Advanced Vehicle/Highway Systems and Urban Traffic Problems

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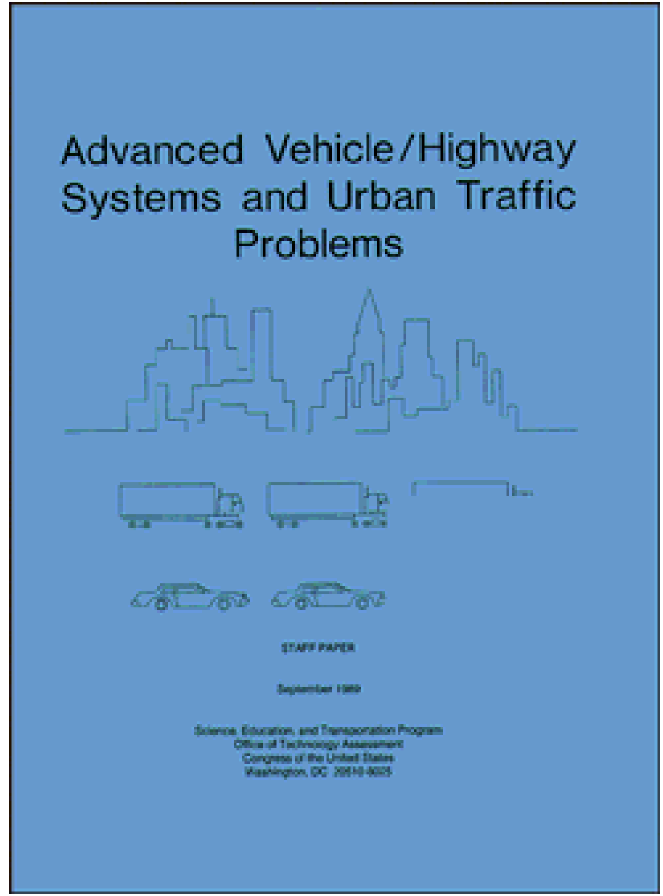

ADVANCED VEHICLE/HIGHWAY SYSTEMS AND URBAN TRAFFIC PROBLEMS

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Advanced Vehicle/Highway Systems and Urban Traffic Problems

SUMMARY

Traffic congestion plagues every major urban area in the country, costing millions of dollars annually in lost time from delays and contributing to serious air quality problems. While many approaches to these issues have been tried - including building more roads, creating high occupancy vehicle (HOV) lanes, and promoting car pooling and public transportation - none has achieved more than modest success. Advanced Vehicle/Highway Systems (AVHS), an umbrella term for several interdependent vehicle and road technologies, offer potential for reducing congestion and the air pollution it engenders, and for improving highway safety.

The term AVHS includes technologies for:

- automatic vehicle identification and billing;
- weighing vehicles in motion;
- collision warning and avoidance;
- driver information and route guidance
- advanced traffic operations control and optimization; and
- automatic vehicle control - both steering and headway.

OTA concludes that AVHS technologies now available can increase roadway efficiency and throughput by 10 to 20 percent, make travel time more predictable, improve safety, and cut down harmful emissions, although by themselves they cannot solve our urban traffic problems. If road capacity is increased and road travel made more desirable, more motorists can be expected to take to the roads, counteracting some reductions in congestion. If even moderate success is to be achieved in combating these issues in the near term, other strategies, such as car pooling, HOV lanes, use of alternative fuels, congestion pricing, and other forms of transportation systems management must also be pursued aggressively.

However, emerging AVHS pose no conflicts with other traffic management strategies, can be used in conjunction with them, and indeed, may facilitate certain aspects. These multiple benefits from AVHS argue for the immediate further development of AVHS and greater investment in research, development, and operational testing. More aggressive Federal leadership in organizing and supporting research could assist States and localities in addressing urban transportation infrastructure problems. States (notably California) and some universities have established cooperative public/private programs that provide good models.

OTA finds that substantial short-term national advantages could come from Federal policies and programs to encourage implementation of advanced traffic operations control systems. Through large-scale, high-profile, government supported research programs abroad, such as Prometheus and Drive in Europe and various others in Japan and other countries, foreign transportation research has advanced far beyond that in the United States in many areas. As AVHS technologies are implemented, extensive in-vehicle and roadside instrumentation will be needed. The size of this potential market and the strong priority given AVHS abroad raise concern that the United States will lose out in developing and producing "transportation electronics" products unless steps are taken soon.

Most in-vehicle systems are dependent for successful operation on beacons, detectors, and other components based in the infrastructure and usually supplied by the public sector. Without assurance that local or State governments will equip the transportation network with such beacons and detectors, manufacturers of in-vehicle systems are reluctant to press ahead, despite the threat of foreign competition. Existing limitations on the use of Federal grant money for these systems could be eliminated, and other types of urban transportation assistance could be made contingent on the installation of these systems. Federal policies could encourage and facilitate the necessary interjurisdictional coordination between agencies that manage freeway and arterial traffic.

Federal participation in testing and demonstration programs of vehicle identification, driver information, and collision warning and avoidance technologies could speed advancement of in-vehicle equipment. Government leadership in addressing standardization issues early would also aid development of these technologies. Finally, how drivers interact with AVHS technologies is not fully understood. Attention to safety and human factors is a top priority, and active participation in these areas by Federal agencies responsible for highway safety is warranted.

OTA concludes that Federal effort and dollars invested in assisting State and local governments in moving ahead with AVHS could do double duty. They could support much needed programs to address urban traffic congestion as well as boost industry by helping create the public infrastructure necessary to communicate with advanced products that are almost market ready.

Advanced Vehicle/Highway Systems and Urban Traffic Problems

INTRODUCTION

In February 1989, the Subcommittee on Transportation of the Senate Committee on Appropriations requested that OTA examine advanced vehicle and highway technologies and assess their potential to increase the capacity of the transportation infrastructure. This document examines a wide range of these technologies, but focuses on those commonly known as advanced vehicle/highway systems (AVHS) and on related technologies that affect or complement AVHS.

