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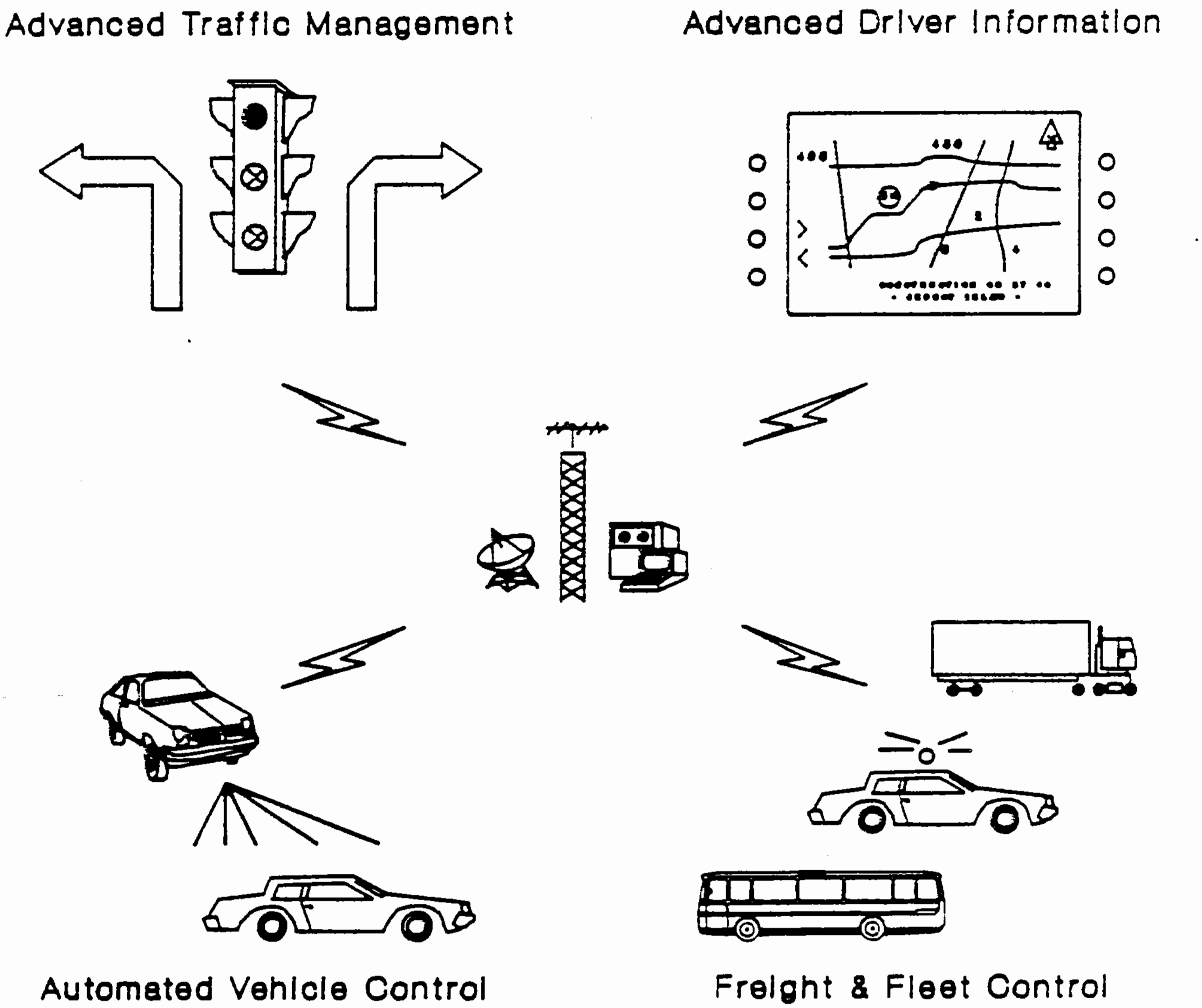
U.S. Department of Transportation
Office of the Secretary of Transportation

Report to Congress on Intelligent Vehicle-Highway Systems

March 1990



THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

March 14, 1990

The Honorable Robert C. Byrd
Chairman, Committee on Appropriations
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I have the pleasure of forwarding to you a report on Intelligent Vehicle-Highway Systems (IVHS), as required by the Conference Report on the Department of Transportation and Related Agencies Appropriations Act, 1989.

The report assesses ongoing European, Japanese, and U.S. IVHS research initiatives; it also analyzes the potential effects of foreign IVHS programs on the introduction of advanced highway technology in the United States and how it could affect domestic automobile manufacturers. The report concludes that IVHS technologies have the potential to reduce highway congestion, promote safety, and improve personal mobility and recommends that there be a national industry/government effort to promote IVHS technologies. We intend to bring together representatives of all sectors associated with IVHS development to discuss how best to proceed. Through a cooperative effort, we plan to discuss the agenda for research and development and major operational field demonstrations.

On May 15, 1989, we issued a Discussion Paper to solicit comments on a number of IVHS policy issues. A Federal Register notice was issued announcing the Discussion Paper and establishing a Public Docket to receive comments. Over 100 comments were received from other federal agencies, state and local governments, motor vehicle manufacturers, computer and electronics companies, transportation user groups, trade associations, university transportation researchers, and transportation consultants. The comments were overwhelmingly favorable to the idea of support for IVHS development.

I look forward to working with you in implementing the recommendations outlined in this report.

Sincerely,

Samuel K. Skinner

Samuel K. Skinner

Enclosure

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

March 14, 1990

The Honorable Jamie L. Whitten
Chairman, Committee on Appropriations
House of Representatives
Washington, D.C. 20515

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Office of the Secretary of Transportation

Report to Congress on Intelligent Vehicle-Highway Systems

March 1990

Office of Economics
Office of the Assistant Secretary
for Policy and International Affairs

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I. FOREWORD AND EXECUTIVE SUMMARY

The Conference Report on the FY 1989 Department of Transportation (DOT) Appropriations Act directs the Secretary of Transportation to report to the Congress on Intelligent Vehicle-Highway Systems (IVHS). The purpose of this report is to

-- assess ongoing European, Japanese, and U.S. IVHS research initiatives;

-- analyze the potential impacts of foreign IVHS programs on the introduction of advanced technology for the benefit of U.S. highway users and on U.S. vehicle manufacturers and related industries; and

-- make appropriate legislative and/or programmatic recommendations.

Chapter II describes what an IVHS is and why there has been growing interest in the development and use of IVHS technologies to improve the safety and efficiency of the highway system. Chapter III describes various IVHS technologies and discusses how each of them could affect highway travel. Chapter IV describes the major European and Japanese IVHS research programs. Chapter V describes IVHS programs now underway in the United States. Chapter VI discusses the effect of foreign IVHS programs on highway users and on U.S. motor vehicle and electronics companies; it also discusses the benefits domestic highway users could receive if IVHS technologies were widely adopted. The last chapter presents our conclusions and recommendations.

Unless improvements are made to the nation's highway system, the growth in highway traffic will increase congestion and reduce mobility. There will also be a sharp increase in accidents by the year 2020. Moreover, economic losses from accidents could exceed $100 billion per year. Even in those areas where congestion is not a major problem, the speed of automobile travel and complexity of the highway systems have left many drivers apprehensive about driving. Many drivers do not have the reflexes to take appropriate action in emergency situations. Of particular note is the growing number of older drivers. These drivers have slower reaction times and poorer vision than younger drivers.

In the commercial sector, traffic tie-ups caused by truck accidents are causing some local and state policy makers to consider restricting motor carrier access to some urban freeways. Shippers and motor carriers are also placing a higher premium on operating efficiency. Improvements in truck pick-up and delivery schedules and the ability of traffic managers to track trucks will generate better service for shippers and increased operating efficiency for trucking companies.

The DOT believes that the use of IVHS technologies can make an important contribution to alleviating these highway problems and improving personal mobility. While the application of advanced technology to the automobile and the highway is not a panacea for the nation's urban congestion and safety problems, IVHS technology has the potential to improve highway operations, increase the effective capacity of the highway system, and enhance motor vehicle safety.

Europe and Japan have focused, well-funded programs to develop, test, and implement IVHS technologies. Unless U.S. firms and the public sector become more involved in the development of IVHS technologies, the foreign programs now underway may give European and Japanese firms a long term competitive advantage over U.S. firms in manufacturing and marketing products that incorporate these technologies.

On May 15, 1989, the DOT issued a Discussion Paper to solicit comments on IVHS policy issues. A Federal Register Notice was issued announcing the Discussion Paper's availability and establishing a Public Docket to receive comments (see Appendix B.) One hundred and five (105) comments were received and placed in the Docket; 34 comments were received from state and local transportation agencies, federal agencies, and foreign government agencies; 18 comments were received from universities; 36 private companies responded; and 17 trade associations and highway users' groups submitted comments. There is widespread support for a national IVHS effort from private sector companies, state highway and transportation agencies, highway users' groups, universities, and private researchers. A summary of the comments is included as Appendix C.

Because of the potential benefits of IVHS and the competitive implications, we recommend that the federal government take a more active role in IVHS research and operational demonstrations. Federal participation, however, must be in the form of a public/ private cooperative partnerships, because of the industrial, technological, and commercial aspects of such a program. The DOT proposes that a national cooperative effort be established to foster the development, demonstration, and implementation of IVHS technologies. The principal federal role will be to coordinate and facilitate research and development, assist in the planning and conduct of demonstrations and other evaluative programs, coordinate the standards and protocols, and to participate in research directly related to our operating and regulatory responsibilities. Federal research will not be for hardware development; that is a private sector responsibility. A final federal function will be to work with state and local governmental units to encourage the prompt implementation of proven technology in the traffic management/safety areas. These public sector investments would be eligible, as they currently are, for federal aid financing.

There is a need to coordinate IVHS standards and protocols. A national cooperative effort would provide the forum for the identification, discussion, and enactment of national technical standards. Private firms, state and local governments, the National Telecommunications and Information Administration, the Federal Communication Commission, and the National Institute of Standards and Technology should participate in establishing these standards. It is desirable that any standards adopted in the United States be coordinated with those of other countries, especially Canada and Mexico. With a view toward establishing a unified North American standard for various IVHS elements, officials from the United States should discuss proposed standards with appropriate Canadian and Mexican officials. International cooperation in IVHS research could be beneficial, and we will be considering this issue further.

The DOT intends to bring together representatives of all sectors associated with IVHS development to discuss how best to proceed. Through a cooperative effort with interested parties, we plan to establish the agenda for research and development and major operational field demonstrations. We recommend this effort be funded by the private sector, state and local governments, and the federal government. For fiscal years 1990 and 1991, the DOT has included in its research program certain initial projects related to IVHS technologies. We anticipate that longer term federal funding for this effort will be addressed in upcoming reauthorization proposals for the DOT's highway construction, highway safety, and mass transportation program. At that time, we shall also address any legislative changes needed to promote a cooperative effort in the area of IVHS research and demonstration.

II. INTELLIGENT VEHICLE-HIGHWAY SYSTEMS: AN OVERVIEW

This chapter provides an overview of how IVHS technology may alleviate some of our nation's highway problems.

A. Technological Advances

Often referred to as "smart cars" and "smart highways," IVHS represents the marriage of the vehicle, the driver, and the highway. IVHS incorporates advanced communications technology, computers, electronic displays, warning systems, and vehicle/traffic control systems; IVHS technologies would allow two-way communications between highways and vehicle operators. Until recently, many of the IVHS technologies discussed in this report would have been hard to envision. But in the last few years there have been major changes in computer technology, communications, and electronics technologies that make it feasible to consider the use of IVHS technologies at a reasonable cost.

Microelectronics are becoming pervasive in motor vehicles. In the next decade, the value of vehicle electronics as a proportion of total vehicle costs is expected to increase from six percent to 20 percent. Indeed, the computer chips used in some automobiles today have the same power as IBM's original personal computer. More and more mechanically based systems are being controlled and/or replaced by more reliable and more flexible electronic systems, including automatic transmissions, power steering, power brakes, antilock brakes, fuel injection, and cruise control.

These advances in computers, electronics, and telecommunications have also led to the evolution of highway management systems in several metropolitan areas. Control of highway operations and highway safety are being improved through electronic detection, closed circuit television, radio, variable message signing, and ramp metering. Highway surveillance and control system technology make it possible to detect and rapidly clear incidents that now account for over half of vehicle delay in major metropolitan areas.

While much of the discussion in this report is about how IVHS technology would work and about information received by the vehicle operator, IVHS technologies could also allow travelers to receive traffic information in their homes. Travelers could then determine which route is preferable, whether to use public transit, or whether to carpool.

B. Current Trends In The Highway System

For the foreseeable future, highway travel is likely to remain the dominant mode of personal transportation. Highway traffic volumes are forecast to double on America's highway network from 1.9 trillion vehicle miles of travel (VMT) in 1988 to 3.8 trillion VMT in 2020. Unless improvements to the system are made, this growth in traffic will increase congestion and reduce urban and rural mobility. There will be a sharp increase in accidents with the possibility of 100,000 fatalities per year by the year 2020 (given today's fatality rates). Moreover, economic losses from accidents, which already exceed $100 billion per year, will increase.

