

Development and
Deployment of
Standards for
Intelligent
Transportation
Systems

Review of the Federal Program

SPECIAL REPORT 280

Development and Deployment of Standards for Intelligent Transportation Systems

Review of the Federal Program

Committee for Review of the U.S. Department of
Transportation's Intelligent Transportation
Systems Standards Program

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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**Committee for Review of the U.S. Department of Transportation's
Intelligent Transportation Systems Standards Program**

Jonathan L. Gifford, *Chair*, George Mason University

Jules A. Bellisio, Telemediators, LLC

A. Ray Chamberlain,* Parsons Brinckerhoff

Irwin Dorros, NAE, Independent consultant

William F. Johnson, Independent consultant

Samuel Krislov, University of Minnesota, Minneapolis–St. Paul

Alexander Lopez, Metropolitan Transit Authority of Harris County,
Texas

James R. Robinson, Virginia Department of Transportation

Steven E. Shladover, University of California, Berkeley

William M. Spreitzer, General Motors Corporation (retired)

Scott E. Stewart, IBI Group

Phillip J. Tarnoff, University of Maryland, College Park

James L. Wright, Minnesota Department of Transportation

Transportation Research Board Staff

Stephen R. Godwin, Director, Division of Studies and Information
Services

Consultant

Andrew C. Lemer, Matrix Group, LLC, Baltimore, Maryland

* A. Ray Chamberlain chaired the committee from March 2000 to March 2002.

Preface

“Intelligent” transportation systems (ITS) apply computers, information management, advanced electronics, and communications technology to reduce traffic congestion, enhance safety, save energy, and in other ways generally improve the performance of the nation’s highways and transit. The U.S. Department of Transportation (USDOT) has for some time pursued initiatives to encourage adoption of ITS technology in domestic applications and to support the competitiveness of U.S. ITS providers in international markets.

One of these initiatives is intended to encourage the development and widespread adoption of technical standards that may be used to specify the operational characteristics of ITS components and subsystems. Acting under legislative mandates, USDOT formally established an ITS Standards Program in 1996 and assigned the program’s administration to a Joint Program Office (JPO) that had been created earlier to span the mode-specific perspectives of the Federal Highway Administration, the Federal Transit Administration, and other modal administrations.

In 1999, JPO asked the Transportation Research Board (TRB) to conduct a 1-year review of the ITS Standards Program. The committee appointed to undertake that review (the Phase 1 study) published its findings and recommendations in *Standards for Intelligent Transportation Systems: Review of the Federal Program* (TRB, 2000). As the Phase 1 study was being completed, JPO asked TRB to extend its review, concentrating particularly on USDOT’s longer-term role in encouraging widespread adoption of ITS standards in practice.

USDOT and TRB staff developed a proposed scope for this Phase 2 study, which subsequently was approved by the National Research Council’s (NRC’s) Governing Board as the following Statement of Task:

Statement of Task: Review of the USDOT's Intelligent Transportation Systems (ITS) Standards Program (Phase 2)

The Department of Transportation's (DOT) Joint Program Office (JPO), which is responsible for developing a national architecture and selected standards to encourage the development and deployment of "intelligent transportation systems" (ITS) technology in the United States, in 1999 asked the National Research Council's Transportation Research Board (TRB) to review the JPO's ITS Standards Program and critique the strategy being used by the program to introduce ITS standards. A committee appointed to undertake this review published the findings and recommendations from its year of work (Phase 1) as *Standards for Intelligent Transportation Systems: Review of the Federal Program* (National Academy Press, 2000).

The JPO asked TRB to continue to advise the DOT on matters arising from the ITS Standards Program, particularly concerning the DOT's role in achieving widespread adoption of ITS-infrastructure standards in practice. During Phase 2, the committee will focus on emerging obstacles to effective standards deployment. The committee will assist the DOT in gaining an understanding of obstacles to deployment and developing strategies to overcome them. Issues such as the following exemplify those obstacles, as they are presently perceived:

- ITS standards developed and deployed with federal assistance are intended to balance the interests of purchasers and suppliers of ITS equipment while enhancing the public benefits of investments in ITS technology. Suppliers, however, have a more immediate commercial interest in understanding and shaping those standards, and have consequently been more active participants in the standards-development process. How may the DOT best assure that broad public interests are appropriately reflected in national ITS standards?
- Standards are effective only to the extent they influence the capabilities and configuration of systems put into operation. Federal assistance for developing and publishing standards, informing the professional community about those standards, and implementing demonstration installations that embody the standards are among the tools being used in efforts to "deploy" the standards in practice. Are there tools not now included within the JPO's Standards Program that might be particularly effective means for encouraging standards deployment? What

measures should the DOT use to assess the overall effectiveness of its standards-deployment activities?

- “Interoperability” has been identified by many transportation professionals as the primary objective for the setting of ITS standards. The term refers generally to the idea that devices from various suppliers, installed in various locations and used by the diverse public, will work together, that devices can communicate with one another, that signals from one device will mean the same thing to the recipient that the sender intended. However, disagreements among participants in ITS standards development have prevented reaching consensus on a precise working definition of the term that may be used to judge whether ITS equipment and software have achieved adequate “interoperability.” Can communication among separate installations be assured without requiring some degree of hardware and software interchangeability? Does the functional meaning of interoperability vary among ITS-standards applications areas? How much interoperability is needed to achieve the broad public benefits envisioned in the concept?

The committee will offer guidance on the questions raised in the Statement of Task in one or more letter or more formal brief reports.

A new committee was appointed, with members drawn largely from the Phase 1 study committee. The new committee met three times during 2001, twice more in 2002, and once in 2003. The committee identified various issues arising from the study’s scope and discussed these issues with USDOT staff and other technical experts who were invited to make presentations and participate in the committee’s discussions. Members then deliberated among themselves to agree on suggestions and recommendations. The committee’s meetings, each approximately 2 days in length, were held at TRB facilities in Washington, D.C. The committee presented its interim findings and recommendations in four letter reports to USDOT. This document is the final report of the Phase 2 study.¹

¹ This report is meant to be a complete statement of the outcome of the committee’s deliberations. However, summaries of the letter reports are included in Appendixes B through E, and copies of the letters may be found on the Internet at www4.nas.edu/trb/onlinepubs.nsf/web/reports?OpenDocument, under the heading “Committee for Review of the U.S. Department of Transportation’s Intelligent Transportation Systems Standards Program.”

Various factors shaping the ITS Standards Program that provided the context for the committee's discussions are reviewed in Chapter 1. The committee's analysis of the major issues that have arisen in the standards program's implementation and progress is presented in Chapter 2; in some cases these issues arose from the sum of the committee's discussions rather than from a single meeting and letter report. In Chapter 3, the committee's perceptions of program characteristics associated with these issues that could be obstacles, over the longer term, to effective deployment of federally supported ITS standards are described. Finally, the committee's specific recommendations for future management of the program to overcome these obstacles are given in Chapter 4. Several appendixes provide details and background of the Phase 2 study.

During the period of the committee's deliberations, the September 11, 2001, attacks on New York's World Trade Center and the Pentagon and subsequent events dramatically altered many people's perceptions of the role of transportation generally and particularly the role of ITS in public safety and homeland security. Although the committee's members recognize the significance of these matters and inevitably considered them in subsequent discussions, they are largely outside the study's scope and are not directly addressed in this report.

The committee is grateful to the various individuals who participated in its meetings and shared their insights on the matters at hand.

Emil Wolanin, Chief of Transportation Systems Management for Montgomery County, Maryland, described his county's efforts to apply ITS technology. Glen Hansen of the Howard County, Maryland, Department of Police described the issues of interdepartmental and inter-jurisdictional coordination for "incident management." Robert Deroche, then with Peek Traffic Systems, Inc., described standards development activities, particularly with regard to dynamic message signs and traffic signal systems, and how those activities relate to introducing standards into practice.

Robert Rausch, an independent consultant, discussed the data needs and data exchange challenges associated with ITS, and efforts to devise robust ITS data models. Lee Armstrong, also an independent consultant, described issues of standards development and deployment for dedicated short-range communications for ITS. He was joined in these dis-

cussions by Broady Cash with ARINC in Annapolis, Maryland, Jules Madey of the New York State Thruway Authority, and Paul Najarian of ITS America.

Bruce Schopp of the National Electronics Manufacturers Association; Joe Stapleton, formerly with the Georgia Department of Transportation and now with URS Corporation; and Bo Strickland, representing the American Association of State Highway and Transportation Officials, discussed their experience with development of common data structures and definitions underlying ITS standards development, particularly as they relate to the ITS Data Registry (refer to Appendix E).

Andrew C. Lemer, Ph.D., provided technical support to the committee and drafted the committee's reports under the committee's guidance and the supervision of Stephen R. Godwin, TRB's Director of Studies and Information Services. Jocelyn Sands, Frances Holland, and Amelia Mathis of TRB provided invaluable assistance with report preparation, meeting arrangements, and committee correspondence.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee and staff are grateful to the following individuals for their review of the draft report: Frederick T. Andrews, Colts Neck, New Jersey; Steven J. Fenves, National Institute of Standards and Technology, Gaithersburg, Maryland; Greg Larson, California Department of Transportation, Sacramento; and Chelsea C. White III, Georgia Institute of Technology, Atlanta. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the committee's findings and recommendations, nor did they see the final report before its release.

The report's review was overseen by Lester A. Hoel, University of Virginia, Charlottesville. Appointed by NRC, he was responsible for

making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final report rests entirely with the authoring committee and the institution.

Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. The report was edited by Gail Baker and prepared for publication by Senior Editor Norman Solomon, working with Javy Awan, TRB's Director of Publications.

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Executive Summary

This document is the final report from the Transportation Research Board's (TRB's) review of the Intelligent Transportation Systems (ITS) Standards Program of the U.S. Department of Transportation (USDOT). Responding to USDOT's request in 1999, TRB appointed a committee to review the ITS Standards Program and critique the program's strategy for introducing ITS standards. This report concludes the second phase of that review.¹

Many transportation professionals share the view that ITS technology can substantially improve the performance of surface transportation systems and thereby yield significant benefits to system users and the nation as a whole. Acting under the authority of two successive major pieces of federal transportation legislation—the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21)—USDOT has acted to establish a national ITS architecture and standards for selected ITS technology, with the ultimate intent of speeding domestic adoption of ITS technology and maintaining the competitiveness of U.S. industry in international ITS markets. USDOT's ITS Standards Program, formally initiated in 1996, has supported a variety of standards development and deployment activities. USDOT budget allocations for standards-related activities have totaled \$7 million to \$10 million annually.

Many of these activities have relied on an existing institutional framework provided by standards development organizations (SDOs)—professional and trade groups that serve as forums for discussion among

¹ A Phase 1 report was published, *Standards for Intelligent Transportation Systems: Review of the Federal Program* (TRB, 2000).

industry, government, and other interested parties. USDOT provides funds to participating SDOs, but committees of volunteers devise the standards. Each SDO adopts standards through a formal process typically involving a ballot of the SDO's members once the authoring committee has judged its work to be complete. The standards themselves are published and distributed by the responsible SDO. USDOT has supported development efforts for more than 90 specific standards since the ITS Standards Program's inception. USDOT staff report that 82 standards had been published by mid-September 2003.

The ITS Standards Program authorizing legislation (TEA-21) was scheduled to expire at the end of September 2003 and has since been extended. Administration proposals² include provision for continuing the ITS activities called for in TEA-21. The standards program could in any case continue as part of USDOT's broader ITS program. The TRB committee appointed to conduct the review of the ITS Standards Program presumes that the program will continue or be reauthorized in a modified form. The committee believes that investments in ITS in general, and in the development and deployment of standards to facilitate ITS adoption in particular, are a wise and appropriate use of government funds.

Although there has been substantial progress since the standards program started, ITS development and deployment are still in an early stage. It would be premature, in the committee's view, to make definitive judgments about the program's success or failure in speeding adoption of ITS applications. The committee believes that the ITS Standards Program's objectives have been appropriate, its overall strategy has been reasonable, and its execution so far has made credible contributions to achieving congressional mandates set out in ISTEA and TEA-21 legislation. The committee commends USDOT and congressional efforts to ensure reauthorization of the ITS Standards Program in new legislation and urges that federal funds be appropriated and applied to support continuation of the program's activities.

Looking toward this continuation of federal support for ITS standards development and deployment, the committee believes that improvements in the ITS Standards Program can be made to enhance future program effectiveness. Recognizing that implementing the committee's various sug-

² The administration's proposed bill is being called the Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (SAFETEA).

gestions will require funds and professional resources that may exceed those made available to the standards program, the committee concludes its Phase 2 study with the following seven specific recommendations.

- 1. The Joint Program Office (JPO) should invest its standards development and deployment resources in accordance with a clearly delineated assessment of (a) the need for the standard as an enabler of important ITS services and (b) national benefits to be gained through that standard's accelerated promulgation. The potential contribution to achieving functional interoperability at a national scale is certainly a key indicator of benefits; however, contributions to safety, security, technological leadership, international trade, and other valid federal concerns are also justifiable bases for providing federal support.**

The bases for allocating ITS Standards Program resources could be explained more clearly and the allocations could be more tightly targeted than they are now. There is a particular need for more detailed explanations of why certain standards have been selected for federal support and how those standards are expected to contribute to achieving standards program goals. Because resource limitations certainly will influence decisions to provide federal support for particular ITS standards and because the range of development and deployment activities that could warrant such support is large, the committee anticipates that pursuing this recommendation may limit the number of standards being developed with federal support. An evaluation of which standards merit JPO's continuing support might usefully include the consequences of not providing federal support for development of a particular standard—for example, delay or failure of stakeholders to reach a consensus if federal support is withheld.

- 2. JPO should develop explicit measures of effectiveness for the ITS Standards Program that are outcome oriented and make clear the principle that standards should be used and thereby return substantial benefits on the public's investment.**

The point appears obvious but, in the committee's view, bears repetition: JPO-supported standards must be applied if they are to be effective. Each activity receiving JPO support must show a high likelihood of contributing to the adoption of ITS technology in the U.S. transportation

system. Clearer reporting of the progress of the standards program—and of ITS deployment generally—is needed. Measures of program effectiveness also would help in determining what precise mix of investments in testing and validation is likely to be most productive.

3. JPO and standards developers supported by JPO should adhere strictly to the following sequence of stages in the ITS standards development process:

- **Testing** to ensure that the proposed standard can be used in field applications and will perform as expected (such testing should be completed before a proposed standard is submitted for balloting and adoption within an SDO-based development process);
- **Formal adoption** through balloting or another mechanism that unambiguously identifies a standard as being sufficiently mature for use in practice;
- **JPO assessment of readiness for deployment**, which would likely consider the number of applications that might realistically be expected in the near term (e.g., 3 to 5 years), the number of manufacturers and system integrators capable of delivering ITS installations meeting the standard, and the availability of information and materials to facilitate the standard's application, such as sample specifications, documentation, and training programs; and
- **Postadoption support** (e.g., training and maintenance), which should not be pursued before a standard has passed through the stages of formal adoption and assessment of readiness for deployment.

Steps essential to the long-term effectiveness of federally supported standards appear in some cases to be missing from the standards development process, most notably testing to ensure that the standard can be used and will function as intended. JPO's assessment of a standard's readiness for deployment will encourage the standard's use, while post-adoption support will reduce the initial costs users incur in learning about new technologies.

4. Rulemaking should be used sparingly or not at all for ITS standards; rulemaking may be more justifiable for ITS standards supporting safety and security.

While rulemaking can be an effective and sometimes necessary means for establishing technical standards, the time required is long compared with the speed of ITS technology's evolution, the costs are high compared with the benefit of marginal increases in the likelihood that effective standards will be used, and the risks of imposing ineffective standards are significant.

5. JPO should support the full range of activities required to make standards development and deployment effective over the longer term, including testing and demonstration to validate standards and ensure that they can be used, establishment by the stakeholder community of a national ITS independent verification and validation capability, training for standards users, and maintenance of standards that have been developed with federal support.

Such activities, undertaken for a selected small set of standards, together would represent a balanced strategy for ensuring the standards program's contribution to the broad objective of rapid ITS deployment. To ensure broad stakeholder participation, and because budgetary constraints sometimes make it difficult for state and local officials to play a sustained role in standards development and deployment, this recommendation encompasses continued JPO support for travel and other costs incurred by qualified public-sector participants and continued participation and support for U.S. involvement in international ITS standards development. Early adopters play an important role in ensuring that standards are mature, usable, and effective, and they should be compensated for the higher costs they incur—for example, through appropriate administration of ITS demonstration projects.

6. JPO should undertake explicitly to streamline the process for developing and revising standards.

As ITS technology progresses, needs for new standards and substantial revisions of existing standards are likely to arise. More direct guidance and involvement in the SDO-based standards development process may improve its efficiency—for example, by continuing to ensure qualified professional staff support for SDO committees. In the future, some new ITS standards may be developed more effectively through mechanisms

other than formal SDOs (industry and user consortia, for example), provided that the standards development process continues to permit participation by all interested stakeholders. USDOT should entertain proposals for support of development and deployment of all appropriate ITS standards, whether from an established SDO, an industry consortium, or other developers. It should apply explicit criteria for judging appropriateness and make decisions with due consideration for budgetary constraints and other relevant factors.

- 7. USDOT should consider judicious expansion of the standards program to embrace services that span the interface between in-vehicle and roadside infrastructure subsystems, consistent with the program's goals, the role of government as a stakeholder in the advance of ITS technology, and efficient investment of government resources to achieve public purposes, particularly with regard to achievement of national interoperability.**

The interface between in-vehicle and infrastructure subsystems is crucial to ITS success. While the demarcation of that interface is not yet precisely defined, the interface itself is likely to be a fertile area for ITS innovation.

Introduction

Highway planners, engineers, and the public at large look forward to the increasing application of computers, communications, and information technologies to produce high-performing “smart” or “intelligent” transportation systems (ITS). Such systems will collect, store, process, distribute, and use data about the movement of vehicles, people, and goods to enhance safety and security, reduce traffic congestion, save energy, and in other ways improve generally the performance of the nation’s highways and transit. ITS applications include traffic management, advanced vehicle control and safety enhancement, traveler information services, electronic payment of tolls, public transportation management, emergency response and incident management, commercial vehicle operations, railroad grade crossing safety improvement, and in the future perhaps more. ITS combines technologies that are rapidly evolving with time-tested and more slowly changing design, construction, and government purchasing practices.

