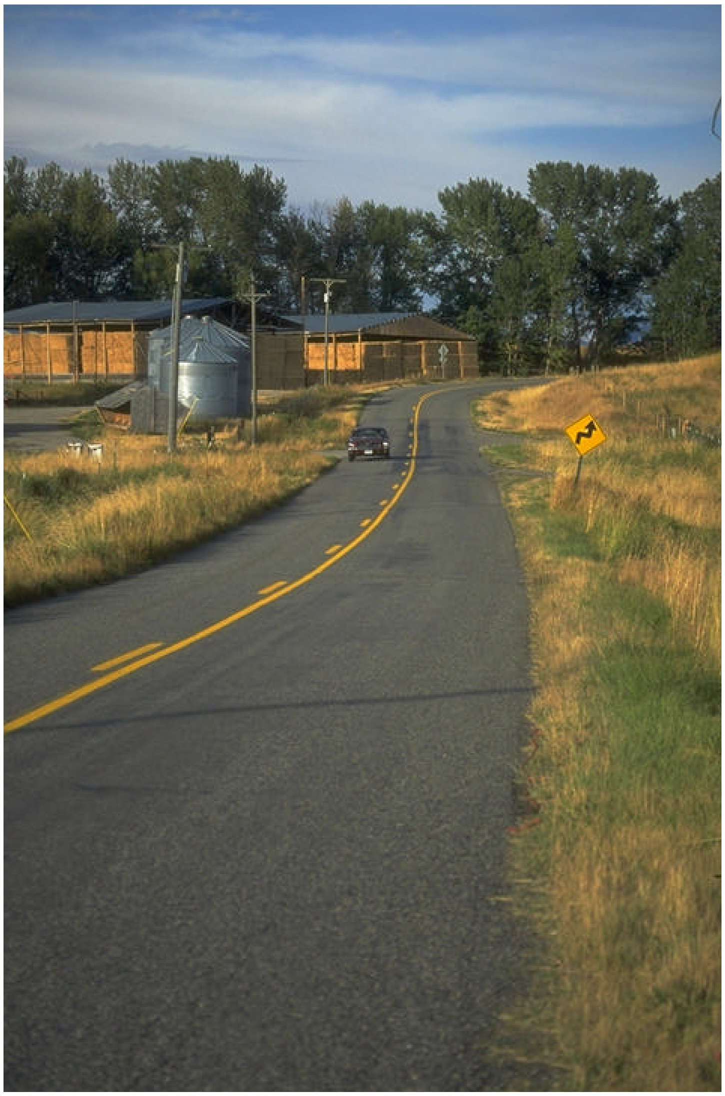
# A Caltrans Program for Advancing Rural Transportation Technology



## February 1997

*TABLE OF CONTENTS*

*TABLE OF CONTENTS*

# 1. Introduction

## *1.1. New Tech Program*

The California Department of Transportation (Caltrans) established a New Technology and Research (New Tech) Program to review opportunities for advanced transportation technologies in California transportation development and to pursue the research, development, testing and demonstration of promising technologies.(1)

The Caltrans New Tech Program focused initial energy and attention on problems plaguing urbanized areas such as traffic congestion, safety, energy use and air pollution. The Caltrans emphasis on big city problems mirrored the national program emphasis by the United States Department of Transportation (U.S. DOT) and the Intelligent Transportation Society of America (ITS America). ITS America was originally titled IVHS America relating to Intelligent Vehicle Highway Systems (IVHS). IVHS has since been changed to Intelligent Transportation Systems (ITS) to reflect the multimodal nature of ITS.

Caltrans, in late 1991, began inquires into rural concerns dealing with advanced transportation technologies. It became apparent that those dealing with Intelligent Transportation Systems (ITS) and other advanced transportation technologies felt that rural areas were not a concern and that technologies and systems developed for large city areas could be easily adapted to a rural setting.

In 1992 Caltrans embarked on a research study titled: “A Caltrans Program for Advancing Rural Transportation Technology” (PARTT). The researchers were Professor Joe Armijo: Department of Civil and Agricultural Engineering, Montana State University, and John West: Program Manager, New Technology and Research, Caltrans.

# 2. Purpose of Study

## *2.1. Determine need*

To investigate the need for rural transportation technology and determine the applicability of advanced transportation technologies currently under development in rural problems and settings.

## *2.2. Extent of application*

To investigate the extent of rural applications of advanced transportation technology in the United States and abroad.

## *2.3. Develop research, demonstration, deployment*

To develop a rural technology research, demonstration and deployment agenda for Caltrans.

## *2.4. Implementation*

To develop a plan, program and organization for advanced rural transportation technology for Caltrans.

### 2.5. Research Center

To establish a national and international center for rural transportation technology research and education.

### 2.6. Influence

To influence national policy and programs concerning rural transportation technology.

## 3. Study Methodology

### 3.1. Literature review

Current available literature on topics pertinent to the study of intelligent transportation systems (ITS) was selected and reviewed.

### 3.2. Discussion

Significant groups with an interest in the development of ITS were solicited for their input. These groups were not limited to the following organizations; however, the listed organizations and individuals were most prominent.

- Rural Caltrans districts. From the start, it was felt that rural stake-holders needed to have a significant input.
- Transportation representatives from several rural states. The highest probability for success of an ITS system will be afforded if system compatibility is addressed from the start, not as an afterthought.
- ITS America staff
- Federal Highway Administration staff
- US DOT Secretary Mr. Federico Pena🕮
- Staff of Congressional Representatives
- Members of the ITS America Advanced Rural Transportation Systems Committee
- Conference discussions at Rural Transportation Technology Conferences (held in Redding, California; Keystone, Colorado; and Blacksburg, Virginia)
- The Western States AASHTO Research Advisory Committee🕮

🕮 Senator Max Baucus facilitated the effort to have rural transportation issues presented to Secretary Pena
in Billings, MT, April 1993

🕮 AASHTO/RAC: Robert J. Reilly, Secretary, Transportation Research Board (TRB) (202)334-3227

### 3.3. Influence National Opinion

ITS Technology is new to most Americans. It has not yet entered the mainstream of consumer electronics. Rural communities cannot wait for ITS technology to trickle down. Non-urban areas must be a part of the emerging architecture of ITS planning and implementation. The researchers, Armijo and West, have sought to positively influence the national policy in the following ways:

- Armijo and West provided the first national discussion on advanced rural transportation technology in the second draft of the "IVHS America Strategic Plan". (January, 1992)

- Through Caltrans, Armijo and West lobbied successfully for the establishment of an IVHS America committee to deal specifically with rural transportation technology concerns. (IVHS America established the Advanced Rural Transportation Committee in April, 1992.)

- Redding, California was the site of the first conference dealing with rural transportation technology. The conference was sponsored by FHWA, Montana State University, UC Berkeley - Institute of Transportation Studies, Arizona Department of Transportation, California Department of Transportation, Montana Department of Transportation, South Dakota Department of Transportation, Texas Department of Transportation, and Wyoming Department of Transportation. (September, 1992)

- The Western Transportation Institute (WTI) was established on the campus of Montana State University. WTI is the result of cooperation between Caltrans, the Montana Department of Transportation (MDT) and Montana State University. WTI will be closely associated with Partners in Advanced Transit and Highways (PATH), MDT, Caltrans and several western states. (February, 1995)

## 4. Need for Rural Transportation Technology🕮

### 4.1. Rural Systems

Two-lane rural highways are the backbone of the rural transportation network. These roads function to carry local traffic as well as commercial vehicles, transit vehicles, school buses, recreation traffic and commuter traffic destined for a metropolitan area. As shown in Figure 1, 81% of road mileage occurs in rural areas. No less than 50,000 communities in the United States today are rural. Additionally, there is a system of multi-lane divided highways serving the metropolitan centers by traversing rural areas.

National policy, in regard to transportation technology, is primarily focused on the problems associated with urban traffic congestion. Secondary consideration is given to safety, air quality control, traveler

🕮Adopted from " Improving Rural Transportation Through Advanced Transportation Technology: Working Armijo and John West, September 1992; presented at the Redding, California Rural Transportation Technology Conference information and energy conservation. All of these areas are also of concern to the rural transportation system; however, the primary focus of rural transportation technology is **safety.**

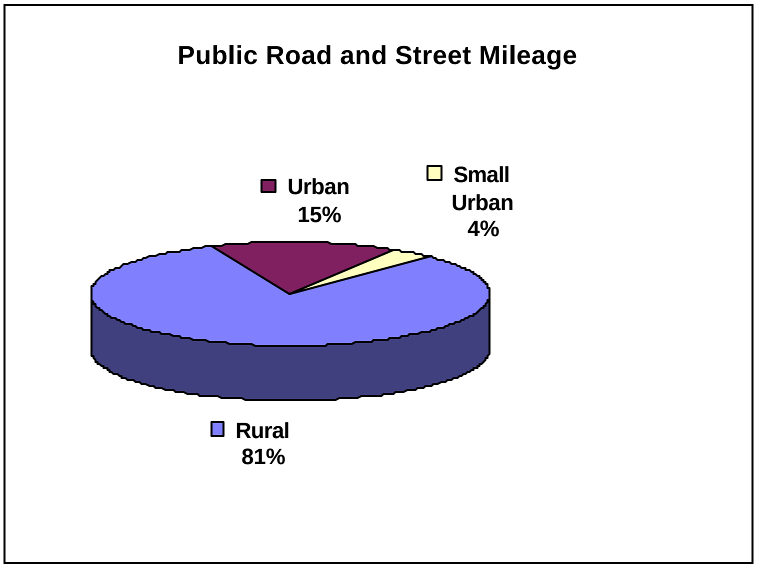



**Figure 1**

Source: JHK & Associates

### *4.2. Rural System Characteristics*

Rural transportation systems may be conveniently divided into two types: low volume rural systems and higher volume rural systems. The systems exhibit the following characteristics:

- *Low volume rural systems* feature rural two lane highways with low traffic volumes. Traffic stream vehicle composition for these roads is an ever-changing proportion of work and recreation trips for automobiles, recreation vehicles, transit, school and inter-regional busses, and commercial vehicles. The general characteristics of these roads are to have sub-standard alignment, poor sight distances (vertically and horizontally), narrow lanes, narrow or non-existent shoulders, steep grades, black ice, and fixed obstacles close to the roadway. All of these features combine to create an unforgiving transportation environment. Maintenance dollars on this type of road are often siphoned to higher volume roads. Highway patrol may be infrequent or non-existent. The hazard of animal crossings is increased. The number of drivers advancing in years is high.

- *Higher volume systems in rural areas* feature two-or-more-lane highways / expressways / freeways that serve or pass through rural areas. Generally these systems were built to higher standards and have substantially fewer safety problems than associated with the low volume systems. Higher volume systems also receive better maintenance and police patrolling.

### 4.3. Urban System Characteristics

*Urban transportation systems* include high volume, two-or-more-lane-highways / expressways / freeways and fixed rail transit systems carrying mostly work trips. Most travel occurs on multi-lane freeways that were built to high safety standards. Urban systems receive good maintenance and constant highway patrol activity.

Urban and rural transportation systems have different characteristics and uses, and will require different technology development and applications.

