the large number of toll tags in the area (more than 200,000) by putting three toll tag readers along a key arterial in the area to measure travel time. This system detects when incidents occur, measures the effectiveness of attempts to improve travel time, and tracks travel time as a performance measure over months and years. The information is provided to travelers through signs in the roadway median (Davis 2000).

There is also research being conducted on using cell phones in vehicles as traffic probes; however, privacy issues may accompany this new technology. ITE roundtable participants seemed encouraged by the new technologies becoming available to collect arterial information. Although the provision of arterial information is not yet considered a success, it does hold promise because of new surveillance technology.

AUTOMATED ENFORCEMENT

What is automated enforcement?

Automated enforcement uses camera technology to photograph the license plates of traffic law violators. The most prominent form of automated enforcement is red light running enforcement. The purpose of RLR enforcement is to reduce the number of violations and ultimately lead to safer intersections. More than 22 percent of all urban crashes in the United States are caused by noncompliance with intersection controls—which amounts to more than 1.8 million crashes annually (FHWA Web Page). Automated RLR enforcement is a tool that can be used to encourage compliance and prevent crashes.

Levels of deployment

Automated enforcement is not tracked in U.S. DOT's Metropolitan ITS Deployment Tracking Database. Deployment levels were obtained through websites on the subject. Automated RLR enforcement is being used in approximately 40 communities in the United States. Currently, nine states have passed legislation allowing automated RLR enforcement, while 10 additional states are considering such legislation (Insurance Institute for Highway Safety Web Page). There are 14 automated speed enforcement programs (involving either freeways or arterial streets), mostly in the western United States.

One of the reasons for the relatively widespread use of automated enforcement technologies is the active involvement of industry and vendors. The private sector has

frequently offered to defray many associated deployment costs in return for receiving a percentage of revenues gained from the ticketing process. While this model has facilitated rapid rise of this technology, it must be employed carefully to ensure that deployments are safety-driven and not motivated by profits.

What are the benefits of automated enforcement?

Automated RLR enforcement can yield benefits in reduced crashes, reduced violations, and increased intersection efficiency. Table 3-8 shows the benefits at several deployment sites. Additionally, revenues from traffic fines may help defray some of the capital and/or operating costs. However, issues of public perception and acceptance dictate that cost savings not be a prime motivator for system deployment. In addition, if the systems perform their function properly, they should ultimately increase compliance and thus lead to decreased ticket revenue.

The benefits of automated speed enforcement are not as well documented and, therefore, red light enforcement benefits alone are presented.

Table 3-8. Benefits of Automated Red Light Enforcement at Various Sites

Site	Impact on Violations and Citations	Impact on Crashes
New York, NY	Violations reduced by 34%	Angle crashes reduced by 60-70% Some increase in rear-end crashes
Howard County, MD (2 sites)	Warnings reduced by 21-25% Citations reduced by 42-50%	Collisions reduced by 40%
Oxnard, CA	Violations reduced by 42% at sites Violations reduced by 22% city wide	Collisions reduced by 24%
San Francisco, CA	Citations reduced by 42%	Injury crashes reduced by 24%
Scottsdale, AZ	Violations reduced by 20%	Collisions reduced by 55%
Minnesota	Citations reduced by 29% for all vehicles Citations reduced by 63% for trucks	unknown
Fairfax, VA (9 sites)	Citations reduced by 44%	unknown

Source: FHWA Web Page.

What are the deployment challenges?

Concerns have been raised that automated enforcement violates a person's privacy. While legal opinions do not support this claim, the perception still exits. Also, as stated above, the public may perceive the systems as revenue generators for the police or for the system vendors. In many cases, the vendor pays for system installation and, in turn, generates revenue from violations. Educating the public about the benefits of the systems may dispel these concerns. Participants in the ITE roundtable

agreed that automated enforcement should be encouraged, but that safety aspects need to be demonstrated to the public to gain acceptance.

What does the future hold?

Automated RLR enforcement is moderately deployed at this time; however, it appears to have a strong future. The media have given the systems significant attention, while the number of states considering legislation is increasing rapidly. The Federal role in supporting development of these systems may be limited to public education on the systems and the dangers of red light running.

Automated speed enforcement does not share the same level of public support. Seven out of 10 deployment tests of automated speed enforcement have been discontinued from lack of support (Public Technology, Inc. 1999).

INTEGRATION OF ARTERIAL TRAFFIC MANAGEMENT SYSTEMS (ATMS)

What does the integration of ATMS involve?

There are three types of ATMS integration: (1) integration across jurisdictions, (2) integration with transit and emergency operations, and (3) integration with freeway management. Integration across jurisdictions includes the coordination of traffic signals among different agencies and, in some cases, the sharing of signal control.

Arterial management integration with emergency operations usually takes the form of traffic signal preemption. Preemption provides an automatic green light to emergency vehicles despite traffic conditions and current signal phase. This exception allows the emergency vehicle to move safely and more efficiently through the intersection.

Priority for transit vehicles is similar to preemption, except that the green phase is not automatically implemented. Rather, the green time is either extended or reduced to more efficiently move the transit vehicle.

An integrated arterial freeway corridor is one that shares information and/or control between adjacent freeway and arterial management systems. At a low level, this integration may involve a freeway management agency providing information on freeway incidents to neighboring arterial systems. With more complex systems, arterial travel times, speeds, and conditions may be shared with freeway management to adjust VMS, HAR, and freeway ramp meters. Conversely, freeway travel times, speeds, and conditions may be shared with arterial management and used to optimize traffic signal timings and inform arterial travelers. Such integration may also use incident response timing plans to respond to traffic diverted from the freeway to the arterial.

Where have arterial ATMS been integrated?

Interjurisdictional coordination

Of the 78 largest metropolitan areas, 54 percent report coordinating fixed timing plans across jurisdictions, and 62 percent report planning to do so before 2005.

Integration with transit and emergency operations

More than half the agencies accounted for in the ITS deployment tracking database offer some preemption measures for emergency vehicles (see Table 3-9). Priority for transit is used less frequently than preemption for emergency vehicles, owing largely to concerns over disruption to surrounding traffic. (See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?" for more detailed information on priority for transit vehicles).

Table 3-9. Extent of Emergency Preemption Deployment

Percent of signals that allow for preemption for emergency vehicles	Number of agencies by type (percentage)		
	State DOT	County Agency	City Agency
100% to 25%	9 (17%)	26 (26%)	53 (29%)
1% to 24%	25 (47%)	38 (36%)	81 (45%)
0%	19 (36%)	41 (38%)	48 (26%)
Total (340 agencies)	53 (100%)	105 (100%)	182 (100%)

Integration with freeway management

According to the ITS deployment tracking database for 1999, 74 (out of 361) arterial management agencies, or 20 percent, provide arterial travel times, speeds, and conditions to freeway management agencies. Conversely, 20 (out of 106) freeway management agencies, or 19 percent, provide information on freeway conditions to arterial management agencies. It is unknown how each agency uses the information. Actual integration of arterial and freeway management—where agencies actively use information from freeway management to better manage arterial roadways—is expected to be much lower than these percentages. For example, fewer than a half dozen integrated freeway/arterial diversion systems use both freeway and arterial incident response plans to incidents, and share real-time incident and travel time conditions with each other and the public.

What are the benefits of integration?

Interjurisdictional coordination

Coordination across jurisdictions can yield delay reductions by providing a seamless travel corridor. Interconnecting previously uncoordinated signals and providing newly optimized timing plans and a central master control system can reduce travel time by 10 to 20 percent (Meyer 1997). For example, the metropolitan planning organization in Denver acted as an organizer in getting area jurisdictions to work together to coordinate signals. Travel time reductions on the Denver arterial corridors ranged from 7 to 22 percent (Meyer 1997).

Integration with transit and emergency operations

Delays at traffic signals usually represent 10 to 20 percent of overall bus trip times (Gordon et al. 1996). Priority for transit vehicles can reduce delay caused by stopping for red lights. (See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?" for more benefit information). Emergency vehicles experience benefits from traffic signal preemption, with travel time reductions of around 20 percent (Mitretek Systems 1999).

Integration with freeway management

Integrating arterial, freeway, and incident management in San Antonio, Texas, led to travel time reductions of 20 percent during major incidents. The Integrated Corridor Traffic Management (ICTM) project in Hennepin County, Minnesota, experienced benefits from the interjurisdictional relationships formed. Under ICTM, agencies were encouraged to look at the corridor as a whole rather than as separate jurisdictions. For example, before the implementation of ICTM, traffic signals and ramp meters were operated by a variety of nonintegrated systems within separate jurisdictions. ICTM used SCATS to integrate the metered ramps and arterial traffic signals (Booz-Allen & Hamilton 1999).

The Coordinated Highways Action Response Team (CHART) program in Maryland is another example of integration between freeway and arterial management. Surveillance on freeway exit ramps and along the arterial are used to adjust and refine traffic signal timing, especially critical when incidents occur on the freeway and traffic is diverted to the arterial roadways. Adjustments can be made to the traffic signals to accommodate the additional traffic diverted from the freeway (MD DOT undated).

What are some of the challenges of integration?

According to participants of the ITE roundtable discussion, lack of multijurisdictional organization and support continues to be the major impediment to integration. Jurisdictions often may not have the same goals. Furthermore, they may not see the need or opportunity for integrated management. There are also technical issues concerning the compatibility of different systems and technologies.

What does the future hold?

Decision-makers need to become better educated about the benefits of integrated systems and interjurisdictional coordination. This goal may be accomplished by further studying the benefits of integration. ITE roundtable participants called on vendors to help integrate different technologies by opening their architectures and allowing agencies to work together without having to purchase new systems.

CONCLUSION

Each of the technologies discussed in this paper shows the potential for benefits; however, only a few have reached widespread deployment. Reasons for the limited deployments vary, but include cost, institutional barriers, uncertainty of benefits, and technological incompatibilities.

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chapter 4
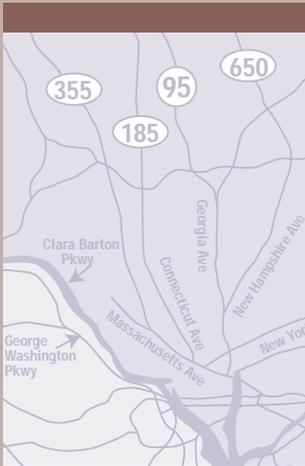
WHAT HAVE WE LEARNED ABOUT ADVANCED TRAVELER INFORMATION SYSTEMS AND CUSTOMER SATISFACTION?
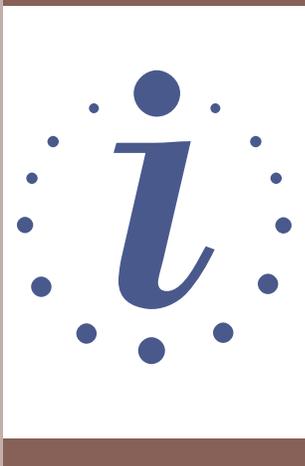
EXECUTIVE SUMMARY

This paper synthesizes customer satisfaction findings from advanced traveler information systems (ATIS) research and evaluations dating from 1996.[1] Recent project evaluations from the Metropolitan Model Deployment Initiative (MMDI) in Seattle, San Antonio, and Phoenix are featured more prominently because these deployments provided a natural use setting and thus a more reliable context for assessing customer satisfaction.

For purposes of this paper, ATIS is defined in two ways: (1) real-time network information, whether traffic or transit; and (2) traveler information, such as route guidance or destination information, provided on advanced technologies, such as mobile phones enabled by wireless application protocol (WAP), personal digital assistants (PDAs), the Internet, and in-vehicle computers. This paper's focus is on public sector ATIS services, although one section does address ATIS business models, with selected private services included in that discussion. Content is constrained by the availability of ATIS customer satisfaction evaluations, placing certain ATIS applications beyond the scope of this paper, along with the ability to provide a general overview of the state of the art or practice of ATIS products and services.

Evaluation findings suggest that customer demand for ATIS traffic services is based on four factors: (1) the regional traffic context, (2) the quality of the ATIS services, (3) the individual trip characteristics, and (4) the characteristics of the traveler. The regional traffic context includes attributes of the region, such as highway-roadway network and capacity, levels of traffic congestion, and future highway-roadway expansion plans. Information quality determines whether, how frequently, and with what level of confidence travelers consult traveler information. The trip purpose, the time and length of the trip, and the particular route or route choices available to the individual traveler all significantly affect whether individuals consult traffic information. The fourth factor includes user values and attitude characteristics, which are important determinants of use patterns, behavioral responses, and valuation of ATIS.

Conditions predicting high demand for ATIS transit services are not as well studied, but appear to be related to the complexity and variability of the transit network, the age of the transit rider population, and the level of technological sophistication of riders.

Drivers report that they consult ATIS to assess traffic congestion on their routes, decide among alternate routes, estimate trip duration, and time their trip departures. They regularly change their trips or their trip expectations based on traffic congestion information. ATIS customers identify four primary benefits of the service: saved time, avoided congestion, reduced stress, and avoided unsafe conditions.

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[1] In 1996, a report was prepared by Dr. Christine Johnson for Charles River Associates and John A. Volpe Transportation Systems Center summarizing all ATIS user acceptance evaluation and research performed to that point. *User Acceptance of ATIS Products and Services: A briefing book on the current status of JPO research* (March 1996) summarized findings from the U.S. DOT-sponsored field operational tests and traveler decision and behavior research performed in the 1960s. Findings from this study formed the research and evaluation framework pursued through the ITS User Acceptance Research program and the Metropolitan Model Deployment Initiative customer satisfaction evaluation. This paper builds on findings of the earlier study.

All travelers agree that ATIS services must provide accurate, timely, reliable information, and be safe and convenient to use. Drivers with experience using ATIS provide a more detailed and informed set of customer requirements. They seek the following:

- Camera views that portray road conditions.
- Detailed information on incidents.
- Direct measures of speed for each highway segment.
- Travel time between user-selected origins and destinations.
- Coverage of all major freeways and arterials.
- En route access to good traffic information.

ATIS transit customers want services that provide real-time information both pre-trip and en route, a good quality user interface, and convenient access to detailed system information. Customers cite the following benefits of transit ATIS: reduced stress, improved satisfaction with the decision to take transit, and greater control over time and travel decisions.

Kiosks and WinCE mobile computers, deployed and evaluated as part of the MMDI, did not prove to be popular ATIS venues for traffic or transit information. For kiosks, the problems included poor placement in relation to the trip decision, unreliable performance, and a challenging user interface. Traffic and transit information on mobile hand-held computers received little notice from travelers. This circumstance may have been related to low market penetration of the WindowsCE devices and insufficient promotion of the new traveler information services.

Drivers who watched traffic reports on cable television community access channels in Seattle and Tempe, Arizona, found the television broadcasts to be more useful than traffic reports on the radio. However, overall response to the surveys was weak, suggesting low viewership. A partial explanation may be the lack of program advertising, as most respondents reported learning about the broadcast when "channel surfing."

In-vehicle navigation systems have yet to reach their predicted level of market penetration. Currently, they are available in rental cars and as an option in luxury cars; however, the number of auto manufacturers with the navigation system option is expected to double in model year 2001. Developers insist that the product will not achieve full market potential until real-time traffic is integrated into the routing algorithm.

The business model for delivery of and payment for ATIS traffic services is still in flux. ATIS companies face multiple challenges. Traffic data must be collected by individual agreement with each state and every transportation authority across the country. The data are variable in scope and quality, and there is no established consumer market. In-vehicle personal computers (PCs) and navigation devices, an important venue for sale of traffic information services, have been slow to market. The geocode used by one major traffic information supplier to identify the location of traffic is inconsistent with the geocode embedded in another major manufacturer's

map database and navigation software. Venture capitalists are hesitant to invest in companies whose product depends on government resources or cooperation. Not surprisingly, none of the private sector ATIS businesses dealing in traffic information services in the United States have made a profit on that service.

If current operational tests prove that mobile phones can be used as traffic probes, businesses may be able to contract with one primary source for standardized traffic data, and mobile phone traffic data will reduce or remove ATIS businesses' dependence on public sector data sources, improving their ability to attract private investment.

Current market trends suggest that an increasing proportion of all employed Americans will carry some form of mobile telecommunications device. This circumstance creates a good business opportunity for information service providers. Assuming that ATIS companies can address the issues currently confronting them, ATIS services will be included in mobile information subscription packages. Recent Federal Communications Commission (FCC) enactment of a national three-digit traveler information number (511) should further accelerate customer use of ATIS. Automotive companies are developing integrated in-vehicle information systems, which will connect all aspects of the auto's maintenance and operating systems with Internet access, entertainment and productivity programs, and mobile two-way voice and data exchange. Consumer interest in the in-vehicle system is expected to be high. Taken as a whole, these trends suggest that more consumers will be exposed to telematic services and have the opportunity to use an ATIS service. Customer satis-faction with ATIS and long-term use will depend on the quality of the information.

This summary identifies many ATIS deployment issues that merit further investiga-tion. The hypothesis developed to explain consumer response to ATIS is drawn from a very small and idiosyncratic sample of regions. An issue made prominent by its absence is customer satisfaction with ATIS transit information, and its ability to influence mode choice. Such data are critical to transit authorities' ATIS investment decisions. Finally, several promising ATIS applications suffer from lack of publicity. Now that ATIS benefits are sufficiently well documented, it may be useful to "field test" an advertising campaign for its ability to attract new ATIS consumers.

The following table summarizes deployment levels and relative levels of success for selected ATIS services. The data are drawn from the Metropolitan Intelligent Transportation Systems (ITS) Deployment Tracking Database.[2] Comments also draw from work prepared for the February 2000 workshop addressing the ATIS data gap.[3] The Intelligent Transportation Society of America (ITS America) and the U.S. Department of Transportation (U.S. DOT) jointly sponsored the workshop, held in Scottsdale, Arizona. For purposes of this paper, "success" when applied to an ATIS service means that the service is well subscribed by the consumers it was designed to serve.

[2] The three different deployment levels are defined as follows: Deployed in fewer than 10 percent of the largest 78 metropolitan areas = Limited Deployment; Deployed in between 10 percent and 30 per-cent of the largest 78 metropolitan areas = Moderate Deployment; Deployed in more than 30 percent of the largest 78 metropolitan areas = Widespread Deployment

[3] Specifically, *Features of Traffic and Transit Internet Sites,* Jonah Soolman and Sari Radin, and *Advanced Traveler Information Service: Private Sector Perceptions and Public Sector Activities,* Sari Radin, Basav Sen, and Jane Lappin, John A. Volpe Transportation Systems Center, Cambridge, MA.

Table 4-1. ATIS Summary Table

ATIS Service	Deployment Level	Limiting Factors	Comments
Real-time traffic information on the internet	Widespread Deployment	While deployment is widespread, customer satisfaction with the services seems related to local traffic conditions and website information quality	**Mixed**—the characteristics of the websites vary, depending on the availability and quality of the user interface and underlying traffic data.
Real-time transit status information on the Internet	Limited Deployment	Transit authorities have limited funds for ATIS investments and little data that establish a relationship between ridership and ATIS	**Holds promise**—where the service is available, reports suggest that there is high customer satisfaction with the service
Static transit system information on the Internet	Widespread Deployment		**Successful**
Real-time traffic information on cable television	Limited Deployment	Limited by information quality and production costs, although one service provider has developed a way to automate production	**Successful**—as evaluated in a highly congested metropolitan area where consumers value the easy, low-tech access to traffic information
Real-time transit status information at terminals and major bus stops	Limited Deployment	Cost	**Successful**—where evaluated in greater Seattle
Dynamic message signs	Widespread Deployment	Positive driver response is a function of sign placement, content, and accuracy	**Successful**—drivers really appreciate accurate en-route information
In-vehicle navigation systems (no traffic information)	Limited Deployment*	Purchase cost	**Holds Promise**—as prices fall, more drivers will purchase the systems
In-vehicle dynamic route guidance (navigation with real-time traffic information)	No commercial deployment; the San Antonio MMDI installed prototype systems in public agency vehicles*	Irregular coverage and data quality, combined with conflicting industry geocode standards, have kept this product from the market	**Holds Promise**—manufacturers are poised to provide this service once issues are resolved
Fee-based traffic and transit information services on palm-type computers	Unknown Deployment	Service providers make this service available through their websites, actual subscription levels are unknown	**Jury is still out**—requires larger numbers of subscribers becoming acclimated to mobile information services

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

INTRODUCTION

In 1996, an ATIS user acceptance research and evaluation retrospective was prepared that summarized findings from the traveler behavior literature of the 1960s and from the U.S. DOT-sponsored ITS field operational tests. This paper picks up from there, synthesizing findings from ATIS user-response research and customer satisfaction evaluations dating from 1996, including several field operational tests. Recent project evaluations are featured more prominently because they offered ATIS services to the general public for regular use, thus providing a more natural and more reliable context for assessing customer satisfaction.

This paper draws primarily from the following sources:

- MMDI customer satisfaction evaluations of the Puget Sound traffic conditions website.
- TrafficTV in Seattle.
- Metro Online transit website in Seattle.
- TransitWatch® real-time bus departure times at two transit centers in Seattle.
- TrafficCheck traffic television in Tempe, Arizona.
- Focus groups with drivers along highway segments equipped with dynamic message signs in San Antonio.
- Observations of customer use of the Trailmaster travel conditions website in Phoenix.
- Transguide travel conditions website in San Antonio.

Only two ATIS transit services were deployed within the MMDI evaluation time frame. Similarly, there were fewer ATIS transit field operational tests than traffic tests. As a result, this paper addresses more ATIS traffic services than transit or multimodal services.

Note: In most instances where the term "ATIS" is used, it refers to a traffic or transit information service providing consumers with access to real-time network conditions.

EXTERNAL CONTEXT INFLUENCES ATIS CUSTOMER RESPONSE

Findings from the MMDI evaluation and other research suggest that customer demand for ATIS traffic services stems from four factors:

- Regional traffic context.
- Quality of the ATIS services.
- Individual trip characteristics.
- Characteristics of the traveler.

Regional traffic context includes attributes of the region, such as highway-roadway network and capacity, levels of traffic congestion, and future highway-roadway expansion plans. Prime ATIS markets appear to be highly congested regions with

limited build-out options, constrained alternate route possibilities,[4] and frequent unpredictable traffic events (e.g., weather, crashes, overturned truck).

Quality of ATIS services is at least as important as the level of network congestion. Information quality determines whether, how frequently, and with what level of confidence the traveler consults traveler information. Quality also determines whether the information will meet customer needs with respect to personal benefit and value.

Trip purpose, time of trip in relation to peak congestion periods, trip length, and particular route or route choices available to the traveler all have a significant effect on whether he or she consults traffic information. To a limited extent, the availability and convenience of alternative mode choices for a given trip affects ATIS use. Departure time flexibility, or lack thereof, is another determinant in the choice to consult traffic information.

The fourth factor considers the values and attitudinal characteristics of the user, or potential user, of ATIS products and services. These characteristics are important determinants of user awareness, use patterns, behavioral responses, and valuation of ATIS. For example, user attitudes toward timeliness affect response as do user preferences, such as a desire to be in touch at all times, or to ask a person for assistance rather than use a computer.

Fewer opportunities have existed to assess transit customer response to ATIS services. Conditions that suggest high demand for ATIS transit services appear to be related to the complexity and variability of the transit network, the age of the transit rider population, and the level of technological sophistication of the riders. Younger riders expect transit information to be as easily accessed as that provided by any market-based service. Their expectations are probably conditioned by the current service economy and by information available on the Internet. Technologically sophisticated riders are aware of many of the tools available for tracking cars and buses, and can easily imagine the personal benefits of real-time transit status information, in addition to the other services that advanced media can provide.

ATIS CUSTOMERS[5]

Almost all ATIS customers are employed commuters, with the greatest use of ATIS occurring during peak commuting hours. More ATIS traffic customers are male, but among ATIS transit customers, use rate by gender is about even. Based on the MMDI survey trends, primary demographic factors are the ATIS customers' mode of

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[4] The hypothesis that a constrained set of alternative routes is a positive factor for ATIS acceptance is based on a comparison of the three evaluated MMDI sites: San Antonio, Phoenix, and Seattle. Drivers seem most concerned about knowing traffic conditions in networks where they have limited alternative route options and thus must plan ahead for route diversion. Where the network offers many possible alternate routes, drivers seem more sanguine about diverting after they have encountered the congestion, without need of advance information for trip planning.

[5] For more details on the segmentation of the ATIS consumer market, see "Who are the likely users of ATIS? Evidence from the Seattle region", S.R. Mehndiratta, M.A. Kemp, J.E. Lappin, and E. Nierenberg, paper number 001103, presented at the 79th meeting of the Transportation Research Board, Washington, DC, January 2000. Also see "A Profile of the Emerging ATIS Consumer: Evidence from the Metropolitan Model Deployment Initiative Sites" by S.R. Mehndiratta, et. al. (Winter 2000), *ITS Quarterly*.

transport, commute trip characteristics, level of education, age, and comfort with advanced technology.

ATIS market segmentation based on attitudes and values related to the need for control, the value of time, personal travel preferences, and use of advanced technologies successfully identifies much of the current ATIS customer market, differentiating ATIS customers from others with similar demographic characteristics. To help characterize and identify these segments, they were labeled as control-seekers, webheads, or pre-trip information seekers.

Control-seekers dominate the ATIS customer market. In addition to high technology and gadget use, this segment is also defined by high use levels of portable devices like laptops and cellular phones. These customers consult ATIS to save time, to use their time efficiently, to stay on schedule, and to stay informed. Control-seekers use information more intensively than the general population.

Webheads comprise the second largest group of ATIS customers. This group is the most technologically savvy in the sample. Its members are marked by high computer and Internet use, both at home and at work. However, their interest appears linked to the Internet medium and may not migrate to mobile platforms as Web-based information becomes mobile.

Individuals in the low-tech, pre-trip information seekers market segment have a low acceptance and comfort level with the Internet and Web-based information. Consistent with this characterization, individuals belonging to this segment comprised much larger shares of the Transit Watch, TrafficTV, and TrafficCheck user populations—all three information services delivered on television or by means of a television-style monitor. This group is older, includes slightly more males than the sample, and is generally somewhat less comfortable with technology. For example, members of this segment prefer to ask a person for information rather than rely on a computer. Nevertheless, this customer segment represents a large portion of the current ATIS customer pool and can be expected to continue to demand high quality information services on low-tech media in the future.

WHY DRIVERS CONSULT ATIS AND HOW THEY USE IT

Drivers consult ATIS to reduce trip uncertainty. They want to lessen the impact of traffic congestion delay and aggravation, and increase their control over time. Washington Department of Transportation (DOT) traffic website customers consulted the site for five reasons, representative of those offered by most ATIS users. They are listed here in order of importance:[6]

- To assess traffic congestion on their routes.
- To judge the effects of incidents on their trips.
- To decide among alternate routes.
- To estimate their trip duration.

[6] From May 11 through June 8, 1999, a banner on the Wisconsin DOT traffic website invited users to respond to an on-line survey to help improve the website. A total of 608 users completed the question-naire.

- To time their trip departures.

Drivers using ATIS report that they regularly change their trip or their trip expectations based on traffic congestion information. For instance, they:

- Change time of departure.
- Change part or all of their route of travel, potentially lengthening trip mileage or duration.
- Adjust their expectations, listen to an audiotaped book, bring an extra compact disc, make phone calls, reschedule appointments, and/or make alternative arrangements.

They reported four primary personal benefits from their use of the Wisconsin DOT traffic website (in order of importance):

- Saved time.
- Avoided congestion.
- Reduced stress.
- Avoided unsafe conditions.