The term AVHS refers to advanced technologies that are applied to motor vehicle transportation and traffic operations, such as technologies for:

- automatic vehicle identification and billing;
- weighing vehicle in motion;
- collision warning and avoidance;
- driver information and route guidance;
- advanced traffic signal control and optimization;
- automatic incident detection; and
- automatic vehicle spacing – both steering (lateral) and headway (longitudinal).

AVHS does not include technologies used in vehicle manufacture, road construction, or mass transit system design and operations.

Domestic research in most areas of AVHS was active in the 1960s, but tapered off during the 1970s as funding and interest declined. Recently, AVHS has received renewal attention in the United States for several reasons. As air pollution and traffic congestion have worsened, many see AVHS as tools for increasing road safety, reducing traffic delay and incident response time, and increasing traffic capacity. Since a large portion of congestion is caused by accidents, significant benefits can result from reducing both the number of accidents and the time it takes to clear the roadway after an accident occurs - actions that do not require AVHS, but can be made easier by them. Others see AVHS as a means for reducing fuel consumption and air pollution, making commercial shipping more efficient, and easing the driving task for physically limited drivers. But perhaps the major reason for the renewed interest is the high level of attention being given AVHS by European and Japanese researchers. Europe and Japan both have high-profile government-sponsored research and development programs under way which include participation by industry and academia. As U.S. participation in these foreign programs is limited -- and, in some cases, prohibited - automobile manufacturers and technology experts familiar with AVHS raise concerns that the United States is falling behind in research and technology development. U.S. manufacturers fear that they will beat a competitive disadvantage relative to foreign firms when AVHS “products” enter the motor vehicle market.

AVHS TECHNOLOGIES AND APPLICATION IN THE UNITED STATES

AVHS technologies are generally divided into four subcategories’ -- advanced driver information systems, advanced traffic management systems (ATMS), automated vehicle control systems (AVCS), and commercial and fleet operations. These subcategories are interdependent and have substantial overlap. Thus, while it is possible to consider each AVHS category separately, the advantages of any single technology are multiplied when used in conjunction with technologies from one or more of the other categories. As one example, data gained from advanced traffic management systems could be converted to a form compatible with driver information systems and transmitted to motorists to provide current traffic information.

For this document, OTA has adopted a terminology and classification system similar to that used by groups such as Mobility 2000 (see p. 9), the U.S. Department of Transportation, and the transportation research community.

Advanced Driver Information (ADI) Systems

ADI systems give drivers current information on road and traffic conditions so that they can plan their routes to avoid areas of congestion. ADI systems range from one-way audio communications to interactive video communications, and some of the more advanced systems plan routes automatically after the driver has provided origin and destination information. The systems can be home-, office-, or vehicle-based. While they can operate independently, they are much more useful with information about the transportation infrastructure -- current roadway and traffic conditions.

Traffic reports on commercial radio stations represent the most basic of the ADI technologies. in limited use, ***highway advisory*** *radio* and its variations use dedicated frequencies (usually at the ends of the broadcast spectrum) to transmit traffic information. Tested, but never implemented, *automatic highway advisory radio* (AHAR) can automatically do some or ail of the following:

- signal the driver that an advisory notice is about to be broadcast;
- mute the program the driver is currently listening to; and
- tune the radio to the AHAR frequency.

Teletext and *videotex* systems, which have been used in Europe for route planning, are usually accessed from the home or office and provide travelers with written information on traffic conditions. interactive versions of such systems allow drivers to query databases for optimal path information and to receive written route instructions. *Vehicle-based navigation systems* automatically track vehicle location, and some, using computerized map bases, show the current location on an electronic map display of the surrounding area. When the driver enters origin and destination information, these systems can provide detailed advice on which streets to follow and when to turn. Enhanced versions of such devices that have communication links to the infrastructure are being developed; these allow the incorporation of current road and traffic information into route guidance.

Despite the diverse technologies involved in driver information systems, the systems all aim at warning motorists of congestion, so they can alter their routes or reschedule their trips to reduce tie ups. Similarly, navigation devices -- even those without communication links - have potential to reduce traffic congestion by informing motorists of routes that can minimize time spent and distance traveled.

Advanced Traffic Management Systems

ATMS include urban traffic control systems, incident detection systems, highway and corridor control systems, and ramp metering systems. Urban traffic control systems coordinate traffic signal operations throughout a given area based on traffic patterns as measured by detectors in the roadway. in the United States, highway control systems almost always remain separate from urban traffic control systems, and there are few integrated systems in place thus far. ATMS hardware consists of sensors, traffic signals, ramp meters, changeable message signs, and communication and control devices integrated into a single system. This allows for surveillance and control of traffic in areas so equipped. Because current traffic detectors, which are usually embedded in the roadway, are susceptible to frequent failure, new methods of measuring traffic are being investigated to improve the performance and reliability of the systems. These include among other technologies, infrared sensors and machine vision systems (video cameras linked to a computer that analyses the images to generate traffic flow and congestion information).[2]

One of the more advanced urban traffic control systems in place in this country is the Automated Traffic Surveillance and Control system (ATSAC), a computerized traffic signal control system installed by the Los Angeles Department of Transportation. Based on the Urban Traffic Control System Enhanced software package developed by the Federal Highway Administration (FHWA), ATSAC was put into operation several weeks prior to the 1984 Olympic Games. initial

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2. Panes Michalopoulos, Department of Civil and Mineral Engineering, University of Minnesota, and Robert Behnke, Research Administration and Development, Minnesota Department of Transportation, "Testing and Field implementation of the Minnesota Video Detection System," unpublished manuscript, n.d.

installation included 118 intersections and 396 detectors in a 4 square mile area centered at the University of Southern California and the Los Angeles Coliseum. It has since expanded to include areas of the San Fernando Valley and central business district for a total of 371 intersections. The airport and Westwood areas are targeted for later implementation, and by 1991, the system is expected to include 1,600 intersections. ATSAC is funded by a combination of FHWA, a traffic mitigation fund financed by developer fees, and distributions from the Petroleum Violation Escrow Account fund.[3]

ATSAC operators use color graphics workstations, which allow any portion of the surveillance area to be monitored at any desired level of resolution: from traffic flow data at the intersection level (such as volume and occupancy[4]) to a broader view of traffic behavior over a region. ATSAC gives the current status of any traffic signal in the network, allows manual override from the control center, and gives traffic flow data for any functioning pavement imp detector in the network. When first installed, ATSAC selected, usually by time of day, a signal timing plan out of a library containing several plans. It has since evolved into a system that automatically selects (and switches) timing plans by matching current traffic patterns against historical data. Fine tuning of signal operations can be accomplished by manual override or automated control of critical intersections. Critical intersection control allows the system to alleviate local congestion while still adhering to the overall strategy of the existing timing plan.