One way to illustrate the difference is to compare the safety problems of each and the potential application of technology to those problems.

### 4.4. Safety and Technology: Rural and Urban Highways

The types of accidents occurring on urban highways differ from those occurring on rural highways. The severity is also different. Figure 2 shows that only 40% of the national vmt occurs in rural areas; yet, rural areas account for 60% of the accidents causing fatalities.

Urban Highways

The primary urban highway accident types are:

1. Rear end collisions
2. Lane changes

In addition, wet pavement, poor visibility, cross median accidents, striking objects and stranded motorists are serious safety problems.

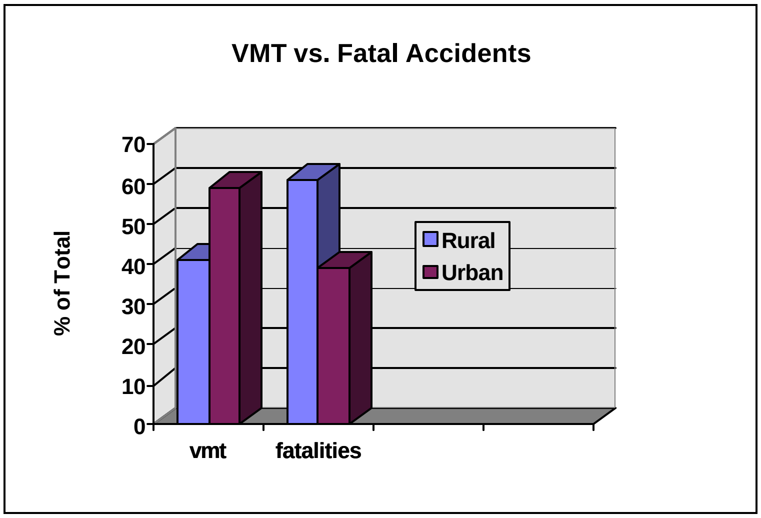



**Figure 2**

Source: JHK & Associates

Rural Highways

The primary rural highway accident types are:

1. Leaving the roadway
2. Passing (head on collisions)
3. Visibility (fog, snow, blowing dust)
4. Wet or slippery pavement
5. Striking animals or other objects

In addition, striking vehicles on the shoulder, stranded motorists and timely access to medical services are serious safety problems.

Will emerging technology, designed to deal with rear end collisions and lane change accidents, also deal effectively with head-on collisions caused by unsafe passing? How will the new technology deal with animals or other obstacles? We cannot, at this time, answer these questions.

What is clear, at this time, is that roadway installed technology used in the low volume rural systems will have to be substantially lower in cost than roadway installed systems developed for the urban setting. Economic feasibility is **crucial** to the rural setting.

Rural transportation systems will be able to utilize some of the technology developed for urban systems directly and without modification. Some technologies, with modification, will be useful in the rural transportation system. In some cases, however, entirely new technology will have to be developed for the rural setting.

Vehicle installed technologies (smart vehicles) are very promising. Will travelers who most often use their vehicles in rural settings be willing to opt for intelligent vehicle hardware and software in future purchases? Will these same travelers retrofit existing vehicles?

### 4.5. National Attitudes

Steadily, over the past twenty years, national interest in rural transportation systems has declined. The problems of urban traffic congestion and related air quality, noise, and energy issues have overwhelmed those who deal with transportation issues at federal, state and regional levels. It is no surprise, then, that officials developing the transportation system of the future have their sights on urban areas. Additionally, it is no surprise that many of these same officials believe new technology programs that solve urban transportation problems will do so also for rural areas.

These conclusions are a matter of attitude, and represent real obstacles to the advancement of rural transportation technology. Those who deal with transportation systems of the future tend to have an urban attitude. In the past two years there has been some national recognition of the importance of advanced transportation technology in rural areas and some change in national consciousness, but the urban attitude continues to prevail.

There remains a critical need to forge a rural attitude, to deal with the serious transportation problems in rural America, and to bring rural communities into full and active partnership in the national advanced transportation technology program.

## 5. Rural Transportation Technology in the United States

In 1992 there were very few programs dealing with rural transportation technology, either in this country or abroad.

An Agenda for Research, Development and Demonstration (RD&D)

The following agenda for research, development and demonstration has been developed to implement rural transportation technology. While advanced transportation technologies encompass more than just highways, the two-lane road is the primary transportation mode in rural America. Therefore, the agenda has been developed primarily around ITS functions, recognizing that vehicles and highways will likely receive most of the early attention. The agenda first presents the components necessary for research. These components are traveler needs, communications, and ITS functions. The traveler needs to identify areas within the current rural transportation system that can possibly benefit from the advances. Communications is the necessary link from the traveler to all ITS functions. ITS functions address user services that take advantage of technological advancement to improve rural travel. Rural ITS functions are divided within this agenda into the following: Rural Weather Information Systems, Rural Traveler Information Systems, Rural Transit/Paratransit, Rural Traveler Emergency Alert Systems, Rural "Mayday" Systems, and Rural Commercial Vehicle Operations.

### *5.1. Traveler Needs*

Rural ITS research will only be effective if the needs of the rural traveler are properly assessed. This involves investigating areas of rural transit that can benefit from the scope of ITS technologies.

Travelers have a need for real time information representative of what hazards or services are available in their immediate vicinity. Year round posting of SLIPPERY WHEN WET, ROCK SLIDE AREA (or other such intermittent hazards) may anesthetize travelers to the true hazard they may be approaching. Weather information, especially in the west, can be highly localized and very difficult to predict by standard long range forecasting. Clear sky in the valley gives no warning of snow squalls in a pass several thousand feet above. Remote location accidents often result in death for no other reason than emergency medical system (EMS) services could not be notified quickly enough, or if notified in a timely manner, were not provided with adequate and accurate accident location information.

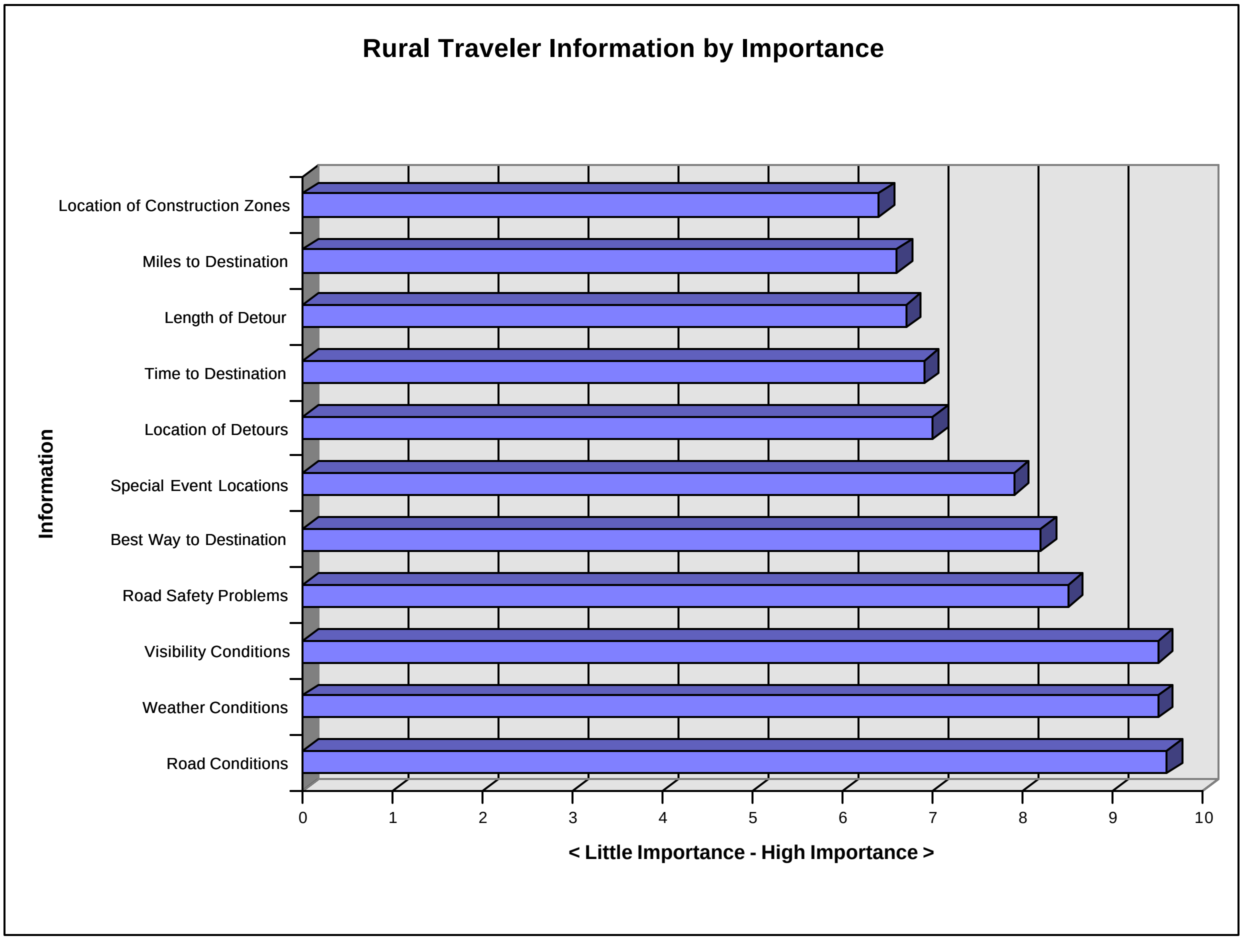



**Figure 3**

Source: Minnesota Guidestar

## *5.2. Communications*

ITS technology cannot be fully deployed unless a parallel development occurs in communications technology.  There will be an incredible increase in the number of discrete nodes that must be capable, at the least, of broadcasting a request for data (and then receiving that data).  Systems in parallel to communications will process the data in real time and apprise the intelligent vehicle operator of system status and/or display the requested information.  ITS communication must be of adequate bandwidth, fast, reliable, and **available** in rural settings.

Generally, communications are divided into categories by three parameters based on the capabilities. First, communication is either wire or wireless.  Wire, as the name implies, uses a physical wire line, such as a telephone line, to send data.  Wireless communications use radio frequencies to send data from one node to another without a physical connection (e.g., cellular phone).  The second parameter is the range of the communication.  The range indicates the distance between the sender and the receiver. For discussion purposes range is typically divided into:

1. Short Range (<200 m)
2. Local Area (<5 km)
3. Regional (<20 km)
4. Wide Area (>20 km)

The last parameter divides communications into either one way or two way. An example of one way communication is highway advisory radio, where road information is sent from a central location to the vehicle, but the vehicle only receives the data and cannot send any messages back. A two way communication system allows messages to be sent to and from each node. Generally wire, short range and one way communications are less expensive than wireless, long range, and two way respectively. However, certain applications may require wireless, long range and/or two way communications.

The following are current wireless communications technologies which may be applied directly to ITS.

- *Infrared* technology is line of sight and short range. Many hand held calculators and some computers use this technology to communicate with peripheral devices. This technology may be useful in road-to-vehicle or vehicle-to-vehicle applications.