In passing the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA),¹ Congress established a national program to encourage efficient and rapid adoption of ITS technology in the U.S. surface transportation system and assigned responsibility for the program to the U.S. Department of Transportation (USDOT). The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998, continued the ITS program and extended USDOT’s responsibilities.

USDOT initially assigned the task of establishing its ITS programs to the Federal Highway Administration (FHWA). However, recognizing that ITS applications are not restricted to highways, USDOT in 1994

¹ Public Law 102-240, 105 Stat. 1914.

established a Joint Program Office (JPO) to span the mode-specific perspectives of FHWA, the Federal Transit Administration, and USDOT's other modal administrations and to assume federal responsibilities for ITS development and deployment. JPO administers programs for developing the ITS national architecture and selected standards to encourage ITS development and deployment. JPO's ITS Standards Program, formally initiated in 1996, is designed to advance ITS technology by accelerating the emergence of generally accepted standards for ITS infrastructure.

STANDARDS PROGRAM ORIGIN AND CONTEXT

An early challenge faced by those involved in implementing USDOT's ITS program was how to motivate establishment of a national *architecture* and *standards*² that together would guide ITS development in the United States and promote *interoperability* of ITS components, in the sense that ITS systems should be able to exchange and share information freely across jurisdictional boundaries.³ The architecture was envisioned as a guideline or functional framework that would support a common understanding among the many developers and users of ITS about the parts of the systems and how those parts would interact to provide useful services. USDOT efforts to develop an architecture began in 1993 (before JPO's creation) and in 1996 yielded an initial release of the National ITS Architecture, a product of several private-sector and quasi-governmental organizations working in contractor teams with USDOT staff. Subsequent updates have expanded and refined that architecture.⁴

The National ITS Architecture identifies the functions to be performed by ITS components and the ways in which the components can be interconnected. The architecture relates multiple functional subsystems (e.g., for traffic management, emergency vehicle operations, or provision of traveler information) and general communications links among those subsystems. The functional subsystems cluster roughly into groups corresponding to physical elements of transportation management sys-

² Section 6053(b) of ISTEA directs USDOT to develop and implement standards and protocols.

³ The idea of interoperability is discussed further in subsequent sections of this report.

⁴ The most recent version of the National ITS Architecture, released in July 2003, is Version 4.0. Previews of Version 5.0 were available as this report was being written (Figure 1-1b).

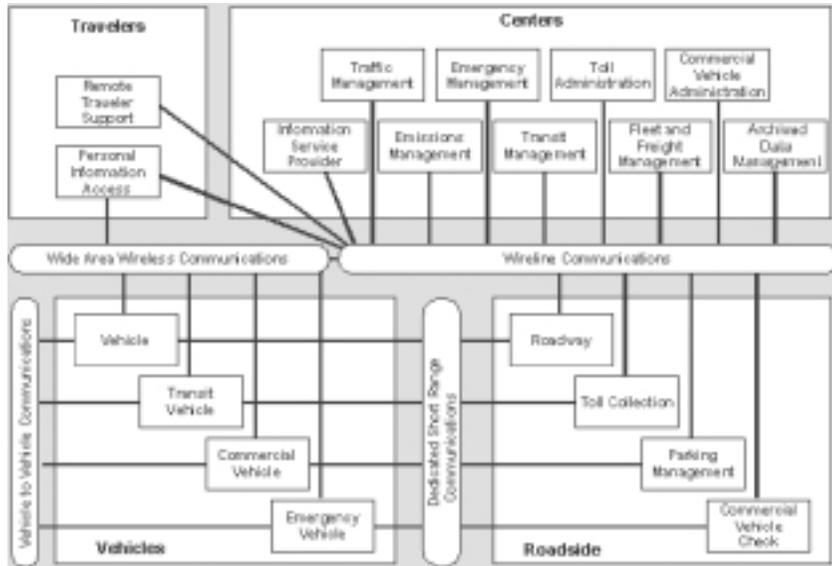
tems within four major classes: communication and control centers, the roadside infrastructure, vehicles, and travelers (see Figure 1-1).⁵ Data moving through this web of interconnected elements are analyzed, interpreted, and acted upon to provide specific *services* such as controlling traffic flows, collecting tolls, routing emergency vehicles, reporting on road and traffic conditions, and the like.

For services to be made operational, the hundreds of components and relationships among them that the architecture outlines must be specified in much greater detail. The idea of standards in principle encompasses this specification. Standards describe what data elements each component provides, how data should flow through the system, what types of messages pass between components, and how components conceptually fit together to provide a desired service. Standards may present definitions, data elements, measurements, communications exchanges, and hardware and software configurations that define a system's characteristics and performance. For ITS installations, for example, standards may define data elements and message sets used by all traffic control devices and systems, or certain physical characteristics of a particular type of device.

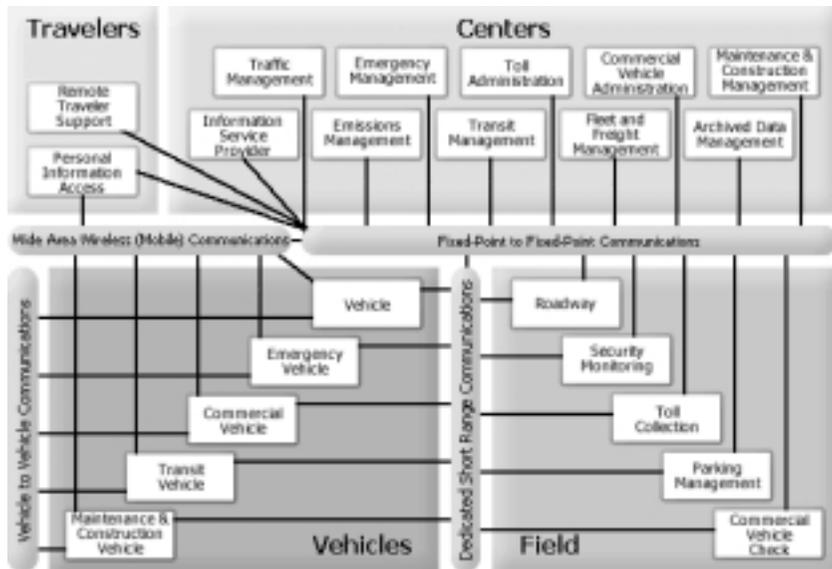
In the ITS Standards Program, standards also encompass *protocols*, which define how data are to be exchanged among ITS elements, including such matters as addressing, security, and priority of messages. Protocols are collections of rules for moving data elements and messages between devices and systems.

These broad definitions notwithstanding, there is no general agreement about standards' scope or degree of precision. The standards envisioned by one person or team may not necessarily be accepted by others or become universal in practice. The standards adopted by one equipment manufacturer for its own products, for example, may or may not conform to the standards of another manufacturer or the requirements

⁵ The architecture's initial description, shown in Figure 1-1a, has been only slightly modified (Figure 1-1b). The architecture as a whole, however, has been further articulated. Services, for example, have increased in number and are grouped into eight user services bundles (Appendix G). As part of Version 4.0, *standards requirements* provide "a non-redundant, streamlined view of the essential data requirements for on-going ITS standards activities. This entry point provides a concise set of data requirements for each physical architecture interface. By following the links, you can traverse to the physical and logical architecture components associated with the standards requirements for each interface" (www.itsa.org/archdocs/web/homepg.htm).



(a)



(b)

FIGURE 1-1 Schematic view of National ITS Architecture (a) as initially described to the committee and (b) as included with Version 5.0. (Source: itsarch.iteris.com/itsarch/version5.0beta/index.htm.)

BOX 1-1

Objectives of the ITS Standards Program

- Promote the ability of public-sector agencies to choose ITS products and services from multiple suppliers
- Promote the creation of an innovative ITS market
- Facilitate interoperability at all levels
- Ensure the safety of the traveling public
- Facilitate deployment of ITS technologies
- Support testing and evaluation of standards
- Promote the international competitiveness of American industry

of a particular customer. There is, in fact, remarkably less standardization in surface transportation systems than might be expected.⁶ If ITS standards themselves are to function effectively and the benefits of a national architecture are to be realized, the standards must be used widely in actual ITS technology installations.

JPO effectively commenced standards development activities in 1996, following initial release of the National ITS Architecture. As stated by USDOT, the goal of the ITS Standards Program is to foster the voluntary, widespread use of interoperable ITS by accelerating the development and deployment of ITS standards. JPO staff presented to the Phase 1 study committee a number of other specific objectives—in addition to interoperability—that have guided development of the ITS Standards Program within the context of this broad goal (see Box 1-1).

ITS INFRASTRUCTURE

In pursuing these objectives, JPO has drawn a broad distinction between infrastructure and in-vehicle systems. *Intelligent infrastructure* refers to

⁶ These systems are designed and put in place by a myriad of local and state government personnel and their consultants, equipment manufacturers, and service providers. Standardization is greatest in cases that affect basic safety (e.g., the colors and shapes of traffic signals and signs).

systems that monitor operating conditions and prevent or respond quickly to problems (for example, a vehicle crash), provide improved information to travelers and operators, and support intelligent-vehicle operations. The term *intelligent vehicles*, in contrast, encompasses in-vehicle systems designed to assist drivers and intervene in vehicle control to reduce the risk of crashes, help drivers acquire and use information, and facilitate transportation system management (for example, reducing congestion). Public agencies construct and manage intelligent infrastructure, while manufacturers and travelers determine the characteristics of vehicles using that infrastructure.

JPO has focused the standards program's resources primarily on traffic management systems, transit, public safety, and other aspects of ITS infrastructure, for at least two reasons. First, federal program funds for ITS deployment will be used primarily by state and local government agencies to procure ITS infrastructure; vehicles, in contrast, are produced and operated primarily in the market-driven context of the private sector. Second, government planners have presumed that substantial market incentives will motivate private-sector development of intelligent-vehicle standards without government support.

The committee notes that this distinction between in-vehicle and infrastructure components becomes technologically less distinct for many ITS applications that entail close integration of the two. In some cases, the success of a technological innovation on one side of the interface will depend on the adoption of a matching innovation on the other side. In other cases, new components may effectively shift a function from one side of the interface to the other. In any case, the success of ITS deployment will depend on actions by both government and private-sector participants, each potentially influencing in-vehicle and roadside elements of an ITS application. While the standards program has focused on infrastructure, JPO does administer programs that include in-vehicle ITS components—for example, the Intelligent Vehicle Initiative.

USDOT STRATEGY FOR STANDARDS DEVELOPMENT

JPO's strategy for ITS standards development has relied on encouraging professional consensus through the work of preexisting standards devel-

opment organizations (SDOs)—professional and trade groups that serve as forums for discussion among industry, government, and other interested parties. USDOT provides federal funds that participating SDOs use to support staff and cover direct costs of standards development activities, but committees of volunteers devise the standards. Each SDO adopts standards through a ballot among its members once the authoring committee has judged its work to be substantially complete. The standards themselves are published and distributed by the responsible SDOs. Intellectual property rights associated with the standards—copyrights on the words of the standard and possibly patent rights associated with inventions, if any are embedded in the standard—are presumed by SDO and JPO staff to be owned by the SDO.

The technical scope of ITS, even if one considers only ITS infrastructure, extends beyond the expertise of organizations that traditionally have played key roles in setting surface transportation standards. JPO has solicited interest and secured the participation of such organizations as the American Association of State Highway and Transportation Officials, as well as the American Public Transportation Association, the Institute of Electrical and Electronics Engineers, and the Institute of Transportation Engineers (see Box 1-2).

Each SDO operates for the most part under cooperative agreements with USDOT. Participating SDOs work on standards that are agreed by USDOT and the responsible SDO to warrant federal support, within the limits imposed by JPO budgetary resources. Each SDO follows its customary procedures to develop standards assigned to it. USDOT funds may cover such direct expenses as consultants who give technical support to the committees of volunteers that develop the standards, travel for public-sector participants in those committees, and the SDO's general overhead. The time individuals spend in the standards development process is effectively donated by their employer companies or agencies. Private-sector participants frequently pay their own travel costs, often regarding their expenses as justified by the commercial advantages derived from early knowledge of and actual influence on the standards. Critics of the process note that many government agencies and smaller firms do not have adequate resources to participate effectively, even with the government assistance that is available.

BOX 1-2

SDOs Listed as Participants in the ITS Standards Program

- American Association of State Highway and Transportation Officials*†
- American National Standards Institute†, Committee X12, Electronic Data Interchange
- American Public Transportation Association
- ASTM*†
- Electronic Industries Alliance
- Institute of Electrical and Electronics Engineers*†
- Institute of Transportation Engineers*†
- National Electrical Manufacturers Association†
- Society of Automotive Engineers*†
- Telecommunications Industry Association

*Organizations that had signed cooperative agreements with USDOT as of April 2000.

†Organizations listed in 2003 as actively participating in ITS standards development activities.

USDOT has supported development efforts for more than 90 specific standards since the ITS Standards Program's inception. By mid-July 2000, 30 standards had been published by the SDOs.⁷ JPO staff reported to the committee in September 2003 that 82 standards have been approved by SDOs, that is, they are published or ready for publication. JPO staff reports that USDOT budget allocations for standards-related activities have totaled \$7 million to \$10 million annually.

As the SDOs began to make standards available for public use, JPO staff recognized that success in meeting congressional mandates would depend ultimately on use of these federally supported standards in new installations of ITS equipment and control systems. JPO began to shift the focus of the ITS Standards Program toward deployment activities that could

⁷ "Published" means that the standard is available for purchase from the responsible SDO.

BOX 1-3

Principal Elements of USDOT's ITS Standards Program

- Development—support of SDOs in developing selected consensus standards specified in the National ITS Architecture
- Testing—application of selected standards in realistic settings
- Outreach and education—provision of information and materials supporting standards dissemination (e.g., website, direct mailings, training workshops)
- Technical assistance—field office staff, peer-to-peer activities to assist standards users
- Policy support—guidance and policy for public agencies implementing ITS

accelerate the standards' acceptance and use (see Box 1-3). Although use of ITS standards produced by the SDOs is meant to be voluntary, Section 5206 of TEA-21 explicitly requires that ITS projects carried out with federal funds (that is, actual ITS installations) “conform to the national architecture, applicable standards or provisional standards, and protocols.” The federal rulemaking process is USDOT's primary instrument for designating particular standards as criteria for eligibility for federal funding.⁸

The standards program is scheduled to continue at least through September 2004, when authorization associated with TEA-21 will expire. (The legislation itself expired at the end of September 2003.) Proposed new legislation—the Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (SAFETEA)—includes provision for continuing the general requirements and activities called for in TEA-21 related to ITS architecture and standards.⁹ The standards program could continue in any case, without specific legislative authorization, as part of USDOT's broader ITS program.

⁸ However, USDOT can and has sought to encourage use of standards without making them mandatory—for example, by providing education and training resources to help users specify ITS installations incorporating the new standards.

⁹ See Section 5504 (www.fhwa.dot.gov/reauthorization/ssa_title5.htm#sec5504).

PHASE 1 STUDY RESULTS

The Transportation Research Board's (TRB's) Phase 1 study of the ITS Standards Program commenced as the program was beginning the transition from development to deployment. The Phase 1 study committee was asked to consider several questions.

- Was the program's strategy for standards development and adoption appropriate for meeting the program's goals?
- Was the strategy being implemented effectively and adjusted to encourage effective deployment of standards developed under the program?
- How might the program's activities be altered, if at all, to improve the program's likelihood of success?

The committee concluded, as presented in the Phase 1 report, that JPO had taken a generally sensible and orderly approach to the development and implementation of selected ITS standards as a means of aiding the realization of the National ITS Architecture. Reliance on established SDOs to mobilize and organize stakeholder participation in standards setting, while not without limitations, is a proven strategy and well accepted in both U.S. and international practice. JPO had made appropriate efforts to broaden the technical scope and qualifications of participants in standards development. While recognizing that new standards might be identified that would merit federal support, the committee also endorsed JPO's then-emerging efforts to shift the standards program toward standards deployment.¹⁰

The committee made nine specific recommendations in the Phase 1 report (see Box 1-4). Two of the recommendations addressed matters related to the National ITS Architecture. While the architecture is not within the standards program's scope, the Phase 1 study committee felt these matters had important implications for standards development. The other recommendations for enhancing the standards program's effectiveness are as follows.

- More explicit and detailed description of the relationship among the National ITS Architecture, the standards included in the ITS Standards

¹⁰ In fact, the number of standards under development or published with JPO support increased from about 80 to more than 90 from the time the Phase 1 study was completed to the present.

BOX 1-4

Phase 1 Study Recommendations for Enhancing ITS Standards Program Effectiveness

[From *Standards for Intelligent Transportation Systems: Review of the Federal Program* (TRB, 2000)]

1. JPO should describe more explicitly and in greater detail the relationship between the National ITS Architecture and the standards that have been included in the ITS Standards Program. JPO should state more clearly its criteria for determining in the future which proposed standards warrant federal support for their development and deployment. While the potential for contributing to functional interoperability is certainly a key criterion, contributions to safety, security, technological leadership, international trade, and other valid federal concerns are also justifiable bases for providing federal support.
2. Each ITS standard in the JPO program should undergo an open development and adoption process in which all stakeholders may fully participate, regardless of which SDO provides leadership for the standard's development. This process should include appropriate validation or demonstration prior to final adoption of a proposed standard. To ensure an open process and adequate validation, as well as to ensure that U.S. standards are given full standing in international markets, standards developed with JPO support should meet criteria for approval by the American National Standards Institute (ANSI) as American National Standards, including the criterion that at least one of the organizations responsible for a standard's development be ANSI accredited.
3. In the future, JPO should devote federal funds to developing only those standards for which there is a clearly stated national need for government support. The statement of

(continued on next page)

BOX 1-4 (continued)

**Phase 1 Study Recommendations for Enhancing
ITS Standards Program Effectiveness**

need should identify explicitly the standard's role in the realization of the National ITS Architecture.