To assist in traffic surveillance and incident management, closed-circuit television cameras are being installed at important intersections. These cameras, which are controllable from the traffic control center, can pan and zoom to provide a wide area of coverage or a detailed view over a smaller area. They assist in incident management and provide visual confirmation of traffic behavior to the operators.

3. Edwin Rowe, Department of Transportation, City of Los Angeles, personal communications, Aug. 19 and Aug. 30, 1989.

4. Occupancy refers to the amount of time a vehicle spends over a detector.

A 1987 study to determine the traffic flow and economic benefits of using ATSAC concluded that significant improvements were attained in all areas measured: travel time (13 percent decrease), number of stops (35 percent decrease), average speed (15 percent increase), fuel consumption (12 percent decrease), and vehicle emissions (-10 percent). computerized signal control also provided rapid detection of faulty sensors and the identification of unusual traffic patterns due to incidents. Estimated cost savings to motorists (business and truck trips only) as a result of lower operating costs and time saved recovered the $5.6 million construction cost of ATSAC after only 8.6 months of operation. The annual operating costs are recovered with the first week of operation every year.[5]

One shortcoming of ATSAC for the greater Los Angeles area is that it relieves street congestion only. Freeway congestion is not monitored or controlled by ATSAC, since freeway traffic falls under the authority of the California Department of Transportation (Caltrans). Although some traffic coordination does take place between Caltrans and the City of Los Angeles, the lack of an integrated traffic management system has been a severe limitation to the system. Recognizing this, the major transportation agencies in the Los Angeles area initiated the Smart Corridor demonstration project (see p. 15), which will include selected city-operated surface streets and State-operated freeways in a single traffic management system. One of the few large scale systems in place in this country that manages both freeway and arterial-street traffic is Information for Motorists (INFORM), a traffic monitoring and control system along a 35-mile east-west corridor on Long Island. Other integrated systems planned or in progress are located in the States of Washington and Texas, and in Phoenix, Minneapolis, and Houston.[6]

Automated Vehicle Control Systems

Included in this category are collision warning and avoidance devices, of which radar-based ones are the best known, automatic headway (longitudinal) control, and automatic steering (lateral) control. Such systems are intended to automate all or part of a trip so that less driver action is

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5. Edwin Rowe et al., ATSAC Evaluation Study (Los Angeles, CA: City of Los Angeles, Department of Transportation, July 1987).
6. Lyle Saxton, Federal Highway Administration, personal communication, July 24, 1989.

required. While full trip automation is not expected within the next decade, stand-alone components of AVCS, such as collision avoidance and vehicle-following technologies (employing radar detection with automatic braking and "smart" cruise control) have been tested extensively and could be used in automobiles within several years.

Automatic headway and steering control should eventually provide substantial safety and throughput improvements. First, collision warning and avoidance devices can give drivers more time to respond to hazardous situations, thus reducing accidents. Second, groups of vehicles equipped with reliable headway control devices could increase traffic throughput because less space between vehicles would be needed, allowing vehicles to travel at higher speeds than are safe under current highway conditions. In addition, "rear enders" could be almost eliminated, increasing safety and reducing accident-related congestion. Automatic steering control has the potential to hold vehicles at lane centers more reliably than human drivers and thus permit an increase in the number of lanes without widening roads in congested urban areas. However, several safety issues must be addressed by research on these technologies; these include problems stemming from sudden vehicle mechanical failure (such as flat tires) from unexpected driver incapacity due to illness or other factors, and from accidents that occur for other unforeseen reasons.

Commercial and Fleet Operations

Included in this category are automatic vehicle identification (AVI), weigh in motion (WIM), automatic vehicle classification, and automatic vehicle location (AVL). AVI systems most commonly use vehicle-based transponders (radio- or microwave-based), which can be "read" by equipment at fixed points. The readers can be placed along a route or at a facility where information needs to be exchanged or billing needs to take place (such as bridge or toll road entrances and exits, weigh stations, and ports of entry). Additional AVI technologies include optical and infrared systems, inductive loop systems, and surface acoustic wave systems. AVI-equipped vehicles need not slow down for data transfer, and since most present toll booths and State ports-of-entry require commercial vehicles to stop, widespread AVI implementation should reduce delay at bridges, toll roads, and State boundaries. AVI could also be used to control access to parking facilities and other restricted areas and to provide traffic data for travel flow and congestion monitoring.

AVI technology is being implemented in several areas of the country and is primarily used for automated toll collection. An example of this type of application is the toll collection system now being implemented in Northern Virginia on the Dulles Toll Road. Subscribers to this system will have their vehicles fitted with transponders. When a subscriber's vehicle passes through the toll plaza along one of the dedicated AVI lanes, power emitted from an in-pavement microwave antenna activates the transponder, which then emits a signal identifying the vehicle, The subscriber's prepaid toll account is then debited electronically. Tests of similar systems have been performed at the Coronado Bridge in San Diego, the Mississippi Bridge into New Orleans, the Lincoln Tunnel, and the Dallas North Tollway (in full operation as of July 31, 1989).[7]

WIM systems weigh heavy vehicles as they are moving. They use road-mounted sensors that determine vehicle weight by taking into account axle weights, vehicle length, and vehicle speed. By also calculating axle spacing, WIM devices can classify vehicles and determine their compliance with weight standards. Technologies used for WIM include piezoelectric sensors, deep pit systems, shallow weighscale systems, bending plate systems, and bridge systems. The most accurate WIM systems currently have accuracies within 10 percent of true vehicle weight, limiting their usefulness for enforcement purposes.[8] Vehicles under a prescribed weight can pass, but vehicles near or above that weight must stop at weigh stations for more accurate measurements. However, information about truck weights provided by existing WIM systems has already proven useful for highway research.