These use patterns, behavioral responses, and benefits are similar among all drivers surveyed as part of the MMDI ATIS evaluations. In the following section, critical features identified by ATIS customers refer back to decisions the information supports and the benefits it provides.

CRITICAL FEATURES OF AN ATIS TRAFFIC SERVICE

The National ITS Program fielded qualitative market research in 1996 on various traffic information concepts with drivers in congested regions (Charles River Associates 1997).[7] While the opinions of these drivers were based on their experience with radio broadcast traffic information, their traffic information concerns have proven to be true of all drivers surveyed since. Survey respondents were (and are) concerned with:

- Accuracy.
- Timeliness.
- Reliability.
- Cost (capital and operating).
- Degree of decision guidance and personalization.
- Convenience (ease of access and speed).
- Safety (of operation).

Surveys of drivers with long-term personal experience using ATIS through the Web, by telephone, on a prototype in-vehicle device, or on cable television provide a more detailed and informed set of customer requirements. These requirements, which help to define ATIS service quality, are discussed below.

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[7] Twelve focus groups (two in each location) were fielded in New York City, Washington, D.C., Boston, Philadelphia, Los Angeles, and Orange County, California.

Camera Views

All respondents value the video camera views displayed on websites and cable television.[8] Video camera views provide drivers with the opportunity to exercise their own judgment of the road's conditions. For every service that provided video camera views, survey respondents asked for a time stamp, a clear description of the camera's location, and its direction. Some website respondents observed that camera images were slow to load on their computers, and others commented that on some sites the cameras were frequently out of order. These service problems lessened consumers' interest in using traffic websites. Respondents also asked for clearer images, especially during inclement weather.

Information on incidents

Drivers want detailed and up-to-date information on incidents. They use this information in combination with their own experience of the road network to estimate the intensity and duration of incident-related traffic congestion. They want to know exactly where the incident occurred, at what time, and the type of incident. They also want to know the impact of the incident on traffic speeds, both on the road where the incident occurred and on adjacent area roads. For services that provide color-coded congestion maps, such as the Wisconsin DOT, some drivers wanted to see icons indicating that an incident had occurred, and to be able to click on that icon for further details. Others found icons distracting, but wanted to be able to move their cursor over the map, observe whether there were incidents underlying congestion, and then click for details.

Direct measures of speed for each highway segment, and travel time between user-selected origins and destinations

When selecting among alternate routes, most drivers want to know which route will get them to their destination most quickly. This preference suggests that the service provide either time of travel between two points or direct measures of speed for each highway segment. While many respondents wanted both, more frequent users of the Wisconsin DOT website rated direct measures of speed as more important. Graphically represented traffic speed and volume were also very important service features to TrafficTV viewers.

Dynamic route guidance

Are drivers more interested in receiving dynamic route guidance, or do they prefer advisories of traffic delays that allow them to exercise judgment in selecting an alternate route?   There are several answers to this question (Schofer, Koppelman, and Charlton 1997). First, in general, women are somewhat more likely to accept dynamic route guidance, while men prefer delay advisories. It appears that most drivers believe they can select better alternate routes for their local areas than any service could provide. Others prefer to set a delay threshold and receive dynamic route guidance for any traffic event that exceeds their threshold, particularly true for

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[8] One service provider remarked that when her company added camera views to their website, usage of the site doubled.

drivers in unfamiliar areas.   Finally, drivers become more accepting of dynamic route guidance if, through use, they find that it gives good advice.

Coverage

Survey respondents want ATIS coverage of all major freeways and arterials in their region, along with information on high-occupancy vehicle (HOV) lanes and express lanes in the region.   However, this preference may be a function of the regional road network where the surveys were fielded and the types of services evaluated. Specifically, in greater Seattle, most of the traffic congestion is on the freeways and major arterials. Further, the services cover primarily freeways, so potential customers are drivers who would find that information useful, not drivers who commute primarily on local streets. In contrast, drivers in suburban Chicago wanted more information on local streets. The sensible conclusion from these data is to provide traffic information according to local driving patterns, and to prioritize coverage by market demand, providing it first on roads with the most congestion.

Timing of information updates

While the surveys did not explore the exact timing required for traffic condition updates, drivers in Seattle felt that traffic conditions in their region were sufficiently dynamic to justify frequent updates, particularly along heavily congested roads, during peak traffic hours, and along critical segments such as the bridges. In Phoenix, website users complained that camera images, in particular, were not updated frequently enough. Generally, all ATIS customers want to know when the service was last updated, and will use the interval to estimate current traffic conditions.

Mobile ATIS

Drivers want reliable, accurate, relevant traffic information while driving. For many trips, pre-trip traffic information is outdated by the time the driver reaches a potential route diversion decision. This situation is where the greatest demand for ATIS currently exists, more so than pre-trip. Drivers recognize the safety challenge of delivering information to them, and most respondents expressed safety concerns about mobile phone use when driving. Nevertheless, drivers want to be able to press an ATIS button when approaching congestion or a route choice and quickly know which route would be least congested.

Local weather conditions

Weather affects traffic conditions. In Seattle and San Francisco, where microclimates create different weather conditions in neighboring cities, drivers want to know what to expect. In Boston and Minneapolis, severe weather conditions have a profound impact on traffic. Heavy rains affect driving conditions in San Antonio, and dust storms stop traffic in Phoenix. Nearly all drivers surveyed want appropriate, relevant weather conditions included with their traffic information. Bad weather is another form of incident, and drivers want to know when the weather affects road conditions, but do not value the information if there is nothing significant to report.

User interface and operating characteristics

User comments on interface and operating characteristics are a function of the platform used to convey the information. Website users are particularly aware of the multidimensional information opportunities presented by the Web, and are especially sensitive to the problem of computer and Internet speed. Currently, most Web users access the Internet at work and thus have fairly fast connections to websites. But lack of quick access to the Internet is one reason more commuters do not check the traffic website in the morning. Slow downloading of images also frustrates Web users, whose expectations for computing speed may outstrip the capabilities of the website's servers, especially if the site's capacity is overburdened at rush hour or during inclement weather. Dedicated users will stay with a Web service that is occasionally slow, but marginal users may not.

Both Web users and television (TV) viewers require clear and uncluttered visual presentation of information. Traffic congestion maps that use green, amber, and red to suggest traffic speeds are ranked higher for ease and speed of comprehension. Graphics must be large enough to see easily on television screens of different sizes and resolutions. Most television viewers want the screen image to be supplemented by an audio voiceover description of traffic conditions and suggestions for alternate routes when freeways are congested.

Because phone service users are frequently phoning from the road, they require fast and easy access to information. New voice recognition software that would let callers tell the service which road segment or region to describe would be a great improvement over push-button information trees, particularly for drivers. Advertising, which appears on some telephone ATIS services just before the traffic information is provided, interferes with the speed of information delivery and irritates customers.

ADDITIONAL SUGGESTIONS FROM ADVANCED ATIS TRAFFIC SERVICE USERS

The quality and popularity of the Washington State DOT traffic website in Seattle created an opportunity to survey a small number of especially advanced ATIS users who made much more intensive use of the site than average customers. These users provided expert suggestions for website improvements likely to be predictive of the improvements that average customers will seek in the near future. Further, these suggestions may represent the type of improvements that help customers differentiate between a service they can access free of charge and services that offer added value sufficient to merit a fee.

Ramps

Seattle meters its freeway ramps, and during peak hours some ramps have far greater backups than others do. Advanced users would like to choose among possible on-ramps for the shortest possible queue.

Trends

Advanced users have discovered that one can predict trends based on a time-series sample of current traffic conditions. They accomplish this result by repeated checking of conditions over a period of 15 or 30 minutes. They suggest that it would be useful for the service to state whether conditions are currently getting worse, or whether they are improving.

Predictive information

Predictive information refers to both near-term traffic predictions based on current conditions, and forecast conditions, based on what can be expected on average for certain times of the day, days of week, or weather conditions.

Because traffic conditions are dynamic, a route that looked clear at time of departure may be severely congested 10 or 20 minutes into the trip. Advanced users recommend that ATIS use current information in combination with historic data to provide customers with near-term predictive information on their route conditions. Drivers can then make en route choices using "current" information instead of information that was current at the time they started out.

Archived traffic information can forecast traffic conditions, enabling customers to plan ahead. For example, upon approaching the Labor Day weekend, MetroCommute of Greater New York advised its customers to plan on departing the city at 5 p.m. Friday for the best travel times to vacation areas. And, in a retrospective analysis, a 5 p.m. departure from the city provided drivers with the best trip time of the day.

Windows of opportunity

Advanced users have observed the existence of periods of relatively uncongested travel that appear in the midst of traffic congestion, even during peak hours. They would like to see these windows of opportunity identified by the ATIS service.

Flash major events on the map

Major events are like incidents in their impact on traffic congestion. Advanced ATIS users would like to be reminded of an impending event through a visual cue on the traffic map, with details provided by cursor or double click. Users in Seattle suggested, for example, a flashing King Dome icon on evenings when there is an event at that venue.

Parking information

Many cities have insufficient downtown parking to accommodate peak demand. Advanced users would like to know which lots have availability and which are full, to avoid driving around in congestion, searching for a space. Some respondents suggested they would switch modes when parking lots were full. This service would be more valuable to customers if it were coupled with an advanced parking reservation and payment system.

CRITICAL FEATURES OF AN ATIS TRANSIT SERVICE

Transit customers seek to lower the trip time uncertainty they commonly experience with transit. They want information that increases their control over time and travel decisions.

Evaluation findings indicate that ATIS transit customers want services that provide real-time information both pre-trip and en route, good quality user interface, and convenient access to detailed system information. Customers cite the following benefits of transit ATIS:

- Reduced stress.
- Improved satisfaction with the decision to take transit.
- Greater control over time and travel decisions.

Because one of the two major transit ATIS evaluations—MMDI—was Web-based, many of the user suggestions below refer to website enhancements.

Real-time transit information on Web, by phone, at bus stops, and on monitors at malls and office parks near major transit centers

Transit riders would like more and better information on location and arrival/departure time of their bus, and on any connecting bus their trip may require. They would like convenient access to the information through a variety of media and at bus stops. Some respondents suggested an abbreviated key sequence for mobile phone users that would connect directly to an automated bus status line, similar to mobile phone services offered for traffic information. Other respondents felt that it would be useful to have real-time bus information provided on monitors in nearby shopping malls and office buildings.

More sophisticated and detailed Web interfaces

Transit riders who are Internet users would like to see transit websites that fully exploit the potential of the Web to use multiple information dimensions. Survey respondents complained about two-dimensional sites whose pages function like pages in a book and do not take full advantage of the medium's capabilities.

Point-to-point itineraries (Web)

Riders would like to be able to enter origin and destination, whether by point-and-click on a map, or through addresses or landmarks, and receive a detailed, printable transit trip itinerary, including travel time, relevant fares, and schedules.

Point-to-point itineraries for multi-modal trips (Web)

Similar to the request above for transit trips, riders would also like to receive trip itineraries that incorporate other modes of travel.

Recommended trip times and routes for fastest travel (Web)

Some transit riders expressed a desire to be able to enter their origin and destination and be told which times of day and which bus routes would get them to their destination in the least amount of time.

Detailed maps of routes, with stops, and transfer locations (Web)

In Seattle, focus group participants described the difficulty of being able to interpret from a route map or schedule where the bus stopped, and, in particular, where to go for the transfer bus. They would like access to more detailed street maps showing exactly where each bus stops.

Secure on-line bus pass purchases (Web)

Customers would like a secure way to purchase transit passes on-line, rather than travel to a transit center to purchase passes in person.

WHICH ATIS SERVICES AND VENUES HAVE NOT WORKED AND WHY

Unsuccessful ATIS traffic applications[9]

Traffic kiosks

Kiosks and WinCE mobile computers, as deployed and evaluated for the MMDI, did not prove to be popular ATIS venues for traffic information. For kiosks, the problems included poor placement in relation to the trip decision, unreliable performance, and a challenging user interface. Customer interest in traffic information on kiosks seems to improve where the kiosk offers additional services and information.

Two other consumer information venues were abandoned in 1995 following earlier market deployments: faxed traffic reports and single-purpose in-vehicle traffic information devices. The lack of consumer response to faxed traffic reports can likely be attributed to a variety of factors, including new product inertia, low-quality information, and insufficient marketing. Single-purpose in-vehicle traffic information devices, regardless of platform, suffered from poor-quality information relative to cost, premature marketing, and consumer resistance to single-purpose electronic devices.

The jury is still out: Current ATIS traffic applications

Cable television (as deployed and evaluated)

Traffic information was broadcast on cable community access channels as part of the MMDI in Seattle and Phoenix. Response to the surveys was not strong, which may be a function of low viewership. Most respondents reported learning about the broadcast when channel surfing. Commercial television ratings do not include such stations, so there is no way to know actual viewing levels. Traffic information on television will likely develop into a more valuable venue for travelers, especially for the morning commute trip, as marketing improves viewer awareness of the broadcast and user interface quality is improved.

Survey respondents who were viewers found the service more useful than traffic information on the radio. For those people who are traffic information consumers, as with many respondents in Seattle, TV fills a "low-engagement" niche: very little

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[9] These applications were unsuccessful as evaluated in the context of the MMDI; they may be successful in other settings or in the future.

effort is required to turn on the television and absorb the message. In contrast, the Internet is frequently a "high-engagement" medium because of the time and attention required to boot a computer, connect to the Internet, open the website, and find the needed information. The value of the service is linked to the quality of information, including coverage and presentation. More viewers watch in the morning than in afternoon, and there appear to be more viewers in the more congested region of Seattle as opposed to Tempe, Arizona, which has far lower congestion levels.

Traffic information on WinCE mobile computers

Traffic information on mobile hand-held computers was available as part of the MMDI in Seattle and Phoenix, but received little notice from travelers, probably because of low market penetration of the WindowsCE devices and insufficient marketing and promotion of the new traffic information services. This venue for traffic information should be reconsidered with better market conditions and should become a more popular venue as wireless communications improve.

In-vehicle navigation devices (as observed)

In-vehicle navigation systems are available primarily in rental cars and as an option in luxury cars, including those made by Range Rover, BMW, Porsche, and Jaguar. The number of car manufacturers with the navigation system option is expected to double from the 2000 to the 2001 model year. A low level of customer demand beyond these markets stems from high price/value ratios for most drivers. Some demand exists for units in the aftermarket, but manufacturers find current sales levels disappointing. Developers insist that the product will not achieve market potential until real-time traffic is integrated into the routing algorithm. Ultimately, navigation and route guidance will be part of broader functioning in-vehicle information systems.

The jury is still out: ATIS transit applications[10]

Kiosks

As with traffic information, kiosk-based transit services (as deployed and evaluated) suffered from frustrating user interface, unreliable performance, and no marketing. Examples may exist of transit information kiosks located in pedestrian areas, convenient to the transit system entrance, that provide riders with useful information; however, few evaluations have been made of kiosks as ATIS venues. Therefore, transit kiosks should not be abandoned as an information platform based on evaluation findings to-date.

WinCE mobile hand-held computers

Mobile hand-held computers as platforms for transit information (as deployed and evaluated) suffered from low market penetration of devices and insufficient marketing and promotion of services. Once mobile two-way computers and telephones become more functional and more common, the platform should provide those riders who own them a convenient method for accessing real-time transit information.

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[10] These transit applications were unsuccessful as evaluated during the MMDI evaluation period, 1997-1998; they may be successful in another context or at another time.

ATIS BUSINESS MODELS: A WORK IN PROGRESS

Business models for delivery of and payment for ATIS services are still in flux. Currently, ATIS is one component of the much larger information services business. The telematics business considers ATIS traffic information (but generally not transit information) as one of several mobility services included with navigation, concierge services, personal safety, and security. Understanding has evolved over the past decade of how ATIS would be sold, in response to several factors, including changes in the underlying technology, our understanding of the customer, and, in the case of the Internet, the basic business proposition.

Currently, approximately a dozen private companies are seeking to "package" traffic information and sell it at a profit to consumers. Some of the companies are closer to the raw traffic information data and make their business by creating a standardized traffic information product to sell to information service packagers and retailers, such as I3, OnStar,™ and ATX. A subset of traffic information companies supplements public sector traffic data with proprietary data obtained with cameras, private probes, and aircraft. Approximately a half dozen companies are also working to sell ATIS directly to consumers, primarily through the Internet. The Web-based companies have a two-part approach: (1) making general traffic information available free on their websites, usually combined with advertisements; and (2) providing customers interested in more tailored traffic information subscription services with personalized traffic alerts delivered at the times and on the media of their choosing. Also on the retail side of the business are manufacturers of in-vehicle information systems and navigation devices, as well as on-line navigation services like MapQuest, Telcontar, and Rand McNally, which seek to offer their customers the added dimension of real-time traffic route guidance.

ATIS companies face multiple challenges:

- The underlying "product"—real-time traffic information—cannot be manufactured in a controlled environment; instead, it must be collected by individual agreement with each state and transportation authority, or in some cases with private companies, across the country.

- The data are variable in scope and quality and are provided in nonstandardized formats. This condition creates an obstacle for information wholesalers and telematics service companies who require that their consumer services be uniform in quality and available nationwide.

- No established consumer market exists for real-time traffic information other than radio broadcast reports.

While the tools used to measure and record traffic data have remained relatively stable until now, the media used to communicate with consumers has changed dramatically over the past five years, perhaps improving market opportunities for ATIS, but almost certainly diverting companies' product development resources.

Telematics platforms, such as in-vehicle PCs and navigation devices—an important venue for sale of traffic information services—have been slower than expected to

market, and much slower to reach middle market prices needed for more popular customer acceptance.

The geocode used by one major traffic information supplier to identify the location of traffic is inconsistent with the geocode embedded in another major manufacturer's map database and navigation software. This problem is currently being addressed in an ITS America telematics industry forum.

An uncertain profit horizon has constrained private investment in ATIS businesses. Competition for venture capital is fierce, and the best ranked opportunities have established consumer demand, a standardized product, and no dealings with government agencies. Because government is not motivated by the same market logic as business, venture capitalists are hesitant to invest in companies whose product depends in any measure on government resources or cooperation.

Thus far, the bulk of funds invested in the development and dissemination of ATIS have come from the public sector, and none of the private sector ATIS companies dealing in traffic information services have made a profit on that service in the United States.

Proof through current operational tests that mobile phones can function as traffic probes will significantly affect the ATIS business model. First, it creates the opportunity for a national, standardized source for traffic information. This circumstance will provide businesses with the possibility of contracting with only one source for traffic data, rather than the myriad sources tapped now. It may solve the problem of variable service quality. If successful, it will reduce ATIS operating costs, although some of the cost will shift to purchasing data. And, of particular importance to the growth and development of this business niche, mobile phone traffic data will reduce or remove ATIS businesses' dependence on public sector data sources and improve its ability to attract venture capital and other private investments.

WHAT THE FUTURE MAY HOLD

The Internet has had the effect of increasing consumers' expectations of information availability, quality, and responsiveness. This effect is readily seen among ATIS website customers, who are encouraged by sites that continually improve functionality and features, and are likely to stop consulting websites that do not. Each month, additional households invest in Internet connections. As a consequence, it is likely that all types of services will establish websites to communicate with customers. To attract and retain Internet customers, ATIS sites must improve in line with the medium as a whole and with customers' expectations.

Several new venues for ATIS traffic and transit services are emerging on the market: mobile hand-held computers, Internet phones, and in-vehicle information systems. All three will rely on the evolution of the WAP currently under development and endorsed by the telematics industry. It will enable mobile, direct two-way wireless access to the Internet, which will simplify the current wireless information delivery path to customers and enable faster personalized Internet access. The market penetration of these devices is expected to be significant.

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On July 21, 2000, the FCC assigned a national three-digit traveler information number, 511, to give callers quick access to traffic and transportation information. Advocacy for a uniform, national three-digit access code came from both public and private sectors, with the expectation that one uniform, national access number would improve customer service and reduce operating and marketing costs. U.S. DOT has made $5 million available to states for conversion to 511. ATIS service providers anticipate that 511 will help to increase customer awareness and use of ATIS services nationwide.

Integrated in-vehicle information systems are envisioned to connect all aspects of the automobile's maintenance and operating systems with Internet access, entertainment and productivity programs, and mobile two-way voice and data exchange. In addition to WAP, two recent industry protocols enable this service: the ITS Data Bus (IDB) will provide plug-and-play standards for in-vehicle telematics applications, while the Automotive Multimedia Interface Consortium (AMIC) will provide corresponding vehicle electronics interfacing applications with the automobile operating system. Consumer interest in the in-vehicle system is expected to be high.

The widespread practice of driving while using mobile telephones and other wireless communications devices has created new highway safety hazards. Research findings from the National Highway Traffic Safety Administration suggest that "as use of in-vehicle wireless communications technology increases there will be an associated increase in crashes if little changes" (U.S. DOT, Investigation of Safety Implications, Nov. 1997). Further research is required to establish standards for safe use of in-vehicle communications devices, including mobile phones, PDAs, and in-vehicle computers.

Conversely, mobile phone users have helped to improve incident management and emergency response times by phoning police immediately following traffic accidents and other highway incidents. Increased use of in-vehicle telematics devices that automatically notify police in the event of an airbag deployment may further improve incident management and emergency response times.

NEXT STEPS

A set of working hypotheses was developed from the MMDI customer satisfaction evaluation findings that may explain why some regions have stronger ATIS customer response than others. The hypotheses describe external conditions for high-demand ATIS markets, ATIS customer characteristics, valued ATIS service features, and traveler behavior in the presence of traffic and transit information. While it is possible that these findings can be generalized to other regions with similar conditions and services, no data support the assertion. Additional ATIS customer satisfaction and traveler behavior research in regions with different network conditions and ATIS services would enrich our understanding of how to accelerate the deployment of ATIS consumer services.

More data are available to describe customer response to ATIS traffic information than customer response to ATIS transit information, partly because of the limited number of ATIS transit services available for evaluation. Further, while the potential size of the traffic information market is quite large and national in scope, the corresponding market for transit information is much smaller. Private sector firms with interest in the ATIS consumer services market may neglect transit information services for lack of market size and lack of consumer response data. In the absence of reliable data describing the impact of ATIS on ridership levels, public transit authorities—faced with competing needs and limited funds—neglect ATIS investments. More customer evaluation data may help to accelerate deployment of ATIS for transit customers and enable a more thorough evaluation of the influence of information on ridership levels, retention, and mode choice.

Finally, many ATIS program managers and several evaluation findings have observed that ATIS services are not well-known among potential customers. Very few, if any, ATIS deployments have been sufficiently well capitalized to afford an advertising campaign. The subsequent lack of awareness among potential ATIS customers has slowed ATIS deployment, as it is difficult for potential investors to distinguish between lack of interest and lack of awareness among travelers. ATIS services require advertising if they are to attract customers and achieve success, whether measured as constituent service or as profits.

ACKNOWLEDGMENTS

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chapter 5

WHAT HAVE WE LEARNED
ABOUT ADVANCED PUBLIC
TRANSPORTATION SYSTEMS?

EXECUTIVE SUMMARY

This paper discusses advanced public transportation systems (APTS) technologies, assesses the extent of their deployment, and judges their degree of success. While it covers APTS technologies in use by bus and demand-response service operations, rail and ferryboat services are beyond its scope.

The primary source of deployment-level information is a 1998 survey by the John A. Volpe National Transportation Systems Center (Volpe Center) that encompassed 525 transit agencies operating fixed-route bus and/or demand-response services (Casey 1999). This data source differs from that used in other chapters of this report (78 metropolitan areas as opposed to transit agencies) and, consequently, deployment levels for a technology here could differ from those determined in other chapters for the same technology. Using the selected deployment level standards outlined in Chapter 1,[1] APTS technologies have reached the deployment levels shown in Table 5-1.

Table 5-1. APTS Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Automatic vehicle location	Moderate Deployment	Cost, fleet size, service type, staff technological competence	**Successful**—use continues to grow, new systems principally use GPS technology but usually augmented by dead reckoning
Operations software	Widespread Deployment	N/A	**Successful**
Fully-automated dispatching for demand response	Research & Development*	Still in research and development stage	**Jury is still out**
Mobile data terminals	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—reduces radio frequency requirements
Silent alarm/covert microphone	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—improves security of transit operations
Surveillance cameras	Limited Deployment*	Cost	**Holds promise**—enhances on-board security. Deters vandalism
Automated passenger counters	Limited Deployment	Cost	**Holds promise**—provides better data for operations, scheduling, planning, and recruiting at lower cost

[1]The three different deployment levels used in this paper are defined as follows: Deployed in fewer than 10 percent of the 525 transit agencies surveyed = Limited Deployment; Deployed in between 10 percent and 30 percent of the 525 transit agencies surveyed = Moderate Deployment; Deployed in more than 30 percent of the 525 transit agencies surveyed = Widespread Deployment.

Table 5-1. Continued

Technology	Deployment Level	Limiting Factors	Comments
Pre-trip passenger information	Widespread Deployment	N/A	**Successful**—improves customer satisfaction
En-route and in-vehicle passenger information	Limited Deployment	Cost, lack of evidence of ridership increases	**Jury is still out**
Vehicle diagnostics	Limited Deployment	Cost, lack of data on benefits	**Jury is still out**
Traffic signal priority	Limited Deployment	Institutional issues, concerns about impacts on traffic flows	**Holds promise**—reduces transit trip times. May reduce required fleet size
Electronic fare payment	Limited Deployment	Cost	**Holds promise**—increases customer convenience

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

All the above technologies have been proven to work and are in full operation at varying numbers of transit agencies. Agencies have reported benefits resulting from implementation of each of these technologies. Although some benefits have been quantified, most of those reported herein are claims or statements from deploying agencies. In spite of the lack of quantified benefits, transit agencies that have deployed or will soon deploy APTS technologies have concluded that potential benefits of the added functions and services that these technologies provide outweigh the capital and operating expenses. Several transit agencies have stated that a principal reason for installing APTS technologies is to help them provide better service for customers and safer service for both customers and vehicle operators.

Despite measured benefits and other benefits realized but not measured, many agencies are not considering APTS technologies. Possible reasons include cost (although some less sophisticated, low-cost APTS systems are available),[2] a lack of awareness of benefits, small fleet size, type of service provided, resistance to change, and absence of personnel knowledgeable about APTS. Nevertheless, a comparison of results from the most recent Volpe Center survey and a previous survey (Casey and Labell 1996) revealed that APTS technology deployments increased substantially between 1995 and 1998. Deployments are expected to continue to increase faster for those making up the more basic elements of APTS deployments (e.g., automatic vehicle location [AVL], operations software, mobile data terminals, silent alarms, and covert microphones). Also, greater use of AVL data is expected in the areas of real-time service adjustments, scheduling changes, route planning, and customer information.

[2] Some less sophisticated, low-cost APTS systems are available for purchase, as evidenced by the figures in the lower end of cost ranges contained in the technology discussions. However, these systems will not provide the functionality many transit agencies desire.

INTRODUCTION

The Federal Transit Administration created the Advanced Public Transportation Systems program as its part of the U.S. Department of Transportation's (U.S. DOT's) National Intelligent Transportation Systems (ITS) Program. The APTS program was established to encourage use of current and emerging technologies in the fields of electronics, information processing, information displays, computers, and control systems to improve the quality and usefulness of public transportation services. Effectively integrated and deployed, APTS technologies can enhance safety, transportation mobility, operational efficiency, and environmental protection.

The objective of this paper is to assess which APTS technologies have been successful, which ones have not been successful (and why), where success is unclear, and what can be expected in the future. The following APTS technologies are discussed:

- Automatic vehicle location.
- Operations software.
- Mobile data terminals.
- Silent alarms/covert microphones/surveillance cameras.
- Automatic passenger counters.
- Automated passenger information.
- Vehicle diagnostics.
- Traffic signal priority.
- Electronic fare payment.

