

A COMPARISON OF INTERNATIONAL IVHS

by

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Prepared for
CVEN 689
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August 1993

EXECUTIVE SUMMARY

The *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States* suggests that congestion is the major problem facing American transportation in the next century. Congestion costs this country billions of dollars a year in terms of man-hours, fuel consumption, maintenance costs, and pollution. Therefore IVHS in America has focused on reducing congestion (increasing mobility) as its primary objective. Systems have been, and are being developed in this country to combat the problem of congestion.

The United States is not the only country to develop IVHS. Japan has been researching and developing IVHS since the 1960s. Europe has been developing systems since the mid 1980s. Other countries such as Canada, Australia, and China have recently started developing their own systems. The United States should actively follow the developments of IVHS in other countries to improve the technologies and systems that will be used in this country. Their programs and systems should be thought of as learning tools that we should use to improve American IVHS.

Countries around of the world are facing the problems of increased congestion, increased number of accidents, and a decrease in air quality. Traditional methods for improving traffic conditions have reached the point where either they are not wanted by the public or they will no longer work. For this reason, many countries have turned to IVHS to help solve their problems. It is clear that every transportation problem has numerous answers and that different countries are using different methods for solving their problems.

To remain a world leader in IVHS, the United States needs to learn from other countries. The exchange programs between the United States, Europe, and Japan must continue and be encouraged to grow. The legal and social aspects of IVHS technologies must be settled before large-scaled implementation of IVHS can occur. Social aspects, such as, privacy and cost fairness will have to be addressed before the American public will accept IVHS. Without the support of the population, IVHS will never survive. While technologies are being developed, American companies need to find markets outside the United States.

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INTRODUCTION

Surface transportation in the United States is at a crossroads. The mobility we prize so highly is threatened. Many of the nation's roads are badly clogged. Congestion continues to increase, and the conventional approach of the past - building more roads - will not work in many areas of the country, for both financial and environmental reasons. (1)

This is the first paragraph of the *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States*. It suggests that congestion is the major problem facing American transportation in the next century. Therefore IVHS in America has focused on reducing congestion (increasing mobility) as it's primary objective. Systems have been, and are being developed in this country to combat the problem of congestion.

Congestion costs this country billions of dollars a year in terms of man-hours, fuel consumption, maintenance costs, and pollution. Therefore, one possible motivation for IVHS is the saving of all those billions of dollars. In 1991, over 41,000 people died and over five million people were injured on America's highways.(1) Another possible motivation for IVHS is the safety of the travelling public. The following are the goals of IVHS America has for the United States:

- 1) To improve the safety of surface transportation.
- 2) To increase the capacity and operational efficiency of the surface transportation system.
- 3) To enhance mobility and the convenience and comfort of the surface transportation system.
- 4) To reduce the environmental and energy impacts of surface transportation.
- 5) To improve effectiveness and efficiency of the surface transportation system, now and in the future, thereby improving productivity of individuals, organizations, and the economy as a whole.
- 6) To develop a viable and profitable U.S. based IVHS industry.
- 7) To redirect the transportation profession, expand the capabilities of existing transportation organizations, and bring new organizations into the transportation field.
- 8) To develop and demonstrate a new institutional structure for technology development and deployment in the U.S.

The United States is not the only country to develop IVHS. Japan has been researching and developing IVHS since the 1960s. Europe has been developing systems

since the mid 1980s. Other countries such as Canada, Australia, and China have recently started developing their own systems. The United States should actively follow the developments of IVHS in other countries to improve the technologies and systems that will be used in this country. Their programs and systems should be thought of as learning tools that we should use to improve American IVHS.

Purpose of Paper

The purpose of this paper is to focus on international IVHS and the technologies used to implement their programs. This will be accomplished by:

- 1) Examining the major IVHS technologies in use in Europe, Japan, Australia, Canada, and other newly industrialized countries,
- 2) Exploring the motivations behind the selection of these technologies,
- 3) Examining the direction that each country is currently following,
- 4) Comparing these technologies, motivations, and directions with those in the United States,
- 5) Consolidating the information to compare activities in foreign areas to the United States, and,
- 6) Recommend actions the United States should take to remain among the world leaders.

Scope

This report will examine IVHS technologies in the areas of ATMS, ATIS, and AVCS from several foreign countries or areas and compare these technologies to those in the United States. These countries or areas include; Japan, Europe, Australia, Canada, and other newly industrialized countries. In recent years, transportation professionals have taken a first hand look at IVHS in other countries. Reports of the trips along with the impressions gathered by some of the professionals who went on these trips will be the basis of this report.

JAPANESE IVHS

Japan is a group of islands in the western Pacific Ocean. The total land mass of these four islands is approximately equal to the land mass of California. Since the islands are extremely mountainous, only twenty percent of the land is used by the people on a daily basis. This is important because Japan has nearly half the population of the United States living in an area approximately equal to the size of the state of West Virginia.(2)

Background

Historically, Japan has used wheeled transportation far less than other western countries. Nearly all transportation before the late 19th century was on foot or by horse. During the modernization of Japan during the late 19th and early 20th centuries, an extensive railroad network was developed that supported the increased need for transportation. At this time the Japanese road network was very poorly developed. The use of the automobile in the 1930s was limited to a few trucks, buses, and taxis. After World War II, the Japanese government began many programs to increase economic growth. With this economic growth came technological growth and during the 1960s, the number of automobiles exploded. (2) This growth in the number of automobiles led to several major problems for the Japanese; an increase in the number of traffic related fatalities, an increase in the level of congestion, and a decrease in air quality.

Increase in Congestion

Figure 1 presents the increase in the number of vehicles since 1970. As can be seen from the figure, a steady increase has occurred over the years since 1970 and the rate of increase has grown since the late 1980s. Table 1 compares the Japanese road system to that of the United States. This table shows that the number of miles of the Japanese road system is only 18% of the road miles of the United States. The increase in the number of vehicles, along with a limited road system has caused congestion to increase dramatically.

Increase in Accidents

Figure 2 shows the number of fatalities and the number of injuries in Japan over the last 35 years. It can be seen that the increase in the number of automobiles in the late 1980s, as seen in Figure 1, corresponds with an increase in the number of fatalities in the late 1980s. Accidents with fatalities at the present time have the following characteristics:

- 1) Significant increase in fatalities is found in people with the ages between 16 and 24, and over 65,