AVL systems currently have their primary application in commercial fleet operations, although public fleets such as police, public transit, and emergency vehicles could also benefit. They typically identify vehicle location and transmit it to a central location for monitoring or dispatch purposes. An AVL system consists of equipment that locates the vehicle - usually based on dead reckoning, map

7. Amtech Systems Corp., Dallas, TX, informational document, September 1988.
8. Neil Emmett, Castle Rock Consultants, personal communication, Apr. 28, 1989.

matching, proximity to roadside beacons, or radio determination -- and mobile communications equipment that relays this information to the central location. AVL can provide real time information on shipment status and eliminates the need for (time-consuming) driver-to-control-center communication.

CURRENT AVHS RESEARCH IN THE UNITED STATES

Although there has been little formal national coordination of AVHS research and development, some State departments of transportation and cities have participated in AVHS research and implemented AVHS technology. Early regional and jurisdictional programs were in the areas of urban traffic signal control and automatic vehicle identification. in 1987, prompted by European and Japanese industry/government programs and by Caltrans in the United States, representatives from universities, industry, and Federal, State and local governments organized an effort to exchange information and define research needs. This group has evolved into Mobility 2000, an informal association of individuals interested in advanced transportation technologies that has focused on organizing research efforts to avoid duplication and on promoting a national cooperative program in AVHS. An assessment of AVHS is about to be undertaken by the Transportation Research Board (TRB), to develop recommendations for the staging of new systems and necessary research and development.

Because no large-scale national research effort has previously existed for AVHS, research has taken place on different categories of AVHS at a variety of universities. Most funds have been provided by State departments of transportation, FHWA, and industry. Four major U.S. Department Of Transportation (DOT) transportation centers are currently involved in AVHS research -- the University of California at Berkeley, the University of Michigan, the Texas A&M University System, and the Massachusetts institute of Technology (MIT); AVHS work is ongoing at other universities as well -- the University of Texas at Austin and the University of Minnesota, for example.

California currently has the most active research program. The California Program on Advanced Technology for the Highway (PATH) was established in 1986 by Caltrans at the Institute of Transportation Studies of the University of California at Berkeley. The major research areas of PATH are roadway electrification, vehicle automation, and navigation systems. Demonstration and testing are important priorities of these efforts, and special test facilities in Richmond, San Diego, and possibly Davis will be used for field experiments. The Richmond site will consist of a test track to be used for roadway electrification experiments, and the San Diego site will consist of a segment of Interstate 15 to be used for highway automation experiments. Portions of the street network surrounding the Richmond site will be linked to the site and used for low-speed navigation and longitudinal and lateral control experiments. A 2,500-mile road test of a radar braking-equipped vehicle is also planned. Funding for PATH, totaling $11 million, comes from FHWA, the Urban Mass Transportation Administration, and Caltrans. Additional sponsorship is being sought from the California utility industry, the automotive industry and other private sector groups, and the U.S. Department of Energy.[9]

The University of Michigan began planning its AVHS research program 2 years ago. The program is a joint effort of the University of Michigan Transportation Research institute and the College of Engineering. Its research covers four areas: traffic science, human factors, communication system architecture, and collision avoidance. There are currently plans to establish a metropolitan Detroit field laboratory for experimentation with various AVHS packages. Public sponsors of the Michigan research are the Michigan DOT, FHWA, the National Highway Traffic Safety Administration (NHTSA), and Transport Canada. Private sponsors committed to date are primarily automobile manufacturers and electronics companies.[10]

Texas A&M's Texas Transportation Institute (TTI) has two major AVHS projects under way. The first project involves research in traffic modeling, traffic signal control, and communication between vehicles and signal systems. The goal of this project is to develop an adaptive, real-time

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9. Institute of Transportation Studies, University of California at Berkeley, "California Program on Advanced Technology for the Highway (PATH)," brochure, January 1989.

10. Robert D. Ervin, University of Michigan Transportation Research Institute, personal communication, Aug. 29, 1989.

traffic signal control system. The second project, the goal of which is to develop an autonomous vehicle, involves research in automatic vehicle control, sensing, and machine vision. The idea is to develop a vehicle capable of planning its own route and executing this plan while still taking into account external factors, such as stop signs and other vehicles. While TTI is funded at about $15 million annually, its AVHS work accounts for only about $250,000 of this. The Texas State Department of Highways and Public Transportation contributes $200,000 for the AVHS research described above while FHWA and NHTSA each contribute $25,000. These same organizations, plus the National Cooperative Highway Research Program, fund about 90 percent of TTI's overall research. [11]

MIT's Center for Transportation Studies is conducting AVHS research in a variety of areas, although the program is in an early stage of development. One project, to be undertaken jointly with the Massachusetts Department of Public Works (MDPW), will focus on congestion reduction technologies for the Boston metropolitan area: bus guideway systems, driver information systems, and advanced traffic management and control systems. One goal of this work is to establish guidelines for a demonstration program. Another project, funded in part by FHWA, will assess the potential role of MIT and the State of Massachusetts in a national cooperative AVHS research program. NHTSA is providing funds for a project at MIT to assess the European DRIVE and PROMETHEUS programs (see pp. 17 & 18). NHTSA is also sponsoring work that will investigate advanced driver information system (ADIS) technologies and human factors in collision avoidance. Finally, as the lead university of the Region 1 University Transportation Center, MIT is supporting research on information technology and route guidance systems. State support is coming from the MDPW; Federal support is coming from FHWA, NHTSA, and the University Transportation Centers Program; and private sector seed support is coming from the UPS Foundation.'*

G. Sadler Bridges, Texas Transportation Institute, The Texas A&M University System, personal communication, July 7, 1989.

12. Joseph M. Sussman, Center for Transportation Studies, Massachusetts Institute of Technology, informational document, n.d.