- 4.* JPO should undertake to have the National ITS Architecture reviewed by an independent organization to ensure that technological advances have not rendered underlying assumptions or resulting portions of the architecture obsolete. If portions of the architecture are no longer useful for achieving national interoperability, they should be appropriately modified or deleted.
- 5.* JPO should devise and implement a mechanism to ensure that the National ITS Architecture as a whole is reviewed and updated periodically. This process should entail significant private-sector participation.
6. JPO should develop explicit plans to ensure long-term support and updating of the ITS standards within its program. Long-term support might encompass training and other activities designed to enhance technical proficiency among users of the standards, as well as periodic review and revision to ensure the effectiveness of standards that are implemented.
7. JPO should continue to seek to attract broader private-sector involvement, particularly from such fields as broadband wireless telecommunications and data management. To this end, a technically qualified and independent advisory group should be designated and assigned responsibility for ensuring that the standards are reviewed and updated periodically as appropriate.
8. JPO and DOT as a whole should use rulemaking sparingly and only when there is a demonstrable need to enforce particular standards to achieve national objectives of ITS interoperability. JPO's assessment of the readiness of any

standard for rulemaking should include completion of adequate validation and/or demonstration to ensure that the standard performs as desired. The committee recommends further that rulemaking be undertaken only for standards for which there are clearly established procedures for periodic review and updating to prevent these rules from hindering continued technological innovation.

9. JPO should continue to participate and support U.S. involvement in appropriate International Organization for Standardization technical committee activities. In addition, greater attention should be given to other opportunities for influencing international standards, for example, through organizations operating under the auspices of the North American Free Trade Agreement or the Asia-Pacific Economic Council.

*Recommendations 4 and 5 were not reconsidered in the Phase 2 study.

Program, and the criteria for determining that proposed standards warrant federal support for their development and deployment (Recommendation 1).

- Broad participation in standards adoption by stakeholders not directly engaged with the SDO that provides leadership for the standard's development, and inclusion of these stakeholders in demonstrations aimed at validating a standard's effectiveness and utility before its final adoption (Recommendation 2).
- Sharper focus of the standards program's resources on standards for ITS aspects for which national rather than regional uniformity is clearly warranted—for example, national interests in the realization of the National ITS Architecture (Recommendation 3).
- Explicit attention to long-term maintenance and updating of the ITS standards developed with USDOT support, including training and other activities designed to enhance the technical proficiency of standards users, as well as periodic review and revision to ensure the effectiveness of standards in use (Recommendation 6).

- Assignment of an independent advisory group—with extensive private-sector involvement, especially from such fields as broadband wireless telecommunications and data management—responsible for ensuring that standards are periodically reviewed and updated as warranted by technology change and ITS implementation experience (Recommendation 7).
- Spraying use of rulemaking to require use of federally supported standards and only when there is a demonstrable need to enforce particular standards to achieve national objectives of ITS interoperability (Recommendation 8).
- Continued JPO support for U.S. involvement in international ITS standards activities (Recommendation 9).

In the initial stages of the Phase 2 study, the reconstituted committee reviewed the Phase 1 recommendations and, as will be explained in Chapters 2 and 3, endorses the continued relevance of these seven recommendations to standards deployment and long-term effectiveness.

DEPLOYMENT AND THE PHASE 2 STUDY

The Phase 2 study focused on emerging obstacles to effective standards deployment and how those obstacles might be overcome. As the study commenced, these emerging obstacles—as they were perceived by USDOT and TRB staff—included the challenges of balancing the interests of purchasers and suppliers of ITS equipment while enhancing the public benefits of investments in ITS technology, ensuring that federally supported standards are used in practice, and ensuring appropriate interoperability within and among ITS installations.

JPO described the standards program deployment efforts in terms of *applications areas* (see Box 1-5). The committee selected several applications areas for particular attention (Box 1-6) and used them to structure committee meetings.¹¹ Development of standards supporting these areas had progressed substantially, and the applications appeared to

¹¹ In addition to the five applications areas, JPO requested that the committee consider efforts to develop the ITS Data Registry (ITSDR) (see Appendix E). The ITSDR is not an applications area but rather a tool to facilitate standards development and possibly interoperability across ITS applications areas.

BOX 1-5

ITS Standards Applications Areas

(Adapted from USDOT–JPO groupings; **bold** indicates areas emphasized in the Phase 2 study)

Center to center

Data archival

Incident management (emergency management systems)

Rail coordination

Traffic management

Transit management

Traveler information

Center to roadside

Data collection and monitoring

Dynamic message signs

Environmental monitoring

Ramp metering

Traffic signals

Vehicle sensors

Video surveillance

Center to vehicle/traveler

Mayday

Transit vehicle communications

Traveler information

Roadside to roadside

Roadside to vehicle (e.g., dedicated short-range communications)

Signal priority

Toll/fee collection

BOX 1-6

Applications Areas Discussed by the Committee

(See Appendix A.)

National Transportation Communications for ITS Protocol for Dynamic Message Signs: Defines the parameters for communication across the interface between traffic information center controllers and roadside display units of dynamic message signs used to provide information to road users (e.g., on congestion, crash incidents, or lane closures).

Emergency Management Services: Defines information to be communicated among agencies responsible for incident and emergency management in highway operations and how communications are to occur. Incident management (IEEE 1512 series standards), which aims to maintain or restore traffic flow following vehicle crash or other disruption, entails message set and data dictionary and data definition issues. This is a subset of emergency management, which includes activities of fire, ambulance/rescue, and law enforcement as well as traffic management operations agencies.

National Transportation Communications for ITS Protocol for Traffic Signals: Defines data sets and communication protocols for traffic signal controllers linked into multisignal networks managed from centralized locations.

Center-to-Center/Traffic Management: Defines message sets and data exchanges to enable communication among separate transportation management centers (e.g., within single jurisdictions) within a multiagency and multijurisdiction regional setting for coordinated management of large systems of traffic control devices.

Center-to-Center/Transit Management: Defines data sets and communication protocols for transit-vehicle operations management,

including passenger information and fare collection, enabling more efficient route operations and multivehicle route management from centralized transportation management centers.

Dedicated Short-Range Communications for 5.9 GHz: Defines system for communicating between vehicles and roadside ITS components for collection of information about traffic and environmental conditions and dissemination of information for traffic control and public safety applications. System will operate in the 5.9-GHz segment of the radio frequency spectrum, where it has coprimary status with limited other uses.

offer significant benefits if made available within the nation's transportation system.¹²

In its early discussions, the committee reflected on the characteristics and sources of standards that ultimately would be effective in directing ITS technology deployment, as a way to judge what standards and deployment activities should have priority for government support (see Box 1-7). Federal legislation emphasizes the role of standards as a means for realizing a national architecture, and JPO in its early work had made a distinction between higher-priority foundation standards and standards intended to facilitate specific ITS services.¹³ The standards program's stated objectives provide a broader motivation for designating standards warranting government support.

The committee considered, however, that effective standards could as well originate from sources without government support. A particular manufacturer or systems integrator might be so successful in the marketplace that its product would become the de facto standard for the nation. If particular standards can reasonably be expected to emerge

¹² Committee staff grouped specific standards then in JPO's program (Appendix A) according to their role in supporting these applications areas; specific standards and protocols may support more than one applications area.

¹³ Foundation standards (e.g., certain data dictionaries) are intended to facilitate development of other standards.

BOX 1-7

Committee Characterization of Categories of ITS Standards, by Origination

- Standards developed with federal development support
 - Standards developed explicitly to implement or facilitate the National ITS Architecture
 - Foundation standards
 - Standards to implement specific services defined by the National ITS Architecture
 - Standards identified by sources other than the National ITS Architecture that are likely to enhance achievement of federal ITS goals
- Potential standards not developed with federal development support

without government support, then such support may not be warranted, even if the standards would contribute directly to achieving program objectives or realizing a preferred national architecture.

The committee then considered how it might judge the likely effectiveness of federal support for development and deployment of ITS infrastructure standards and identified three primary criteria: goal consistency, role consistency, and efficiency (see Appendix F). Goal consistency refers to a standard's contribution to implementation of specific services within the framework of the National ITS Architecture, a primary target of standards program goals. Role consistency refers to the appropriateness of federal support for a particular standard's development and deployment, recognizing that government support implies substantial public benefit and the likelihood that an effective standard will not be forthcoming without federal support. Efficiency refers to the balance among costs of a standard's development and deployment and potential benefits or losses from not having effective standards in place when ITS technology is implemented. These criteria underlie much of the committee's discussion, although no effort was made to rate explic-

itly any single standard or group of standards. The selection of applications areas for Phase 2 consideration reflected the committee's general view that the standards in these areas would rate relatively well on the basis of these three criteria.

Within this context, the committee sought to identify obstacles to effective ITS standards deployment and how those obstacles might be overcome. In some cases, the committee's views on these obstacles, and on underlying issues of standards in general, arose from discussions over the course of several meetings. Because concepts related to achieving interoperability are fundamental to the standards program, they are discussed first in Chapter 2.

Issues of Federal Involvement in Intelligent Transportation System Standards

The nation's surface transportation system develops and operates through the interaction of government and the private sector. The former builds and maintains roads and other infrastructure, and the latter provides and uses vehicles and other equipment that depend on that infrastructure. So it is with intelligent transportation systems (ITS). While federal legislation provides the basis for the ITS Standards Program and other government involvement in ITS, market forces play an important role in shaping how ITS development and deployment will progress.

As the committee commenced discussion of the questions posed for the Phase 2 study, committee members drew on their understanding of this interaction of market forces and legislative mandates, and on their experience with standards for new technology generally, to identify issues in three broad areas that they believe have significance for the standards program's ultimate effectiveness:

- Understanding the practical meaning of interoperability as a concept and goal underlying the ITS Standards Program,
- Achieving balance among stakeholder interests in standards development and deployment, and
- Facilitating deployment and application of federally supported standards through government action.

UNDERSTANDING INTEROPERABILITY

The ITS Standards Program has engaged telecommunications, electronics, and information management professionals, as well as civil engi-

neers, traffic engineers, construction specialists, and others more typically concerned with highway system planning and management. This rich multidisciplinary mix has introduced new ways of thinking about highway traffic and its management and has presented communication challenges. Common understanding of the concepts and principles needed in developing and deploying ITS infrastructure standards has sometimes been slow to emerge.

Open Systems

That ITS applications should be developed as *open systems* has been a strongly held and fundamental principle. An open system¹ is one in which there is some degree of transparency with respect to what the specific characteristics of the various subsystems are and how they interact and communicate to provide the functionality of the system as a whole. In an open system, proprietary technology of one manufacturer ideally does not impede the introduction of new products and services produced by others to replace or augment subsystems. For hardware, the precise design of the system and its parts is available for all to see and use. For software, the source code is available as well as the compiled program that is used on a computer. In many applications, however, system open-

¹ As is often the case, the widely used term has many meanings. In ecology and general systems theory, a system is open if it exchanges energy or materials with the outside environment. Information may be exchanged as well, in that an open system is generally understood to be relatively responsive to stimuli from external entities in its environment. In the context of technology applications, more restrictive definitions are found. The U.S. Department of Defense, for example, defines an open system as one that “implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems, and to interact with users in a style that facilitates portability” (IEEE POSIX 1003.0/D15 as modified by the Tri-Service Open Systems Architecture Working Group; see www.acq-ref.navy.mil/tools/turbo/topics/aa.cfm). Carnegie Mellon University’s Software Engineering Institute defines an open system as “a collection of interacting software, hardware, and human components designed to satisfy stated needs, with interface specifications of its components that are fully defined, available to the public, and maintained according to group consensus in which the implementations of the components conform to the interface specifications” (www.sei.cmu.edu/opensystems/welcome.html). The Alliance for Telecommunications Industry Solutions uses similar terms, a “system with characteristics that comply with specified, publicly maintained, readily available standards and that therefore can be connected to other systems that comply with these same standards” (www.atis.org/tg2k/_open_system.html).

ness is a matter of degree; a system may be relatively open even if it incorporates one or more closed or proprietary subsystems.

Proponents of the open systems approach argue that open systems encourage competition among firms and technologies and facilitate expansion or upgrading when new technology and improved products become available.² Critics claim that pursuit of open systems undermines commercial creativity by restricting how improvements may be made and substantially reducing the commercial advantages of developing innovative products. If a system must be open, an innovator must make his or her otherwise-proprietary idea generally available, and others then may profit by offering a product or service incorporating that idea. However, licensing fees and other such arrangements allow inventors to reap benefits from their ideas, even if their new product or service is quickly joined by competitors on the basis of the innovator's idea.

For example, IBM's early decision to make the details of its PC architecture readily available underlies the creation and growth of hundreds of companies producing hardware components, software, and peripheral devices that work more or less interchangeably within the PC framework.³ Apple computers, in contrast, are based on proprietary designs that Apple has refused to license, which arguably has deterred software developers and limited the market for compatible products. Because important aspects of PC hardware and software have been adopted so widely, they have become de facto standards to which new products must conform if they hope to succeed in the market. Companies sometimes may seek to gain commercial advantage by being first to bring a new product to market and thus achieving such success that others adopt their designs (Shapiro and Varian 1999).

The prospect of open ITS systems generally appeals to state and local agencies that anticipate purchasing them, because the agencies wish to avoid becoming locked in by purchases of proprietary equipment and

² Arguments for the open systems approach are frequently heard, for example, in the context of computer hardware and software development and defense systems procurement. The activities of the U.S. Department of Defense's Open Systems Joint Task Force are illustrative; refer to the brochure at www.acq.osd.mil/osjtf/pdf/brochure00.pdf.

³ The most widely used operating system for PCs, Microsoft's Windows, is based on proprietary software. Microsoft makes its intellectual property available to other software developers who are willing to pay the company's licensing fees and comply with its licensing restrictions.

software that can be repaired and upgraded only by single suppliers. Open ITS systems, these agencies anticipate, will attract multiple suppliers and competition, giving purchasers a choice among alternative systems.

Open Standards

Open systems in electronics and telecommunications may achieve their openness by using, for example, modular subsystems, widely accepted and preferably nonproprietary interfaces, and well-defined protocols and standards developed and adopted by recognized standards bodies or the commercial marketplace. Standards defining relevant characteristics of subsystems and their interactions, made readily available to anyone wishing to provide or modify these subsystems, are a means for ensuring that a system is, at least in the limited sense addressed by the standard, open.

In contrast to standards based on ideas that may have been developed by a single person or company and then adopted by others, *open standards* are devised through a process in which all stakeholders who choose to participate have a voice. Open standards typically emerge as a consensus from committees of stakeholders, usually including representatives of users, consumers, producers and other providers, and government. If the standards development mechanism is “open,” then the resulting standards are open standards. The standards development organization (SDO)–based process that the Joint Program Office (JPO) has supported is such an open process.

Developers of ITS standards (open or otherwise) generally must resolve the tension between two conflicting aims. On the one hand, developers wish to define standards only as required to ensure that their systems perform as desired. Too much or premature standardization may restrict the flexibility and innovation of those who will be responsible for implementing specific applications. On the other hand, developers seek to ensure that diverse populations of intelligent vehicles and intelligent infrastructure will function and interact effectively to provide safe and efficient service throughout the nation. Inadequate or belated imposition of standards risks inefficiencies, losses of service, and hazardous conditions in the nation’s transportation system.

ITS Standards Program decisions to provide federal resources to support development of particular infrastructure standards have reflected

this tension. The committee recommended in the Phase 1 study that JPO be vigilant to ensure that standards supported under the program were clearly and explicitly needed for realization of the National ITS Architecture and were unlikely to be developed without federal support. In the Phase 2 discussions, as well, the committee observed that there is no general agreement within the ITS community that standards-setting by government is necessarily beneficial. As JPO's efforts have shifted further toward deployment of standards that have emerged from the SDO-based development process, the standards user's need for widely disseminated, clear explanations of the potential benefits of using the federally supported standards has become increasingly apparent.

Implementing Interoperability

Many professionals believe that open ITS standards will encourage desirable *interoperability*⁴ of ITS systems, ensuring that users will be able to exchange data. Standards-based interoperability would mean that ITS applications installed by different agencies and jurisdictions will be able to work together smoothly to provide consistent services throughout a region or the nation as a whole. Standards-based interoperability would enable public safety and emergency response services personnel to operate efficiently across jurisdictional lines. Standards-based interoperability would assist government officials and their consultants when they undertake to design and procure a specific system or installation by ensuring active competition among suppliers nationwide and, to the extent that U.S. and international standards are compatible, globally.

In application, the concept of interoperability is complex, with technical, procedural, and institutional dimensions. The ITS standards

⁴ As is the case with open systems, there are various definitions of interoperability. At a fairly general level, it is "the ability of a system or product to work with other systems or products without special effort on the part of the customer" (whatis.techtarget.com). The Institute of Electrical and Electronics Engineers (IEEE) defines interoperability as "the ability of two or more systems or components to exchange data and use information" (IEEE Std 610.12-1990, *IEEE Standard Glossary of Software Engineering Terminology*), while the Department of Defense (DoD) defines it as "the ability of systems, units, or forces to provide data, information, material, and services to and accept the same from other systems, units, or forces, and to use the data, information, material, and services so exchanged to enable them to operate effectively together" (DoD Directive 5000.1, *The Defense Acquisition System*, May 12, 2003).

development program has been marked by the persistent inability of its participants to agree on working criteria for judging whether proposed standards will be effective in contributing to interoperability among ITS components and subsystems.

For example, manufacturers may offer a device conforming to a particular standard designed to ensure interoperability, such as the National Transportation Communications for ITS Protocol (NTCIP) for traffic signals. Each manufacturer also may add unique “optional” features to gain competitive advantage in the commercial marketplace. Even if these added features were judged by others to be appropriate for inclusion in the standard, the speed with which manufacturers can add new features exceeds the rate at which the SDO-based standard can be changed. Manufacturers may reasonably assert that product differentiation does not sacrifice interoperability and does benefit ITS purchasers. Purchasers understandably may question the assertion, for example noting that traffic signal controllers produced by one manufacturer cannot be replaced with those provided by a second manufacturer without a change of functionality.⁵

Adhering directly to published interface standards is one way that products—subsystems—can work together with other products (i.e., achieve some degree of interoperability). For example, a set of standards has been developed for how the World Wide Web should operate. The hypertext markup language and hypertext transfer protocol, which are used to create and transmit Web pages, enable any user with conforming software to gain access.