Most Americans want to continue to rely primarily on their automobiles for their travel needs. Moreover, the movement of business to suburbs results in commuter and business travel patterns that are often not conducive to the use of conventional public transit. Thus the automobile will continue to be the primary source of mobility for most Americans.

Fresh approaches are needed to address the imbalance between road capacity and demand. New road capacity will continue to be built (especially in outlying suburban areas of growing metropolitan areas), but the high cost of both land acquisition and construction, and local opposition to further construction in major metropolitan areas will make this a less feasible alternative. We need to find ways to use existing highway capacity more efficiently. Solutions to road congestion must encourage greater use of public transit and ride sharing, as well as variable peak-load tolls and other non-traditional highway allocation techniques. Nevertheless, IVHS technologies could increase the capacity of the highway system.

Despite dramatic improvements over the last generation, highway safety remains a major concern. In terms of reducing the number of accidents, the greatest potential benefit of IVHS may occur in urban areas, while the greatest benefit of IVHS in terms of reducing the number of deaths and injuries is apt to occur outside of congested highways. Although most crashes occur in congested areas, most serious injuries and fatalities occur in non-congested areas. Only 12 percent of fatal crashes occur on interstate highways, freeways, and expressways. In fact, most crashes occur on roads with low speed limits.[1] Half of all fatal crashes occur on roadways with a speed limit less than 55 miles per hour, and almost one-third occur at intersections and other junctions.

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[1] Ninety percent of urban and 46 percent of rural crashes occur on roadways with speed limits below 50 miles per hour.

Even in those areas where congestion is not a major problem, many drivers are apprehensive about driving in certain sections such as on freeways and during night time and bad weather. Many drivers do not have the reflexes to take appropriate action in emergency situations. Providing more and better information and assistance to drivers can help to make all driving safer.

Of particular note is the growing number of older drivers in the population. In 1984, approximately 12 percent of the population was 65 or older; by 2020, it is estimated that this group will represent almost 20 percent of the population, or 51.5 million persons. More than 40 percent of these older Americans will be over 75. Many of these older Americans are and will continue to be dependent on the automobile. These drivers have slower reaction times and poorer vision compared to younger drivers. Increased driver automation and on-vehicle driver information and assistance systems could be particularly important to older Americans.

In the commercial sector, shippers and motor carriers will continue to place a premium on operating efficiency. Improvements in truck pick-up and delivery schedules and the ability of traffic managers to track trucks will generate better service for shippers and increased operating efficiency for trucking companies.

A major contributor to congestion in urban areas is the traffic delays caused by truck accidents. In one city, for example, a major truck semi-tractor incident occurs every three days, and two-thirds of these accidents cause a blockage of two or more lanes for a significant period of time. This has led some local and state policy makers to consider restricting truck operations on some urban freeways. Such regulations could reduce motor carrier operating efficiency. Implementation of appropriate IVHS technology could be a viable alternative to such restraints.

Commercial vehicle operations are subject to regulations on registration, permits, size and weight, operating hours, taxation, and vehicle safety. These regulations often entail controls, inspections, and monitoring by state, local, and federal officials. While such controls are necessary, they do impose compliance costs. IVHS technologies have the potential to reduce these costs.

Highway travel affects air quality and energy use. If traffic congestion is reduced, either absolutely or relative to what it otherwise would have been, there will be an improvement in air quality.[2]

There is a similar link between traffic congestion and fuel use. If drivers have and use better information on alternate routings or possible delays, travel time and trip circuity will be reduced. IVHS technologies could thus reduce fuel use.[3]

C. National Economic and International Concerns

As a society we need to be concerned whether we are devoting sufficient resources to maintaining the nation's infrastructure. The relative share of the nation's resources being devoted to public infrastructure affects U.S. productivity. Infrastructure requirements are a major focus of Secretary Skinner's National Transportation Policy Review. The adoption of IVHS technologies could be an important component of new transportation facility investments as the country moves into the 21st century.

Another issue that is beginning to receive more attention is whether U.S. firms are falling behind foreign firms in promoting new technologies and generating new products and services from these technologies. There is concern among some analysts and policy makers that this is occurring in the automobile industry as well. A concern over the loss of U.S. preeminence in automotive technology was a major theme of many of the comments submitted in response to the DOT's Discussion Paper.

Finally, there is the issue of whether foreign-developed IVHS technology would be appropriate for the U.S. highway system. This issue is discussed in Chapter VI.

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[2] To the extent that IVHS technology obviates the need to limit traffic, there could be some decline in air quality unless appropriate counter-measures are taken.

[3] Again, if the success of IVHS technology permits an increase in highway travel that would not otherwise be allowed, there may be a net increase in petroleum use.

III. TYPES OF INTELLIGENT VEHICLE-HIGHWAY SYSTEMS

IVHS technologies stem from advances in electronics, communications, and information processing. In this chapter, we describe various IVHS technologies and discuss how they could change highway operations.

A. Advanced Traffic Management Systems

Advanced Traffic Management Systems (ATMS) provide the means for local transportation officials to monitor traffic conditions, adjust traffic operations, and respond to accidents. They include traffic detectors, computerized traffic signals, adjustable speed limit signs, and changeable roadside information signs and lights. ATMS reduce traffic congestion and delays and permit shorter response times for local authorities to respond to traffic incidents. These systems can also improve the productivity of commercial fleets, enhance highway safety, produce energy savings, and improve air quality.

Twenty-nine (29) state-of-the-art systems are either under development or are operational in the United States. The implementation of state-of-the-art traffic management systems in metropolitan areas is necessary for the adoption of most of the IVHS technologies discussed in this chapter.

By providing early traffic incident detection and management and by redistributing traffic to less congested portions of the highway network, ATMS can influence vehicle operators' route choices. ATMS use sensors to locate disturbances in traffic flows and to identify congestion points and accidents. Working in concert with other traffic management techniques, including traffic signal timing, ramp metering, lane closures, variable speed limits, express and reversible lanes, ATMS are used to control traffic flows along freeways and corridors. Traffic advisories from traffic management centers can help prevent secondary accidents and direct vehicles away from congested areas.

Today, 80 percent of the existing 204,000 traffic signals at urban intersections operate under isolated intersection control or fixed-time coordinated control. Only about 20 percent of traffic signals in urban areas are under computerized control, which allows traffic signals to be adjusted when incidents occur.

A promising technology, adaptive traffic signal control, is now being developed. Systems employing this technology evaluate traffic conditions and implement new timing sequences so that the timing of traffic lights change as traffic conditions change.

Interactive traffic signal control, the next generation of traffic signal control, is still in the conceptual stage. Eventually, however, interactive traffic signal control systems will link real-time traffic monitoring, short-term travel forecasting, and electronic route guidance to integrate highway control and traffic signal control into an integrated traffic management system. Using information on traffic volumes and speeds, these systems will optimize signal timing; they also will provide route guidance to vehicles based on actual traffic conditions. These systems will also be able to predict the number and type of vehicles that will be on a particular route segment; they could also give special signals and instructions to different classes of vehicles.

An important element of ATMS is detection and response to traffic incidents. The average elapsed time between a minor traffic incident on an urban highway and its detection by local authorities is about 45 minutes. But even a minor traffic incident can increase congestion. By reducing the time between when an incident occurs and when local authorities respond to it, there is the potential to minimize traffic congestion; moreover, by allowing emergency vehicles to respond more quickly, fatalities might be reduced.

Another example of ATMS is the use of automated vehicle identification to smooth access to restricted highways. In particular, the use of vehicle identification is being implemented at a number of bridges and toll roads to provide for automated fare collection. Vehicles are equipped with a device that lets them pay on a periodic basis and pass through toll booths without stopping to pay the toll.

There are many other possible uses of ATMS. For example, vehicle identification devices could help locate stolen vehicles; they could be used to monitor restricted or hazardous cargoes; they could assist police, fire personnel, and other emergency vehicle operators identify hazardous cargoes; they could provide the means for implementing road pricing systems; and they could enhance personal security, especially for persons traveling late at night or along lightly traveled segments of a highway.

B. Advanced Driver Information Systems

Advanced Driver Information Systems (ADIS) provide drivers with information on congestion, navigation and location, traffic conditions, and alternate routes. The information could involve local accidents, weather and road conditions, alternate routes, recommended speeds, and lane restrictions. In consort with crash warning systems, information could be provided on potentially dangerous driver, vehicle, road, or environmental conditions. ADIS could also provide information that would assist the vehicle operator plan his or her trips.

There are a number of technologies available to provide drivers with such information. Some of these technologies use equipment external to the vehicle. For example, there are location and identification systems in use or under development relying on LORAN-C, GEOSTAR, or proprietary satellites. These systems use sophisticated triangulation techniques to determine vehicle locations. Other systems use "dead-reckoning" -- that is, the current location of a vehicle is computed by measuring the direction and distance the vehicle has gone from a known starting position.[1] Another type of ADIS near implementation is Traveler's Advisory Radio, which uses part of a FM radio signal to broadcast traffic information.

Specific types of ADIS technologies include:

- On-board replication of maps and signs;
- Pre-trip electronic route planning;
- Traffic information broadcasting systems;
- Safety warning systems;
- On-board navigation systems; and
- Electronic route guidance systems.

The on-board display of roadside signs would provide a safety and navigation benefit; such devices could replicate warning or navigational roadside signs that may be obscured during inclement weather or when the message should be changed, such as to lower speed limits during ice, rain, or snow conditions. Roadside information and warning signs displayed inside vehicles, would improve their effectiveness, especially for drivers with impaired vision or driving in bad weather. Messages could also be tailored to particular types of vehicles.

Safety warning systems can provide information critical to avoidance of crashes. These systems could provide proximity warning to avoid sideswipe and backup accidents resulting from blind spot problems. To ameliorate the problem of rollover with high center-of-gravity vehicles, devices would be used to sense and warn the driver that the vehicle is approaching rollover threshold. To address the problem of crashes due to driver distraction or impairment, safety warning systems could be used to sense and warn the driver of degraded performance. Information could be displayed from collision warning systems to warn of the presence of vehicles ahead of a driver to reduce both rear-end and frontal crashes related to drivers' limitations in judging the speeds and positions of the preceding or approaching vehicle.

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1 Dead-reckoning techniques eventually develop cumulative error. To correct this error, in some cases the dead-reckoning estimate is "map-matched" -- the estimate of the current position is matched to the closest point on a predetermined map. In other cases, the dead-reckoning position is corrected periodically through external information on a vehicle's actual location.

Route planning, improved maps, and more accurate and consistent signs can reduce trip distances and transit times. Pre-trip electronic route planning systems are being developed and are available at certain car rental counters. With these systems, the traveler's origin and destination are entered into a computer and a printout of directions is produced. For trip planning purposes, these systems can estimate minimum time, distance, or travel-related expenditures. Route-planning systems can also provide information on public transportation, including information on bus stop locations, schedules, and the location of subway and bus terminals.

Traffic information broadcasting systems provide information on traffic conditions, enabling drivers to alter their routes. With some systems, transmissions are received through car radios after drivers are alerted to turn the radio to a specific frequency. With other systems, special receivers must be installed. Existing examples of these systems include Highway Advisory Radio in the United States and the ARI (Autofahrer Rundfunk Information) system in Europe. Various traffic information broadcasting systems are being considered for use in the United States.

On-board navigation and location systems also provide information on video display terminals in the vehicle or use dashboard signals. More sophisticated systems, termed electronic route guidance systems, provide real-time information on traffic, road, and weather conditions and provide route guidance to the motorists that reflects real-time traffic conditions. These video display terminals show the highway network and the location of the traffic problems, allowing drivers to change routes and make more informed decisions.

The regional phone companies, IBM, Sears, AT&T, and many smaller companies are developing and implementing videotext systems and services for the home. These could be used to improve the transportation information base for individual mode and route choices.

C. Freight and Fleet Control Operations[2]

Included under this category are the technologies and fleet control operations intended to enhance the efficiency of operating trucks and fleets of vehicles. Such systems also improve the efficiency of regulatory compliance, vehicle inspection, and fleet

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[2] Some discussions use the term "Heavy Vehicle and Commercial Operations" (HVCO) in discussing these technologies. The two terms are generally interchangeable.

monitoring operations. Several of these systems are being used today.

Fleet management systems allow a central controller to know the location of the company's vehicles, to monitor their progress, and to communicate with them. Even though it requires substantial capital expenditures, many private transportation companies have decided that the benefits outweigh the costs of deploying IVHS vehicle location systems. If a publicly supported IVHS infrastructure is developed, it would be desirable for the private systems now in operation to be compatible with public systems. The cost of providing fleet management systems would be considerably reduced, facilitating implementation of such systems and providing productivity and safety benefits to a greater percentage of the commercial fleet.

Vehicles operating in a fleet often have different physical and operating characteristics than do passenger automobiles. When designing IVHS technologies, these differences must be taken into account. For example, any intelligent vehicle highway system needs to recognize operational limitations, such as width, length, height, or weight; it also needs to take into account regulatory restrictions, such as required routings of hazardous cargoes or local prohibitions on truck travel.

