U.S. Department of Transportation
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Key Findings from the Intelligent Transportation Systems (ITS) Program

What Have We Learned?

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Key Findings From The Intelligent Transportation Systems (ITS) Program: What Have We Learned?

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Executive Summary

Intelligent Transportation Systems (ITS) apply advanced and emerging technologies in such fields as information processing, communications, control, and electronics to surface transportation needs. ITS encompasses a number of diverse program areas including Advanced Traffic Management Systems, Advanced Traveler Information Systems, Commercial Vehicle Operations, Advanced Crash Avoidance Systems, Automated Highway System, Advanced Public Transportation Systems, and Advanced Rural Transportation Systems. Since ITS is primarily a research program, key findings obtained are considered a valid basis for reporting on what has been achieved. Accordingly, this paper provides answers to the question "What Have We Learned?" on the ITS program. Some of the key findings in the various program areas are summarized below. Additional findings may be found in the body of this paper.

Research in Advanced Traffic Management Systems has led to development of improved surveillance systems, network modeling tools, and incident detection and traffic signal control algorithms.

The use of in-vehicle route guidance displays for Advanced Traveler Information Systems has proven to be technically viable and has met with public acceptance. If properly designed, these systems do not degrade safety when used under operational conditions.

There are no showstoppers for achieving Commercial Vehicle Operations program goals. Weigh-in-motion, automatic vehicle identification, electronic data interchange, and wireless communications technology have proven to meet program needs. By learning to integrate these technologies, the electronic purchase of credentials, automated clearances, and the screening for safety of vehicles, drivers, and carriers have become feasible. They all provide productivity benefits to fleets and states.

Research in Advanced Collision Avoidance Systems has resulted in a preliminary understanding of the performance features needed for effective collision avoidance systems. These are based on a thorough analysis that was carried out on collisions and the events that lead up to them.

A series of precursor analyses have given insight into design alternatives for an Automated Highway System, as well as the throughput and safety benefits that would be realized from its implementation.

Electronic fare payment and automatic vehicle location technologies have demonstrated benefits for Advanced Public Transportation Systems.

For Advanced Rural Transportation Systems, requirements have been developed that take into account important findings on the characteristics of the rural infrastructure, road network, and traffic distribution. Mayday systems are a top priority for the rural environment.

Techniques have been developed that successfully exploit a number of emerging technologies. Recent advances in GPS, sensors, personal computing, high speed digital wireless broadcasts, and the information super highway have been incorporated across many parts of the ITS program.

The development of a national architecture has identified important synergies across the program. This promotes the integration of common elements for multiple purposes, such as the use of electronic tags for toll collection and measuring traffic flow. Functional requirements, communications categories, and standards requirements have been identified. The architecture has led to an understanding of standards that are needed for national compatibility and will serve as key enablers for the rest of the program.

Mainstreaming of the ITS program requires that it be integrated into the larger planning process. A number of outreach and education initiatives have been undertaken to achieve this.

The primary cross-cutting finding is that institutional issues, and not technical obstacles, serve as the main barrier to implementing ITS. Other important findings include the importance of integrating systems, and the achievement of early successes throughout the ITS program by using iterative development techniques.

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Introduction

Background on the ITS Program

Congress established the Intelligent Transportation Systems (ITS) program with the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). "ITS applies advanced and emerging technologies in such fields as information processing, communications, control, and electronics to surface transportation needs. If these technologies are effectively integrated and deployed, there could be a number of benefits including more efficient use of our infrastructure and energy resources, and significant improvements in safety, mobility, accessibility, and productivity." [1]

Note the final *s* in "Intelligent Transportation System**s**". ITS is not a monolithic system that will be built. It is not even a system of systems. Instead, ITS is a multi-faceted approach for addressing transportation needs. Some of these approaches are already commercially viable and are here today. Others represent long-term research. Some ITS systems will be implemented by the private sector, others by the public sector. But most will be implemented by the public and private sectors working together in partnerships to achieve their respective aims. The areas that ITS encompasses are described in the following paragraphs [2 and 3]:

Advanced Traffic Management Systems (ATMS) are the foundation for the other areas of ITS. ATMS provides the surveillance that gathers information needed by the other areas. Loop detectors and advanced techniques such as video surveillance are used. ATMS processes this information to determine traffic flow, measure congestion, and detect incidents. It also provides such control functions as adjusting signal timing. Many jurisdictions have begun implementing Traffic Management Centers to carry out ATMS functions.

Advanced Traveler Information Systems (ATIS) disseminate information to the traveling public over a variety of distribution channels. Among these are cable TV, digital broadcasts, the Internet, kiosks, and personal hand-held devices. ATIS can assist in pre-trip planning as well as in providing guidance while the traveler is en route. Multi-modalism between the personal automobile and transit is a constant theme of ATIS.

Commercial Vehicle Operations (CVO) improve motor carrier safety and productivity. The use of technology for improved and targeted inspections addresses the safety goal. To enhance productivity, mitigation of the regulatory burden is accomplished by reducing paperwork through electronic transactions, weigh-in-motion, and automatic vehicle identification technologies. State and international boundary crossings are a particular focus area for this. For CVO to be successful, information links must be established among various entities including regulatory agencies, dispatch centers, roadside facilities, and in-vehicle devices.

Advanced Vehicle Control and Safety Systems (AVCSS) encompass two areas. The first of these is the **Advanced Collision Avoidance Systems (ACAS)** area, which focuses on crash *avoidance*. This is in contrast to traditional vehicle safety systems (seat belts, air bags, etc.), which mitigate the harmful effects of accidents that occur. Collision avoidance systems facilitate safety by enhancing driver performance. Reducing the number of crashes results in fewer injuries and fatalities, and in lower societal costs. Roadside and in-vehicle devices are used to facilitate safety, with initial systems self-contained within the vehicle. Depending on the system, they can give drivers better awareness of their surrounding (e.g., blind spot situation displays), warn the driver of hazardous situations, or eventually even compensate for driver errors.

The culmination of AVCSS technology would result in the **Automated Highway System (AHS)**. Such a system would involve "hands off" driving, and could result in both safety and capacity improvements. A National AHS Consortium has been established to demonstrate and coordinate long-term research in this area.

Advanced Public Transportation Systems (APTS) apply ITS technology to the needs of public transit. This includes fixed route systems as well as route deviation and demand-responsive modes. Systems include bus, rail (heavy, light, and commuter), vans, carpools, and shared-ride taxis. Some APTS systems are directly visible to the traveling public (e.g., transit information systems), while others are associated with transportation management (e.g, scheduling systems).

Much of ITS was developed to address urban needs. Nonetheless, many ITS technologies have found application in the wide range of rural environments. **Advanced Rural Transportation Systems (ARTS)** are a collection of ITS technologies (ATMS, ATIS, etc.) applied to the rural environment. The diverse rural environments have distinct needs from urban environments and even from each other. As a result, the reasons for, and the nature of, rural ITS applications often differ from those found in the urban areas.

Reporting Progress on ITS

How does one go about reporting progress achieved to date on the ITS program? To be sure, there are some notable deployment successes that could be cited. However, ITS is not a deployment program; there are no separate categorical grants to deploy a certain number of lane miles of ITS technology by a certain date. To measure the success of such a program by the number of deployments would be misleading and unfair.

Rather than focusing on deployment, ITS has concentrated on such areas as research, operational tests, evaluation, architecture development, and technology assessment. Findings obtained from these initiatives during the formative stages of the program help form the basis for deployment in the years ahead. We should, accordingly, focus on the *findings*. The answers to the question "What Have We Learned?" provide a more valid basis for ascertaining what has been achieved.