- *Broadcast subcarriers* piggy-back on existing communication frequencies. Subcarriers are advantageous in that they can be readily added to existing infrastructure.

- *Cellular phone* service is becoming so popular that the Federal Communications Commission (FCC) has released new frequencies for use by the industry. Even in rural areas more cell towers are being built all the time because of user demand. This is a highly reliable technology which shows promise to ITS.

- *Low Earth Orbit Satellites* (LEOS) are low altitude orbit satellites. These satellites require low power because of the low orbit, and are less expensive to place in orbit than high altitude satellites.

- *Other*: Spread Spectrum, Microwave, and others

System communication needs may be categorized as follows by type:

1. management center to management center
2. management center to roadway
3. vehicle to roadway
4. vehicle to vehicle

<u>Management Center to Management Center</u>

Data is communicated between management centers (e.g., highway department to highway patrol) typically through a wire line, two way link. Range depends on the physical distance between the centers in question. These links are used to share information and coordinate efforts between management centers.

Management Center to Roadway

This type typically uses wire line communication. Again, range depends on the physical distance between the physical structures, management center and roadway. These communication links are used by management centers to remotely gather traffic and road condition data (e.g., loop detectors and closed circuit TV), disseminate portions of this data to the travelers (e.g., variable message signs) and remotely adjust traffic control devices (e.g., adjust timing of ramp metering and signal timing).

Roadway to Vehicle

Roadside to vehicle communications are short range, wireless communications and can be either one or two way depending on the application. This type involves those devices that warn, or inform the driver of conditions present on the highway and collect vehicle characteristics at the roadside. Such devices are particularly useful in rural settings where difficult terrain and two-lane highways are present. In addition, this type is currently in use in toll collection (Automatic Vehicle Identification, AVI). Several states also use variable message signs that require activation by an approaching vehicle.

Vehicle to Vehicle

This application is not as critical to ITS deployment as the first three, in that this type of communication is only used in a few applications. Vehicles will send data to each other by short range, two way, wireless communication. Such devices may be used to transmit data between platooning vehicles in automated highways or transmit traffic and road information, bypassing the management center.

## *5.3. ITS User Services*

ITS has already proven effective in many operational tests throughout the country. The following sections outline those ITS user services offering the highest potential for improving rural transportation systems. Rural ITS user services are divided into the following areas:

- Rural Weather Information Systems (RWIS)
- Rural Traveler Information Systems (RTIS)
- Rural Transit/Paratransit
- Rural Traveler Emergency Alert Systems (RTEAS)
- Rural “Mayday” Systems (RMS)
- Rural Commercial Vehicle Operations (Rural CVO)

One author characterizes a system architecture as:

> “...a description of how the many elements, or subsystems, of a system work together to perform the system’s actual functions. In the case of IVHS, an architecture will lay out the

specific functions performed by the in-vehicle equipment, by roadside devices, by traffic management facilities and by information distribution centers. The architecture will also describe how these systems interact by defining the types and characteristics of information that are exchanged."(2)

Although the following section does not outline how specific products work, it does give the reader an idea of how the products work together. It is imperative for each of these, and any rural system, to be able to conform to a nationwide system architecture.

Rural Weather Information Systems (RWIS)

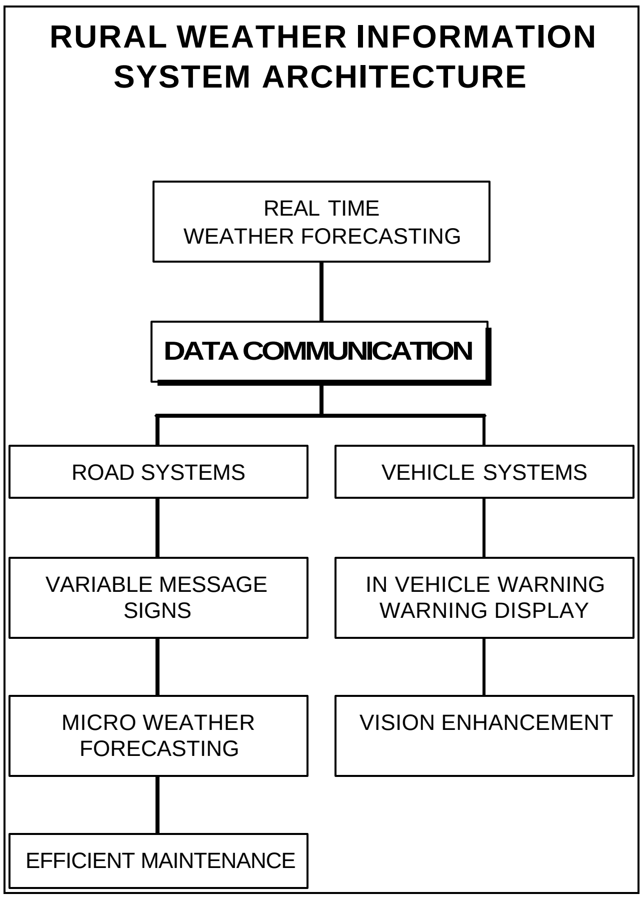



**Figure 4**

Real Time Weather Information

Frequent, rapid weather changes, often occurring in rural settings, provide hazards for both local and tourist traffic. Messages that do not provide real time information can misinform the traveler creating a possibly dangerous situation. Efficient and effective ways of predicting and sensing these changes need to be communicated to the motorist. This is especially important for instilling confidence in the traveler that the information received is true and up-to-date

Data Communications

Data Communication is the heart of a rural weather system. Data communications is essential to bring messages of road and weather/visibility conditions at a remote station to maintenance personnel and rural travelers. RWIS would have a heavy reliance on roadside to vehicle communications.

Micro Weather Forecasting

Micro weather forecasting uses such technologies as pavement sensors and visibility precipitation monitors. Pavement sensors provide temperatures that are used to predict road conditions and the need for de-icing treatments. The information from the sensors is stored and analyzed to predict the degree of safe travel. Visibility/precipitation sensors have possible applications in most weather conditions and have a two-fold benefit; they measure the level of visibility and the type of precipitation. This information is especially important in weather conditions such as freezing rain and heavy snow storms where visibility and road conditions can suddenly turn severe.

In a study in New Jersey, roadway weather information systems were installed in four locations. The report of the study concluded that utilization of the system leads to a reduced deicing chemical usage and savings in manpower and equipment. The report suggested that the greatest benefit would come from a statewide application of the devices.(3)

Variable Message Signs

Variable message signs (VMS) are a means of distributing real time information to the traveler. A variable message sign can be changed at any time, giving the reader the confidence that the information is current. VMS are currently used in mountainous regions to warn travelers that a pass may be closed due to adverse weather conditions. This allows travelers the option of changing their plans before the congestion occurs in an undesirable location. Additionally, the sign may advise the driver of a safe speed and give real time justification for the advisory (see below). Once installed, VMS can be used in favorable weather conditions to inform traffic of physical characteristics in the road such as alignment or grade. Colorado is currently testing VMS as a means to warn truck traffic of long steep grades on Interstate 70, west of Denver.


**Figure 5: Variable Message Sign, VMS**

From **Traffic Technology International**, Spring 1995

Several types of VMS are available. One study looked at three common types: shuttered fiber optic, light-emitting diode (LED), and electromagnetic flip disk. The study investigated the performance of the VMS and standard roadside signs in three areas: target value (how noticeable a sign is or how well it attracts the motorist's attention), legibility distance (the distance from which a driver is able to read a sign), and view comfort (measure of discomfort caused by glare or harshness of light). The study concluded that fiber-optic and LED VMS compared reasonably well with conventional signs, and **all** VMS signs were easier to read than conventional freeway guide signs.

A large concern with VMS signs is legal aspects of the entities controlling the signs. Questions arise such as: What happens if the sign turns on when it shouldn't, giving drivers a false warning, lessening subsequent effectiveness? What if the driver has complete confidence in the device and it fails to function, providing a loss of safety to the driver? Such malfunctions may leave the entity open to tort liability. Tort liability is a valid concern due to the increasing number of liability cases. In almost every state, sovereign immunity has either been abolished by judicial decisions undermined by legislative modifications to governmental immunity.

In-Vehicle Warning Display

In-vehicle warning displays work in a manner similar to VMS, providing real time warnings. In-vehicle warning displays come directly to the driver, making them more likely to be noticed.


Figure 6: Delco Electronics, Head-up Display
From **Traffic Technology International**, Spring 1995

Currently, there are two common types of in-vehicle displays: active matrix liquid crystal display (AMLCD) and head-up display (HUD). The AMLCD is a hide away screen similar to that found on a lap-top computer. The screen may be equipped with a touch screen and/or buttons to allow the driver to interface with the computer. The HUD projects an image on the windshield of the automobile.

In-vehicle warnings would most likely be activated by a roadside communication device or by a local official.

Vision Enhancement

Vision enhancement systems may increase travel safety in poor weather conditions such as blowing snow or dust, or limited visibility conditions such as nighttime driving or fog. Rural settings offer an excellent opportunity for operational testing of vision enhancement systems due to the often sparse traffic and poorly illuminated highways.

Cars today are equipped with a bright option on the light switch, a primitive form of vision enhancement. Europe is currently working on an advanced form of vision enhancement through the Program for European Traffic of Highest Efficiency and Unprecedented Safety (Prometheus). Jaguar has been testing vision enhancement technologies in different versions of its XJ6 model as part of the program. The car is equipped with an infrared camera placed on the inside of the windshield. The camera creates a thermal image from the heat emissions of other cars, lights, signs, human bodies, and other objects producing heat. A computer then translates the thermal image into visual image that can either be displayed on an AMLCD or HUD. The images are clearer than anything the human eye can see on a dark night or in a fog, making the device particularly advantageous in the rural environment.

Efficient Maintenance

Higher levels of efficiency in maintaining rural roads can be achieved if maintenance operators are equipped with the knowledge of remote road conditions. Currently, rural maintenance personnel are sent out to monitor highways in possible poor weather conditions. This may cost money in manpower and unneeded equipment use in times when weather conditions are good at remote stations. It may also take needed equipment and personnel away from areas that need attention. Micro sensors at remote locations could provide the maintenance personnel with information required to monitor remote locations.

Rural Traveler Information Systems (RTIS)

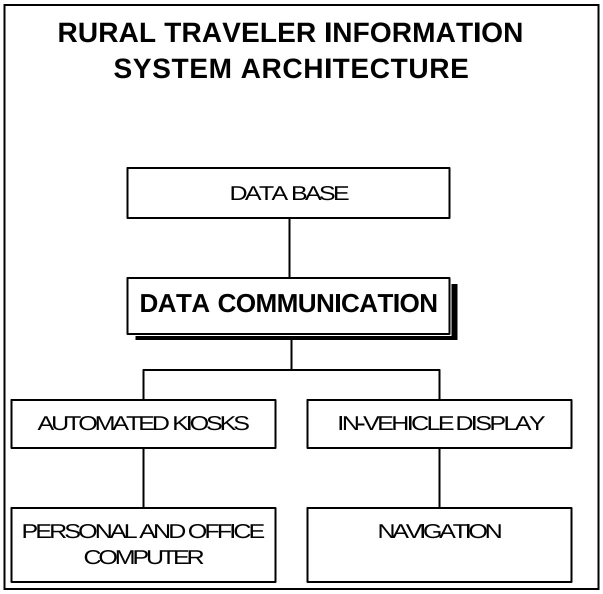



**Figure 7**

Useful Traveler Information

Useful information transmitted to the traveler can aid a driver in finding a desired location. The need for useful information increases during seasons of high tourist volumes when large portions of rural travelers may be unfamiliar with the area. Travelers need to know such things as motel locations and availability, locations of restaurants, locations of visitor information centers (VIC), nearest emergency medical facilities (MAF), best routes and more. This information is often equally vital to rural communities which rely heavily on tourist traffic for an economic base.