Although not a "technology" itself, integration is also discussed, as it is a major factor in the successful implementation of APTS and is usually the most difficult implementation issue.

The technologies discussed herein have all been installed by at least some transit agencies and are in full operation at those sites. Deployment information, except for data on Internet websites, was collected during the fall of 1998 and was published by the John A. Volpe National Transportation Systems Center. In the Volpe Center survey, 525 transit agencies operating fixed-route bus and/or demand-response services were interviewed to determine their level of APTS technology deployment. This database differs from that used in Chapters 2, 3, 4, and 6, which used data from the 78 largest metropolitan areas rather than from individual transit agencies. Consequently, the deployment levels identified here may be different from the deployment levels for the same technology reported in other chapters.

The benefits discussed in this paper are primarily findings from other APTS research and evaluation activities, and consist mainly of claims or statements from deploying agencies. Useful input was also received from attendees at the transit management roundtable session at the Institute of Transportation Engineers (ITE) 2000 International Conference, held in Irvine, California, in April 2000.

Capital cost information, obtained in the Volpe Center study, was not included in the published report. (Collection of cost data was not a major objective for the

survey, but agencies did provide some acquisition cost information.) Other cost data for certain APTS hardware and software components can be found in the ITS Joint Program Office (JPO) database compiled by Mitretek Systems from a number of studies and plans.[3] Additionally, the requirement in the Transportation Equity Act for the 21st Century (TEA-21) that all recipients of ITS deployment program funds report cost information should provide much more cost data in the future.

Agencies surveyed in the Volpe Center deployment study were unable to provide any real useful information on the cost of operating APTS technologies. Although operating cost is an important consideration, most agencies deploying transit APTS did not have reduced operating costs as an objective. In fact, many agencies will experience an increase in operating costs stemming from additional dispatching and information technology staffing requirements and equipment maintenance expenditures. Potential operational cost savings will result from deployment of some APTS technologies, however, which can reduce other operational expenses, as illustrated in the discussions of individual technologies. As several transit agencies have stated, a principal reason for installing APTS technologies is to help them provide better service for customers and safer service for customers and vehicle operators. The ability to automate the provision of transit information to potential customers has also been a consideration for some agencies.

APTS TECHNOLOGIES

The following sub-sections describe the various APTS technologies, their benefits, their level of deployment, and their costs (where available).

Automatic Vehicle Location

AVL is a computer-based tracking system. For transit, the actual real-time position of each transit vehicle is calculated and relayed to a control center. The three principal methods of determining vehicle position are as follows: using signals from signposts, dead-reckoning, and using signals from global positioning system (GPS) satellites.

In the signpost system, a series of radio beacons or signposts are placed along the routes. A short-range communication device on the vehicle receives the identification signal transmitted by the signpost. Because location of each signpost is known, vehicle location is determined at the time of passing. The distance traveled since passing a signpost, as measured by the vehicle odometer, is used to estimate the vehicle position along its route at any given time. However, this method is limited because signposts are placed at fixed locations. Thus, changes in routes could require the installation of additional signposts. Additionally, the system is incapable of tracking vehicles that stray off route.

Dead-reckoning is a method of determining vehicle position by measuring distance traveled from a known location (through odometer readings) and direction of travel (through compass headings). Because this method of position determination is less

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[3] These data can be accessed through the ITS Benefits and Costs Database at http://www.mitretek.org/its/benecost.nsf.

precise than the others, dead-reckoning is usually supplemented by GPS or a few strategically placed signposts to recalculate position at certain intervals.

GPS technology uses signals transmitted from a network of satellites orbiting the earth and received by a GPS antenna placed on the roof of each vehicle. A GPS receiver, connected to the antenna, calculates position by measuring the antenna's distance (the travel time of radio signals) from at least three satellites. However, there are inaccuracies in the signal due to reflections by the atmosphere or from tall buildings. To correct for these errors, a measured GPS signal offset is used to adjust the calculated position. As a result of this differential correction, many GPS receivers can calculate position to within a few meters. GPS is the method of choice for most new AVL systems.

The two most common methods of transmitting location data to dispatch are through polling and exception reporting by means of wireless communications. Under polling, the computer at dispatch polls each vehicle in turn, asking for its location. Once all the vehicles have been polled, the computer starts again with the first vehicle and repeats the cycle. With exception reporting, each vehicle reports its location to dispatch only at specified intervals or when it is running off schedule beyond selected tolerances. Exception reporting makes more efficient use of available radio channels, which are often scarce commodities. Many agencies use a combination of polling and exception reporting.

AVL is the basic building block for other transit APTS applications that depend on knowing vehicle location. AVL provides the location data needed for operations software, silent alarms, automatic passenger counters, real-time passenger information, in-vehicle signs and annunciators, and traffic signal priority, based on schedule adherence. AVL provides transit agencies with much more and better data than they could previously afford to collect manually. Vehicle location data are used by many transit agency personnel, including dispatchers, vehicle operators, schedulers, planners, maintenance staff, customer information staff, and street supervisors. A major benefit of AVL is the dispatcher's ability to quickly send response personnel to the precise location of an incident or emergency. AVL-equipped buses can also act as probes for monitoring traffic flow on freeways and arterials. Another major benefit reported by transit agencies was improved schedule adherence:

- Milwaukee County Transit System, Milwaukee, Wisconsin, reported an increase of 4.4 percent, from 90 to 94 percent.
- Kansas City Area Transit Authority, Kansas City, Missouri, reported a 12.5 percent increase, from 80 to 90 percent.
- Regional Transportation District, Denver, Colorado, reported an increase of between 12 and 21 percent on various routes.

Despite the benefits AVL systems can provide, they had achieved only moderate deployment status in 1998, with just 61 agencies (12 percent) having fully operational systems.

Although the cost of an AVL antenna and receiver is relatively modest, agencies reporting AVL costs in the Volpe Center study typically included all APTS

technologies implemented in conjunction with AVL: software, dispatch center equipment, mobile data terminals, silent alarms, covert microphones, new or upgraded communications, and possibly automatic passenger counters. Reported costs for AVL systems ranged from $1,200 to $23,000 per vehicle, with a median cost of about $8,000. Three groupings of costs were evident. One group of six systems fell between $1,220 and $2,500 per vehicle. Another grouping of seven systems fell within the $6,500-$9,600 cost range. Six systems in the third group ranged in cost from $11,000 to $18,000. Finally, there was a single outlier cost of $23,000 per vehicle. Some systems include AVL for both fixed route and demand-response services. The wide range of costs can be attributed to the differences in the number and functionality of the APTS applications specified, the variation in the number of vehicles to be equipped, and the amount of customized software required. Agency staff costs for system development and training are typically not included in cost calculations.

Operations Software

Operations software is used to develop and display information for a variety of transit decision-making activities. Software is a key element of APTS installations, and a geographic information system (GIS) is a major software component.[4] AVL system software can combine vehicle location data with map data and display them on dispatchers' computer monitors, together with attributes easily customized by each transit agency (e.g., vehicle status, vehicle operator, schedule adherence, and incident information).

Software programs can assist transit agencies in performing a number of functions. Software programs currently support bus dispatchers in making real-time service adjustments (when service begins to deteriorate[5]) and in directing response to vehicle incidents and emergencies. Software programs prioritize calls from vehicle operators for response by the dispatchers and automatically record and print reports of AVL and various other information desired by the agency. Software can provide data to coordinate the intra- or intermodal transfer of passengers from one vehicle to another where services intersect—either through dispatcher involvement or direct vehicle-to-vehicle contact. Software programs can calculate whether traffic signal priority should be requested based on schedule adherence and, in more advanced concepts, on the bus load factor (if real-time information is available from an automatic passenger counter). Programs can assemble and analyze data from different sources to provide assistance to the following:

- To schedulers in adjusting schedules.
- To planners in adding or reducing service.
- To maintenance staff in programming preventive maintenance or identifying vehicles with potential maintenance problems.

[4] GIS is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates.

[5] A research initiative undertaken by the John A. Volpe Center and the Massachusetts Institute of Technology will develop software to automate the service adjustment process when the system recognizes that service is deteriorating.

- To customer information staff for answering information requests or providing trip itineraries.
- To street supervisors for monitoring service.
- To administrative staff for generating reports.
- To operations staff to play back vehicle runs for checking operator performance or customer complaints.

Software is also used in the scheduling, dispatching, recordkeeping, and billing for demand-response services. The Winston-Salem Transit Authority, Winston-Salem, North Carolina, reduced operating cost by 8.5 percent per vehicle mile with computer assisted dispatching (CAD) software. Blacksburg Transit's CAD software helped the agency increase passenger-carrying productivity from 0.8 to 2.0 passengers per vehicle hour. Higher-end systems able to receive trip requests by touch-tone phone, schedule trips, and transmit vehicle schedules to operators without manual intervention offer even greater potential for enhanced efficiency.

A total of 170 transit agencies, or 32 percent, have used software to assist certain tasks, helping operations software attain widespread deployment. However, despite potential benefits, few agencies with AVL systems exploit the software's full capabilities. As yet, most agencies are not using software to analyze schedules, plan service changes, coordinate transfers, or provide real-time information to customers. Much greater use could be made of some software applications that offer significant benefits.

The cost of operations software is seldom separated from the overall cost of an AVL system. However, the contract price for the 1,335-vehicle AVL system for the Regional Transportation District in Denver, Colorado, listed operations software at approximately $1.4 million (Weatherford and Castle Rock Consultants 2000). More software cost data are available for demand-response services. The cost of demand-response software reported by close to 50 agencies in the Volpe Center study generally ranged from $15,000 to $120,000, with exceptions being three agencies placing it at less than $10,000 and seven agencies at $300,000 or more. The median value was $50,000. As with AVL cost figures, demand-response software cost rises as the level of sophistication and the number of functions desired increases.

Mobile Data Terminals

A mobile data terminal (MDT) is an in-vehicle device with a small screen to display messages and time, plus a series of buttons to send preset messages to the dispatch center. Where installed, MDTs are the primary communications means between operators and dispatchers. In AVL-equipped vehicles, the MDT-type device is usually augmented by computational capability that calculates vehicle location, compares location and time to the schedule, and determines the vehicle's schedule adherence, which can be displayed on the screen. This combination is commonly called an in-vehicle logic unit. For purposes of this discussion, the term "mobile data terminal" represents both devices.

The ability to send preset messages with the push of a button makes it easy for operators to report certain occurrences to the dispatch center. Examples include

mechanical problems, vehicle stuck, fare dispute, lift not working, relief not arrived, etc. The "request to talk" and the "priority request to talk" buttons are the means by which the operators notify the dispatchers that they wish to talk via radio. Dispatchers contact operators either by radio or through messages sent to their MDTs. Voice or MDT messages can be directed to an individual bus, specific groups of buses, or the entire fleet.

Use of MDTs has reduced voice radio traffic by as much as 70 percent for the Ann Arbor Transportation Authority, Michigan, and the Rochester-Genesee Regional Transportation Authority, New York. This voice traffic reduction may reduce the number of voice channels an agency requires. A reduction in voice traffic can be an important result, where available radio frequencies are scarce and highly sought-after by other agencies—the case in many locations.

MDTs are also used to coordinate vehicle-to-vehicle transfers of passengers on intersecting routes. MDTs allow vehicle operators to coordinate the transfers directly, without dispatcher involvement. Connection coordination can be an important customer satisfaction consideration, as missed connections—especially on long headway routes—can discourage future patronage by affected riders.

MDTs are also useful in providing routing instructions and messages to demand-response vehicles. MDTs can provide an electronic manifest of customer pick-ups and drop-offs. Use of MDTs can also facilitate additions or deletions to the vehicle's otherwise predetermined route. MDTs are particularly useful for those agencies dispatching in real time.

The number of transit agencies employing MDTs is unknown, as the Volpe Center study did not track this technology. Virtually every AVL system would be expected to include MDTs; in fact, there would likely be more MDT systems than AVL systems, because MDTs are deployed in demand-response systems that do not have AVL. Therefore, MDTs are presumed to have achieved the moderate deployment level.

Although not specifically covered in the Volpe Center study, one agency quoted a price for MDTs as part of its software procurement. Pierce Transit, Tacoma, Washington, paid $330,000 for MDTs for their 92 demand-response vehicles, or slightly under $3,600 per unit, including software.

Silent Alarm/Covert Microphone/Surveillance Cameras

Silent alarms, covert microphones, and surveillance cameras installed in vehicles enhance the safety and feeling of security of operators and passengers. The silent alarm system consists of a button placed in a concealed location near the driver. When pushed, it activates an alarm in the dispatch office. With most AVL systems, the vehicle from which the alarm was sounded is more frequently tracked than with the normal polling interval, and the dispatcher has the ability to open a secret microphone on the vehicle to try and ascertain the problem. What the dispatcher hears through the microphone is useful in helping to decide the type of assistance to send to the vehicle. The AVL system provides vehicle location so response personnel can proceed to its exact position.

Surveillance cameras have also been placed on some vehicles. These cameras can capture a picture of individuals who cause incidents and may discourage criminal activity. The pictures have also been used to check the validity of personal injury claims made by persons alleging to have been injured on the vehicles. The images may be stored on the vehicle for later download, or relayed to dispatch in near real time.

Measurements of safety or security improvements from AVL system implementations have been scarce. However, Denver's Regional Transportation District reported a 33 percent drop in operator and passenger assaults after AVL, silent alarm, and covert microphone system installation.

The Volpe Center study did not track deployment of silent alarms, covert microphones, and surveillance cameras. Nevertheless, it is presumed that two of the three devices have achieved moderate deployment, as virtually every AVL system includes a silent alarm and most have a covert microphone. Silent alarm systems could even outnumber AVL systems, as they can be installed without an AVL system. In such instances, if the operator is unable to tell the dispatcher his or her position, the dispatcher must use judgment to ascertain the vehicle's location. To date, only a few surveillance camera systems have been installed, cost probably being the limiting factor.

The Volpe Center study did not solicit any cost figures for these technologies.

Automatic Passenger Counters

Automatic passenger counters (APCs) are devices that automatically collect data on passenger boardings and alightings. APCs have three basic components: (1) a method of counting each passenger boarding and disembarking, and a method of distinguishing between the two; (2) a technology able to determine vehicle location when boarding and disembarking occur; and (3) a data management system capable of transmitting the data in real time or storing the data for later transfer and use. Counters are usually treadle mats placed on the steps or infrared beams projected horizontally or vertically at each doorway.

APCs provide much more ridership data than agencies previously collected at a lower cost. Further, a few agencies have stated that APC data are more accurate than those collected manually. Ridership data may be used in several ways, including for National Transit Database reporting, route analysis and planning, adjustments to schedules, and new passenger shelter positioning. These data could also be used to monitor load factors in real time for possible insertion of additional vehicles when circumstances warrant. The Metropolitan Atlanta Rapid Transit Authority, Georgia, reported $1.5 million in operational savings through adjustments to schedules using AVL and APC data.

APCs are not included with all AVL systems. Twenty-four agencies (5 percent) with existing APC systems were recorded in the Volpe Center study. The most likely reason for limited deployment of APCs in the past has been cost. Some older APC installations cost between $5,500 and $6,250 per vehicle (Alameda Contra Costa Transit District, Oakland, California; Central Ohio Transit Authority, Columbus,

Ohio; and Bi-State Development Agency, St. Louis, Missouri). As the cost per unit appears to be decreasing, based on recent cost figures ($2,500 at San Joaquin Regional Transit District, Stockton, California; $1,600 at Ventura Intercity Service Transit, Ventura, California; $1,200 at Tri-County Metropolitan Transportation District, Portland, Oregon), APCs should become more prevalent. The decrease in cost for these agencies likely stems from the inclusion of APCs as part of a package of APTS technologies rather than stand-alone systems. It is also possible that the sale of more units and advances in component technology have helped to decrease unit cost.

Automated Passenger Information

There are several types of passenger information and methods of delivery. Information can be provided to customers and potential customers before they begin their trip, while they are en route but not on board a transit vehicle, or after they are on board a transit vehicle. Overall, automated information is widely deployed. However, when separated by the individual types of information, only pre-trip information systems have been widely deployed, while en route and in-vehicle information systems achieved only limited deployment. Probable reasons for lack of greater deployment of en route and in-vehicle information systems are that they are nonessential, extra-cost items, with no solid evidence of their increasing transit ridership.

Pre-trip information can consist of routes, maps, schedules, fares, fare media, and park-and-ride lot locations. Information can include real-time vehicle arrivals and full trip planning itineraries. Devices used to obtain pre-trip information include the telephone, the Internet, pagers, personal digital assistants, and cable television (TV). Depending on their location, kiosks could also provide pre-trip information.

Automated pre-trip information is consistent and more accurate than that relayed by information operators. Accurate information, especially real-time information, reduces the anxiety of transit use and is particularly important for longer headway routes. Real-time vehicle arrival information allows passengers to time their arrival at stops, thereby reducing their wait time and exposure to weather and criminal elements. Not all agencies that could give real-time information to passengers are planning to provide it, for fear the information will not be accurate and passengers will miss their buses.

Automating the information provision process, particularly with voice response units, has reduced the telephone wait time of customers wanting information (from 85 seconds to 27 seconds at New Jersey Transit) and increased the call handling capability and productivity of transit information centers (a 21 percent increase in San Diego County). Fewer customer information staff may be needed, as the Rochester-Genesee Regional Transportation Authority has reported.

Telephone and the Internet are the most generally available and frequently used methods of obtaining pre-trip information for most people. A separate study by the Volpe Center of transit agency websites,[6] which most transit agencies have, reviewed the websites of 613 transit agencies operating bus or demand-response services.

[6] Results of the Volpe Center Internet website search can be found at http://transitweb.volpe.dot.gov.

Ninety-four percent, or 578, provided pre-trip passenger information (i.e., at least route maps or schedule/fare information). Twenty-five, or 4 percent, of sites allow customers to obtain origin-to-destination trip itineraries, although not always on-line.

Access by hand-held devices and TV are used to a much lesser degree, as there is low market penetration of hand-held devices, and the number of locations displaying transit information on TV is quite small.

Eight agencies with strictly automated telephone information provided cost data in the Volpe Center deployment survey. Six quoted acquisition and installation costs between $32,000 and $126,000, the mid-range being between $75,000 and $100,000. The two other agencies quoted costs of $400,000 and $1 million. Three agencies provided cost data for both telephone and Internet information. These cost figures were $23,000, $28,000 and $132,000. The cost to set up an Internet website was quoted as $1,000 and $4,000 by two agencies. No cost data were provided for other pre-trip delivery methods.

En route information such as vehicle arrival times (scheduled or predicted) can be provided by electronic signs, monitors, and kiosks. Signs and monitors are usually placed in passenger shelters or at transfer centers. Kiosks are usually placed at major activity centers served by transit.

The principal benefit of en route devices is the elimination of vehicle arrival uncertainty, which makes the passenger more comfortable using transit and may increase ridership. One liability has been travelers' perception of kiosks as frustratingly slow or frequently out of service.

The Volpe Center study found 21 agencies, or 4 percent, providing en route transit information. Even where en route devices were deployed, typically only a small number were actually installed in any service area because of their cost to purchase, maintain, and operate.

The only en route cost data provided were for kiosks. Three agencies quoted costs of $5,000, $6,250, and $15,000 per kiosk.

In-vehicle information is provided by electronic signs and automated voice announcements (annunciators) of stops and transfer opportunities. Electronic signs are usually placed at one or two high-visibility locations inside the vehicle.

Signs and annunciators relieve the operator of having to announce stops, as required by the Americans with Disabilities Act. These devices provide passengers with better information, as not all operators announce stops, and even those who do may be difficult to hear. Additionally, signs help hearing-impaired passengers and allow operators to drive more safely by concentrating on driving without having to make announcements.

The Volpe Center study found that 14 agencies, or 3 percent, provide in-vehicle transit information. This limited deployment probably stems from signs and annunciators being extra-cost, nonessential items.

No cost data were provided to the Volpe Center on in-vehicle signs and annunciators.

Vehicle Diagnostics

Vehicle diagnostics provide information to the dispatch center and the maintenance department of the transit agency about the condition of certain vehicle components. This information is acquired through sensors connected to the components to be monitored. Items frequently monitored include engine temperature, oil pressure, brakes, and tire pressure. Diagnostic information can be relayed to the dispatch center and/or the maintenance department in real time, which allows a vehicle to be taken out of service immediately if the problem is severe, or stored on the vehicle for later retrieval.

Diagnostic information warns of impending component failures when readings begin to exceed normal operating ranges. Attention to problems identified before failures occur should improve service reliability by reducing the number of vehicle break-downs and resulting service delays. Early detection can also prevent potentially serious situations or costly repairs or replacements.

Deployment of diagnostic systems is limited (12 agencies, or 2 percent). One possible reason is the lack of quantitative data on savings from advanced failure warning or reductions in on-road breakdowns.

The Volpe Center study did not solicit cost data for vehicle diagnostic systems.

Traffic Signal Priority

Traffic signal priority allows transit vehicles to progress along their routes with less delay at signalized intersections equipped with specialized receivers and controllers. A transit vehicle approaching a signalized intersection transmits a signal to the traffic signal controller. Depending on the traffic signal phase at the time the signal from the vehicle is received, the controller grants an extension of the green phase until the vehicle passes, or until advancement of the next green phase. The signal from the vehicle to the traffic signal controller can be sent manually or automatically if the vehicle is AVL-equipped. Similarly, transit vehicle priority can be employed at signals that meter the flow of traffic at freeway ramp entrances. Another method of transit priority is to provide an exclusive transit lane at the intersection and give that lane an advance green phase so that transit vehicles can start ahead of traffic. No information was uncovered on signal preemption for transit, which would immediately turn the traffic signal to green upon a transit vehicle's approach.

Signal priority produces faster, more reliable transit service and reduced operational cost. Six agencies (Kitsap Transit, Bremerton, Washington; Pierce Transit, Tacoma, Washington; Annapolis Transit, Anne Arundel County, Maryland; Phoenix Transit, Arizona; Metropolitan Atlanta Rapid Transit Authority, Georgia; and Los Angeles County Metropolitan Transportation Authority, California) have reported reduced travel times ranging from 4.2 percent to 19 percent from operation or tests of signal priority. (Other agencies benefiting from signal priority have not reported travel time changes.) If enough running time is saved, reduction in the number of vehicles needed to operate service may even be possible. However, resistance is often encountered from traffic departments of the cities and counties that control local streets, as granting priority for transit may degrade traffic flow. Granting transit

vehicles priority would have a greater impact on streets with progressive signal timing. Requesting priority only when transit vehicles are behind schedule by a certain degree or when carrying a sufficient number of riders can mitigate negative impacts. Another mitigating technique, as implemented by Montgomery County, Maryland, is to optimize travel for all individuals—private vehicle occupants and transit riders.

Sixteen transit agencies, or 3 percent, reported having priority for their vehicles at traffic signals. Several test installations, which showed significant benefits for transit operations, were never made permanent after the test period.

The cost of providing transit agencies with priority at traffic signals is normally a shared cost between the agency operating the traffic signal system and the transit agency. Two agencies reported on-board equipment costs: Pace Suburban Bus, Arlington, Illinois ($200-$250 per bus), and Ben Franklin Transit, Richland, Washington ($1,000 per bus). The Chicago Transit Authority cited an installation cost of $125,000 for five signalized intersections.

Electronic Fare Payment

Electronic fare payment (EFP) systems for transit are of two types—those that use magnetic stripe cards and those that use smart cards. Fareboxes that count and display the value of coins or tokens deposited are not considered APTS technology. Magnetic stripe cards require a contact between the card's stripe and a device that validates the card for the trip taken (i.e., a monthly pass) or a read-write device that can deduct the fare from the value stored on the card and restore the remaining balance. A smart card that contains a microprocessor may interface with the reader by direct contact or by radio frequency. A smart card can have both contact and contactless interfaces. Smart cards have greater security, higher reliability, and higher resistance to fraud than magnetic stripe cards, but are more costly. A major convenience of a contactless card is that it need not be removed from a wallet or purse as long as it passes close to the reader.

Both types of cards offer additional convenience for the rider, as there is no need for exact change or frequent standing in line to purchase tokens or tickets. Transit agencies can benefit from the reduction in the labor-intensive manual handling of cash, tickets, or tokens and the reduced chance of fraud or theft, which has saved millions of dollars for New York City Transit, for example. However, payment by cash on transit systems can probably never be totally eliminated.

Increased revenues result from reduced fare evasion, interest on the money between the time a card is purchased and the time it is used up, and, possibly, from increased ridership. Smart card systems provide added benefits of security for lost or stolen cards (if they are registered with the agency), discounts for frequent transit use, greater flexibility in fare products, and reduced paper transfers and equipment maintenance (owing to fewer fare collection equipment moving parts). Smart cards permit collection of more detailed ridership data for use in route planning and travel time studies. They also allow development of seamless regional, multi-agency, multi-application systems, including parking and retail. Contactless cards also result in faster throughput.

Excluding monthly magnetic stripe, pass-only systems, the Volpe Center study found 23 operational magnetic stripe (4 percent) and seven operational smart card (1 percent) fare collection systems. A probable reason for the limited EFP deployment is that replacing an existing fare collection system can be expensive. Capital costs for seven of the agencies providing EFP cost data ranged from $8,500 to $10,200 per vehicle. The other five agencies paid between $2,500 and $6,000 per vehicle. The median cost was slightly over $8,500 per vehicle. Some systems incorporate both magnetic stripe and smart cards.

Integration

The difficulty of getting systems to work together continues to be a major obstacle to successful APTS installation. The more APTS elements an agency implements, the more difficult the integration task becomes. The integration problem has been the cause of many delays, while recent transit APTS systems have been implemented more rapidly. Both the equipment and software have become more "off the shelf." Nevertheless, these improvements do not guarantee that implementations will proceed smoothly, on budget, or on schedule.

A principal integration problem involves software. For early systems, the software had to be newly developed—an arduous task. As experience is gained with more systems, the basic software has become more standardized and transferable. Nevertheless, because transit agencies do not all want the same features or capabilities, a certain degree of customization is necessary at each location. The less customization specified by a transit agency, the easier and quicker the installation will be. Also, developing input data for the software can be a considerable undertaking.

Although integration of APTS with other ITS services and modes has been limited to date, some notable examples of multimodal integration do exist. Houston TranStar's transportation management center (TMC) is staffed by City of Houston, Harris County, Houston Metro, and state personnel who cooperate on all aspects of transportation management. The New York City Metropolitan Transit Authority is implementing an AVL, which will provide real-time vehicle location and arrival information to TRANSCOM[SM] (Transportation Operations Coordinating Committee), where it will be widely available through the iTravel information network. The Metropolitan Atlanta Rapid Transit Authority receives live pictures of traffic conditions from the TMC's video cameras over a fiber optic cable and can choose which cameras to view, as well as point the cameras in the desired direction. In other locations, integration mainly takes the form of highway and transit agencies sharing traffic and incident information via telephone.

CONCLUSIONS

Using deployment criteria described in the Introduction, data from the Volpe Center reports place APTS technologies at the following levels, as depicted in Table 5-2:

Table 5.2. Deployment Levels for APTS Technologies

APTS Technologies	Deployment Level		
	Widespread	Moderate	Limited
Automatic Passenger Counters			❖
Automatic Vehicle Location		❖	
Electronic Fare Payment			❖
En Route Passenger Information			❖
In-Vehicle Passenger Information			❖
Mobile Data Terminals*		❖	
Operations Software	❖		
Pre-Trip Passenger Information	❖		
Silent Alarms/Covert Microphones*		❖	
Surveillance Cameras*			❖
Traffic Signal Priority			❖
Vehicle Diagnostics			❖

* Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Only operations software and pre-trip automated passenger information have reached the widespread deployment level. Given the number of agencies in the process of implementing or programming AVL systems (100 additional agencies), this technology will reach widespread deployment in a few years. Because mobile data terminals, silent alarms, and covert microphones are typically deployed with AVL systems, these technologies are also expected to reach widespread deployment status. Automated passenger counters (40 additional agencies), traffic signal priority for transit (40 additional agencies), and electronic fare payment (68 additional agencies) should attain moderate deployment status. Increases in deployment of vehicle diagnostic systems (31 additional agencies), surveillance camera, and en route and in-vehicle passenger information systems will likely not be sufficient to move these technologies out of the limited deployment category.

