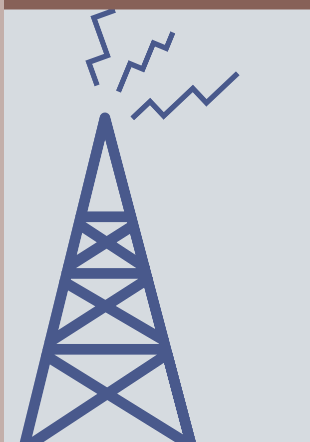
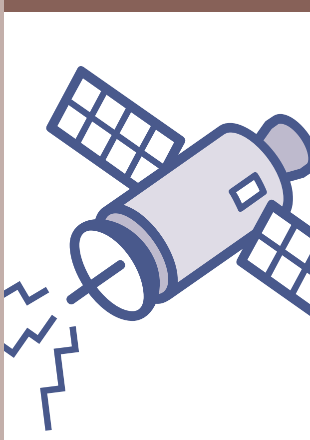
chapter 7





WHAT HAVE WE LEARNED ABOUT CROSS-CUTTING TECHNICAL AND PROGRAMMATIC ISSUES?

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EXECUTIVE SUMMARY

Introduction

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

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

Findings

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

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

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

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

Analysis Tools: Current transportation planning tools and techniques do not address the impacts of traffic operations management, including ITS impacts. To evaluate such approaches, the variance of factors such as travel demand, incidents, and weather must be considered. New tools and techniques, such as IDAS (ITS Deployment Analysis System), PRUEVIIN (Process for Regional Understanding and EValuation of Integrated ITS Networks), and TRANSIMS (TRansportation ANalysis SIMulation System) have been or are being developed to address these shortcomings.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Recommendations

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

Traffic Sensing (Surveillance)

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

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

Standards Development and Deployment

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

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

Evaluation Voids

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

Tracking New Technologies

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

INTRODUCTION

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

Scope

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

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

SENSORS AND SURVEILLANCE

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

Successes

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

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

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

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

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

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

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

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

The Jury is Still Out

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

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

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

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

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

Unsuccessful Approaches

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

COMMUNICATIONS

Successes

The Internet

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

Dedicated Short-Range Communications

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

Fiber Optics for Wireline Communications

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

Digital Subscriber Line technologies

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

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

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

The Jury is Still Out

High Speed FM Subcarrier Systems for ITS

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

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

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

Unsuccessful Approaches

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

220 MHz Radio Channels

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

CDPD for Two-Way Traveler Information Services

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

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

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

Emerging Communications Media

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

Wireless Internet

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

Local Area Wireless

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

DSRC at 5.9 GHz

The FCC recently approved radio spectrum in the 5.9 GHz band for ITS DSRC applications, consistent with a worldwide trend to move DSRC applications to higher frequencies in the 5.8-5.9 GHz bands. In the United States, increasing use of the 902-928 MHz industrial, scientific, and medical band has raised concerns that the band will be too crowded and noisy to support a growing range of potential DSRC applications, including toll collection, drive-through purchasing, and intersection collision avoidance systems. Discussions are under way to determine how to allocate spectrum in the 5.9 GHz band and to address the need for standards. Various new local area wireless standards (e.g., IEEE 802.11 and Bluetooth) are being examined to see if they or a portion of them may provide the basis for standardization. At the same time, these new local area wireless standards may end up being used for many potential new DSRC applications. Using these alternative approaches instead of DSRC technology will mitigate the need to migrate to the 5.9 GHz band.

Low-Power FM Licenses

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

High-Speed Fixed Wireless

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

The Internet

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

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

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

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

- XML-based traveler information: the Society of Automotive Engineers Advanced Traveler Information Systems Committee has recently begun work on an XML-based version of their traveler information message set standard. At least one state is using XML on the server side to prepare Web pages and is publishing the XML-based information as well, for reprocessing by others.
- Location referencing: the Open Geographic Information Systems (GIS) Committee is developing an XML-based standard for Web-based exchange of geographic information. ITS mapping standards committees are investigating XML.
- Archived Data User Service (ADUS): to the extent that XML is used by systems providing archived data, it will impact this new area of ITS. In addition, XML may provide the basis for exchange of some ADUS information.
- Electronic payment systems: the open financial exchange protocol used by home banking software and by the banks and investment companies they link to is being updated to be XML-compliant. New financial exchange standards with broader applicability are also being developed using XML, which may affect future ITS electronic payment applications.

ANALYSIS TOOLS

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

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

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

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

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

ARCHIVED DATA

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

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

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

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

ARCHITECTURE

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

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

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

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

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

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

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

STANDARDS

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

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

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

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

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

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

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

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

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

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

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

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

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

ADDITIONAL FUTURE DEVELOPMENTS

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

- Continued integration of services and components. There will be increased integration of various ITS user services within a locality, as well as increased integration across local jurisdictional boundaries. In many areas, this event will be a loose integration based on information exchange, but in some areas, transportation needs will drive tighter integration, despite current institutional barriers.
- Continued migration of analytical and simulation tools that integrate ITS and operational analyses into the transportation planning process.
- Reduced need for differential GPS or supplemental position determination methods, stemming from removal of the intentional "selective availability" degradation in GPS accuracy. Elimination of selective availability in May 2000 increased the accuracy of basic GPS data from about 100 meters to between 10 and 20 meters.
- Continued impact of new information technologies. A current example is the emergence of extensible markup language for automated Web-based information exchange. This innovation will bring both opportunities and challenges. Newer, cheaper, and simpler tools will enhance the ability of both the public and private sectors to bring services to citizens and customers. At the same time, the rapid evolution of technology and related standards will continue to make implementation decisions difficult. This circumstance will be true, regardless of whether the technology is purchased or the service leased from a service provider.
- Lower cost and new methods for evaluating ITS. Archiving of ITS data will lower the costs of evaluation and performance monitoring and, perhaps more importantly, will provide new methods and metrics for assessing and evaluating the effectiveness of transportation operations.

- Development of national traveler information systems. Multiple private, state/regional, and national projects will promote necessary data and message standards and database developments, leading to interstate and national level traveler information systems.
- Expanded use of weather information systems. Increased focus on rural needs will expand research, testing, and deployment of improved road weather information systems. Sensing and warning networks will expand, and new tools for integrating and fusing information to aid decision-makers will be developed.
- Increasing statewide integration for areas outside of major metropolitan areas. This integration may include statewide public safety answering points and statewide traffic and emergency management coordination.
- Increased efficiency of transit and paratransit services for health and human services. This increase will result from greater coordination and expanded brokerage services between agencies.
- More widespread vehicle-based safety systems, such as collision warning systems.

RECOMMENDATIONS FOR NEXT STEPS

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

Traffic Sensing (Surveillance)

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

Standards Development and Deployment

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

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

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

Evaluation Voids

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

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

Tracking New Technologies

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

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