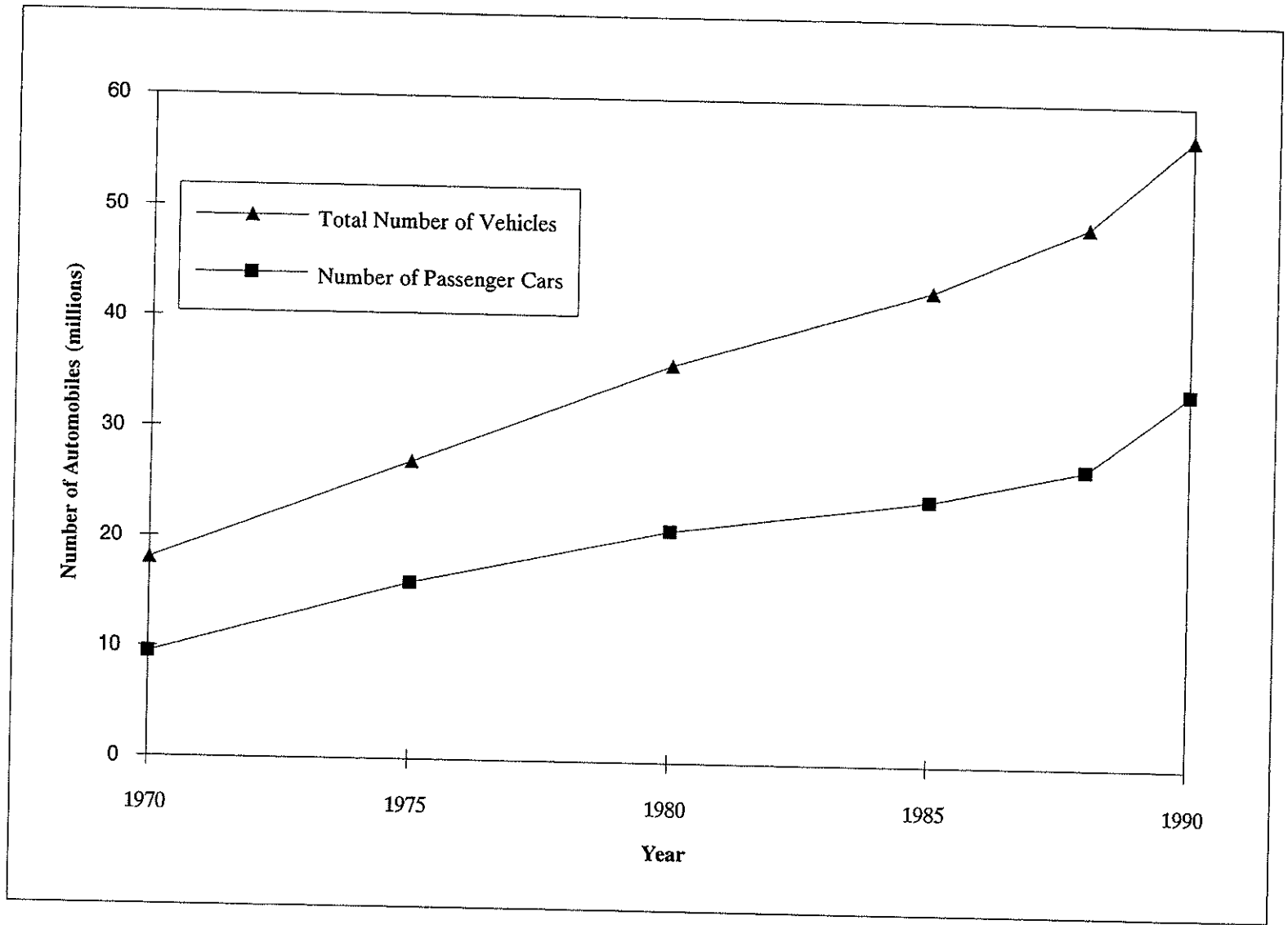


Figure 1. Number of Vehicles and Number of Passenger Cars in Japan. (3)

Table 1. Comparison of the Japanese and US Road Systems (as of 1988). (4)

| Road Type | Length of Road Systems in Japan Total Miles | Length of Road System in the US Total Miles | Length Ratios Japan/US |
|-----------------------|---|---|------------------------|
| Expressways | 2,700 | 45,000 | 6% |
| Primary Highways | 29,000 | 259,000 | 11% |
| Prefecture (State) | 80,000 | 499,000 | 16% |
| Local (County & City) | 575,000 | 3,073,000 | 19% |
| Total | 686,700 | 3,876,000 | 18% |

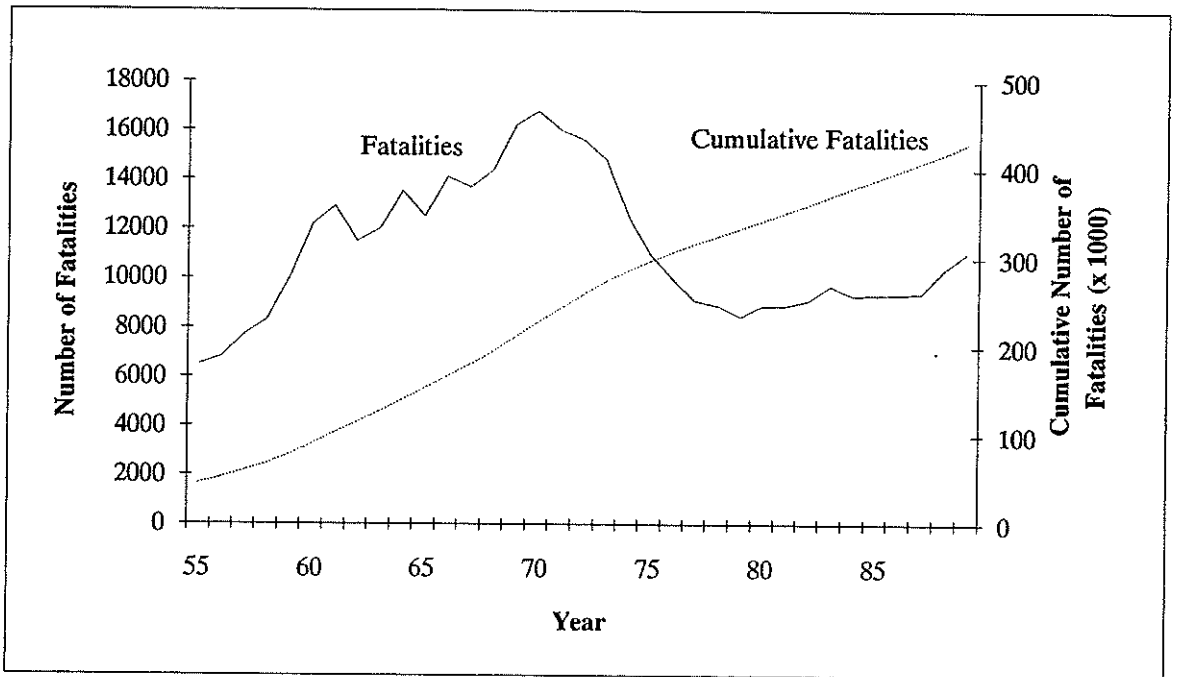
- 2) Fatalities of drivers and passengers have increase much more than those of pedestrians,
- 3) Accidents in the nighttime have increase much more than in daytime, and a ration of fatal accidents is higher than in the daytime, and,
- 4) Accidents have increase at weekends (the day of the week when the number of fatalities is the largest is Sunday). (3)

Decrease in Air Quality

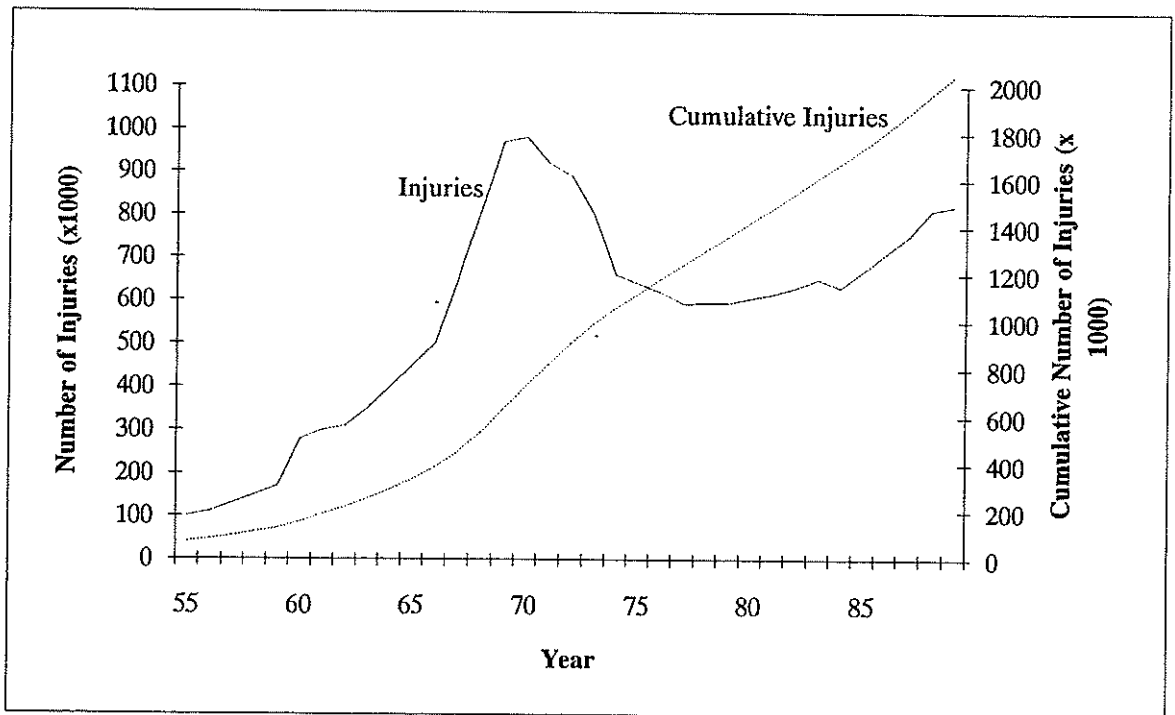
Japan has the strictest limits for air quality in the world. Air pollution caused by CO and SO₂ has been reduced to below legal limits by controlling the emissions from each automobile. However, air pollution caused by HC and NO₂ have not been reduced and pollution caused by CO₂ and fluorine is becoming a serious problem.(3)