FHWA and Other Federal Funding

FHWA's role in AVHS research and development has been largely indirect. There is an increasing trend toward joint sponsorship of research projects, with FHWA being one of many funding sources, in conjunction with others, such as State departments of transportation, matching highway trust fund monies, Highway Planning and Research allowances, and private sources. FHWA sponsors AVHS research and development through its Office of Safety and Traffic Operations Research and Development, which is part of the Office of the Associate Administrator for Research, Development, and Technology. The Office of Implementation conducts technology transfer and implementation (for example, test and evaluation of prototype systems). Estimated FHWA funding for AVHS totaled $2.5 million in 1966. Most of this amount came from the contract research program. Approximately $1 million was appropriated directly to PATH, and the rest was distributed among two research efforts known as High Priority National Program Areas (HPNPA). These are 3- to 5-year projects aimed, respectively, at supporting ADIS and freeway control system research. HPNPA funds support, and are coordinated with, directly related State and university research and demonstration projects. However, the contract research program is not the traditional funding source for these activities. '3

NHTSA provided grants for a broad range of AVHS research in 1966, including projects at the University of Michigan, MIT, The Texas A&M University System, and the University of Iowa. The Iowa project is coordinated by the National Science Foundation and is intended to determine the feasibility of constructing a driving simulator capable of reproducing the motions motorists feel while driving. NHTSA is also supporting a TRB assessment of AVHS. With FHWA and Caltrans, NHTSA is supporting a California project to evaluate collision avoidance radar and headway control systems. Finally, NHTSA is collaborating with FHWA in a project to develop human factors guidelines and evaluation methodologies for in-vehicle information systems. Table 1 summarizes FHWA and NHTSA funding for AVHS in 1988.[14]

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13. Saxton, op. cit., footnote 6.

14. National Highway Traffic Safety Administration, "NHTSA IVHS Activities -- Ongoing and Planned," informational document, n.d.

Table 1.- Department Of Transportation AVHS Funding in 1988

Recipient or co-participant	Purpose	Amount
NHTSA Funds		
University of Michigan	Seed money	$25,000
MIT .	Seed money	$25,000
The Texas A&M University System	Seed money	$25,000
Caltrans, Ford, and Radar Control Systems, Inc.	Evaluate collision avoidance radar and headway control systems	$100,000
University of Iowa	Feasibility study of driving simulator	$100,000
Transportation Research Board	Assessment of AVHS technologies	$85,000
Federal Highway Administration	Develop human factors guidelines and evacuation methodologies for in-vehicle information systems	$250,000
FHWA FUNDS		
California Program on Advanced Technology for the Highway (PATH)	Congressional directive	$970,000
AVHS research	Contract research	
Freeway management R&D		$300,000
Traffic computer simulation R&D		$200,000
Pathfinder cooperative experiment		$350,000
Advanced driver information systems R&D		$500,000
Other imperative and miscellaneous R&D		$150,000
Selected examples from among these AVHS research projects		
University of Minnesota	Machine vision for traffic detection	$253,000
University of Texas	information approaches to improve transportation system performance and technological, engineering, and economic feasibility of a high-speed corridor	$230,000
Transportation Research Board	Assessment of AVHS technologies	$85,000

Technologies Currently Under Research

HELP Program

HELP (Heavy Vehicle Electronic License Plate) is a research and demonstration program intended to develop and test a variety of AVHS technologies: AVI, WIM (including automatic vehicle classification), satellite datalinks, and data communication networks. Additionally, it is intended to show the compatibility between heavy vehicle management technology and many institutional and administrative regulations within and between States. HELP and its demonstration component, the Crescent Demonstration Project, have the following goals: assess the viability of the technologies, improve institutional arrangements (e.g., "one-stop service" for permits and fees; interstate and international border crossings, safety regulations, and tax requirements), measure efficiency and productivity, and identify additional applications of the technologies. An additional motivation behind the HELP program is to develop performance specifications for future heavy-vehicle AVHS work. [15]

initiated in 1963 by representatives of the Arizona and Oregon Departments of Transportation, the program has expanded to include many participants from across the United States and Canada: 13 States (their departments of transportation and motor carrier representatives), Transport Canada, the province of British Columbia, and the Port Authority of New York and New Jersey. The demonstration corridor will run down the West Coast along interstate 5 and across to Texas along Interstates 10 and 20. Demonstration managers hope to include 5,000 trucks. The following features will be evaluated: 1) bypassing of weigh stations and ports-of-entry by AVI-equipped trucks; 2) compliance checking and permit and fee processing at highway speeds; 3) monitoring of hazardous materials; 4) vehicle taxation; 5) size, weight, and speed enforcement; and 6) State data collection for facility planning and management. HELP is funded by each participating State. The Canadian and U.S. portions of the project will be coordinated but funded separately, that is, British Columbia is paying only for the portion of the work in that province.[16]

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15. C. Michael Walton, Department of Civil Engineering, University of "Texas at Austin, personal communication, Apr. 26, 1969.

16. C. Michael Walton, "Advanced Heavy Vehicle Management Systems," informational document, n.d., and personal communication, Aug. 31, 1969.

Smart Corridor

The Smart Corridor project, a major California effort funded by the State and local governments, will test the effectiveness of integrating vehicle navigation, traffic monitoring and control, and communications technologies over an area along the Santa Monica Freeway and arterial streets known as the Smart Corridor. The project will use highway advisory radio broadcasts, changeable message signs, menu-driven telephone information systems, and videotex to provide current traffic information to motorists along the demonstration corridor. The major goals of the Smart Corridor are to achieve full instrumentation of the corridor; assess how motorists change their driving behavior when given current traffic information from a variety of sources; implement improved traffic management strategies such as route diversions, and link the traffic monitoring and control systems of several organizations, including Caltrans, the California Highway Patrol, the Department of Transportation of the City of Los Angeles, the Los Angeles Police Department, and the Southern California Rapid Transit District. '7

In the Pathfinder demonstration project, a part of the Smart Corridor project, 25 vehicles will be equipped with dead reckoning, map matching, navigation devices, and have communication links to a traffic control center. The navigation devices will thus be capable of displaying current traffic congestion and incident information (as transmitted from the traffic control center) on their electronic maps. Drivers will be selected to represent a cross-section of the population, and their route selection (and modification) behavior will be studied closely. The goals of Pathfinder are to assess the value of "dumb" navigators, which have no communication links; assess the value of "smart" navigators, which can display areas of expected delay; and assess the value of using navigator-equipped vehicles as traffic flow sensors for central traffic monitoring and control.[18] pathfinder is funded by Caltrans, FHWA, and General Motors at a level of $1.6 million, plus General Motors' contribution of vehicles and consulting services.