Another way to achieve interoperability is to use a “broker” of services that can convert one subsystem’s interface into another’s interface “on the fly.” For example, the common object request broker architecture and its object request broker are used in ITS center-to-center applications to link centers that otherwise might not be able to communicate.

⁵ Some stakeholders would like to ensure *interchangeability* of certain subsystems or components of the system, an ability to exchange or replace parts made by one manufacturer with those made by others. Electric light bulbs equipped with the standard household screw base, for example, are to some extent interchangeable, although some might exceed the safe wattage rating of a particular fixture. In addition, even if safe wattages are assured, other aspects of their functionality may differ (e.g., frosted or clear glass, long-life filaments, protective coatings), further limiting the bulbs’ interchangeability. Subsystems or components that are interchangeable are presumably equally interoperable with other subsystems with which they are expected to interact.

Differences among applications in how data elements, communication messages, and management variables are defined and recorded can subvert interoperability. For example, the committee learned of efforts by two agencies (one state, one local) to implement traffic management systems in a suburban Washington, D.C., area. Developers of both ITS implementations had considered nascent standards supported by the U.S. Department of Transportation (USDOT). The systems were presumed compliant with the traffic management data dictionary (TMDD). Nevertheless, as the separate projects approached the procurement and installation stages of their implementation, an independent review found that there was not a good match between the data elements of the two systems, and many data elements were not included in the TMDD at all. In addition, the data-naming conventions used in one system were incompatible with widely used database software employed by the other jurisdiction; those conventions, while popular, had not been considered as an essential functional characteristic of the first system. Regardless of the value of the TMDD standard itself, expectations for the extent of its contribution to achieving interoperability appeared to have been inflated. Others hoping to use the standard to ensure interoperability may be disappointed.

In general, any substantial effort to train potential users or otherwise encourage the use of the TMDD and other ITS standards appears premature until there have been demonstrations of their effectiveness.⁶ More fundamentally, continuing federal expenditures to support development and deployment of particular standards appear inappropriate unless persuasive arguments can be presented that they will facilitate interoperability.

Bearing on these matters are the efforts to develop the ITS Data Registry (ITS DR), an online database of the data concepts defined and used in ITS standards that were developed with USDOT support. The ITS DR is not an ITS standard, but JPO requested that the committee consider the activity at one of its meetings.⁷ The ITS DR is intended to promote

⁶ In its third letter report, the committee commented on its concern that users were being trained and otherwise encouraged to adopt some standards before the standards had been adequately tested (Appendix D).

⁷ The committee delivered a letter report on the subject (see Appendix E).

uniformity of data concepts from one standard to another and reuse of previously developed data concepts, and thereby to be a means for encouraging harmonization of standards across all applications areas. In so doing, the ITS DR could be a fundamental tool for promoting and attaining broad ITS interoperability. Agreeing that these ITS DR objectives are important, particularly this harmonization, the committee recommended that JPO maintain its commitment to ITS DR development, despite difficulties being encountered in the concept's current development efforts.

Market Concerns

To support the goal of deploying ITS technology quickly throughout the nation, the committee conjectured, one might interpret interoperability in terms of three principal criteria: (a) an agency anywhere in the nation would be able to purchase an ITS component from any of several producers and reasonably expect this component to work with the rest of the agency's system, (b) mobile users (e.g., automobiles and trucks) would experience the same high level of ITS service as they travel across the nation, and (c) developers of ITS technology would be assured that the market for their products is truly national in scope.

However, many ITS functions do not require interactions among system components above a local or regional level. There is no compelling reason, the committee observed, why a traffic information and management center in Boston, for example, should be able to communicate directly with its counterpart in Phoenix. Why, then, should agencies in either region be expected to compromise on the functional requirements they seek to purchase or the costs they must pay for their systems so that their hardware and software will meet national standards?⁸

USDOT implicitly acknowledged the differences among regions by establishing that the National ITS Architecture is intended to be a comprehensive framework rather than a mandatory structure. The National ITS Architecture is meant to encompass all services that might be included in particular ITS installations in the United States. Local implementations

⁸ Producers may reasonably claim that having to meet different standards for each purchaser of systems raises the producers' costs and therefore the prices for all purchasers.

of the national architecture, each referred to as a “regional ITS architecture,” would be tailored to meet local needs by adding to or omitting services defined in the National ITS Architecture. The national architecture’s developers assumed that implementation of all the services defined by the National ITS Architecture within any single metropolitan area, state, or other region would be highly unlikely.

Federal regulations provide policies to implement conformance with the National ITS Architecture—a requirement under the Transportation Equity Act for the 21st Century for federal funding of ITS projects—by guiding adherence of ITS projects to an approved regional ITS architecture. According to these regulations, the regional ITS architecture should include a *concept of operations* describing the roles and responsibilities of participating agencies; existing or required agreements for operations; and a conceptual design describing system functional requirements, interface requirements, information exchanges, and key standards supporting regional and national interoperability (USDOT 2001).

The Phase 1 report urged that USDOT minimize use of rulemaking to make these standards mandatory for projects receiving federal funding, and the committee confirmed the earlier recommendation in its Phase 2 discussions. The committee generally favors JPO’s emphasis on encouraging rather than requiring use of ITS standards and recognizes that providing education and training resources can be an effective means for doing so, subject to the reservations expressed above. Such a strategy means, however, that some implemented ITS projects may not conform to federally supported standards and therefore that the ITS market may be more fragmented than would otherwise be the case.

The committee observes that even if all ITS installations were required to use identical equipment, most of the ITS infrastructure products and services used would be what some industry observers term “small runners.”⁹ The domestic market for ITS infrastructure is, at best, small by comparison with in-vehicle ITS components or other telecommunication and information technology applications. In the absence of comprehensive market studies, committee members estimated, for example, that the annual U.S. market for fixed variable message signs¹⁰ [which

⁹ The term referred initially to manufacturing runs too small to realize economies of scale.

¹⁰ This is in contrast to moveable signs, such as those used in construction work zones.

might use the dynamic message sign (DMS) standards] may be 200 to 300 units. The equipment and installation are purchased under low-bid procurement methods, with fewer than 10 producers likely to be interested in bidding to supply the few signs that a single state might purchase. The domestic market for traffic signals may total 20,000 signals annually, but producers estimate that any single procurement of fewer than 500 signals is too small to justify making changes to meet unique requirements such as new standards.

Such conditions—which are unlikely to differ substantially even if standards are adopted nationwide—make it difficult for any single supplier to set prices high enough to defray the costs of offering new technology unless the purchaser accepts that the new technology will be acquired at higher prices. State agencies are likely to be reluctant to risk incurring higher costs by requiring new technology that they cannot be certain will function as desired. The idea that open ITS standards will facilitate development of a national market is then plausible, in the committee’s view, but not necessarily compelling.

ACHIEVING BALANCE AMONG STAKEHOLDER INTERESTS

The committee observes that even among those who agree that standards are necessary and useful, there has been persistent debate about how standards are best developed and put into practice. Microsoft’s Windows operating system has become a de facto standard because it satisfies users’ demands and, according to some of the company’s critics, because of the success of Microsoft’s commercial initiatives against its competitors. Whether the product has clear technical superiority is a matter of opinion; there are no organizations or groups to assert that all computer users should conform to the Windows framework. “Stop” signs and other conventional highway signage, in contrast, have been standardized through agreements worked out over decades among engineering professionals and government agencies and then adopted as regulations embodied in the federal *Manual on Uniform Traffic Control Devices*. The “QWERTY” letter arrangement used for typewriters, keyboards, and the like throughout the English-speaking world became popular as a result

of its developers' commercial success, but now is a de facto standard in which no particular individual or group holds any proprietary interest.¹¹ Because of such diverse standardization experience, the appropriateness of the federal government's role and the specific procedures for achieving ITS standardization have remained controversial.

SDO-Based Standards Development Process

As explained above, the Phase 1 report concluded that the ITS Standards Program's basic strategy for standards development—relying on existing SDOs—has merit. SDOs such as the American Association of State Highway and Transportation Officials and the Institute of Transportation Engineers have for decades provided forums for development of highway and transit system design and management standards. The Society of Automotive Engineers, the Institute of Electrical and Electronics Engineers, and other organizations participating in the ITS Standards Program have similar histories in their respective fields of interest. Federal policies generally emphasize reliance on industry consensus standards. For these reasons, the Phase 1 committee agreed that USDOT's decision to pursue the SDO-based strategy was sensible.

However, each SDO has its own established procedures for developing consensus. These procedures generally are similar in their use of volunteers to draft standards and balloting to designate that the proposed standards may be released for broad use, but they differ on crucial details of how an emerging consensus becomes a standard. Some SDOs allow

¹¹ Christopher Latham Sholes (1819–1890), a U.S. mechanical engineer, patented the precursor of the modern typewriter in 1868. The mechanism of this machine could not keep up with the speed of its users, causing keys to jam. An associate of Sholes, James Densmore, suggested spreading the distance between keys for letters commonly used together to slow down typing. The new design, today's standard QWERTY keyboard, substantially solved the problem. It was not until 1874, however, after Sholes had sold his rights to the invention to Densmore and the latter had convinced Philo Remington (whose company also manufactured rifles) to market the device, that the product appeared on the market. It was several more years—with further improvements by Remington engineers—before the QWERTY design achieved broad market success. The story has generated a large body of literature, particularly concerning the question of whether other keyboard arrangements might have brought greater benefits to users once the mechanical problems of accommodating fast typists were solved. See P. A. David, *Clio and the Economics of QWERTY*, *American Economic Review* Vol. 75, No. 2 (May 1985), pp. 332–337; and S. J. Liebowitz and S. E. Margolis, Path Dependence, Lock-In, and History, *Journal of Law, Economics, and Organization*, April 1995, pp. 205–226.

for the release of “provisional” standards before they are fully approved by all stakeholders, on the principle that use of the standards in the field is the only way to verify their effectiveness. Other SDOs insist that standards cannot be issued until a ballot signifies that all stakeholders judge the standards to be complete. The committee observes that these differences are significant in their impact on the degree to which proposed standards are tested and demonstrated in use before they are made generally available.

SDOs generally have little control over who participates in standards committees. Some committees have benefited from the support of well-qualified technical staff employed to conduct background research and draft standards text for review and comment by volunteer committee members.

The committee notes finally that SDO procedures share at least one common characteristic: they are deliberate and therefore relatively slow, particularly compared with the rate of change in telecommunications, computing, and other technologies underlying ITS. If the examples of other telecommunications and information processing products are relevant, ITS infrastructure standards will require periodic revision to avoid obsolescence and may face the problem even before their initial publication. Once a standard is published, however, the SDO may have only the income from sale of the document to reinvest in the standard’s revision.

Standards Evolution and Change

Actual use of a standard in applications is the best demonstration of its effectiveness. Given the variation among SDO procedures, however, the committee observes that formal testing, observation of in-service applications, or other verification of functioning may or may not be considered a routine part of a particular standard’s development process. Apparently in recognition of the problem, JPO initiated a standards testing program in 1999.¹² Standards testing entails working with state and local transportation officials who will undertake to procure and install

¹² USDOT staff presented a description of the plan for the testing program at ITS America’s 1999 Annual Conference (see www.itsa.org/committe.nsf/0/ad6c8e8be1ccbac6852567ad0066d730?OpenDocument).

ITS systems using federally sponsored standards in their designs and specifications. Each such installation typically would involve the application of several standards. According to USDOT staff and guests who participated in discussions with the committee, actual testing progress has been slow. Results available for this study (e.g., DMS) demonstrate that the standards alone may not be adequate to ensure that transportation agencies can procure ITS installations that reliably satisfy the agencies' requirements.

Committee members discussed strategies used in other fields to increase the likelihood that standards will work and that products designed to conform to the standards will function effectively. One of these strategies, independent verification and validation (IV&V, or simply IVV), is practiced in the telecommunications industry and extends well beyond simply testing a standard. IV&V relies on a partnership between product developers and qualified testing and verification personnel to deal in some degree with the problems of rapidly evolving technologies and the inability of standards to specify all product details. The committee recommended in its first and second letter reports (see Appendixes B and C) that USDOT facilitate establishment of a national ITS IV&V capability. The recommendation and its bases are discussed further in Chapters 3 and 4.

Factors other than demonstrated effectiveness also influence whether a standard will be widely used. Once a standard is published and made available to the public, its use in practice is voluntary unless and until some authority adopts the standard as a requirement—as part of a procurement specification, for example. ITS standards that are adopted through the federal rulemaking process determine the eligibility of projects for federal funding, but adoption of standards by agencies not seeking federal funding remains voluntary.

Participants in the committee's meetings estimated that the complete rulemaking process—including response to public comments and possible revision of the proposed rule before it becomes final—could extend over a period of 18 months or more.¹³ In addition, some participants estimated that, at most, one-quarter of ITS infrastructure installations nationwide (by dollar volume) would be implemented with federal funds.

¹³ JPO staff stated that some of the ITS standards (e.g., dedicated short-range communications for commercial vehicle operations) may be proposed for adoption through federal rulemaking.

This combination of delay in setting requirements and limited applicability of those requirements suggests that federally supported standards are unlikely to gain wide application unless users find them clearly helpful. The committee also took these observations as added support for its endorsement of the Phase 1 recommendation that rulemaking should be used sparingly, if at all, in deployment of ITS standards.

As previously noted, participants in the committee's meetings reported that the SDOs and USDOT staff have agreed that the ITS standards, viewed as intellectual property, belong to the SDO. SDOs generally expect to derive revenue from the sale of standards and, as mentioned, may anticipate using this revenue to defray at least a portion of the costs of further development and updating of standards. Even when the market for standards documents is large, which is not the case for ITS infrastructure, SDO revenues from the sale of standards certainly will be inadequate to support standards maintenance over the longer term.

FACILITATING STANDARDS DEPLOYMENT

The ITS Standards Program's shift in emphasis toward support for dissemination and implementation is reflected in JPO budgets and spending. JPO staff reported early in the Phase 2 study that approximately 60 percent of USDOT's overall ITS standards budget (totaling some \$7 million to \$10 million annually) in mid-2001 was allocated to standards testing and validation, outreach, and training activities. Support for standards development, 90 percent of the ITS standards budget in the initial stages of the standards program, was receiving approximately 30 percent of the program's budget during the period of the committee's Phase 2 deliberations.

Outreach and education activities are intended to engage the interest of federal, state, and local transportation stakeholders involved in ITS implementation and to provide them with useful information and materials that will help familiarize them with ITS standards and their use. The ultimate objective of these activities is to encourage adoption of federally supported standards in ITS installations.

JPO supports production of program brochures, fact sheets, implementation guides, sample procurement specifications, case study reports,

and other materials made available both online and in more traditional formats. Training courses prepared by USDOT and the SDOs present groups of standards to practitioners in areas where ITS deployments are being considered. In addition, regional USDOT Resource Center personnel and a peer-to-peer program offer technical assistance resources to potential standards users. Materials are often targeted for a specific audience, such as city traffic engineers or state department of transportation staff.

The committee judged that much of the material it was shown could be helpful to potential users of federally sponsored standards, but it also heard anecdotal reports that state and local agency personnel sometimes have been overwhelmed by the amount of information produced by the ITS Standards Program. One guest at a committee meeting termed the situation “information overload.”

Because ITS is in its infancy, the committee suggests that much of the information now available will be used primarily by agencies—and their consultants—that are considering adoption of new technology and the standards that presumably help to define that technology. Broadcasting information to a general audience without regard to when the information is likely to be useful may be counterproductive, in that the complexity and unproven nature of the standards may discourage their use. Here again, the committee discussed whether some of JPO’s deployment activities are premature.

The committee observed that testimonials from well-accepted authorities to the effect that a standard provides the functionality required could help speed wide adoption of the standard. Demonstration projects, pilot or exemplar deployments, and other techniques for showing agency professionals that ITS infrastructure meeting the standards can be delivered at reasonable cost are similarly useful, in the committee’s experience, for encouraging adoption of standards. The committee discussed such strategies in some depth. See the second letter report (Appendix C) and Chapter 3 for details.

As more standards have been published, JPO has sought to measure and publicize the standards program’s accomplishments. For example, USDOT presents an “ITS Benefit of the Month” on its ITS website (www.its.dot.gov) and maintains an ITS Benefits and Costs Database,

both using information primarily from test applications. While the committee endorses testing as a part of standards development, members expressed some concern in their discussions that estimates of benefits based on such tests may be premature. The proof of the standards' value will be in their influence on operational ITS installations, and more time will be required before a sufficient sample of installation experience is available for observation.

Complex political issues typically must be resolved to achieve an ITS installation—bringing together several political jurisdictions and functional agencies in a region, for example, each one hesitant to risk embarrassment with its constituents if the jointly designed project fails to perform as planned. The committee observes that as much as a decade may be required for a single installation to be implemented. Because no more than a few ITS projects will be under consideration each year, it may be some time before outcomes of the ITS Standards Program become apparent.

JPO staff reported in mid-2001, for example, that federally supported NTCIP for DMS standards were being cited in many requests for proposals (RFPs) issued by state transportation agencies. In addition, JPO reported, all major producers of DMS equipment were offering products asserted to be NTCIP-compliant. At that time, however, JPO was still working to develop sample specifications that agencies might use to procure DMS and other NTCIP-compliant ITS equipment.¹⁴ Whether RFP citations and supplier marketing materials prove to be meaningful indicators of the standards' effectiveness has not yet been shown.

JPO reported to the committee during the study that plans for DMS standards applications projected a "mature marketplace" for the standards by October 2004. JPO staff asserted in fall 2003, as the study was being completed, that such a mature marketplace for the standard has been established. Examination of the characteristics of this mature marketplace could provide bases for judging whether the USDOT-supported standards have become effective. Other indicators—the numbers of compliant devices in use, for example, and the increase in those numbers

¹⁴ JPO staff reported in mid-September 2003 that an initial version of the DMS sample specification has been completed.

over time—could be better measures of how effective the USDOT activities have been. In any case, the committee agreed that objective measures of the program’s effectiveness will be important to the longer-term success of federally sponsored ITS standards and considered the matter further in developing its recommendations.