These problems have caused the Japanese to begin the development of IVHS. Development began in the early 1970s and has continued to grow and become stronger. Robert Ervin from the University of Michigan described the forces behind the Japanese commitment to IVHS as the following "7 C's":

- 1) Congestion causes the average vehicle speed to be below 10 mph through much of the daytime, even on expressways,
- 2) Conditioning by the Japanese government has 20 years of progress behind it in providing motorist information services, so motorists have come to expect continuing improvement,



a) Fatalities



b) Injuries

Figure 2. Number of Accidents and Injuries in Japan (3)

- 3) Centralization of national highway construction and national traffic control are supplied by the Ministry of Construction and the National Police Agency, respectively,
- 4) Continuity in Japanese IVHS programs has been underway for almost 20 years, giving government and industry the opportunity to "learn by doing",
- 5) Customers, such as executive buyers, who simply take "the full option package" in car purchases, provide an early market for automobile navigation systems, sparking industry competition,
- 6) Collaboration between government and industry in the IVHS area has been ongoing since 1973, with coordination by the Ministry of International Trade and Industry (MITI), and,
- 7) Cash is readily available because Japanese right-of-way is so expensive that stretching the serviceability of roadways through IVHS makes strong economic sense.(4)

Development of IVHS

In the late 1950s, the Japanese decided that the problems of lack of space, highway congestion, pollution, and safety problems could not be solved by solely building more roads. Instead they chose to combine information and communication technologies to the infrastructure.(5) Japan has focused its energies on three types of IVHS; advanced traffic management systems (ATMS), advanced travellers information systems (ATIS), and advanced vehicle control systems (AVCS).

Advanced Traffic Management System

In the late 1960s, Japan decided to computerize traffic signal controllers. Several small experiments were conducted on arterial streets in the mid-1960s, but not much technical information was acquired from the experiments. A committee was organized in the late 1960s to examine the results of the experiments and to set specifications for the hardware and the configuration of the control algorithms.(2) In 1970, one hundred traffic signals in downtown Tokyo were put under the control of a centralized traffic control center. It was estimated that the computer controlled intersections reduced travel times and stops, and saved man-hours and gas consumption equivalent to an amount 5.7 times greater than the installation costs. (6)

With the successful implementation and satisfactory performance of the small system, the number of signalized intersections under computer control was increased. The National Police Association (NPA) decided to expand the system in the metropolitan Tokyo area and begin systems in other major metropolitan areas by subsidizing 50% of the installation costs.(2) This program continues today with 43,000 of 135,000 signalized intersections under central computer control. Japan has 161 traffic signal control centers operated by the NPA.

The largest traffic signal control center in Japan is in the city of Tokyo. This center is probably the best example of a comprehensive, modern traffic control system for a city street network. It controls 6,564 out of the 13,064 signalized intersections in the city, uses 8621 vehicle detectors in the system, has 80 variable message signs, uses 104 CCTV units, and has 14 roadside radio units. The traffic control center's large wall map display shows 461 of the intersections in the network. (5) The Japanese are currently using three or four pre-timed signal plans which are calculated using techniques such as TRANSYT. Offsets are determined either through trial and error or by simulations. The traffic center is considering the use of SCOOT and SCAT to develop a real-time optimization control strategy for use in a new system. The new system will become part of a broader Universal Traffic Management System (UTMS). (5)

All of the 130 miles of expressways in Tokyo are tollways. The Japanese have not used ramp metering or electronic toll collection to improve traffic conditions on the expressways. When congestion reaches a certain level, the access ramps are simply closed and the manual toll collection acts as a metering device. (7) The NPA has chosen to use ultrasonic detectors instead of inductive loop detectors because of the maintenance difficulties of the loop detectors. Ultrasonic detectors make up 97 percent of all detectors in Japan. (7)

Vehicle detectors on major intersections are placed 150 m., 300 m., 500 m., and 1000 m. from the intersection to carry out signal control and to measure the traffic queues at the intersection. Detectors placed on expressways are used to locate accidents and congestion. CCTV is used to confirm incidents and this information is relayed to drivers by HAR and by the variable message signs. The traffic control center receives traffic information, analyzes the information, and makes decisions concerning the traffic conditions every five minutes. (8)

Advanced Travellers Information Systems

The Japanese have focused a large effort on advanced travellers information systems. The first test of ATIS was the Comprehensive Automobile Traffic Control System (CACCS). In 1977, 1330 vehicles were equipped with on-board receiver units that were used for route guidance. 103 roadside units were placed in a 30 km² area southwest of Tokyo that fed information to the on-board units. As a vehicle with the on-board equipment passed a roadside unit, a destination code and an ID number would be passed from the vehicle to the roadside equipment. A guide table, which defines the turning direction for each destination, was stored in the roadside equipment and was updated every fifteen minutes with new traffic information. The roadside equipment determined the best route to take to the destination and would send turning instructions to the vehicle. The vehicle ID was used to measure travel times between units. (6) The test showed that travel time was reduced by 13% for vehicles equipped with the on-board navigation equipment and simulations showed that if the system was implemented on a city wide basis, fuel consumption would be reduced by 3 to 7%. (3)

In the mid-1980s, two projects were being developed to provide real-time traffic information to vehicles equipped with on-board receivers and displays. These projects were

the Road/Automobile Communications System (RACS) and the Advanced Mobile Traffic Information and Communications System (AMTICS). Each program sought to provide traffic information, but each system had its own method of data transmission. RACS used a beacon system for communications while AMTICS adopted a teleterminal system for communications. The two programs are discussed below.

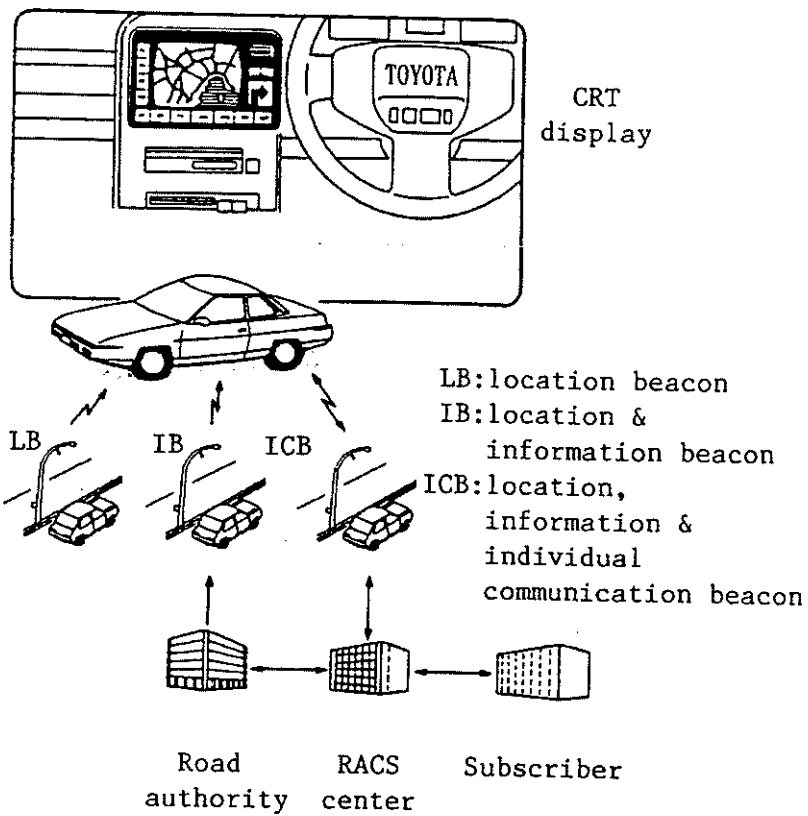
RACS - The Road/Automobile Communications System was initiated in 1986 by the Ministry of Construction. The RACS system consists of the RACS center, roadside beacons and the in-vehicle communications and navigation devices. The on-board devices communicate by radio to the roadside beacons which then communicate with the center through a cable network. The principle functions of the system are listed below:

