STATUS OF IVHS TECHNICAL DEVELOPMENTS IN THE UNITED STATES
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ABSTRACT
This paper addresses the state of domestic technical developments in the five components of Intelligent Vehicle Highway Systems (IVHS): Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO), and Advanced Public Transportation Systems (APTS). Each component and current operational tests are briefly described. Particular emphasis is given to three current large-scale operational field tests (Pathfinder, TravTek, ADVANCE) to illustrate the integration of the IVHS components.

INTRODUCTION
The Intelligent Vehicle/Highway Systems (IVHS) program is a major initiative of Government, Industry, and Academia to apply advanced technology to the operation of the Nation's surface transportation system, so as to improve mobility and transportation productivity, enhance safety, maximize the use of existing transportation facilities, conserve energy resources, and reduce adverse environmental effects. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) recognized this need and authorized approximately $660 million over six years to fund IVHS efforts. Additional investments will be made by state and city governments and the private sector. The IVHS program consists of five broad, interrelated areas: Advanced Traffic Management Systems, Advanced Traveler Information Systems, Advanced Vehicle Control Systems, Commercial Vehicle Operations, and Advanced Public Transportation Systems.

THE IVHS COMPONENTS

Advanced Traffic Management Systems (ATMS): Advanced Traffic Management Systems use advanced technology to monitor traffic conditions and provide real-time adjustments to traffic control systems so as to ensure optimum traffic flow rates and respond to incidents sooner and more effectively. Some examples of ATMS are coordinated signal systems, electronic toll and traffic management (ETTM) systems, and traffic surveillance systems based on image processing and radar. ATMS applications in selected corridors have significantly reduced delay, travel time, and accidents.

Advanced Traveler Information Systems (ATIS): Advanced Traveler Information Systems provide to travelers ATMS data on current traffic and road conditions, vehicle location and navigation information, and safety warning messages, and also allow travelers to signal for help when needed, via mobile communications systems. ATIS offers significant potential benefits in reductions in travel times and associated benefits by enabling travelers to more efficiently use the transportation network based on real-time status information.

Advanced Vehicle Control Systems (AVCS): Advanced Vehicle Control Systems employ advanced sensor and control technologies to assist the driver in responding to the immediate environment on the roadway. AVCS will develop in an evolutionary manner, seeking first to enhance the driver's perceptions of his or her immediate environment. Products will include sensors which detect obstacles in vehicle blind spots, collision warning systems, and infrared vision enhancement systems. A further evolution of AVCS will be collision avoidance systems which take temporary control of vehicle operation. The long term potential of AVCS is to provide fully automated vehicle/highway systems. Full scale deployment of AVCS offer dramatic benefits, such as vastly increased highway capacity through the use of tightly packed automated vehicles traveling at freeway speeds, and increased safety by reducing the potential for driver error.

Commercial Vehicle Operations (CVO): The Commercial Vehicle Operations component of IVHS is aimed at improving the safety and operational efficiency of commercial vehicles by applying advanced technology to the unique needs of commercial users. For instance, weigh-in-motion (WIM) and Automatic Vehicle Classification (AVC) systems are currently used by States for weight enforcement. Automatic Vehicle Identification (AVI) systems are used by motor carriers for electronic toll collection and other applications requiring the interchange of data with the roadside, to reduce the number of required stops enroute. Automatic Vehicle Location (AVL) systems, which enable individual vehicles to be tracked, combined with messaging systems, are

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revolutionsizing fleet management techniques.

Advanced Public Transportation Systems (APTS): Advanced Public Transportation Systems build upon the technologies of the other IVHS components to enhance all types of public transportation. The increased level of service made possible by these systems results in a more attractive transportation option for the public, thereby increasing ridership, and reducing the burden on the congested highway system. APTS include AVL and communications systems to enhance fleet management operations, electronic fare media, and new techniques to more effectively use and monitor HOV lanes.

CURRENT IVHS OPERATIONAL TESTS IN THE U.S.