Data Communication

Like the other rural ITS, RTIS must rely on communication to transmit real time data to the traveler. In some components, the communication needs for RTIS are not as demanding as other systems because information needs are more for convenience than safety. However, even these communications must be done in an accurate and timely manner to avoid hazards associated with travelers losing their way.

Automated Kiosks

Automated kiosks offer the traveler the option of searching through a prepared database for information of interest. The kiosk is usually a computer with a simplified user interface that allows the traveler to quickly search through a diversified supply of information. Kiosks could be installed at rest areas, tourist information centers, major hotels, major tourist attractions, and truck stops. Tennessee has recently promoted the idea of automated kiosks at several welcome centers, hotels, and tourist attractions. The kiosks use a touch screen to give travelers information on area attractions. Additionally, the kiosks are able to print out directions to an attraction.

In-Vehicle Display

An in-vehicle display would give the traveler real time information on road conditions or local attractions. The display would be connected to an on-board computer that could communicate with information systems installed at various locations. The information systems would contain data on local attractions. Alternatively, the traveler could obtain information from a purchased database. The database would include information on the area of travel and could be purchased as part of a pre-trip planning similar to travel brochures and maps currently used.

Travtek, a project in Orlando, Florida, completed a one-year demonstration in March 1993. The project equipped 100 Oldsmobile cars with an in-vehicle display and navigation system. The cars were rented through the American Automobile Association and gave travelers real-time information and directions as they traveled through the city. Program participants and evaluators agreed that the cars were beneficial for traveling through the city.


**Figure 8: Delco Electronics' Telepath 100, an outgrowth of Travtek**

From **Traffic Technology International**, Spring 1995

Personal or Office Computer

Information can be accessed via the Internet from home or office computers. Such information can be used to plan trip options before the traveler leaves their office or home. Such options may include route selection, mode selection, or deciding not to make the trip at all.

Navigation

Vehicle location information is desired by the vehicle user for the purpose of detecting current position. From this information, the user can determine a route to the destination. At the present time there are four commercially available systems for tracking and navigation.(4)

1. GPS/DR (Global Positioning System/Dead Reckoning)
2. Hybrid GPS
3. RDSS (Radio Determination Satellite Service)
4. TRF/RDS (Terrestrial Radio Frequencies/Radio Data Systems)

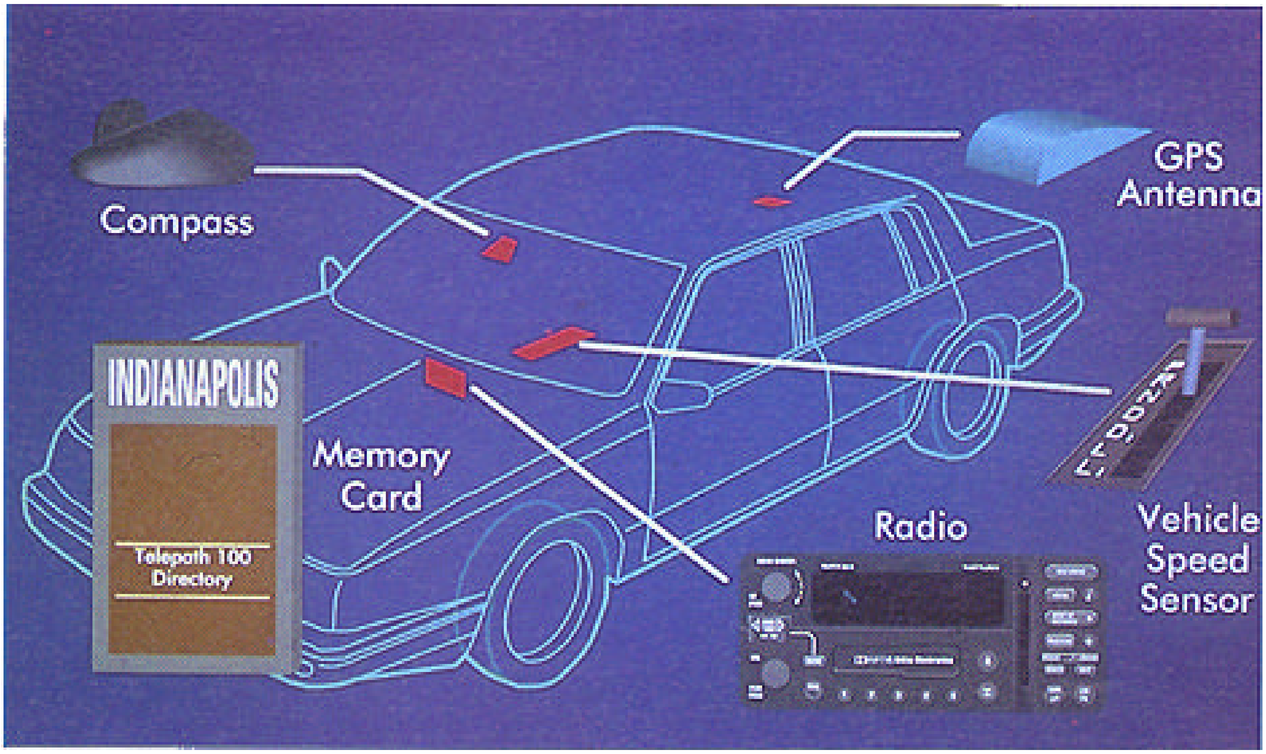



**Figure 9: Delco Electronics, Intelligent Vehicle, Telepath 100**

**Telepath 100,s radio can display the distance and direction to a requested location.**

From **Traffic Technology International**, Spring 1995

Global positioning and dead reckoning (GPS/DR) are useful where continuous position monitoring is not necessary. The areas in which GPS are used must be free of obstacles (tall buildings) that could interfere with the satellite signal. Terrestrial landmarks are necessary to enhance the speed at which the system can find a position. Dead reckoning devices, which are inertial sensors that keep track of acceleration and speed from a known point, keep the GPS component supplied with a point of reference.

Hybrid GPS systems exist that utilize low-earth-orbit satellites or geo-stationary satellites. Geo-stationary satellites stay in the same position over the earth and can cover a broad transmission area. Low-earth-orbit satellites (LEOS) are at varying positions relative to the earth's surface. They cover a small portion of the earth at a time but cover a broad area with each orbit.

Radio Determination Satellite Service (RDSS) utilizes geo-stationary satellites (or LEOS) and offers the additional benefit of positioning to communications.

Terrestrial radio frequencies (TRF) may also be used for navigation and tracking. The method uses AM, FM, or cellular radio data systems (RDS), and/or paging communication infrastructure. The RDS system measures the time it takes for radio waves to arrive at the vehicle from the transmission tower. By using two towers a location may be determined.

Rural Transit/Paratransit

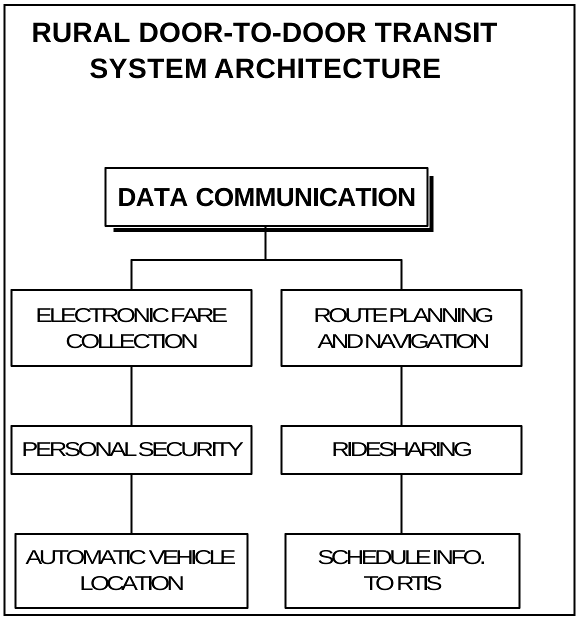



**Figure 10**

Rural transit systems generally operate with low budgets and large, low density service areas. There are people, with no other means of travel, that depend on transit or paratransit for groceries, doctor appointments and other needs. In order to meet these needs, rural transit and paratransit providers need to operate efficiently.

Electronic Fare Collection

Fare collection can be improved through the use of credit, debit, and/or smart cards. Smart cards are like debit cards except account balance information is carried on the card, instead of in a central database. There is no more need for exact change, easing the burden on passengers and transit vehicle operators.

Personal Security

This includes the use of closed circuit television cameras and/or rural mayday systems onboard transit vehicles. The transit systems will have less crime and improved safety. This lowers operating costs and adds to the safety and security of the passengers.

Automatic Vehicle Location (AVL)

AVL is found by the same means as navigation, discussed above. The vehicle location is determined by GPS, dead reckoning, or some other automated means. After the vehicle position is known it is sent to the dispatcher for management purposes.

Advanced Fleet Management

Information is received by the dispatcher concerning weather, traffic and road conditions, and location and status of vehicles. This information is used to help calculate the optimal routes and scheduling, possibly with the aid of computers. Also, transit systems may improve efficiency and service by operating a door-to-door service. Here, travelers request rides at certain times and locations, and the dispatcher will include this request information with the information mentioned above to determine the optimal routes. This is better than a fixed route system in that routes may be modified to pick up and drop off passengers closer to the desired locations, and efficiency can be improved in low volume areas.

Ridesharing

This service promotes carpooling by matching riders with drivers. If travelers are driving, or need a ride, they can phone this service with information about departure time and location, and destination location. The ridesharing service will match travelers with similar trip information.

Transit Schedule Information to RTIS

Transit schedule information is sent to a rural traveler information system. The RTIS will make this information accessible to travelers through kiosks, in-vehicle displays, and personal computers.