REFERENCES

Abbreviation

USDOT U.S. Department of Transportation

Shapiro, C., and H. R. Varian. 1999. The Art of Standards Wars. *California Management Review*, Vol. 41, No. 2, pp. 8–32.

USDOT. 2001. *Intelligent Transportation System Architecture and Standards*. 23 C.F.R., Part 940, Sec. 9.

Overcoming Impediments to Effective Intelligent Transportation System Standards

The committee devoted much of its attention to considering ways that issues raised in Chapter 2 might be addressed. In its discussions, the committee anticipated that the administrative context and structure of the Intelligent Transportation Systems (ITS) Standards Program will not change substantially and that the program will continue under new legislation or as an element of the U.S. Department of Transportation's (USDOT's) broader ITS activities following expiration of the current authorizing legislation, the Transportation Equity Act for the 21st Century.

This chapter presents the committee's suggestions of three broad objectives for modifying the program to avoid or overcome the potential impediments to its effectiveness described in Chapter 2:

- Facilitating common understanding and practical achievement of interoperability in ITS applications,
- Encouraging continuing growth of the market for ITS technology, and
- Encouraging accelerated adoption of ITS applications.

ACHIEVING INTEROPERABILITY

As the preceding discussion has illustrated, devising workable definitions of "interoperability" in the ground transportation system and achieving consensus about the degree to which the concept is worthy of pursuit at national or regional scales are problems that predate ITS. Many of the specific characteristics of transportation infrastructure that in the past have been left largely to local preference are now concerns for those who seek to ensure national interoperability of ITS components.

Consider emergency management services (EMS) applications, which the committee discussed early in the Phase 2 study and in its second letter report. Participants in the committee's meetings described substantial technical and institutional incompatibilities that characterize EMS currently operating in many regions. Cellular telephones, which are now used to make the great majority of vehicle crash and other traffic incident reports to 911 call centers, had no particular role in initial EMS service definitions. The software and hardware systems that most 911 centers use are proprietary. Police and fire officials in adjacent jurisdictions typically use different radio frequencies, possibly different ways of reporting incident locations (e.g., street address versus distance from intersection) and characteristics, and even different terminology for incident types and responses. Traffic agencies, which typically are not part of the EMS infrastructure, may use incident detection algorithms that are unable to accommodate reports from outside their jurisdictions, despite the impact an incident in an adjacent jurisdiction could have on traffic conditions within their purview. A consequence of these incompatibilities has been that incidents sometimes must be reported upward and through dispatch centers to cross jurisdictional boundaries, with increased possibilities for miscommunication, error, and delay. Effective ITS standards ideally would facilitate direct communication—for example, automatically translating incident location information or enabling emergency-response vehicles to actuate traffic signal preemption across jurisdictional boundaries.

Consider another example, collecting tolls or other road user charges, that was discussed by the committee, particularly with regard to dedicated short-range communications (DSRC).¹ Toll-financed facilities typically are operated by distinct authorities that make their own decisions to meet their fiscal responsibilities to bondholders. The benefits that toll payers might receive in avoiding tollbooth delays by having a single way to prepay for using facilities of multiple authorities—in several states, for example—may require an older authority to purchase new equipment or a new authority to forgo a more recent and more capable system. Data security requirements for financial transactions, combined with the intense competition among financial services providers (e.g., Visa

¹ See the committee's third letter report (Appendix D).

and MasterCard), also may inhibit agency efforts to achieve interoperability across institutional boundaries, even when the agencies use similar toll-collection equipment. Such issues have slowed efforts to devise common billing and collections procedures to enable travelers to use a single toll tag on highway trips through multiple states.²

As these examples illustrate, achieving ITS interoperability requires that institutional and political as well as technical factors be addressed. Committee members' experience in the telecommunications industry has shown that achieving interoperability often requires interchange and even a form of cooperation among separate and sometimes competing entities, although the cooperation may be indirect. Providers of independent verification and validation (IV&V) services,³ for example, may have contractual relationships with several competing firms working on similar products. The IV&V provider maintains a strict separation of each client's proprietary information but brings to every client a deep knowledge of the standards and other operational requirements that the products must meet. This knowledge, applied in product development, adds to the value that all clients receive as well as to the likelihood that the final products will achieve interoperability.

Each application presents unique problems, however, suggesting to the committee that ITS interoperability may best be understood as a functional criterion within the context of specific applications areas rather than as a unified concept broadly encompassing all ITS. The committee concludes that there would be value in preparing an explicit explanation within each applications area of the extent to which national interests will be served by achieving functional interoperability among systems.⁴ Such an explanation would be a useful part of the "concept of operations" that is meant to be prepared during the standards development process.

² Electronic payment services are now included in the National ITS Architecture. To deal with such problems, the International Bridge, Tunnel, and Turnpike Association has been working with technical and financial partners to devise a system of trusted transactions (the OmniAir concept) to be used in DSRC applications.

³ As described later in this chapter, these providers typically offer testing and consulting services during product development to ensure that standards are met and to resolve uncertainties when standards inadequately specify product characteristics important to achieving interoperability.

⁴ For example, should all traffic control centers nationwide be interoperable, perhaps to allow any center to take over the activities of another center that is out of service?

EXPANDING THE ITS MARKET

One of the principles underlying federal involvement in ITS standards development has been that common national standards will facilitate development of a national market for ITS products. The committee agrees that the slow rate of diffusion of technology in the ground transportation system and the pattern of stakeholder interests in ITS impose practical limits on how well that principle can be realized.

Diffusion of New Technology

As discussed previously, a slow rate of technology “migration” or upgrading to new capabilities in traffic control systems is characteristic and, to some extent, unavoidable. Most agencies purchase only a few signals or signs at any one time, and such new equipment is typically expected to remain in service for some time, possibly decades. Agencies then have substantial “legacy” investments—with institutional and cultural components, in that staff members are familiar with their systems—that deter adopting new technology. As meeting participants commented early in the Phase 2 study, Montgomery County, Maryland, has some 800 signal controllers that would need to be replaced or somehow retrofitted to incorporate National Transportation Communications for ITS Protocol (NTCIP) standards. While such actions might be taken gradually as individual controllers require service, the need to train maintenance staff to deal with two types of controllers, stock larger inventories of spare parts, and resolve software differences could encourage an agency to make a change immediately and completely. Local agencies as well as USDOT most likely would avoid the disruption as well as the cost of immediate, wholesale replacement of otherwise functional devices to procure new ITS technology.

In addition, the prospect that continuing technology evolution may quickly make new investments obsolete deters some users from becoming “early adopters,” those among the first to make commitments to install new technology. For instance, meeting participants commented that no consensus had been reached on what application of DSRC at 5.9 GHz will convince agencies to make the investment in ITS infrastructure—

such as roadside transceivers—needed to enable other applications to be implemented.⁵ Public safety applications (e.g., EMS) appear promising.

Considering that comment, the committee suggested that building on the base of installed toll collection systems may hold substantial promise for making investment in the DSRC infrastructure appealing. Although the capability and philosophy of service of DSRC and current toll tags are very different, many users already are committed to the idea of using automated collection systems. The committee estimated that the E-ZPass toll tag system prevalent from Maryland to Massachusetts,⁶ for example, has some 10 million individual users, a small percentage of the nation's more than 200 million registered motor vehicles but a substantial share of those using toll facilities and certainly more substantial than other currently functional ITS applications areas. Committee members and guests commented that batteries in the oldest toll tags now in use are approaching the end of their 7-year expected service life. The need to replace these tags offers an opportunity to introduce a DSRC-compliant, in-vehicle device that could then be used for other applications.

Industry sources presented to the committee estimates that the price for this new device might be as high as \$100 initially, but could drop to perhaps \$25 in 4 to 5 years as technology evolves and the market expands. These prices are higher than those for existing toll tags but compare favorably with experience with cellular telephones, for example, and could gain user acceptance. The committee surmised that the incremental infrastructure costs of adding 5.9-GHz DSRC to existing toll collection installations (which operate in the 915-MHz band) would be small.

Because state and local agencies often use some federal funds in purchasing new traffic control equipment, the committee discussed provision of supplemental federal funds for adopting ITS applications and standards as a means of encouraging such adoptions. For DSRC at 5.9 GHz, this supplemental funding could speed the transition from existing systems to the new standard by facilitating, for example, incremental early

⁵ In consumer electronics, telecommunications, and some other fields, people speak of the “killer ap” (i.e., application) that will dramatically increase demand for a new technology.

⁶ The committee was told that efforts were being made to extend the system to toll facilities in Virginia and throughout New England.

replacement of otherwise-functional components that do not meet the 5.9-GHz standards. The committee agreed that the basic strategy could be extended to other ITS applications areas.

Shifting Allocation of Private and Public Interests

The committee agreed that the patterns of interests and responsibilities among multiple private- and public-sector stakeholders in ITS are changing. For example, traffic flow and congestion information is now collected primarily by public agencies, but increasing numbers of private firms provide traffic information to motorists and expect to derive revenue from the service (albeit sometimes indirectly, perhaps through advertising).

It may be that ITS applications could make it commercially feasible for private firms to collect traffic data and become both primary sources and users of traffic flow and traffic incident information. These firms presumably would define for themselves the “message sets” that structure how traffic flow data are stored and transmitted, without regard for government-sponsored standards. While government agencies have been responsible for buying and operating the roadway detectors and signals that comprise traditional traffic-control infrastructure, private firms could easily adopt new technologies (e.g., satellite-based monitors and probe-vehicle detection) that would not only overlap government functions but also blur the distinction between infrastructure and in-vehicle ITS components.

These changes suggested to the committee that the Joint Program Office (JPO) should reconsider the focus on infrastructure, which arguably was sensible in the initial stages of the ITS Standards Program. Concerns for security of traffic-control system operations and privacy of travel data, in the committee’s view, warrant federal leadership, for example, in setting minimum standards for veracity and reliability of privately provided information that could influence transportation system performance, and in allocating liability when privately collected traffic data are unavailable or erroneous.⁷ USDOT could expand the standards program

⁷ For example, the committee discussed the use of “probe” vehicles operating in the traffic stream to collect information.

to embrace more fully the broad scope of ITS technology by designating nationwide operating frameworks such as those used in 911, 311, and 511 services.⁸ Another possible model is the Federal Communications Commission requirement that cellular telephone providers be able to supply with a specified precision the location of telephones they service.⁹

ADOPTING ITS APPLICATIONS

As the committee repeatedly remarked, simply increasing ITS market potential will not ensure that ITS applications are adopted. Purchasers of the technology, as well as its producers, must be convinced that the rewards of innovation are worth the risks. The committee considered how the balance of risks and rewards might be shifted to favor ITS adoption.

Verifying Effectiveness of ITS Components and Standards

The testimony of USDOT staff and guests at the committee's meetings indicates that there are few, if any, objective and generally applicable criteria, tests, or demonstrations to assure users that particular ITS components can meet standards and function as desired. For example, the number of U.S. suppliers of products and services used for traffic control centers is small.¹⁰ Most claim to offer applications that conform to NTCIP standards. However, functional characteristics differ among producers' systems, and purchasers have no objective means for testing whether these varied products do indeed meet the claim of conformance to the standards.

Also, there are no generally accepted tests for verifying center-to-center interoperability. Examples presented in the committee's meetings were persuasive that interoperability is not ensured simply by conformance with existing NTCIP standards. Agencies participating in early application of NTCIP for dynamic message signs found that equipment

⁸ Each is a universally reserved telephone number providing channels, respectively, for emergency reporting, for nonemergency public-assistance requests, and for traveler information reporting.

⁹ Service providers must be able to deliver to public safety officials the latitude and longitude of a caller, accurate to at least 410 feet two-thirds of the time.

¹⁰ The U.S. market is split among about six system integrators and a similar number of management equipment suppliers.

from different manufacturers initially could not be used together, even though the equipment conformed in all aspects to the draft standards.

Drawing on its experience, the committee suggested a variety of mechanisms for verifying that products embodying new standards function as desired in a particular application. The state of California, for example, certifies functionality by issuing a qualified products list (QPL) that is used in that state's purchasing. The QPL has been widely accepted as a de facto assurance of standards compliance for items on the list and sometimes of the competence of producers as well. The committee suggested in its second letter report (Appendix C) that federal support might be provided to motivate a state agency or a group of states acting together to create and maintain an ITS QPL.

For standardized communications protocols and message sets, the committee suggested that USDOT sponsor development of "test suites" for suppliers and agencies to use in verifying interoperability. Such suites could be made widely available on CD-ROM or as "test environments" on the Internet.

The committee suggested that establishing a "reference implementation" is another means for verifying interoperability and conformance to standards. A reference implementation is a prototype complete system that is generally agreed to provide desired functionality and to meet desired standards. The capabilities of a new piece of equipment or software can be tested by demonstrating that it works within the context of the reference implementation. An implementation in the field, within a region's traffic management system, can function as a reference implementation. However, setting up the reference implementation within an independent testing facility may be a way of avoiding giving a particular competitive advantage to one ITS supplier, as with a demonstration project, for example. The committee suggested, in either case, that federal support for a set of reference implementations of ITS applications is justifiable.

Providing well-formulated sample or "model" specifications can also be an effective means for facilitating adoption of ITS standards, the committee suggested.¹¹ Education and training of agency staff and their con-

¹¹ This tactic is most useful for products (for example, signal controllers) rather than whole installations. JPO staff reported that development of sample specifications is planned for at least some applications supported under the ITS Standards Program.

sultants are likely to be needed to ensure that these sample specifications are appropriately modified for specific applications because most agencies lack the technical expertise to use such specifications most productively. The committee understands that JPO has begun to support development of sample specifications and associated education materials.

As described previously, independent verification and validation, as an institution and as a set of closely related activities, has functioned in the telecommunications industry to meet many of these product-testing needs and, through experience gained with multiple products, to provide effective testing and refinement of the underlying standards. The independent testing laboratories that provide the IV&V service certify that equipment and software conform to standards. Through the expertise of its staff and long-term involvement with product developers, the IV&V institution becomes a repository of knowledge on standards and their underlying technology, and enhances the product development effort by providing advice and guidance to developers at all stages of that effort. In the committee's experience, product developers typically pay the immediate direct costs of contracting with the IV&V laboratory and receive value from the laboratory's certification (which enhances the product's marketability) as well as from the laboratory staff's participation in development.¹²

The committee agreed that the relatively small aggregate U.S. market for ITS infrastructure technology may not sustain more than one or two IV&V organizations. State and local agency buyers have diverse concerns, which they seek to resolve by specifying the characteristics they want in new equipment. These variations frustrate suppliers' efforts to take advantage of economies of scale (and to pass along the benefits through lower costs, enhanced capabilities, or both). The committee suggested that development of IV&V capability at a national level is warranted. USDOT could motivate establishment of one or a very few national IV&V providers for ITS. An ITS IV&V institution could serve as a mediator among purchasers and manufacturers to ensure that standards are met and compromises made as needed to bring buyers and producers together. The IV&V agency or laboratory could develop and distribute test suites or test environments and could prepare an ITS QPL. Because each

¹² Careful internal management practices, as already noted, enable the IV&V institution to work simultaneously with competing companies, even on similar products.

of these activities adds value to the ITS deployment process, the ITS IV&V institution could plausibly be supported by fees for services it provides to ITS suppliers and users, although its services in refining the standards themselves could justifiably be supported by the standards program.

Providing Direct Incentives to Encourage Early Adopters

Although the committee expressed some reservations about the applicability of evidence being presented on the benefits being realized in ITS projects,¹³ such information may encourage ITS producers and users to make the effort to understand and apply federally sponsored standards. The committee is not aware of any analyses of the potentially adverse consequences of adopting ITS technology that does not conform to the federally supported standards. It suggests that such targeted information could be helpful in marketing the standards to potential users and in marketing the standards program as a whole to elected officials and their staff who are responsible for the program's funding.

Because successful demonstrations of the standards' use are likely to be the most effective means for encouraging wider adoption of ITS standards and technology, JPO efforts to encourage early adoption could be an effective way, in the committee's view, to speed standards' deployment. Early adopters of any new technology face the risks of added costs to refine untested applications or to replace unsatisfactory components of an installation. The committee suggested that USDOT might encourage early adopters to implement demonstrations by making ITS innovation "seed money" available to supplement normal capital grants. The committee agreed that even relatively small supplements (e.g., \$50,000), to cover an agency's added administrative and technical costs, might be adequate to attract participants to test standards.

Maintaining Standards

Throughout both phases of the Transportation Research Board study, the committees expressed serious concern that standards development

¹³ The previously described ITS Benefits and Costs Database and reports on the "ITS Benefit of the Month" are maintained by one of JPO's contractors and made available on the Internet (www.benefitcost.its.dot.gov).

organizations participating in the ITS Standards Program may not be able or willing to devote adequate resources and put in place effective mechanisms to ensure that ITS standards are maintained. The technologies underlying ITS continue to evolve at a rapid pace that will necessitate periodic review and updating to keep standards from becoming obsolete. The ITS standards business model appears to rely on revenues from standards sales to fund the maintenance efforts, but such revenues, by themselves, are not likely to be sufficient to support the required work. The committee suggested that allocating funds to ensure that USDOT-supported ITS standards are adequately maintained would be appropriate and an effective use of federal resources.

Recommendations

As its Phase 2 review of the program ended, the committee agreed that adoption of intelligent transportation systems (ITS) can substantially improve the performance of the U.S. surface transportation system and thereby yield significant benefits to the system's users and to the nation as a whole. Investments in ITS generally and in the development and deployment of standards to facilitate ITS adoption in particular are, in the committee's view, a wise and appropriate use of government funds. The committee commends efforts by the U.S. Department of Transportation (USDOT) and Congress to ensure authorization of the ITS Standards Program in new legislation and urges that federal funds be appropriated and applied to support continuation of the program's activities.

Nevertheless, as the preceding chapters explain, the committee believes that improvements in the ITS Standards Program can be made. The committee recognizes that implementing its suggestions for overcoming obstacles to widespread adoption of ITS standards will require funds and professional resources that may exceed those available to the standards program. The following specific recommendations represent the committee's views of how best to enhance future program effectiveness, considering the varied market forces and legislative mandates that influence the establishment and general functioning of new technology standards.