Several IVHS operational tests are now underway in the United States, and a large and diverse array of additional tests are in the planning stages. Three current large-scale operational test programs are described below. Subsequently, the remainder of the domestic operational tests which are in the planning or early implementation stages are briefly described. AVCS efforts are addressed separately at the conclusion of this section, as this technical work is in the preliminary research stage.

Pathfinder

Begun in 1988, Pathfinder is the first in-vehicle navigation system project in the United States. It is an experimental project to assess the benefits of providing real-time traffic congestion information to drivers, which will enable them to modify their routes and thus avoid congested areas. An additional goal is to evaluate the utility of using vehicles as traffic probes, whereby vehicles automatically report traffic speeds back to a central traffic monitoring system as an additional source of traffic information. It is therefore considered a combination ATMS/ATIS system. The experiment is a cooperative project between the Federal Highway Administration, the California Department of Transportation, and General Motors, with $2,5M in total funds. Twenty-five cars have been equipped with Pathfinder hardware.

This experiment is taking place along a 13 mile stretch of the Santa Monica Freeway between Santa Monica, California and Los Angeles, known as the Smart Corridor. The Corridor includes the freeway service roads and five major parallel arterial roads which can be used as alternatives to the freeway.

Pathfinder consists of three subsystems. The vehicle subsystem hardware is based on an Elak Travelpilot, which is a navigational system that displays electronic road maps (stored on compact disks) on a monochrome CRT display. Congestion data is received via an RF link. This data is presented to the driver in three ways: visually (via symbols on the map display), textually, and aurally (using digital computerized voice). The central subsystem performs the function of fusing congestion data from the arterial street computer system, the freeway computer system, the Pathfinder vehicles, and other sources. This congestion data is then passed to the communications subsystem, which uses a packet radio system to broadcast congestion data for the entire area to all vehicles once per minute. Each vehicle then provides a return transmission of vehicle location, heading, and speed during a pre-assigned time slot within the minute.

The Pathfinder hardware was implemented for test in July 1990, and the project is currently in the second phase of a three phase evaluation.

TravTek

Travel Technology (TravTek) is a public/private partnership involving the City of Orlando, the Florida Department of Transportation, the Federal Highway Administration, General Motors, and the American Automobile Association (AAA). The cost of the system, including a one year operations period and subsequent evaluations, is estimated at $12M. A combination ATMS/ATIS system, TravTek is providing traffic congestion information, motorist services ('yellow pages') information, tourist information, and route guidance to operators of 100 specially equipped test vehicles in the Orlando metropolitan area. The route guidance reflects real-time congestion information, which is received via broadcasts from a central Traffic Management Center.

The in-vehicle system provides the driver with up-to-the-minute traffic information and routing. Routing to selected destinations is provided on a turn-by-turn basis. Additional supporting hardware consists of a UHF-FM data communications transceiver to exchange information with the Traffic Management Center, and a GPS receiver to augment the dead-reckoning navigation system. The Traffic Management Center collects traffic information through a variety of means, similar to Pathfinder, including link travel time transmissions from the TravTek vehicles themselves.

The system entered its initial test phase in early Spring, 1992. Seventy-five of the vehicles are being rented to AAA members through a rental car company, and the remaining 25 vehicles are reserved for specially designed experiments, which will quantitatively evaluate the benefits and human factors aspects of the system.

ADVANCE

ADVANCE is by far the most ambitious field operational test planned to date in the United States. Designed for the Chicago area, the project is a cooperative partnership that currently involves the Illinois Department
of Transportation, the Federal Highway Administration, Motorola, Inc., and the Illinois Universities Transportation Research Consortium. The ADVANCE system will provide up-to-the-minute traffic information to 5,000 private and commercial vehicles, at the same time gathering traffic information from the vehicles as they traverse the road network.