Scope of this Paper

This paper provides answers to the question "What Have We Learned?" from the various operational tests, R&D projects, and outreach activities that have been carried out to date on the ITS program. The answers to this question are grouped into eleven subject areas. The first seven subject areas address specific portions of the ITS program: ATMS, ATIS, CVO, ACAS, AHS, APTS, and ARTS, which are described above. The remaining four areas are more global in scope: technologies, architecture and standards, mainstreaming, and cross-cutting findings.

The ITS community can be justifiably proud of the many key findings that have been obtained over the past five years. However, in bringing the findings together in a paper such as this, there is a danger that they will be misconstrued. A reader could misinterpret the many findings to mean "We've answered all the important questions. ITS is a closed book." To alleviate this possible misinterpretation, some of the findings are accompanied by research questions that remain. The intent is to put the findings in a larger context. The message is, "Yes, we've learned a lot. But there are also key questions that need further work." The major challenge of deploying ITS components in an integrated manner nationally in urban and rural areas still remains. This will require a concentrated focus by USDOT. Hopefully, progress over the next several years will answer many of these questions. Perhaps those answers will even serve as the basis for another paper on key findings several years from now.

Having addressed what this paper is about, it may also be worthwhile to state what it is *not*. This paper neither summarizes accomplishments, nor documents ITS benefits. For the former, the reader is referred to the many journal articles as well as reports to Congress. For the latter, FHWA publication *Assessment of ITS Benefits: Emerging Successes* is a good source of material.

How Information Was Obtained for This Paper

Most of the material presented here was obtained by interviewing USDOT and other experts responsible for various aspects of the ITS program. For their cognizant program areas, they were asked, "What have we learned? What key findings have been obtained, since the outset of the ITS program?" Their responses were assimilated and combined into the overall findings presented here. In several cases, responses from one or more individuals were combined into a single bullet item found in this paper. Because of the interpretative and somewhat subjective nature of this process, comments are not attributed to individuals. Published documents used to supplement the interview materials are cited when findings are directly extracted from them.

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[1] ITS America and USDOT, National ITS Program Plan, 1995. Volume I, page 2.

[2] ibid., Volume II.

[3] USDOT, *Intelligent Vehicle Highway Systems A Public/Private Partnership,* 1 October 1991.

Advanced Traffic Management Systems (ATMS)

A number of questions have been raised as to the most effective way to manage traffic, integrate functions within a traffic management center, and coordinate among centers in adjacent jurisdictions. Over the past several years, ATMS research, operational tests, and the implementation of traffic management centers in a number of jurisdictions have begun to provide some of the answers:

Traffic Flow Theory

- Basic R&D has led to a better understanding of traffic flow theory. For the first time, there is beginning to be an understanding of traffic behavior under "no control" situations (i.e., non-signalized intersections along freeways), an understanding of the relevant human factors, and a better quantification of fuel consumption and emissions. This basic R&D has also allowed a better understanding of how to forecast demand. Future work will focus on roundabouts (traffic circles) and sign controlled intersections (stop signs and yield signs) at the surface street level.

Surveillance

- Although there are recognized benefits of using advanced surveillance systems (e.g., video), many jurisdictions have not taken advantage of them. They still rely on basic loop detector systems. As part of the ATMS R&D program, methods and procedures have been developed that allow a better understanding of the traffic situation using these basic systems.
- Loop detector failures have been a continuing problem at a number of sites. Video appears to be a promising alternative, but its long-term failure rate remains to be determined. [1]

Network Modeling

- Modeling techniques have been developed to account for larger, complex traffic networks instead of point solutions. These new techniques have been put into the TRAF family of models and made available to practitioners by FHWA. Actual state users have experienced significant cost savings and decreased time-to-implement by using these models.

Incident Detection

- The state-of-the-art of incident detection for freeways has been advanced. Algorithms have been developed that reduce the false alarm rate while simultaneously decreasing the time to detect a valid incident. Work is still needed on surface street incident detection issues. These are addressed in a planned FHWA R&D study.

Traffic Control Strategies

- No single algorithm is robust enough to implement a traffic control strategy for an entire network. Instead, a flexible platform is needed that accommodates the different needs in various portions of the network. A remaining question is how to coordinate these algorithms at the network boundaries.

Open Traffic Management Center (TMC) Design

- Jurisdictions need the ability to have a multi-vendor environment so that products and components from different vendors can be integrated into a functional TMC. This also provides maintenance benefits: if a sensor or signal device from one vendor needs repair, a product from a different vendor can be substituted. This should lower overall inventory and maintenance costs while significantly reducing system down time.

Open Architecture Interfaces

- The FHWA Turner Fairbank Highway Research Center's Traffic Research Laboratory (TReL) has clearly demonstrated the need for open architecture interface standards, in particular the National Transportation Communications for ITS Protocol (NTCIP).

R&D Process

- Innovative approaches are needed for transitioning the expertise and products to the field so that ATMS advances can be incorporated into standard practice; traditional R&D products and processes do not suffice. The Professional Capacity Building initiative in FHWA's Office of Traffic Management and ITS Applications is intended to address the technology transfer issues.
- Given the sophistication of the ATMS products and technologies being developed by R&D, there is the need to engage in a comprehensive field testing process. This is to ensure the products have deployability potential, that they significantly improve the operation of the networks where they are deployed, and that they are a stepping stone in the continuing advancement of the state of the art.

Beacons for Surveillance

- Using toll tags for measuring traffic flow has been demonstrated to be both technically feasible and cost effective. In fact, Houston is successfully exploiting this technique.

Probe Vehicles

- As part of the ADVANCE project, equations have been developed that determine the number of probe vehicles needed to provide a suitable level of coverage on the road network.
- Modeling results show that if only 1% of the vehicles serve as probes in a corridor network, one-half of the maximum possible benefit of a fully detectorized system is achieved.

Cellular Surveillance

- The CAPITAL operational test demonstrated that cellular phone technology can be used to track a vehicle's position and speed. However, for measuring traffic flow, this technology requires a denser deployment of infrastructure than had been anticipated, which has significant cost implications.

Human Factors [2]

- Research with the ATMS Human Factors Research Simulator has identified some of the parameters in control room automation that interact with TMC operator performance. For instance, results indicate that using an automated Incident Detection and Location System (IDLS) results in higher operator performance than with manual detection. Also, when using an IDLS, operator performance is enhanced when the system provides short detection latencies and high hit rates.
- Human Factors Simulator research has demonstrated that for closed circuit TV cameras monitoring roadways for incidents, that cameras with preset views results in better operator performance than manually selected views.
- A comparative analysis of the design and operation of different kinds of advanced control centers (e.g., highway traffic, FAA, military) describes the critical input, data processing, and output functions that are identified with optimal control of roadway traffic. This analysis provided human factors lessons learned for operations such as early use of computer rapid prototyping packages to design display screens to minimize human factors interface issues and the importance of keeping the operator "in the loop" when using automated systems. [3]

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[1] Booz-Allen and Hamilton, Inc., *Field Operational Tests Lessons Learned,* prepared for FHWA, May 6, 1996.

[2] The material on human factors was supplied by HSR-30 staff at FHWA's Turner Fairbank Highway Research Center.

[3] Kelly, M.J., Gerth, J.M., and Whaley, C.J., Comparable Systems Analysis: Design and Operation of Advanced Control Centers, FHWA-RD-94-147, August 1995.