- 1) Navigation - As the vehicle passes a location beacon, the on-board equipment receives a location signal which is used to correct any errors from the dead-reckoning navigation system.
- 2) Road & traffic information - As the vehicle passes a location - traffic information beacon, current traffic information, construction information, and lane closure information is transmitted to the vehicle. The on-board navigation system then selects the information that is relevant to the current trip, and uses the information to select the optimum route. Additional information on parking lot location and vacancy conditions can also be provided.
- 3) Private communications - Videotext and/or fax messages can be relayed between the vehicle and a subscriber when a vehicle passes a individual communications beacon. Digitized voice messages can also be handled. In addition, provision has been made for Automatic Vehicle Monitoring (AVM) for fleet operators.(9)

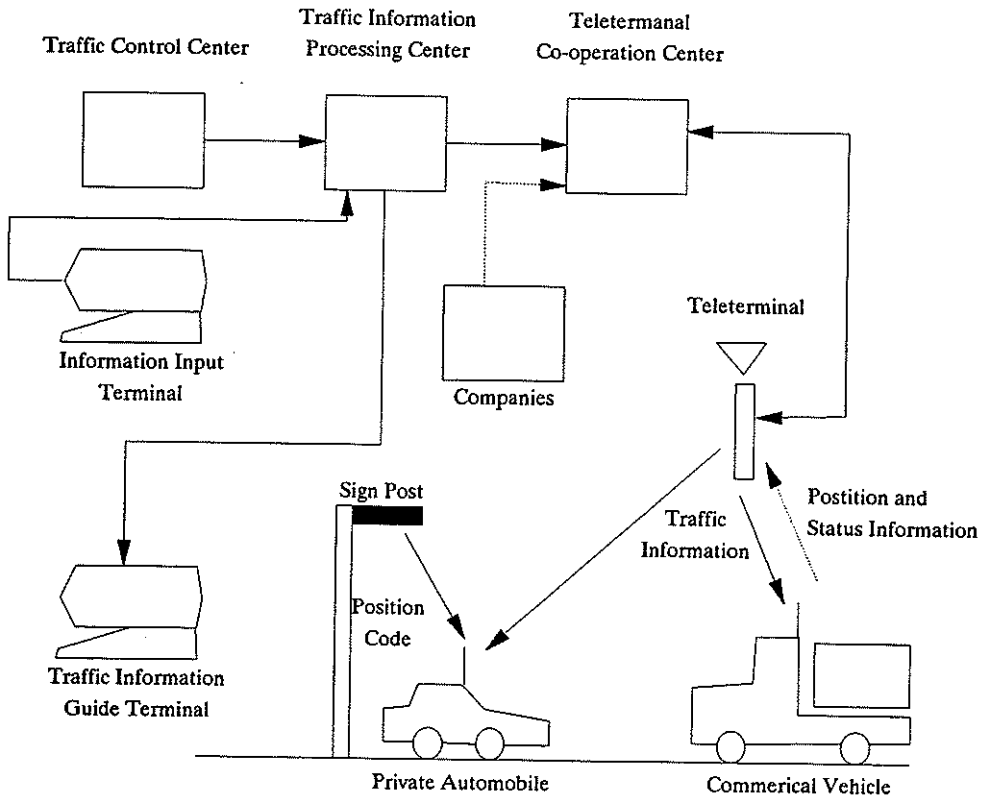
The RAC system can be seen in Figure 3.

A field test of the system proved that the system is beneficial to both the vehicle occupants and the road authorities. Vehicle operators especially liked the voice synthesis when receiving traffic information. It is expected that this system will be incorporated into any future systems.

AMTICS - The Advanced Mobile Traffic Information and Communication System (AMTICS) was initiated in 1987 by the National Police Agency. This program was developed to compete with RACS and keep the NPA in the traffic management field. AMTICS features a direct presentation of traffic information to drivers with the on-board audio visual equipment from the traffic control centers and also features the use of commercially available mobile data communication systems.(2) The system was successfully tested in metropolitan Tokyo in 1988 and at the Flower and Green Exposition in Osaka in 1990. Figure 3 presents the AMTICS system.



a) RACS



b) AMTICS

Figure 3. RACS and AMTICS Design (6,9)

Direction of Japanese IVHS

The Japanese are integrating the concept of info-mobility into their IVHS. A model of info-mobility can be seen in Figure 4. In a mobility system there are three separate subsystems; the driver, the vehicle, and the road environment. While the basic mobility system is sufficient for safe and efficient automobile driving, "gaps" between these three subsystems are causes of accidents and congestion. Accidents and congestion are caused by a mismatching of the driver subsystem and the vehicle subsystem, or of the vehicle subsystem and the road environment subsystem. In the info-mobility concept, the three subsystems are surrounded by information systems. The information system is what makes automobile driving safer and more efficient. In terms of IVHS, advanced traffic management systems are located in the road environment subsystem, advanced drivers information systems are located mainly between the driver subsystems and the road environment subsystems, and the advanced vehicle control systems are mainly located around the vehicle subsystems. (3)

The Japanese have already deployed a very extensive traffic management system that gathers information from the road environment. This system operates with 43,000 of 135,000 signalized intersections under central computer control. These signals are operated from 161 traffic signal control centers operated by the NPA. Estimates suggest that it will take the United States twenty years of aggressive deployment of systems to approach the size of the Japanese system. (10) In 1991, the fifth five year plan for traffic management was implemented. This plan called for five new systems to manage traffic:

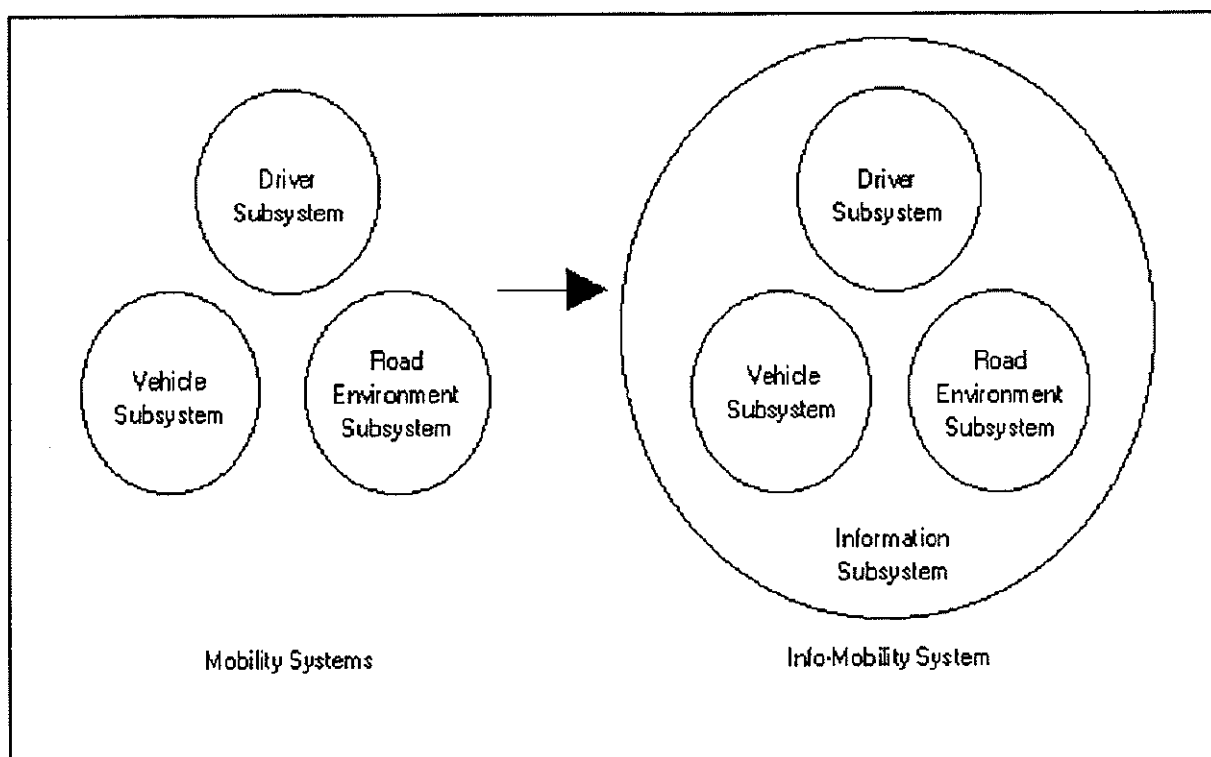


Figure 4. Info-mobility Concept.(3)

- 1) Over-speed Restraining System - A system consisting of microwave radar units, television surveillance cameras, and changeable message warning boards are to be used to detect over-speed vehicles. Vehicles would then be alerted of their excess speed through the use of warning boards. For vehicles that continued to speed, license plates would be photographed and digitized to extract information on the driver of the vehicle.
- 2) Illegal Parking Restriction System - Television cameras would be installed at major intersections to monitor and suppress illegal parking in congested areas. Voice warnings would be given when an illegal parking attempt was made and the authorities would be contacted if the vehicle was not moved.
- 3) Parking Information Systems - This system would gather information from parking lots around the city and transfer occupancy information to vehicles through variable message signs, on-board receivers, radio or telephone.
- 4) Green Extension Function for Minor Road Users - For the elderly or handicapped, who need extra time to cross the road, a small transmitter would be carried by the user. This transmitter would broadcast to the traffic signal that extra time is needed for the pedestrian phase.
- 5) Speed Activated Signal Control Function - This system would detect high-speed vehicles and change the traffic signal ahead of the driver to cause the vehicle to stop. The system is designed to cause high speed drivers to stop at every signal.(8)

These five new systems attempt to promote a safer driving environment for all who use the network of roads by discouraging illegal behavior and by provide extra information to the driver.