ADVANCE will offer an in-vehicle functionality similar to TravTek. A combination GPS/Dead-Reckoning system, combined with a map displayed on a color CRT, will provide location information. Based on a destination entered by the driver and current traffic information, optimum routes will be computed and provided to the driver using the CRT and synthesized voice. Any changes in traffic conditions that occur enroute are provided to the driver, and the option to recompute the route is provided.

The infrastructure supporting ADVANCE is unique from other current operational tests, in that vehicle probe data is a primary, rather than secondary, source of traffic information. If this technique is successful, the need for extensively instrumented roadways can then be reduced, with significant savings in infrastructure costs.

A dedicated RF communications system has been designed to connect the probe vehicles to the Traffic Information Center (TIC). The TIC will receive dynamic link time data from the vehicles and will broadcast to the vehicles information on travel times which deviate from the norm. Inbound transmission (from the vehicles) is spontaneous and is based upon a contention protocol. The outbound transmission is continuous.

Begun in 1991, ADVANCE is currently in the preliminary design and testing stage. A small initial fleet will be deployed in late 1992, with the entire fleet deployed during 1993. At that point, 18 months of steady-state operations will commence, followed by an additional year of testing of more advanced concepts. Total system cost will be $35-40M.

OTHER IVHS OPERATIONAL TESTS

Advanced Traffic Management Systems

INFORM, Long Island, New York: INFORM integrates surveillance and control of three freeways, cross, and arterial streets. Traffic information is provided via Changeable Message Signs. This system is now operational.

TRANSOCOM, N. New Jersey/New York City Metro area: TRANSOCOM uses 1000 commercial vehicles equipped with ETM transponders as traffic probes, with readers placed at strategic locations to monitor speed. This project is currently in the preliminary design phase.

SMART, Los Angeles, California: In this project, traffic is monitored via an extensive network of inductive loop detectors. Changeable message signs, Highway Advisory Radio, and kiosks are used to pass congestion information to drivers. This system will be completed in 1993.

Guidestar, Minnesota: This program will evaluate multiple IVHS technologies. Program elements include traffic information systems for traffic managers and motorists, centralized integration/coordination of traffic signals, and traffic surveillance based on image processing. The program is currently in its early stages.

Satellite Communications Feasibility Study, Philadelphia, Pennsylvania: Satellite communications will be evaluated as a means of passing freeway surveillance and control data from the roadside to the local operations center, to include video images. The feasibility study will be completed in mid-1992.

Urban Congestion Alleviation Project, Northern Virginia: This is a small, initial effort to test the usefulness of a Video Imaging Detection System on a heavily traveled freeway bridge in monitoring traffic flow and detecting incidents. This system will be operational in mid-1992.

Multi-jurisdictional Live Aerial Video System, Montgomery County, Maryland and Fairfax County, Virginia: This system employs a video communications link from an aircraft down to a traffic operations center for these two counties which share a congested freeway. The system is expected to be operational in mid-1992.

Connecticut Freeway ATMS, Hartford, Connecticut: This is a statewide freeway surveillance and control program. Included in the project will be an evaluation of roadside mounted radar traffic detectors and CCTV for incident detection/verification. The program is currently in the preliminary design stage.

FAME, Seattle, Washington: This multi-faceted program includes a demonstration of an integrated system for a local freeway which automatically modifies arterial signal control timings in response to freeway conditions. This project is currently in its implementation phase.

Integrated System Project, Anaheim, California: This project addresses congestion in response to numerous area special events through the use of a computerized traffic control system, Highway Advisory Radio, CCTV, and changeable message signs, and electronic coordination with the regional State traffic operations center. This project is operational.

Advanced Traveler Information Systems

DIRECT, Detroit, Michigan: DIRECT will evaluate various low cost means of providing traffic information to motorists. These include Radio Data Systems (which transmit data on a subcarrier section of FM broadcast signals), Automatic Highway Advisory Radio, Highway Advisory Radio, and cellular phone. The experiment will use 30 specially equipped vehicles. The project is now in
a preliminary design phase.