Advanced Traveler Information Systems (ATIS)

At the outset of the ITS program, in-vehicle and other ATIS devices were promising but unproven technologies. There were questions as to whether a useful user-friendly system could be designed that would meet with acceptance by the traveling public. There were also safety concerns. Methods were developed to address these concerns, and in many cases the questions have been answered:

In-Vehicle Display Devices

- TravTek and other operational tests have shown that in-vehicle display devices using moving maps, GPS, dead-reckoning, and map matching technology are technically feasible.
- Operational use has shown that properly designed in-vehicle devices do not degrade safety.

Benefits and Impact on Driver Behavior

- The TravTek operational test resulted in measurable benefits in terms of travel time, travel distance, number of wrong turns, and number of vehicle stops, as well as a small safety benefit. [1] (see also [2])
- ATIS information would be of limited utility if drivers do not act on the information. However, for a limited sample in Houston [3] "53 percent of the participants reported that they had altered some aspect of their tripmaking behavior [in response to real-time information, and that] ... 33 percent of the participants said that they diverted to another roadway while en route because of the travel time and incident information."
- Modeling results indicate that when an ATIS system consisting of route guidance and multi-modal trip planning is integrated with other ITS components in an urban environment (such as in the Intelligent Transportation Infrastructure or ITI), it can reduce non-recurrent delay by 1/3 to 1/2.

Public Acceptance

- The traveling public has been very receptive to in-vehicle route guidance devices. Devices with or without real-time travel information have proven acceptable. Furthermore, concerns about the ability of the public to use route guidance devices (the VCR syndrome) have not been borne out. Rental car vendors report that users will pay for them on rental vehicles. "The TravTek operational test reported that the median price users said they were willing to pay for a TravTek-like system was about $1000." [1] (see also [2]) Currently, several vendors are offering devices for sale to the public. Nonetheless, how much the public is willing to pay to purchase in-vehicle devices for their own vehicles remains an issue.

Public Acceptance (continued)

- Consumer acceptance research showed that private travelers use traffic information to make rerouting decisions, and appreciate the receipt of the information even when they don't reroute.
- On the ADVANCE project, drivers already familiar with the road network preferred generating their own routes as opposed to using the ones generated by the in-vehicle device. These same drivers expressed a high level of interest in real-time information that is tailored to their routes. [4] Several alternatives for achieving this have been suggested; research would be needed to determine which is the most appropriate.

Human Factors

- The most important design principle to follow in designing in-vehicle devices is consistency of the material presented on an in-vehicle display with the corresponding material displayed on road signs. [5]
- Experiments have resulted in a set of preliminary human factors design guidelines for in-vehicle driver interfaces. [5]
- For determining the safety of in-vehicle devices, the most appropriate performance measures are standard deviation of lane position, mean and standard deviation of speed, and the mean frequency of driver eye fixations to other locations. [6]

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[1] USDOT, *Technical Summary, TravTek Operational Test Evaluation Final Reports,* FHWA-RD-96-037, March 1996.

[2] USDOT, *TravTek Global Evaluation and Executive Summary,* FHWA-RD-96-031, March 1996

[3] Gerald L. Ullman, Kevin N. Balke, William R. McCasland, and Conrad L. Dudek, *Benefits of Real-Time Travel Time Information in Houston,* Intelligent Transportation Systems of America 1996 Annual Meeting, April 15-18, 1996, preprint of paper 100, page 3.

[4] Joseph L. Schofer, Frank S. Koppelman, and William A. Carlton, *Familiar Driver Perspectives on ADVANCE and Future Dynamic Route Guidance Systems,* May 21, 1996.

[5] Paul Green et al, *Preliminary Human Factors Design Guidelines for Driver Information Systems,* FHWA-RD-94-087, December 1995.

[6] Paul Green, *Human Factors of In-Vehicle Driver Information Systems: An Executive Summary,* FHWA-RD-95-014, December 1995.

Commercial Vehicle Operations (CVO)

At the outset of the CVO program, there were a number of unanswered questions about the distribution of intelligence between the vehicle and the infrastructure, the distribution of data across platforms, and the integration of databases. Furthermore, there were questions regarding the maturity and integration of the various technologies. The CVO program has provided a number of answers in these areas:

No Showstoppers

- There are no showstoppers for achieving CVO program goals. Deployment of most ITS/CVO services is technically feasible; Weigh-in-Motion (WIM), Automatic Vehicle Identification (AVI), Electronic Data Interchange (EDI), and wireless communications have all proven to meet the needs. The institutional barriers to ITS/CVO deployment are greater than the technical constraints. The challenges are in developing standards and linkages among systems. [1]

Information Needs

- There is a large overlap in the information needs of the various state agencies that are responsible for commercial vehicle operations. Also customs, immigration, transportation, and various state agencies have different missions, but they all have similar information needs. This means that an integrated electronic clearance system is technically feasible domestically and at borders.

End-to-end Systems

- End-to-end systems can now be developed that integrate multiple technologies and operate in real-time. Vehicles can be identified in a high traffic environment. These data can be integrated with vehicle classification and weigh-in-motion results for system input. On the HELP/Crescent and Advantage I-75 projects, this information was successfully used to generate real-time database queries. An end-to-end capability can then be achieved by combining these technologies with vehicle/roadside communications and in-vehicle information. This allows real-time feedback to drivers as to whether to proceed or pull over for inspections.

Distribution of Data

- The appropriate place to keep most data is at the authoritative source, in the state with the jurisdiction, and not at a central location. However, there is a need for national clearinghouses to either distribute the data or point to the location where they are stored.

Distribution of Fees

- The International Registration Plan (IRP) has been effective in allowing carriers to "write a single check" to a base state, rather than having to pay each of them separately. However, national financial clearinghouses are needed to reduce the paper work associated with redistributing the fees among the states in accordance with carrier mileage.

Distribution of Intelligence

- Development activities have determined that a read/write tag with limited data is the most appropriate solution. For the most part, the tag should contain IDs, with most of the rest of the needed information residing in the infrastructure systems.

Electronic Filing

- Laptop computer technology can be exploited to perform inspections and provide more timely information to safety databases. The several month delay associated for filing inspection reports with a manual system can be reduced to under one day with the automation, thereby reducing data entry costs.

Automated Mileage Recording

- Interstate carriers must file quarterly mileage and fuel reports by state. The results of automated mileage recording are acceptable to auditors. GPS and map matching make automated mileage recording technically feasible. It remains to be learned the degree to which this technology finds marketplace acceptance.

Screening Vehicles

- An inspection selection algorithm has been developed that targets higher risk carrier vehicles. It uses the most recent carrier safety data, which are electronically downloaded to roadside sites. Methods are under development to prevent vehicles or drivers placed out-of-service from proceeding without correcting the equipment or service violations.
- Roadside brake testing technologies are available for screening which trucks should have more detailed brake inspections. Since brake inspections are time consuming, there is real benefit in targeting the appropriate vehicles for inspection. Further, they measure brake performance rather than surrogates such as push rod travel.

Electronic Screening

- A mainline automated clearance system can provide measurable, and over the long-term significant, fuel savings as a result of by-passing weigh stations. [2]
- Electronic screening also results in significant time savings for carriers that pay their drivers by the hour who passed fixed weigh stations. [3]

Standards

- There is a need for a common way to identify vehicles electronically to implement an integrated clearance system. Such systems also need a single method for communicating between the vehicles and the roadside. Two sets of standards will be key for CVO: Electronic Data Interchange (EDI) and dedicated short-range communications .

Electronic Purchase of Credentials

- Techniques have been developed to obtain one-stop electronic credentials from all relevant state agencies where a fleet operator's home office resides. This provides economic benefits to the state agencies and to the commercial carriers. A remaining challenge is the establishment of national clearinghouses that provides electronic mechanisms for state-to-state communications; for the most part, these communications are still paper transactions.