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17. Rowe, op. cit., footnote 5.
18. Robert E. Parsons, director, Program on Advanced Technology for the Highway, Institute of Transportation Studies, University of California at Berkeley, testimony before the House Subcommittee on Transportation, Aviation, and Materials, Committee on Science, Space, and Technology, June 7, 1989.

AVHS ABROAD

AVHS activity in many other countries is better organized and coordinated and has greater government and private sector support than in the United States, in large part because of severe urban traffic congestion problems caused by increased automobile ownership and old urban road systems built to handle far fewer cars. The urgent need to keep vehicles moving has focused research and development and led to recent advances in AVHS, especially in Europe and Japan.

AVHS in Use

One of the most advanced automated traffic signal control systems is the Sydney Coordinated Adaptive Traffic System (SCATS), based on a computerized version developed in the 1970s by the Department of Main Roads, New South Wales (Australia). Originally implemented in Sydney, SCATS is now used in several cities in Australia and New Zealand, and in Shanghai and Singapore. It uses the same sensing and control technology as Los Angeles' ATSAC, but differs in its underlying control philosophy. Instead of selecting predetermined timing plans based on time-of-day or traffic pattern matching and adjusting signal timing at critical intersections only, SCATS is fully adaptive and continually adjusts traffic signal operations "on the fly" to match moment-to-moment demands of road traffic.[19]

Just as in the case of ATSAC, the SCATS implementation produced dramatic improvements in travel time (23 percent decrease), vehicle stops (46 percent decrease), and fuel use (12 percent decrease), as compared with uncoordinated signal control.[20] However, it is unclear whether SCATS' fully adaptive control philosophy produces significant benefits over a sophisticated use of

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19. Department of Main Roads, New South Wales, Australia, "SCATS: Sydney Co-ordinated Adaptive Traffic System," brochure, September 1983.

20. Ibid.

predetermined timing plans, as in ATSAC. Studies conducted in 1984 on the Melbourne implementation of SCATS showed mixed results: fully adaptive control gave slightly better results on main arterials, and predetermined timing plan control gave slightly better results on side streets.[21]

The British SCOOT (Split, Cycle time and Offset Optimization Technique) system is another advanced urban traffic control scheme. A collaborative project between the Transport and Road Research Laboratory and three traffic signal companies -- Ferranti, GEC, and Plessey - SCOOT was first installed in Glasgow in 1975. Like SCATS, it is traffic responsive and automatically adjusts signal timings. Assessments conducted in Glasgow and Coventry showed an average savings in delay of 12 percent compared with pm-calculated, fixed-time, signal control systems.[22] SCOOT is operational in about 30 cities in the United Kingdom, Hong Kong, Beijing, and Red Deer (Canada) .23

While not ail urban traffic control systems in other countries are as advanced as these, a significantly greater proportion of cities abroad have traffic-responsive systems in place than do cities in the United States.

Research

Europe

The two largest European AVHS programs are PROMETHEUS (Programme for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe); both include government and private sector funding and research. PROMETHEUS is part of the Eureka collaborative European research and development (R&D) initiative aimed at boosting European competitiveness. Thus, a main objective of PROMETHEUS – in addition to efficiency and safety -- is a stronger European position in the automotive electronics market, and U.S. participation is prohibited PROMETHEUS is an 8-year research effort expected to

21. B.J. Negus and S.E. Moore, “The Benefits of SCRAM: The Maroondah Highway Survey,” ARRB Proceedings, vol. 12, part 4, 1984.
22. R. D. Bretherton et al., Transport and Road Research Laboratory (UK), “The Use of SCOOT for Traffic Management,” presented at the Second International Conference on Road Traffic Control, London, 1988.
23. K. Wood, Transport and Road Research Laboratory, Department of Transport (UK), personal communication, June 28, 1989.

cost $800 million. Participants include most of the major European-owned automobile manufacturers; more than 70 research institutes and universities from West Germany, France, the United Kingdom, Italy, and Sweden; and more than 100 electronics and supplier firms. Industry research will focus on electronic driver aids, vehicle-to-vehicle communications, and vehicle-to-road communications. The universities and research institutes will focus on basic research in artificial intelligence, in-vehicle processing hardware, communications methods and standards, and evaluation methodologies. The breakdown of research expenditures by country will be as follows: Germany 40 percent, France 25 percent, Italy 20 percent, Sweden 10 percent, and the United Kingdom 5 percent.[24]

PROMETHEUS' active research phase began In 1988 and is scheduled to last until the end of the program in 1994. This phase will include projects designed by the participating companies and intended to show technical feasibility of the various AVHS technologies. Since the final result envisaged for each project is a commercial product, many projects will remain proprietary to the individual companies.

Other Eureka projects include CARMINAT, DEMETER, ERTIS, EUROPOLIS, and TELEATLAS. CARMINAT, sponsored by Renault and Philips, focuses on real-time driver information aids. DEMETER and TELEATLAS are developing digital map base technologies, ERTIS is developing AVL and other telecommunications technologies, and EUROPOLIS is concerned with traffic monitoring and control.[25]

DRIVE is a 3-year collaborative R&D program focused on technologies for road infrastructure rather than on in-vehicle technologies. In fact, many PROMETHEUS projects related to road infrastructure and traffic management have fallen under the management of DRIVE. DRIVE'S goals are to improve road safety, improve transport efficiency, and reduce environmental pollution, and the effort is funded half by the Commission of the European Communities and half by government and

24. Andrew Graves, University of Sussex, Science Policy Research Unit, "PROMETHEUS: A New Departure in Automobile R&D?" unpublished manuscript, May 1989.

