IntelliDrive^{SM} Rural Risk Warning System (IRRWS):

A North/West Passage Rural Vehicle Infrastructure Integration Demonstration Project

FINAL REPORT

by

Western Transportation Institute (WTI)
College of Engineering
Montana State University

For the
North/West Passage Pooled Fund

Sponsored by
Research and Innovative Technology Administration
United States Department of Transportation

April 2010

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This document is the final report for the North/West Passage Rural Vehicle Infrastructure Integration Demonstration Project. It summarizes the work conducted by the Western Transportation Institute at Montana State University to develop a demonstration concept for the IntelliDrive^{SM} Rural Risk Warning System (IRRWS), on behalf of the North/West Passage Pooled Fund States.

The primary components of this report include:

- A background section that provides an introduction to the concept of Vehicle Infrastructure Integration (VII), a description of the North/West Passage Pooled Fund, and an overview of previous research that served as a foundation to this project
- The goals and objectives of the research
- A summary of the initial literature review
- A summary of the use case analysis, including a listing of the VII use cases identified as potentially appropriate for deployment in a rural setting
- The outcomes of the North/West Passage pooled fund meeting, at which researchers presented the initial concept and solicited input for further development
- Operational scenarios, which describe how the system could benefit a range of users under a variety of circumstances
- A summary of impacts and benefits
- Subsequent development and deployment efforts by project stakeholders

BACKGROUND

Vehicle-Infrastructure Integration (VII) is an initiative for communication of information between smart vehicles, equipment and sensors on the roadway, and information service providers and managers. While today many applications of Intelligent Transportation Systems (ITS) are being implemented on the roadway, VII adds the dimension of smart vehicles that gather and share data with other vehicles, devices, and infrastructure. VII applications are being defined to improve transportation safety, efficiency, and convenience by sharing information between vehicles on the roadway, Traffic Management Centers (TMCs) and other information service providers.

The current application of VII has been largely limited to urban applications, although sixty percent of roadway deaths occur in rural areas. Until recently, the implementation of VII in rural areas has remained largely unexplored and untested, and as a result there are significant gaps in current VII research.

WTI has been working with the North/West Passage Pooled Fund, which consists of the departments of transportation for states along the I-90 and I-94 corridor, to develop a concept for a VII demonstration and testbed, in order to highlight and explore application of VII specifically as it relates to the unique problems and issues in a rural environment.

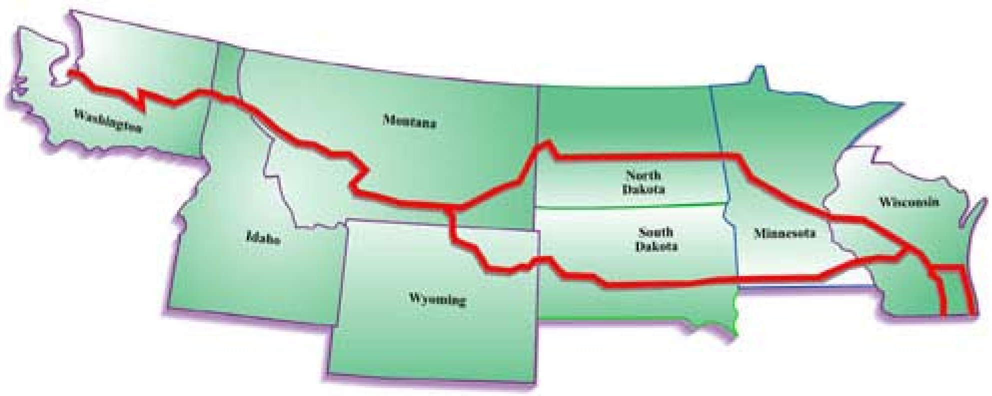

Figure 1: North/West Passage Corridor

Leveraging Previous Research

The study of solving rural transportation issues by the implementation of communications technology is one of WTI's core strengths. WTI has conducted numerous related projects that provided a foundation for this project.