Rural Traveler Emergency Alert Systems (RTEAS)

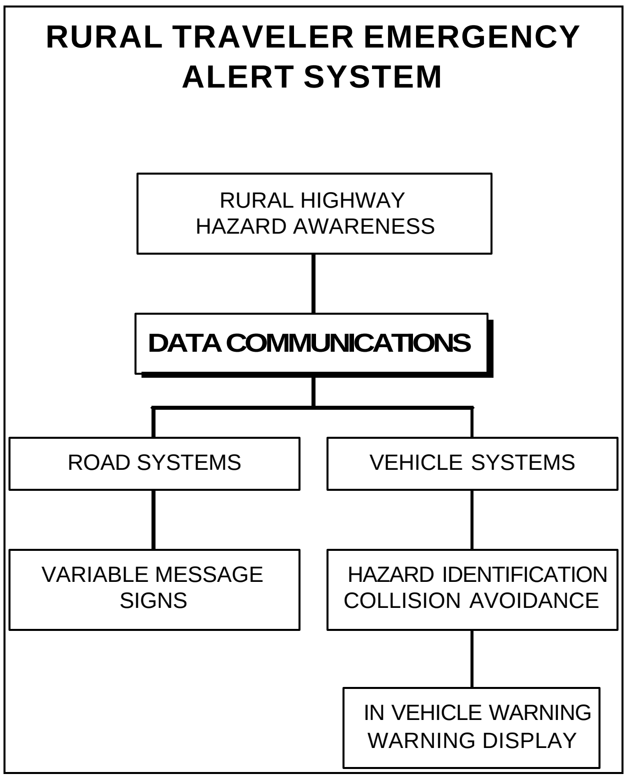



**Figure 11**

Rural Highway Hazard Awareness

Rural highways often wind through mountain passes or roller coaster over hilly plains, creating a situation of limited sight distance. It is difficult and costly in these areas to match design speeds with speeds often traveled. Frequently, there are obstacles in the road, slow-moving vehicles and domestic or wild animals crossing the road. Rural travelers may not be familiar with the presence of these dangers on the highway.

Data Communication

Rural Traveler Emergency Alert Systems usually require short range transmissions because they constantly provide data about the surroundings of the vehicle. The transmissions will most likely occur from roadside to vehicle. The roadside devices will most likely require remote power sources, as rural highways are not always located near power lines.

Road Hazard Warning

A road hazard may consist of a fallen rock, hay, dead animals or other such obstacles in the roadway. A road hazard may activate a variable message alongside the road, or an alarm in an oncoming automobile. An example location might be a scene where rock slides are common. A device would scan the road constantly for rocks on the highway. When a fallen rock is sensed, the device would emit a frequency or turn on a variable message sign (VMS). The oncoming car would then be warned in advance of the danger ahead. Another example might be detectors placed on slow moving vehicles. In addition to using conventional slow moving vehicle signs, slow moving operators could use a device on the slow vehicle that would emit a frequency, activating a warning signal for approaching traffic.

Animal Hazard Identification

The animal hazard identification device would be similar to the road hazard warning, only created especially for animal interaction. Animal hazard technology would not only benefit the traveler but would additionally improve the safety to wild and domestic game often found crossing rural highways. The device may work to either warn the driver or warn animals of potential dangers of approaching traffic.

Anti-Collision

An anti-collision device located on the vehicle could either warn the vehicle of approaching hazards, or in sophisticated systems, actually take control of the vehicle. Delco Electronics is currently developing FOREWARN collision warning systems. The systems use side, rear and forward looking radar to detect potential collisions. In 1993, they began equipping school buses with systems which are used to sense children moving within systems detection area while the bus is stopped. In addition, Delco recently released a side collision warning for large trucks.

The goal of any collision avoidance device is to improve safety by giving the driver additional time to react. One study has indicated that if drivers are given an additional half-second to react, they could avoid 60% of all rear-end collisions, 50% of intersection accidents, and 30% of all head-on collisions.

In-Vehicle Warning Display

In-vehicle warning displays transmit the information of the hazard directly to the driver, increasing the reaction time. By directly warning the driver, the in-vehicle warning displays are more effective than the traditional ANIMAL Xing or WATCH FOR FALLING ROCKS signs that are currently used. Additionally, the in-vehicle display, assisted with an audible alarm, is more assertive than traditional warning signs.

Rural "Mayday" Systems (RMS)

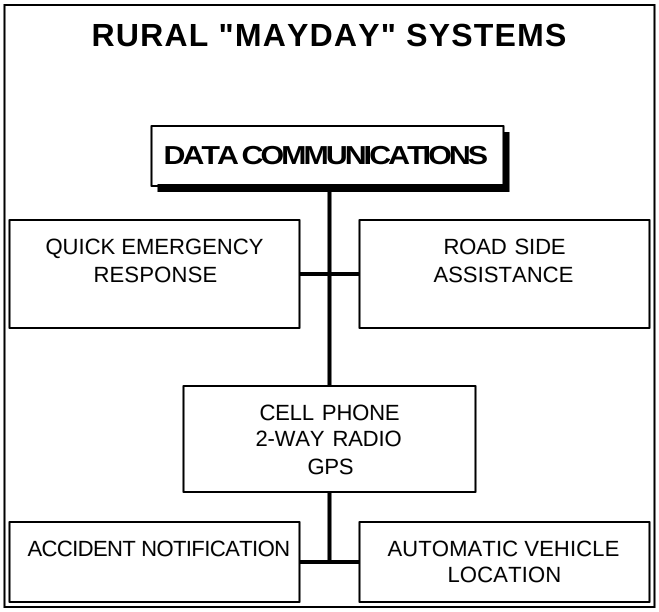



**Figure 12**

Quick Emergency Medical Response

In most serious accidents, the time from the occurrence of the accident to response by emergency medical services is critical. This time is often delayed by difficulty in finding a quick means of reporting the accident. The time can be delayed even further with difficulty in locating the accident. Even safety at non-critical emergencies, such as minor accidents or obstacles on the highway, could be improved if quick responses were obtained.

Roadside Assistance

Although mechanical problems on rural highways usually do not create large congestion problems, they may also create safety problems. A car with a flat tire on the blind side of a sharp curve can cause a safety hazard to traffic, even though the traffic is sparse. The driver of a vehicle with mechanical problems may have difficulties finding a quick means of obtaining a tow truck. Quick roadside assistance can be especially helpful to motorists caught in adverse weather conditions such as winter storms or a hot desert, particularly as more and more recreationists access remote areas.

Data Communications

Data communication is the vital link within a Rural "Mayday" System. Communication is essential for providing information to a dispatcher and letting a traveler know that help is on the way. RMS will often require long distances (possibly hundreds of miles) over which data must travel.

Cellular Phone Service

Only recently have companies such as AT&T and Comnet 2000 begun to provide cellular phone capabilities to rural communities. These cellular phones offer an advantage to users of quick emergency response. Cellular phones could be a first phase of implementation of Rural "Mayday" Systems. This would require implementation of a *-1-1 or *-1-2 service to rural areas. As opposed to the conventional 9-1-1 service, *-1-1 or *-1-2 is used to enable the cellular phone user to reach the closest dispatcher. Implementation of an emergency rural phone service may require a less expensive rate for rural users who intend to use the phone primarily for emergency purposes.

Serving rural customers is often costly for companies because the customers are fewer in number and spread over a wider area. Only recently have rural communities been able to acquire services such as caller ID and other sophisticated cellular services. With the advancement of these services also comes the possibility of increased use of digital communications.

Accident Notification Systems

An accident notification system consists of a device mounted on the vehicle that has the ability to communicate to a 9-1-1 dispatcher and receive confirmation from the dispatcher that the message was received. The device could either be tripped by a button in the vehicle or a device that sensed a serious collision. The advantage of the latter is that in a case where the driver is unconscious, a signal would still be sent. However, cases may arise where an alarm is accidentally set off by a non-injury accident.

In addition to notifying the EMS, North Carolina (in cooperation with Motorola, Inc.) is working on a system which would make a recording of the accident similar to the black box on an aircraft. The data from the recording would be sent to the emergency room, giving physicians an idea of what occurred in the accident, and thus an idea of possible injuries.

Automatic Vehicle Location

A necessary component of the accident notification system is an automatic vehicle location (AVL) device. The AVL determines the position of the accident utilizing one of the navigation/tracking devices discussed earlier. The emergency medical service (EMS) team or roadside assistance can then use this information to get a location of the incident providing for quicker response time. AVL is currently in use in several locations throughout the country. Pactel has developed a system primarily for retrieving stolen cars. Although the system is only available in some urban areas, it has proven to be a useful solution.

Rural Commercial Vehicle Operations

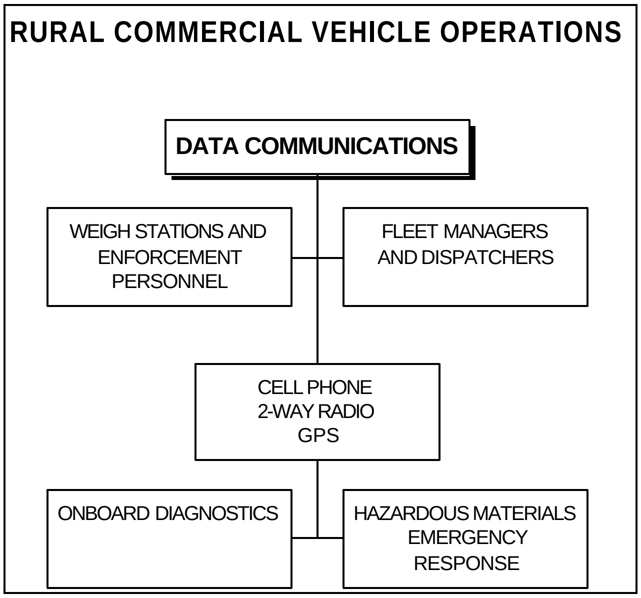



**Figure 13**

Commercial Vehicle Safety and Efficiency

Safety and efficiency of commercial vehicle traffic is key to a successful transportation system. In 1994 medium to heavy trucks caused 450,000 accidents resulting in 108,330 injuries and 4,420 deaths in the United States. This country's land transportation of manufactured goods is done predominantly by truck. The trucking industry incurs costs in the order of $5 million due to traffic delays. Safety can be improved by alerting the driver of unsafe vehicle components through diagnostics. Efficiency can be improved by advanced fleet management techniques and automating inspection.

Data Communications

For commercial vehicle operations communication links are needed between the truck, the enforcement officials and the carrier/dispatcher. Vehicle to roadside communication is required between the truck and enforcement officials for electronic clearance. An important link is between the enforcement officials and the carrier for automatic purchase of credentials.

The technology applications for CVO have been categorized into user services, which are briefly described below:

- The **Commercial Vehicle Electronic Clearance** service will allow safe and legal carriers to travel without stopping for compliance checks at weigh stations, ports-of-entry, and other inspection sites. Enforcement personnel will be able to electronically check safety, credential, and size and weight data before transponder-equipped vehicles reach an inspection site, selecting only potentially unsafe vehicles for an inspection.

This service will also support the North American Free Trade Agreement (NAFTA) by allowing international carriers that are safe and legal to have expedited checks at the Mexican and Canadian borders.

- The **Automated Roadside Safety Inspection** service will use safety data provided by the Electronic Clearance service combined with state-of-the-art technology to allow for more selective and rapid inspections. Through the use of sensors and diagnostics, inspectors will eventually be able to check vehicle systems and driver requirements, and ultimately driver alertness and fitness for duty.

- The **On-Board Safety Monitoring** service will non-intrusively monitor the driver, vehicle and cargo, and notify the driver and carrier (and possibly enforcement personnel) if an unsafe situation might involve the status of driver fatigue, vehicle systems, or cargo shift. This service will tie into the latter stages of the Automated Roadside Safety Inspection and Electronic Clearance Service.

