chapter 1

WHAT HAVE WE LEARNED ABOUT ITS? A SYNTHESIS

Author:
Professor Joseph M. Sussman
Massachusetts Institute of Technology

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

[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 Transport-ation 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 applications, 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

[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 network—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 supporting 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

[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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