All APTS technologies appear to work and to provide benefits to the implementing agencies, as well as directly or indirectly to their customers. Agencies implementing APTS have expressly determined that the benefits outweigh the costs. A comparison

of data from the two Volpe Center deployment studies shows that individual APTS technology deployments increased by a minimum of 44 percent and a maximum of 160 percent over the three-year interval.

While this paper did not cover rail or ferryboat operations, technologies such as AVL operations software, surveillance cameras, automated passenger information, vehicle diagnostics, traffic signal priority, and electronic fare payment would apply equally as well to heavy and/or light rail systems, and, in some instances, to ferryboats.

From the customer perspective, APTS deployments can lead to measurable improvements in transit service and ease of use. However, whether these improvements appreciably change public perception and resistance to using transit is yet to be seen. There are many reasons why people do not ride transit, such as incompatible land-use patterns, free or inexpensive parking, lack of comfort and privacy, affordability of driving, and unsuitability for trip-chaining and carrying packages, which cannot be overcome by APTS applications.

From the transit agency perspective, APTS technologies offer a wide array of benefits. Some of the benefits have been measured, while many more have been realized but not measured. Nevertheless, many agencies still are not considering APTS technologies. For some agencies, certain APTS technologies may not be appropriate because of the small size of their operations or the type of services they provide. Other agencies may not be considering APTS technologies because of cost, lack of awareness of benefits, resistance to change, or absence of personnel knowledgeable about APTS. Also, APTS technologies have the reputation of being difficult to implement, although recent installations have been quicker and less troublesome. For the most part, technologies are proprietary from vendor to vendor and can be difficult to operate and maintain for transit agency personnel with little advanced technology experience. Many agencies are still uncertain as to how APTS can be used to fundamentally change transit operations and services for the better.

To overcome these deployment obstacles, agencies need to be more informed about the relative benefits and costs of APTS technologies, which requires that continued evaluations be conducted to quantify and publicize these benefits and costs. It is imperative that transit agencies be made aware of what works and how to implement these technologies. As such, education and training of transit agency personnel on APTS technologies is critically important. The APTS Mobile Showcase, a 48-foot expandable trailer that traverses the country functioning as a research laboratory, standards testing facility, and briefing room on wheels, is a step in this direction.

THE FUTURE

It is anticipated that:

■ APTS deployments will continue to increase and AVL, silent alarm, covert microphone, and automated passenger information technologies will likely reach widespread deployment levels.

- Implementation periods will be shorter as more experience is gained and the software becomes more standardized.
- More APTS technologies will be included in installations as more benefit and cost data from applications of these technologies are documented and publicized.
- Removal of selective availability (a degradation of signals from the orbiting global positioning satellites), announced in May 2000, has increased the accuracy of vehicle location GPS to the extent that the need for differential correction of the GPS location calculations may no longer be necessary.
- New software will be developed that will result in AVL data being used to a much greater extent in making on-street service corrections (in some cases automating this process), adjusting schedules, planning route changes, and providing customer information.
- Transit operations will increasingly be integrated with TMCs for sharing information on traffic conditions and incidents and, to a lesser extent, for providing traffic signal priority for transit vehicles.
- The cost of APTS implementations will continue to be a major impediment, although not the only impediment, to greater deployment.

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chapter 6
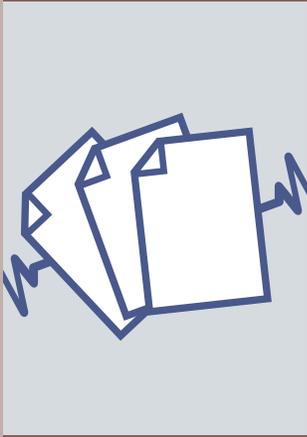
WHAT HAVE WE LEARNED
ABOUT ITS FOR COMMERCIAL
VEHICLE OPERATIONS? STATUS,
CHALLENGES, AND BENEFITS
OF CVISN LEVEL 1 DEPLOYMENT
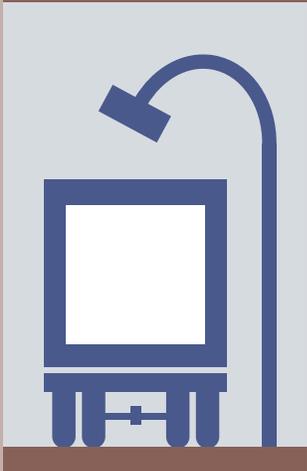
EXECUTIVE SUMMARY

Intelligent transportation systems (ITS) offer significant benefits to state motor carrier agencies, the motor carrier industry, and the traveling public. New and emerging technologies, information systems, and communications networks provide the framework for states, the Federal Government, and private stakeholders to electronically collect and exchange motor carrier safety and interstate registration and tax payment information. Use of these technologies supports initiatives by state and Federal agencies, in partnership with the motor carrier industry, to improve highway safety, simplify government administrative credentialing operations, enhance productivity, and reduce delays for safe and legal carriers.

The Federal Motor Carrier Safety Administration (FMCSA) established goals to reduce commercial vehicle fatalities 50 percent by 2010, with a baseline of 5,374 fatalities in 1998, and to reduce the number of persons injured in commercial vehicle crashes 20 percent by 2008, with a baseline of 127,000 injuries in 1998. An overriding objective of the ITS technologies designed for roadside operations is to reduce the number of crashes involving large trucks and the resulting personal injury and property damage. Using ITS technologies, enforcement personnel have access to up-to-date safety and credential information for motor carriers as well as for individual vehicles. This access can improve highway safety by allowing state and federal enforcement officials to concentrate their resources on high-risk carriers and vehicles.

Three main ITS technology areas designed for commercial vehicle operations (CVO) applications are safety information exchange, electronic screening, and electronic credentialing. Since 1991, the U.S. Department of Transportation (U.S. DOT) has sponsored numerous field demonstrations of new technologies. The Commercial Vehicle Information Systems and Networks (CVISN) Model Deployment Initiative (MDI) is one such test involving a handful of states. The goal of the CVISN program is to assist states in achieving an initial, "ambitious but achievable" level of deployment in the three technology areas discussed below. According to FMCSA, 38 states have indicated they are planning to achieve this initial level of deployment, called Level 1 (see Table 6-2 below and Richeson 1999), by September 30, 2003, depending on the availability of federal ITS deployment funds and state resources.

Safety Information Exchange Technologies

Safety information exchange technologies make more up-to-date motor carrier safety information available to enforcement officers at the roadside. The use of motor carrier and vehicle-specific safety performance data by state agencies conducting roadside inspections has grown significantly in recent years. As of December 1999, 84 percent of states were using Aspen, a software system that facilitates recording and processing of inspection data and provides historical information on the safety performance of motor carriers. Other advanced systems for exchanging safety information at the roadside are also being developed.

Electronic Screening Systems

Electronic screening systems allow certain commercial vehicles (e.g., those with good safety and legal status) to bypass roadside inspection and weigh stations. Such systems are technically feasible and offer tangible, time-saving benefits. Dedicated Short-Range Communications (DSRC) technologies provide reliable communication between moving vehicles and roadside enforcement operations. Much growth in electronic screening has occurred since the emergence of three programs: HELP (Heavy Vehicle Electronic License Plate) PrePass, NORPASS (North American Pre-clearance and Safety System), and Oregon's Green Light. Currently nearly half the states in the United States and nearly 7,000 motor carrier fleets are participating in such electronic screening programs.

The benefits of electronic screening, which are widely acknowledged, vary by carrier type and operating practice. Early field operational tests estimated an average time savings to participating motor carriers of between 1.5 and 4.5 minutes per bypass. States benefit from electronic screening in reduced inspection queues, which reduce the need and costs to build bigger weigh stations. Electronic screening also helps states focus more of their inspection resources on high-risk carriers. Most in the CVO industry agree that interoperability, or the ability for a vehicle to operate with the same equipment and under similar rules as it travels from state to state, is critical to the success of electronic screening at the roadside.

Electronic Credentialing Systems

Electronic credentialing systems provide for electronic administration of interstate registration, fuel tax payment, and other credentials. Preliminary estimates from systems deployed in Kentucky suggest that states and motor carriers using them can save up to 75 percent of the current costs for credentials administration. The integration of legacy credentialing systems with new applications requires careful planning. Sound technical leadership from state personnel familiar with the business application is also important. Two issues that concern the future direction of electronic credentialing are (1) determining data communications standards and protocols and (2) determining which software system (specialized computer programs or Web applications) motor carriers most prefer and accept. In cooperation with states and other stakeholders, FMCSA has taken a survey to evaluate its policy for electronic credentialing to determine needed changes. Results from this survey are expected in early 2001.

The Future

Some advanced roadside technologies, such as weigh-in-motion equipment and Aspen software, are already widely deployed. However, the type and amount of safety information for use during roadside inspections, or for selecting vehicles for inspection, is likely to change dramatically as faster and less costly wireless communication technologies become available. Systems such as SAFER (Safety and Fitness Electronic Record) data mailbox will permit greater use of vehicle-specific safety data (e.g., prior inspection results) during vehicle inspections. Thus, continued development and refinement of systems such as Aspen and CVIEW (Commercial Vehicle Information Exchange Window) are needed.

The growth in electronic screening is also expected to continue. However, carrier enrollment is heavily dependent on solving interoperability issues among the states. Furthermore, as states determine the type of bypass criteria to use, they must communicate these criteria to the carriers and, to the degree possible, establish some level of uniformity within key corridors.

Recent deployment successes, along with the desire to reduce credentialing costs, will help promote further deployment of electronic credentialing. It now appears that multiple solutions, including personal computer- (PC) and Web-based systems, as well as current "paper" systems, will be needed to satisfy the various needs of a diverse industry.

Table 6-1 presents the deployment status of the CVISN technologies that are part of Level 1 deployment, and identifies limiting factors for systems that are not widely deployed. Deployment levels, determined from surveys of states (Radin 2000, PTI 2000), are divided into three categories: Limited (less than 10 percent of states), Moderate (between 10 and 30 percent of states), and Widespread (more than 30 percent of states).

Table 6-1. CVISN Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Safety Information Exchange			
Laptop computers with Aspen or equivalent	Widespread Deployment	N/A	**Successful**
Wireless connection to SAFER at roadside	Moderate Deployment	Technical challenges with communications among systems	**Holds promise**—for identifying frequent violators of safety laws
CVIEW or equivalent	Limited Deployment	Connections to legacy state system	**Jury is still out**—being tested in three or four states
Electronic Screening			
One or more sites equipped with DSRC	Widespread Deployment (no. of states); Limited Deployment (no. of carriers)	Interoperability	**Holds promise**—deployment trend is positive
Electronic Credentialing			
End-to-end IRP & IFTA processing	Limited Deployment	Challenges and costs of connecting legacy systems	**Holds promise**—potential for significant cost savings to states and carriers
Connection to IRP & IFTA clearinghouses	Limited Deployment	Institutional issues	**Jury is still out**—cost savings can only be realized with widespread deployment

Most of the major CVISN technologies have achieved some degree of success. Thus far, the most successful component, demonstrated by widespread deployment, is the use of laptop computers for safety information exchange. Wireless connection to SAFER, electronic screening with DSRC, and end-to-end electronic processing of international registration plan (IRP) credentials have been successfully deployed in some states and will likely enjoy widespread deployment as technical and institutional issues become resolved. The use of license plate readers for automated vehicle identification has not been successful because of low reliability. Most states are relying on voluntary participation of motor carriers in electronic screening programs, which use more reliable DSRC for vehicle identification and communication with the driver. The other components—CVIEW and participation in clearinghouses—show promise, but technical and institutional issues still need to be resolved.

One of the key lessons learned over the past few years is that collaboration among states in cooperation with the Federal Government is key to success. Through the ITS/CVO Mainstreaming program and other state organizations, states have been working together to identify and solve technology problems. The ITS/CVO Mainstreaming program is an FMCSA initiative designed to foster and support ITS deployment and to communicate ITS program information to all stakeholders (U.S. DOT 2000).

Many of the issues presented in this paper were identified and discussed extensively in forums with state officials, who are key stakeholders in future CVISN deployment. Their views on what works and what needs improvement must be considered when charting the future direction of this technology deployment.

INTRODUCTION

ITS is significantly changing the way Federal and state motor carrier agencies conduct business with the motor carrier industry. New technologies are helping to streamline credentialing operations, reduce delays for safe carriers, and improve highway safety by focusing enforcement resources on high-risk carriers. ITS designed for commercial vehicle operations includes the following:

- Safety information exchange technologies to facilitate the collection, distribution, and retrieval of motor carrier safety information at the roadside. These data help enforcement staff focus scarce resources on high-risk carriers and drivers, which, in turn, helps to reduce the number of crashes involving commercial vehicles.
- Electronic screening systems, which allow commercial vehicles that maintain good safety and legal status to bypass roadside inspection and weigh stations. This technology saves time and money for participating carriers and allows states to devote more resources toward removing unsafe and noncompliant carriers.
- Electronic credentialing systems for electronic submission, processing, approval, invoicing, payment, and issuance of credentials; electronic tax filing and auditing; and participation in clearinghouses for electronic accounting and distribution of registration fee payments among states.

Other ITS topics of current interest in the area of CVO include fleet and freight management systems, which are private sector ITS/CVO initiatives, and electronic commerce (e-commerce), which promises to have a great effect on CVO in the years ahead. However, the focus of this paper is on roadside and credentialing systems, deployed by the public sector.

Since 1991, U.S. DOT has sponsored numerous field operational tests to demonstrate new technologies and encourage their deployment. At the same time, it developed some of the key technology components, such as the SAFER database, containing current motor carrier safety data, and the Aspen software that allows state enforcement officers to access the data from computers at roadside. Aspen is a data management software system for collecting and disseminating information on commercial vehicles and drivers. It is interconnected with the SafetyNet and Motor Carrier Management Information System (MCMIS) services, and acts as a front-end interface or umbrella for several functions, including an inspection selection system (ISS), past inspection queries (PIQs), and software for conducting and reporting on individual vehicle inspections.

CVIEW is a related application that provides an interface between state legacy systems and SAFER. CVIEW is a state-owned and state-operated version of the SAFER system. It provides a state with a single point of access to its intrastate safety and credential information and provides SAFER with information about the interstate carriers, vehicles, and drivers based in the state (SAFER 1998).

In 1996, U.S. DOT sponsored the CVISN Model Deployment Initiative involving two "prototype" states—Maryland and Virginia—and eight "pilot" states: California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, Oregon, and Washington. FMCSA developed a three-step strategy of planning, design, and deployment for states embarking on CVISN deployment. In the planning step, a state attends two ITS/CVO training courses and develops an ITS/CVO business plan. For design, a state attends a third training course and participates in a series of three CVISN deployment workshops to complete a CVISN program plan and top-level system design. Once the plan is accepted by FMCSA, a state can proceed with deployment, based upon the availability of Federal and state resources. The goal of the CVISN initiative is to have each state achieve an "ambitious but achievable" level of deployment, called Level 1, in each of the three technology areas shown in Table 6-2. To achieve Level 1 deployment, states must:

- Establish an organizational framework among state agencies and motor carriers for cooperative system development.
- Create a state CVISN system design that conforms to the CVISN architecture and can evolve to include new technology and capabilities.
- Implement all the elements of three capability areas, as described in Table 6-2 (Richeson 1999). These systems must be implemented using applicable architectural guidelines, operational concepts, and standards.

Table 6-2. CVISN Level 1 Deployment

Safety Information Exchange
■ Use of Aspen (or equivalent software for access to safety data) at all major inspection sites ■ Connection to the SAFER system so that states can exchange "snapshots" of information on interstate carriers and individual vehicles ■ Implementation of the CVIEW (or equivalent) system for exchange of intrastate snapshots and for integration of SAFER and other national/interstate data
Electronic Screening
■ Electronic screening at one or more fixed or mobile inspection sites ■ Readiness to replicate electronic screening capability at other sites
Electronic Credentialing
■ Automated processing (application, state processing, issuance, tax filing) of at least international registration plan (IRP) and international fuel tax agreement (IFTA) credentials; readiness to extend to other credentials [intrastate, titling, oversize/overweight carrier registration, and hazardous material] ■ Connection to IRP and IFTA Clearinghouses ■ At least 10 percent of transaction volume handled electronically; readiness to sign up more carriers; readiness to extend to branch offices where applicable

Source: Richeson, K.E., Introductory Guide to CVISN (May 1999).

At least three states—Maryland, Virginia, and Kentucky—have demonstrated Level 1 capabilities in all three areas, and many others have made significant progress in one or two areas. The CVISN initiative is now being expanded to other states. According to the FMCSA, 8 of the 48 contiguous states have been fully funded to achieve Level 1 deployment by September 30, 2003. An additional 30 states have indicated that they expect to complete Level 1 deployment by September 30, 2003, depending on receipt of FY 2001 Federal ITS deployment or state resources to support CVISN deployment. CVISN deployment Levels 2 and 3 are currently being defined; it is assumed that states will pursue these levels of deployment without Federal support.

Expected costs and benefits of CVISN technologies have been analyzed in several studies. For reference, a pilot project to deploy CVISN roadside and credentialing technologies in the State of Washington in 1997 through 1999 was estimated to incur incremental costs of $2.7 million, with support expenses estimated to average approximately $600,000 per year for 10 years (Washington State 1998). A benefits study by Mitretek Systems, citing an earlier study by the American Trucking Associations (ATA) Foundation, predicted benefit/cost ratios between 1:1 and 19.8:1 for electronic credentialing; between 1.9:1 and 6.5:1 for electronic screening; and between 1.3:1 and 1.4:1 for automated roadside safety inspection (Mitretek Systems 1999). A benefit/cost assessment in Maryland, which combined CVISN credential processing and safety enforcement technologies, estimated worst-case benefit/cost ratios to be 1.45 for state agencies and 6.67 for motor carriers

(Bapna et al. 1998). Several of these analyses were based on preliminary cost estimates prepared before actual deployment, so findings should be interpreted with caution.

This paper summarizes what has been learned concerning the benefits, costs, issues, and challenges experienced by states and private organizations involved in developing and deploying ITS/CVO technologies. Much of the information is based on Battelle's experience as the independent evaluator for the CVISN Model Deployment Initiative and related field operating tests, including those involving eastern states that make up the I-95 Corridor Coalition. However, many of the opinions herein are derived from organizations participating in developing and deploying these technologies. Some of their views were obtained in formal discussions at recent conferences and meetings, including the following:

- Institute for Transportation Engineers (ITE) 2000 International Conference, April 2000, Irvine, California.
- CVISN MDI Prototype and Pilot States Program Managers Meeting, April 25, 2000, Tampa, Florida.
- Great Lakes and Southeast States CVISN Mainstreaming Conference, May 11–12, 2000, West Palm Beach, Florida.

At each of these forums, a brief presentation—"The Evaluator's Perspective on Deployment Status, Challenges, Benefits, and Outlook"—was followed by facilitated discussions. Participants were encouraged to offer opinions on successes, failures, obstacles, lessons learned, and issues to be resolved. A summary of what we have learned about ITS for CVO is presented in the following sections, organized under the three CVISN technology areas. A brief overview at the end predicts what the future might hold and includes ideas about what needs to happen to help ensure success.

SAFETY INFORMATION EXCHANGE

FMCSA has established goals to reduce commercial vehicle fatalities 50 percent by 2010, with a baseline of 5,374 fatalities in 1998, and to reduce the number of persons injured in commercial vehicle crashes 20 percent by 2008, with a baseline of 127,000 injuries in 1998. Although FMSCA plans new research (e.g., the Large Truck Crash Causation project) to better understand the causes of these crashes, vehicle safety defects and driver violations of the Federal Motor Carrier Safety Regulations (FMCSR) are known to contribute to a portion of them (Volpe Center 1999). Therefore, more and more state agencies responsible for enforcing safety regulations are deploying new technologies that enable enforcement personnel to use current motor carrier and vehicle-specific safety performance data—obtained through safety information exchange—during roadside inspections.

In 1996, about 64 percent of states deployed roadside computers with an early version of Aspen, the software that facilitates recording and processing of inspection data and provides historical information on the safety performance of motor carriers (Radin 2000). Since then, FMCSA activated the SAFER database, which contains

carrier safety data as well as recent inspection results, and Aspen was enhanced to take advantage of more current data being available at the roadside. As of December 1999, 84 percent of states were using Aspen, with more than half connected to the SAFER system (Pennsylvania Transportation Institute 2000).

In parallel with SAFER activities, FMCSA has also implemented the Performance Registration Information Systems Management (PRISM) program. PRISM, formerly referred to as Commercial Vehicle Information System (CVIS), links motor carrier information, including inspection information, with registration and licensing information. The PRISM project was piloted in five states for four years, ending in 1997. The pilot study showed that a link could be established between Federal and state information systems and that commercial vehicle registration could serve as a powerful enforcement tool in motor carrier safety programs (Office of Motor Carrier Research and Standards [OMCRS] 1999). Currently, 15 states participate in PRISM (Hart 2000), and U.S. DOT expects to add four to five new states each year for the next several years (OMCRS 1999).

This growth in deployment of safety information exchange technology stems in part from recognition by state commercial vehicle enforcement agencies that this technology facilitates the inspection process and helps focus inspection resources on high-risk carriers (i.e., those with poor safety records). Forthcoming results from a roadside screening study in Connecticut show computers to offer an advantage in helping inspectors select high-risk carriers for inspection from other vehicles in the general population (Battelle 2000). However, this advantage is expected to increase as states develop new ways to integrate this capability into electronic screening and other types of vehicle screening programs at the roadside.

One of the advantages of Aspen is that it provides a tool to record, store, and transmit inspection results. Previously inspection reports had to be handwritten, then keyed in and checked for errors before being submitted in batches to Federal databases. Although cost savings result from eliminating this activity, these savings are offset by the additional time required from enforcement staff to enter the data at roadside for transmission to Federal and state databases (Battelle 2000). A budget analysis performed for U.S. DOT concluded that direct savings to the states from roadside electronic safety systems, including clearance, would generally be less than the cost to deploy and operate the systems (Apogee Research, Inc., 1997).

All states use this data reporting feature of Aspen. However, many differences characterize the way states make use of the data it provides. For example, Aspen contains the ISS, which provides a safety rating for each motor carrier organization (Lantz 2000). As shown in Figure 6-1, ISS gives a rating as well as a description of the carrier's safety record. But despite its name, most states do not use ISS to select vehicles for inspection. Instead, inspectors look up the ISS rating only after a vehicle has been selected for inspection. Two reasons explain this approach: (1) some states have laws that require "probable cause" to stop a vehicle for inspection and (2) there are logistical problems with entering a motor carrier identification number and interpreting results while the vehicle is moving through an inspection site. Nevertheless, inspectors report that they use information from ISS to adjust the way

they conduct inspections. For example, the inspector might choose to adjust the level of inspection, or pay particular attention to safety issues reported in the past regarding the carrier in question.

Figure 6-1. Example of the Inspection Selection System Data Available through Aspen

On the other hand, Connecticut officials have found a way to use ISS in selecting vehicles for inspection. Two weigh stations in Connecticut use weigh-in-motion equipment to prescreen trucks. Trucks that fail the screening or are otherwise chosen to stop at the fixed scale are screened again using ISS and prioritized for inspection. This is the only known use of ISS for prescreening trucks at the road-side. A study of the screening efficiency at these sites indicates that a vehicle from a high-risk carrier is twice as likely to be inspected than if inspections were performed at random (Battelle 2000). This efficiency may be due in part to inspector experience, but the study shows that efficiency is slightly greater at sites where the technology is more fully utilized. Also, the inspectors themselves report that ISS helps to improve their efficiency.

Another form of safety information exchange that shows promise is the SAFER data mailbox (SDM). Several states have tested or are routinely using SDM to transmit inspection reports directly from the roadside to the SAFER system. They can also receive previous inspection reports by performing a past inspection query on individual trucks stopped for inspection. States use a variety of communication methods to exchange safety information, including standard telephone lines (land lines) and wireless systems (e.g., cellular or digital). Figure 6-2 shows one way to configure SDM.

Initially, SDM was developed to help identify trucks (and drivers) violating out-of-service (OOS) orders. OOS orders are issued when serious vehicle defects or driver violations must be remedied before the vehicle can return to the highway. SDM was conceived as a tool for helping states identify trucks that leave an inspection site before OOS violations are corrected. However, given the time it takes to enter a vehicle license number, transmit a PIQ to SAFER, retrieve past inspections, and review the results, SDM will not have a big impact on catching OOS order violators unless systems are routinely used to automatically identify vehicles and process the information. Also, this system cannot reach its potential until it is up and running in many more states where officials are committed to uploading inspection results in a timely manner. Currently, some states can upload inspection results by wireless communication immediately following inspection; others perform uploads only once a week.

Figure 6-2. Typical Configuration of SAFER Data Mailbox (SDM)
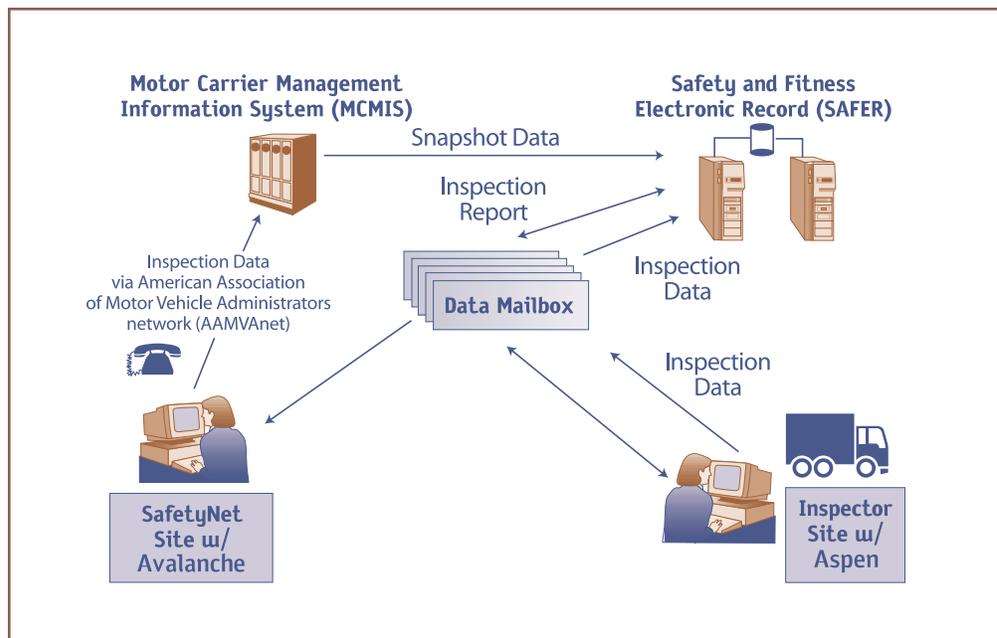
Some eastern and southern states are now using SDM on a regular basis. Connecticut, for example, reports that inspectors routinely identify recently inspected commercial vehicles. Out of 1,095 PIQs performed in Connecticut during a two-month period in 1999, inspectors found 115 cases (11 percent) where an inspection had not been made on the vehicle in question within the past 45 days. OOS orders had been issued to 40 out of 115 vehicles with positive PIQs. Interviews with inspectors in Connecticut and elsewhere revealed SDM to be helping inspectors identify trends in violations, as some carriers tend to repeat the same kinds of violations over time. The general reaction of states using SDM is positive.