- 1. The committee recommends that the Joint Program Office (JPO) invest its standards development and deployment resources in accordance with a clearly delineated assessment of (a) the need for the standard as an enabler of important ITS services and (b) national benefits to be gained through that standard's accelerated promulga-**

tion. The potential contribution to achieving functional interoperability at a national scale is certainly a key indicator of benefits, but contributions to safety, security, technological leadership, international trade, and other valid federal concerns are also justifiable bases for providing federal support.

The committee agrees that the bases for allocation of the ITS Standards Program resources could be explained more clearly and the allocation could be targeted more tightly. A commonly accepted understanding of the practical meaning of ITS interoperability has not yet emerged. The National ITS Architecture, which might contribute to developing that understanding, is at best a framework describing the relationships among specific ITS services and standards. Even with such understanding, various stakeholders often have differing interests and priorities with regard to standards development activities that should receive federal support, and USDOT must be responsive to stakeholders' concerns. The committee agrees that there is a need for more detailed explanations of why particular standards have been selected for federal support and how those standards are expected to contribute to achieving standards program goals.

Resource limitations certainly will affect decisions to provide federal support for particular ITS standards. Standards are valuable only to the extent that they are used in practice, and resource requirements extend to deployment after standards are endorsed by their developers. Testing and demonstrations of a standard's effectiveness are necessary stages in development and deployment. Once in use, standards must be maintained by correcting errors, accommodating advances in technology, and responding to evolutionary changes in the architecture the standards support. Standards are more likely to be used in the first place if they facilitate the application of new ITS technology. Recognizing these many demands for resources, the committee anticipates that pursuing this recommendation may limit the numbers of standards being developed with federal support. Restricting and even reducing the number of standards being developed with federal support would enable further investments in activities that extend beyond the typical range of the standards development organizations (SDOs). In evaluating which standards merit JPO's continuing support, it might be useful to include the consequences of not providing federal support for development of a particular standard—for example,

delay or failure of stakeholders to reach a consensus if federal support is withheld.

2. The committee recommends that JPO develop explicit measures of effectiveness for the ITS Standards Program that are outcome oriented and make clear the principle that standards should be used and thereby return substantial benefits on the public's investment.

The point appears obvious but in the committee's view bears repetition: JPO-supported standards must be applied if they are to be effective. If, as the committee recommends, JPO undertakes to focus its development and deployment investments on a smaller set of standards, it becomes increasingly important that each activity receiving JPO support show a high likelihood of contributing to the adoption of ITS technology in the U.S. transportation system. Clearer reporting of the progress of the standards program and ITS deployment generally is needed.

These measures of program effectiveness would be helpful also in determining what precise mix of investments in testing and validation is likely to be most productive. The committee agrees that JPO has appropriately recognized the need to encourage various decision makers to adopt federally supported standards—for example, by providing training and informational materials aimed at government officials and their consultants. If such efforts precede the completion of standards development, prematurely encouraging use of standards before they have been demonstrated to be effective, the effort is likely to be counterproductive.

3. The committee recommends that JPO and standards developers supported by JPO adhere strictly to the following sequence of stages in the ITS standards development process:

- **Testing** to ensure that the proposed standard can be used in field applications and will perform as expected (such testing should be completed before a proposed standard is submitted for balloting and adoption within an SDO-based development process);

- **Formal adoption** through balloting or another mechanism that unambiguously identifies a standard as being sufficiently mature to be used in practice;
- **JPO assessment of readiness for deployment**, which would likely consider the number of applications that might realistically be expected in the near term (e.g., 3 to 5 years), the number of manufacturers and system integrators capable of delivering ITS installations meeting the standard, and the availability of information and materials to facilitate the standard's application, such as sample specifications, documentation, and training programs; and
- **Postadoption support** (e.g., training and maintenance), which should not be pursued before a standard has passed through the stages of formal adoption and assessment of readiness for deployment.

The committee finds that steps appear to be missing from the development process for some standards, steps that are essential to the long-term effectiveness of those standards. Testing to ensure that the standard can be used and will function as intended has been highlighted in previous discussion. While SDO-based standards development procedures typically include formal adoption mechanisms, some SDOs may issue “interim” standards for application and testing and others may have no such designation, raising the possibility that the maturity or readiness for unrestricted application may vary among standards. JPO's assessment of a standard's readiness for deployment will encourage the standard's use, and postadoption support will reduce the initial costs users incur in learning about new technologies.

4. The committee recommends that rulemaking be used sparingly or not at all for ITS standards; rulemaking may be more justifiable for ITS standards supporting safety and security.

Ideally, standards will be used because they offer foreseeable benefits to their users. Requiring their use should not be necessary. The committee recognizes that rulemaking can be an effective and sometimes necessary means for establishing technical standards, but the time required for rulemaking is long compared with the speed of evolution of ITS technology, particularly in the context of the time required for standards

development. The costs associated with rulemaking and monitoring that federal requirements are met in procurements are high compared with the benefits of marginal increases in the likelihood that effective standards will be used. The risks of imposing ineffective standards that then cannot easily be changed or discarded are significant. For at least these three reasons, the committee chose to reiterate this recommendation from the Phase 1 study.

- 5. To give greatest encouragement to standards users and to the adoption of ITS technology generally, the committee recommends that JPO support the full range of activities required to make standards development and deployment effective over the longer term, including appropriate research and development, testing and demonstration to validate standards and ensure that they can be used, establishment by the stakeholder community of a national ITS independent verification and validation (IV&V) capability, training for standards users, and maintenance of standards that have been developed with federal support.**

While the scope of the standards program should be carefully focused, other activities can enhance the program's contribution to the broad objective of rapid ITS deployment. Appropriately structured support for establishment of a national ITS IV&V capability, continuation of education and outreach efforts, funding for activities to advance understanding of new ITS applications for which standards may be needed, and support for maintenance of standards as technology and market conditions evolve together would represent a balanced strategy for achieving the long-term objective.

To ensure broad stakeholder participation in all these activities, and because budgetary constraints sometimes make it difficult for state and local officials to play a sustained role in standards development and deployment, this recommendation encompasses continued JPO support for travel and other costs incurred by qualified public-sector participants and continued participation and support for U.S. involvement in international ITS standards development. Early adopters play an important role in ensuring that standards are mature, usable, and effective, and compensating early adopters for the higher costs they incur—for example,

through appropriate administration of ITS demonstration projects—is also warranted.

6. The committee recommends that JPO undertake explicitly to streamline the process for developing and revising standards.

The emphasis of the preceding recommendations has been on the deployment of standards, but as ITS technology progresses, needs for new standards and substantial revisions of existing standards are likely to arise. The committee finds that JPO has exercised fairly limited influence on the SDO-based standards development process and that more direct guidance and involvement may improve the efficiency of that process. Experience suggests that the availability of committed professional expertise and leadership contributes to the speed of standards development and the quality of the resulting standards. JPO might do well to act more aggressively to ensure such staff support for SDO committees. In the future, some new ITS standards might be developed more effectively by using mechanisms other than formal SDOs (for example, industry and user consortia), provided that the standards development process continues to permit participation by all interested stakeholders. USDOT should entertain proposals for support of development and deployment of all appropriate ITS standards, whether from an established SDO, an industry consortium, or another developer. It should apply explicit criteria for judging appropriateness and make decisions with due consideration for budgetary constraints and other relevant factors.

7. The committee recommends that USDOT consider judicious expansion of the standards program to embrace services that span the interface between in-vehicle and roadside infrastructure subsystems, consistent with the program's goals, the role of government as a stakeholder in the advance of ITS technology, and efficient investment of government resources to achieve public purposes, particularly with regard to achievement of national interoperability.

So far, the ITS Standards Program has been aimed primarily at ITS infrastructure, although JPO activities generally have included in-vehicle as well as infrastructure components of ITS. The committee observes that the interface between in-vehicle and infrastructure subsystems is crucial to

ITS success. While the demarcation of that interface is not yet precisely defined, the interface itself is likely to be a fertile area for ITS innovation. Such applications as real-time traffic routing and congestion management, advanced emergency management, and traveler safety and information services will depend on close integration of decisions about in-vehicle and roadside components. The public benefits will increase rapidly as the proportion of the vehicle fleet equipped for these applications increases.

Standards Applications Areas Considered in the Committee’s Review

This listing of standards for each applications area is derived from a U.S. Department of Transportation (USDOT) deployment-oriented matrix distributed to the committee at its first meeting. The classification of standards within each area as “primary” or “related” was made by support staff to facilitate committee discussion in subsequent meetings. The number and specification of standards included in USDOT’s Intelligent Transportation Systems (ITS) Standards Program have changed somewhat during the period of the committee’s study, but no effort was made to revise these lists.

NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL FOR DYNAMIC MESSAGE SIGNS

Defines the parameters for communication across the interface between the traffic information center controllers and roadside display units of dynamic message signs used to provide road users with information, for example, on congestion, crash incidents, or lane closures.

Primary Standards

NTCIP 1201	Global Object Definitions [AASHTO 1201]
NTCIP 1203	Object Definitions for Dynamic Message Signs [AASHTO 1203]
NTCIP 2301	Application Profile for Simple Transportation Management Framework [AASHTO 2301]
NTCIP 2303	Application Profile for File Transfer Protocol [AASHTO 2303]

Related Standards

NTCIP 1101	Simple Transportation Management Framework [AASHTO 1101]
NTCIP 1102	Base Standard: Octet Encoding Rules [AASHTO 1102]
NTCIP 1103	Simple Transportation Management Protocol [AASHTO 1103]
NTCIP 2001	Class B Profile [AASHTO 2001]
NTCIP 2101	Point-to-Multipoint Protocol Using RS-232 Sub-network Profile [AASHTO 2101]
NTCIP 2102	Subnet Profile for Point-to-Multipoint Protocol over FSK Modems [AASHTO 2102]
NTCIP 2103	Subnet Profile for Point-to-Point Protocol Using RS-232 [AASHTO 2103]
NTCIP 2104	Subnet Profile for Ethernet [AASHTO 2104]
NTCIP 2201	Transportation Transport Profile [AASHTO 2201]
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile [AASHTO 2202]

EMERGENCY MANAGEMENT SERVICES

Defines information to be communicated among agencies responsible for incident and emergency management in highway operations and how communications are to occur. Incident management [Institute of Electrical and Electronics Engineers (IEEE) 1512 series standards], which aims to maintain or restore traffic flow following a vehicle crash or other disruption, entails message set and data dictionary and data definition issues. This is a subset of emergency management, which includes fire, ambulance/rescue, and law enforcement as well as traffic management operations. These agencies have diverse objectives, communications requirements, and needs for traffic and roadway information.

Primary Standards

IEEE P1512-2000	Standard for Common Incident Management Message Sets (IMMS) for Use by EMCs
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IEEE P1512.1	Standard for Traffic IMMS for Use by EMCs
IEEE P1512.2	Standard for Public Safety IMMS for Use by EMCs
IEEE P1512.3	Standard for Hazardous Material IMMS for Use by EMCs
IEEE P1512.a	Standard for Emergency Management Data Dictionary
NTCIP 1301	Message Set for Weather Reports
NTCIP 1402	TCIP—Incident Management Business Area Standard (note: TCIP = transit communications interface profiles)

Related Standards

ITE TM 1.03	Standard for Functional Level Traffic Management Data Dictionary
ITE TM 2.01	Message Sets for External Transportation Management Center (TMC) Communication
NTCIP 1102	Base Standard: Octet Encoding Rules
NTCIP 1401	TCIP—Common Public Transportation Business Area Standard
NTCIP 1405	TCIP—Spatial Representation Business Area Standard
NTCIP 2104	Subnet Profile for Ethernet
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile
NTCIP 2303	Application Profile for File Transfer Protocol
NTCIP 2304	Application Profile for Data Exchange ASN.1 (DATEX)
NTCIP 2305	Application Profile for Common Object Request Broker Architecture (CORBA)
NTCIP 2501	Information Profile for DATEX
NTCIP 2502	Information Profile for CORBA

NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOL FOR TRAFFIC SIGNALS

Defines data sets and communication protocols for traffic signal controllers linked into multisignal networks managed from centralized locations.

Primary Standards

NTCIP 1201	Global Object Definitions [AASHTO 1201]
NTCIP 1202	Object Definitions for Actuated Traffic Signal Controller Units [AASHTO 1202]
NTCIP 1210	Objects for Signal Systems Master [AASHTO 1210]
NTCIP 1211	Objects for Signal Control Priority [AASHTO 1211]
NTCIP 2301	Application Profile for Simple Transportation Management Framework [AASHTO 2301]

Related Standards

NTCIP 1101	Simple Transportation Management Framework [AASHTO 1101]
NTCIP 1102	Base Standard: Octet Encoding Rules [AASHTO 1102]
NTCIP 1103	Simple Transportation Management Protocol [AASHTO 1103]
NTCIP 2001	Class B Profile [AASHTO 2001]
NTCIP 2101	Point-to-Multipoint Protocol Using RS-232 Subnetwork Profile [AASHTO 2101]
NTCIP 2102	Subnet Profile for Point-to-Multipoint Protocol over FSK Modems [AASHTO 2102]
NTCIP 2103	Subnet Profile for Point-to-Point Protocol Using RS-232 [AASHTO 2103]
NTCIP 2104	Subnet Profile for Ethernet [AASHTO 2104]
NTCIP 2201	Transportation Transport Profile [AASHTO 2201]
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile [AASHTO 2202]

CENTER-TO-CENTER/TRAFFIC MANAGEMENT

Defines message sets and data exchanges to enable communication among separate transportation management centers (e.g., within single jurisdictions) within a multiagency and multijurisdiction regional setting, to enable coordinated management of large systems of traffic control devices.

Primary Standards

ITE TM 1.03	Standard for Functional Level Traffic Management Data Dictionary
ITE TM 2.01	Message Sets for External TMC Communication
NTCIP 1210	Objects for Signal Systems Master
SAE J2353	Data Dictionary for Advanced Traveler Information System (ATIS)
SAE J2354	Message Set for ATIS

Related Standards

IEEE P1512.1	Standard for Traffic Incident Management Message Sets for Use by EMCs
IEEE P1512.a	Standard for Emergency Management Data Dictionary
NTCIP 1102	Base Standard: Octet Encoding Rules
NTCIP 1301	Message Set for Weather Reports
NTCIP 2104	Subnet Profile for Ethernet
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile
NTCIP 2303	Application Profile for File Transfer Protocol
NTCIP 2304	Application Profile for DATEX
NTCIP 2305	Application Profile for CORBA
NTCIP 2501	Information Profile for DATEX
NTCIP 2502	Information Profile for CORBA
SAE J2529	Rules for Standardizing Street Names and Route IDs
SAE J2540	Messages for Handling Strings and Lookup Tables in ATIS Standards

CENTER-TO-CENTER/TRANSIT MANAGEMENT

Defines data sets and communication protocols for transit-vehicle operations management, including passenger information and fare collection, enabling more efficient route operations and multivehicle route management from centralized transportation management centers.

Primary Standards

ITE TM 2.01	Message Sets for External TMC Communication
ITE TS 3.TM	Message Sets for External TMC Communication
NTCIP 1401	TCIP—Common Public Transportation Business Area Standard
NTCIP 1403	TCIP—Passenger Information Business Area Standard
NTCIP 1404	TCIP—Scheduling/Runcutting Business Area Standard
NTCIP 1407	TCIP—Control Center Business Area Standard
NTCIP 1408	TCIP—Fare Collection Business Area Standard
SAE J2353	Data Dictionary for ATIS
SAE J2354	Message Set for ATIS

Related Standards

ITE TM 1.03	Standard for Functional Level Traffic Management Data Dictionary
NTCIP 1102	Base Standard: Octet Encoding Rules
NTCIP 1301	Message Set for Weather Reports
NTCIP 1402	TCIP—Incident Management Business Area Standard
NTCIP 1405	TCIP—Spatial Representation Business Area Standard
NTCIP 2104	Subnet Profile for Ethernet
NTCIP 2202	Internet (TCP/IP and UDP/IP) Transport Profile
NTCIP 2303	Application Profile for File Transfer Protocol
NTCIP 2304	Application Profile for DATEX
NTCIP 2305	Application Profile for CORBA
NTCIP 2501	Information Profile for DATEX
NTCIP 2502	Information Profile for CORBA
SAE J2529	Rules for Standardizing Street Names and Route IDs
SAE J2540	Messages for Handling Strings and Lookup Tables in ATIS Standards

DEDICATED SHORT-RANGE COMMUNICATIONS FOR 5.9 GHz

System for communicating between vehicles and roadside ITS components for collection of information about traffic conditions and dissemination of information for traffic control and public safety applications. System will operate in the 5.9-GHz segment of the radio frequency spectrum, where it has coprimary status with limited other uses.

Primary Standards

ASTM n/a	Standard Specification for 5.9-GHz Data Link Layer
ASTM n/a	Standard Specification for 5.9-GHz Physical Layer
ASTM PS 105-99	Specification for Dedicated Short-Range Communication Data Link Layer: Medium Access and Logical Link Control

Related Standard

ASTM PS 111-98	Specification for Dedicated Short-Range Communication Physical Layer Using Microwave in the 902–928 MHz
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Summary of Letter Report 1, Standards Deployment and Use

The committee held meetings in March and June 2001—each approximately 2 days in length, at the National Research Council’s facilities in Washington, D.C.—to initiate its second-phase study and to discuss standards deployment and use, standards maintenance, and the U.S. Department of Transportation’s (USDOT’s) continuing role in using standards to encourage adoption in the United States of beneficial intelligent transportation systems (ITS) technology. Because members who had participated in the first study were generally familiar with the standards program, the committee was able to focus relatively quickly on segments of the program associated with specific ITS standards applications areas [as defined by the Joint Program Office (JPO)] and potential impediments to achieving widespread adoption of standards applicable to those areas. The committee’s first letter, issued in September 2001, offered conclusions and recommendations in five areas: (a) government involvement in setting ITS standards, (b) strengthening deployment efforts, (c) independent verification and validation (IV&V), (d) standards maintenance, and (e) scope of government involvement.