Trucking companies have supported the development of IVHS technologies. For example, a growing number of trucking companies have sophisticated satellite-based computer location and dispatching system. As another example, Federal Express is introducing a system to keep track of where its packages are, the amount of freight in its trucks, and to whom and when each package was delivered. Federal Express can monitor the progress of its vehicles and can adjust schedules throughout the day.

Fleets of vehicles can often be used to test IVHS technologies. The government should assist in setting standards and practices to promote IVHS technology.

D. Automated Vehicle Control Systems

Automated Vehicle Control Systems (AVCS) are those technologies that are designed to help the driver perform certain vehicle control functions. Using data collected by on-board sensors, AVCS provides information to vehicle operators which allows them to make decisions quickly and accurately or which allows appropriate action to be taken independent of the operator.

Driver performance is dependent on the quality and timeliness of the information the operator receives as well as how he or she responds to it. A driver must constantly assess his or her speed in relation to other vehicles and judge gaps for merging and passing; moreover, the driver must anticipate the actions of other vehicle operators and make decisions on the timing of lane changes, merging, and intersection maneuvers. Crash avoidance systems can provide vehicle operators with early warning of potentially dangerous situations. Crash avoidance systems include proximity warning to address sideswipe and backup accidents resulting from blind-spot problems, rollover threshold warning systems to address vehicle rollovers, driver inattention warning systems, and collision warning devices to reduce rear-end accidents.

Future AVCS technology will adjust vehicle control systems to account for changing operating conditions. Thus AVCS will prevent situations that would result in the driver losing control of the vehicle. Under most circumstances, the driver would not even be aware of the system's operation; the control system will simply intervene and manage critical operations.

At the most advanced level, AVCS would take over driving tasks on dedicated highways. Vehicles could operate automatically on these highways at relatively high speeds with minimal personal intervention. Such systems offer the promise of substantial gains in highway productivity and safety.

A number of AVC technologies available or under development include:

- o Antilock braking systems;
- o Speed control systems;
- o Adaptive speed control;
- o Driver warning system;
- o Driver assist system;
- o Radar braking;
- o Automatic headway control;
- o Automatic lateral control;
- o Proximity warning;
- o Smart cruise control;
- o Automatic speed control; and
- o Automated highway system.

Antilock braking and speed control systems are already available on some American and foreign vehicles. Research and development is occurring on variable speed control, radar braking, automatic headway control, and automatic steering control.

Many of these systems could be adopted in the near future. However, implementation and operational use of fully automated highways are probably at least 30 years away. Even then, there is no guarantee that the technology will develop, that public and private benefits of this technology will exceed its costs, or that this technology will be widely accepted by vehicle operators.

Nevertheless, far more than any other type of IVHS technology, AVCS are the most diverse and have the greatest potential for substantial public mobility and safety benefits. We should pursue the research needed to implement near term technologies and to provide the knowledge base for implementation of these technologies in the next century.

IV. FOREIGN IVHS RESEARCH PROGRAMS

To date, foreign governments and industries have undertaken more research, development, and demonstration projects in support of IVHS technology than has the United States government or its motor vehicle and supplier industries. The European and Japanese IVHS research programs appear to be well-funded, have strong central organizations, and clear objectives. In this chapter, we provide information on these programs.

A. European Programs

EUREKA is a $5 billion, 19-country program that is designed to stimulate cooperative research and development between industries and governments in Europe; a major goal of the program is to improve European industrial competitiveness. Most of the European IVHS programs are included in the EUREKA program. In addition to PROMETHEUS (discussed below), EUREKA includes the following IVHS-related programs:

- EUROPOLIS -- a $150 million, seven-year research project to design automated road systems and to develop technologies to automate driver functions;

- CARMINAT -- a four-year research project to develop in-vehicle electronic navigation and communications systems;

- ATIS -- an $8.5 million, five-year project to provide pre-trip information on traffic conditions; and

- ERTIS -- a $2.7 million, three-year project to develop a common road information and communications system for motor carriers across Europe.

Two IVHS programs not associated with either EUREKA or the European Community are ALI-SCOUT and AUTOGUIDE. Developed in the Federal Republic of Germany by Bosch/Blaupunkt and Siemens, ALI-SCOUT is a route-guidance system that uses infra-red transmitters and receivers to transfer navigation information between roadside beacons and on-board displays in appropriately equipped vehicles. Earlier versions of a route guidance system were tested along a 60-mile stretch of German autobahn. A more advanced ALI-SCOUT system (LISB) has been tested in Munich and is undergoing testing in West Berlin.

AUTOGUIDE is the British version of the ALI-SCOUT system. A test of this technology is now underway in London and in a corridor between London and Heathrow Airport; it is anticipated that roadside beacons will cover the London area and then Great Britain by the early 1990s.

PROMETHEUS: One of the two most important European IVHS programs is PROMETHEUS, which stands for PROgraMme for European Traffic with Highest Efficiency and Unprecedented Safety. Primarily a private sector initiative, PROMETHEUS is aimed at developing a uniform European traffic system incorporating IVHS technology. To carry out this program, a consortium of European automobile companies, supplier companies, electronic firms, and university research institutes has been formed.

The general objectives of the PROMETHEUS program are to improve traffic safety, enhance vehicle operating efficiency, and reduce the adverse environmental effects of automobile travel. The specific objective of the PROMETHEUS program is to design "intelligent vehicles" and "electronic traffic-flow detectors," thus improving communication between drivers and providing automatic crash avoidance. Safety is a major aspect of the PROMETHEUS program, and a target of reducing European traffic fatalities by 50 percent by the year 2000 has been established. A major economic objective of PROMETHEUS is to improve European competitiveness in the world automotive electronics industry.

The PROMETHEUS system is designed to be a European-wide traffic management and control system using three major levels of information transfer or communication --- intelligent driver aids on-board the vehicle, communication networks between vehicles, and communication and information systems that link vehicles and roadside facilities.

PROMETHEUS began in 1986 and is an eight-year, $800 million program. Program objectives are formulated by an 11-member Steering Committee that consists of representatives from motor vehicle companies. The Committee defines a basic research program and a program of industrial research. European government involvement comes through the PROMETHEUS Council. Along with the research community, the Council helps coordinate basic research activities. Table 4.1 shows how various PROMETHEUS research projects are classified between basic and industrial research.

PROMETHEUS will fund development work up to the point where private firms decide upon the appropriate technology. These firms are then free to design new products in competition with each other.

The PROMETHEUS project is now at a critical stage. The "Definition Phase" has been completed, and a report, Topics of Research, defining hundreds of "functions" (i.e., products and services) that will be developed has been published. The project is now underway, and a coordinated research plan among the automobile suppliers and the electronics firms has been prepared. A large number of individual projects will be accomplished in the short time remaining until 1994 when integration of the results of the many projects is scheduled to begin.

TABLE 4.1

PROMETHEUS RESEARCH FUNCTIONAL AREAS

INDUSTRIAL RESEARCH

-- PRO-CAR: on-board, self-contained technologies to monitor vehicle performance and provide drivers with information and assistance;

-- PRO-NET: communication between vehicles; and

-- PRO-ROAD: communication between vehicles' on-board computers and the road.

BASIC RESEARCH

-- PRO-ART: the use of artificial intelligence in the vehicular system;

-- PRO-CHIP: the use of microelectronic components for various automobile subsystems;

-- PRO-COM: communication between the vehicle and the driver, another vehicle, and the road; and

-- PRO-GEN: an evaluation of the impact that changes in motor vehicle technology are expected to have on traffic levels and patterns.

Source: Swedish Prometheus Team "Prometheus."

DRIVE: The other major European IVHS program is DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). DRIVE is a European Community program of collaborative research and development to find ways to alleviate road transportation problems through the application of advanced information and telecommunications technology. The stated goal of DRIVE is to improve road safety, promote transport efficiency, and reduce environmental pollution. In 1985, studies were conducted for the European Community on driver information systems. These studies confirmed the need for such a program, and the DRIVE program was initiated in June 1988.

The DRIVE program focuses on the transmission of information between vehicles and the road. A major goal of the DRIVE program is to develop standardized technology so that any products or services developed as a result of this program could be used throughout the European Community. The program encompasses collision avoidance systems and other safety systems. The DRIVE program is also examining implementation issues, such as conflicting national policies on traffic signalling.

DRIVE will bring industry and research institutes together to pursue new developments in road transport. The program includes research, development, and assessment of a number of road transport information technologies; the evaluation of strategic choices of candidate systems; and the standardization and common functional specifications that relate to the development of advanced transport infrastructure and traffic management systems for a number of European IVHS programs (e.g., PROMETHEUS, EUROPOLIS, and CARMINAT).

Participants in the DRIVE program include representatives from the public sector, motor vehicle and supplier industries, and highway users. The DRIVE management team reviews the program objectives and accomplishments four to six times a year. The DRIVE workplan was drawn up by the European Community in consultation with member states, industry representatives, and representatives of road-user organizations. DRIVE has a total committed funding level of between $132-$150 million over a three-year period, of which half is from the public sector and half is from the private sector.

DRIVE will support "pre-competitive" research and development to determine how best to exploit emerging information technologies that affect road transport. DRIVE research proposals are carried out under rules established by the European Community's Research and Development Framework Program. DRIVE began awarding contracts for 60 projects in January 1989. Table 4.2, which is appended to this chapter, provides a list of recently awarded DRIVE contracts and projects. The contracts awarded will run for up to three years. This round of contracts has been referred to as DRIVE I. There is speculation that after these contracts are awarded any remaining funds will be re-bid and that additional funding is being considered.

Specific research proposals are selected in response to an open solicitation and involve the participation of at least two independent partners (all of the participants cannot be from the same country). Moreover, at least one of the partners must be an industrial concern. Projects are funded through "shared-cost" contracts, and the group awarded a contract is expected to bear a substantial share of its costs. In the case of universities and research institutes, the European Community may contribute up to 100 percent of the project's costs. Organizations from countries that are not members of the European Community may participate in the program, although they are expected to meet their share of the project's costs.

Some respondents to our Discussion Paper believe that DRIVE is a very successful program. One respondent concluded that "... the DRIVE program ... is the most influential program in shaping European directions ... ."[1] This individual also believed that "... DRIVE's underlying comprehensive analysis and planning and the strong systems approach to project coordination provide examples that are more relevant to how the U.S. should proceed."

Until recently, no non-European firms were participating in the PROMETHEUS programs.[2] We understand that PROMETHEUS recently accepted the request of Opel, a European affiliate of General Motors, to participate in PROMETHEUS. We understand that Opel will be an "associate member" of the governing committee of PROMETHEUS. Beyond that, there has been no formal cooperation between European research initiatives and U.S. companies. Many respondents to DOT's Discussion Paper pointed out the beneficial aspects of closer cooperation among IVHS research programs.

There is precedent for closer collaboration. There is a project agreement between the United States DOT and the Federal Ministry of Transport of the Federal Republic of Germany concerning highway engineering and operations research. This agreement was signed in 1972 and has been renewed periodically. The current agreement expired in October 1989 and is now being renewed. One area covered under the agreement is "Motorist Information Systems" (specifically, in-vehicle systems). To date, cooperation under this agreement has been limited to the exchange of literature and research reports with infrequent site visits. This agreement could be useful in achieving closer cooperation.

European governments and firms have undertaken broad-based programs to develop and implement IVHS technologies. The two major European research programs, PROMETHEUS and DRIVE, are quite different, however. PROMETHEUS is vehicle oriented and DRIVE is traffic management oriented. DRIVE also has a significant public transit component not present in PROMETHEUS. Also, PROMETHEUS is largely a private sector effort while DRIVE has been organized by the European Community.

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1 "Comments of Robert L. French and Associates to the IVHS Discussion Paper," June 12, 1989.

2 Karl-Heinz Faber, Senior Vice President, Mercedes-Benz of North America, "Comments on IVHS Discussion Paper," July 25, 1989, page 7.

B. Japanese Programs

Japan has two major IVHS research programs: Advanced Mobile Traffic Information and Communication System (AMTICS) and Road-Automotive Communication System (RACS). Both of these programs emphasize communications and traffic control. There is also an "automotive chauffeuring project" underway in the Ministry of International Trade and Industry.

These programs have been given a high priority by the Japanese government. Traffic congestion in Japan is a major problem. Also, the Japanese government wants to encourage technological innovation in the Japanese automotive and electronics industries.

AMTICS: Sponsored by the National Police Agency, the Ministry of Posts and Telecommunications, the Japan Traffic Management and Technology Association, and 59 private companies, AMTICS is a relatively sophisticated traffic control system that transmits traffic congestion information from a traffic control center to an in-vehicle display. The AMTICS system has the capability to provide "static" information and "dynamic" information.

The system's static information component uses in-vehicle compact discs (CD-ROM) and in-vehicle video display terminals to display road maps, local traffic regulations, and the location of parking lots, hospitals, gas stations, and other useful information. When fully operational, AMTICS' dynamic component will use roadside beacons to provide real-time information on traffic conditions, weather and accident warnings, and parking space availability.