While states have encountered challenges in attempting to deploy roadside computers with Aspen, ISS, and SDM, there appear to be no major impediments to widespread deployment. Difficulties include selection of hardware (hardened for field use), costs and availability of wireless communication services, and finding of qualified internal or external support for developing and integrating computer systems. Efforts such as the I-95 Corridor Coalition and the CVISN Mainstreaming program are helping to resolve these problems by providing forums for information sharing and joint efforts on technology issues. Mainstreaming is a formal program established by FMCSA to promote deployment of CVISN through cooperative planning and problem solving by participating states.

Finally, a key factor in the future of roadside enforcement activities involves deployment of CVIEW or equivalent systems. The purpose of CVIEW is to integrate interstate and intrastate carrier safety data, driver and vehicle information, and a variety of carrier credentials and insurance data. These data will be made available at the roadside in the form of "snapshots" and will be shared with neighboring states.

FMCSA has sponsored and funded development of CVIEW to facilitate state-level exchange of inter- and intrastate carrier, vehicle, and driver safety and credential data to support electronic screening operations and to allow states greater control and flexibility for establishing interfaces with internal state legacy systems. FMCSA will continue to fund development and maintenance support of CVIEW through Version 3.0, which includes all the capabilities required for CVISN Level 1 deployment. As of January 2001, FMCSA will not continue to support CVIEW development because of funding limitations. States that elect to develop a CVIEW system based on the FMCSA-sponsored model will be required to assume responsibility for CVIEW enhancement and maintenance operations.

ELECTRONIC SCREENING

Starting in the early 1990s, field operational tests, such as Advantage I-75 (Interstate 75 corridor), HELP/Crescent (I-5 corridor), and Oregon Green Light demonstrated the technical feasibility and time-saving benefits of using electronic screening systems for commercial vehicle operations. In particular, these tests proved that DSRC technologies provide reliable communication between moving vehicles and roadside enforcement operations. However, most of the growth in electronic screening deployment has occurred with the emergence of three programs: HELP, PrePass, NORPASS, and Oregon's Green Light. Currently, as Table 6-3 shows, 25 states in the United States and nearly 7,000 motor carrier fleets participate in these programs. Furthermore, total truck enrollment in the three programs has grown by approximately 100 percent per year for the past few years.

Table 6-3. State and Motor Carrier Participation in Electronic Screening Programs

	Pre-Pass	NORPASS	Green Light
States	17	7	1
Trucks	129,393	7,500	13,000
Fleets	5,019	800	1,000

PrePass, NORPASS, and Green Light provide similar services and enabling technologies to participating states and motor carriers. Both PrePass and NORPASS assist participating states in recruiting and enrolling motor carriers and provide flexible options to states for motor carrier enrollment and bypass criteria. However, significant differences characterize their business models and operations. PrePass uses private capital to build the infrastructure for automatic vehicle identification (AVI), then recovers those costs through user fees. Generally, trucks pay $0.99 per bypass, up to a specified limit. On the other hand, NORPASS uses state-owned AVI infrastructure and charges an annual administration fee of $45 per truck. Green Light is constructed and administered by the Oregon Department of Transportation (DOT). Oregon offers preclearance to motor carriers at no charge.

The potential benefits of electronic screening are widely acknowledged. The early field operational tests estimated an average time savings to participating motor carriers of between 1.5 and 4.5 minutes per bypass (U.S. DOT 1998). Carriers with good safety records also expect to have fewer inspections. States benefit from electronic screening because it helps them reduce station traffic and thereby avoid the costs of building bigger weigh stations, which can cost as much as $1 million or more, depending on size and on the type of facilities and technologies included. Electronic screening also helps states focus more of their inspection resources on high-risk carriers. As previously discussed, results from a roadside screening study in Connecticut demonstrated that computer-based inspection screening offers an advantage in helping inspectors target high-risk carriers for inspection (Battelle 2000). Integrating electronic screening and safety information exchange capabilities will likely extend this advantage to a higher percentage of the commercial vehicle traffic.

Several key issues can affect further deployment of electronic screening. Most people in the CVO industry agree that interoperability, or the ability for a vehicle to operate with the same equipment and under similar rules as it travels from state to state, is critical to increased participation. Interoperability has three primary dimensions: technical, operational, and business. Technical interoperability refers to the type of DSRC transponders used. So far, transponder type has not been a problem, as all electronic screening applications are using the same equipment. However, interest exists for establishing interoperability with other applications, such as electronic toll collection and border crossings.

Operational interoperability refers to criteria used to enroll and, more importantly, permit trucks to bypass weigh stations. Motor carriers can be expected to want the same bypass criteria as vehicles travel from state to state. Complete uniformity of enrollment and bypass criteria is unlikely to occur, however, because states have different regulations and requirements. For example, states with high volumes of hazardous material (HAZMAT) cargo are likely to have different regulatory priorities than states that deal with agricultural products. Also, differences among states in truck size and weight regulations will lead to differences in bypass criteria. Some success has been achieved toward operational interoperability with the Commercial Vehicle Safety Alliance defining e-screening eligibility categories and the Intelligent Transportation Society of America (ITS America) CVO Committee's Policy Subcommittee working toward establishing minimum enrollment criteria.

The interoperability issue receiving the most attention involves business, namely the relationship between the separate PrePass and NORPASS systems. Some believe that it will be necessary to establish one business entity so that all carriers can deal with multiple states through a single business plan. However, this view is not universal. Features of PrePass and NORPASS are attractive to different types of motor carriers and state agencies. For example, states with an existing AVI infrastructure at fixed sites may prefer the NORPASS plan, whereas states that rely more on mobile enforcement (i.e., stopping and inspecting vehicles along the roadway) or have fewer available capital resources may prefer the PrePass plan. Also, the different fee structures (annual versus use-based) are likely to be attractive to different types of carriers.

Recently, PrePass and NORPASS established a one-way interoperability agreement whereby qualified motor carriers enrolled in NORPASS can operate in the PrePass network (Werner 2000). No corresponding agreement was reached concerning PrePass carriers operating at NORPASS sites. Most agree that some type of interoperability is necessary to attract more carrier participation. However, few agree on the best solution. Some states have negotiated, or are in the process of negotiating, special interoperability arrangements with both PrePass and NORPASS; however, these agreements may not apply to bordering states. While finding a Federal solution has been suggested, it is not a popular choice. The best solution, according to some of the state CVISN program managers, is to have every state pursue business arrangements either with PrePass or NORPASS, then work within the program to achieve interoperability as needed. Most believe that the issues will be resolved through the marketplace.

ELECTRONIC CREDENTIALING

State agencies and motor carriers agree that electronic credentialing offers opportunity for significant cost savings related to motor carrier registration processes. Preliminary estimates, based on experiences in Kentucky, are that cost savings using electronic credentialing can be as high as 75 percent for both the state and the participating motor carriers. For the state, this percentage translates into a potential cost savings of $20 per processed credential. A budget analysis of costs and benefits

over time in eight case study states concluded that electronic credentialing can be financially self-supporting (Apogee Research, Inc., 1997).

Although most states are committed to deploying electronic credentialing, these systems have not yet achieved the same level of widespread deployment as experienced roadside systems. This result primarily stems from the many technical challenges involved in establishing interfaces between new and legacy, or archival, databases and software systems.

To date, three states—Maryland, Virginia, and Kentucky—have successfully demonstrated Level 1 capabilities for electronic credentialing. These states are now working with a limited number of carriers to test and refine the developed systems. Additional development continues as issues are identified. The experiences of these states, as well as those of the other seven CVISN pilot states, are being shared with others through FMCSA-sponsored mainstreaming efforts and training workshops.

Some of the lessons learned by pilot and prototype states deal with understanding the scope of the project and obtaining the appropriate capabilities to get the job done. Originally, many states had unrealistic expectations that making new systems operational was a simple "plug and play" exercise. However, integration of legacy systems (e.g., licensing, insurance, fee payment, invoicing) with new applications (e.g., SAFER, carrier automated transaction [CAT] software, and Web applications) requires careful planning. Furthermore, some states relied too heavily on technical support from outside contractors without providing adequate technical leadership from state personnel familiar with the business applications. The use of in-house capabilities is considered important, particularly given the shortage of qualified contractors familiar with credentialing operations.

Two issues concern the future direction of electronic credentialing: (1) type of data communications that should be adopted and (2) type of software system (specialized computer programs or Web applications) preferred by and acceptable to motor carriers. The first issue focuses on which of two standards to use for data transmission—electronic data interface (EDI) or eXtensible Markup Language (XML). Some prefer EDI because it is well established; however, others find XML to be more appropriate for Web applications. FMCSA recently sponsored a study to explore the technical approach preferred by large carriers, service providers, fleet management system vendors, and states for electronic credentialing. Results, expected to be available in late 2000, will be used by FMCSA to issue new policies on electronic credentialing.

Originally, the CVISN architecture focused on the use of specialized computer-to-computer (also called PC-based) software, such as the CAT system. With this application, participating carriers obtain the specialized software, then dial in to state credentialing systems to perform various functions (e.g., new and renewal applications, invoicing, error checking, etc.). Discussions with motor carriers using this system in Kentucky reveal that it works well, with carriers experiencing time and cost savings of up to approximately 75 percent.

Since 1999, interest has grown in developing Web-based systems that allow carriers to conduct credentialing business over the Internet. The key advantage of this

approach is that any carrier with access to a Web browser can participate in electronic credentialing. Discussions with motor carriers and credentialing software developers suggest that both PC-based and Web-based systems will be needed to satisfy the variety of needs within the motor carrier industry. Figure 6-3 shows the dual interface approach being considered.

Figure 6-3. Dual Interfaces for Electronic Credentialing
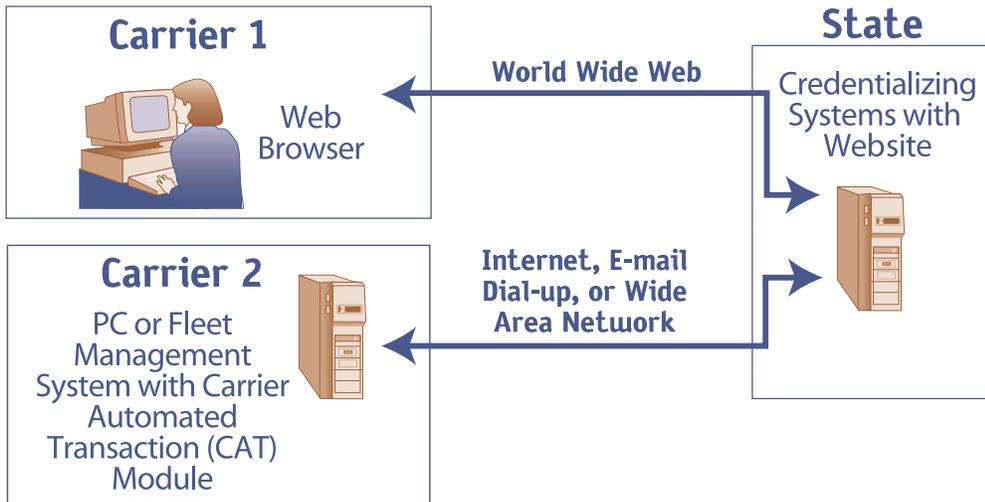
A VIEW OF THE FUTURE

Because of rapid changes in technology, especially in the areas of computer electronics and communication, predictions of where CVISN technology will be in five or 10 years are difficult to make. Nevertheless, a good starting point is to look at the key technology components in terms of their current deployment level, conceptually illustrated in Figure 6-4.

Some technologies used in roadside operations, such as weigh-in-motion equipment, and software systems, such as Aspen (including ISS), are already widely deployed. On the other hand, license plate readers, because of their inherent inaccuracies, are not likely to play a key role in roadside operations. In addition, FMCSA is planning to examine new technologies that identify commercial vehicles not equipped with transponders. Automated inspection technologies, such as those used to detect defective brakes, are still being developed and tested.

Figure 6-4. Conceptual View of the Status of CVISN Technology Deployment in 2000

	R&D	Technology Test	Operational Test	Limited Deployment	Widespread Deployment
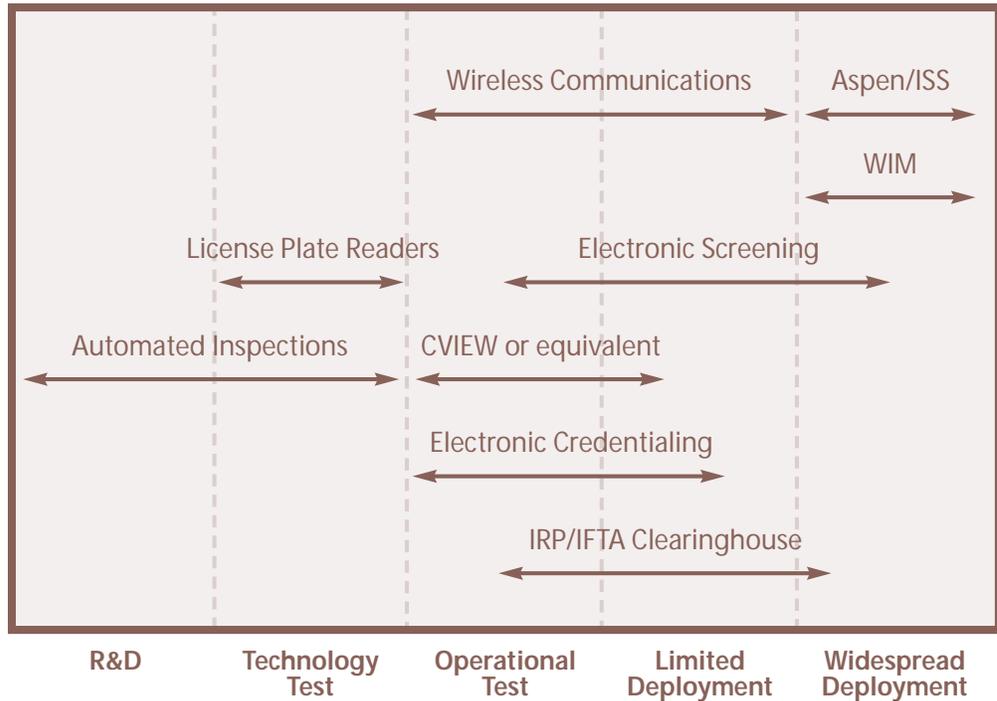
Growth in electronic screening is expected to continue, both in terms of the number of states participating and number of screening sites. Carrier enrollment, a key to success, is heavily dependent on solving interoperability issues. Furthermore, as states decide the type of bypass criteria to use, they must communicate these criteria to the carriers and, to the degree possible, establish some level of uniformity within key corridors.

The type and amount of safety information that will be used to conduct roadside inspections or to select the vehicle for inspection is likely to change dramatically as faster and less costly wireless communication technologies become available. Systems like the SAFER data mailbox will permit greater use of vehicle-specific safety data (i.e., prior inspection results) during vehicle inspections. Collection and dissemination of other types of data, such as driver information and crash and citation data, will be integrated into roadside systems like Aspen and CVIEW— necessitating continued development and refinement of these systems.

Although electronic credentialing got off to a slow start, recent successes and the desire to reduce costs will help promote further deployment. It now appears that multiple solutions, including PC- and Web-based systems as well as current "paper" systems, will be needed to satisfy the various needs of a diverse industry.

The IRP and international fuel tax agreement (IFTA) clearinghouses, which are being developed to facilitate distribution of funds among states, are still in the early stages of deployment. The IRP clearinghouse currently has 11 states participating in a pilot project. The IFTA clearinghouse has two participating states, with eight more signed up to participate.

One of the key lessons learned over the past few years is that collaboration among states, in cooperation with the Federal Government, is key to success. Through the mainstreaming program and corridor coalitions, states have been working together to identify and solve technology problems. Many of the issues presented in this paper were identified and discussed extensively in such forums. As key stakeholders in the future deployment of CVISN, their views on what works and does not work must be considered in charting the future direction of this technology deployment.

ACKNOWLEDGMENTS

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chapter 7
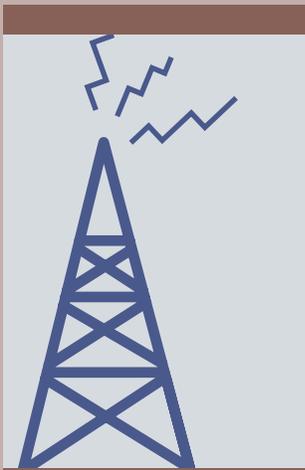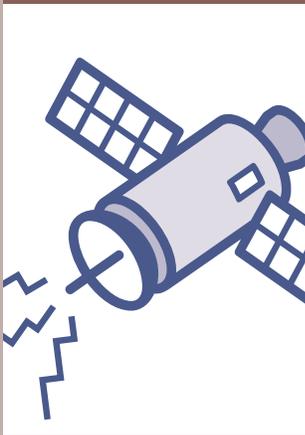
EXECUTIVE SUMMARY

Introduction

This paper strives to answer the question, "What have we learned about cross-cutting technical and programmatic issues over the last decade of the National ITS Program?" In addition to contributing to the overall topic of what we have learned about intelligent transportation systems (ITS), this paper looks at new areas where ITS investments should be made. It focuses on major findings or trends, rather than providing a comprehensive list of findings derived over the last decade of ITS work. Because it is not possible to develop a precise or quantitative definition for success, this paper qualitatively considers two main factors: (1) demonstrated success in contributing to one of the key measures for ITS benefits, which include delay reduction, capacity increase, cost savings, crash and/or fatality reduction, and customer satisfaction; and (2) amount and rate of deployment achieved compared to time elapsed since the technology or method was first demonstrated. For example, a technology that has low levels of deployment but has just emerged from the research and development (R&D) stage may be considered promising, whereas a technology with the same level of deployment that has been commercially available for over a decade might be considered unsuccessful.

This paper discusses sensors and surveillance, communications, analysis tools, archived data, architecture, and standards. Each of these topics cuts across the domain-specific subsets of ITS, such as freeway management, arterial management, transit systems, and commercial vehicle operations.

Findings

While successes and failures characterize individual technologies, successful technologies do exist and do meet ITS requirements for sensing and communications. The information processing area needs further algorithm development for specific ITS applications.

Surveillance: Sensing and surveillance of traffic flows are key enabling technologies, needed for efficient management of both freeways and arterials, for integrated freeway/arterial management, and for real-time traveler information. The lack of traffic flow sensors in many areas and roadway types continues to inhibit the growth of traveler information and improved transportation operations management systems.

Cell phone reports from drivers have proved the quickest means of identifying urban incidents. Where present, video cameras provide effective confirmation and information on the precise location and nature of the incident, and the needed response. New cellular geolocation techniques have great promise for providing low-cost traffic probe information on arterials as well as freeways, but field testing is just beginning.

Communications: New Internet-based services and wireless data communications technologies have the greatest potential for influencing future ITS direction.

Analysis Tools: Current transportation planning tools and techniques do not address the impacts of traffic operations management, including ITS impacts. To evaluate such approaches, the variance of factors such as travel demand, incidents,

and weather must be considered. New tools and techniques, such as IDAS (ITS Deployment Analysis System), PRUEVIIN (Process for Regional Understanding and EValuation of Integrated ITS Networks), and TRANSIMS (TRansportation ANalysis SIMulation System) have been or are being developed to address these shortcomings.

Archived Data: Increasing use of sensors and information for real-time operations promises to reduce the incremental cost and improve the quality of information used for long-range planning, transportation operations analysis, safety improvement tracking, and other potential new applications. In addition, new technology, such as low-cost global positioning system (GPS) receivers and handheld computers, can do the same for traditional data collection processes.

Architecture: The National ITS Architecture has proven to be an important tool for promoting both technical and institutional integration of ITS. A growing acceptance of the need for regional architectures is occurring within the United States. In addition, the National ITS Architecture effort is being used as a model for national architecture work in many foreign countries.

An architecture maintenance program is needed to keep the National ITS Architecture current and meaningful to increasing numbers of ITS deployers throughout the country who are seeking integrated ITS solutions and system interoperability. Current procedures for achieving this task in the most timely and economic fashion should be reviewed to make the process a smooth one.

Standards: The federal program of providing funding to expedite and facilitate development of ITS standards has had many successes. In particular, work on the ITS Data Bus (IDB) was accelerated and handed off to the private sector, and development of the National Transportation Communications for ITS Protocol (NTCIP) family of standards is being accelerated. The standards program is undergoing a critical period, as the first generations of standards-based products are being deployed.

The availability of Federal funds, however, has led to a large number of concurrent efforts, some of which would not exist without partial Federal funding. Partly because of so many parallel efforts, some standards in important subject areas may not be receiving sufficient evaluation and critical review from the appropriate developer and user community.

In a few cases, standards development efforts have been unsuccessful because of the perception by participants that their proprietary interests outweighed the potential benefits of uniform standards. This result occurred in the area of Dedicated Short-Range Communications (DSRC) and in high-speed FM subcarrier communications.

A need exists for agreed-upon testing procedures related to standards, although there is disagreement over whether third-party independent testing is needed or whether vendor self-testing and warranties are adequate.

Deployment Levels: Table 7-1 summarizes the status and deployment levels of the technologies discussed in this paper. Some areas, such as the National ITS Architecture program, are not included, as they do not lend themselves to such a summary.

In most cases, deployment level is based on the number of cities reporting deployment of the technology in the 1999 survey of ITS deployment. To reiterate deployment category definitions, if the technology was deployed in fewer than 10 percent of the 78 cities surveyed, it is categorized as having limited deployment. If 10 to 30 percent of cities deployed the technology, it is categorized as moderate deployment. Greater levels are categorized as widespread deployment.

In the Comments column of the table, the classification "Holds promise" reflects technologies that are successfully operational in at least one location, with potential for much wider deployment. The "Jury still out" category is used for two different cases: for technologies that have been available for some time but may or may not catch on broadly, and for technologies so new that they have not yet advanced beyond field testing—no matter how promising the tests may appear. For example, the current, newer technology using cellular geolocation for providing traffic flow information is in the testing stages. If it works, the technology has tremendous potential for deployment, but because it has not been used operationally and has not demonstrated technical and cost feasibility, it is placed in the "Jury still out" category.

Table 7-1. Cross-Cutting Technical Issues Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Sensor and Surveillance Technologies			
Cell phones for incident reporting	Widespread Deployment*[†]	N/A	**Successful**
Cell phones for emergency notification	Limited Deployment*[†]	Relatively new, mostly sold in new vehicles, takes long time to reach 30% of vehicle fleet	**Successful**—number of equipped vehicles growing rapidly
GPS for position, determination, automatic vehicle location	Moderate Deployment in fleets (transit, trucking, emergency vehicles)[‡]	N/A	**Successful**—use continuing to grow. See footnote
Video surveillance	Widespread Deployment	N/A	**Successful**
DSRC (toll-tags) for travel time data	Limited Deployment	Mostly used only in areas with electronic toll collection. Requires power and communications to readers	**Successful**—holds promise
Direct link between Mayday systems and public safety answering points	Limited Deployment[†]	Still in research and test phase, significant institutional policy and technical issues	**Jury is still out**—no known deployments
Cellular geo-location for traffic probes	Limited Deployment	New technologies just beginning field trials	**Jury is still out**—older technology unsuccessful

Technology	Deployment Level	Limiting Factors	Comments
Communications Technologies			
Loop detectors	Widespread Deployment	N/A	**Successful**
Alternatives to loop detectors	Widespread Deployment	Initial cost, familiarity	**Holds promise**—video widespread, others limited, many cities only use for a few locations
Real-time, in-vehicle traffic information	Limited Deployment*[†]	Cost, commercial viability	**Jury is still out**
LIDAR for measuring automotive emissions	Limited Deployment[†]	Minnesota test was unsuccessful, technology didn't work well enough	**Unsuccessful**—no known deployment
Communications Technologies			
Internet for traveler information	Widespread Deployment	N/A	**Successful**—free services **Jury is still out**—on commercial viability
High speed Internet	Limited Deployment[†]	Slow rollout, availability limited	**Holds promise**
Fully-automated Internet-based Exchange	Limited Deployment[†]	New technology	**Holds promise**
DSRC	Widespread Deployment	N/A	**Successful**—current use mostly limited to Electronic Toll Collection
DSRC at 5.9 GHz	Limited Deployment[†]	Frequency just recently approved for use, standards in development	**Jury is still out**—no known deployments in U.S., but used in other countries at 5.8 GHz
Fiber optics for wireline communications	Widespread Deployment	N/A	**Successful**
Digital subscriber line	Limited Deployment	New technology, first applied to ITS in 1999	**Holds promise**—several deployments, many more locations considering
220 MHz radio channels for ITS	Limited Deployment	ITS is too small a market to support unique communications systems	**Unsuccessful**—only known use during Atlanta test during the 1996 Olympic Games
High speed FM subcarrier for ITS	Limited Deployment[†]*	Low demand to-date for in-vehicle real-time data	**Jury is still out**—multiple conflicting "standards" and proprietary approaches, competition from other wireless technologies

Technology	Deployment Level	Limiting Factors	Comments
Communications Technologies			
CDPD for traveler information	Limited Deployment [†*]	Lack of real-time information to send, limited use of CDPD by consumers	**Unsuccessful**—CDPD will soon be overtaken by other wireless data technologies
Wireless Internet	Limited Deployment [†*]	New technology	**Jury is still out**—on ITS uses, general use predicted to grow rapidly
Local area wireless	Limited Deployment	New Technology	**Jury is still out**
Low power FM	Limited Deployment [†]	Just legalized by FCC, first licenses not yet granted	**Jury is still out**—Brand new, no deployments yet
High speed fixed wireless	Limited Deployment [†]	New Technology	**Jury is still out**
Analysis Tools			
Models incorporating operations into transportation planning	Limited Deployment [†]	Emerging technology, cost and institutional issues may become factors for some approaches	**Jury is still out**—IDAS available, PRUEVIIN methodology demonstrated, TRANSIMS in development

Quantitative deployment tracking data are not available. Deployment level was determined by expert judgment.

† For in-vehicle consumer systems, deployment levels are based on the percent of users or vehicle fleet, not number of cities available. For example, real-time in-vehicle traffic is available in over two dozen cities, but the percentage of drivers subscribing to it is small.

‡ For AVL using GPS in transit, the moderate-level assessment is based on the percent of transit agencies using the technology according to a 1998 survey of 525 transit agencies conducted by the John A. Volpe National Transportation Systems Center. This measure was used for consistency with the transit section of this report. If the 78 major metropolitan areas are used as a measure, then the deployment level is "widespread," as 24 of 78 cities use GPS-based AVL.

Recommendations

Based on what has been learned to-date about cross-cutting technical and programmatic issues, the following recommendations are made for future national level activities.

Traffic Sensing (Surveillance)

The U.S. Department of Transportation (U.S. DOT) should encourage deployment of traffic sensing (surveillance) systems, provide deployment incentives, and consider establishing minimum surveillance requirements for portions of the National Highway System. The use of electronic toll-tag technology as traffic probes should be considered wherever there is a significant existing base of tag-equipped vehicles.

Testing of cellular geolocation technologies for collecting travel time data should be a near-term priority.

Standards Development and Deployment

Federal support should continue for a limited set of key standards, including maintenance, updates, and revisions of recently approved standards. The first generation of products and deployments will identify necessary revisions.