GOVERNMENT INVOLVEMENT IN SETTING ITS STANDARDS

While federal legislation establishes USDOT’s authority and responsibility to support development and deployment of ITS standards, much of the nation’s ITS infrastructure will be put in place by state and local government agencies with federally provided financial assistance. There is, however, no general agreement within the ITS community that standards setting by government is necessarily beneficial. Many complex factors

bear on the issue of what role, if any, the federal government should play in encouraging ITS adoption—including experience with standards development in other fields of technology, theories of how technological innovation progresses, concerns about ITS market scale and scope, and differences in practices among the 50 states and many local government agencies.

Once developed, standards must be used in practice if they are to yield benefits. JPO has responsibility for both development and deployment of standards within its purview and was shifting the standards program's emphasis from the former to the latter activity. The committee reviewed JPO's standards deployment efforts and emerging products of those efforts, on balance endorsing the proposition that government support for standards development and deployment can facilitate more rapid adoption of ITS technology and, in particular, that rapid adoption will be encouraged if federally supported standards are used in practice. The committee concluded that JPO, in progressively shifting its program to focus on deployment of standards previously developed with USDOT support, was appropriately allocating its resources to activities most likely to enhance the benefits ultimately derived from federal investments in ITS technology.

STRENGTHENING DEPLOYMENT EFFORTS

The committee was told of JPO's efforts to encourage dissemination and use of ITS standards; these efforts included production of informative printed documents and online materials, and in-field testing. The committee recognized that these efforts were still in relatively early stages for most of the ITS applications areas in which federally supported standards were being developed and recommended that JPO increase the effectiveness of its deployment efforts generally through three types of action:

- Developing materials that present clearly both the likely benefits of using federally supported ITS standards and the potentially adverse consequences of adopting ITS technology that does not conform to the federally supported standards, targeted to inform ITS suppliers (e.g., equipment and software producers, system integrators) and users (e.g., local and state agencies undertaking ITS procurements);

- Providing sample specifications for state and local agency use in ITS procurements, incorporating those standards that have been developed and tested; and
- Addressing outreach and education materials to an audience that includes not only government agency personnel concerned with the procurement of ITS technology but also private-sector consultants and system integrators, because these latter professionals are most responsible for many of the technical decisions that shape ITS applications.

INDEPENDENT VERIFICATION AND VALIDATION

Drawing on their experience in other areas of technology procurement, the committee members asserted that determining whether particular products conform to standards is a difficult problem that can be effectively addressed with IV&V. IV&V involves the use of independent testing laboratories to certify that ITS equipment and software conform to standards. As a repository of knowledge on standards and their underlying technology, the IV&V laboratory can enhance the supplier's product development effort by providing advice and guidance to developers at all stages of that effort.

Believing that IV&V can contribute significantly to achieving the overall goals of federal involvement in ITS applications, the committee recommended that buyers of ITS be responsible for ensuring that ITS products they purchase are subjected to IV&V, but that suppliers pay the immediate direct costs of contracting with an independent testing laboratory to verify that their products meet required standards. USDOT's role should be one of motivating and facilitating establishment of a successful ITS IV&V capability in the United States.

Because the aggregate market for ITS technology is relatively small, that market may not sustain more than one or two IV&V organizations. Because the many state and local agency buyers of ITS technology have diverse concerns and priorities, the market will be too fragmented to support effective IV&V unless the activity is consolidated at a national level. USDOT can encourage public agencies to accept supplier-paid IV&V as evidence of standards fulfillment, without resorting to added verification by individual state- or multistate-sponsored laboratories

such as now are widely used for testing materials and products. The committee suggested that USDOT proactively encourage candidate testing organizations to participate in the IV&V program and seek to ensure that a viable business model for ITS IV&V is implemented, a model that ideally will be self-supporting, will not impose excessive costs or constrain technological innovation, and will be staged to ensure that early participants do not bear a disproportionate share of start-up costs.

STANDARDS MAINTENANCE

Because the technologies underlying ITS continue to evolve at a rapid pace, the committee observed, ITS standards also must evolve if they are to remain relevant and useful. For this evolution to occur, the developers and users of ITS standards must be prepared to monitor, maintain, and update these standards. The committee questioned, however, whether JPO and participating standards development organizations were prepared to devote adequate resources and put in place effective mechanisms for ensuring that ITS standards are maintained. The committee recommended that USDOT explicitly address this matter and allocate sufficient funds to ensure that federally supported ITS standards are adequately maintained—and, if necessary, seek congressionally designated funding for this purpose.

SCOPE OF GOVERNMENT INVOLVEMENT

The committee recognized that the standards program had focused primarily on standards for ITS “infrastructure” as distinct from in-vehicle components, but such applications as dedicated short-range communications, real-time traffic routing and congestion management, and emergency management will require close integration of decisions about infrastructure and in-vehicle components. The committee therefore recommended that the larger goals of encouraging rapid ITS adoption warrant expansion of USDOT’s programs to embrace more fully the broader scope of ITS technology. Because funds beyond those currently authorized might be needed to support such scope expansion, the committee urged that USDOT seek congressionally designated funding for this purpose.

Summary of Letter Report 2, Obstacles to Rapid Standards Deployment

The committee held its third meeting of the Phase 2 study in November 2001. On the basis of previous discussions and negotiations between Joint Program Office and Transportation Research Board staff, the committee's intent in holding that meeting was to understand the dimensions of emerging obstacles to effective standards deployment and potentially develop effective strategies to overcome those obstacles. Like its predecessors, the third meeting was held over the course of 2 days at the National Research Council's facilities in Washington, D.C. A letter report was delivered to the U.S. Department of Transportation (USDOT) in January 2002.

The committee observed that as the first generation of standards was made available to intelligent transportation systems (ITS) vendors and purchasers and other standards users, potential obstacles to achieving the standards' widespread adoption in practice started to become more evident. Many of these obstacles reflected a mismatch among the interests of purchasers and vendors of ITS components and the public at large who will benefit from deployment of ITS technology.

SLOW MIGRATION AND TECHNOLOGY LEGACY

One potential obstacle is related to the typically slow rate of technology "migration" or upgrading to new capabilities in traffic control systems. This obstacle is to some extent unavoidable, because most agencies purchase only a few signals or signs at any one time. Such equipment is often purchased with substantial federal funding assistance and, regardless of the sources of funds, is typically expected to remain in service for 30 to 40 years. These agencies then have substantial "legacy" investments—

with institutional and cultural components—that constrain their willingness and ability to adopt new technology meeting new standards. In addition, the prospect that continuing technology evolution may quickly make new investments obsolete deters some users from making early commitments to newly introduced applications. While recognizing that greatly increased spending for new equipment may not be practical, the committee recommended that USDOT manage federal funding programs in ways that will speed the transition from existing traffic control to ITS—for example, by facilitating early replacement of otherwise-functional signal system components that do not meet ITS standards.

PRIVATE AND PUBLIC ROLES AT THE INTERFACE BETWEEN INFRASTRUCTURE AND IN-VEHICLE ITS COMPONENTS

Another obstacle relates to the overlapping and shifting distribution of responsibilities for development and operation of ITS applications. For example, traffic flow and congestion information is now collected primarily by public agencies. Some committee members suggested that private firms may find it feasible to collect and use their own traffic information to support their Internet-based ITS applications. Private firms that become both primary sources and users of traffic flow and traffic incident information define for themselves the “message sets” that structure how traffic flow data are stored and transmitted. Similarly, government agencies have been responsible for buying and operating the fixed infrastructure of traffic control, but the distinction between the functions provided by infrastructure (e.g., including satellite and probe-vehicle components as well as fixed roadside facilities) and those provided by in-vehicle ITS components is becoming more difficult to define. These observations prompted the committee’s conclusion (stated in its previous letter and reiterated here), that “the larger goals of encouraging rapid ITS adoption warrant expansion of the DOT’s programs to embrace more fully the broader scope of ITS technology.” Considering government roles in developing 911, 511, and 311 services and new requirements for Global Positioning System capabilities in cellular telephones, the committee concluded that USDOT can help motivate, facilitate, or direct private-sector actions to address concerns at the ill-defined but

increasingly important interface between infrastructure and in-vehicle ITS components. These concerns could include security of data and traffic control systems, coordination of product performance characteristics among otherwise competitive producers, and allocations of liability in cases when privately collected traffic data are unavailable or erroneous.

CRITERIA AND TESTS FOR ENSURING THAT STANDARDS ARE MET

A third and very immediate obstacle to effective standards deployment is the lack of objective and generally applicable criteria, tests, and demonstrations to ensure that particular ITS applications do indeed conform to those standards and are interoperable. For example, most of the small number of U.S. vendors of products and services used for traffic control centers claim to offer applications that conform to the National Transportation Communications for ITS Protocol (NTCIP) standards. However, functional characteristics differ among the systems of various producers, and purchasers have no objective means for testing whether these products do indeed meet the claim of conformance to standards. Furthermore, there are no generally accepted tests for verifying center-to-center interoperability, an important objective of federal policy that is not assured simply by conformance to existing NTCIP standards.

The committee recommended that standards development generally include establishing ways that users can ensure that new components meet those standards and are interoperable and that USDOT provide funding and other appropriate incentives to ensure that such tests and criteria are available. The committee then proposed several strategies for doing so.

Independent Verification and Validation

Independent verification and validation (IV&V) was recommended in the committee's previous letter as a proven means for ensuring that technology-based components and systems meet standards and are interoperable. The committee proposed that a national ITS IV&V capability be established, with buyers of ITS responsible for ensuring that ITS products they purchase are subjected to IV&V, and suppliers paying the immediate direct costs of contracting with an independent testing

laboratory to verify that their products meet required standards. USDOT should facilitate ITS IV&V by encouraging public agencies to accept supplier-paid IV&V and encouraging candidate testing organizations to participate in the program, and should work with both to ensure that a viable ITS IV&V business model is implemented. The national ITS IV&V should be self-supporting without imposing excessive costs or constraining technological innovation and should be staged to ensure that early participants do not bear a disproportionate share of start-up costs.

The committee previously noted that the small aggregate market for ITS infrastructure technology would necessitate that IV&V capability be established at a national level, although more than one testing facility might be required to address the variety of ITS applications areas. After considering the matter further, the committee noted useful precedents and existing institutions that might become providers of ITS IV&V.

For example, California’s “qualified products list” has been widely accepted as *de facto* assurance of standards compliance for items on the list and sometimes of the competence of producers as well. An individual state acting from such an experience base or on behalf of larger organizations (e.g., “lead state” programs) could provide the nucleus for establishing a complete IV&V capability. Multistate groups such as the coalitions that have formed along I-95 in the mid-Atlantic and the I-75 corridor could play a sponsorship role, with the lead state’s agency laboratory or other existing institutions serving as the ITS IV&V provider. Sponsors would be responsible for pooling funds from participating IV&V users, which could include foreign as well as domestic ITS vendors and government agencies. Instead of a single state’s laboratory, alternative bases for developing the ITS IV&V capability could include a federal laboratory (for example, USDOT’s Turner–Fairbank Highway Research Center), a private–public partnership program such as the Civil Engineering Research Foundation’s Highway Innovative Technology Evaluation Center program, or a university-based transportation research center.

Test Suites and Test Environments

The committee proposed that USDOT encourage development of “test suites” for vendors and agencies to use in verifying interoperability of standardized communications protocols and message sets. Such suites

could be made widely available on CD-ROM or as “test environments” on the Internet. The agency or laboratory responsible for IV&V could develop and distribute these test suites or test environments.

Sample Specifications

The committee proposed that USDOT encourage development of well-formulated sample standard or “model” specifications as another very effective means for encouraging wide application of ITS standards, primarily for products such as signal controllers. The committee cautioned, however, that education and training of agency staff would be needed as well, because most agencies lack the technical expertise to use such specifications most productively.

Reference Implementations

A reference implementation is a prototypical complete system that is generally agreed to provide desired functionality and to meet desired standards. The capabilities of a new piece of equipment or software may be tested by demonstrating that it works within the context of the reference implementation. The committee proposed that such reference implementations could be another instrument for verifying conformance to ITS standards and interoperability—for example, an installation in the field—within a region’s traffic management system. The committee suggested, however, that setting up reference implementations within an independent testing facility may avoid giving a particular competitive advantage to one ITS vendor, as would be the case, for example, if a demonstration project were used.

INCENTIVES TO EARLY ADOPTERS

Another obstacle to effective standards deployment is related to the special risks faced by early adopters of new technology. Early attempts to apply new standards in practice almost always encounter unanticipated difficulties. The committee heard anecdotal evidence that early adopters of ITS infrastructure technology have incurred higher costs than expected because untried equipment or software incorporating untested standards

initially failed to perform as expected. Such costs may discourage others from participating in prototyping and demonstration of new ITS infrastructure. The committee noted that more explicit incentives may be needed to encourage early adopters to demonstrate ITS applications incorporating federally supported standards.

The justification for compensating early adopters for higher costs they incur is the role they play in working out unexpected problems and then demonstrating the benefits of new technology conforming to federally sponsored standards. The excess costs return benefits when subsequent users avoid the need to repeatedly adjust or even replace systems designed to meet poorly formulated standards. These benefits—avoided costs—accrue to USDOT and the nation as a whole. The committee therefore recommended that compensating early adopters for the higher costs they incur is an appropriate use of federal funds, provided that such compensation is distributed in a limited and replicable manner.

Summary of Letter Report 3, Lessons from Dedicated Short-Range Communications

The committee held its fourth meeting of the Phase 2 study in June 2002. The meeting was postponed because of the September 11, 2001, terrorist attacks on the Pentagon and New York's World Trade Center. While the discussions ranged broadly over the general issues of development and deployment of standards for intelligent transportation systems (ITS), the principal applications area considered was standards for dedicated short-range communications (DSRC). A letter report was delivered to the U.S. Department of Transportation (USDOT) in September 2002.

Discussion at the meeting focused on current efforts to develop standards for DSRC in the 5.9-GHz frequency band. Because the potential applications of DSRC are so broad, DSRC standards potentially will shape the activities—and markets—of a wide range of industries. Committee members and other meeting participants observed that earlier efforts to develop a DSRC standard in the 915-MHz band are widely judged to have been unsuccessful. The failure is attributed largely to participants' inability to resolve conflicts among the interests of companies already involved in providing products and services using that band.

The current standards development effort focused on the 5.9-GHz band, which is being facilitated by the Joint Program Office (JPO), is characterized by many participants as an emerging success story, although the committee noted that its success ultimately will be determined by the standard's effective deployment. In the absence of entrenched commercial interests of equipment vendors and with better definition of the requirements to be met by the standard, participants have reached key agreements. The committee was told but did not seek to confirm that industry consortia are prepared to begin manufacturing chipsets and hardware conforming to the DSRC standard and that several vehicle

manufacturers have expressed strong interest in applying the DSRC 5.9-GHz technology.

A potential concern with DSRC applications is the absence of enabling infrastructure, such as roadside antennas. The committee was told that the market for DSRC could be very large, but clearly defined business models—and the key applications likely to drive consumer adoption of DSRC technology—have not yet emerged.

USDOT staff members suggested to the committee that public safety applications might justify public investment in the development of necessary roadside infrastructure. In discussing the point, committee members suggested that building on existing toll collection systems might be an effective means of encouraging both deployment of DSRC technology and incremental development of DSRC infrastructure. The committee noted that, despite the failure to gain widespread acceptance of a comprehensive DSRC standard for ITS, the more narrowly targeted 915-MHz toll tag technology has now been deployed successfully to more than 10 million users. The committee suggested that this limited success within a broader failure offers both lessons and opportunities.

MARKET OPPORTUNITY—NEED FOR A PLAN

Despite conflicts within the earlier standards development process, electronic toll collection is now an established market and has yielded significant public benefits. That market and its institutional framework could represent an opportunity for more rapid deployment of other DSRC technology. Toll tags have been in use for approximately 6 years; batteries in the oldest tags are approaching the end of their 7-year expected service life. The need to replace these tags offers an opportunity to introduce a DSRC in-vehicle box that might then be used for other applications. The committee heard credible estimates that the price for this new box might initially be as high as \$100 but could drop to perhaps \$25 in 4 to 5 years as technology evolves and the market expands. These prices are higher than those for existing toll tags but do not appear to be unreasonable for user acceptance. The incremental infrastructure costs of adding 5.9 GHz to existing toll collection installations is estimated to be small.

Committee members agreed that a marketing plan is needed for DSRC, a plan of action for encouraging deployment of DSRC technology, and that sponsoring preparation of such a plan would be an appropriate component of USDOT's standards development program. The public benefits of DSRC, which increase linearly with the miles of DSRC-equipped roadway but exponentially with the number of equipped vehicles, will depend on the proportion of the vehicle fleet equipped with DSRC capabilities. Thus activities to encourage rapid adoption of in-vehicle DSRC capability arguably merit inclusion in USDOT's ITS Standards Program.

DEMONSTRATION REQUIRED FOR SUCCESSFUL DEPLOYMENT

The committee observed that the standards program must in general resolve a tension between the desire to expedite the delivery of new standards and the need to demonstrate successful applications of those standards to ensure they can be used in practical ITS installations, as illustrated by such promising examples—terming them “successes” may be premature—as industry's adoption of National Transportation Communications for ITS Protocol object definitions for dynamic message signs. If the standard for DSRC at 5.9 GHz is emerging as another potential success, demonstration of its use will be essential to realizing that potential.

The committee noted that since the initial release of the National ITS Architecture was completed in mid-1996, JPO's activities have supported work to develop and encourage the use of more than 80 distinct standards. Some of these standards are more crucial than others to realizing the goals of the National ITS Architecture, but all of them require demonstration as well as development for successful deployment. Encouraging widespread use of standards that have not been demonstrated in successful field applications diverts resources from the activities needed to make other standards successful. Given the inevitably limited resources available to the standards program, the committee recommended that JPO focus its efforts on encouraging use primarily of a smaller group of standards important to rapid deployment of sufficiently

mature ITS technologies. While the committee members did not have the resources and time themselves to specify which standards should be included in this smaller group, the committee recommended that each selected standard include a well-articulated concept of operations and clearly stated requirements that are met by the standard, reflecting that concept of operations. The committee recommended further that JPO fund training and outreach efforts only for those standards that have been applied successfully in pilot or demonstration installations.