For the advanced travellers information systems and the advanced vehicle control systems are being developed in two projects. These two projects are VICS (Vehicle Information and Communication System) and SSVS (Super Smart Vehicle Systems).

Vehicle Information and Communication System

In 1990, three government agencies, the National Police Agency, the Ministry of Posts and Telecommunications, and the Ministry of Construction, proposed to unify the RACS and AMTICS programs into one program, the Vehicle Information and Communication System, (VICS). On October 25, 1991, the VICS Promotion Council was organized. This organization is comprised of two hundred and five companies and/or organizations and is responsible for bringing VICS into practical use in a short period of time. The council initially decided on a March 1993 date for implementation. Numerous committees and subcommittees have been organized to decide on the standards and systems that will be utilized in the VICS program. The three main committees of the council are the steering committee, the commerce committee, and the research committee. The steering committee is in charge of selecting subcommittees, setting time tables, and public relations activities.

The commerce committee is in charge of funding, safety guidelines, operation standards, type of database, and the computer systems that will control the system. The research committee is in charge of selecting the type of information to be transmitted, the method of transmission, and the system configurations to transmit data.(11)

Current plans call for a VICS using dedicated VICS traffic information centers for collecting, processing, and distributing and/or transmitting the traffic and motorist information. A combination of the beacon data transfer system from RACS and the teleterminal data transfer system from AMTICS will probably be used.(5)

Super Smart Vehicle System

The Super Smart Vehicle System (SSVS) is intended to be the model for which all research and development for the next twenty to thirty years is to be geared toward. The program is to fully embrace the concept of info-mobility. SSVS consists of four parts; traffic control, driver assistance program, road transport environment, and automatic driving. The following are examples of the types of systems that will be a part of SSVS.

Traffic Control

- 1) Guide Light - A part of the road in front of a car is lighted according to the speed of the car.
- 2) On-board Monitoring of Traffic - The Mean Speed and Travel Time of a vehicle is transmitted to a control center.

Driver Assistance System

- 1) Bird's Eye View System - Bird's eye views of intersections and street are broadcasted to automobiles.
- 2) Detection of Driver Condition - A dozing or sick driver can be detected and monitored.
- 3) Detection of Road Surface Condition - Road conditions such as ice on the road is transmitted to the automobile.
- 4) Adaptive Cruising Control - Speed of the vehicle is controlled by traffic conditions and road surface conditions

Road Transport Environment

- 1) Demand Car System - Uses small passenger cars like a demand bus system.
- 2) Automatic Accident Detection/Reporting - Accidents are detected by the vehicle and reported to the police and hospitals.
- 3) Automatic Tolling - For the toll collection at parking lots and on toll roads.

- 4) Reservation of Roads - A motorist may reserve space on congested roadways for a reduced toll.

Automatic Driving

- 1) Semi-automatic Steering Control - Corrections are made by the vehicle when the driver makes an error.
- 2) Automatic Obstacle Avoidance - Obstacles are detected by the vehicle and avoided.
- 3) Autonomous Driving - Completely automatic driving is performed without any ground equipment.
- 4) CCVS with Ultra Light Vehicles - Control Configured Vehicle Systems would incorporate the use of single seat vehicles linked together mechanically or by communications to form a single vehicle. (3)

Table 2 presents the expected penetration into the Japanese market for SSVS technologies. As can be seen in the table, by the year 2020, the Japanese expect that 10% to 80% of the various SSVS technologies will be used. These systems are expected to decrease the amount of accidents within the country. Table 3 shows the expected decreases in accidents due to the SSVS technology. With over 9400 accidents in 1992, the Japanese expect to reduce the number of accidents by the use of SSVS by up to 43% in 2020.(12)

Figure 5 presents the control structure of Japanese IVHS. There are five major organizations that are in control of development and deployment of IVHS. The Ministry of International Trade and Industry (MITI) is in charge of the development of the Personal Vehicle System and the Super Smart Vehicle System. The National Police Agency, the Ministry of Construction, and the Ministry of Posts and Telecommunications have joined to work on the Vehicle Information and Communication System. The Ministry of Transport is in charge of the Advanced Safety Vehicle.

Table 2. Market Penetration of the SSVS Technologies (12)

| SSVS Technology | Phase | | |
|---------------------------------------|---------|---------|---------|
| | by 2000 | by 2010 | by 2020 |
| Obstacle Detection | 20% | 50% | 80% |
| Road Geometry Detection | 10% | 40% | 40% |
| Collision Warning | 10% | 60% | 80% |
| Automatic Braking/Steering | | 10% | 60% |
| Pedestrian Detection at Intersections | | 10% | 60% |
| Driver Assistance at Intersections | | 10% | 60% |
| Automatic Lane Following | | | 10% |

Table 3. Accident Decrease by the SSVS Technologies (12)

| Results from SSVS Technology | Phase | | |
|------------------------------|---------|---------|---------|
| | by 2000 | by 2010 | by 2020 |
| Number of Accident Decreases | 415 | 1896 | 4090 |
| Ratio of Accident Decreases | 4.4% | 20.1% | 43.4% |