Speed Warning

- Results from the Dynamic Truck Speed Warning operational test had positive safety impacts from using a Variable Message Sign (VMS) to provide a recommended safe speed to truckers along a long downgrade. In particular, the frequency of use of escape ramps (a surrogate measure for safety) decreased when the speed warning system was in operation. [4]

Who Benefits

- Regardless of technical feasibility, the CVO program could not succeed without both state and industry acceptance. CVO benefit studies indicate that carriers and drivers perceive CVO as having a positive benefit. Expected benefits to trucking fleets include time and cost savings, and reduced paperwork.
- CVO offers cost reductions to the states from reduced paperwork and reduced data entry. States are also benefiting from the reduced error rates that result from electronic filings; previously a large fraction of the forms had to be returned to the fleets for error correction.

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[1] Cambridge Systematics, Inc., National ITS/CVO Program Requirements, December 7, 1995.

[2] Booz-Allen and Hamilton, *Advantage I-75 Project Completion Plan,* February 5, 1996

[3] *Assessment of ITS/CVO User Services: Qualitative Benefit Cost Analyses,* prepared by the ATA Foundation, Inc. for FHWA, June 1996.

[4] Booz-Allen and Hamilton, *Dynamic Truck Speed Project Completion Plan,* February 5, 1996

Advanced Collision Avoidance Systems (ACAS)

ACAS focuses on crash avoidance, through the use of roadside and in-vehicle electromechanical and communications devices. Categories of crash avoidance include avoidance of longitudinal collisions (i.e, rear-end, head-on, and backing collisions), lateral collisions (i.e., merging and lane changing collisions, and lane and road departures), and intersection collisions. Avoidance systems for these categories are associated with varying degrees of difficulty and technical risk, with intersection collision avoidance perhaps being the most difficult.

The following has been learned on the ACAS program:

Understanding of Collisions

- An early activity was a detailed analysis of the precipitate events of motor vehicle collisions. A thorough knowledge and understanding of accident data has been obtained that goes beyond the statistical summaries that were previously available. A thorough analysis of accident files, including a detailed analysis of individual crashes, was completed. As a result, there is now a understanding of the types of collisions and the events that lead up to them.
- An analysis of causal factors determined that 90 percent of crashes result from driver-related factors.

Collision Avoidance Benefits

- A benefits assessment of three potential collision avoidance countermeasures determined that they have the potential to reduce the number of crashes by 17 percent, thereby avoiding 1.1 million crashes annually. This translates into an annual economic benefit (i.e., cost savings) of $25 billion, not including savings due to injury prevention or reduction in injury severity. The benefit/cost ratio would depend on the cost of the countermeasure systems [1].

Collision Avoidance Systems

- Based on the analysis of collisions, a preliminary understanding of the performance features needed for effective collision avoidance systems has been obtained. Performance specifications are currently under development for several types of countermeasure systems.
- In designing countermeasures, the requirements of all classes of drivers must be taken into consideration. For example, countermeasures must be designed to ensure that older drivers do not become confused or disoriented by warning or automatic control systems. Similarly, the countermeasures must take into account that the behavior of commercial drivers may differ from that of drivers in private automobiles. [2]

Collision Avoidance Technologies

- Collision avoidance systems must accommodate various weather and traffic situations, curves, and straight road segments. They must have the ability to differentiate potential and imminent collision situations from the presence of signs and other benign roadway features and situations. Furthermore, drivers need to be warned about threats in a timely manner without distracting them from the driving task. Although much progress is being made and there are no technical showstoppers, it is difficult for existing technologies to meet all these requirements at prices acceptable to the consumer.

Simulation Study Techniques

- Experimental techniques for collision avoidance studies are difficult because subjects cannot be put at undue risk in an experiment. Techniques are being developed for collecting performance data in a simulated environment and measuring the difference in performance between baseline conditions and conditions in which a proposed collision avoidance system is present. The need for the use of moving-base simulations has been identified for carrying out the collision avoidance studies. A remaining challenge is to extrapolate the simulator results to benefits that will be realized in a real-world environment.

Potential Health Hazards

- The FCC has set aside RF spectrum and specified power limits for collision avoidance countermeasures. An evaluation determined that, to the current state of knowledge, radiation at the power limits specified by FCC will not produce health hazards.

Older Driver Needs

- An assessment of older driver needs found that for the foreseeable future, ITS crash avoidance devices are likely to have limited benefits for older drivers. [3] This is because these drivers need the most assistance in complex situations (e.g., intersection collisions), for which the near-term availability of countermeasures is unlikely. In the near-term, backing crash countermeasures are a candidate for assisting older drivers.

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[1] NHTSA Presentation by Deputy Administrator Philip R. Recht at ITS America Annual Meeting, April 1996.

[2] ITS America and NHTSA, *Peer Review of the National Highway Traffic Safety Administration Program,* draft workshop proceedings dated June 10, 1996.

[3] R.J. Hanowski et al, *Analysis of Older Driver Safety Interventions: A Human Factors Taxonomic Approach,* "Proceedings of the Fifth Annual Meeting of the Intelligent Transportation System Society of America", March 15-17, 1995.

Automated Highway System (AHS)

When the AHS program began, a wide range of system implementation options were under consideration. There were questions about the feasibility of addressing all requirements with the current state-of-the-art in technology. There was also uncertainty about the magnitude of benefits that could be realized. A series of precursor systems analyses and the first stage of AHS concept evaluations have provided answers in a number of these areas:

- *Benefits* — The magnitude of safety, throughput, and air quality benefits achievable with AHS has been scoped.
- *Early Winners* — Transit and commercial vehicle operations have been identified as being potential "early winners" that can benefit from AHS. AHS can make transit more attractive to long distance commuters. It would allow buses to enjoy safe travel with reliable travel times. AHS can provide the benefit of a light rail service while retaining the flexible routing of a bus that is not available on a fixed guideway system. For commercial vehicle operations, AHS offers advantages in the long distance trucking arena. Fleet convoys are one of the possibilities. Both transit and commercial vehicle applications also are seen as a means to facilitating the phase-in of AHS deployment.
- *Distribution of Intelligence* — A better understanding has been gained on the distribution of intelligence between the vehicles and the roadway infrastructure for AHS. A fully infrastructure-controlled system has been rejected; some intelligence will reside in the vehicle. For example, vehicles must be able to directly sense/detect other vehicles. However, the infrastructure can provide global assistance for merging operations, emergency handling, and flow control. [1]
- *Dedicated Lanes* — To achieve maximum safety and throughput benefits, dedicated lanes are needed for AHS. However, AHS technologies would ideally accommodate a mixed operation in which AHS and non-AHS vehicles operate together. This is because fixed operation is seen as a promising migration path for evolution towards a fully automated system. [1]
- *Physical Barriers* — Physical barriers are seen as the best method for separating lanes for manually driven and automated vehicles. There will still be safety and throughput benefits without such barriers, but to a lesser extent than with them.
- *Driver Backup* — The driver should not be expected to act as an immediate backup for vehicle control in an emergency situation. [2,3]

Acceptance	•	Drivers of all ages of the University of Iowa simulated AHS were comfortable with the high speed (95 mph) in the AHS but preferred long gaps (>1 meter) between vehicles. [4]
Regional Optimization	•	The need to evaluate benefits on a region-wide level has been strongly established. Through site-specific application of enhanced traffic management techniques and proper infrastructure design, traffic flow at entry and exit must be optimized. Several viable approaches have been postulated; research is needed for choosing among them.
AHS Technology	•	Detection of roadway obstacles (debris, animals, etc.) presents a particular hazard for AHS and represents a major technical challenge. The National AHS Consortium is currently investigating several promising technological approaches to this problem.