U.S. DOT should closely monitor deployments of standards-based traffic management and roadside products. Much skepticism surrounds the utility of these standards; any failures will be well-publicized and cause a setback of the National ITS Program. U.S. DOT should be prepared to react quickly if standards-based products are not being developed, or if problems impede deployments of standards-based products. The appropriate action would depend on the nature of the problem. One example would be "tiger teams" to quickly provide assistance in deploying standards-based products. These teams would help identify the problem, devise solutions for the particular deployment, and use lessons learned to recommend changes to avoid similar problems in the future.

Evaluation Voids

U.S. DOT should continue efforts to close gaps in the knowledge of ITS impacts. Gaps exist in the areas of ITS integration, rural ITS, traveler information benefits, and transit maintenance management. Types of knowledge gaps deal with more than just benefits and cost information. Information is also missing on how ownership, intellectual property, and liability issues are resolved.

Tracking New Technologies

New technologies and trends should continue to be identified and assessed for their potential positive or negative effects on ITS.

INTRODUCTION

This paper strives to answer the question, "What have we learned about cross-cutting technical and programmatic issues over the last decade of the National ITS Program?" Because it is not possible to develop a precise or quantitative definition for success of ITS in terms of cross-cutting technical and programmatic issues, this paper qualitatively considers two main factors. The first is a technology's demonstrated success in contributing to one of several key measures for ITS benefits, including delay reduction, capacity increase, cost savings, crash and/or fatality reduction, and customer satisfaction. The second factor is the amount and rate of deployment, compared to time that has elapsed since the technology or method was first demonstrated. For example, a technology having low deployment levels, but just emerging from the R&D stage, may be considered promising, whereas a technology with the same level of deployment that has been commercially available for more than a decade might be considered unsuccessful.

Scope

ITS is defined as the application of advanced sensor, communications, and information processing technology to improve the safety and efficiency of surface transportation systems. Sensors and communications technology often serve multiple ITS application areas; therefore, they are a prime focus of this paper on cross-cutting issues. Specific information processing techniques or algorithms are often more closely related to a single ITS application area and are not discussed in this paper.

This paper discusses sensors and surveillance, communications, analysis tools, archived data, architecture, and standards. Each of these areas cuts across domain-specific subsets of ITS, such as freeway management, arterial management, transit systems, and commercial vehicle operations. (See Chapter 8 for a discussion of cross-cutting institutional issues.) Following discussion of the major cross-cutting areas is a section on additional new technologies that may impact ITS and a final section of recommendations for the National ITS Program. Focus is on success in the field, rather than on R&D results; however, research and field test results are included where relevant.

SENSORS AND SURVEILLANCE

Sensors and surveillance systems for measuring traffic flow and identifying incidents are key enabling technologies for freeway management, arterial management, and traveler information.

Successes

Cellular phone calls from motorists have proven to be the most frequently used means of first identifying incidents in metropolitan cities. Incidents are usually reported by cell phone before they are detected and reported by incident detection algorithms using data from equipped roadways.

Cell phones combined with GPS-based vehicle location are a successful combination for emergency notification. Commercially available systems such as OnStar™ and RESCU have proven popular with consumers. Automatic crash notification systems, which automatically trigger an emergency call based on certain parameters like air bag detonation, have been successfully tested and are just now becoming commercially available on some new cars.

In general, GPS has emerged as the clear technology of choice for position determination and is used in transit, commercial vehicle, and emergency management fleets. GPS dominates other forms of radio-based location determination (e.g., LORAN-C). GPS-based position determination is also used to determine passenger vehicle position for emergency response and navigation systems. Today GPS is often supplemented with other systems such as dead-reckoning or map-matching, which handle shortcomings in GPS accuracy that were present before the removal of selective availability, announced in May 2000. These supplemental systems also address areas where the GPS signal is lost, as often occurs when a vehicle is surrounded by tall buildings.

At present, the other technology with significant but limited use is electronic sign-post-based vehicle location for transit fleets. These systems use transponders at key points, such as bus stops, to track vehicles, but cannot track a vehicle between points. This technology represents an older, legacy technology typically deployed before GPS-based systems were available and proven. It is not the technology of choice today.

The Federal Communications Commission (FCC) rule requiring geolocation of cellular 911 emergency calls may lead to new, non-GPS approaches for ITS location determination. The geolocation function can have many other uses beyond emergency call location. These systems can also use GPS-equipped phones, but alternative approaches that use radio triangulation from multiple cell sites or location pattern matching of multipath signatures are also being tested and deployed.

Video surveillance of freeways has been effective in reducing incident verification time and in guiding the appropriate response. Video cameras are continuing to be widely deployed on metropolitan freeways, with limited deployment under way on some arterials.

Use of toll-tags for collecting travel time data on non-tolled roads holds promise. The technology has been successfully used in several areas, including Houston, Texas, and northern New Jersey. San Antonio, as part of the Metropolitan Model Deployment Initiative, used toll-tag technology to collect travel time information, even absent toll roads in the area. Instead, tens of thousands of volunteers were successfully solicited to equip their vehicle with tags. Despite these successes, deployment of this technique has been limited, even in areas with electronic toll collection (ETC) and large fleets of tag-equipped vehicles. One limitation cited is the cost of bringing power and communications to the tag reader sites.

An important research result is that only a small percentage of the vehicle fleet needs to serve as traffic probes to provide useful traveler information. In fact, in one simulation study of an incident on an interstate freeway, half the maximum travel time benefit was obtained with only 2 percent of vehicles providing probe information. This result is important, as it greatly reduces the chicken-and-egg problem of needing a large number of participating vehicles before participants see any benefit. A need still exists, however, to verify these research results in the field.

The Jury is Still Out

Current emergency notification systems have a communications link to private, centralized response centers. When public safety assistance is required, these centers then contact the appropriate emergency offices based on the vehicle's location. The FCC has mandated geolocation of mobile 911 calls beginning in 2001. As implementation proceeds, it is unknown whether the current model for manual and automated call handling will continue, or will eventually be supplemented or replaced with direct links between the in-vehicle system and the local public safety answering point. Questions have also been raised concerning the ability of these new technologies to provide location information in some rural areas.

The use of cellular geolocation to collect traffic flow information is a promising new area, but testing is needed. An operational test of older cellular geolocation technology—the CAPITAL (Cellular APplied to ITS Tracking And Location) test—revealed many problems with the technology then available. The FCC mandate, however, has brought about major investments in this technology, and several companies using varying approaches believe they have systems that can be used to collect traffic flow information. Results from early tests should be available within one or two years.

At least one operational test—ADVANCE (Advanced Driver and Vehicle Advisory Navigation ConcEpt)—identified problems with processing vehicle probe data from multiple vehicles traveling on arterials. The problem is that random variations, such as stopping at a red traffic light, can make a significant difference in reported travel time. In addition, the best algorithms for combining data from multiple types of sensors are still under investigation. Several research projects on travel time data fusion are currently under way.

Embedded loops remain the predominant form of traffic detection technology, whether for presence, volume, or speed detection. Many alternatives are on the market, including video processing systems, sonic detection systems, and microwave radar, but their market penetration is still relatively small. The Metropolitan ITS Deployment Tracking Database (ITS Deployment Tracking Database 1999) shows that while a large number of cities have deployed one or more of these technologies, often deployment is limited to a handful of locations. Many transportation practitioners remain unconvinced that these new approaches have a significant advantage over loops. Concerns have been raised about the reliability of loops, and many people desire a more reliable alternative that is not more expensive. Proponents and some users of these alternative systems argue that they have a lower total life cycle cost than loops.

Real-time, in-vehicle traffic information and route guidance, as well as for-fee, pre-trip services have not yet proven successful. One constraint limiting their use is the limited availability of real-time surveillance information.

Unsuccessful Approaches

Light detection and ranging (LIDAR) was tried as a remote sensing tool for measuring automotive emissions. The prototype system only operated accurately under restrictive conditions of location and pollution type. The system was also found to be cumbersome to operate and not practical for traffic pollution monitoring (U.S. DOT 1998). Tests of other remote sensing technologies, however, were more successful.

COMMUNICATIONS

Successes

The Internet

The Internet has emerged as the primary source of pre-trip travel information. In most or almost all cases, this information is provided at no charge. In many cities with both phone and Internet traveler information services, the Internet service receives much higher usage. In addition, Web-based forms are beginning to be used for commercial vehicle credentials registration as part of a broader trend for government agencies to provide services over the Internet. This event is not surprising, given that more than 70 million people in the United States now have access to the Internet, and more than 700 people gain access every hour. At the same time, it is important to remember that 70 million people represent only 25 percent of the U.S. population, so the majority of citizens do not have Internet access.

Dedicated Short-Range Communications

Electronic tolls and commercial vehicle credential checking are two of the few ITS applications that use lower layer communications protocols unique to ITS. The DSRC systems for these applications have been widely and successfully deployed. Although various vendors and operators have been unable to agree on a single, open standard for DSRC, the technology is clearly successful. DSRC at 5.9 GHz is further discussed in the "Jury Still Out" section below.

Fiber Optics for Wireline Communications

When the ITS program began, debate still took place over the merits of coaxial cable (coax) versus fiber optics for freeway video systems. This debate has ended, with fiber optics the clear medium of choice for any new fixed cable installations.

Digital Subscriber Line technologies

Digital subscriber line (DSL) technologies are an emerging success story and reflective of technologies characterized as "holding promise," despite limited deployment to date. DSL allows high-speed digital signals, including video, to be carried over existing copper twisted-pair wiring. It provides an alternative to laying new fiber optic cabling where existing leased or owned twisted-pair wiring already exists, which is the case for many centrally controlled traffic signal systems around the country.

DSL for ITS applications was successfully field tested in 1999 in Fairfax City, and Alexandria, Virginia. As of April 2000, Baltimore, Maryland, has 30 cameras up and running over DSL, and at least two other cities are drafting procurement specifications. More than 15 additional cities have requested information in the technology. One city—Birmingham, Alabama—was able to install a camera and DSL communications link in only 2 1/2 hours, with near full-motion video over 12,000 feet of 25-year-old wire. Given these results within such a short time frame, this technology must be characterized as a success.

DSL deployed for ITS systems uses digital subscriber lines owned by the transportation agencies. Delays reported in ordering DSL service over lines leased from local telephone companies are consistent with reported experience with DSL installations in general—and with other new technologies when they are first offered.

The Jury is Still Out

High Speed FM Subcarrier Systems for ITS

FM subcarrier systems are widely used for both data and voice transmissions. RBDS (Radio Broadcast Data Systems) is a standard for low-speed FM subcarriers in the United States. Subcarrier technology involves piggybacking a second channel on commercial FM broadcast frequencies, providing an inexpensive one-way wireless communications medium. Specially equipped radios are required to receive the signals. This technology was viewed as a low-cost medium for broadcasting traveler information. It was successfully field tested in several cities; however, only one company currently provides such a traveler information service, albeit in 30 markets.

Two reasons have been cited as possible explanations for this low use. The first is immaturity of the in-vehicle traveler information market, partially due to lack of adequate surveillance information. Without an application, there was no need for this communications medium. The second reason, further discussed in the standards section of this paper, was the inability of the ITS and FM broadcasting communities to agree on a single standard for high-speed subcarriers. The prolonged debate and lack of resolution may have chilled the market for such systems.

FM subcarriers may yet see broader use for ITS, but will face competition from digital broadcasting and alternative two-way systems, which are becoming increasingly widespread. It is unclear whether the use of high-speed subcarriers for ITS will increase, stay level, or decline.

Unsuccessful Approaches

Several wireless communications technologies that were considered likely to receive widespread use in ITS applications have not achieved this level of success. The technologies themselves work, but ITS applications have not been built around them.

220 MHz Radio Channels

Blocks of radio spectrum became available in this band, and the ITS program initially obtained 12 channel pairs for ITS applications. Outside of limited use in Atlanta, Georgia—for tests held during the 1996 summer Olympic Games—no use has been made of these frequencies. In fact, six channel pairs were turned over to the U.S. Postal Service at its request. The consensus view is that ITS is too small a market to support development of unique communications services and devices.

CDPD for Two-Way Traveler Information Services

Cellular digital packet data (CDPD) is a technology for exchanging digital information over the Nation's analog cellular phone systems. The service is widely available in metropolitan areas (over half the U.S. population is currently served).

The National ITS Architecture program envisioned CDPD as a primary means of providing two-way communications to moving vehicles for ITS services. CDPD has been successfully used by a number of transit and public safety agencies for wireless data communications, but has not been used for commercial in-vehicle traveler information. The primary reason is the same as for one-way FM subcarrier information: the immaturity of the in-vehicle traveler information market. Technologies such as CDPD exist for providing the communications link, but the services that would use the link do not yet exist.

As the United States, along with the rest of the world, moves to digital cellular technologies, CDPD use will most likely peak and then decline, which is why this technology is characterized as unsuccessful for this application rather than placed in the "Jury still out" category.

Emerging Communications Media

Communications technologies continue to evolve rapidly. The areas where rapidly evolving technology may have a significant impact on ITS include wireless communications, the Internet, and the convergence of the two into the wireless Internet. It is too soon to categorize these technologies in terms of success in ITS applications.

Wireless Internet

While more people in the United States have Internet than cell phone access, this circumstance is not true in the rest of the world, and cell phone access in this country is growing at a rate similar to or faster than the Internet access rate. At the same time, second and third generation cellular technologies support much faster data transmission, which will further wireless access to the Internet, including Internet phones and other Web-enabled devices. Traveler information will be one of many services available over these media—through handheld portable devices and as an integrated part of in-vehicle telematics systems.

Local Area Wireless

A number of recent and emerging technologies exist for providing local area wireless data networks. These include the Institute of Electrical and Electronics Engineers (IEEE) 802.11 wireless local area network standard and the Bluetooth Initiative for wirelessly linking notebook personal computers (PCs), handheld devices, and peripherals. (The Bluetooth Initiative has recently added an interest group for in-vehicle communications.) These technologies may make interactions between handheld portable and in-vehicle telematics more seamless. Portions of the technology may also be applicable to the next generation of DSRC.

DSRC at 5.9 GHz

The FCC recently approved radio spectrum in the 5.9 GHz band for ITS DSRC applications, consistent with a worldwide trend to move DSRC applications to higher frequencies in the 5.8-5.9 GHz bands. In the United States, increasing use of the 902-928 MHz industrial, scientific, and medical band has raised concerns that the band will be too crowded and noisy to support a growing range of potential DSRC applications, including toll collection, drive-through purchasing, and intersection

collision avoidance systems. Discussions are under way to determine how to allocate spectrum in the 5.9 GHz band and to address the need for standards. Various new local area wireless standards (e.g., IEEE 802.11 and Bluetooth) are being examined to see if they or a portion of them may provide the basis for standardization. At the same time, these new local area wireless standards may end up being used for many potential new DSRC applications. Using these alternative approaches instead of DSRC technology will mitigate the need to migrate to the 5.9 GHz band.

Low-Power FM Licenses

This technology is not new, but is newly legalized. In the past, no provisions existed for licensing low-power FM radio stations, and the FCC only recently issued rules providing for such licenses. These rules specify highway advisory radio (HAR) as an allowed use. FM has the potential to provide a much clearer signal to drivers than many current AM HAR systems, and most cars currently have FM radios. However, the U.S. Congress is currently considering several bills to overturn the FCC ruling.

High-Speed Fixed Wireless

A number of new radio spectrum sections and new commercial services available for high-speed wireless voice and data connectivity are becoming available. These alternatives to owned or leased wireline links will increase competition and provide connectivity that might not otherwise be available.

The Internet

While the Internet itself is not a new medium, several new features and uses are emerging that may impact ITS. The first is the slowly growing use of high-speed, always-on Internet access via cable modems or DSL. This technology turns the home PC into a convenient information appliance. As this type of access becomes more prevalent, it will increase routine use of the Internet as an information source.

A second rapidly emerging application is the use of the Internet for electronic commerce, whether business-to-consumer, business-to-business, business-to-government, or government-to-citizen. This application will push more and more transactions and services to the Internet.

Finally, a related trend is the move to fully automated Web-based information exchange. Most Web-based information exchange today is semi-automated. An automated server provides information for display on a screen read by humans. In some cases, the user then re-enters the relevant pieces of information into another processing system. This method is being supplemented by automated server-to-server information exchange using XML (eXtensible Markup Language). Potential impact areas for ITS include the following:

- XML-based vocabularies as a supplement to or replacement for American National Standards Institute (ANSI) X12 electronic data interchange standards for Commercial Vehicle Information Systems and Networks (CVISN) applications, fleet management, and intermodal freight shipments.

- XML-based traveler information: the Society of Automotive Engineers Advanced Traveler Information Systems Committee has recently begun work on an XML-based version of their traveler information message set standard. At least one state is using XML on the server side to prepare Web pages and is publishing the XML-based information as well, for reprocessing by others.

- Location referencing: the Open Geographic Information Systems (GIS) Committee is developing an XML-based standard for Web-based exchange of geographic information. ITS mapping standards committees are investigating XML.

- Archived Data User Service (ADUS): to the extent that XML is used by systems providing archived data, it will impact this new area of ITS. In addition, XML may provide the basis for exchange of some ADUS information.

- Electronic payment systems: the open financial exchange protocol used by home banking software and by the banks and investment companies they link to is being updated to be XML-compliant. New financial exchange standards with broader applicability are also being developed using XML, which may affect future ITS electronic payment applications.

ANALYSIS TOOLS

Experience has shown that traditional transportation planning analysis cannot assess the impact or capture the benefits of more efficient transportation operations, such as those obtained using ITS. The traditional approach to transportation planning analysis assumes no day-to-day variability in demand and no incidents or weather effects, and assigns vehicles to their optimal routes. With these simplifying but unrealistic input assumptions, little or no benefits can be shown for increasing the amount of information available to travelers and transportation operators, or for real-time management of transportation resources.

ITS research has identified several new analysis methods to address these limitations. The ITS Deployment Analysis System tool allows benefits estimates to be made for specific ITS investments. Using methodologies consistent with current planning analyses, IDAS imports planning model data and allows users to estimate incremental costs and benefits of adding ITS deployments to existing planning alternatives.

PRUEVIIN methodology allows off-the-shelf planning and traffic models to be merged, and explicitly captures and analyzes effects of variations in demand, weather, and incidents. These enhancements are made possible by improvements in modeling techniques and computer processing power, allowing large areas and vehicle populations to be modeled at the mesoscopic level.[1] For example, 300,000 vehicle trips in a morning peak period can be simulated in sufficient detail to capture ITS impacts. Finally, the TRANSIMS model, now under development, uses synthetic household trip generation and microscopic traffic simulation to analyze transportation planning issues.

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[1] Traffic models can be categorized into three categories: macroscopic, microscopic, and mesoscopic. Macroscopic models look at overall vehicle flows, speeds, and rates, and do not explicitly model individual vehicles. Microscopic models model individual vehicles and their interactions, including headway, gap acceptance, lane changing, etc. Mesoscopic models are hybrids; they model and track individual vehicles, but model their travel using flow equations and simple queueing models.

Macro-level estimates indicate that large cost savings can result from using ITS in conjunction with conventional construction to meet increases in travel demand. Also, ITS projects can typically be completed more quickly, resulting in a faster return on investment and lower disbenefits associated with major construction. Because ITS improvements offer a means of deferring capital investments, they can be viewed as buying an option with an estimated value (the economist perspective) or as optimizing the allocation of the available budget. New approaches to life cycle costing may be needed to accurately and adequately capture these impacts.

ARCHIVED DATA

The Archived Data User Service was added to the National ITS Architecture in 1999. Information collected for real-time operations or from ITS technologies has many additional uses. Of course, some communities have archived this type of information for many years, efforts that the ADUS program will recommend expanding, along with developing new tools and approaches for effectively using this information to improve surface transportation operations.

The growing deployment of ITS sensors has the potential, if planned appropriately, to lower data collection costs. For example, if sufficiently accurate, freeway loops could provide continual, around-the-clock traffic counts, eliminating the need for separate tube counters to provide snapshot traffic counts.

A second example of potential cost savings stems from increasing availability of urban travel time information to support real-time traveler information systems. Such data, if properly archived, can be used as input to new forms of simulation models that can replace more expensive field studies involving paired drivers. One example is HOWLATE (Heuristic On-Line Web-Linked Arrival Time Estimator. HOWLATE uses archived travel time data to assess the user benefits of traveler information systems. It also provides a mechanism to track road, link, and network-wide trends in average travel time and travel time variability.

Finally, new technology can simplify and improve traditional data collection processes. For example, off-the-shelf GPS receivers coupled to notebook PCs or handheld computers can automate floating car and speed run data collection, reducing cost and improving accuracy.

ARCHITECTURE

The National ITS Architecture has proven to be an important tool for promoting both technical and institutional integration. The architecture has provided a basis for developing ITS standards and for developing local and regional architectures, promoting use of the systems engineering process in ITS.

Many areas are either developing or starting to develop regional architectures, with a growing acceptance of the need for such work to provide a framework for project coordination and integration. Most of these areas are using the National ITS Architecture as a tool to reduce the time and effort required to develop their tailored regional architecture. U.S. DOT has developed a software tool, "Turbo

Architecture," which is available through McTrans™ Center for Microcomputers in Transportation at the University of Florida. This tool has the potential to greatly assist production of regional and project architectures for those using the National ITS Architecture as a basis for the communications and interface framework. Importantly, this software tool will associate interfaces within the developed architecture to standards that could potentially help in detailed system design and system-to-system interoperability. Areas using the National ITS Architecture include Virginia, Maryland, Baltimore, Pittsburgh, Dallas, New York City, the mid-Ohio region and Washington, DC.

In addition, many countries initially skeptical of the need for an overall National ITS Architecture have come to recognize the value of such an approach, pioneered by the United States. National and multinational architectures have now been developed or are being developed by many nations and groups, including the European Community, Korea, Japan, Australia, Canada, Italy, the Netherlands, and the International Organization for Standardization (ISO).[2] Many of these countries explicitly or implicitly borrow from the U.S. National ITS Architecture.

To continue to be useful, the National ITS Architecture must and should be maintained to accommodate new or revised ITS user services. The current process for accommodating new or revised user services, however, is costly and time-consuming. This issue raises an important concern, as several new services are under consideration and require the architecture to be kept up-to-date. The current process involves intensive and time-consuming efforts to:

- Coordinate development of informal user requirements from the stakeholder community.
- Translate informal requirements into formal "user service requirements."
- Implement requirements in a revised architecture, down to the lowest level of the current national architecture.
- Update related documents such as the standards requirements document.
- Elicit review by the user community.

This process adds time and significant cost to the overall National ITS Program. It would be appropriate to revisit these procedures and determine ways to reduce the time and cost involved in maintaining the National ITS Architecture. Areas for consideration include streamlining the requirements generation process, reducing the level of detail maintained in the current architecture, and eliminating maintenance on some of the noncore architecture documents, such as the standards requirements document.

STANDARDS

With some important exceptions, ITS systems use standard off-the-shelf communications media and applicable general purpose data communications standards. Standards unique to ITS are developed primarily for application messages exchanged

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[2] ISO is the short-form name of the organization, not an acronym, hence the apparent mismatch between the formal name in English and the letters "ISO."

over these media. One notable exception is DSRC for such applications as ETC and commercial vehicle prescreening.

ITS standards can allow equipment from multiple vendors to interoperate, reducing lock-in to single vendors and allowing easier upgrades or expansion of systems. ITS standards also make it easier to add new capabilities and, ultimately, reduce cost.

The ITS standards program is based on a unique partnership, with U.S. DOT providing partial funding to facilitate and expedite he development of ITS-specific standards. The concept is to use the voluntary standards development process normally used in the United States, but with additional funding for specific types of support that facilitate and speed standards development.

Federal funding is made available on a case-by-case basis for the following purposes:

- To pay for consultant time to help draft standards.
- To cover travel and per diem costs of state and local public sector participants, to ensure that the standards development process adequately represents the customer perspective.
- To conduct testing to ensure quality and completeness of a standard.
- To cover certain administrative costs associated with developing ITS standards.
- Where appropriate, to fund limited participation in international standards development.

The standards program has led to many successful standards development efforts. In particular, federal support has expedited the development of several important standards, including the in-vehicle ITS Data Bus and NTCIP family of standards, particularly the center-to-roadside subset.

At the same time, availability of Federal support has generated a large number of concurrent efforts, which has made it difficult to track and coordinate efforts and ensure proper focus on critical and timely areas. In addition, some of these efforts, while useful, do not address critical needs and lack the necessary push for successful development and adoption of standards. Some standards efforts would not merely slow down, but would evaporate without Federal funding, which indicates the standard is not essential. Having a large number of concurrent efforts also dilutes available resources, attention, and oversight. Some standards may not be getting sufficient evaluation and critical review from a broad enough base of product developers and users before being adopted.

A few unsuccessful efforts to develop standards have occurred where a perception held that proprietary interests of individual product developers were greater than the benefits of uniform standards. For example, the DSRC area has no approved standard for this reason, and high-speed FM subcarrier communications finally adopted multiple incompatible standards after much delay and forum-shopping.

On a more minor note, the time from start of a standards development effort to availability of standards-conforming products was often underestimated. ITS standards typically take several years or more to develop, and at least another year before products that implement the standard become commercially available.

Despite these problems, a large number of useful ITS standards have been completed, and products that comply with the standards are being developed and deployed. ITS standards are undergoing a critical period within the ITS community, which has expressed skepticism about their value. Successful projects will greatly aid in overcoming the hesitation to move to new, standards-based products, while well-publicized failures will set the program back, regardless of reason for the failure. Guidance and assistance must be available to ensure that first adopters are successful in deploying standards-based systems.

Some critics have cited the need for independent testing of products for standards conformance, including participants at the Institute of Transportation Engineers (ITE) 2000 International Conference in April 2000. Others have stated that vendor self-testing and warranties would be adequate. Both groups have urged standardardized testing procedures.

ADDITIONAL FUTURE DEVELOPMENTS

The main reason for the "What Have We Learned About ITS" Initiative was to identify successes, failures, and open issues to help in planning the future of the ITS effort. To conduct this planning, one must not only look back at what has been learned, but also look forward to what is expected. This section briefly identifies some of the expected near-term developments in ITS:

- Continued integration of services and components. There will be increased integration of various ITS user services within a locality, as well as increased integration across local jurisdictional boundaries. In many areas, this event will be a loose integration based on information exchange, but in some areas, transportation needs will drive tighter integration, despite current institutional barriers.

- Continued migration of analytical and simulation tools that integrate ITS and operational analyses into the transportation planning process.

- Reduced need for differential GPS or supplemental position determination methods, stemming from removal of the intentional "selective availability" degradation in GPS accuracy. Elimination of selective availability in May 2000 increased the accuracy of basic GPS data from about 100 meters to between 10 and 20 meters.

- Continued impact of new information technologies. A current example is the emergence of extensible markup language for automated Web-based information exchange. This innovation will bring both opportunities and challenges. Newer, cheaper, and simpler tools will enhance the ability of both the public and private sectors to bring services to citizens and customers. At the same time, the rapid evolution of technology and related standards will continue to make implementation decisions difficult. This circumstance will be true, regardless of whether the technology is purchased or the service leased from a service provider.

- Lower cost and new methods for evaluating ITS. Archiving of ITS data will lower the costs of evaluation and performance monitoring and, perhaps more importantly, will provide new methods and metrics for assessing and evaluating the effectiveness of transportation operations.

- Development of national traveler information systems. Multiple private, state/regional, and national projects will promote necessary data and message standards and database developments, leading to interstate and national level traveler information systems.

- Expanded use of weather information systems. Increased focus on rural needs will expand research, testing, and deployment of improved road weather information systems. Sensing and warning networks will expand, and new tools for integrating and fusing information to aid decision-makers will be developed.