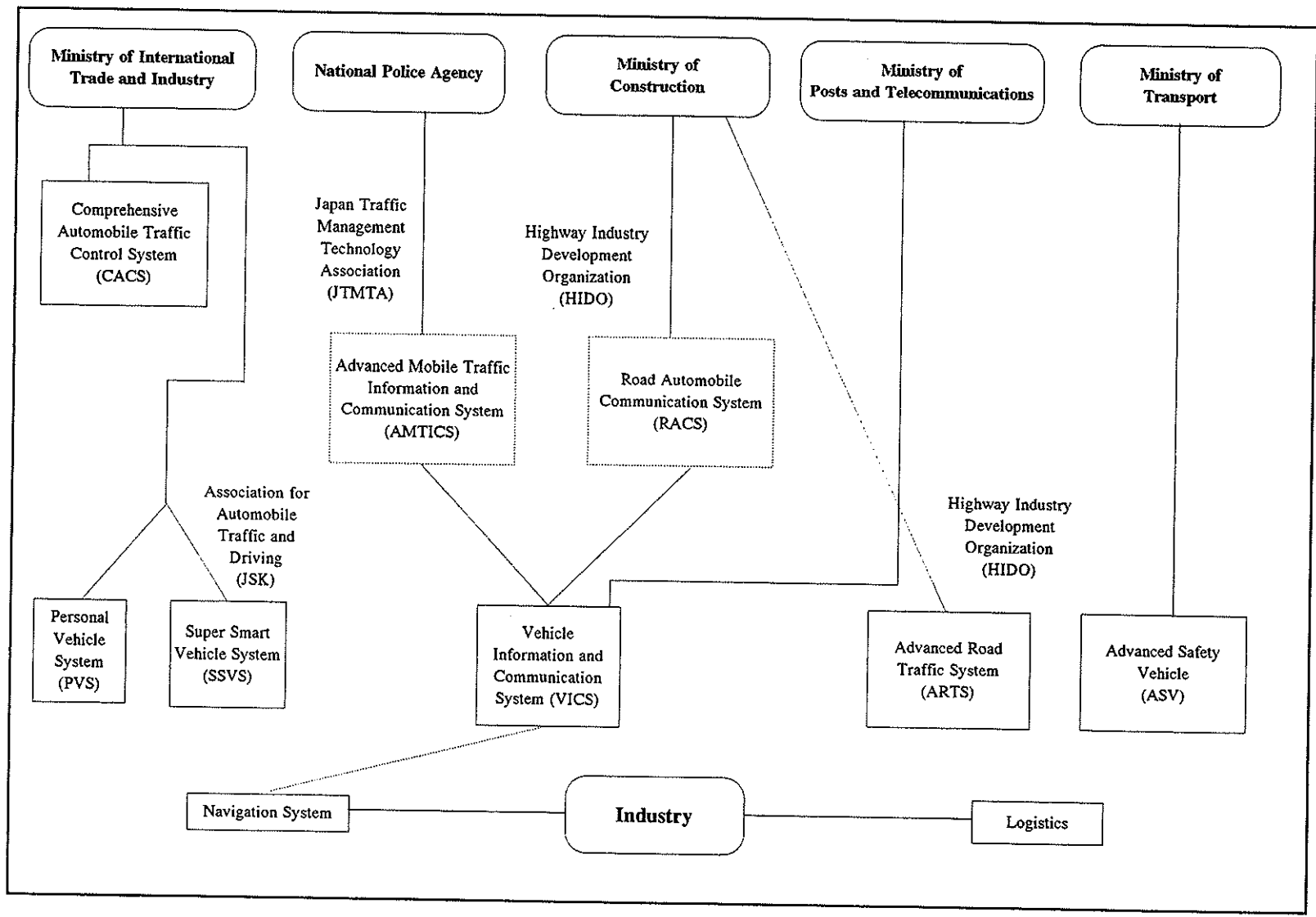


Figure 5. IVHS Activities in Japan (7)

EUROPEAN IVHS

Cities in Europe have not been able to escape the transportation problems that the rest of the world is facing. The level of congestion is continuing to deteriorate, the number of traffic related deaths is increasing, and the problem of pollution is growing worse. Traditional methods for improving traffic conditions have reached the point where either they are not wanted by the public or they will no longer work. This is why in the early 1980s the Europeans began to work on IVHS.

As the countries within Europe decide on the fate of the European Community, transportation leaders have seen the importance of having compatible intelligent vehicle-highway systems in every country. If every country chose different standards for the components of their system, the benefits of the free trade would be lost to the complexity of transportation between countries. Therefore two projects have started to give continuity to the research and development of systems in Europe. These programs are PROMETHEUS and DRIVE. The technologies and systems derived from these two programs will be the direction that the European Community will follow.

PROMETHEUS

PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) was started in 1986 by the automobile manufacture, Daimler-Benz. It is a privately funded program that is focusing it's energies on improvements on the automobile. The program was opened to other European automakers who agreed to share any information or technological breakthroughs with the other partners.(13)

The PROMETHEUS organization grouped the activities of the organization into three tasks:

- 1) Travel and Transport Management - Selection of the means of transportation, of the route and of the travel time.
 - Travel information services will inform a user on the status of the entire transportation system.
 - Dual mode route guidance will combine on-board systems and infrastructure support for optimized performance and early introduction.
 - Commercial fleet management uses methods developed in PROMETHEUS in the transportation of freight.

- 2) Harmonization of Traffic Flow - Cooperation with other road users and the traffic management center.
 - Cooperative driving is a general concept which uses information from other vehicles or from the infrastructure to inform, warn, or interact.
 - Autonomous intelligent cruise control will allow vehicles to maintain a given headway.
 - Emergency systems will support vehicles and traffic control by automatically contacting emergency services.
- 3) Safe Driving - Keeping control over the vehicle.
 - Vision enhancements will attempt to reduce accidents in low vision conditions through the use of video cameras and UV headlights.
 - Proper vehicle operations will introduce advanced vehicle control systems to improve the actions of the driver.
 - Driving and reducing collision risks will investigate strategies for collision avoidance.(14)

Many of these programs are well under way. Basic systems for travel information services, autonomous distance warnings, and dual mode route guidance are ready to be implemented. Full systems will be ready for full implementation in the years between 1993 and 1997.(14)

DRIVE

While PROMETHEUS focused on the automobile, DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) focused on the infrastructure. DRIVE seeks to apply advances in information and communications technology to road transport in order to improve traffic safety, efficiency, and the quality of the environment. DRIVE is a publicly funded program that was open to any and all proposals for research and development. The program began in 1988 and the first phase was completed in 1991. Seventy two projects were funded and the results were quite promising. DRIVE II is now currently underway and is continuing the research from DRIVE. DRIVE II consists of 56 projects that are currently under contract. Thirty six of these projects are pilot projects that are limited in their scope. The remaining twenty projects are R&D projects that support the thirty six pilot projects. The program is divided into seven areas; demand management, traffic and travel information, integrated urban traffic management, drivers assistance and cooperative driving, freight and fleet management, and public transportation management.(13)

Demand management is focusing on pricing mechanisms to regulate the distribution of traffic. Access control, congestion pricing, and parking policies are all demand management techniques used by the EC. The goal of traffic and travel information systems

is to bring common technologies to different areas of the EC. Local governments have their own ideas about how systems should work and getting dozens of separate governments to agree on a common system is difficult.(13)

Major Projects in Europe

The following section reviews some of the progress made by Great Britain, Germany, and France in the area of IVHS.

Great Britain

Freeway management is very similar to that of the United States. Television cameras monitor sections of the freeways for incidents and congestion. In addition to the television surveillance, detector loops are located at 1/2 kilometer intervals and motorist call boxes are located every kilometer.

TrafficMaster is a private sector traveller information system that provides information on several freeways around London. Through an agreement with the local authorities, TrafficMaster has installed 230 infrared detectors on 250 miles of roadway. Subscribers pay \$830 to have the system installed in their vehicles and \$31 per month for the information. The information consists of speed data between links. The user can see the speeds on the segments of freeway and decide which route to take. TrafficMaster plans to install additional detectors on several other routes in 1992 and 1993.(13)

Germany

The Germans use overhead changeable message signs for the control of traffic. Every 3/4 kilometers a overhead sign signals the speed limit for that section of roadway. If an incident occurs, the upstream overhead signs will lower the speed limit accordingly. This helps to prevent congestion by slowing the rate at which traffic reaches the incident. Overhead signs are also capable of changing the destination names on the sign. If a certain destination has two routes that can be used to reach that destination and an incident occurs on one of the routes, the signs can be changed to lead traffic to the open route.

Berlin served as a test site for the Ali-Scout navigation and route guidance system. Traffic information is broadcasted to vehicles through infrared beacons at 240 signalized intersections. The on-board computer would then determine the optimum route to a given destination and provide directions for that route. Directions were given through the use of a flashing arrow on the dashboard of the car. A voice synthesizer also gave instructions on proper lane choice and in advance of turns.(13)

France

Rural tollroads in France are under control of a company named COLIROUTE. COLIROUTE monitors traffic through the use of loop detectors placed between interchanges. Traffic data is sent to a centralized traffic control center and transmitted to automobiles by FM radio. COLIROUTE owns a radio station that transmits traffic information every fifteen minutes through transmitters that are placed 7 km apart. Electronic toll collection is being experimented with along the tollroads. They hope to have a fully operational system before two proposed tunnels are completed in Paris.

The French in-vehicle navigation system currently being developed is named CARMINAT. The system uses a color display and a symbolic guidance display to provide information to the driver. A synthesized voice can also be used to provide information. It is assumed that real-time traffic data would be used to determine the shortest, fastest, most scenic, or the most economical route.(13)

OTHER COUNTRIES IVHS

As more and more countries realize that their transportation systems are not capable of handling increased demands, they are feeling the pressure from the public to improve their systems. Old methods of increasing capacity, such as building new roads or widening existing roads, are not as viable as they use to be. Therefore, countries are turning to IVHS technologies to solve their problems. Each country has a unique set of circumstances that causes that country to seek IVHS solutions and their experiences should be examined. The remainder of this section looks at some of the IVHS applications in Australia, Canada, and Taiwan.

Australia

Australian cities are facing many of the same economic, social, and environmental problems that are occurring all over the world. The Australian road authority (VicRoads) has encouraged the development of IVHS technologies to combat Australian transportation problems. These problems include communities expecting transportation to have a lower impact on the environment than it currently does, restrictions on expanding the current network of roads with the building of new lanes or new roads, and a new realization that roads cannot be operated in isolation of other modes of transportation.