AMTICS basic design was completed in October 1987. Pilot experiments using 11 passenger cars and a bus in central Tokyo began in April 1988 and were completed in June 1988. Twelve private companies developed pilot systems.

The network for the acquisition of real-time traffic data has been completed. AMTICS can be modified to allow communication between vehicles, thereby making full use of its "teleterminal" communication system. Construction of the teleterminal system is progressing and is now providing traffic information/communication service for 23 wards of Tokyo. Another teleterminal system is being considered for Osaka. A wider scale implementation of the AMTICS system is planned for 1990.

RACS: Another Japanese IVHS program is the Road-Automotive Communication System (RACS). Using a different communication technology, RACS is a parallel research project. RACS is sponsored by the Public Works Institute of the Ministry of Construction, the Highway Industry Development Organization, and 25 private companies.

RACS consists of roadside communication beacons, vehicle on-board units, and a systems center. RACS collects and disseminates information between roadside beacons and vehicles. The system functions are classified into navigation, roadside information, and message systems.

The navigation methodology uses "autonomous dead reckoning"; that is, on-board information is corrected by roadside beacons and updated with information on traffic and parking. In combination with the on-board navigation system, the driver receives real-time traffic information, thus making navigation changes possible. Also, communication between vehicles and roadside beacons makes it possible to monitor and locate specific vehicles, to collect traffic data, and to distribute messages, facsimile and other types of radio communication services.

The first road test of RACS began in March 1987 and was carried out in an area of about 350 square kilometers (extending over the southwestern part of Tokyo and the northern part of Yokohama). This test used 74 location beacons (each with a digital road map) and eight cars having car navigation units (receiver, microcomputer, and terminal). Our understanding is that the test confirmed the location beacons' effectiveness.

The second road test for RACS began in March 1988. For this test, 91 beacons and improved digital road maps were used. Two information beacons also were installed to provide real-time data and traffic information. During this phase of testing, inductive radio-type location system beacons were used. The radio zone of communication of the inductive radio system is about five meters in length.

Road traffic information is compiled in digital format at the Tokyo Expressway Control Center and sent through the information beacons to equipped vehicles. Data furnished to drivers through this system include information on congestion, construction work, accidents, traffic control, and estimated travel time. A digital road map shows the vehicle's current location and various routes and provides information on traffic patterns. For the demonstration, a data base of digital road maps of the test area was prepared. The structure and content of this data base were improved using the results of the 1988 road tests. In order to avoid the difficulty of using induction radio beacons to provide information to a moving vehicle, the information beacons were installed at toll gates. Microwave technology will be used to transfer data to moving vehicles.

The third field test of RACS will assess the total concept of RACS (i.e., navigation, information, and individual communication). Eight microwave beacons will be installed along a 40 kilometer section of an expressway. The communication between each vehicle and the communication center will enable automatic vehicle identification, automatic vehicle monitoring, and message correspondence. The high transmission speed will also enable the transmission of FAX messages. This field test is the last test before moving to widespread deployment. Upon receipt of a license, installation of the microwave beacons is expected to begin in 1990.

The Japanese have expressed an interest in sharing information and having cooperative research with U.S. firms. This proposed cooperative activity is part of an existing (June 1988) United States-Japan Agreement on Cooperation in Research and Development in Science and Technology. Under this agreement, the United States and Japan could exchange research data and experimental evaluation results for advanced driver information systems, with site visits and face-to-face meetings when possible. No additional cooperative research would be undertaken specifically as a result of this agreement.

TABLE 4.2

RECENTLY AWARDED DRIVE PROJECTS

Contract Number	Project Title
1001	Integrated Public Transport Vehicle Scheduling and Control Systems
1002	Short-Wave Microwave Links: Present and Future
1003	Requirements and System Specification for Dynamic Traffic Measures
1004	A Feasibility Study for Monitoring Driver Status
1005	PREDICT - Pollution Reduction by Information and Control Techniques
1006	Factors in Elderly People's Driving Abilities, Stages I and II
1007	An RTI (Road Traffic Informatics) System Based on Cellular Radio
1008	Strategies for Integrated Demand Management Systems
1009	Vehicle Location Systems Using Satellites
1010	Prototyping a Navigation Database of Road Network Attributes (PANDORA)
1011	Integration of Dynamic Route Guidance and Traffic Control Systems
1012	Road Safety Management Combining Knowledge-Base and Database Technologies
1013	Comparative Evaluation of the Different Radiating Cables and Systems Technologies
1014	Integrated Model for the Analysis of Urban Route Optimisation (IMAURO)
1015	Artificial Intelligence-Based Systems for Traffic Control
1016	An Information System for Improved Road-User Safety and Traffic Performance

TABLE 4.2 (CONTINUED)

1017	Changes in Driver Behavior Due to the Introduction of RTI Systems
1018	The Total Traffic Management Environment
1019	Computer-Aided System for Scheduling Information and Operation of Public Transport in Europe (CASSIOPE)
1020	Tidal Flow Systems
1021	Task Force European Digital Road Map
1022	Realisation of a Real Urban Traffic Control System (Dynamic Programming)
1023	A New Integrated RTI-Oriented Transport Planning Process (EUROTOPP)
1024	Driver Information Systems
1025	Evaluating User Reactions on New European Transport Technologies (EURONETT)
1026	Integration of Computer Vision Techniques for Automatic Incident Detection
1027	A European System for International Road Freight Transportation (EUROFRET)
1028	Tunnel Integrated Control System (TUNICS)
1029	Standards for RDS-TMC Throughout Europe
1030	Microwave Communications Systems for Traffic Monitoring and Pricing
1031	An Intelligent Traffic System for Vulnerable Road-Users
1032	Standardisation of Traffic Data Transmission and Management (STRADA)
1033	Automatic Policing Information Systems (AUTOPOLIS)
1034	Road Information and Management Euro-System
1035	Motorway Traffic Flow and Control
1036	Evaluation Methods and Criteria

TABLE 4.2 (CONTINUED)

1037	Definition of Standards for In-Vehicle/Man-Machine Interface
1038	Data Acquisition and Communication Techniques and Their Assessment for Road Transport (DACAR)
1039	Survey of Potential Application of Artificial Intelligence to Solving Traffic Engineering Problems
1040	Safety Scenario Identification of Hazards
1041	Generic Intelligent Driver Support System (GIDS)
1042	Accident Data Collection and Analysis
1043	DRIVE Integrated Telecommunications
1044	Freight Logistics Efforts for European Traffic (FLEET)
1045	PARCMAN - Parking Management, Control, and Information Systems
1046	A Framework for Integrated Dynamic Analysis of Travel and Travel (FRIDA)
1047	Integrated Approach to Congestion Prevention and Incident Detection for Road Traffic
1048	Advanced Control Strategies and Methods for Motorway RTI System in the Future
1049	Field-Trials
1050	Driving and Accident Co-ordinating Observer
1051	Procedure for Safety Submissions for RTI Systems
1052	Inter-urban and Road Utilisation Simulation (ICARUS)
1053	Modelling of Emission and Consumption in Urban Areas
1054	System and Scenario Simulation in Urban Areas
1055	Artificial Intelligence Techniques for Traffic Control
1056	System Integration for Accident Congestion Detection and Traffic Monitoring

TABLE 4.2 (CONTINUED)

1057	System Engineering and Consensus Formation Office (SECFO)
6538	Road Condition and Weather Monitoring Systems
6015/2	Strategies for Preventing Road Traffic Congestion

SOURCE: Traffic Engineering + Control, March 1989, pp. 149-151.

V. IVHS PROGRAMS IN THE UNITED STATES

A number of IVHS-related research and demonstration projects are underway in the United States. This chapter summarizes these programs.

A. Federal Government

Three DOT operating administrations, the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Urban Mass Transportation Administration (UMTA), have IVHS-related research and development responsibilities. Two of these administrations now conduct IVHS research projects in selected areas but, until recently, neither had a formal IVHS research and development program. UMTA has supported IVHS-related research but currently does not have a program.

For some time, the FHWA research program has included activities that involved advanced driver information systems, as well as issues related to the deployment and operation of in-vehicle information and navigation systems. Included in this research program is the PATHFINDER project, which the FHWA is co-sponsoring along with the California DOT (CALTRANS) and General Motors. PATHFINDER is a field evaluation of an in-vehicle urban freeway navigation and information system. This experiment is being conducted in the Los Angeles area using 25 vehicles equipped with electronic navigation systems. The project began September 1988; a one-year field test will begin in March 1990. PATHFINDER will provide the first assessment of IVHS technology in actual use in the United States. FHWA is also working with other industry and government agencies to develop additional cooperative field demonstrations and is funding several IVHS state/university activities.

The NHTSA research program addresses issues related to the use of advanced technology to improve highway safety. As part of these activities NHTSA has provided seed money for IVHS planning studies at a number of universities. In addition, NHTSA has provided support to MIT (through the Future of the Automobile Program) to study the European PROMETHEUS program. NHTSA has also co-funded a grant administered by the National Science Foundation to the University of Iowa for a study to define a state-of-the-art driving simulator that will meet the needs of NHTSA, FHWA, other federal agencies, and industrial firms.

Further, in collaboration with CALTRANS, the Ford Motor Company, and Radar Control Systems, NHTSA is participating in the evaluation of a collision avoidance radar system as a headway control system on the San Diego Freeway. In a joint project with the FHWA, human factors guidelines and evaluation methodologies will be developed for in-vehicle information systems.

Other federal research programs, too, are relevant to the development of IVHS technology. The U.S. Bureau of the Census, for example, has developed TIGER (Topologically Integrated Geographic Encoding and Referencing) -- a digital mapping system. While TIGER has many desirable features, many parties believe that it is inadequate as a motor vehicle location and navigation technology.[1] In addition, the Federal Interagency Committee on Digital Cartography coordinates the federal government's various digital mapping activities.

B. State and Local Governments

Several state governments are involved in IVHS research, development, and demonstration. For example, CALTRANS has a program to evaluate whether advanced highway technology can increase the capacity of California's highway system. Most of California's efforts are being undertaken through the University of California-Berkeley. CALTRANS has committed $5.5 million to the University's programs and plans to continue providing long term funding. CALTRANS is also evaluating various IVHS technologies in the traffic management and road maintenance areas.

The Heavy Vehicle License Plate (HELP) program is supported by a multi-state consortium.[2] HELP is testing whether heavy trucks operating along a major truck corridor are able to use transponders to communicate with state regulatory and law enforcement officials, thereby eliminating the delay caused by stopping for manual verification of regulatory compliance. The information transmitted electronically replaces the manual review of certain mandatory truck documents and weighs the truck as it crosses state borders. The project is being conducted along Interstate 10 from the New Mexico/Texas state lines, west through New Mexico, Arizona, and California, then north from Los Angeles along Interstate 5 through California, Oregon, and Washington into British Columbia.

Other states, too, are involved in IVHS research projects. The State of Texas is implementing several advanced traffic signal control projects and freeway and street traffic surveillance and control projects. The State of Maryland is proceeding with a comprehensive Travelers Advisory Radio system to provide localized

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1 See, for example, Jim Woods, Project Engineer, Federal Express Corporation, "Comments on IVHS Discussion Paper," July 10, 1989.

2 The States supporting the HELP program are Alaska, Arizona, California, Colorado, Idaho, Iowa, Minnesota, Nevada, New Mexico, Oregon, Pennsylvania, Texas, Virginia, and Washington. HELP is also receiving assistance from the Port Authority of New York and New Jersey.

traffic information to motorists. The State of Virginia is considering the use of part of a new highway being built in Roanoke County as a test site for IVHS technologies.

Several urban areas have begun to test and implement various IVHS technologies. In the Los Angeles area, the "Santa Monica Smart Streets Corridor Demonstration Project" is scheduled to begin in 1990. Sensors on the Santa Monica Freeway and five parallel alternate streets will feed traffic flow data to the Caltrans Semi-Automated Traffic Management System (SATMS) and the City of Los Angeles' Automated Traffic Surveillance and Control computers. The computers will make use of "expert system" algorithms to evaluate traffic conditions and make response decisions. The Smart Streets Corridor system will oversee the incident-detection function of its computers; it will also evaluate traffic conditions and operator inputs and will recommend coordinated responses for each agency's systems. Current traffic information will be made available to motorists for pre-trip planning through various media such as telephone dial-up, personal computers, radio, and television. Motorists will be provided with traffic advisories through changeable message signs, highway advisory radios, and commercial radio.

In the New York City metropolitan area, an inter-governmental agency, the Transportation Operations Coordinating Committee (TRANSCOM), is considering various means to provide motorists with real-time information on traffic conditions. TRANSCOM is now using several regional trucking firms to test a traffic alert system of both scheduled (e.g., road work) and unscheduled (e.g., accidents and weather) highway incidents.

The Port Authority of New York and New Jersey has been investigating the use of automatic vehicle identification and multiple geostationary satellites to facilitate the movement of traffic at toll booths at their tunnels and bridges. A project to use transponders to measure delays at toll bridges and tunnels is being discussed.