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[1] National Automated Highway System Consortium, *Automated Highway System (AHS) WBS C1 Draft Final Report,* February 16, 1996.

[2] USDOT, *Automated Highway System Program Report to Congress,* September 1995.

[3] USDOT, *The Ability of the Driver to Deal with Reduced Capability in an AHS,* FHWA-RD-95-108, 1996.

[4] USDOT, *Human Factors Aspects of Transferring Control from the Driver to the AHS with Varying Degrees of Automation,* FHWA-RD-95-108, 1995.

Advanced Public Transportation Systems (APTS)

Many ITS technologies appear to have promising applications in the transit arena. The program has provided lessons as to the degree with which these potential benefits are realizable in the real world, and has uncovered questions that remain to be answered:

Electronic Fares

- Both technical and institutional issues regarding the use of first generation smart cards have been identified. From the technology perspective, when RF proximity cards are designed solely for transit use, they are a viable technology in both rail and bus environments. However, techniques have not yet been developed to effectively use commercial smart cards (Master Card, VISA, etc.) in transit applications. In the institutional arena, Wilmington DE identified the techniques for financial card clearinghouse in a multi-use card, multi-operator system environment. However, institutional issues regarding the use of commercial cards have not been resolved.
- Benefits to transit operators from the use of automated fare payment systems include establishment of more sophisticated fare pricing systems, improved revenue security, and lower cost for handling cash. [1] However, it has not yet been determined whether the ease of use of electronic fare payment will induce people to use transit.

Transit Fleet Management

- For transit fleet management systems, techniques have been developed to exploit personal computer technology, including geographic information systems, wireless communications, and automatic vehicle location systems.
- The use of fleet management systems has led to demonstrated improvements in schedule performance. There is substantial return on investment if the operator takes advantage of the information that the system provides. Some transit agencies have saved bus trips and even required fewer buses through the better scheduling that was made possible. However, to date, most operators do not do so. Furthermore, only the larger operators (more than 100 buses) have deployed fleet management systems because of the costs of the operations center. Yet it is the smaller operators, who generally cover a larger geographic area, who are in greatest needs for these systems.
- Real-time vehicle component monitoring can prevent interruptions of service by identifying bus components that are in danger of failing and causing an on-street breakdown.

Pre-trip Traveler Information

- Automated pre-trip traveler information systems can provide information more quickly with reduced costs. Some phone calls from transit users do not even require human intervention by the operator. [1] These systems have also met with rider acceptance, as the implementation of telephone information systems greatly increases the number of persons calling to obtain specific transit information.
- Tests have demonstrated that disseminating information via kiosks, signage, home PCs, cable television, and personal communicators is feasible. However, it remains to be determined which of these techniques is most effective. It also remains to be determined whether any of them, when transit information is combined with traffic data, will induce travelers to switch from cars to transit.

Dynamic Ridesharing

- On the Bellevue Smart Traveler project, participants liked the concept of dynamic ridesharing and the associated technologies. Focus groups have indicated that the dynamic ridesharing concept is appealing. A remaining challenge is how make such a system work in practice. Experience has shown that travelers are more willing to offer rides than to accept them. As a result, there have been few actual matches made. [2] Forming a system around a common place of employment, or building upon existing (non-dynamic) ridesharing programs have been offered as possibilities to be investigated for overcoming personal safety and other concerns that have raised.

Automatic Vehicle Location (AVL) Systems

- AVL systems have been found to provide a wide range of benefits to transit systems. Among the benefits experienced are safety (for response to crime or medical emergencies), on-time performance, and reduced costs for schedule adherence. [2]

To summarize, many of the anticipated benefits of automation appear to have been realized. An area with potential benefits to be demonstrated in the near future is automated en route transit information systems. [4]

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[1] USDOT Federal Transit Administration, *Advanced Public Transportation Systems: The State of the Art Update '96,* January 1996.

[2] Washington State Transportation Center, *Bellevue Smart Traveler: Design, Demonstration, and Assessment,* August 1995.

[3] USDOT Federal Transit Administration, *Advanced Public Transportation Systems Benefits,* January 1996.

[4] USDOT Federal Transit Administration, *Review and Assessment of En-Route Transit Information Systems,* July 1995.

Advanced Rural Transportation Systems (ARTS)

Advanced Rural Transportation Systems (ARTS) apply ITS technologies and approaches to the rural transportation environment. This environment has different characteristics and needs from those in congested urban areas. Rural environments are also more diverse than urban ones. They encompass farmlands, recreational facilities, and remote pass-through areas. As a result, no one set of ITS technologies can be applied equally across all rural areas.

Studies conducted in recent years have found the following about the rural ITS environment with respect to ITS:

- *Rural Infrastructure* — The lack of an FM and a cellular communications infrastructure in remote rural areas drives the need for alternative technologies. To be sure, in recent years cellular coverage has expanded to cover the entire Interstate system, providing emergency communications for many motorists. However, because of the small population spread over a large geographic area, the private sector is unlikely to extend this infrastructure to provide complete coverage in the near term. The economic issues and technological feasibility of using AM subcarrier and satellite systems to fill this gap are being tested.
- *Mayday* — Fifty-six percent of all fatal accidents occur on rural roads, with only 11% of these fatalities occurring on Interstates. The higher speeds and dangerous terrain in rural areas also result in more serious injuries for non-fatal crashes. However, the nature of the rural infrastructure described above presents obstacles to achieving timely responses in cases of emergency. The response times for accidents in rural areas are significantly higher than they are for accidents in urban areas. [1 and 2]. Not surprisingly, Mayday systems have been cited as a top priority for addressing rural needs.
- *Distribution of Traffic* — The distribution of traffic along various routes has been quantified. Most travel occurs on a small portion of the nation's road network. Conversely, fifty percent of the route miles, predominately rural, carry only five percent of the traffic. [3] The resulting data enable cost/benefit ratios and the efficiencies of implementing ITS in a rural environment to be defined and distinguished from that of the urban environment.

Road Network

- The relatively sparse road network in rural areas can result in a limited number of alternative routes. [4] (In urban settings, ATIS systems depend upon such alternatives to achieve rerouting.) Conversely, the sparse network means that timely information at the outset of a trip, when alternative routes are still available, can lead to large time savings for an individual traveler.

User Needs

- Several studies of the traveling public and public officials have been carried out regarding rural traveler needs. All the surveys and focus groups found that "there is a clear need for traveler information in rural areas and that these areas can benefit from ITS applications." [5, page 669] The findings across several such studies (see [5] and references cited therein) have reinforced each other, thereby leading to a validated user needs profile for ARTS.
- The types of ATIS information needed in a rural environment have been numerically prioritized, with Mayday leading the list. In addition, issues regarding research technologies for meeting these needs have been identified. [6 and 7]
- On the Yosemite Area Traveler Information (YATI) project, travelers exiting Yosemite National Park were surveyed to find out what types of information they would prefer on changeable message signs. They indicated preference for information on road closures, current traffic conditions, parking availability, and campsite availability. [8]
- The following was learned from focus groups [9]:

  "Many rural transit agencies are demand-responsive and require information on passenger needs but don't have computerized databases."

  "Vehicle diagnostics, road, traffic and weather conditions, and vehicle location and navigation services would be valuable for safety and operations of both fixed-route and demand-responsive service."

Road Weather Information

- Rural road weather information systems provide information on snow, ice, and other hazardous weather conditions. Two types of users have found such information to be valuable: the traveling public and state agencies, such as those involved in snow removal.