- The **Commercial Vehicle Administrative Processes** service will allow carriers to purchase credentials and to collect and report fuel and mileage tax information electronically. Through automation, this service should provide to carriers and States a significant reduction in the paperwork burden and has the potential for simplifying compliance operations.

- The **Hazardous Materials Incident Response** system will provide emergency personnel at the scene of a hazardous materials incident immediate information on the types and quantities of hazardous materials present in order to facilitate a quick and appropriate response.

- The **Commercial Fleet Management** service will provide information links between drivers, dispatchers, and intermodal transportation providers and enable carriers to take advantage of real-time traffic information as well as vehicle and load location information, to increase productivity.

## *5.4. ITS Projects*

FHWA Rural ATIS Project(5)

In response to growing interest in rural transportation, FHWA contracted with JHK & Associates in 1992 to perform a three year study on Rural Applications of Advanced Traveler Information Systems. The completion date of the project has since been extended to November of 1997. Subcontractors for the project include Virginia Polytechnic Institute and State University (Virginia Tech), Hughes Aircraft, Bell Atlantic and Olson Market Research.

"The project's objective is to guide federal programs with respect to intelligent vehicle and highway system (IVHS) technologies in rural and small urban areas, and to provide guidelines for ATIS implementation efforts by state and local government agencies in meeting rural travelers needs."

ENTERPRISE

The ENTERPRISE program provides a forum for the collaborative intelligent transportation system research, development and deployment. The program is supported by government and industry from seven states, two Canadian institutions, the Dutch Minister of Transportation, and the Federal Highway Administration.(6)

ENTERPRISE rural transportation technology projects currently underway include:

- A rural mayday project
- Rural ITS broadcasting using an AM subcarrier
- Highway-based and activated advisory/warning signs to prevent on-off the road accidents
- Dedicated short range communication for CVO and traveler information
- Standards on Internet traveler information

ENTERPRISE also has several survey-type projects underway that examine opportunities for application of rural transportation technology.

Minnesota Guide Star Program🕮

Guidestar is Minnesota's ITS program. Its operation is directed by the Minnesota Department of Transportation and the Center for Transportation Studies at the University of Minnesota. Its objectives include the broad range of ITS areas - ATMS (Advanced Traffic Management Systems), ATIS (Advanced Traveler Information Systems), CVO (Commercial Vehicle Operations), APTS (Advanced

---

🕮 Minnesota Guidestar Program, Minnesota Department of Transportation, Minnesota Road Research Project, Materials & Research Laboratory; 1400 Gervais Avenue; Maplewood, MN 55109

Public Transportation System) and AVCS (Advanced Vehicle Control Systems). Guidestar efforts include:

- A Rural IVHS (Intelligent Vehicle Highway System - a phrase now called Intelligent Transportation System) Scoping Study, a federally funded project which has identified transportation needs and concerns of rural travelers in Minnesota.
- Genesis studies the impacts of using personal communications devices (PCD's) to inform travelers of real time traffic conditions and transit information.
- Travlink will test of Advanced Transfer Information and Automatic Vehicle Location systems on transit ridership and transit behavior.
- On-board Automated Mileage and Stateline Crossing System is an operational test demonstrating an automated CVO fuel tax and registration apportionment system.
- Various other studies involving sensors testing, smart cards, and commercial vehicles.

Washington State's VENTURE Plan

VENTURE is Washington's plan initiated in 1993 by the Washington Department of Transportation to implement statewide intelligent transportation system technologies.(7) VENTURE currently has a rural transportation technology demonstration on I-90, 40 miles east of Seattle in the vicinity of Snoqualmie Pass. This project provides safety related traveler information through variable speed and roadway condition messages.

SWIFT is another ITS project which delivers traffic information to travelers through pagers, laptop computers, and specially equipped car radios.

A Mayday system is also being demonstrated in the Puget Sound region. This system is cellular phone based and is entitled PUSHME.

In addition, VENTURE is also analyzing three rural corridors in order to assess which ITS technologies would mitigate the existing transportation problems. These corridors include Interstate 5, Interstate 90, and a joint project with Idaho and Oregon on Interstate 84.

Idaho Storm Warning IVHS Operational Test

This project is one of the seventeen operational first test projects nationwide that were awarded by FHWA in 1993 in response to a solicitation for IVHS implementation. Only two of the awards were made to rural projects, both of which are on interstate highways. The project is a partnership of the Idaho Department of Transportation, CH2M Hill Consulting Engineers, Surface Systems, Inc., and Santa Fe Technology, Inc. The current completion date is December 1997.(8)

The purpose of the operational test is to investigate various sensor systems that could provide accurate and reliable visibility and weather data which could, in turn, be used to provide general warnings, speed advisories, and possible road closure information to travelers via variable message signs. The primary goal is to improve safe travel along an area of Interstate 84 and reduce the high accident incidence due to low visibility conditions.

Virginia Tech Rural Center of Excellence(9)

The Virginia Polytechnic Institute and State University, (Virginia Tech) is home of CTR (Center for Transportation Research) and FHWA - IVHS Research Center of Excellence (RCE). It was one of three centers (University of Michigan and Texas Transportation Institute, also) established by FHWA in September of 1993. Projected funding through the RCE amounts to $5 million in federal funding and $3.5 million in matching funds from the state and industry for the next 5 years. Public affiliates include the Virginia State Department of Transportation, Center for Innovative Technology and Transportation Research Council.

Proposed research activities of the CTR span the functional areas of ITS and the most recent area, ARTS (Advanced Rural Transportation Systems). Virginia Tech - CTR is the university designate for the aforementioned FHWA / ATIS rural study and hosted the third annual rural ITS conference in September, 1994.

California Rural Technology Projects

In July of 1992, Governor Pete Wilson signed into law a program to establish a multimodal Advanced Transportation Systems (ATS) Program.(10) This program was developed to research, demonstrate and deploy advanced technologies to improve the movement of people, goods, services and information. The ATS program has developed important partnerships through the California Aliance for Advanced Transportation Systems (CAATS) to ease the implementation of ITS in California. In addition, the plan outlines a fifteen year deployment plan and a five year program plan. As part of this effort, coordinated through the Caltrans New Technology and Research Program, California has several rural technology demonstrations underway. The following are their descriptions:

**Sierra Project(11)**

The Sierra project (called "Snow Wars") is a weather, traffic and highway condition gathering and destination system for Interstate 80 between Auburn, California, on the western slope of the Sierra Mountain Range and the Nevada state line.

The Sierra project has several components:

- A SCAN roadway weather information system to collect meteorological information.
- Weather radar to track storm cells.
- Pavement sensors to determine pavement condition.

- A traffic monitoring system.
- Changeable message signs, highway advisory radio and the California information network to provide information to travelers.
- The Kingsville snow management (control) center to collect and disseminate information.

**Visibility Warning Project(12)**

In November 1991, during a period of California drought, a major dust storm blew up on Interstate 5 in a rural area of California between Los Banos and Bakersfield. During the storm 164 vehicles were wrecked, 17 motorists were killed and 119 injured.

The California Department of Transportation (Caltrans) has installed a visibility warning system in that area of Interstate 5. The warning system includes a micro weather forecasting system, wind activated meteorological devices, closed circuit television and changeable message warning signs. The system is operated by Caltrans and the California Highway Patrol from control centers in Fresno, California, 40 miles from the project.

**Caltrans District 10 Advanced Fog Monitoring and Warning System Evaluation**

An independent evaluation of the Caltrans District 10 Automated Fog/Weather Monitoring System is being conducted under the Program for Advancing Transit and Highways (PATH). This evaluation is taking place during the winters (January - March) of each of the three years of the study. These months were selected because they correspond to the fog season in the respective study area. The following evaluation tasks will be conducted:

- Technical assessment: The objective of this task is primarily to verify and document the system under test.
- Influence on driver behavior during fog conditions: This includes an assessment of the degree to which driver behavior is influenced by the automated fog detection and warning system.
- Net impact on traffic safety: Data before and after the installation of the system will be compared to assess, in a gross sense, the efficacy of the system in reducing traffic loss due to inclement weather.
- Visibility sensor output comparison with perceived driver visibility: Video images displayed and monitored remotely will be used to manually access visibility at the test locations using visibility targets. Observations will be recorded and compared to correlate visibility readings.

- System reliability: Evaluators will analyze collected information to determine unreliability or serviceability problems and suggest remedial actions, if appropriate.

**Yosemite Area Traveler Information Project(13)**

The Yosemite Area Traveler Information (YATI) project is a $2.24 million demonstration project to better manage Yosemite's four million annual visitors. YATI is a cooperative effort by local, state, and federal agencies to provide current information about the 11,000 square mile, five-county region containing and surrounding Yosemite National Park. By providing current reliable information on transit, activities, parking, accommodations, and attractions, the project gives travelers an array of options for their visit. This will in turn help to reduce congestion, improve air quality, promote tourism and economic growth, and eliminate unnecessary trips. YATI utilizes a network of high-tech communications systems to provide travelers with up-to-the-minute information about traffic and weather conditions, as well as the status of transportation and recreational facilities throughout the entire Yosemite region. Components of the YATI system include:

- Changeable message signs: These specially designed, programmable signs are strategically located throughout the region and are used to inform travelers of current unusual traffic or other conditions (e.g., bad weather, fire, construction, incidents, etc.). They can also direct travelers to other components of the YATI system where they can receive additional information.

- Highway advisory radio: Roadway signs and notices on the changeable message signs direct motorists to tune in to a specific radio frequency for information regarding highway conditions and recreational opportunities. These pre-recorded announcements are broadcast on low wattage AM or FM transmitters that cover a small radius. Travelers are directed to the nearest YATI kiosk for further information.

- Multimedia kiosks: Allow travelers to access the entire YATI database through a user friendly touch-screen system. Each kiosk contains traveler information for the entire region, as well as local advertising and information of local interest. All of the information available through the world wide web is also available on these kiosks. Travelers have the ability to print out maps and selected subscriber (advertiser) information. Future planned enhancements include both graphics and short video clips, complete with voice-overs and soundtracks.

- Internet website (http://www.yosemite.com): All of the information available on the kiosks is available on this website.

- Traveler advisory telephone: Travel planning information will also be available via a telephone database of audio information (pending implementation).

## TransCal

TransCal, a comprehensive interregional traveler information system (IRTIS) for the Interstate 80, US Highway 50 region, integrates roadway conditions, incidents, traffic, transit, weather, travel mode (car, transit, train, air), and traveler services (yellow pages) data. It showcases emerging capabilities in computing, communications, and consumer electronics that can improve the availability and quality of traveler information so that travel decisions can be based upon the most current and accurate information available.

The TransCal project will also design and test a satellite-based emergency notification system to enable travelers to summon aid in emergency situations. A Tahoe Frequent Passenger Program to encourage greater transit usage in the Tahoe basin by providing incentives to use alternative transportation will also be initiated by TransCal.

## Kern County Early Deployment Plan

The Kern County Council of Governments (COG), the metropolitan planning organization for the Bakersfield metropolitan area, received a federal grant for the preparation of a strategic plan for the deployment of ITS technologies appropriate for Kern County. The COG ITS plan will provide a road map for incorporating consideration of ITS into the transportation decision making process. Since most of Kern county is rural, its planning process can provide useful input for early deployment planning in predominately rural areas.