Transportation-related Geographic Information Systems (GISs) are being developed too. A GIS is, essentially, a computerized map and data management system designed to capture, store, retrieve, analyze, and display map data. These systems will allow the assimilation, integration, and presentation of data collected by different divisions within a particular agency, as well as other agencies. The American Association of State Highway and Transportation Officials has created a working group to develop a charter for a permanent task force on GIS. The task force would promote the use of GIS through education, mapping standards, information exchange, and vendor requirements for the development of transportation applications. Through the National Cooperative Highway Research Program, state highway departments are sponsoring a $220,000 research project to design a framework for transportation-related GISs.

The use of electronics to facilitate the movement of traffic through toll barriers has been growing. Automatic vehicle identification and electronic toll collection technologies are being implemented or tested in the following sites:[3]

- Dallas North Tollway - Texas Turnpike Authority
- Delaware River Port Authority toll bridges
- Dulles Toll Road - Virginia DOT
- Greater New Orleans Bridge - Mississippi River Bridge Authority
- Grosse Ile Bridge - Grosse Ile Bridge Company
- Lincoln Tunnel - Port Authority of New York & New Jersey
- Illinois State Toll Highway Authority
- San Diego-Coronado Bridge - California DOT

A major concern with these projects, especially for interstate truckers, is the proliferation of incompatible systems.

C. Universities

The Institute of Transportation Studies at the University of California-Berkeley has the most ambitious academic program to develop IVHS technology. This effort, Program on Advanced Technology for the Highway (PATH), was established in 1986. PATH is a multi-year, $56 million program to develop automation, electrification, and navigation technologies. Financial support for the program has been provided principally by CALTRANS, but also by FHWA, UMTA, NHTSA, the Ford Motor Company, Radar Control Systems, and Systems Control Technology. Since PATH is only 18 percent funded, additional funding is being sought from public and private sources.

The Texas Transportation Institute at Texas A&M University has initiated an advanced highway transportation technology program, to develop applications of new technologies to highway transportation. This program receives support from the Texas State Highway Department and is intended to provide systems for actual use on Texas state highways. The Institute is developing real-time traffic signal optimization programs, as well as an autonomous research vehicle capable of recognizing stop signs, performing vehicle following, and seeking a path through a complex obstacle field.

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[3] Source: Neil D. Schuster, Executive Director, International Bridge, Tunnel, and Turnpike Association (IBTTA), "Comments on IVHS Discussion Paper," July 5, 1989.

The University of Michigan Transportation Research Institute and the College of Engineering have completed a one-year planning effort supported by government and industry to develop an agenda for an IVHS research and development program. As part of this planning exercise, these organizations conducted a Delphi study of the most feasible development and implementation schedules for IVHS technologies[4]; they have also sponsored a display of relevant U.S. technologies and have supported work on "smart chip" technology for roadway information systems. As the next step, the University of Michigan has developed a formal IVHS program to conduct basic and applied research, train students, and provide coordination services to enable the delivery of intelligent systems technology for improving highway travel.

To support IVHS research, MIT has received support from the State of Massachusetts' Department of Public Works, the U.S. DOT, and private companies. MIT's focus is on technology, systems analysis, and economic, international, and organizational issues. One project underway at MIT is to identify possible technological innovations and guidelines for a possible demonstration associated with the reconstruction of the Central Artery that traverses downtown Boston and the construction of a third Harbor Tunnel between downtown Boston and Logan Airport. MIT is also conducting a study to determine Massachusetts' role in a national program of cooperative research to develop and apply advanced technology consisting of communications, computers, and control to the vehicle/highway system to achieve improvements in urban traffic flow. Finally, under NHTSA sponsorship, MIT is conducting research to assess the effect of new communications and control technology on safety and human factors in automobile collision avoidance systems.

Researchers in numerous other universities are conducting IVHS-related research, including the University of California-Davis, the University of Florida, the University of Minnesota, the University of North Carolina, the University of Virginia, Penn State University, and Vanderbilt University.

D. <u>Private Sector</u>

We have limited information on the research and development activities being conducted by the major domestic motor vehicle and electronics manufacturers. With a few exceptions, however, we believe the manufacturers are concentrating their research on near term product development and less on long term innovations.

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[4] A Delphi technique can be used to collect and analyze the informed judgments obtained from members of a group of experts on a particular issue or technology.

Substantial research activity is occurring in the development of driver information systems, with a considerable amount of research, and even some testing, underway in evaluating various approaches to on-board navigation and location systems. Testing and evaluation of various means of presenting that information to the driver is being conducted too.

General Motors, for example, is working on automatic vehicle location and identification, navigational aids, motorist information and communication systems, trip planning and route guidance, advisory traffic messages, dashboard displays as driver aids, head-up displays, advanced vehicle control ("steer-by-wire," "brake-by-wire," "drive-by-wire"), adaptive cruise control, near obstacle detection systems, collision warning, collision avoidance, fleet management, vehicle communications, and a variety of supporting technologies such as sensors and actuators.

Computers that are now standard in automobiles and trucks will foster the use of IVHS technologies. For example, computer systems used to monitor engine performance may be used to monitor and process navigation information. Moreover, research underway in the safety area could adopt IVHS technology or provide ancillary IVHS uses. For example, companies are conducting research into various types of collision detection, collision warning, and collision avoidance systems. This research may well make use of advanced automation technologies.

Automotive technologies are often developed outside of motor vehicle manufacturing companies. It is not surprising, then, that a considerable amount of research and interest in IVHS technology is centered among electronics companies. Several electronics companies are offering vehicle location products, and development is underway to improve these systems and to develop vehicle navigation systems. The Motorola Corporation has been working on a number of IVHS products that will collect and process data for highway officials and drivers. Included in the types of products are design, installation and maintenance of advanced radio frequency communication networks, advanced digital signal processing semiconductors, global positioning system satellite receivers, microwave devices and automotive electronics design and packaging approaches.

E. National Coordination

There is no formal national organization for coordinating or directing IVHS research and activities. Several groups have begun to discuss the need for such an organization.

Mobility 2000 is an informal coalition of industry, university, and federal, state, and local government participants who are convinced that IVHS technology will make highways more productive and vehicles safer and more efficient. This organization has become active in bringing attention to IVHS goals and developing an appropriate research, demonstration, and deployment agenda. The Texas Transportation Institute and the Texas State Department of Highways and Public Transportation has published the proceedings of a February 1989 Mobility 2000 workshop that outlines the major purposes of IVHS and discusses the major research, coordination, and demonstration activities that may be needed to implement IVHS.[5]

The Highway/Vehicle Technology Committee of the Highway Users Federation, composed of representatives from major U.S. transportation companies, is identifying the value of IVHS and how such systems can be used. It is also providing a forum to expedite information exchanges among business, government, and the research community.

The Council of University Transportation Centers, made up of most of the academic transportation centers and institutes, has established a task force on IVHS to provide information and expertise to the government in this area and act as a liaison between the U.S. DOT and the academic community.

The International Bridge, Tunnel, and Turnpike Association has established an Automatic Vehicle Identification Task Force to explore the feasibility of national or international automatic vehicle identification and electronic toll collection standards; this task force will act as a liaison between their members and the supplier industry and between members and other organizations. The Society of Automotive Engineers has several committees working on IVHS issues.

To summarize: While many separate domestic programs dealing with IVHS technology exist, no central, permanent organization is coordinating the separate elements or ensuring that research is conducted on the various social and technological issues before IVHS products can be developed by private companies and adopted for general use.

The U.S. DOT believes that there should be greater coordination among the many activities that are underway and a better forum for the exchange of ideas in order to monitor IVHS developments and to support IVHS research, develop operational demonstration projects, and support IVHS implementation. A national cooperative IVHS effort would serve as a forum to provide information on the progress of IVHS activities.

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5 Mobility 2000, "Proceedings of a Workshop on Intelligent Vehicle-Highway Systems," February 15-17, 1989.

VI. ECONOMIC IMPACT OF IVHS TECHNOLOGY

Well-funded foreign IVHS programs could result in a loss of leadership for U.S. firms in the development of IVHS technology and in the manufacture and sale of IVHS products and services. Also, if U.S. companies do not manufacture products and services using IVHS technology, it could reduce the international competitiveness of domestic automotive and electronics companies. In this chapter, we evaluate these issues.

A. Use of IVHS Technology

If domestic firms did not manufacture IVHS products, it would not preclude these technologies from being adopted in the United States. The United States is the largest market in the world for motor vehicles. Regardless of whether domestic firms manufacture IVHS products, foreign manufacturers will still offer them for sale in the United States.

Some U.S. industry representatives have suggested that if domestic firms do not develop IVHS technology, their companies will enter into licensing or joint-venture arrangements with foreign companies. Such comments would suggest that U.S. firms may not need to promote IVHS technology for American consumers to receive the benefits of this technology. Nonetheless, unless U.S. firms develop IVHS technology, they may not be in a position to determine how these technologies evolve or which technologies are adopted. For example, the European systems must take into account all the different languages used across Europe. To do this, these systems must either limit displays to graphic symbols or include some sort of text translation procedure. These restrictions limit the amount of information these systems convey and/or increase their costs. For the most part, such information limitations or added costs would not be necessary for IVHS technologies adopted in the United States.

Key components of the nation's highway system must be equipped with the appropriate IVHS technology to facilitate highway management and communication between the highway and the vehicle. Technical standards for communication among systems in the United States are needed to ensure compatibility among systems.

There is an issue as to whether the United States will forfeit leadership in the development and manufacture of IVHS products and services to countries that are now developing this technology. Already, U.S. motor vehicle manufacturers and automotive electronic manufacturers have foreign subsidiaries and affiliate companies that provide components and equipment for U.S.-assembled automobiles. This strategy could be used for IVHS products and services too.

While the further development of the "world car" has many positive consequences, it is not clear what the U.S. contribution will be if "high tech" automotive components are manufactured abroad. Domestic automotive and electronics firms may have a comparative advantage as innovators of new, advanced products, rather than as manufacturers of products using existing technologies. Thus, it is unclear whether a "wait and see" approach to IVHS technological developments would be a successful business strategy. Experience to date seems to suggest that foreign companies that develop a technology are often able to maintain a competitive advantage in manufacturing products that embody that technology. In addition, major technological developments often lead to spin-off products and applications not originally anticipated. There is every reason to believe that such phenomena could occur with the development and adoption of IVHS technology.

Today, electronic components account for about six percent of the value of an automobile, implying an automotive electronic equipment market of about $8.5 billion per year out of domestic automobile sales of $140 billion. It is estimated that by the year 2000 this percentage will rise to 20 percent, which implies an automotive electronics market of at least $28 billion per year.[1]

Capital expenditures for the roadside IVHS equipment will also be substantial. State-of-the-art freeway surveillance and control systems using existing technology cost about $1 million per mile. Using this figure as a benchmark, the infrastructure capital costs for 20,000 miles of near- and medium-term IVHS projects would be on the order of $20 billion.[2]

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1 This estimate does not include any increase in U.S. motor vehicle sales nor does it include potential export sales of IVHS products or automobile incorporating IVHS equipment.

2 Most of the capital investment is currently eligible for federal aid grants financed from the Highway Trust Fund. Additional expenditures for the operation and maintenance of these systems could be funded by state or local governments or by private contractors operating the system on a subscription basis. To help place the $20 billion figure in perspective, total state, local, and federal expenditures on highways in FY 1987 were approximately $53 billion.

B. Costs and Benefits of IVHS

The ultimate goal of IVHS technology is to improve mobility and to make highway travel safer. It is anticipated that successful development and use of IVHS technology will eliminate some of the more onerous, difficult, and dangerous driving tasks in much the same way that automatic transmission, cruise control, and well-designed highways have made driving easier and improved driving performance.

An estimate of the net benefits of IVHS technologies is, as many parties have pointed out, important to designing and deploying these technologies in a cost-effective manner. At this time, however, it is only possible to conceive of the costs and benefits of adopting various IVHS technologies in the most general terms.

An a priori evaluation of the implementation of these systems is similar to what must have been made by policy makers in the early 1950s who were then considering whether to build the Interstate Highway System. At that time, there was no way they could have imagined the changes to American society that resulted from a nationwide system of limited access, high speed, high capacity highways. Similarly, while we can imagine and evaluate some of the implications of using IVHS technologies, inevitably, many more applications will arise as these technologies are adopted and modified.

A frequent comment to the DOT's Discussion Paper was that the DOT should attempt to quantify the benefits and costs of adopting various IVHS technologies, although some parties stated that it is premature to conduct such analyses because the form IVHS technology will take and its ultimate role in the nation's highway system is so speculative. While it is necessary to evaluate the likely benefits and costs of IVHS technologies, at this time it is premature to conduct a rigorous cost-benefit analysis of specific IVHS technologies.

For example, various technologies could be adopted to provide navigation and location information to vehicles. Some systems use vehicle-based equipment, others rely on satellites, and others use roadside beacons. In addition to engineering differences, each technology adopted will generate a different stream of costs and benefits. For example, map-matched, dead-reckoning navigation systems have moderate external capital costs but, instead, rely on vehicle computational systems that should result in higher costs per vehicle. Also, this type of system, in and of itself, would not have the capability to evaluate real-time traffic information.