Demand Responsive Service

- The transit needs in a rural environment differ from those in urban ones. They are oriented more towards the provision of human services and less towards the daily commutes that are characteristic of urban transit. As a result, demand responsive service is particularly important. Computer assisted dispatching and automated vehicle locations for demand responsive service has increased the ridership and productivity of these systems. The improved recordkeeping that ITS technologies provide has also substantially reduced fraudulent billings for social service trips.

Coordination of Services

- A GIS study currently underway for the Community Transportation Association of America depicts which rural regions have transit services and at what levels. Many rural regions have multiple transit providers. Substantial cost savings could be achieved by coordinating the activities of the various rural transit and para-transit services. ITS technologies such as GIS, electronic fare media, and AVL offer the potential to aid transit operators in overcoming the institutional barriers that currently stand in the way of such coordination.

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[1] Minutes of the ITS America ARTS Committee, April 16, 1996.

[2] FHWA, *Highway Statistics 1994,* October 1995, as quoted in ref [2] below.

[3] Mitretek Systems, *Background Information and Strategy for a Rural Intelligent Transportation Infrastructure (ITI),* April 10, 1996, page 7.

[4] ibid., page 8.

[5] R. Sivanandan, *et al.,* "An Assessment of Rural Traveler Needs for ITS Applications", *Proceedings of the 1995 Annual Meeting of ITS America,* March 15-17, 1995, Volume 2, pages 659-670.

[6] Mitretek Systems, op. cit., page 17.

[7] JHK and Associates, *Rural Applications of Advanced Traveler Information Systems (ATIS),* for FHWA, August 1995.

[8] John Gard and Paul P. Jovanis, "Implementation of a Rural ATIS: Initial Findings from the YATI System", *Proceedings of the 1995 Annual Meeting of ITS America,* March 15-17, 1995, Volume 2, pages 639-645.

[9] Briefing charts prepared by FHWA. Based on findings in *Rural Applications of Advanced Traveler Information Systems (ATIS),* by JHK and Associates, August 1995.

Technologies

"ITS applies advanced and emerging technologies in such fields as information processing, communications, control, and electronics to surface transportation needs." [1] To be sure, the application of technology should only be driven by user needs. Technology should not be implemented for technology's sake, but to address real-world problems. The ITS program has identified a number of areas where current technology can be successfully applied in a cost-effective manner. The following discusses some of the technologies that are involved:

Dedicated Short Range Communications (DSRC)

- The ability of Dedicated Short Range Communications (DSRC) technology to address a range of toll and CVO applications has been demonstrated. This technology has also proven to be flexible. For toll applications, a single tag can contain multiple accounts. For CVO, a single reader was developed to read tags by two different vendors. However, this was done for only a single pair of vendors in this multi-vendor environment. Further, there is no known cost-effective means of reading both active and passive tags by a single reader. Finally, DSRC's potential to combine both toll and CVO applications in a single system has not yet been demonstrated.

Global Positioning System (GPS)

- GPS has proven to be a "big winner" across multiple ITS user services. It has become a ubiquitous public utility. Selective Availability has not proven to be a big obstacle and differential GPS will be more widely available than originally expected. High accuracy techniques built upon GPS have been examined and offer promise as part of a sensor suite in future automated systems.

Map Databases

- Accurate digital map databases are a key supporting technology of most of the ITS user services. Previously produced maps, such as the Tiger files used for the Census, serve as a starting point for ITS map databases. However, these maps must be enhanced to provide more accuracy as well as additional fields and attributes. Private companies have been doing so for maps of major urban areas.

FM Subcarrier

- In the U.S., high data rate FM subcarrier systems that utilize commercial FM radio station transmitters have been demonstrated to be technically feasible for use in a mobile environment. These higher data rates are needed because those available with the Radio Broadcast Data System (RBDS) standard, while useful for reporting congestion and incidents, are insufficient to meet the long-term requirements for disseminating link travel time information.

LIDAR Technology	•	LIDAR (Light Detection and Ranging) measurements of vehicle emissions was found to be useful for emissions model calibration and planning. However, this technology does not appear to be appropriate for real-time measures of pollutants arising from the current traffic flow.
Vehicle Sensors	•	A thorough examination of sensor technologies determined that a variety of sensor approaches are sufficiently mature for incorporation into vehicle control systems.

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[1] USDOT and ITS America, *National ITS Program Plan,* March 1995, Volume 1 page 2.

Architecture and Standards

The need for an architecture to provide an overall framework was identified early in the ITS program. As a result, FHWA sponsored the development of a National Architecture. In addition, a Commercial Vehicle Information Systems and Networks (CVISN) Architecture has been developed, and a number of standards development activities are underway. In the course of these activities, a number of important findings have been learned:

Multiple Viewpoints

- In developing an architecture, it's essential to take multiple views of the system. No one view gives a complete picture. Instead, the system must be described from various perspectives.
- The National Architecture is described by three layers: transportation, communications, and institutional. Within the transportation layer there are several views: an operations view (the theory of operations), a functional view (the logical architecture), and a physical view (the physical architecture). In addition, the standards documents give a view on standards needs and the key interfaces to standardize. All these complementary views provide unique perspectives, and all are important.
- For the CVISN Architecture, a conceptual view (concept of operations), a process view (logical architecture), data view, applications view, impact on stakeholders, and a technology view (computers, communications, weigh-in-motion, etc.) all proved important.

Flexibility

- To be effective, a national architecture has to be flexible enough to accommodate diverse geographic settings and variations in local environments.

Functional Requirements

- The logical architecture portion of the National Architecture has defined a detailed set of functional requirements for each of the 29 user services that are defined in the National ITS Program Plan. The physical subsystems that will be needed to deliver these services have also been identified. An important remaining task is to incorporate the highway-rail intersection user service into the National Architecture.

Synergisms

- The national architecture identifies a number of important synergies. This facilitates integration of common elements for multiple purposes. For example, common network surveillance can be used for traffic signal control, incident management, and as a source of information for traveler information. Toll tags can be used for electronic toll collection and as traffic probes.

Communications Categories

- The National Architecture identifies four general categories of communications requirements: wireline, wide areas wireless (broadcast and two-way), dedicated short range, and vehicle-to-vehicle. The architecture also designates the role that each of these categories has in meeting the functional requirements. Several viable candidate communications technologies have been identified for each of these categories. Which technologies are most appropriate for each application will be determined through standardization activities and market forces.
- Communications analysis has shown that, when properly configured, several two-way wide area wireless technologies currently exist that meet the ITS requirements for collecting and disseminating traveler information. However, these technologies are not standalone systems dedicated to ITS; they also carry non-ITS data traffic. Cellular Digital Packet Data (CDPD) is one of the viable technologies. Because much of the current cellular system can become overloaded in certain areas during peak periods, configuring CDPD for ITS requires CDPD-only channels to deliver most messages, regardless of priority, during peak loading conditions. Dedicated ITS-only channels are not required. On the other hand, CDPD will perform poorly if not properly configured: discrete event simulations results show that several minutes of delay may be experienced if shared voice/data channels are used.

Standards Identification

- Through a synthesis of various inputs -- the National Architecture, an ITS America survey, workshops, etc. -- there is now a prioritized list of standards needs. National interoperability and Intelligent Transportation Infrastructure (ITI) integration were key considerations in developing this list. In addition, the National Architecture program has partitioned architecture flows into a series of standards requirements documents. These can be used by the standards development organizations for their standards setting activities.