## Sutter County Field Operation Test

This weather detection and reporting demonstration is designed to show that a call box can measure selected weather parameters of interest, automatically determine a pre-set alarm condition, and call the appropriate traffic management facility. The traffic management center (TMC) would then activate one or more traveler information systems to inform drivers of the weather hazard. Additional information such as the expected length of the condition and its location can be broadcast over the highway advisory radio network.

This demonstration will examine the ability of the call box with interface to external sensors that measure various weather parameters of interest. These parameters include ambient air temperature, dew point, wind speed, precipitation and restrictions to visibility (fog and dust). The demonstration will also determine the ability of the call box to automatically report parameters that exceed pre-set thresholds. The TMC will maintain information concerning potential weather hazards as a function of measured parameters and will generate appropriate traveler alerts to be transmitted to changeable message signs or other traveler information systems such as highway advisory radio. The evaluation factors for this demonstration are listed below:

- Real-time parameter measurement accuracy.
- Ability to remotely load threshold parameters.
- Adverse effects on call box power budget.

- Efficiency of data transmission protocol.
- Ability to integrate received alarm data into the TMC system.

# 6. Caltrans Plan and Program

***The following is intended as a recommended Caltrans Plan and Program for Advancing Rural Transportation Technology.***

It is recommended that Caltrans establish a program within the Caltrans New Technology and Research Program in order to continue the PARTT agenda. This section outlines the potential purpose, vision, and goals of this program.

Purpose

The purpose of the Caltrans Program for Advancing Rural Transportation Technology (PARTT) is to focus proper attention on the transportation concerns of rural California and to assure the appropriate application of rural transportation technology to rural transportation problems. PARTT directly implements the California Transportation Plan and is a major element of the Advanced Transportation Systems Program Plan.

Vision

The PARTT vision is for a safe and efficient transportation system for rural California through application of advanced transportation technologies.

Goals

PARTT goals include:

1. Promote the continued research development and demonstration of ITS in rural California.

2. Establishing and pursuing a consensus program of advanced transportation technology research, development, testing and demonstration for rural California.

3. Establishing a Western Transportation Institute (WTI) for Rural Transportation Technology Research and Education with ties to the Program for Advanced Transit and Highways (PATH) and Caltrans. (The WTI was established on the campus of Montana State University in February 1995).(14)

## *6.1. RD&D Initiatives*

Five new rural transportation technology initiatives are recommended. They are complementary to California projects already underway, to other national and international programs, and to the previous national accomplishments of PARTT. The five initiatives include operational test programs in rural weather systems, mayday systems, transit systems, commercial systems, and driver alert systems. The initiatives will also seek to ensure compatibility with other rural and interregional systems.

Rural Weather Systems

A rural weather system operational program would involve a test bed that would utilize micro weather monitoring equipment to advise drivers of frequent, rapid weather changes. The system would utilize existing remote monitors currently used to advise maintenance personnel of wind speed, wind direction, air temperature, relative humidity, precipitation, pavement temperature, and pavement conditions. The remote weather system would additionally be installed with a device to measure visibility. The information from the remote stations would be transmitted to a central station where the data would be compiled to give a comprehensive update of the remote road conditions. This information could then be transmitted to the traveler via variable message signs (VMS) or in-vehicle displays. Variable message signs would be the most valuable on routes such as mountain passes or high wind areas where poor weather conditions are common. VMS would be placed strategically giving travelers real-time information to enhance safety in treacherous weather conditions. Transmitters activating in-vehicle displays may also be used to give the traveler real-time weather and road information. The transmitter would be placed at a location where a micro weather monitoring system is in place. If the weather monitor sensed a sudden change in weather, for example poor visibility in blowing sand, the monitor would immediately activate the transmitter warning. The advantage of both the VMS and the in-vehicle display over conventional road signs is that the information is current, giving the traveler more confidence in the information.

The Caltrans projects (Sierra Project, Interstate 5 Visibility Warning), and the Idaho storm warning project are weather systems currently being deployed on interstate highways. Application to rural two-lane roads is proposed for study in this initiative. Route 395 in eastern California, or the Route 299 Alturas-Redding corridor, offer numerous locations for consideration. Planning, design and installation of a total site require nearly a year, following funding authorization and site location.

Savings would likely be possible through utilization of existing hardware and Caltrans sign inventories. Availability of power and communication medium (radio, telephone, hard wire) would also affect costs but could be partially addressed in the site selection process.

**Vision enhancement technology**, although not as readily available as weather and visibility sensors, would be considered under this initiative. The need for vision enhancement arises when travelers find themselves in situations of sudden loss of visibility caused by a snow squall, blowing dust, fog, or darkness. While a weather-visibility system can forewarn travelers, it can do nothing for the traveler who is unavoidably caught in a localized storm. Travel, particularly in mountainous areas, frequently involves driving in poor conditions if one wishes to maintain mobility. As a result, safety is compromised, as shown by 1991 data from Fatal Accident Reporting System (FARS). Approximately 12,486 fatal collisions or 33.8% of all fatal collisions occurred during foggy or dark conditions.

Improved visibility would help the driver in avoiding potential collisions with other vehicles, fences and railings, pedestrians, wildlife and livestock, or obstacles in the line of travel and would assist the driver in complying with highway signs.

The most promising current technical applications that could improve the driver's perceptual abilities during inclement weather is Infrared Imagers, or IRIs. These systems detect the infrared energy radiated by all warm objects and transform that energy into a visual display which the driver can then observe. One of the most striking advantages of IRIs is that no light source is needed. Thus, the driver can obtain an infrared image in the line of travel ahead without the need for headlights or street illumination. However, it should be remembered that IR systems are based on identifying differences in infrared energy intensity (as opposed to visible light) emanating from different objects. Thus, they will be used as a supplement to visual perception and not as a total replacement for it.

The more complex and sensitive IR systems, such as forward-looking infrared radar (FLIRs) for the military, require that the detector arrays be cooled to extremely low temperatures. However, an un-cooled FLIR system for motor vehicles has been built and demonstrated. This system provides drivers with nighttime visibility of objects and lane markings in the line of travel at a range up to three times greater than that available from headlights alone.

The high demand for IR capabilities, for both the military and civilian applications, is driving considerable development activity in this field. Further advances in IR performance and reliability (such as two-dimensional, high-density, un-cooled detector arrays) are anticipated.

Passive sensors that are sensitive to microwave energy could provide improvements in some aspects of the low-visibility problem, but their development for the civilian vehicle application is not as far advanced as that of IR sensors. Passive millimeter-wave imaging sensors use a focal plane array to produce radiometric images even in dense fog and most inclement weather. Current systems operating at 94 Ghz are installed on aircraft to allow pilots to land safely under all weather conditions. A distinct disadvantage of such systems, however, is that a large aperture is required to obtain a good cross-range resolution.

Other technologies being explored by the European PROMETHEUS program for driver visual enhancement include ultra-violet illumination and infrared illumination in conjunction with charge-coupled-device cameras.

Most infrared imagers, or thermal imaging systems, use detectors to gather information about the infrared energy levels and then process this information into a form that can be visually displayed. The earliest IR systems included an electro-optical multiplexer, or E-O Mux, which used light-emitting diodes (Eds) to reformat (i.e., process) the data and transmit it via TV camera to a monitor which displayed that data to viewer. More recent systems have replaced the E-O Mux with solid state components.

The feasibility of vision enhancement equipment raises several questions such as adaptation of military equipment, affordable cost, effectiveness in reducing accidents and human factors in use of products. The National Highway Traffic Safety Administration (NHTSA) is considering a R&D project entitled "Performance Specifications: Vision Enhancement Systems for Nighttime and Inclement Weather" to address these questions.

ITS America in its National Program Plan (5-94) estimates a timetable of 1993-94 for assessment of the state of the art, 1996-97 for evaluating technologies for implementations and 1998 for operational tests.

This initiative would assure that Caltrans would input into the development of vision enhancement technology and maintain consideration of those technologies into rural transportation. In particular, the question of cost affordability for rural dwellers would have to be scrutinized.

A budget for this portion of the initiative would depend on the extent of Caltrans involvement, which could range from passive vigilance of the NHTSA study to direct participation in development with the defense conversion industry. Considering the potential benefit, it is recommended that Caltrans engage in the acceleration of vision enhancement development.

Rural Mayday Systems

A rural mayday initiative gains acceptance when consideration is given to fatality statistics. Fifty-seven percent of all fatal accidents occur in rural areas, where 20,604 fatal rural accidents occurred in 1994. Coupled with these figures are comparisons of emergency notification/response times which are two times greater for rural accidents.(18) These figures are national averages and are likely more contrasting in remote areas of the West.

Mayday systems take on even more importance as more and more travelers venture into harsh, remote areas in search of seasonal recreation. Exposure to harsh environments and increasing criminal acts are creating additional need for mayday capability.

Two of the 17 ITS Operational Tests, selected by FWHA in 1994, illustrate potential mayday systems and their objectives. The second project, in Colorado, will offer some information on rural applications, although in proximity to heavily traveled Interstate 70 in the Denver areas.

Several of Caltrans' current rural and interregional projects can directly assist in the implementation of this initiative.

Rural Driver Alert Systems

**Rural driver alert systems** fall into two categories. In one, the driver is not impaired but still needs assistance to cope with unforeseen hazards. Passing maneuvers, fallen rock on the roadway, animals crossing the road, and oncoming vehicles veering out of the lane are dangers that are amplified when sight distances are limited. The second category involves the driver, who may be impaired by fatigue, drowsiness, alcohol, drugs, poor vision or possibly handicapped by illness. Leaving the roadway, resulting in single vehicle roll-overs or impact with road-side objects, causes numerous fatalities. At worst, head-on collisions may result in either category. In 1994, 15% of all fatal collisions were head-on.[18]

Head-on crash warning and control passing warning and control are being addressed in the Longitudinal Collision Avoidance user service of ITS America. Candidate sensors, to forewarn drivers of obstacles in their path, include microwave, millimeter-wave radar, laser radar (also know as lidar, or light detection and ranging), and video image processing. There are a few commercial radar-based headway detection systems and several systems based on image processing currently on the market for rear-end collision avoidance that may have some applications for crash warning. However, research is underway in improving all three of these technology areas. Combinations of these technologies, such as radar plus image processing, into a single system are possible. Ultrasonic and infrared technologies are also being explored.