Similar dichotomies exist for many of the generic IVHS technologies discussed in this report. A choice will often have to be made between IVHS technologies with substantial infrastructure requirements and low on-vehicle equipment costs and technologies with lower infrastructure costs but higher costs per vehicle. In short, rigorous calculations of the costs and benefits of generic

IVHS technologies should be prepared at a future date. While we have not prepared such analyses, we describe some of the issues involved in estimating the potential benefits of adopting various IVHS technologies.

Congestion: Much of the interest in IVHS technology stems from concern over traffic congestion in urban areas. A recent estimate of the impact of congestion is that in 1987 the cost of congestion (including extra fuel, increased accidents, and time lost) in the 25 largest U.S. metropolitan areas was about $42 billion.[3] Since this study only estimated congestion costs for the largest U.S. cities, and since it did not estimate future delays, this is only a partial estimate of congestion costs. Some of the costs of delay are borne by business as a result of additional time that employees must travel, and some are borne by individuals, either through reduced leisure or added stress. We do not know how successful various IVHS technologies will be in reducing delays, but if they reduce delay costs by as little as ten percent -- and most analysts believe this is a conservative estimate -- they would generate societal benefits of over $4 billion per year.

Safety: Another benefit of IVHS technologies is its impact on highway safety. Motor vehicle crashes are a leading cause of deaths and injuries in the United States. Over 120 million automobiles are in use today in the United States, and between 10 million and 30 million are involved in crashes each year. These accidents result in 47,000 fatalities and 3.3 million injuries annually and personal and property costs of over $74 billion. A ten percent reduction -- a conservative estimate -- in these costs would entail direct social benefits of $7.4 billion per year plus the lives saved and pain and suffering averted.

There exists a potential to improve traffic safety through the adoption of IVHS technologies. For example, studies show that 50 percent of all rear-end and intersection-related collisions and 30 percent of collisions with oncoming traffic could have been avoided had the driver recognized the danger 0.5 seconds earlier. Over 90 percent of these crashes could have been avoided had the drivers taken countermeasures one second earlier.[4] Highway detection, warning, and avoidance technologies have the potential to expand the driver's margin of safety in high risk situations.

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[3] Cited in Mobility 2000, "Proceedings of a Workshop on Intelligent Vehicle-Highway Systems," February 16-17, 1989, page 4.

[4] Karl-Heinz Faber, "Statement Before the Motor Vehicle Safety Research Advisory Committee," February 27, 1988, Washington, D.C.

In the context of highway safety, Emergency Medical Services (EMS) provide prompt, appropriate prehospital emergency medical aid at the scene of the crash and en route to a hospital. Studies have indicated that while 20 percent of all fatal crashes resulted in instantaneous death and another 59 percent were of such severity that the injured party could not be saved with current medical knowledge, 21 percent of those injured could have survived if they could have been given appropriate medical care immediately.[5]

Any delay of response to a medical emergency is recognized to be a critical factor affecting the potential for the injured party's survival. For example, it was observed that there was a 26 percent survivability rate with immediate medical attention; with a delay of only six minutes, the survivability rate declined to 24 percent; and with a delay of 60 minutes the survivability rate declined to seven percent.

For purposes of comparison, in a study of emergency medical response time in rural areas, the average delay from time of incident notification until the patient was delivered to the hospital was about 60 minutes, with a standard deviation of about 33 minutes. Thus for about 68 percent of rural emergency medical responses to motor vehicle crashes, the delay in delivery to the hospital ranged from 27 minutes to 93 minutes. Significant improvements in the delivery of medical services could be realized if IVHS technologies were adopted.

Security and Theft: In 1986, there were about 1.2 million automobile thefts. The estimated value of these vehicles was over $5.5 billion. IVHS systems are now available that allow law enforcement authorities to locate stolen automobiles. For example, some automobiles are equipped with a radio transponder that can be activated by the owner if the vehicle is stolen. Police are supplied with a radio receiver to locate the current position of those vehicles. The same vehicle-identification technology used to provide personalized travel information and used to pay tolls automatically could be used to locate stolen vehicles. Several trucking companies have installed satellite location systems and have recovered stolen vehicles through this technology.

The same technology that informs highway authorities of the location of vehicles could also provide a distress call in emergency situations. Any estimate of the net benefits of IVHS technology should consider the number of crimes that might be averted if police could be notified automatically.

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5 Cited in C.J. Glass, "Emergency Medical Services for Highway Safety," Office of Traffic Safety Program, NHTSA.

Vehicle Occupancy: IVHS technologies could help increase average vehicle occupancy and provide up-to-date information to aid travel planning. Awareness of ridesharing opportunities such as transit, carpools, and vanpools will be increased too. Formation of ridesharing arrangements may even be encouraged. Overall, increased vehicle occupancy levels could result. IVHS technologies can identify conditions specified for preferential routing and can activate control devices that give vehicles preferential treatment.

Comfort and Convenience: Any estimate of the benefits derived from the adoption of IVHS technologies should also include some measure of the value of improving the comfort and convenience of driving. For example, commuting in heavy traffic on urban freeways is usually not done for pleasure but is often an arduous, stressful task performed only to get to work. Adding a measure of automation to such commuting trips may be valued highly by commuters.

Insurance: The adoption and use of IVHS technologies will likely have a positive effect on insurance claims and insurance rates. (The value of this benefit is a subset of the benefits enumerated above.) To the extent that IVHS systems reduce accidents and reduce thefts, there should be reduced insurance claims and premiums. Insurance policies, however, would have to take into account those circumstances where IVHS technologies fail. Also, if IVHS technologies incorporated into the automobile increase the cost of the typical automobile, insurance premiums will rise accordingly.

Other Issues: Other issues must also be addressed before these systems are adopted. For example, any IVHS technology adopted must take into account the age distribution of the motor vehicle fleet. If the purchase and use of these products is not mandatory, there will not be universal adoption of these technologies. Moreover, the speed and extent to which IVHS technologies are adopted will depend not only on their perceived private and social benefits but on the willingness and ability of consumers to purchase them.

In summary, IVHS technology has the potential to play a major role in future highway travel. The major outstanding issue is whether U.S. firms will help shape and guide the course of this technology or whether U.S. industry and highway transportation users will rely on IVHS products developed and manufactured elsewhere. While it is expected that the net benefits to society from the use of IVHS technologies will be substantial, it is important that a more thorough and systematic analysis be conducted of the costs and benefits of the various technologies.

VII. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents our conclusions and recommendations regarding IVHS technology and the need for a national cooperative effort.

A. The Need for IVHS Development and Demonstration

The DOT believes that IVHS technologies will reduce congestion, promote safety, and improve personal mobility. A range of technologies already exists that could contribute to reducing vehicle delay, increasing highway capacity, and improving highway safety. More advanced IVHS technology offers the prospect of even greater benefits.

Extensive testing and analysis will be needed to determine which IVHS technologies are the most cost effective. The cooperative research effort should be a blend of technologies that have the potential for providing near term benefits as well as longer term research on promising advanced systems.

Unless U.S. firms and the public sector become more involved in developing IVHS technologies, the well-funded European and Japanese IVHS programs could give their manufacturers a competitive advantage in developing and marketing IVHS products and services. It is estimated that the automotive electronics market alone will amount to at least $28 billion annually by the year 2000. Also, the highway infrastructure costs for these systems will likely exceed $20 billion. Thus, we are talking about a very substantial potential market for IVHS products and services.

The federal government has a role in promoting the development of IVHS technology. Federal participation, however, must be in the form of a public/private cooperative partnership; IVHS technologies incorporate too many industrial, technological, and commercial aspects for the federal government to develop them alone.

There is widespread support from private companies, state highway and transportation agencies, highway users' groups, universities, and private researchers for a national IVHS effort.[1] Almost all

[1] Even among those respondents who are unwilling to support a national IVHS program at this time, there are many who support initial work on IVHS technology, pending a comprehensive examination of the benefits and costs of the various technologies.

the respondents to the DOT Discussion Paper supported a national research, development, and demonstration program that would form the basis for implementing IVHS technologies.[2] For example, the following companies support a national IVHS effort: General Motors, Motorola, Chrysler, Ford, Paccar, AT&T Network Systems, Federal Express, Nissan, and Mercedes-Benz of North America.

Officials from state and local governments also support a national cooperative IVHS effort. States with serious urban highway congestion problems, such as California, Illinois, Indiana, New Jersey, New York, Michigan, Pennsylvania, and Virginia (as well as Los Angeles and metropolitan New York City) support such a program. There were also expressions of support from states not generally considered to be "urban," such as Arkansas, Arizona, Iowa, Kentucky, Nebraska, New Mexico, and Vermont.

Overwhelmingly, the individual researchers that responded to the Discussion Paper support a national IVHS effort. Representatives from the University of California-Berkeley, Texas A&M University, the University of Michigan, the MIT, the University of Florida, the University of Minnesota, Penn State University, the University of North Carolina, Vanderbilt University, the University of Virginia, and the Council of University Transportation Centers (a consortium of university transportation centers) supported the concept of a national cooperative IVHS effort.

Finally, industry and highway user groups, including the American Association of State Highway and Transportation Officials (AASHTO), the Highway Users' Federation, the American Trucking Association, and the American Automobile Association, support a national IVHS effort. In addition, the League of American Wheelmen (an organization for bicyclists) supports a national IVHS effort.

B. Recommendations

The DOT recommends a national cooperative effort to foster the development, demonstration, and use of IVHS technologies. We further propose that this effort be formulated and coordinated jointly by industry and government. The tasks would include formulating a plan for IVHS-related research, demonstration, and implementation; providing a forum to discuss and decide upon necessary national standards, protocols, and performance specifications for IVHS equipment; disseminating information and research results on IVHS technologies; and coordinating U.S.

[2] A more detailed discussion of the comments received on the Discussion Paper is contained in Appendix C.

research efforts with those underway in Europe and Japan. Such a national cooperative effort would not be primarily a federal program, but would, instead, be a true cooperative partnership.

To be successful, a national cooperative IVHS effort must have the cooperation and financial commitment of private firms and state and local governments. The DOT intends to discuss this issue with industry officials and state and local government policy makers before reaching a decision on the federal government's level and share of funding. The principal federal role will be to coordinate and facilitate research and development, assist in the planning and conduct of demonstrations and other evaluative programs, coordinate the standards and protocols, and to participate in research directly related to our operating and regulatory responsibilities. Federal research will not be for hardware development; that is a private sector responsibility. A final federal function will be to work with state and local governmental units to encourage the prompt implementation of proven technology in the traffic management/safety areas. These public sector investments would be eligible, as they currently are, for federal aid financing.

The federal contribution will depend upon a significant commitment to this effort by the private sector and state and local governments. We anticipate that our funding recommendation will be made in the DOT's legislative proposal for reauthorization of the federal highway and urban transit program and of NHTSA's highway safety program.

C. <u>IVHS Program Goals</u>

Based upon our review of the comments submitted on the discussion paper and follow on work, it seems that the principal goals of IVHS should be

- to increase traffic movement efficiency of urban streets and highways using advanced traffic management systems, including real-time, traffic responsive control strategies and integration with advanced information systems;

- to enhance individual's information on route choice, traffic conditions, traffic incidents, and mode choice through advanced in-vehicle driver information systems and traffic information systems;

- to increase vehicle occupancy levels by providing better information on ride sharing opportunities and priority access to high occupancy vehicles using advanced communication and information systems;

- to improve safety of highway operations through the use of in-vehicle safety advisory, warning and crash avoidance systems;

- to increase the efficiency, safety, and reliability of trucks, buses, taxis, and other highway-based fleet operations using safety warning systems and communication, vehicle identification, and safety backup systems;

- to improve highway operating performance, including vehicle throughput and trip predictability in major urban traffic corridors through the use of automated vehicle control technology; and

- to increase future levels of highway service (higher speeds and increased safety) for intercity and rural highway travel using partially automated vehicle control systems.

Although an IVHS cooperative organization will have to establish a work plan and establish priorities, our preliminary thoughts on the areas to be included in a cooperative effort are discussed below.

Advanced Traffic Management Systems (ATMS): State-of-the-art traffic management systems already have a modest level of computerization and can provide some traffic management capability in metropolitan areas. These systems are central to the ability to monitor current network traffic conditions, evaluate alternative control options, and implement actions to manage overall traffic operations.

Widespread implementation of areawide traffic management control systems throughout the United States is essential in order to have in place the infrastructure for existing and evolving IVHS technology. The application and deployment of today's existing IVHS technology in the major metropolitan areas, for example, would provide immediate benefits, as well as allow for the testing of new technology. As an initial part of the effort, incentives must be established for metropolitan areas to install areawide traffic management systems. Public funds should be provided for metropolitan areas to undertake comprehensive areawide system planning and to facilitate deployment of these systems.

Research and demonstration projects should be undertaken to continue developing the supporting traffic management subsystems technologies: detectors and surveillance devices, communications equipment, and operating software, including the use of artificial intelligence and expert system improvements. Work on computer-based traffic models is critical to analyze traffic network problems and to develop accurate control measures.