Standards Development

- One of the key outcomes of the ITS research and development will be a set of standards for the messages sent from one ITS element to another, as well as standards on the communication channels used. Although the important messages have been assigned to the appropriate communications categories, these messages will need to be standardized if national interoperability is to be achieved. There are few message standards currently in place, but in the communications arena many of the existing wireline standards are applicable and can be used as is.

Standards Development (continued)

- For standards to be effective and widely accepted, they must be developed through recognized national standards development organizations. The recognized authority in a given area must be the one responsible for standards in that arena.

- The development of the National Transportation Communications for ITS Protocol (NTCIP) demonstrated the value of a steering group for effective standards development. This group keeps that standards development process focused and must have representation from vendors and users to ensure that their interests are represented. FHWA's partial funding of the steering group helped speed up the standards development process.

Location Referencing Standards

- Location referencing has been identified as a key enabling technology to a wide range of ITS services. However, no single location referencing scheme will work for all user services. Therefore, there is a need for flexibility to allow location referencing information to be transmitted in a variety of standard formats across applications.

National Datum

- The need has been identified for a national datum of surveyed reference points that will be used in conjunction with location referencing standards. Major nodes along the National Highway System have been proposed for the datum. Further studies are underway to determine the resolution requirements for the datum and to establish rules for where the datum points are to be located.

Radio Spectrum

- There has been recognition by the Public Safety Wireless Advisory Committee that ITS applications qualify for public safety spectrum use. FHWA is working closely with NTIA and FCC to identify and acquire spectrum for ITS applications.

- To meet ITS requirements, spectrum is needed for Dedicated Short Range Communications (DSRC). Spectrum in the 5850-5925 MHz band, which can be shared with other services, has been identified.

Mainstreaming

For the program to be successful, ITS must get incorporated into the mainstream of transportation planning, operations, and budgeting. The following findings should be taken into consideration as part of this process:

ITS Planning

- To be effective, local ITS planning (Early Deployment Plans, etc.) must be integrated into a larger regional planning process. If ITS planning is a separate parallel process, there will be no buy-in and it will not become part of the mainstream planning process. However, it is recognized that implementation of ITS has some significant differences from road construction projects. Therefore, it may be desirable to separate the ITS *development* process from that used for other transportation projects.
- To better accommodate ITS, the planning process, currently focused on capital improvements, must be modified to consider day-to-day traffic operations and the funding required to carry them out.
- The following are some characteristics that have been found to be key for successful Intelligent Transportation Infrastructure (ITI) planning [1]: having a realistic assessment of funding, forging agreements, using subgroups or committees, not over-committing to data collection, connecting ITI to other transportation planning, involving as many interested parties as possible, appointing a project leader from the lead agency, and being results-oriented.

Decision Making

- Many jurisdictions are already buying Intelligent Transportation Infrastructure (ITI) components, but don't necessarily associate them with ITS. The challenge is how to foster this awareness of ITS, in particular with regards to integrating the components.

Outreach

- There are many different constituencies that must be addressed as part of an outreach program. Traditionally, USDOT has been most comfortable working with transportation agencies such as state DOTs. There is a need to refocus the overall approach for reaching other constituencies.

Professional Capacity Building

- There exists a need to enhance the considerable civil engineering expertise of transportation professionals with the skills needed to efficiently design, build, and operate an intelligent transportation system. To address this need, FHWA has begun a Professional Capacity Building Program.

Professional Capacity Building (continued)

- For university students, systems engineering courses are needed as part of civil and transportation engineering undergraduate curricula. State agencies need to ensure that there are career paths for electronic and systems engineers so that their skills can be utilized on ITS projects

Assistance and Guidance

- Workshops, one-on-one support, experience sharing, "ITS champions", and guidance documentation are some of the assistance and guidance initiatives being considered for facilitating the incorporation of ITS into the planning process. For them to be effective, it must be recognized that no one technique fits all circumstances. Combinations of techniques must be tailored to the sites and individuals involved. However, it remains to be seen which combinations will prove to be most effective.

CVO Mainstreaming

- The CVO institutional issues working groups proved valuable in establishing a state-wide customer service mindset. Multi-state consortia with facilitators proved to be the most effective. They found that the most significant barrier to mainstreaming was the inability for states to work in a coordinated, multi-jurisdictional fashion because of a lack of common goals and shared vision. Discussions between carriers and the state identified different ways of simplifying compliance functions while ensuring current levels of compliance. It was also found that states and carriers will cooperate when costs are low and benefits outweigh costs. [2] Accordingly, to educate decision-makers on the benefits of CVO, FHWA is continuing its outreach activities with multi-state and state/industry forums. State and regional champions will coordinate and conduct seminars and workshops.

Interjurisdictional Coordination

- Methods have been learned for encouraging many reluctant diverse agencies to get involved quickly with ITS. In the CVO area, $50,000 of catalyst money was granted to states with minimal strings attached. This brought together, for the first time, the multiple state agencies dealing with commercial carriers on a daily basis. States were encouraged to set their own agenda as appropriate for their conditions with minimal Federal prescriptions. In some cases, this lead to one of the state transportation agencies serving as the champion for ITS. Serious dialogues were established for the first time and led to the realization of the benefits of using integrated regional approaches. This model of seed money may prove appropriate for rural applications where economic development agencies (instead of transportation agencies) can take the lead.

Consumer Acceptance

- Private travelers find traffic information an attractive feature when bundled with for-pay services (stock quotes, weather, sports scores, etc.). However, they would be unwilling to directly pay for it alone unless it offers a significant improvement over the traffic information that is currently available free of charge.
- Commercial drivers are receptive to ITS technology for safety and security, but have privacy concerns about its use for surveillance purposes.
- For transportation managers in all sectors, the biggest obstacle to ITS is the Operation & Maintenance (O&M) costs.
- Focus groups with local elected officials revealed that their prime consideration when deciding to adopt ITS is the competitive advantage it offers in attracting new business, expanding current business, or improving the quality of life of their constituents.
- For route choice decisions, travelers are generally more interested in having ATIS for long-distance trips or for travel in unfamiliar areas. They are less interested in having ATIS for local or familiar trips. Travelers are also more interested in having en-route information than they are in having pre-trip information. [3]

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[1] FHWA, *The Local Government Guide to the Intelligent Transportation Infrastructure,* draft dated May 21, 1996 citing the *Interim Handbook on ITS Planning.*

[2] Jeff Loftus, *Summary of IVHS/CVO Institutional Issues,* FHWA, October 4, 1996.

[3] Briefing charts prepared by Charles River Associates, Inc. for the ITS JPO, dated March 1996.

Cross-Cutting Findings

The same findings cited by one individual for a particular part of the ITS program were often later cited by someone else as applying to a different part of the program. These "cross-cutting" findings, which span across multiple parts of the ITS program, have been collected together and appear below:

Institutional Issues

- Institutional issues are the main barrier to implementing ITS. Across the board, the various domain experts said that there are no technology showstoppers that must be tackled before progress can be made in their areas. The technology is viewed as being "easy" when compared to the magnitude of institutional problems that are faced. To be sure, there remain technical challenges that need to be addressed. But for the most part, overcoming them has been shown to be doable. For example, there are interoperability issues, but these can be addressed through standards development.

Integrated Systems

- Although significant benefits are derived from implementing individual ITS components, even greater benefits can be realized by integrating them. Two types of integration are important: between different types of systems within a jurisdiction (e.g., between freeway management and incident management systems), and across jurisdictional boundaries in a metropolitan area or region. By having each system work smoothly with the others, synergies between them can be exploited. Accordingly, the Intelligent Transportation Infrastructure (ITI) initiative places heavy emphasis on integration.