25. Robert L French, Robert L. French & Associates, "Monthly Letter Report on Automobile Navigation," December 1988.

industry of participating countries. To be eligible for DRIVE sponsorship, a project must include participation from at least two member states, and one participant must be a commercial entity. Currently, DRIVE research projects are funded at $140 million, including industry support.

An example of European driver information system research is Leit- und Informationssystem Berlin (LISB), or Berlin guidance and information system, a large-scale demonstration project similar to Pathfinder. About 500 vehicles equipped with navigation and communication devices are guided through a road network comprising almost the entire area of West Berlin: 3,000 kilometers of road, 4,500 intersections, and 1,300 traffic signals. Of the signal-equipped intersections, 250 have infrared beacons capable of transmitting traffic and guidance information to, as well as receiving information from, the on-board navigators. Plans for the ongoing field trial include adding 200 more vehicles and continuing until September 1990, when a final report describing technical feasibility, driver acceptance and benefit, traffic flow benefits, and strategies for standardization and introduction of similar systems in West Germany and Europe will be issued. LISB is sponsored by the West German Federal Ministry of Research and Technology, the Berlin Senate, Siemens, and Bosch. Equipment is supplied by BMW, Daimler Benz, Opel, Mannesmann/Kienzle, and Volkswagen.[26]

Autoguide is the City of London's adaptation of LISB and uses virtually the same technology. The area covered by Autoguide consists of 4 square miles in the Westminster section of London as well as a corridor between Westminster and Heathrow Airport. It includes five beacons and is currently in the demonstration phase. The demonstration project is being supported by motoring organizations, equipment suppliers, transportation engineering consultants, London Buses, British Airports Authority, and United Kingdom motor manufacturers. Private sector sponsorship is planned for a pilot system, which is expected to involve 1,000 vehicles and up to 300 beacons, and cost 5 to 10 million pounds sterling.[27]

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26. Siemens AG, "LISB Leit- und Informationssystem Berlin," brochure, n.d.
27. United Kingdom, Department of Transport, "Guidelines for Pilot Autoguide System Proposals," brochure (Annex 3), January 1989.

Japan

Japan has two major AVHS research projects: Road/Automobile Communication System (RACS) and Advanced Mobile Traffic Information and Communications System (AMTICS). RACS is a joint program of the Public Works Research institute of the Ministry of construction and 25 private companies. Its goal is to establish a roadside beacon-based driver navigation and communication system. The system has three major components: navigation, traffic information, and individual communication. Navigation is performed by vehicle-based dead reckoning units. Positional error is corrected using map matching or beacon referencing. Road traffic and parking space information is communicated to the driver by roadside beacons, which are linked to a central information center. Based on the driver's destination, the navigation unit selectively passes on information from the beacon to the display screen. individual communication is also accomplished with beacons. When the vehicle passes each beacon, high-speed data transfer is possible. This enables paging, facsimile transmission, and various other bidirectional communication services between the vehicle and the environment. Tests of the system started in March 1987 in a region covering parts of Tokyo and Yokohama City.[28]

AMTICS is sponsored by the National Police Agency and the Ministry of Posts and Telecommunications. About 50 companies are participating through the Japan Traffic Management and Technology Association. Designed for route guidance and information in urban areas, AMTICS employs in-vehicle navigation devices that use dead reckoning with map matching. Rather than roadside beacons, AMTICS uses teleterminals (similar in operation to cellular radios) for communication between the navigation units and the traffic control center. A pilot test of this system is underway in Tokyo.[29]

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28. K. Takada and T. Wada, "On the Progress of Road/Automobile Communication System," presented at the First International Conference on Applications of Advanced Technologies in Transportation Engineering, San Diego, CA, February 1989.

29. Robert L. French, Robert L. French & Associates, "The Roles of Cooperative Programs in Developing Vehicular Navigation and Route Guidance Systems," presented at the First international Conference on Applications of Advanced Technologies in Transportation Engineering, San Diego, CA, February 1989.

CONCLUSIONS

AVHS encompass a wide and complex variety of technologies, such as artificial intelligence, image processing, machine vision, expert systems, advanced materials, and microelectronics. The status of various AVHS technologies in the United States may be found in table 2. OTA concludes that, although by themselves they cannot solve our urban traffic problems, AVHS technologies offer significant potential for:

- increased throughput and efficiency;
- more predictable travel time; and
- greater safety for all motor vehicles; as well as
- greater productivity and efficiency for commercial and fleet operations.

if employed with adequate attention to human factors, driver information and collision avoidance technology can speed travel by preventing accidents and resulting congestion, and improve safety by warning motorists of hazardous road and traffic conditions so they can respond accordingly. Sufficiently advanced automatic vehicle control technologies can respond even when appropriate action is not taken by motorists. in the area of commercial and fleet operations, AVI, AVL and WIM technologies have already been shown to improve efficiency by reducing administrative stop times and enabling effective distribution of fleet vehicles.

Experts predict throughput increases in the range of 10 to 20 percent, with commensurate reductions in delay and travel time, if existing, information-level AVHS technologies are implemented. However, if road capacity is increased and road travel made more desirable, more motorists can be expected to take to the roads, counteracting some reductions in congestion. Consequently, even in the most optimistic of scenarios, reductions in traffic congestion attributable to current AVHS technologies may turn out to be modest. AVHS is thus by no means the short-term answer to the Nation's urban congestion (and vehicle-caused air pollution) problems. if even moderate success is