Research is needed on traffic management control strategies that are responsive to real-time variations in traffic conditions. Research, demonstration, and evaluation of communication systems will be needed so that individual driver destinations will be known and overall traffic control parameters (e.g., signals, ramp meters, reversible flow lanes) can be adjusted to optimize individual route choice and overall network traffic flow on a real-time basis. There should also be research on means to identify multiple occupancy vehicles and means to activate preferential routing for such vehicles.

Advanced Driver Information Systems (ADIS): Accurate and timely traffic information is essential for intelligent motorist route selection and diversion around accidents, construction, or other traffic disruptions. Effective motorist information systems can improve the quality of driving, reduce driver anxiety, and provide additional benefits to tourists and other travellers.

Research and demonstration programs are needed to develop and test various route choice and traffic conditions driver information systems, including navigation capability, on-board information storage, and communications links with traffic information sources. Another promising area is to develop and field test the safety advisory and warning capability of ADIS. As these systems develop, they should be demonstrated and evaluated in operational settings in major metropolitan locations with substantial traffic problems.

Research is needed to determine the optimum approach to providing information on present location and desired destination. This individualized route information could be the basis for a major enhancement to area traffic control by allowing traffic signal, freeway control, and similar decisions to be made on a real-time basis.

There should also be research on how to provide traffic information to drivers before they leave home, including traffic conditions, transit and ride sharing alternatives, weather conditions, and airport delays. Research is also needed to develop and test ways to provide information to promote ride sharing.

Freight and Fleet Control: There is a direct relationship between efficient commercial transportation and the nation's economic vitality. Advanced technology already is being placed in operation to enhance individual fleet and truck operations. These systems include automatic vehicle identification, automatic vehicle location, and vehicle satellite data communication links. Research is needed to evaluate the productivity and cost-reduction benefits to carriers and regulators of IVHS technologies and additional national demonstrations of IVHS technologies similar to the HELP project described on page 30.

Research is needed to develop truck-related collision warning, crash avoidance technology, and impaired driver detection technologies; these technologies are especially important for commercial vehicles. Means should be developed to help prevent the loss of driver control and to provide site-specific warnings to some commercial vehicles. Research should continue on ways to improve the detection of impaired drivers.

There should be research on systems to prevent truck-related collisions. Research should be undertaken to develop systems for real-time routing of commercial vehicles, taking into account their operational and regulatory needs.

Automated Vehicle Control (AVC): In order to establish higher levels of performance and safety, automated vehicle control is a logical direction for future vehicle/highway systems. These systems will result in greater traffic flows, even under poor weather conditions. These systems will result in greater highway utilization -- a major benefit in congested urban corridors. For rural and intercity trips, manually controlled vehicles with backup control systems will facilitate safe and reliable vehicle operations at much higher speeds than are now feasible. It is expected that these backup (or partially automated) systems will be deployed in the near term and will eventually evolve into fully automated systems.

While it is not expected that fully automated systems will be deployed in the near future, research should be initiated now. Research should begin to develop the necessary subsystems required for driver warning systems, driver assistance systems, and partial (and eventually fully) automated control. There should also be full scale engineering tests on a test track facility to resolve engineering issues and to evaluate expected operational performance of deployed systems. There should also be selected, limited scope operational demonstrations to provide assessments of system design and to develop public awareness of the system's safety and operational benefits. Finally, there should be research to analyze potential deployment scenarios and to identify prospective initial locations for deployment.

Highway Safety/Human Factors: To assure reasonable levels of system effectiveness, human factors principles must be observed in the application of advanced technology to vehicle and highways systems. These systems must be designed and implemented to meet driver needs with consideration of driver capabilities and limitations. Care must also be taken to assure that driver performance is not impaired nor safety degraded with the introduction of new IVHS technologies. We must also be sure that there are no serious negative consequences for pedestrians and bicyclists.

Research on crash-avoidance systems must be undertaken to evaluate how better information can help drivers avoid unnecessary exposure to high risk situations; to identify means of reducing high risk behavior by providing early warning of dangerous conditions; to identify ways to facilitate earlier and better driver response; and, ultimately, to provide means of reducing driver command and control responsibilities under poor driving conditions.

D. Interim Actions

As a first step to implement a national cooperative effort, the DOT will meet with interested parties. The National Cooperative Research Act of 1984 (NCRA) and the Federal Technology Transfer Act of 1986 (FTTA) will be useful in carrying out the cooperative effort. The NCRA permits companies to engage in research and development under certain conditions without fear of antitrust liability. The FTTA allows companies to provide funds in exchange for the use of federal resources. We shall determine whether additional authority is needed and, if so, include it in the DOT's reuathorization proposal.

In order to provide an information base, there should be a comprehensive state-of-the-art technological and commercial survey of each of the major IVHS program areas. This survey should include a systems review of each IVHS technology and its major components.[3] It should also include an assessment of how the information made available from IVHS can help individuals evaluate their travel options, including whether to drive, to ride-share, or to use public transit. The DOT shall examine whether the various existing assessments are sufficient to establish plans and priorities.

An important requirement for IVHS research is a state-of-the-art, motion-based driving simulator which will meet the needs of the NHTSA, the FHWA, other federal agencies, and private companies. The DOT intends to pursue the feasibility of joint government-industry development of a state-of-the-art world class national research driving simulator to provide the capability for conducting precisely controlled, repeatable experiments which would be dangerous in on-road tests. This simulator will promote the study of traffic safety, as well as engineering studies to support enhanced quality and safety of motor vehicles manufactured in the United States.

The DOT will also undertake certain near term research and demonstration projects in traffic management and driver informations systems. We also intend to update and develop research and analysis tools to develop a better understanding of the combinations of human, environmental, and vehicle factors that result in accidents; the distribution of accidents, fatalities, and injury levels resulting from the interplay of these factors; and to identify how IVHS technologies could reduce accidents.

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3 "Letter to IVHS Docket from John J. Fearnsides and Alexandra H. Argyropolous, the MITRE Corporation," June 9, 1989, pp. 1-2.

The DOT will also initiate studies on the societal impact of IVHS technologies and will begin to identify the institutional and social factors associated with IVHS deployment and use. Included will be studies of implementation issues and how to facilitate coordination across geographic boundaries and whether traffic operation functions could be undertaken by private firms.

There is a need to coordinate IVHS standards and protocols. The national cooperative program should provide the forum to identify, discuss, and enact national technical IVHS standards.[4] Private firms, state and local governments, and the National Telecommunications and Information Administration, the Federal Communication Commission, and the National Institute of Standards and Technology should participate in establishing these standards. As an early step, there should be a study to determine the need for standards for automatic vehicle identification, electronic toll collection, and advanced driver information systems; to identify options; and to recommend a process to establish these standards.

It is important that officials in the United States coordinate IVHS standards with those of other countries, especially Canada and Mexico. With the view toward establishing a unified North American standard for critical IVHS elements, we intend to discuss this issue with appropriate Canadian and Mexican officials.

International cooperation among the various IVHS programs could be mutually beneficial. Thus we shall seek to establish closer ties with both the Japanese and the European IVHS programs. In this regard, we are pleased with the action taken by the PROMETHEUS program to admit the European subsidiaries of American motor vehicle manufacturers to participate in the program.[5] We shall be seeking advice on the role that U.S. subsidiaries of foreign companies should play in a U.S. IVHS research program.

We agree with the suggestion of Mercedes-Benz of North America that the DOT renew an existing U.S.-Federal Republic of Germany bilateral agreement on transportation research cooperation and include IVHS. We shall explore how best to promote international cooperation among national IVHS programs. We shall also determine how U.S. firms might exchange information, undertake international joint projects, and establish international standards.

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4 The specific agency to promulgate these standards and the legislative authority to do so must still be determined.

5 Opel and Ford of Europe. Letter to the Docket from Karl-Heinz Faber, Senior Vice President, Mercedes-Benz of North America, July 25, 1989.

E. Conclusion

The DOT believes that IVHS will reduce congestion, promote safety, and improve personal mobility. An enormous range of technology already exists that could contribute to reducing vehicle delay, increasing highway capacity, and improving highway safety. More advanced systems offer the prospect of even greater benefits.

Extensive testing will be needed to determine which IVHS technologies are the most cost effective. A cooperative research effort should be a blend of technologies that have the potential for providing near term benefits as well as longer term research on promising advanced technologies.

The DOT believes that unless the U.S. firms and the public sector become more involved in developing IVHS technologies, the well-funded European and Japanese IVHS programs could give their manufacturers a competitive advantage in developing and marketing IVHS products and services.

The DOT proposes a national cooperative effort to foster the development, demonstration, and deployment of IVHS technologies. We would support formulating a plan for IVHS-related research, demonstration, and implementation; provide a forum to discuss and decide upon necessary national standards, protocols, and performance specifications for IVHS equipment; disseminate information and research results on IVHS technologies; and coordinate U.S. research efforts with those underway in Europe and Japan.

APPENDIX A

CONGRESSIONAL REQUEST FOR IVHS REPORT

Conference Report To Accompany H.R. 4794
House of Representatives, 101st Congress, 2d Session
Report 100-957
September 22, 1988

Report on "Intelligent" Vehicle/Highway Technologies. The conferees recently have been apprised of extensive research and development programs being conducted by European and Japanese governments and industry to develop advanced vehicle highway technologies to improve traffic flow and to enhance the international competitive position of their own industrial enterprises. In Europe, for instance, the $700 million-$800 million PROMETHEUS program (to develop "smart" vehicles with advanced control and communications systems) is being pursued cooperatively by five national governments and 13 European vehicle manufacturers, with no participation by U.S.-affiliated firms being permitted. A similar closed research program is underway in Japan.

With no comparable U.S. program underway, the conferees are concerned that there may be unwarranted delays in introducing advanced vehicle highway technologies in the U.S. and that U.S. manufacturers and research and development organizations may be placed at critical long-term competitive disadvantages. The conferees therefore direct the Secretary to submit a comprehensive report to Congress within nine months of enactment assessing European, Japanese, and U.S. advanced vehicle highway technology research and development initiatives, analyzing the potential impacts of foreign programs on the introduction of advanced technologies for the benefit of U.S. highway users and on U.S. vehicle manufacturers and related industries, and making appropriate legislative and/or programmatic recommendations. In conducting this study, the Department shall consult with state and local governments and private sector transportation groups and with vehicle and electronics manufacturers.

APPENDIX B

FEDERAL REGISTER NOTICE AND REQUEST FOR COMMENTS

4910-62M
Department of Transportation
Office of the Secretary
[Docket no. 46284] [Notice no. 89-4]

Intelligent Vehicle-Highway Systems (IVHS) Technology; Notice of Availability of Discussion Paper and Request for Comments.

AGENCY: Department of Transportation, Office of the Secretary.

ACTION: Request for Comments: Notice of Availability of Discussion Paper.

SUMMARY: The Conference Report on the FY 1989 Department of Transportation Appropriations Act directs the Secretary of Transportation to report to Congress by July 1, 1989, on Intelligent Vehicle-Highway Systems (IVHS) assessing European, Japanese, and U.S. advanced vehicle-highway technology research and development initiatives. The report will analyze potential impacts of foreign programs on U.S. highway users, vehicle manufacturers, and related industries and make appropriate legislative and/or programmatic recommendations. In conducting this study, the Department is directed to consult with state and local governments, private sector transportation groups, and vehicle and electronics manufacturers. To assist in the preparation of the Report to Congress, the Department has prepared a discussion paper to solicit views and recommendations.

DATE: Comments should be received by June 15, 1989. Late-filed comments will be considered to the extent possible.

ADDRESS: Requests for copies of the discussion paper should be sent to IVHS Discussion Paper, P-30, Office of the Assistant Secretary for Policy and International Affairs, U.S. Department of Transportation, 400 7th Street, S.W., Washington D.C. 20590. Comments should be sent (four copies) to Docket Clerk, room 4107, Docket No. 46284, at the same address.

FOR FURTHER INFORMATION CONTACT: Thomas E. Marchessault, P-30, at the above address; telephone: 202/366-5412.

SUPPLEMENTARY INFORMATION:
The Department has prepared a Discussion Paper on Intelligent Vehicle-Highway Systems (IVHS) to solicit views and recommendations.

The Discussion Paper considers the need for a national Intelligent Vehicle-Highway Systems (IVHS) program in view of the fact that serious urban traffic congestion has been creating the need for traffic operations techniques and systems that will substantially increase highway capacity and improve traffic flow efficiently and safely. The Discussion Paper describes types of Intelligent Vehicle-Highway Systems (IVHS) and their benefits; reviews existing European, Japanese and U.S. Programs; weighs possible impacts of foreign IVHS preeminence on U.S. industry and consumers; discusses goals and a possible research agenda for a potential national IVHS program; and suggests alternative organizations to develop and coordinate a national IVHS cooperative program.

Through the use of advanced computers, telecommunications, and control technology, IVHS can improve communication between drivers and traffic control centers, creating an integrated highway transportation system. Ultimately, with the assistance of IVHS, automobile travel has the potential to become safer, more time and space efficient, more energy efficient, and more environmentally benign.