- Increasing statewide integration for areas outside of major metropolitan areas. This integration may include statewide public safety answering points and statewide traffic and emergency management coordination.

- Increased efficiency of transit and paratransit services for health and human services. This increase will result from greater coordination and expanded brokerage services between agencies.

- More widespread vehicle-based safety systems, such as collision warning systems.

RECOMMENDATIONS FOR NEXT STEPS

Based on what has been learned to date on technical issues, the following recommendations are made for future national-level activities:

Traffic Sensing (Surveillance)

U.S. DOT should encourage deployment of traffic sensing (surveillance) systems, as they are a key enabler for arterial and freeway traffic management as well as for traveler information systems and real-time route guidance. U.S. DOT should promote deployment, provide incentives, and consider establishing minimum requirements for portions of the National Highway System. Use of electronic toll-tag technology as traffic probes should be promoted where appropriate, and testing of cellular geolocation technologies for collecting travel time data should be a near-term priority. The latter recommendation may already be occurring at the state and local levels, and may not require a large Federal role.

Standards Development and Deployment

Federal support should continue for a limited set of key standards, including maintenance, updates, and revisions of recently approved standards. The first generation of products and deployments will identify necessary revisions. Also, as technology evolves, new, overlapping standards will be developed in some areas—a fact of life that must be accommodated.

U.S. DOT should closely monitor deployments of standards-based traffic management and roadside products. Some in the traffic management community are skeptical about the utility of these standards, which call for ongoing education as to their purpose, use, and benefits. Publicizing successful deployments will also help to mitigate skepticism.

Skepticism and a general reluctance to try new "leading edge" approaches will heighten any failures of standards-based procurements. Negative publicity will

create a setback for the National ITS Program. U.S. DOT should be prepared to react quickly if standards-based products are not being developed or if problems ensue with deployments. Appropriate action will depend on the nature of the problem. For example, if standards-related problems develop in a deployment project, U.S. DOT could send in an expert "tiger team" to rapidly assist in identifying the problem and developing a solution for that project. Information gleaned would then be used to guard against similar problems occurring with future procurements.

Evaluation Voids
U.S. DOT should continue efforts to close gaps in knowledge of ITS impacts. Gaps exist in the areas of ITS integration, rural ITS, traveler information benefits, and transit maintenance management. Types of knowledge gaps include more than just benefits and cost information. They also include information on how ownership, intellectual property, and liability issues are resolved. U.S. DOT is already using the identified gaps as criteria for deciding which ITS deployment projects to evaluate at the Federal level, and has begun new research to quantify the benefits of pre-trip traveler information systems.

Efforts to track deployment levels in a cost-effective manner for various ITS services should also continue, as these results are an important consideration in deciding how to make National ITS Program investments.

Tracking New Technologies
New technologies and trends that might affect ITS should continue to be identified and assessed for their potential effects, both positive and negative.

ACKNOWLEDGMENTS

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chapter 8

**WHAT HAVE WE LEARNED
ABOUT CROSS-CUTTING
INSTITUTIONAL ISSUES?**

EXECUTIVE SUMMARY

In 1991, the U.S. Congress initiated the Intelligent Vehicle Highway Systems (IVHS) program, now called the Intelligent Transportation Systems (ITS) program. While Congress was enthusiastic about the potential benefits of using advanced technologies in the surface transportation system, it was also concerned that nontechnical barriers and constraints would impede the progress of the program. Therefore, it instructed the Secretary of the U.S. Department of Transportation (U.S. DOT) to identify significant institutional issues and to study their potential effects on the program. To fulfill this mandate, the U.S. DOT commissioned extensive studies of institutional and legal issues. These activities included evaluations of ITS field operational tests, demonstration projects, and model deployment activities.

In addition to the work of U.S. DOT, representatives of state, regional, and local governments, private sector firms, and academia investigated the impacts of institutional and legal issues. U.S. DOT, Intelligent Transportation Society of America (ITS America), and other professional organizations also sponsored conferences and workshops addressing the impacts of institutional issues.

The major finding of these activities is that no nontechnical or institutional issue has completely halted deployment of an ITS project. While institutional and legal impediments do exist, they either have been or can be overcome. Some areas, such as privacy, public-private partnerships, and government procurement regulations, required legislative change. Other areas, including attracting and retaining staff and dealing with liability issues, require outreach, technical training, and education.

Investigation of barriers showed that the key to overcoming most constraints is realizing that certain problems will arise and must be addressed early in project planning. It should be noted, however, that success did not always come easily. Often, implementors of ITS products and services spent a considerable amount of time and other resources addressing these issues. It was only through their perseverance and commitment that they were able to overcome these barriers.

INTRODUCTION

Since the inception of the IVHS program nearly a decade ago and its continuation as the National ITS Program, the U.S. Congress, other public policymakers, and the transportation community have recognized that nontechnical and institutional issues can adversely affect the implementation of ITS products and services. To address this concern, Congress requested, through the Intermodal Surface Transportation Efficiency Act of 1991, that the Secretary of U.S. DOT prepare two special reports on ITS nontechnical and institutional constraints and barriers.

The Secretary, through his staff, also commissioned other studies to address potential obstructions to ITS implementation. In particular, the ITS Joint Program Office (JPO) oversaw the evaluation of a number of field operational tests and Metropolitan Model Deployment Initiative (MMDI) sites. Furthermore, representatives of state, regional, and local governments, private sector firms, and academia analyzed the potential and real effects of these issues as they deployed ITS. U.S. DOT, ITS

America, and other professional organizations also sponsored conferences and workshops addressing the impacts of institutional issues.

This paper brings together the findings from these activities, addressing the question, "What have we learned about cross-cutting institutional issues?" It discusses how the planning and deployment of ITS projects differ from procedures required by traditional transportation projects, the challenges presented to the transportation community, the issues that may be encountered in the future, and how these issues may already have been addressed.

A NEW AND DIFFERENT ALTERNATIVE

The National ITS Program provided the transportation community with a new alternative for solving transportation problems, offering another tool to better manage the transportation system. In the early days of the program, however, the concept of ITS was not clearly defined and left transportation officials uncertain about the program's direction. Also, the transportation community felt that ITS technologies focused more on highways than transit and was more conducive to freeways than to arterials.

The implementation of ITS products and services also differed from the implementation of traditional construction projects. ITS planning and deployment required coordination among jurisdictions, data sharing, unique technical knowledge, and involvement of nontraditional players. These differences meant that several barriers had to be overcome. Coalitions had to be built where none existed before, and new communication channels had to be created among agencies within a region. Employees with new skills had to be found, and current employees needed to receive new training. Public works personnel had to work with public safety personnel and representatives of private sector firms.

The newness and difference of ITS also caused the creation of additional stumbling blocks. Because public officials were more familiar with traditional, more "tangible" projects and because the benefits of ITS were not readily available, ITS projects required a greater proof of value than traditional projects. Furthermore, staff apathy and/or skepticism had to be overcome.

Other differences were also noticeable. First, ITS involved larger operations and maintenance components than previously experienced in "build and ignore" construction projects. Second, procurement of ITS technologies required a different process than that used for construction projects. Finally and on the positive side, ITS projects were eligible for nontraditional sources of funding, such as funding from the Congestion Mitigation and Air Quality program.

A NEW ENVIRONMENT

Creation of the National ITS Program produced a new work environment for the transportation community. This new framework anticipated the emergence of different emphasis areas within U.S. DOT. It also required the formation of new relationships leading to new alliances among an area's public sector agencies, along

with collaboration of public and private sectors. This environment involves a different portioning of project costs as well.

New Federal Transportation Emphasis Areas

For the past four decades, the Federal Highway Administration (FHWA) emphasized the construction and maintenance of the National Highway System and other roads on the Federal-aid highway system. With that job largely completed, FHWA needed to turn its attention to better operating and managing the assets already in place. Partly in response to the National ITS Program, FHWA management now places a greater emphasis on the management and operation of the Nation's highway system, evidenced by the creation of a core business unit for operations within the agency. The Federal Transit Administration (FTA) increased its emphasis on advanced public transportation systems and services innovations. The planning offices of both agencies now promote ITS solutions within the statewide and metropolitan transportation planning processes.

The most significant change within U.S. DOT caused by the National ITS Program was the creation of the ITS JPO. This office serves as the U.S. DOT's advocate and national leader for ITS research and deployment, establishes strategic direction, and provides cross-departmental coordination of ITS activities.

JPO staff are engaged in many activities new to U.S. DOT. These activities include creating the National ITS Architecture, accelerating the development of standards, and ensuring consistency of federally funded ITS projects with the architecture and standards. JPO staff are also active in developing a program to increase ITS knowledge and skills among transportation professionals; conducting outreach and communications activities that include showcasing benefits of ITS products and services; and evaluating ITS activities, including the tracking of ITS deployments across the United States. Furthermore, the National ITS Program has also led the JPO staff to consider the traveling public as a user of ITS services and to engage in market research to understand user acceptance of ITS products and services and user willingness to pay for them.

New Regional Organizations

Before the inception of the National ITS Program, extensive interactions among transportation agencies were not necessary. The planning and deployment of ITS projects, however, require more in-depth cooperation, coordination, and communications among these agencies. Strong relationships are needed to ensure development of a regional perspective, integration of individual products and services, and effective operation and maintenance of installed systems. Use of a regional organization has proven to foster and maintain the close relationships needed to successfully deploy ITS.

Sometimes an existing organization can be used as the central agency. For example, in the New York-New Jersey-Connecticut metropolitan area, TRANSCOM[SM] (Transportation Operations Coordinating Committee), a coalition of representatives from 15 traffic, transit, and law enforcement agencies in the tri-state area, came to coordinate construction and regional incident management. The agency's role later

broadened to include coordinating the region's ITS activities, including leading the ITS model deployment initiative.

Sometimes new organizations are created. The E-ZPass Interagency Group, which now comprises representatives from 16 toll agencies in seven eastern states (Delaware, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and West Virginia), was created when executives from the region's transportation agencies and toll authorities determined that the successful implementation of a regional electronic toll collection system required a regional management structure. In either case, the concept of a regional transportation body to oversee transportation projects is another facet of the new environment in which transportation professionals must work.

New Public and Private Sector Collaboration

The advent of the National ITS Program brought the public and private sectors together in a new way. The dissemination of data, for instance, necessitated the interaction of public and private sectors. For while the public sector operated the physical infrastructure that collected the data, the private sector operated the media that disseminated them. Often, large bureaucracies and small entrepreneurial firms started working together for the first time. For this collaboration to work, participants had to learn to overcome biases toward the other sector, understand each other's cultures and responsibilities, and establish strong cooperative relation-ships. Working with representatives of another sector was an adjustment for all participants.

Implementing new ITS technologies brought together as partners several govern-mental agencies and private firms, which had previously worked together only in a customer-vendor role. All parties had to adjust to a new business style and working environment. The newness of this type of collaboration also made public sector officials aware that representatives from private firms were entitled to provide input into the decision-making process. Likewise, private sector management had to learn about local, state, and federal procedures and contracting requirements.

The public and private sectors also have different business cultures and biases toward each other. Sometimes representatives from the private sector were not totally aware of the political realities faced by public agencies, and focused only on business issues. Similarly, some public agency staff were unreceptive to innovation and, in the eyes of the private sector, made decisions too slowly. Conflicts also occurred over the public and private sector's differing expectations about proprietary interests and intellectual property rights.

New Cost Flows

With traditional highway projects, costs are weighed more for construction than for operations and maintenance. This scenario is reversed with ITS projects. Very often, the construction costs to deploy ITS products and services are low compared to the costs to operate and maintain them over the system's life cycle. This situation requires transportation officials to present the funding need for operations and maintenance to elected officials and upper management.

Also in this new ITS environment, operations costs can be offset by the generation of revenues. Placing a value on an ITS product or service and determining the distribution of revenues among project participants are activities previously unfamiliar to public sector transportation personnel. Furthermore, providing the funds to construct, operate, and maintain ITS infrastructure is no longer the sole responsibility of the public sector. The National ITS Program created the opportunity for the private sector to be involved in providing services and sharing the costs and revenues to do so.

CURRENT AND FUTURE ISSUES

Implementors of ITS products and services will continue to be confronted by nontechnical issues. Analysts from the U.S. DOT's John A. Volpe National Transportation Systems Center identified areas in which issues have arisen and may continue to arise. They identified these areas through evaluation of model deployment initiative projects;[1] review of nontechnical barrier studies; and discussions with program managers, evaluators, and others involved in the ITS community. These areas were subjectively ranked using responses to an informal survey of ITS program managers and voting results obtained from participants at a roundtable discussion on ITS cross-cutting institutional issues convened during a conference sponsored by the Institute of Transportation Engineers.[2] The following discussion of the issues includes comments from participants of the roundtable session. Ten issues were identified, with the most prominent listed first:

- Awareness and perception of ITS.
- Long-term operations and maintenance.
- Regional deployment.
- Human resources.
- Multi-organizational relationship.
- Ownership and use of resources.
- Procurement.
- Intellectual property.
- Privacy.
- Liability.

These issues are not mutually exclusive. Often an action taken to address one issue may help overcome another.

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[1] On February 26, 1996, U.S. DOT issued a request for participation in the Metropolitan Model Deployment Initiative. The sites to be selected were envisioned as demonstrations and showcases of the measurable benefits resulting from application of an integrated, regionwide approach to transportation management and provision of traveler information services.

[2] The Institute of Transportation Engineers held their 2000 International Conference in April 2000, in Irvine, California. During this conference, U.S. DOT's ITS JPO sponsored seven roundtable discussions. In the session that covered cross-cutting institutional issues, 19 participants representing federal, state, and regional transportation and planning agencies; private firms; and transit properties identified, discussed, and ranked nontechnical issues that have arisen or may occur in the future. This paper incorporates their input.

Awareness and Perception of ITS

Although ITS activities have been under way for approximately 10 years, numerous elected and appointed officials are still not familiar with the concept. Also, some see ITS technologies as "gizmos" looking for a problem to solve. For ITS programs to achieve widespread acceptance, ITS proponents must garner explicit public awareness and support for them. Failure to do so means a lack of financial resources and other support for ITS projects.

Public officials must understand the transportation needs in their area. They must be shown how improving the transportation system will help achieve the goals set for the community, such as those addressing economic development and quality of life. Once the problems and goals have been identified, then the officials can be shown the solutions available to them, which, naturally, would include ITS products and services.

The effective management of the transportation system will always be a goal of the public sector. The operations and maintenance of this system have become increasingly more difficult because of decreasing opportunities for new construction and because of reductions in staff, funding, and other resources. Again, in this context, ITS solutions can be promoted as one way to improve management of the system.

Safety is another area of visible need and concern for public officials. Whenever ITS products and services can help improve safety, they should be touted toward that end.

Often, there is a lack of solid evidence that ITS solutions are effective. The ITS community must continue to develop tools to measure effectiveness and move from empirical and anecdotal knowledge to quantifiable, explicit benefits. Evaluations of deployed ITS must continue, and the findings from these evaluations must be widely publicized.

Lack of awareness continues to be an intra-agency problem in some agencies. Coordination of personnel performing different functions (e.g., planners, ITS personnel, and maintenance staff) may also be limited. Agency management must continue to show how ITS solutions can improve both the effectiveness of the agency as well as the effectiveness of the transportation system.

Management at the San Antonio District of the Texas Department of Transportation (DOT) understood well the need to make ITS visible to decision-makers and the general public. Their public relations staff reached out to the general public through radio and television commercials, printed pamphlets and newsletters, and real-time video images and traffic information on local radio and television news. District management also championed ITS and went before the Texas Transportation Commission to promote it. Furthermore, the San Antonio District approached their management at headquarters and helped them understand the concepts and terms of ITS. They also sponsored tours and demonstrations of their ITS facilities for state and federal elected officials.

The staff of the San Antonio-Bexar County Metropolitan Transportation Planning Organization brought ITS to elected officials through its board and to the general public through citizen task force meetings featuring discussion of the 20-year regional transportation plan. The planning staff discussed ITS before groups and transportation agencies at public hearings for the region's transportation improvement plan.

Long-term Operations and Maintenance

As more and more ITS technologies are deployed, the issue of continued operations and maintenance of these systems becomes more prominent. As previously noted, ITS projects are unlike most typical construction projects in that they are designed for continuous operations. Transportation professionals need to approach planning for ITS projects differently than they have for capital projects. The lack of long-term planning could result in a poor transition from project deployment to day-to-day system operation.

The cost of a project's operation and maintenance must be identified in the project planning stage, and the impacts of these costs addressed. The life cycle of each operational improvement must be considered. Procedures similar to those used in the private sector should be developed to examine capital costs as well as costs for operations, maintenance, and repair. These procedures must be flexible, for sometimes public staff do not know the full cost of operations and maintenance until the technology is installed and operating. In other cases, ITS use is expanded to include new functions. The procedures should be easy to change based on feedback and expanded uses.

Working in a new environment, transportation professionals must address operations and maintenance costs earlier than before in the project timeline, as doing so will bring the need for continued funding before elected and appointed officials—a need often overlooked. Up-front costs for ITS projects are usually less than those for conventional infrastructure projects; however, continuing costs are usually greater than conventional maintenance costs.

Considering operations and maintenance activities early in the project development process will also ensure that the designed system operates as expected, is used as planned, and can be easily maintained. Staff responsible for different functional areas should be encouraged to provide input during the different phases of the project—including, for example, those responsible for operations and maintenance functions in the system design and construction phases. This action will reduce the risk of having to modify the system after it is installed.

Although they did not always start planning for long-term operations and management at a project's initiation, participants in several ITS deployments recognized that this planning should be addressed early in the project's life. They learned that knowing what would happen at a later step might prompt them to change what they did at an earlier step.

To ensure continuation of its ITS activities, Washington DOT staff developed a business plan addressing long-term operations and management of their advanced traveler information system. This plan helped them to understand the direction the project would take once it was deployed. The plan also covered the transfer of control of existing systems and defined public sector and private sector roles.

Management personnel at the Road Commission for Oakland County in Michigan were also concerned about the long-term operation and maintenance of its FAST-TRAC (Faster And Safer Travel through Traffic Routing and Advanced Controls) system. During the field operational test, management wanted to ensure that the advanced traffic management system would be maintained. Given the amount of hardware involved, contractors performed most of the installation. Commission management, however, retained some of the installation work for its technicians, feeling that the new technology would challenge and motivate its staff. Because of their involvement, the staff developed an appreciation of the system and a sense of pride and satisfaction, which helped to ensure its long-term maintenance.

Regional Deployment

So many perceptions exist of what constitutes a region. Metropolitan planning organizations (MPOs) look at the metropolitan area, while politicians look at where their electorate resides. The media looks at its market. In contrast, an ITS program must not be imprisoned by jurisdictional boundaries. Because there are various ways to get people to act regionally, participants of any ITS program should thoughtfully consider how to group the region, identifying the scale of the transportation system serving the region and bringing varied people together.

The adoption of a regional perspective for ITS use is one of the most important strategies for success. A regional perspective means that project participants view projects from the standpoint of other project participants in their region as well as from their own. This outlook, which fosters a more cohesive and integrated project vision for all involved, is key to facilitating development of ITS products and services. Failure to craft such a vision leads to confusion among project participants and often to severe delays. Unfortunately, developing a regional perspective and bringing the necessary players together will continue to be a challenge. Differing agendas of public agencies and differences between public and private sectors will continue to be impediments.

Often within transportation planning and design processes, ITS projects are considered to be in competition with capital projects for a region's transportation funds. In reality, ITS projects should be developed in concert with capital projects. Project planners and designers should routinely consider ITS technologies that could complement the capital project and help to operate it more effectively.

Advancing the routine consideration of ITS solutions in the metropolitan transportation planning process will help foster a regional vision for ITS. Moreover, this action may increase support from elected officials who sit on the MPO's governing board. The MPO structure can also be used to heighten communications among public agencies and the private sector.

Implementers of successful ITS projects have used four strategies to develop a regional perspective: (1) they built on existing relationships, (2) they developed a shared vision, (3) they involved nontraditional players, and (4) they augmented existing systems.

A regional ITS perspective was developed within the New York-New Jersey-Connecticut metropolitan area by following the four strategies outlined above. First, Trips123 project participants built on existing relationships and promoted an existing organization of transportation agencies, TRANSCOM,SM as the lead agency. They then reviewed the ITS plans and activities of the member agencies and selected a course of action best suited for the region. They brought in private sector firms previously not affiliated with TRANSCOM.SM They also augmented existing systems, which included a traffic management and accident detection system, a transit information system, a regional architecture, and the incident and construction data already collected by the agency's operations information center.

Most importantly, participants realized that in order to ensure success, they would have to adjust their priorities or possibly give up some autonomy or control. This event occurred when a request was made to move the implementation of the first phase of the traffic management system from the southern portion of the region to the northern portion. TRANSCOMSM members unanimously decided to accept this request, easily making the decision because they had already developed a regional perspective for traffic management.

Human Resources

Problems in this area may be manifested in several ways. First, public agencies may lack the staff needed to develop, install, and operate ITS. Second, the staff may lack the expertise required. Third, talented public sector staff may be lured to the private sector.

These conditions will occur when a public sector agency has limited resources to hire and train staff, and to provide salaries and benefits comparable to the private sector. This issue intensifies when resources become less available. Project administrators must clearly identify the resources required and bring their needs before management. They must also identify areas in which the private sector can contribute its expertise.

An inflexible agency culture and organizational structure may also lead to problems. Agency personnel may not accept new technologies or develop new ways of doing business, such as modifying the procurement process to accommodate ITS products and services. Activities that promote the benefits of ITS technologies need to continue.

Labor issues may also arise. Installing new technologies will definitely affect the way jobs are performed. Agency managers get concerned that union members may perceive these technologies as increasing their workloads or forcing them to change the ways they do their jobs. The perception may be that ITS will reduce the number of employees needed by an agency or within a particular job category. Project developers should invite union representatives into the ITS development process at an early

stage, not only to explain the project and assuage fears, but also to receive labor's input into the design and operation of the system.

There are several examples of MMDI project participants overcoming possible staff reluctance and insufficient training. In San Antonio, the Ambulance Committee solicited feedback from emergency medical technicians and firefighters concerning the placement of video equipment in ambulances. VIA Metropolitan Transit Authority bus drivers were asked to provide input on the placement of cameras within buses. Operators of the traffic management center were involved in designing the upgrade and expanding the TransGuide center.

The training of San Antonio firefighters and emergency medical technicians on new equipment occurs through a phased program in which a small group is selected and trained and, in turn, trains others. This system works well for the San Antonio Fire Department because the units are geographically dispersed. Fire department management preferred to conduct in-house training, as outside trainers lack familiarity with personnel concerns and with San Antonio Fire Department procedures.

In Indianapolis, Indiana, the Metropolitan Emergency Communications Agency (MECA) was formed to develop a regional emergency communications system. In response to elected and appointed officials' concerns that potential users were adequately trained to use the system, agency staff successfully launched a pilot project. They installed seven mobile data terminals in cars used by the sheriff's department. After a small number of sheriff's deputies used the outfitted cars for a short period of time, MECA staff formally trained them. Following their training and further use of the units, these deputies wrote the user's manual. As additional units were installed, the deputies were able to train their fellow deputies on the equipment, thereby contributing to the system's acceptance and effective use.

Multi-organizational Relationships

The establishment of strong working relationships will continue to be a challenge to the ITS community. As previously mentioned, differing agendas between public sector agencies and between the public and private sectors must be addressed. Public sector personnel must look at the traveling public as their customer and provide a seamless and efficient transportation system. To best serve their customers, managers of public agencies must be willing to give up some of their autonomy and develop a regional perspective when establishing coalitions with other public agencies.

Collaborations between public sector agencies and private sector firms will also continue to confront stumbling blocks. The cultural differences between the two sectors must be considered. The public sector must understand the profit motive and how to work it into a partnership agreement with the private sector. The private sector must understand the public sector's charge to be vigilant for the welfare of all citizens, regardless of their ability to pay more for a product or service.

There are other factors that will hinder the creation of public-private partnerships. For instance, the roles of the public and private sectors still remain unclear in many locations. Often no clear incentives for private sector involvement are evident, and uncertainty still exists about the commercial market and user willingness to pay for

ITS products and services. Project participants must ensure that these vague areas become better defined.

To address the issue of partnering, staff at the Washington DOT developed a business plan for its advanced traveler information system that identifies public and private sector roles. In the Smart Trek MMDI, private sector representatives were included from the inception of the project and involved in developing the project proposal. They have a role in every aspect of the project's development. The Smart Trek decision-making structure includes two deputy project managers and four bundle managers (similar to committee chairmen) from the private sector.

Furthermore, to encourage private sector involvement, public sector participants are trying to develop a market for the private sector. Smart Trek project participants are encouraging private sector information service providers to disseminate traveler and traffic information by making it widely available and free of charge.

The Minnesota DOT developed an innovative process that involved the private sector in the initial identification of ITS partnering opportunities. Rather than issuing a request for contract proposals for specific projects already defined by the public sector, the agency's staff issued a request for proposed partners. This request contains a broad strategic plan presenting many possible ITS applications. Private firms responded with specific project partnering approaches and technologies to meet the state's overall objectives.

Ownership, Sharing, and Use of Resources

Issues in this area may compound as more systems are implemented and as more private sector firms become involved in dissemination of traveler information. These issues include who owns the data generated, whether there should be a charge for the data, how this information will be shared among the partners, and to whom the information will be released.

Complicating this scenario is the recent development by private firms to gather traffic data using cellular phones as traffic probes. It is uncertain whether this new dataset will complement or substitute for the data being collected by public agencies. Should this new approach prove reliable, it will change relationships between existing traffic information providers and traffic data collectors.

Many public sector agencies release data free of charge. Some public agencies, however, are hesitant to release information to the private sector for fear that it will obtain revenues from data collected with public resources. Similarly, some private firms are hesitant to share data for fear the public agency will release proprietary information. Policies covering data issues should be established early in the project.

Because of the media's ability to quickly reach a wide audience, the Washington DOT policy actually gives the media priority over other users. The agency's staff provide video images to the media, but the media outlet has to make the connection. Currently, there are no charges for the connection and none are anticipated. There is, however, no existing policy that would preclude implementing a charge.

In the New York-New Jersey-Connecticut metropolitan area, TRANSCOM℠ staff developed a regional information policy that is applied to numerous projects, including Trips123 and the I-95 Corridor Coalition's Traveler Information project. The policy sets out the information deemed to be "TRANSCOM℠ information" and, therefore, the property of TRANSCOM.℠ The policy further presents who may have access to the information, the level of compensation required for the information, and how compensation will be established. Briefly, the policy states that any public or private organization using the information to generate revenues must compensate TRANSCOM℠ for this use.

Ownership of equipment purchased within the project may be another problem. Questions will arise as to who owns the equipment provided as an in-kind match and who owns the equipment purchased with project funds. A related question is who is responsible for the maintenance of the equipment.

The Texas DOT has a policy stating that Texas DOT staff own and must maintain any equipment they purchase. This policy raised a question of maintenance liability within the Bus Incident Management System project in San Antonio. If the cameras for this system, to be placed on buses owned by the VIA Metropolitan Transit Authority, were bought by the Texas DOT, then according to policy, the cameras would be considered Texas DOT property, and their maintenance would become the responsibility of the Texas DOT. Agency officials felt that maintaining equipment on buses they do not operate would be impractical, so transit authority staff purchased the equipment and assumed maintenance responsibility.