Australia is developing many different IVHS applications, but their focus has been on two projects: Transport Information and Management System (TRIMS), and the Arterial Network Travel Time System (ANTTS). Both systems concentrate on providing traffic information to traffic managers and roadway users. The following is a brief description of these two projects.

TRIMS uses loop detector technology for vehicle detection. This is advantageous in Australia since the majority of signalized intersections have loop detectors installed and the signals are under the control of a SCATS traffic signal system. The loops are used to receive vehicle code and instrument data from a transponder that is attached to a vehicle. The transponder is also capable of receiving a small amount of data, such as a calibration of location, from the loops. A limited test began in June 1991 with 100 vehicles fitted with transponders. Six fixed sites were set up and three variable sites were selected. The variable sites were able to be moved to any of 1800 signalized intersections in the Melbourne area. The test is to be expanded to include more detection sites, provide arrival times for public transportation vehicles, and give advice to motorists concerning congestion, parking, and public transport.(15)

ANTTS uses radio transmitters and receivers to collect traffic information. Roadside interrogators are placed at strategic locations and transmit a signal every half second. When a vehicle with a tag passes the roadside equipment, the tag responds to the signal by transmitting its identification code. The roadside equipment then tells the tag to stop transmitting its ID code for a set period of time. As the vehicle passes a second roadside interrogator, the process occurs again and a central computer matches the ID codes and calculates a travel time for that vehicle between those two points. For a demonstration test

of this project, 16 buses were fitted with tags and 10 intersections along the bus routes were fitted with interrogators. A central computer would estimate the arrival time of the buses at each stop and relay this information to message signs at the stops.(16)

Other projects and IVHS applications are being developed in Australia. These developments include:

- 1) A commercial vehicle tracking system,
- 2) Automatic video enforcement of speed and registration violations,
- 3) Automatic toll collection, and,
- 4) Integration of existing traffic management systems such as SCATS, incident detection, variable message signs into a comprehensive transport management system.(15)

IVHS developments in Australia are being directed at the collection of information that has immediate utility to urban transport system managers and users.

Key factors to the road authorities involving IVHS are the cost effectiveness of any system and the ability of a system to be integrated into existing systems.(15)

Canada

In the 1960s, Canada took it's first steps towards IVHS. A computer controlled traffic management system began operation in Toronto and quickly spread the idea of computerized control across the nation. Freeway management systems began to use changeable message signs and radio broadcasts to inform motorists of traffic conditions. In the 1970s, traffic congestion in the province of Ontario led to the implementation of a network wide traffic management system for street networks and freeway corridors. At the same time, a program to monitor public transportation vehicles began. During the 1980s, the federal government funded a program to develop CVO (Commercial Vehicle Operations) applications. A weigh-in-motion system and an AVI system were developed and are being demonstrated in numerous locations in Canada and the U.S. Over the years, Canadian research has lead to the refinement of traffic monitoring, data processing, and signal timing techniques, and led to the incorporation of microelectronics to increase the capabilities of the systems. In the 1990s, the use of ATMS's is being expanded. The use of variable message signs, CCTV surveillance, and vehicle tracking systems has increased over the entire nation. Reconstruction projects are using variable message signs to inform motorists of lane closures, traffic conditions, and diversions. Closed circuit television is used to monitor the freeways for incidents and congestion. All future projects are being planned with these systems in mind.(17)

Canadian development of IVHS has tended to focus on ATMS and AFMS (Advanced Fleet Management Systems). This focus is now being expanded to include ATIS. Current research and development is underway for several concepts. Two of these concepts are CRCS (Close-Range Road/Vehicle Communications System) and TravelGuide.

Close-Range Road/Vehicle Communications System

A Close-Range Road/Vehicle Communications System (CRCS) is being developed as an advanced AVI system. The system would be made of components that could be added to a base unit. This way, applications can be added as they are developed instead of the entire package being completed at once. The communications system would be the basis for IVHS applications in the areas of ATIS, ATMS, and AVCS. The in the area of ATIS, a CRCS could be used for automatic toll collection, the distribution of real time traffic data, an in-vehicle signing system, and an in-vehicle hazard warning system. The CRCS could be used in an ATMS as a method of collecting traffic information, ramp metering, and bus or light rail priorities at signalized intersections. Applications of CRCS concerning AVCS including, automatic speed control, intelligent cruise control, and advanced communications regarding automated highways.(18)

TravElGuide

TravElGuide is a portable traveler information system that can provide route guidance and route planning assistance to drivers without providing navigation support. Without the connections to a GPS or dead-reckoning navigation system, the device is completely portable and can be carried into the home or office to receive traffic information at any time. The system will receive real-time traffic information on traffic conditions, transit arrival times, and construction zones to calculate optimum travel routes and display these routes on the video screen. Since the system does not provide navigation support, it will be up to the driver to know how to follow the given route. The system can also be used by transit riders to determine which route to take and when the transit vehicle will stop at a given location. Pedestrians could also use the unit to help direct themselves in unfamiliar locations. TravElGuide is still in the concept stage, but R&D projects are aimed at having a demonstration project begin in early 1994.(19)

Taiwan

As a newly industrialized country, Taiwan is rapidly being confronted with the transportation problems that the rest of the world is currently facing. Taiwan has discovered that traditional traffic systems management can only solve transportation problems for a limited time. By building new roads, optimizing signal timings, and increasing license plate taxes, Taiwan only delayed the problems associated with congestion, pollution, energy consumption, and traffic safety, they did not prevent these problems from occurring. Therefore Taiwan has turned to IVHS to help alleviate these problems.

Taiwan's IVHS programs have focused on the ATMS and the ATIS aspects of technology. They have started a large research and development project named Research Directions for Vehicle Route Guidance Systems in Taiwan to evaluate technologies for deployment in Taiwan. Seven projects and/or research areas have been determined to review and analyze IVHS technologies. These seven projects and/or research areas are:

- 1) A traffic control project on the north sections of the Second National Freeway.

- 2) Urban traffic control systems.
- 3) The establishment of a traffic information system along the western highway network, and traffic congestion improvements along the Sun Yat-Sen national freeway.
- 4) Development of telecommunication modernization.
- 5) Development of geographic modernization.
- 6) An urban traffic progression center and traffic information inquiries.
- 7) Location methods applications.(20)

Tables 4 summarizes the progress from these seven areas and table 5 summarizes future research directions in Taiwan.

Table 4. A Summary of Recent Progress for IVHS in Taiwan.

| System Classification | Functions | | A | B | C | D | E | F | G | |
|-----------------------|-----------------------------------|--------------------------|---|---|---|---|---|---|---|---|
| ATMS | Road detection facilities | Detector | X | X | X | | | X | | |
| | | CCTV | X | | X | X | | X | | |
| | | Signpost | | | | | | | | |
| | Incident detection | Incident detection | | | X | | | | | |
| | Traffic control system | The third level traffic | | X | | | | | | |
| | | The fourth level traffic | | | | | | | | |
| | Communications | Infrared | | | | | | | | |
| | | Microwave | | X | | | | | | |
| | | Telephone | X | X | X | X | | | X | |
| | | Radio | X | X | X | X | | | X | |
| ATIS | Traffic information and inquiries | VMS | X | X | X | | | X | | |
| | | Broadcasting and/or call | | | | | | | X | |
| | | TV | X | X | | | | | X | |
| | Location method | Signpost | | | | | | | | |
| | | Dead Reckoning | | | | | | | | X |
| | | Roadside positioning | | | | | | | | |
| | | GPS | | | | | | | X | |
| | Navigation and display | Synthetic Sound | | | | | | | | |
| | | Digital map and GIS | | | | | | | | X |
| Directional display | | | | | | | | | | |
| AVCS | Automatic Sensing | | | | | | | | | |
| | Automatic Control | | | | | | | | | |

- A. Traffic control system on the north section of the Second National Freeway.
- B. Urban area traffic control system.
- C. Traffic information system along the western highway network and the traffic congestion improvement along the Sun Yat-Sen freeway within the Taipei metropolitan area.
- D. Development of telecommunication modernization.
- E. Development of geographic information systems.
- F. Traffic progression center and traffic information systems.
- G. Location method applications.