**FAST-TRAC**, Oakland County, Michigan: FAST-TRAC is a combination ATMS/ATIS project. The ATMS is an advanced adaptive traffic control system, with traffic detection provided by video detection systems. Route guidance will be provided by a European ATIS system, which uses infrared beacons installed at key intersections. As the vehicle passes by each intersection, an optimum route is computed based on real-time traffic information transmitted by the beacon. This project is currently in the early negotiation stage.

**Commercial Vehicle Operations**

HELP/Crescent, Interstates 5 and 10 from British Columbia to Texas: HELP is an effort to implement an integrated heavy-vehicle monitoring system using AVI, AVC, and WIM technology along a major trucking corridor. The project includes approximately 40 equipped roadway locations; to date, 1,500 trucks have been equipped with transponders. The demonstration phase of HELP is called Crescent; Crescent will enter its evaluation phase in Spring of 1992.

Advantage I-75, Interstate 75 in Eastern U.S.: Advantage I-75 will use AVI, AVC, and WIM technology as well, with heavy vehicle monitoring performed through a decentralized management network in this case. This project is nearing completion of its preliminary design phase.

**Two-Way Messaging/Positioning Systems**: These systems are offered by the private sector. Satellite-based systems are used by long-haul truckers, and local fleets exchange data via mobile data nets. Generally, GPS is used to provide positioning. These systems have resulted in dramatic increases in fleet efficiencies.

**Advanced Public Transportation Systems**

Anaheim IVHS Operational Test, Anaheim, California: This project is geared at developing a real-time traveler information system for transit passengers. Information on traffic conditions will be provided by the area ATMS.

**Mobility Manager Demonstrations**: The "mobility manager" concept includes the linkage of various transportation providers to provide an integrated service, traveler information, and electronic fare media technology such as "Smart Cards." Market-oriented techniques are also being evaluated. The Federal Transit Administration (FTA) is sponsoring mobility manager projects in Kensington, Maryland; Rogue Valley, Oregon; and Norfolk, Virginia.

**Smart Bus Demonstrations**: "Smart Bus" technologies include the use of sensors at bus stops which would respond to an "emergency" button on a smart card to enhance personal security, bus fleet AVL systems, and traffic signal preemption systems for buses. FTA sponsored Smart Bus projects are underway in Portland, Oregon; Chicago, Illinois; and Ann Arbor, Michigan.

**Smart Traveler Demonstrations**: A variety of "Smart Traveler" projects are underway in Bellevue, Washington; the State of California; Houston, Texas; and St. Paul, Minnesota. Using mobile communications, rapid ridematching techniques to enhance carpooling are being investigated, as well as several traveler information systems and smart card techniques.

**Advanced Vehicle Control Systems: Current Research**

With respect to AVCS, the automobile manufacturers and other private entities are developing several types of collision warning systems, which will be eventually enhanced to become collision avoidance systems. Vision enhancement systems are also under development for night driving. In addition, the General Motors Research Labs have developed a computer vision system called LANELOK, which uses image processing of lane striping to maintain lateral position on a roadway.

AVCS research is a major component of PATH, a research program being conducted by a partnership of California universities, with government sponsorship. The PATH researchers have developed a "platooning" concept for high density automated highway operations, whereby groups of up to 15 vehicles follow each other at very close spacings. Techniques to facilitate both longitudinal and lateral control are being investigated. Small platoons have been run successfully on test tracks, and testing with larger platoons is ongoing.

The concept of a fully automated highway received a major boost in the ISTEA legislation, which requires that the Federal Highway Administration demonstrate a prototype automated highway in a test track environment by 1997. Thus, a major development program is now being initiated to meet this goal.

**CONCLUSION**

The Intelligent Vehicle Highway Systems development program is now firmly established in the United States, with significant resources being invested by Federal, State, and local governments and the private sector to implement the operational test and research projects described above. This program will continue to grow as a result of increased Federal funding provided in the ISTEA legislation. As IVHS systems move from testing into full scale deployment, safety, mobility, and air quality will be improved, enhancing the surface transportation system and thus the overall productivity of the United States.