Features of potential IVHS fall into four categories: (1) "Advanced traffic management systems" can be used to influence the pattern of route choice by redistributing traffic between geographic areas or between highway systems to reduce delays and accidents; (2) "Advanced driver information systems" are designed to provide additional information to the driver through navigational information and real-time traffic data allowing the driver to follow optimal routes from origin to destination; (3) "Freight and fleet control operations" would allow a central controller to communicate with its vehicles to issue instructions and keep track of route progress. Moreover, traffic signals could be controlled, giving priority to public transportation and emergency vehicles; (4) "Automated vehicle control systems" are designed to take over many driving functions, allowing more cars to travel on highways, at faster speeds, with less wasted time, and in safer condition. These "automated highways" would operate in heavily traveled intercity highways and in selected urban areas.

Comments are solicited on specific issues related to any aspect of IVHS technology and on the proposition of a national IVHS program.

Issued this 10th day of May, 1989, at Washington D.C.

____________(signed)_______________

Patrick V. Murphy
Deputy Assistant Secretary for
Policy and International Affairs

APPENDIX C

PUBLIC COMMENTS AND RECOMMENDATIONS REGARDING INTELLIGENT VEHICLE-HIGHWAY SYSTEMS

This appendix summarizes the comments received on the DOT's May 1989 Discussion Paper on Intelligent Vehicle-Highway Systems. Of the 88 responses, 30 represented state, federal, or local transportation departments or highway commissions, departments, or bureaus; 15 represented university transportation or engineering departments or research bureaus; 13 represented private transportation consulting firms; 13 represented motor vehicle and parts manufacturers, electronics companies, or communication, computer, or other companies; 15 represented trade associations; and three were private citizens.[1]

The discussion paper sought comments on the general issue of IVHS and on the following eight specific questions:

1. Is there a need for a national research, development, and demonstration program that would form the basis for implementation of IVHS technology on a reasonable time-table?

2. What should be the principal goals of a national IVHS program?

3. Is the preliminary research agenda appropriate to achieving the goals we have set forth? What changes/deletions would you suggest? Which elements should be undertaken by the government? Which elements should be undertaken by the private sector? Which elements could most efficiently be undertaken by a cooperative public/private effort?

4. What are the appropriate roles and responsibilities of the federal government, the state and local governments, and the private sector in a national IVHS program that encompasses research, product development, implementation, and operation of the various elements of IVHS?

5. What is the most appropriate organizational structure to manage and direct an IVHS program?

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[1] An additional ten letters acknowledged receipt of the Discussion Paper, indicated that they might comment at a later time, or provided information on particular products. There are also seven additional comments from individuals and parties already included in the total of 88 comments.

6. What funding level, funding sources, and time-table is appropriate to achieving the goals set forth for a national IVHS program?

7. Should the participation of foreign governments and companies be allowed in a U.S. national program? Should their participation be encouraged? Should any distinction be made between Canada and Mexico versus other non-American countries?

8. What other issues are important in considering a national IVHS program?

Several respondents limited their comments to general statements endorsing a national research program. Included in the Public Docket is testimony from a June 7, 1989, hearing on IVHS before the House Committee on Science, Space, and Technology. Many respondents did not explicitly address the eight questions on which comments were sought, and some chose to comment on only one or two questions. A few private firms stated the status of their existing product lines and available technologies that would improve traffic management and did not comment on any of the eight issues on which comments were sought.

Almost all respondents supported a national research, development, and demonstration program that would form the basis for implementing IVHS technology. Beyond that point, however, the respondents expressed a wide diversity of views regarding the scope of the program, the proposed role of federal, state, and local governments, the appropriate organizational structure, and levels and sources of funding.

A. Need For An IVHS Program

Of the 88 respondents, 78 supported a national IVHS program.[2] Those responding favorably stated that there is a "definite need," "an urgent need," "an unquestionable need," "a need for a rational program," "a concept whose time had come," "worthwhile and much needed," "action must be taken now to begin to implement IVHS technologies," and "IVHS will trigger whole new technologies."

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[2] Four respondents did not address this issue -- University of California-Davis, Century 21 All Star Realty, Society of Automotive Engineers, and IBTTA. Four respondents expressed doubt about the need for a national program -- University of California-Davis; Wisconsin DOT; Parsons, Brinckerhoff, Quade, and Douglas, Inc.; and Kayton Engineering. Only one respondent said there was no need for such a program -- South Dakota DOT.

Support for a national IVHS program came from a number of private companies, several state highway and transportation agencies, highway users' groups, as well as private researchers and academics. Representatives of the following companies supported a national IVHS program: General Motors, Motorola, Chrysler, Ford, Paccar, AT&T Network Systems, Federal Express, Nissan, and Mercedes-Benz.

Officials from state and local governments supporting a national IVHS program included States with serious urban highway congestion problems, such as California, Illinois, New Jersey, New York, Michigan, Minnesota, Pennsylvania, and Indiana. There were also expressions of support from the States of Arkansas, Arizona, Iowa, Kentucky, Nebraska, Nevada, New Mexico, Vermont, Virginia, and Washington.

Among those less willing to support a national program at this time are many parties that still support some initial work on IVHS technology, pending a comprehensive examination of the benefits and costs of the various technologies. Included here are those with a positive attitude toward IVHS but who are not willing to support a particular IVHS technology at this time. The Motor Vehicle Manufacturers Association, in particular, concluded that there needs to be a senior level review of IVHS-related policy issues in order to determine whether a national program should be pursued. To accomplish this, the Association recommend that a Presidential Commission be established.

The South Dakota DOT, which does not support a national IVHS program, believes that a need exists to improve traffic capacity, but IVHS technology may not be the appropriate solution.

Virtually all of the academic researchers supported a national IVHS program. Strong supporters included Texas A&M University, University of Michigan, Massachusetts Institute of Technology, Penn State University, University of California-Berkeley, University of North Carolina, and Vanderbilt University. In addition, the Council of University Transportation Centers supported an IVHS program. The University of California-Davis suggested that electrified mass transit would better solve the nation's urban transportation problems.

B. IVHS Goals

Of the respondents who supported a national IVHS program, most concurred with the goals stated in the Discussion Paper. Three respondents were opposed to national research goals, one commenting that specific goals cannot be laid out in advance (University of Michigan), one commenting that local systems can evolve independently (Kayton Engineering), and one commenting that IVHS may not succeed in achieving the goals specified (MVA Systematics, Inc.). Twenty-two (22) respondents did not address this issue.

Most of the comments restated the principal goals expressed in the Discussion Paper, emphasizing the relative importance of one goal over another. A common thread throughout the comments was the emphasis on the goals of improving highway safety, reducing congestion, and improving the efficiency of highway use.

Several respondents added that the a national IVHS program should emphasize the measurement of program costs and benefits. A few respondents indicated that the principal goals of a national IVHS program should include automobile efficiency goals, such as improving vehicle reliability, mandating safety checks, reducing air pollution, and increasing vehicle occupancy. Some respondents commented that a principal goal of a national IVHS program should be to help ensure U.S. international competitiveness. Several respondents commented that a national organization, or forum, should be established to guide technology and resolve major policy and technical issues, in addition to coordinating the development, demonstration, and implementation of new highway and vehicle technologies.

C. Preliminary Research Agenda

Fifty (50) respondents provided comments on the preliminary research agenda included in the Discussion Paper. The reaction to the proposed research agenda outlined in the Discussion Paper was generally favorable, although many respondents had detailed additions or deletions. A number of respondents thought that establishing a research agenda, a funding level and timetable was premature. Some respondents commented that the agenda should include an analysis of the costs and benefits of IVHS technology.

Several respondents commented that the research agenda should include an analysis of human factors, such as the effects of an IVHS program on the mobility and convenience of elderly drivers. Some respondents felt the agenda timetable should be compressed, while others felt a longer term perspective should be taken. Indeed, several respondents commented that the development of an agenda would be premature until a lead coordinating organization was established. Several respondents also thought that local experiments to reduce traffic congestion should be encouraged. Finally, respondents had different views on the importance of research efforts for advanced traffic management systems, advanced driver information systems, and advanced vehicle identification, location, and control systems.

D. Appropriate Roles

Forty (40) respondents provided comments to this question. Those who responded were nearly unanimous that federal leadership and coordination would be required, along with significant input from state and local governments, motor vehicle manufacturers, the highway construction industry, academic and research institutions, and the computer, electronics, and communications industries.

Several respondents commented that the lead federal agency would have to set program standards and that IVHS technology and demonstration projects should not involve solely urban states. One respondent commented that the federal government and the private sector should be equal partners with state and local governments advising at the research and development stage and with private sector firms providing the technology.

Two respondents were opposed to a strong federal role. An engineering firm (Parsons, Brinckerhoff, Quade, and Douglas) advocated a restricted federal role; instead, the firm favored encouraging a private sector consortium to assume the lead in implementing and operating IVHS technologies. Kayton Engineering commented that the U.S. DOT should be restricted to supporting IVHS developments that affect the Interstate Highway System. Kayton Engineering stated that local solutions to congestion and other traffic problems should be devised and coordinated by engineers and academics at local universities.

E. Organizational Structure

Forty (40) respondents commented on this question. There was less unanimity on the type of organization to undertake such a program. Virtually all respondents supported the concept of a public/ private partnership, although there was no consensus on how to organize such an endeavor. Many respondents had either no views on the appropriate organizational structure or had only weak preferences for how a national IVHS program should be organized.[3]

The various types of organizations discussed for coordinating an IVHS program included a Presidential Commission, a government-industry advisory council, a NASA-type agency, a new bureau or agency, or a FHWA/NHTSA/UMTA advisory committee. A few respondents commented that they did not know what organizational structure would best meet the goals of a national IVHS program.

In general, the remaining comments fell into one of three categories:

1) strong central DOT organization;
2) independent public/private organization;
3) Presidential Commission.

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[3] These include, the American Trucking Associations, the New York DOT, MIT, University of Michigan, and Texas A&M University.

Those in favor of a strong DOT role included General Motors, California DOT, Michigan DOT, American Automobile Association, Transcom, and Penn. State University. Those in favor of a strong federal role but in an agency outside of the existing the DOT organization include the Highway Departments and DOTs in the following States: Indiana, Iowa, South Dakota, Pennsylvania, Nebraska, and New Jersey. This option was also favored by Paccar and the University of California-Berkeley. Finally, the concept of a Presidential Commission was suggested by the Motor Vehicle Manufacturers Association, as well as Chrysler, Ford, the Electric Power Research Institute, and the International Bridge, Tunnel and Toll Association.

Respondents affiliated with academic institutions commented that universities should play an advisory role. Kayton Engineering commented that local universities should provide the primary coordinating role. Several respondents, including Penn State University and the Michigan DOT, suggested the use of the Mobility 2000 recommendation. Almost all the respondents stated that U.S. DOT should be the focal point of a national IVHS effort. The University of Michigan, however, took exception to the need for a rigid governmental organization, commenting that "... IVHS must be freed from instituted dogmatism and bureaucratic burden."

F. Funding Levels, Funding Sources, and Timetable

Forty-one (41) respondents commented on this issue. Of those responding, several stated that it was premature to discuss funding. Included here are the Motor Vehicle Manufacturing Association, the American Trucking Associations, and the American Automobile Association. Those respondents that provided specific dollar amounts and timetable indicated a range of $30 to $300 million per year for up to ten years. The Highway Users' Federation and General Motors urged spending $1 billion over ten years.

Some respondents suggested a trust fund to support IVHS developments. The California DOT supported a 0.5 cents per gallon tax; the Michigan DOT suggested a 0.1 cent per gallon tax on gasoline dedicated to IVHS research. One private consultant, Haugen and Associates, suggests a 2.0 cents per gallon tax for IVHS research. Several respondents commented that new sources of funding must be found. A few respondents indicated that any funding and timetable established should be competitive with research efforts underway in Europe and Japan.

G. Participation of Foreign Governments

Forty-two (42) supported some degree of foreign participation. Thirty-three (33) said yes, specifically mentioning the inclusion of Canada and Mexico, and five respondents said no, but added that Canada and Mexico should be given advisory roles. Two (2) respondents were opposed to foreign participation, one commenting that only U.S. companies that are more than 50 percent owned by U.S. citizens should participate. And one respondent suggested that foreign participation should be allowed only if equal participation is allowed for U.S. citizens in foreign programs. Mercedes-Benz commented that an existing U.S.-Federal Republic of Germany bilateral agreement on transportation research cooperation should be extended and should encompass IVHS technologies.

H. Other Issues

Almost half the respondents elaborated on other important issues they believed should be addressed, although many of the comments simply amplified or restated positions or comments addressed previously. The other important issues included:

- the need for an inventory on all possible projects,
- environmental impacts,
- public acceptance,
- public education,
- the loss of right to privacy,
- special needs of the elderly,
- liability issues,
- implications for other transportation modes,
- implementation of existing technologies,
- systems compatibility and interchangeability,
- system failures,
- the need to improve driving skills,
- congestion pricing,
- the role of trucks,
- national standards,
- radio standards,
- institutional barriers to cross-jurisdiction/regional operation, and
- maintenance of advanced systems.
- role of bicycles.