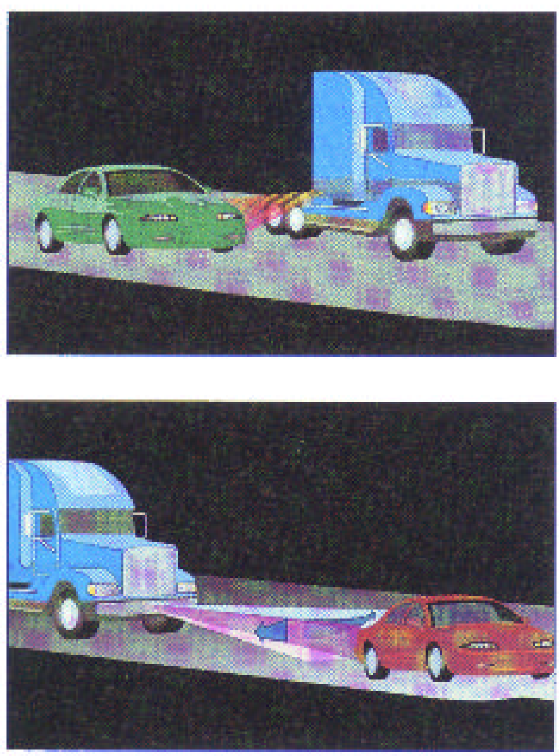


**Figure 14: Delco FOREWARN, 24GHz short range microwave radar**

From **Traffic Technology International**, Spring 1995

The sensing capabilities needed for longitudinal collision avoidance systems could be autonomous or cooperative. Cooperative systems would communicate with other vehicles or the infrastructures, while sensors for autonomous systems are wholly contained within the vehicle.

This Caltrans initiative would assure that R&D on head-on passing systems would receive full attention, which is certainly dictated by the rural traveler needs. It would be prudent for Caltrans to investigate and assess technologies to correlate with activities of ITSA on rear-end and backing crash warning.

**The Impaired or Inattentive Driver** creates an obviously hazardous situation with grave consequences. Fatal accidents due to inattentiveness, driver fatigue, and alcohol accounted for 63% of all fatal accidents in 1994.(18)

For Road Departure Warning and Control Systems, roadlane edge detecting is plausible and can be accomplished by either vehicle-based or cooperative vehicle infrastructure technologies. Vehicle-based components could utilize video image processing, optical scanning or infrared laser scanning techniques. Vehicle-infrastructure concept include vehicle-based radar units and reflectors mounted along the road/lane edge, and coded magnetic array systems utilizing magnets or induction loops imbedded in the road lane. Sensors for these systems might be enhanced by passive infrastructure features to denote land boundaries or traction levels. These could be as simple as painted lines or more complex such as a magnetic marker referencing system. Snow and ice buildup on markers could cause problems. Active lane boundary indicators of certain road features are another possible method of departure warning. For example, a roadside beacon may transmit information about the geometry and speed limit of an upcoming curve to motorists.

Rather than monitor lateral vehicle position, it may be more fruitful to monitor the driver directly. The state of the driver's condition can be determined by one or a combination of different variables such as driver's physiological condition (heat rate, skin resistance, brain wave activity, breath content, eyelid movement, body temperature, etc.), facial movements (eye movements, blinks and head nods), steering movements and corrections, and ability to track within a lane. Variations from a normal alert state could be detected and could trigger an in-vehicle warning. There may be problems with the use of any of the systems that require attaching electrodes to the driver's body. However, a steering wheel recorder or a video camera tracking device may be acceptable.

ITSA proposes to evaluate technologies by 1997 and conduct in-service testing and/or develop products by the turn of the century. This Caltrans initiative would produce cooperative efforts to assure that the potential benefits from rural driver alert systems would be recognized. Development of such systems could be accelerated by Caltrans-defense industry endeavors.

Rural Commercial Vehicle Operations (CVO)

Rural CVO is perhaps the best defined functional area of ITS. With the FHWA leading a partnership of State highway and motor carrier regulatory authorities and the motor carrier industry, CVO development is well planned to achieve its vision of safe and free movement throughout North America. The user services described by ITS America will apply and benefit rural transportation. However, this initiative is needed to direct attention to one aspect of CVO not explicitly covered by the ITSA user services criteria. While the CVO criteria and the rural weather and rural driver alert initiatives will contribute substantially to the safety of rural travelers, the increasing conflict between trucks and tourist traffic requires special attention. Both truck and tourist traffic are increasing on two lane rural roads, such as Routes 395 and 299. The truck traffic, while concerned with safety, is still focused on moving goods as quickly as possible; tourist and recreational travelers are often moving at slower speeds and may have their attention diverted. Recreation vehicles, towed trailers and boats, when mixed with large commercial haulers and buses, create situations that can have disastrous consequences. In addition to the fatalities and injuries, accidents can cause damage to areas of particular environmental fragility such as streams, wetlands and forests.

The On-Board Safety Monitoring services could be developed to include monitoring of truck speeds, which are sometimes in excess of posted speed limits. Even at posted speeds, trucks can impact recreational travelers who are rubbernecking at scenery and wildlife. While both the CVO safety monitoring and inspections will provide a means to check driver alertness, a system is needed to alert the truck driver of approaching hazards (i.e. a Ford Bronco waiting for an RV to turn off the highway into a campground was demolished by a tailgating stock truck/pup on US 191/MT - 4 deaths).

This Caltrans initiative would parallel the national CVO program throughout the remainder of this decade and likely beyond. A voluntary pilot program would be undertaken where trucks could be retrofitted with Delco Electronics' Forewarn systems or similar applications. A similar program to monitor speeds may encounter institutional barriers but would be investigated.

Rural Door-to-Door Transit Initiative

Caltrans is currently initiating a door-to-door paratransit system demonstration for the disabled in Santa Clara County. The demonstration includes paratransit vehicles equipped with high-tech automatic vehicle location and navigation systems and a paratransit dispatch center capable of providing real-time and reservation basis door-to-door transit service. Caltrans and other partners are also initiating a “personalized” public transportation system providing door-to-door service to the public-at-large in the Ontario airport region. The system will include advanced communications, automatic vehicle location, in-vehicle displays, smart cards and readers, and automated, demand responsive dispatching.

The Rural Door-to-Door Transit Initiative would extend this type demonstration to a rural setting where fixed transit service is not practical. Vehicles used during this rural demonstration would be equipped with portable navigation devices capable of responding to previously identified visual landmarks rather than street addresses as well as communication devices to provide the link to the Dispatch Center. Rider-participants would request rides and receive trip information via a variety of interfaces, including telephones, pagers, and other hand-held devices.

## 7. The Future for Rural Transportation Technology

It is fair to say that in early 1992 there was no national program for advancing rural transportation technology. Early attempts by Armijo and West to promote dialogue on rural opportunities for advanced technology were met by smiles or skepticism (or both).

Since 1992 there has been some progress at the national level and in some states in recognition of the need for additional rural emphasis in advanced transportation technology. But not enough.

In 1963 Patrick Moynihan coined the term "benign neglect" to describe a National Administrations policy toward minorities. This may also be a good description of the current national attitude toward transportation problems in rural America. In advanced transportation technology the neglect is caused in most part by the urban emphasis (and urban attitude) described earlier.

The best way to mitigate the prevailing urban emphasis and attitude is to forge an effective and complimentary National rural attitude, a very difficult task.

# 8. Glossary of Terms

| | |
|---|---|
| AAA | American Automobile Association |
| AASHTO | American Association of State Highway and Traffic Officials |
| AM | Amplitude Modulated |
| AMLCD | Active Matrix Liquid Crystal Display |
| APTS | Advanced Public Transportation System |
| AT&T | American Telephone and Telegraph |
| ATIS | Advanced Traveler Information System |
| ATMS | Advanced Traffic Management System |
| AVCS | Advanced Vehicle Control System |
| AVI | Automatic Vehicle Identification |
| AVL | Automatic Vehicle Location |
| Caltrans | California Department of Transportation |
| CVO | Commercial Vehicle Operations |
| CTR | Center for Transportation Research |
| DR | Dead Reckoning |
| EMS | Emergency Medical Service (System) |
| ENTERPRISE | Canadian Forum |
| FARS | Fatal Accident Reporting System |
| FCC | Federal Communications Commission |
| FHWA | Federal Highway Authority |
| FM | Frequency Modulated |
| GPS | Global Positioning System |

| | |
|---|---|
| GPS/DR | Global Positioning System / Dead Reckoning |
| HUD | Heads Up Display |
| ITS | Intelligent Transportation System |
| ITS America | Intelligent Transportation Society of America, formerly IVHS America |
| IVHS | Intelligent Vehicle Highway System |
| LED | Light Emitting Diode |
| LEOS, LEOSAT | Low Earth Orbit Satellite |
| MDT | Montana Department of Transportation |
| NIS | Navigation Information System |
| New Tech Program | New Technology Development Program |
| NT&R | New Technology and Research |
| PARTT | Program for Advancing Rural Transportation Technology |
| PATH | Partners for Advanced Transit and Highways |
| PROMETHEUS | Program for European Traffic of Highest Efficiency and Unprecedented Safety |
| RCE | Research Center of Excellence |
| RD&D | Research Development and Demonstration |
| RDS | Radio Data System |
| RDSS | Radio Determination Satellite Service |
| RMS | Rural Mayday System |
| RTEAS | Rural Traveler Emergency Alert System |
| RTIS | Rural Traveler Information System |
| RWIS | Rural Weather Information System |
| TRAVTEK | NIS demonstration project |

| | |
|---|---|
| TRF | Terrestrial Radio Frequency |
| US DOT | United States Department of Transportation |
| VENTURE | WA DOT ITS demonstration Project |
| VMS | Variable Message Display |
| WA DOT | Washington State Department of Transportation |
| WTI | Western Transportation Institute |

**Disclaimer:**

The information contained in this report was taken from many sources. Where possible, those sources were recognized. However, much of the information was obtained while reading papers, listening to lectures, and personal discussions. The author wishes to acknowledge these people.

## 9. End notes


1. West, J., (1993). Chief of New Technology & Research Program, California Department of Transportation [Personal Communication].

2. Judycki, D, and Euler, G., (1993, April). The Intelligent Vehicle Highway System Program in the United States

3. Balgowan R., (1993). Regional Maintenance Engineer, New Jersey Department of Transportation [Personal Communication].

4. Krakiwsky, Edward J., (1994, Februrary). Innovations in Vehicle Tracking and Navigation, GPS World, pages 42-46

5. Federal Highway Administration, (1994). Preliminary Assesment of Rural Applications of Advanced Traveler Information Systems (Draft Report). JHK & Associates

6. Lacey, N., (1993). Program Administrator, Colorado Department of Transportation [Personal Communication]. (303) 757-9823

7. Briglia P., (1993). Washington State Transportation Center [Personal Communication]. 206.543.3331

8. Kitchener, F., (1993) CH2M Hill, Boise Division [Personal Communication].

9. Laurant, M., (1993) Information Officer, CTR-Virginia Tech [Personal Communication].

10. California Department of Transportation, New Technology and Research Program, (1995). Advanced Transportation Systems Program Plan.

11. Evans, M., (1996). Chief of Division of Operations, California Department of Transportation, District 3 [Personal Communication]. (916) 324-1165.

12. Gomez, D., (1996). Associate Transportation Electrical Engineer, California Department of Transportation, District 6 [Personal Communication]. (209) 488-4163.

13. Loveland, C., (1996). Chief of California Advanced Public Transportation Systems, California Department of Transportation, New Technology & Research [Personal Communication]. (916) 654-9970.

14. Albert, S., (1993). Director, Western Transportation Institute [Personal Communication]. (406)994-6114

18. U.S. Department of Transportation, 1994, Traffic Safety Facts