Another related question is who will be responsible for the eventual replacement of the technology purchased during an ITS project. The City of Bellevue, Washington, provides an example of how public agencies can successfully address this concern. City staff developed an equipment rental fund that is used to replace outdated computers and other equipment. Three independent sub-funds are included within the main rental fund: the electrical equipment rental fund, the mechanical equipment rental fund, and the information services replacement fund. The equipment rental fund was created as an internal process designed to rent equipment to other funds, maintain and repair equipment administered by the fund, and provide equipment replacement through establishment of replacement services. These services are grouped into different functions, each with a separate revenue stream. Although Washington legislation allows all cities within the state to develop equipment replacement funds, the City of Bellevue has developed the most sophisticated procedure.

Procurement

Even when procurement issues have been addressed, they can still impede the progress of some ITS deployments. The lack of flexibility in the procurement process and the public sector's aversion to taking risks contribute to this problem.

ITS participants have found that the traditional approach to procurement is often too restrictive when contracting for the rapidly evolving technologies and systems

that constitute ITS. Changes to legislation, policies, or procedures may be necessary to allow the parties flexibility to use the most appropriate procurement method, as determined by project needs. Failure to be flexible in the procurement process means that acquisition procedures used for construction projects are the only tools available for procurement of advanced technologies.

Because the Maricopa County DOT in Arizona had a flexible procurement process and was able to work with the local stakeholders, AZTech™ Model Deployment Initiative participants determined that it was more efficient to use the county for the official procurement agency than to use the Arizona DOT. Other agencies involved in the project, however, were given the flexibility to use the county as the procuring agency for their selected technologies, or to procure products and services themselves through existing or new contracts and be reimbursed by the AZTech™ project.

Project participants can use a variety of procurement mechanisms, and must choose those best suited to meet their needs:

- Federal competitive process.[3]
- State catalog.
- Multiparty agreements.
- Competitive contracts.
- Sole-source contracts.
- Phased contracts.
- On-call and other existing contracts.
- Design/build contracts.
- Joint, interjurisdictional procurements.
- Turnkey procurements.

ITS project administrators have learned that they also must build flexibility into their contracts. Many felt that contracts based on "cost-plus" payments, lump-sum payments, or "best efforts" and labor hours payments would not ensure tangible results or acceptable products. While the Trips123 project administrators in the New York-New Jersey-Connecticut metropolitan area allowed compensation for design work on a cost-plus-fixed-fee basis, they scheduled deployment compensation on a firm fixed price based on approved designs, and provided operations and management compensation on a firm fixed-price basis.

In San Antonio, Texas, City of San Antonio DOT officials executed a fixed-price contract with their systems integrator, with variations available on each task. Under this contract, the systems integrator offered different options that could be completed under different funding levels. The Texas DOT administrators allowed the task cost variation provisions to be incorporated into the contract, transferring funds among the tasks when necessary.

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[3] Staff at the Washington State Department of Transportation used the U.S. DOT process to select Metropolitan Model Deployment Initiative sites as their competitive process for procuring project participants from the private sector.

Intellectual Property

The proper assignment of intellectual property rights presents a continual challenge to ITS projects. Applications of ITS raise vexing new questions regarding patentable inventions, copyrights, and trade secrets, as well as compilations of data derived from the operation of ITS technologies. The private sector, in particular, has a vested interest in maintaining intellectual property rights to those technologies and services they help develop. These issues must be addressed early in the life of an ITS project to promote the involvement of private sector representatives. Failure to do so will delay entry of private sector firms, along with access to their expertise.

Also, failure to address this issue early may lead to contentious situations. Project participants may be misled by ambiguous contracting language into thinking their rights will be covered. Drafting the proper language into the contract guards against misunderstandings.

Participants in the AZTech™ MMDI struggled with and overcame the issue of assigning intellectual property rights. As a starting point to resolving their concerns, administrators from the AZTech™ project requested clarification of the FHWA's policy on intellectual property rights. A letter[4] from FHWA's associate chief counsel clarified the Federal Government's policy. This letter was then included in all contracts between the public and private sectors.

Following the FHWA's policy, the AZTech™ public officials developed two licensing agreements: one for pre-existing products and privately funded developments and one for products developed with Federal funds during the course of the MMDI. The license for pre-existing products allows public sector participants to make limited use of pre-existing products. The license for products developed during the course of the project allows public sector participants to receive a royalty-free, nonexclusive, and irrevocable license to reproduce, publish, or otherwise use—and to authorize others to use—the publicly funded software, data, and documentation solely for official governmental purposes. The private sector partner similarly retains all ownership rights, including copyrights.

Privacy

To date, ITS professionals have addressed most of the privacy concerns surrounding ITS, including concerns that traffic surveillance cameras would be used for purposes other than monitoring traffic and that information on trucking firms collected by preclearance systems would be released to competitors. With more and different technologies being deployed, however, concerns about privacy may grow.

Each new ITS application may require a database or the collection of additional data. Users of these applications must be informed as to the data being collected and how they will be stored and used. Users may not accept data for non-traffic-management purposes or for identification of individual travel patterns. Agencies must develop strategies to inform their customers about the collection and use of data and to protect their privacy. One strategy should be to use the media to explain the application to the public.

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[4] A copy of this letter is included in the cross-cutting study, *What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights,* EDL No. 11486.

This issue may also intensify if ITS technologies are used for law enforcement, especially automated law enforcement. To reach their full potential for improving traffic safety, applications that both detect and identify traffic law violators, such as red light runners, require the release of identifying driver information to law enforcement personnel. In some instances, this information leads to issuance of a citation or other legal action against the violating driver. The integration of law enforcement and traffic safety technology applications is both highly sensitive and extremely promising. Addressing privacy concerns related to collecting individual driver identifiers is key to public acceptance and success in this area. The Intelligent Transportation Society of America (ITS America) has drafted privacy principles that promote such practices. ITS America expects to finalize and approve the principles by the close of 2000.

Because staff at the University of Washington are developing the traveler information backbone for the Seattle area, a large amount of data is passed through its operations. To protect the privacy of individuals, staff have developed procedures to remove personal information from the data. Each data source linked to the backbone has a computer, or "firewall," to strip out any private data before they go onto the backbone. The stripped data always reside at the source agency. For example, the computer residing at the King County DOT Transit Division extracts bus driver identification before vehicle identification data are passed to the communications backbone.

In Phoenix, transportation officials have tried to counteract concerns about camera use. First, Arizona DOT officials made a linguistic change, replacing the intrusive-sounding "video surveillance" with "video monitoring." This change helped to allay some of the "Big Brother" fears and negative connotations associated with the word "surveillance." Second, in keeping with the limited and defined role of the cameras, agency administrators agreed that this technology should not play a law enforcement role, even when an officer is stationed in the traffic operations center. Third, the AZTech™ participants provide open access to the camera feeds by means of local television. Finally, the AZTech™ managers enacted an informal policy of not retaining any tapes from the camera feeds, thus avoiding the tapes being subpoenaed and used in lawsuits.

Both New Jersey and New York passed laws governing the use of photo-monitoring systems to enforce automated toll collection. These laws specify restrictions on the use of images captured by these systems.

Liability

Although liability concerns were discussed during the early stages of many ITS deployments, liability has not been a major issue to date; however, as with the area of privacy, these concerns may grow over time.

Some ITS applications may require the use of an in-vehicle device, which could create liability issues if drivers claim that such devices distracted them, leading to an incident. Also, the emergence of anti-collision applications may give rise to liability questions if these technologies transfer control of the car from the driver to the technology, and an incident occurs. Also, the failure of a technology or the provision of

inaccurate information by a technology may lead to liability problems, especially with increased use of automated collision notification technologies.

Another area of potential concern is the sharing of system control by more than a single jurisdiction, such as a traffic signal control system. Good planning and engineering practices must be exercised when establishing procedures to share control. Good practices help demonstrate that appropriate standards were used.

Some public sector partners in the Phoenix metropolitan area note that liability issues in their area have already been resolved through discussions in the Signals Working Group, a regional group resulting from a study that looked at coordinating traffic signals along corridors running through several jurisdictions. Through their involvement in the study and working group, participants are confident that only appropriate actions will be taken when representatives of one jurisdiction assume temporary control of another jurisdiction's traffic signal system. One method the group employed was to define and document a series of thresholds under which signal plans can be altered (e.g., in the event of a freeway closure). Representatives of some adjacent municipalities and the Maricopa County DOT have drafted coordination policies and plans to cover signalized corridors bordering two jurisdictions and other multijurisdictional corridors.

CONCLUSION

Original proponents of IVHS and the current ITS community have long stated that institutional issues pose more of a challenge than technical ones. The good news is that these nontechnical barriers can be overcome. The bad news is that they will always be present in one form or another. As discussion of these issues shows, some previously addressed barriers will reoccur throughout ITS deployment. The key to overcoming any constraint is to acknowledge its likelihood and address it early. Project participants should anticipate these obstacles and come to the table prepared to discuss them. They should also look to successes in other areas that demonstrate how nontechnical barriers can be overcome.

ACKNOWLEDGMENTS

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chapter 9

WHAT HAVE WE LEARNED ABOUT
ITS? FINAL COMMENTS

ITS AND CHANGE

Intelligent transportation systems (ITS) represent a sea change in surface transportation, equivalent in a sense to the introduction of air traffic control systems into air transportation. The change is on the scale of what occurred in the second decade of the 20th Century, when creation of the Federal-aid highway program forged a fundamentally new relationship between the Federal Government and state governments, as the idea of a national highway transportation system began to take shape.

The changes today are no less important. The electronic linkage between vehicle and infrastructure represented by ITS has profound implications for surface transportation. But the changes thus far have been largely incremental, the real impact yet to be felt. Integrated, regional systems are examples of the kinds of changes to come.

To truly absorb the functional change in transportation that ITS represents, one must go beyond just creating institutional change in transportation organizations to creating cultural change—reflecting the importance of operations, new technology, and market-based forces, especially in the highway sector. Achieving these cultural changes will take leadership, education, and training.

ITS represents a major opportunity for the transportation profession to evolve to a more sophisticated level. Advanced technologies, systemic thinking about transportation services, and expanded possibilities for important policy initiatives in technology-enabled transportation all create vital professional opportunities— which the educational sector must recognize and build upon.

To conclude, this study imparts the following overarching lessons about ITS:

- **Integrated Systems:** The real leverage of ITS will occur in integrating systems and services. The low hanging ITS fruit, already picked, was often a product of stand-alone deployments. Now the ITS community must be careful not to create its own legacy systems and thereby build barriers to deployment of more advanced integrated systems.

- **Regional Systems:** The ability to deal functionally with transportation management on a regional scale is an important opportunity to enhance transportation system effectiveness.

- **Partnerships:** ITS requires partnerships among public organizations at various levels—Federal, state, local—to achieve its full potential. The long tradition of cooperation among these organizations can be effectively used as a basis for building public-public partnerships.

  Because of its electronic connection to vehicles and infrastructure, ITS requires that the public and private sectors cooperate at a level not previously required for surface transportation. Even though the public and private sectors differ in capability, mission, and philosophy, they can cooperate and they must cooperate to achieve successful ITS deployment on a large scale.

- **Institutionalization of Operations:** ITS enables more effective operation of transportation systems, particularly meaningful in the current environment, where conventional infrastructure is difficult to build. To optimize transportation efficiency, organizations providing transportation infrastructure and services must institutionalize their operations.

- **Political Support and Public Acceptance:** Political support and public acceptance of ITS can come about by carefully focusing on issues that matter—safety and quality of life. Anticipated results should be described both qualitatively and quantitatively, if possible. Further, it is important to create bipartisan political acceptance of ITS and to recognize the media's central role in helping to build the case for ITS.

- **Human Resources:** Deployment of any of the systems described in this report will require transportation professionals who can deal effectively with new ITS technologies and their service and political implications. Educating and training these individuals and integrating them into transportation organizations is a primary consideration.

- **The Traveler as a Customer:** Although a controversial point, surface transportation must be considered a market of divergent customers with varying individual requirements. ITS technologies can greatly enhance provision of differentiated service.

So, what have we learned about ITS? We are at the end of the beginning. The low hanging fruit is gone from the tree, and much has been achieved by choosing clear-cut, sure winners—an appropriate strategy for the first generation of any technology. However, for true deployment success, we must reach higher into the tree, focusing on integrated, regional, and market-driven systems.

That ITS can be an important component of surface transportation is beyond question, but so much more can be done. It is the Internet age and the public's expectations are changing. People, including travelers, are using sophisticated information technology and telecommunications equipment in their everyday lives. The ability to access information from multiple sources with the click of a mouse or television switch is a trend poised to continue.

Intelligent transportation systems are the transportation community's opportunity to be part of this revolution and to advance transportation and the transportation profession. In 1997, the prestigious *Annals of the American Academy of Political and Social Science* published a special issue entitled "Transport at the Millennium."[1] Comprised of 18 essays, it provides a broad perspective on the transportation field: where it has been, where it is now, and where it is likely to go in the future. Two themes dominated:

1. The need for fundamental change in the relationship between the public and private sectors in the transportation industry. These changes involve letting the market work through deregulation and privatization.

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[1] "Transport at the Millennium," *Annals of the American Academy of Political and Social Science* (September 1997).

2. The use of pricing to create a more rational transportation system by overcoming market failure from "unpriced" externalities—such as congestion, environmental impacts, etc.— caused by the operation of transportation systems.

Clearly ITS has both these ideas at its core and can build on them to make a major contribution for years to come.

The papers included in this compendium give a good sense of where we are in seven major ITS areas and how we can advance to the future. They provide real insight into where successes have already occurred, as well as what is preventing further successes in the future. The ITS community can and should build on the information contained herein to take the next important steps.

Finally, the future demands a more stringent judging of ITS technologies. Success should be predicated on more extensive deployment and on integrated, regionally scaled systems. For now, we are on the right track, but in years to come, we must demand more, as more will be expected.

appendix

SUMMARY TABLES

Table 2-1. Incident Management Summary Table

Technology*	Deployment Level	Limiting Factors	Comments
Service patrols	Widespread Deployment	Cost, staffing	**Successful**
Common communication frequencies	Limited Deployment[†]	Cost, institutional issues	**Successful**
Automated incident detection algorithms	Medium Deployment[†]	Technical performance	**Mixed**
Cellular communication for incident detection	Widespread Deployment	Availability, institutional issues	**Jury is still out**
Motorist callboxes	Limited Deployment[†]	Being replaced by cell phone use	**Successful**
CCTV (ground, airborne, high magnification)	Widespread Deployment	Cost	**Successful**
Cellular geolocation (old generation)	Operational Testing[†]	Accuracy	**Unsuccessful**
Cellular geolocation (emerging generation)	Operational Testing[†]	Availability, institutional issues	**Jury is still out**
Regional incident management programs	Limited Deployment[†]	Institutional issues	**Holds promise**

Cross-cutting technologies, such as telecommunications, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issue?"

† Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 2-2. Freeway Management Summary Table

Technology/System*	Deployment Level	Limiting Factors	Comments
Transportation management centers (may incorporate multiple technologies)†	Widespread Deployment‡	Implementation cost, staffing	**Successful**
Portable transportation management centers (may incorporate multiple technologies)	Limited Deployment‡	Implementation cost, staffing	**Successful**
Road closure and restriction systems (may incorporate multiple technologies)	Limited Deployment‡	Institutional issues	**Successful**
Vehicle detection systems (may incorporate multiple technologies)	Widespread Deployment	Cost, maintenance	**Mixed—depends upon technology**
Vehicles as probes (may incorporate multiple technologies)	Limited Deployment	Cost, integration	**Jury is still out**
Ramp metering (includes multiple technologies)	Medium Deployment	Politics, user appearance	**Successful**
Dynamic message signs (includes multiple technologies)	Widespread Deployment	Cost, changing technology	**Mixed—due to operations quality**
Highway advisory radio (includes multiple technologies)	Medium Deployment	Staffing	**Mixed—due to operations quality**
Dynamic lane control	Medium Deployment	Not in MUTCD for mainlanes§	**Successful— especially on bridges and in tunnels**
Dynamic speed control/variable speed limit	Technical Testing‡	Not in MUTCD; may require local legislation to be enforceable	**Holds promise**
Downhill speed warning and rollover warning systems	Limited Deployment‡	Cost	**Successful**

Cross-cutting technologies, such as telecommunications and pavement sensors, are addressed in Chapter 7, "What Have We Learned About Cross-Cutting Technical and Programmatic Issues?"

† A transportation management center may control several of the systems listed further down the table, and will possibly utilize additional technologies, such as video display systems, local area networks, flow monitoring algorithms, geographic information systems, graphic user interfaces, and database management systems.

‡ Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

§ Mainlanes are freeway lanes that are not tunnels or bridges.

Table 2-3. Emergency Management Summary Table

Technology	Deployment Level	Limiting Factors	Comments
GPS/Differential GPS on emergency management fleets	Widespread Deployment	Cost	**Successful**
Mayday systems	Widespread Deployment*	Cost, vehicle choice	**Successful**
Mayday processing centers/customer service centers	Widespread Deployment*	Cost	**Successful**
Public safety answering points	Widespread Deployment*	Cost, staffing	**Successful**
CDPD communication	Limited Deployment*	Availability	**Jury is still out**
Onboard display	Widespread Deployment	Cost, user acceptance	**Successful**
Preemption infra-red signal system	Widespread Deployment	Institutional issues, lack of standards	**Successful**
Computer-aided dispatch	Widespread Deployment	Cost, support staffing	**Successful**
Automatic vehicle location	Widespread Deployment	Cost	**Successful**
Networked systems among agencies	Limited Deployment*	Institutional issues, integration cost	**Holds promise**

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 2-4. Electronic Toll Collection Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Dedicated short-range communication	Widespread Deployment	Need for standard	**Successful**
Smart cards	Limited Deployment	Commercial and user acceptance; need for standard	**Successful**
Transponders	Widespread Deployment	Privacy	**Successful**
Antennas	Widespread Deployment	Technical performance	**Successful**
License plate recognition	Limited Deployment*	Technical performance	**Jury is still out**

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 3-1. Arterial Management Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Adaptive control strategies	Limited Deployment	Cost, technology, perceived lack of benefits	**Jury is still out**—has shown benefits in some cases, cost still a prohibitive factor, some doubt among practitioners on its effectiveness
Arterial information for ATIS	Moderate Deployment	Limited deployment of appropriate surveillance, difficulty in accurately describing arterial congestion	**Holds promise**—new surveillance technology likely to increase the quality and quantity of arterial information
Automated red light running enforcement	Moderate Deployment*	Controversial, some concerns about privacy, legality	**Successful**—but must be deployed with sensitivity and education
Automated speed enforcement on arterial streets	Limited Deployment*	Controversial, some concerns about privacy, legality	**Jury is still out**—public acceptance lacking, very controversial
Integration of time-of-day and fixed-time signal control across jurisdictions	Widespread Deployment	Institutional issues still exist in many areas	**Successful**—encouraged by spread of closed-loop signal systems and improved communications
Integration of real-time or adaptive control strategies across jurisdictions (including special events)	Limited Deployment	Limited deployment of Adaptive Control Strategies, numerous institutional barriers	**Holds promise**—technology is becoming more available, institutional barriers falling
Integration with freeway (integrated management)	Limited Deployment	Institutional issues exist, lack of standards between systems preventing integration	**Holds promise**—benefits have been realized from integrated freeway arterial corridors
Integration with emergency (signal preemption)	Widespread Deployment	None	**Successful**
Integration with transit (signal priority)	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"	See Chapter 5, "What Have We Learned About Advanced Public Transportation Systems?"

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 4-1. ATIS Summary Table

ATIS Service	Deployment Level	Limiting Factors	Comments
Real-time traffic information on the internet	Widespread Deployment	While deployment is widespread, customer satisfaction with the services seems related to local traffic conditions and website information quality	**Mixed**—the characteristics of the websites vary, depending on the availability and quality of the user interface and underlying traffic data.
Real-time transit status information on the Internet	Limited Deployment	Transit authorities have limited funds for ATIS investments and little data that establish a relationship between ridership and ATIS	**Holds promise**—where the service is available, reports suggest that there is high customer satisfaction with the service
Static transit system information on the Internet	Widespread Deployment	N/A	**Successful**
Real-time traffic information on cable television	Limited Deployment	Limited by information quality and production costs, although one service provider has developed a way to automate production	**Successful**—as evaluated in a highly congested metropolitan area where consumers value the easy, low-tech access to traffic information
Real-time transit status information at terminals and major bus stops	Limited Deployment	Cost	**Successful**—where evaluated in greater Seattle
Dynamic message signs	Widespread Deployment	Positive driver response is a function of sign placement, content, and accuracy	**Successful**—drivers really appreciate accurate en-route information
In-vehicle navigation systems (no traffic information)	Limited Deployment*	Purchase cost	**Holds Promise**—as prices fall, more drivers will purchase the systems
In-vehicle dynamic route guidance (navigation with real-time traffic information)	No commercial deployment; the San Antonio MMDI installed prototype systems in public agency vehicles*	Irregular coverage and data quality, combined with conflicting industry geocode standards, have kept this product from the market	**Holds Promise**—manufacturers are poised to provide this service once issues are resolved
Fee-based traffic and transit information services on palm-type computers	Unknown Deployment	Service providers make this service available through their websites, actual subscription levels are unknown	**Jury is still out**—requires larger numbers of subscribers becoming acclimated to mobile information services

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 5-1. APTS Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Automatic vehicle location	Moderate Deployment	Cost, fleet size, service type, staff technological competence	**Successful**—use continues to grow, new systems principally use GPS technology but usually augmented by dead reckoning
Operations software	Widespread Deployment	N/A	**Successful**
Fully-automated dispatching for demand response	Research & Development*	Still in research and development stage	**Jury is still out**
Mobile data terminals	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—reduces radio frequency requirements
Silent alarm/covert microphone	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—improves security of transit operations
Surveillance cameras	Limited Deployment*	Cost	**Holds promise**—enhances on-board security. Deters vandalism
Automated passenger counters	Limited Deployment	Cost	**Holds promise**—provides better data for operations, scheduling, planning, and recruiting at lower cost
Pre-trip passenger information	Widespread Deployment	N/A	**Successful**—improves customer satisfaction
En-route and in-vehicle passenger information	Limited Deployment	Cost, lack of evidence of ridership increases	**Jury is still out**
Vehicle diagnostics	Limited Deployment	Cost, lack of data on benefits	**Jury is still out**
Traffic signal priority	Limited Deployment	Institutional issues, concerns about impacts on traffic flows	**Holds promise**—reduces transit trip times. May reduce required fleet size
Electronic fare payment	Limited Deployment	Cost	**Holds promise**—increases customer convenience

Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Table 6-1. CVISN Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Safety Information Exchange			
Laptop computers with Aspen or equivalent	Widespread Deployment	N/A	**Successful**
Wireless connection to SAFER at roadside	Moderate Deployment	Technical challenges with communications among systems	**Holds promise**—for identifying frequent violators of safety laws
CVIEW or equivalent	Limited Deployment	Connections to legacy state system	**Jury is still out**—being tested in three or four states
Electronic Screening			
One or more sites equipped with DSRC	Widespread Deployment (no. of states); Limited Deployment (no. of carriers)	Interoperability	**Holds promise**—deployment trend is positive
Electronic Credentialing			
End-to-end IRP & IFTA processing	Limited Deployment	Challenges and costs of connecting legacy systems	**Holds promise**—potential for significant cost savings to states and carriers
Connection to IRP & IFTA clearinghouses	Limited Deployment	Institutional issues	**Jury is still out**—cost savings can only be realized with widespread deployment

Table 7-1. Cross-Cutting Technical Issues Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Sensor and Surveillance Technologies			
Cell phones for incident reporting	Widespread Deployment*[†]	N/A	**Successful**
Cell phones for emergency notification	Limited Deployment*[†]	Relatively new, mostly sold in new vehicles, takes long time to reach 30% of vehicle fleet	**Successful**—number of equipped vehicles growing rapidly
GPS for position, determination, automatic vehicle location	Moderate Deployment in fleets (transit, trucking, emergency vehicles)[‡]	N/A	**Successful**—use continuing to grow. See footnote
Video surveillance	Widespread Deployment	N/A	**Successful**
DSRC (toll-tags) for travel time data	Limited Deployment	Mostly used only in areas with electronic toll collection. Requires power and communications to readers	**Successful**—holds promise
Direct link between Mayday systems and public safety answering points	Limited Deployment[†]	Still in research and test phase, significant institutional policy and technical issues	**Jury is still out**—no known deployments
Cellular geo-location for traffic probes	Limited Deployment	New technologies just beginning field trials	**Jury is still out**—older technology unsuccessful
Communications Technologies			
Loop detectors	Widespread Deployment	N/A	**Successful**
Alternatives to loop detectors	Widespread Deployment	Initial cost, familiarity	**Holds promise**—video widespread, others limited, many cities only use for a few locations
Real-time, in-vehicle traffic information	Limited Deployment*[†]	Cost, commercial viability	**Jury is still out**
LIDAR for measuring automotive emissions	Limited Deployment[†]	Minnesota test was unsuccessful, technology didn't work well enough	**Unsuccessful**—no known deployment
Internet for traveler information	Widespread Deployment	N/A	**Successful**—free services **Jury is still out**—on commercial viability
High speed Internet	Limited Deployment[†]	Slow rollout, availability limited	**Holds promise**

Technology	Deployment Level	Limiting Factors	Comments
Communications Technologies			
Fully-automated Internet-based Exchange	Limited Deployment †	New technology	**Holds promise**
DSRC	Widespread Deployment	N/A	**Successful**—current use mostly limited to Electronic Toll Collection
DSRC at 5.9 GHz	Limited Deployment †	Frequency just recently approved for use, standards in development	**Jury is still out**—no known deployments in U.S., but used in other countries at 5.8 GHz
Fiber optics for wireline communications	Widespread Deployment	N/A	**Successful**
Digital subscriber line	Limited Deployment	New technology, first applied to ITS in 1999	**Holds promise**—several deployments, many more locations considering
220 MHz radio channels for ITS	Limited Deployment	ITS is too small a market to support unique communications systems	**Unsuccessful**—only known use during Atlanta test during the 1996 Olympic Games
High speed FM subcarrier for ITS	Limited Deployment †*	Low demand to-date for in-vehicle real-time data	**Jury is still out**—multiple conflicting "standards" and proprietary approaches, competition from other wireless technologies
CDPD for traveler information	Limited Deployment †*	Lack of real-time information to send, limited use of CDPD by consumers	**Unsuccessful**—CDPD will soon be overtaken by other wireless data technologies
Wireless Internet	Limited Deployment †*	New technology	**Jury is still out**—on ITS uses, general use predicted to grow rapidly
Local area wireless	Limited Deployment	New Technology	**Jury is still out**
Low power FM	Limited Deployment †	Just legalized by FCC, first licenses not yet granted	**Jury is still out**—Brand new, no deployments yet
High speed fixed wireless	Limited Deployment †	New Technology	**Jury is still out**
Analysis Tools			
Models incorporating operations into transportation planning	Limited Deployment †	Emerging technology, cost and institutional issues may become factors for some approaches	**Jury is still out**—IDAS available, PRUEVIIN methodology demonstrated, TRANSIMS in development

See footnotes on the next page.

Quantitative deployment tracking data are not available. Deployment level was determined by expert judgment.

† For in-vehicle consumer systems, deployment levels are based on the percent of users or vehicle fleet, not number of cities available. For example, real-time in-vehicle traffic is available in over two dozen cities, but the percentage of drivers subscribing to it is small.

‡ For AVL using GPS in transit, the moderate-level assessment is based on the percent of transit agencies using the technology according to a 1998 survey of 525 transit agencies conducted by the John A. Volpe National Transportation Systems Center. This measure was used for consistency with the transit section of this report. If the 78 major metropolitan areas are used as a measure, then the deployment level is "widespread," as 24 of 78 cities use GPS-based AVL.