Iterative Development

- The importance of iterative development was confirmed in multiple aspects of the program. While there is an appropriate role for comprehensive, all-inclusive, top-down plans, real-world successes were often best achieved using an iterative approach. First, a tangible product is developed. This allows potential participants to see the benefits of a proposed course of action, even though there is no long-range plan in place. The ability for participants to "kick the tires" provides better insight, especially for new capabilities that they are unfamiliar with. This can result in buy-in by various stakeholders more readily than trying to have them reach up-front agreement on a thick paper plan. From there, a larger system can be built and integrated.

Iterative Development Examples

- In Houston Texas, establishing a basic traffic management center with expansion room soon resulted in various operational agencies moving together and coordinating their activities. This was more effective than starting with a comprehensive coordination plan and attempting to have all the parties reach up-front agreement on it.
- Montgomery County Maryland provided basic traffic data on cable TV during a snow storm. Citizens found the roadway conditions information to be very useful. This led to widespread public support and request for "more". Because the data were new, previously available only within the TMC, citizens did not have prior experience with it. It would have been much more difficult to generate support for a paper document that proposed the provision of such data. However, when citizens saw that the data had value to them, it resulted in public support.
- In the ATMS R&D arena, it has been found that an effective R&D process should include a real-world test phase. During this phase, real-world experiences are gained with the R&D products, adjustments are made and techniques refined, leading to full operational tests with evaluations conducted by independent third party evaluators. By providing interim products, that are useful to state and local governments, the process gives visibility to and develops support for the overall project. Skeptics are won over as converts. However, a remaining challenge is how to develop deployment guidance that will allow the converts to deploy the technologies. In particular, tools are needed on how to prioritize the available options.
- The CVO architecture is also developed iteratively. When a layer of the architecture is fleshed out, it is widely coordinated. This often result in corrections not only to that level, but to higher levels as well; that is, iterative development results.
- On the CVO program, it was important to use an incremental approach for reaching the ultimate vision. For example, electronic purchase of paper credentials is an important first step towards the long-term goal of electronic credentials.
- In the ATIS arena, tests have confirmed the importance of user involvement in designing human interfaces.

Iterative Development Examples (continued)

- The ISTEA requirement for demonstrating AHS technology has served an important role in focusing the R&D effort to produce an early, interim product. It also gives the larger stakeholder community the chance to directly experience automated travel and consider this technology for meeting long-term transportation needs.

Widespread Interest

- There is widespread interest in the ITS program in the professional transportation community:

  As of June 1996, ITS America has 824 members, including private sector, Federal, State, and local government, and academic organizations. There are 17 state chapters covering 24 states.

  There are over 98 private firms, 118 state and local governments, and 30 universities involved in the operational test program.

  Over 70 organizations have joined with the ten core members of the National AHS Consortium (NAHSC) to advance AHS R&D.

  A remaining challenge is how to generate a corresponding appreciation of ITS in a broader community that includes the general public.

Evaluators

- To be most effective, an evaluator needs to be brought on board early during a project.
- An "independent evaluator" is sometimes misconstrued to mean one that is isolated from the project. To the contrary, to be effective, an evaluator must be given the opportunity to influence the system design so that the system will accommodate the measurements needed to conduct the requisite tests.
- The need for independent evaluators was learned on both the operational test and R&D program. The evaluator should be under direct contract to the USDOT. This should be done in conjunction with a solicitation that has specific, well-defined objectives that can be formulated as quantifiable questions. Doing so helps to expedite the test, as the parties do not have to formulate a scope and purpose of the test. This also helps to ensure that national questions and objectives are being addressed as part of the project so that focused results can be obtained. (Local goals and objectives for a project are usually focused towards implementation and do not always coincide with the Federal ones, which are often oriented towards study

Evaluators (continued)

issues whose answers can be applied elsewhere. Furthermore, project goals, which are implementation oriented, are sometimes confused with evaluation goals, which are test oriented.) These lessons are now being applied to the Model Deployment procurement.

Public/Private Partnerships

- ITS partnerships have been the catalyst for having different organizations work together. This has been especially true for the public sector. First, they foster *inter-jurisdictional* cooperation, for example by having peer departments exchange traffic information across political boundaries in large metropolitan areas. Second, they foster *inter-departmental* cooperation within the same jurisdiction, for example by bringing together traffic management and emergency response personnel. Such ground work is necessary if regional model deployments and the integration of Intelligent Transportation Infrastructure (ITI) components are to succeed.
- Forming public/private partnerships has often been more time consuming than originally anticipated. One of the reasons for this is that public and private entities have different objectives and concerns about sharing information. Furthermore, it has been found that there is no universal way of forming a partnership; different relationships are needed in different places. For example, the roles of MPOs vary greatly from one geographic location to another, so the partnerships must reflect this fact.
- Although the formation of partnerships was often slow, once the partnerships were formed, the rest of the project schedules typically did not stretch out. That is, projects proceeded along the original time paths, shifted in time to account for the startup process. As projects proceeded, the public/private partnerships were found to work and they provided useful benefits. For example, ten states and Lockheed (now Lockheed Martin) successfully sustained HELP beyond an operational test into HELP, Inc. that provides operational electronic clearance to the participating commercial carriers and states.
- Some unresolved issues with public/private partnerships include the role of foreign manufacturers in US consortia: how can the benefits of foreign technology be realized without undercutting US industry? The NAHSC may offer an example for others to follow: the consortium members have successfully devised a means of sharing technology and involving the participation of foreign manufacturers, while retaining their competitive position so that US technological advantage is protected.

Public/Private Partnerships

- USDOT has gained a better appreciation on the needs of the private sector in forming a public/private partnership. Regardless of the magnitude of the Federal match, the private sector must see a potential return on investment to make their participation worthwhile. The partnering approach must be tailored to the particular project, because some types of projects (e.g., information dissemination) offer more potential return to the private sector than others (e.g., traffic signal control systems). Also, in multi-year efforts, care must be taken that partnerships are not undermined by unstable Federal funding; private sector partners expect funding commitments established at the outset to be fulfilled.

- The following lessons learned were identified in [1]:

  "Public/private partnerships require building trust, understanding, commitment, and communication."

  "Partners' roles and responsibilities need to be clearly defined early in the planning stage."

  "Good leadership and full-time commitment is essential."

  "Systems integrator and evaluation contractors should be brought on-board early."

  "The evaluation process should be initiated during the project planning phase."

  "Complex projects require flexibility by all parties."

  "Contracting flexibility is important."

  "IVHS operational tests need a buy-in at two management levels: upper- and mid-level."

  "Inter-agency cooperation is facilitated by having an advocate in every key agency."

  "Demonstrable benefits are critical to participants and participation by all is critical to success."

  "It is important to make progress. ... Efficiently moving the project on a fast track and doing everything possible to keep near to schedule is important."

Guiding Principles

- Many portions of the ITS program involve multiple stakeholders with divergent interests. For progress to be made without getting bogged down in parochial interests, it is valuable to begin a project by having all parties agree to a general set of principles to guide their activities. These principles were given different names in various contexts: guiding principles, project goals, etc. In some cases they were written down formally and signed. In other cases they were implicitly agreed to. But whatever their form, they allowed projects to proceed and stay on track. When progress was stalled, all parties could go back to the agreed upon principles, to ensure that they were working towards uniform goals and not getting sidetracked on peripheral issues. This proved a valuable technique in all areas where it was applied, including operational test evaluation, CVO, and ATMS.

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[1] Federal Highway Administration, *IVHS Institutional Issues and Case Studies Analysis and Lessons Learned,* DOT-VNTSC-FHWA-94-15, April 1994.

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