Table 2.-- Status of AVHS Technologies

System	Capabilities	Technologies	Status	Current limitations
Automatic Vehicle Identification (AVI)	Exchanges data between vehicle and roadside reader	Radio frequencies; magnetics; optics; ultrasound	Used on some toll roads and bridges (Coronado Bridge, Dallas North Tollway, Lincoln Tunnel)	No standardization
Weigh in motion (WIM)	Determines weight of moving vehicle	Piezoelectric; bending plates; capacitive systems; bridge systems; deep pit systems; shallow weighscale systems	Operational testing taking place at State ports-of-entry (Crescent demonstration)	Accuracy limited to 10%
Automatic Vehicle Location (AVL)	Signals location of vehicle over a wide area	Satellite; Loran-C; dead reckoning with map matching	In use in commercial trucking (Geostar, Qualcomm); public safety (Etak, Motorola)	
Urban traffic control systems	Monitors and controls traffic flow on freeways and arterials	Signal controllers; ramp meters; changeable message signs; loop detectors; video cameras	Most U.S. systems use fixed timing plans; Los Angeles' ATSAC system is traffic responsive	Conflicts of scope (e.g., one city's system may cause congestion in a neighboring community) and jurisdiction (freeways and arterials rarely included in the same system)
Vehicle navigation	Guides driver by electronic maps or audio instructions	(Augmented) dead reckoning; infrared; radio frequencies; magnetic markers	Systems with no links to the infrastructure are in use, mostly by fleets; Pathfinder project will test interactive capabilities of this technology	Real-time traffic information not yet incorporated into system
Collision warning and avoidance	Warns driver of impending collision; enhanced systems apply brakes when necessary	Radar; infrared; acoustic	Systems still under development	Not 100% reliable; radar does not detect nonmetallic obstacles
Lateral control	Steers vehicle automatically	Electric cable; magnetic markers; optical methods; radar	Technology still under development; public (automotive) use not likely for a decade or more; guided buses with dedicated guide-ways operational in West Germany and Australia	Not ready for implementation
Automated incident detection	Detects incidents automatically	Detection algorithms incorporated into urban traffic control systems; machine vision	Simple detection algorithms are used in some traffic control systems; machine vision system installed in Minneapolis	Technology still under development

to be achieved in combating these problems in the near term, other strategies, such as car pooling, HOV lanes, use of alternative fuels, congestion pricing, and other forms of transportation systems management must also be pursued aggressively.

The good news is that AVHS poses no conflicts with these other strategies, can be used in conjunction with them, and indeed, may facilitate certain aspects. For example, vehicle identification technology can be used in congestion pricing schemes and in the enforcement of HOV and other transportation systems management-type restrictions. Moreover, AVHS can bring about improvements in road safety and traffic flow regardless of future changes in urban living and working habits. OTA concludes that these multiple benefits from AVHS argue for the immediate further development of AVHS and greater investment in research, development, and operational testing. More aggressive Federal leadership in organizing and supporting R&D could assist States and localities in addressing critical, urban transportation infrastructure problems. States and some universities have established cooperative programs that provide good models (see table3 for an example).

The Federal Role

Of the many AVHS technologies, several are effective, stand-alone systems without significant standardization issues - specifically, traffic-responsive urban traffic control systems and radar-based collision warning and avoidance devices. Traffic-responsive urban traffic control systems are underimplemented in U.S. cities, and more widespread use could bring immediate road capacity increases for congested urban areas, a fact long-recognized in other countries. Additionally, these systems constitute a fundamental building block or base for AVHS technologies. Thus, OTA concludes that real, short-term national advantages could come from Federal policies and programs to encourage implementation of such traffic control systems. Restrictions on using Federal grant money for these systems could be eliminated, and other types of urban transportation assistance could be made contingent on the installation of these systems. In

Table 3.- Ongoing Research in Advanced Transportation Technologies at a Major University

Project description	Sponsor	Funding
In-vehicle guidance technology	State Advanced Technology Program	$125,000
2. Information and telecommunications approaches to improve transportation systems performance	U.S. DOT	$120,000
3. Research program on characterizing urban network traffic	Major automotive manufacturer	$300,000
4. Driver responses to traffic disruptions	State DOT	$205,000
5. Technological, engineering, and economic feasibility of a high-speed corridor	U.S. DOT	$110,000

SOURCE: OTA, based on State information.

many areas, coordination between systems in adjacent cities and between freeway and arterial traffic is essential. Federal policies could encourage and facilitate the interjurisdictional coordination necessary for such systems.

Complementary advanced driver information and automatic vehicle identification technologies compatible with these systems could lead to more and longer-term safety and capacity advantages. Radar-based collision warning and avoidance technologies promise substantial safety benefits, since they alert drivers to impending collisions, giving them more time to respond. However, an aggressive program of operational testing, demonstration, and investigation into associated legal issues is necessary before these devices can be implemented in everyday use. Liability concerns are raised by private sector developers of collision warning and avoidance devices. Federal participation in testing and demonstration programs of this technology could encourage further technical development and avenues for reducing manufacturers' liability risk. Government leadership in addressing standardization issues early would also aid development of these complementary technologies.

Market incentives are strong for private sector development of in-vehicle navigation devices, particularly those with communication links to the roadway. However, equipment manufacturers are keenly aware of the private sector risk associated with developing these devices, which are dependent for successful operation on beacons, detectors, and other components based in the infrastructure and usually supplied by the public sector. Without assurance that the State or local governments will equip the transportation network with such beacons and detectors, manufacturers are reluctant to press ahead, despite the threat of foreign competition.

Moreover, a second roadblock exists in the need to ensure that navigation maps accurately reflect the street network of a given city. New streets are constructed, existing streets become blocked off due to repair or other special circumstances, and existing streets become altered in unusual ways (one-way to two-way, or vice versa, for example). For safety and congestion reasons, it is important that information on such changes, which are typically coordinated by public sector agencies, be kept current and communicated in a timely manner.

Since market incentives for private sector development of much equipment are dependent on public sector programs, Federal dollars invested in assisting State and local governments could do double duty. They could provide assistance for much needed programs to address urban congestion as well as boost industry by helping create the public infrastructure necessary to communicate with products that are almost market ready. The California Smart Corridor project provides an admirable model of cost sharing for such programs between industry and Federal, State, and local government.

Automatic vehicle identification and automatic vehicle location are highly developed technologies that are already seeing widespread use. The diverse application of these technologies -- both public and private and in other modes of transportation -- calls for flexible systems that are compatible between modes, in different areas of the country (even in other countries), and in areas of application. The Federal Government could provide leadership for development of performance standards for AVHS equipment to ensure such compatibility.

Finally, how drivers interact with AVHS technology is not fully understood. The driving task may be sufficiently complicated by the introduction of in-vehicle devices that drivers become distracted and safety levels are reduced. Attention to safety and human factors is a top priority, and active participation in these areas by Federal agencies responsible for highway safety is warranted.