Table 5. Future IVHS Research Directions in Taiwan.

| IVHS Research Subjects | Relevant Technological Areas | Study Items |
|--|--|--|
| Road information system of freeway and adjacent parallel surface network | <ol style="list-style-type: none"> 1) The Second National Freeway traffic control system 2) The Sun Yat-Sen national freeway system 3) The traffic information system along the western highway network | <ol style="list-style-type: none"> 1) Incident detection algorithm 2) Traffic flow simulation models 3) Pretrip plan and vehicle route guidance 4) VMS plan and associated studies |
| Urban area traffic information system | <ol style="list-style-type: none"> 1) Urban area traffic control systems 2) Urban traffic progression center and traffic information inquiry 3) Public transportation surveillance and control systems | <ol style="list-style-type: none"> 1) Traffic flow simulation models 2) Pretrip plan and vehicle route guidance 3) Adaptive traffic control system 4) Public transportation surveillance and fleet dispatching 5) Car probes system of police car and radio-equipped taxi |
| In-vehicle equipment system | <ol style="list-style-type: none"> 1) Transportation geographic information systems 2) Vehicle positioning methods 3) Traffic information communication network | <ol style="list-style-type: none"> 1) Electronic map 2) Standard format for traffic information display 3) Map matching and artificial intelligence 4) GPS & other location methods 5) Digital radio broadcasting systems |
| Non-stop vehicle traveling system | <ol style="list-style-type: none"> 1) Automatic vehicle identification systems 2) Electronic toll systems | <ol style="list-style-type: none"> 1) Automatic in-motion vehicle plate identification system 2) Standards for electronic toll system and associate administrative studies |

AMERICAN IVHS

The American IVHS program, as it exists today, has not been in existence very long. In August 1990, IVHS America was founded after four years of informal work by professionals in the public, private, and academic sectors. IVHS America is the "umbrella" organization that is in charge of organizing programs and building consensus. The IVHS movement gained strength with the passage of the Intermodal Surface Transportation Efficiency Act of 1991 which provided funding for research, development, and operational testing of IVHS technologies.(1) The following section gives a brief description of the developments of IVHS technologies in America.

ATMS

Very little has been done in America in terms of freeway management. As of 1991 only 55 urban areas have any sort of traffic management system. These systems covered just over 1000 miles of freeway, with the majority of that in Southern California. The Smart Corridor project in Southern California, is integrating freeway management with ATIS to improve traffic congestion and safety. In Chicago, the freeway traffic management program has been around for years. The program combines traffic surveillance, incident management, and travelers information to improve traffic conditions in the area. Most urban areas do not have network-wide arterial control systems in place today, but can control traffic in one direction on individual routes. Additional urban areas are completing engineering studies and within five years, over 50 cities are planned to have operational traffic management systems.

Operational testing is taking place on several systems. Testing on advanced detection devices such as microwave detectors, video detection, and infrared sensors is currently underway. Planning is underway for using variable speed limits to control traffic. Such systems have been successfully used in other countries and are to be tested in urban and rural locations in this country. Automated toll collection projects are currently underway around the country. The Dallas North Tollway has over 40,000 vehicles equipped with advanced vehicle identification tags.(1)

ATIS

A number of systems are being developed and tested using a wide variety of systems and technologies to provide information to the driver. Changeable message signs, HAR, commercial radio, and cellular telephones are used to provide information. In-vehicle systems are combining the navigation and the guidance functions with real-time traffic information to improve the drivers decision making process. Most systems use a combination of dead-reckoning and map-matching to determine the location of a vehicle. The use of Global Positioning Satellites (GPS), is becoming more widely used to locate vehicles. Other systems use beacons to provide vehicles a fix on their position to supplement other systems. Test projects include Travtek in Orlando, ADVANCE in Chicago, and Pathfinder in California.(1)

AVCS

AVCS is considered the most long-term of IVHS applications. Some technologies are currently available in automobiles today. Anti-lock brakes, four-wheel steering, and active suspension are all technologies that have come from the AVCS program. The Greyhound bus company is deploying test vehicles with a radar to provide warning to drivers if they have a headway of less than five seconds, if they overtake another vehicle too rapidly, or if a car is in the bus driver's blind spot.⁽²¹⁾ In the next five years, several large scale tests are planned on backup warning, adaptive cruise control, longitudinal collision warning, vehicle performance monitoring, and lane change and merge warnings.⁽¹⁾

CONCLUSIONS

Countries around of the world are facing the problems of increased congestion, increased number of accidents, and a decrease in air quality. Traditional methods for improving traffic conditions have reached the point where either they are not wanted by the public or they will no longer work. For this reason, many countries have turned to IVHS to help solve their problems. It is clear that every transportation problem has numerous answers and that different countries are using different methods for solving their problems. A method or technology that works in the United States might not work in Europe, but their solution might be just as good.

It is clear that the United States can learn a great deal about Intelligent Vehicle-Highway Systems from other countries around the world. Japan has been experimenting with IVHS for over twenty years. They have the experience and technical knowledge to be able to advise other countries on IVHS subjects. Europe has done a great deal of work on testing different systems and has collected a large amount of data. Countries such as Australia and Canada have begun to focus a great deal of attention on IVHS. This wealth of knowledge from around the world should not be allowed to go unnoticed. The United States needs to learn from the successes and failures of other countries to better improve our Intelligent Highway-Vehicle Systems.

Japan is the world leader in implementing IVHS. This is because of their need for solutions. Traffic problems in Japan are considered by many as the worst in the world. Their extreme transportation problems have been around for many years and it has not been possible for them to build their way out of their problems. Early foresight by leaders saw that they needed new solutions and began programs to solve problems. As new technologies are developed, the Japanese people have come to expect quick implementation of those new technologies. The people use these technologies and then expect more development of new technologies.

The *Strategic Plan for Intelligent Vehicle-Highway Systems in the United States* is an excellent plan for the research, development, and implementation of IVHS programs in America. Having an "umbrella" organization such as IVHS America is an advantage over countries that do not have such an organization. A lead agency or organization helps give a common direction for all programs that are developed. IVHS America gives focus to American IVHS programs which will help America remain a world leader in IVHS.

RECOMMENDATIONS

The United States must continue to learn from other countries. There is a large database of IVHS technological knowledge which needs to be tapped. With the numerous methods for solving transportation problems, it must be expected that other countries will develop programs or technologies that have not been thought of in the United States. The exchange programs between the United States, Europe, and Japan must continue and be encouraged to grow. Foreign researchers and industry personnel must continue to be a part of American technical conferences. Seeing the different points of view that are brought by others involved with IVHS is very important for the continued growth of the American IVHS program.

The legal and social aspects of IVHS technologies must be settled before large-scaled implementation of IVHS can occur. The technological aspects of IVHS will not be the barrier of implementation. While this country remains in it's current "sue happy" mentality, companies will be very cautious in the deployment of new technologies. Countries, such as Japan, do not have these legal problems and because of this, they are far ahead of the United States in the area of AVCS. Social aspects, such as, privacy and cost fairness will have to be addressed before the American public will accept IVHS. Without the support of the population, IVHS will never survive. But with the support of the public, IVHS technologies can make large advancements in a short period of time.

With the downsizing of the United States military, many defense contractors will not have the quantity of work that they use to have. IVHS presents itself as a suitable alternative for these companies. The possibilities of new applications seems endless. Some companies have already started research and development projects, while others are still trying to figure out where to start. IVHS America should help companies that are just starting out by helping them determine where they can fit into the overall plan. Thereby fitting the resources of the companies with the needs of the plan.

While technologies are being developed, American companies need to find markets outside the United States. Japan is doing an excellent job of presenting their advancements to other countries. When these countries decide that they need IVHS technologies, they turn to the systems that they have seen or have heard about. The United States needs to make sure that they do not become so involved with deploying technologies within the U.S. that they forget about the large world market that is available.

ACKNOWLEDGEMENTS

I would like to express my thanks to the professional mentors who participated in the transportation graduate class at Texas A&M University, *Advanced Surface Transportation Systems*, under the direction of Dr. Conrad Dudek. The professional mentors included, Don Capelle, Walter Kraft, Joe McDermott, Dave Roper, Ed Rowe, and Gary Trietsch. Special appreciation is extended to Gary Trietsch for being my mentor for this project.

My deepest thanks and appreciation go to my wife, Ann and my son, Quinn for their understanding, patience, and love during this time. All I can say is that I'm one step closer.

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