Taking this approach could make resources available for increased support of such activities as field testing and maintenance of standards. The committee reiterated its recommendation from previous reports that federally funded support be provided for maintenance of deployed ITS standards to ensure that the standards do not become prematurely obsolete as ITS technology and other federal programs evolve.

Summary of Letter Report 4, Intelligent Transportation Systems Data Registry

The committee discussed the Joint Program Office's (JPO's) activities supporting development of an Intelligent Transportation Systems Data Registry (ITS DR) during its September 2002 meeting. The ITS DR is not a standard, strictly speaking, although the committee noted that an effective data registry would serve as a form of meta-standard, encouraging interoperability among data sets to which various standards refer. The committee's discussions and recommendations were presented in Letter Report 4, delivered to the U.S. Department of Transportation (USDOT) in June 2003.

ITS DR CONCEPT

The ITS DR is being developed as an online database containing the data concepts defined and used in ITS standards that have been developed with USDOT support. Several types of data concepts are included in the ITS DR: data elements defined in data dictionaries, messages defined in message sets, and other data describing the values or ranges of values that data elements and messages may take. The ITS DR is made available to users through a website and associated software that allow these users to add, modify, review, and query data concepts in the database. The registry is governed and operated by a complex organization that includes representation from all the standards development organizations (SDOs) participating in the USDOT ITS standards development program.

The stated objectives of the ITS DR are to promote (a) *uniformity* of ITS data concepts from one standard to another; (b) *reuse* of previously developed data concepts when new standards are developed; (c) *harmonization* or resolution of differences among standards, in terms of how

they define data concepts; and (d) *convenient access* to all the data concepts defined in the many ITS standards. The ITS DR was conceived to serve two distinct audiences: *ITS standards developers*, who would draw on existing data concepts as they undertake to craft new standards, and *ITS standards users*, such as applications developers, system integrators, and buyers of ITS technology, who would find in the DR a convenient single source of information where standards address data concepts relevant to an ITS application under consideration. According to the white paper, the ITS DR is a fundamental tool for promoting and attaining USDOT's goal of interoperability among ITS systems.

CURRENT STATUS

Since the ITS DR was initiated in 1998, progress has been very slow. According to the white paper, more than 2,600 data concepts have been listed in the repository that is the first stage of entry into the ITS DR. Of these, 127 have been identified as requiring harmonization, for example, because their definitions differ in multiple standards. Only 49 of this smaller group are reported to have been substantially harmonized, and none has yet received all review and approvals to achieve "preferred" status, indicating that the data concept has been harmonized, is included in an SDO-approved standard, and is recommended for use in ITS application. The white paper notes that some critics claim the ITS DR management team has adopted rigid rules, conventions, and processes that unnecessarily impede the DR's progress; regardless of the validity of such claims, harmonization is necessarily laborious and time-consuming because it requires compromise among groups that have already invested substantial effort in building a consensus with regard to conflicting concepts.

The white paper asserts that the ITS DR website and associated software are operational but reports that users have found it cumbersome and slow for entry of information about data concepts, and lacking in key features that would encourage its use by the target audience. In view of the experience to date, the white paper's authors suggest that the primary benefit of the ITS DR to USDOT lies in its use as a technical standards development tool, despite the broader audience initially conceived for it.

By mid-2002, USDOT staff members were expressing concern that continued development and maintenance of the ITS DR, in its current form, would represent a substantial cost for the standards program, and that the benefits to be gained may not be proportionate to these costs. The white paper presented three options for streamlining the future management of the ITS DR's development and maintenance: (a) to carry on with the program essentially unchanged, (b) to reduce USDOT's involvement by supporting only those elements of the ITS DR that are needed for ITS standards development, and (c) to discontinue all federal support for the ITS DR, with a likely consequence that the DR would cease to function. The white paper's authors had suggested several variations on the second option, operating for the most part within the context of the current ITS DR management structure. The white paper and its options for the ITS DR's future formed the basis for USDOT's request that the committee discuss the topic.

Representatives of SDOs have expressed concern that the scope of the ITS DR development effort has grown since it was started and agreed that the effort is unlikely to continue in the absence of federal support. They had suggested that some effort is warranted to estimate the potential value of having a fully developed ITS DR. State departments of transportation, for example, could realize very substantial cost savings in using ITS standards if data frameworks encoded in the standards could be simply downloaded from an ITS DR when ITS applications are being developed. They had suggested further that the ITS DR might serve as a basis for harmonizing all government transportation information technology—for example, including data concepts from facility design and management and system planning as well as ITS. A single transportation ITS DR could then be useful in many areas of public-sector transportation management, not simply in the development of ITS technologies.

COMMITTEE OBSERVATIONS

Considering the various objectives and potential benefits of an ITS DR, the committee concluded that the principal benefit of the ITS DR lies in the concept of harmonizing data elements by resolving inconsistencies and conflicts among alternative views of how data should be structured

in ITS applications. Eliminating this concept would substantially diminish whatever value the ITS DR may have and the rationale for continued federal investment in ITS DR development.

The committee recognized that the process being used to achieve harmonization entailed comparisons among standards that have reached advanced stages of development. At these advanced stages, SDOs and the individuals who have participated in developing the standards have made substantial commitments of time and energy to defining data concepts contained in their standards and to the process of circulating those concepts for review and approval. They are understandably reluctant to consider changes that would extend the time and complicate the processes of achieving consensus within their own organizations. The committee recommended that the difficulties and delays of harmonization could be reduced if efforts to achieve harmonization begin earlier in the standards development process. For example, data concepts could be disseminated to all SDOs for comments, from the earliest stages of their development, and reviewed by a central group (as is the case in the ITS DR as currently configured) to identify and seek resolution of conflicts among overlapping concepts. A functional ITS DR could be used in this manner. The committee recommended that facilitating ITS data harmonization warrants JPO support.

The committee agreed that the ITS DR, with effective data harmonization, is potentially a valuable tool that can support ITS deployment as well as ITS standards development. Many committee members saw great merit in the concept of a data registry encompassing, initially, all ITS standards, without regard to whether their development has been supported by USDOT funds, and ultimately data concepts used in other areas of transportation system planning and management. The committee urged that this broader view of the potential benefits of the ITS DR be considered in making decisions about the DR's future support.

The committee also agreed, however, that inadequate software and user interfaces can be a serious impediment to realizing the potential value of the ITS DR. The committee observed that if the ITS DR is to achieve its full potential value, improvements must be made to facilitate its use. USDOT staff reported that the number of users registered at the ITS DR website remained low. The committee observed, however, that

investment in the ITS DR can yield high returns with only a few users, if the ITS DR enables those users to develop new standards with reduced effort or to realize economies by purchasing ITS technology that incorporates proven data concepts. The committee agreed that revision of the website and application software to simplify data input and access is warranted if the ITS DR is to continue as an element of the ITS Standards Program.

USDOT officials must make difficult decisions in allocating funds among the various elements of JPO's standards program. While the committee agreed that the white paper failed to make a compelling case for exclusive reliance on federal support for the continuing development of the ITS DR in its current form, the committee was persuaded that the potential benefits of having a harmonized body of data concepts, accessible through an effective and broadly usable data registry, as outlined in the committee's discussions, may justify continuing federal involvement in ITS DR development and deployment.

Criteria for Evaluating Effectiveness of Federal Support for Intelligent Transportation System Infrastructure Standards

The committee proposed three primary criteria—goal consistency, role consistency, and efficiency—for evaluating the likely effectiveness of federal support for development and deployment of intelligent transportation system (ITS) infrastructure standards.

- *Goal consistency* refers to a standard's contribution to implementation of specific services within the framework of the National ITS Architecture, in principle the target of federal ITS Standards Program goals.
- *Role consistency* refers to the appropriateness of federal support for a standard's development and deployment, with the recognition that support implies substantial public benefit and likelihood that an effective standard will not be forthcoming without federal support.
- *Efficiency* refers to the balance among costs of a standard's development and deployment and potential benefits of having, or losses from not having, effective standards in place when ITS technology is implemented.

Box F-1 describes these three criteria in greater detail. The committee used these criteria implicitly, without attempting to prepare detailed ratings for the various standards or groups of standards in the U.S. Department of Transportation's program.

Criteria for Evaluating Likely Effectiveness of Federal Support for Adoption and Application of ITS Infrastructure Standards

- A. *Goal consistency*—the proposed standards appear likely to enhance achievement of fundamental federal program goals.
 - Standards are intended to encourage intersystem interoperability (e.g., regions exchanging information, vehicles moving between regions) or intra-system interchangeability (e.g., replacement of components with products from other suppliers); and
 - Standards will facilitate ITS specifications by government agencies or multiagency regions.
- B. *Role consistency*—encouraging the standards' adoption and application is consistent with the traditional federal role in developing and managing the nation's transportation system.
 - Benefits of the standards' effective adoption and application will accrue primarily to the public at large (e.g., road users and road neighbors generally); or
 - Both suppliers and purchasers of ITS and components will benefit from the standards' effective adoption and application (e.g., through expanded markets), but mechanisms are lacking to bring them together on common standards; or
 - Purchasers (e.g., agencies) will be the primary beneficiaries and, acting together, have the power to influence supplier design and development decisions.
- C. *Efficiency*—the net public benefits of achieving standards' adoption and application are likely to exceed the net costs of federal actions that would be instrumental in achieving adoption.
 - Benefits of these standards' effectiveness will be great and are likely to be achieved only with federal encouragement; or
 - Costs of failure of these standards to achieve widespread acceptance will be great, and federal action is likely to encourage adoption and application.

APPENDIX G

User Services and User Services Bundles in the National Intelligent Transportation System Architecture, Version 4.0

User Services Bundle	User Services
1 Travel and Traffic Management	1.1 Pretrip Travel Information 1.2 En Route Driver Information 1.3 Route Guidance 1.4 Ride Matching and Reservation 1.5 Traveler Services Information 1.6 Traffic Control 1.7 Incident Management 1.8 Travel Demand Management 1.9 Emissions Testing and Mitigation 1.10 Highway Rail Intersection
2 Public Transportation Management	2.1 Public Transportation Management 2.2 En Route Transit Information 2.3 Personalized Public Transit 2.4 Public Travel Security
3 Electronic Payment	3.1 Electronic Payment Services
4 Commercial Vehicle Operations	4.1 Commercial Vehicle Electronic Clearance 4.2 Automated Roadside Safety Inspection 4.3 Onboard Safety Monitoring 4.4 Commercial Vehicle Administrative Processes 4.5 Hazardous Material Incident Response 4.6 Commercial Fleet Management
5 Emergency Management	5.1 Emergency Notification and Personal Security 5.2 Emergency Vehicle Management
6 Advanced Vehicle Safety Systems	6.1 Longitudinal Collision Avoidance 6.2 Lateral Collision Avoidance

(continued on next page)

User Services Bundle	User Services
	6.3 Intersection Collision Avoidance
	6.4 Vision Enhancement for Crash Avoidance
	6.5 Safety Readiness
	6.6 Precrash Restraint Deployment
	6.7 Automated Vehicle Operation
7 Information Management	7.1 Archived Data Function
8 Maintenance and Construction Management	8.1 Maintenance and Construction Operations

SOURCE: itsarch.iteris.com/itsarch/html/user/userserv.htm.

Study Committee

Biographical Information

Jonathan L. Gifford, *Chair, 2002–2003*, is Associate Professor and Director of the Master’s in Transportation Policy, Operations, and Logistics in the School of Public Policy at George Mason University. Dr. Gifford has conducted research and written extensively on institutional and economic issues in intelligent transportation systems (ITS). He received a B.S. in civil engineering at Carnegie Mellon University and received his master’s and Ph.D. from the University of California, Berkeley.

A. Ray Chamberlain, *Chair, 2000–2002*, is a Vice President with Parsons Brinckerhoff. He was formerly Vice President, Freight Policy, and Acting Managing Director of the American Trucking Associations Foundation, Chief Executive Officer of the Colorado Department of Transportation, and President of Colorado State University. Dr. Chamberlain received a B.S. in engineering from Michigan State University, an M.S. in engineering from Washington State University, and a Ph.D. in engineering from Colorado State University.

Jules A. Bellisio is the Principal of his own consulting practice, Telemediators, LLC. Previously, he was Chief Scientist and Executive Director at Telcordia Technologies, where he remains a Telcordia Fellow. Dr. Bellisio and staff have made key contributions to broadband telecommunications standardization, video compression, and high-definition television. Currently, he consults on the system and physical layer aspects of digital communications and related emerging technologies. A Fellow of the Institute of Electrical and Electronics Engineers, he received a B.S.E.E. degree from the Polytechnic Institute of Brooklyn, an S.M.E.E. from the Massachusetts Institute of Technology, and a Ph.D. from Yale University.

Irwin Dorros is a telecommunications consultant and former Executive Vice President and Chief Technical Officer with Bell Communications Research (now known as Telcordia Technologies). His expertise includes national and international standards, large systems architecture, and systems engineering and design. Dr. Dorros is a member of the National Academy of Engineering. He received B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology and a Doctor of Engineering Science in electrical engineering from Columbia University.

William F. Johnson is an independent consultant and formerly Executive Director, Research and Development, with the Transportation Development Centre, Transport Canada, and a member of the adjunct faculty of Carleton University. He was previously a Principal Research Officer, Computing, with the Intelligence Unit, Greater London Council. His recent responsibilities have included chairing a committee reviewing Canada's ITS standards development. Dr. Johnson is a Director and former Secretary-Treasurer of the Intelligent Transportation Systems Society of Canada. He earned a B.A.Sc. from the University of Toronto and an S.M. and Sc.D. from the Massachusetts Institute of Technology.

Samuel Krislov is Professor of Political Science and Law, University of Minnesota, Twin Cities, and the author of *How Nations Choose Product Standards and Standards Shape Nations* (University of Pittsburgh Press, 1997). Dr. Krislov has served on several National Research Council study committees and was chair (1975–1980) of the Committee on Law Enforcement and Criminal Justice. He is the recipient of a Lifetime Achievement Award, Law and Courts Section, American Political Science Association. Dr. Krislov earned a B.A. and an M.A. from New York University and a Ph.D. from Princeton University.

Alexander Lopez, a specialist in the design and development of advanced traffic signal systems, is a Senior Project Manager for the Metropolitan Transit Authority of Harris County (Texas), Police and Traffic Management Department, Traffic Management Division. He is responsible for the development and management of signalization and communication projects for a regional computerized traffic signal system. He was formerly on the staff of the City of Houston Public Works Department,

Traffic Management and Maintenance Division. Mr. Lopez was an Industry Fellow with ITS America and represented the Institute of Transportation Engineers on the National Transportation Communications for ITS Protocol Joint Committee as a Transit Representative. He holds a B.A. in political science from the University of Houston, University Park.

James R. Robinson is Assistant Director, Mobility Management Division, for the Virginia Department of Transportation (VDOT). In that position, he is responsible for statewide ITS programs and traffic control device standards and specifications. Before joining VDOT, he was employed by the Federal Highway Administration, serving in state and regional offices as well as the Washington, D.C., headquarters office. Mr. Robinson is a graduate of the University of Oklahoma.

Steven E. Shladover conducts research on advanced vehicle control and safety systems and system-level automation at the California Partners for Advanced Transit and Highways Program at the University of California, Berkeley, a major university research program in ITS, where he has served as Deputy Director and AVCS Program Manager. Formerly he was Manager, Transportation Systems Engineering, with Systems Control Technology, Inc. He is active in international standards development, serving as United States Expert and Chairman of the U.S. Working Advisory Group to the International Organization for Standardization's Technical Committee on Transport Information and Control Systems Working Group 14 on Vehicle/Roadway Warning and Control Systems. He was Chairman of the AVCS Committee of IVHS America/ITS America. Dr. Shladover received his S.B., S.M., and Sc.D. in mechanical engineering from the Massachusetts Institute of Technology.

William M. Spreitzer is an advisor on automotive research. He retired as Technical Director of General Motors' ITS Program. He is past Chair of the ITS America Coordinating Council, Chair of the Society of Automotive Engineers Technical Standards Board ITS Division, and Chair of the International Organization for Standardization Technical Committee 204, Transport Information and Control Systems. Mr. Spreitzer received a B.Ae.E. and a P.Ae.E. (honorary) in aeronautical engineering from the University of Detroit.

Scott E. Stewart is a Managing Director of IBI Group, where he is responsible for the firm's transportation/systems practice worldwide. He has directed the design, implementation, and operation of a large number of ITS projects. He is also a Director of ITS Canada. Before joining IBI Group, Mr. Stewart worked in government, including local, regional, and national agencies. He earned a B.Sc. degree in civil engineering at the University of Waterloo.

Philip J. Tarnoff is Director, Transportation Studies Center, University of Maryland. He is founder and formerly President of Farradyne Systems, Inc. (subsequently renamed PB Farradyne, a subsidiary of Parsons Brinckerhoff), one of the largest ITS consulting and systems integration firms in the United States. He was also a Research Engineer with the Federal Highway Administration. He participated in the formation and activities of Mobility 2000 that led to the creation of ITS America and in the development of the organization's strategic and tactical plans. Mr. Tarnoff is currently active in ITS America's Coordinating Council, the Strategic Planning Subcommittee, and the ITS Futures Group. He earned his B.S. in electrical engineering at the Carnegie Institute of Technology and his M.S. in electrical engineering at New York University.

James L. Wright is currently an on-loan executive from the Minnesota Department of Transportation to the American Association of State Highway and Transportation Officials (AASHTO). In this role he is supporting and leading ITS issues of national significance, such as the 511 Program. Before this duty he served as Minnesota's Director of ITS programs. As Minnesota's ITS Director he was responsible for delivering \$100 million in ITS research, development, and deployment. He serves as chair of the AASHTO/Institute of Transportation Engineers Traffic Management Data Dictionary Committee, vice chair of the ITS America Coordinating Council, chair of the 511 National Deployment Working Committee, and English-speaking secretary for the C16 Committee "Network Operations" of the Permanent International Association of Road Congresses—World Road Association. Mr. Wright received a B.S.C.E. from the University of Minnesota and an M.E. from the University of California at Berkeley.

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