WTI studied rural applications of Automated Highway Systems (AHS) for safety and improved operation in the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) project. The project area consisted of a loop roadway system traversing through Wyoming, Yellowstone National Park (YNP) and Grand Teton National Park, connecting Bozeman, Montana with Idaho Falls, Idaho. The problems related to this corridor, such as varied and challenging driving conditions with wildlife, unfamiliar drivers and lack of communications infrastructure are common to many rural environments. With data from this study and WTI's familiarity with the problems of the area, this area was considered as a promising location for field demonstrations and tests of VII technology.

Through the GYRITS project, WTI developed a strategic plan and a regional architecture to guide project selection. During the deployment phase, WTI worked with numerous federal, state, local and private agencies to implement a variety of ITS technologies, including automated vehicle identification, dynamic warning systems, and traveler information systems. The GYRITS project provided an opportunity to conduct a large scale deployment of ITS technologies in a rural environment, while providing stakeholder agencies with new solutions for safety and mobility challenges on key regional corridors.

In addition, WTI has previously or is currently working on many VII and communications related projects in rural areas which include:

- COATS Showcase Work Zone,
- Bicycle Pedestrian Warning System,
- Improve Communications between TMC and TMS Elements in a Rural Environment,
- Automated Safety Warning System Controller,
- Ad-Hoc Routing for Rural Public Safety,
- Redding District Incident Management Responder,
- Mobile Communications Briefcase, and
- Facilitating Special Event Congestion Management in Small Communities.

Each of these projects included an exploration of technologies that either communicate to vehicles on the roadway, or communicate with the infrastructure. Many of these technologies and the deployment lessons learned were instrumental in the development of use cases, systems design and concept of operations for this project.

National Research Priorities

The VII initiative, which is now contained in a broader initiative called IntelliDrive SM, is one of the major initiatives of the Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation (US DOT)[1]. The overarching goal of IntelliDrive SM is to improve transportation safety, relieve congestion and enhance the productivity of America's roadways. [2] With 6 million vehicle crashes per year, 41,000 fatalities on the roadway in 2007 and a direct economic cost of $230 billion dollars, government and industry are looking for a safety solution based on new technologies such as VII and collision avoidance systems. [3]

VII research is being performed by groups such as the Crash Avoidance Metrics Partnership (CAMP) and the Vehicle Infrastructure Integration Coalition (VII-C) which are both actively involved in new safety technologies using VII. VII demonstrations are being performed nationwide, and test beds are appearing in California, Michigan, and New York in conjunction with the ITS World Congress. This project provided an opportunity for the Northwest Passage states and WTI to participate in the IntelliDrive SM initiative and further national research priorities.

GOALS AND OBJECTIVES

The general goals of this project were to research VII specifically in application to rural environments, to develop a concept for a rural VII demonstration and to present findings at the North/West Pooled Fund annual meeting on March 10, 2009. A further purpose of the meeting was for WTI personnel to work with meeting attendees to identify promising/appropriate VII applications in a rural environment, and develop a concept for a demonstration project in this regard.

The specific objectives of this project were to:

1) Conduct a literature review,
2) Review existing VII use cases,
3) Define and develop use cases for rural VII,
4) Present findings at the North/West Passage annual meeting, and
5) Produce a draft high level systems design and concept of operations for a rural VII demonstration.

This document is the final report that summarizes the project tasks and presents the system design and concept of operations.

LITERATURE REVIEW

The research team conducted a review of national literature related to Vehicle Infrastructure Integration research and initiatives. The focus of the review was to identify rural transportation issues that could be addressed through VII and to identify use cases for further study.

Transportation Challenges in the Rural Environment

The US DOT Research and Innovative Technology Administration (RITA) has major research initiatives aimed at improving transportation safety, relieving congestion and enhancing productivity.[4] The VII initiative, which is now contained in a broader initiative called IntelliDrive, solves problems in each of the focus areas.

Of the three problems areas targeted by RITA, safety is arguably the most important in a rural environment. According to the US DOT's Rural Safety Initiative, accidents on rural roads account for over half of the vehicular fatalities while rural roads carry less than half of the nation's traffic. Therefore, the literature review and ultimately this research project focused on VII applications that can be used to improve roadway safety in the rural environment.

Rural Motor Vehicle Crashes and Fatalities

According to the USDOT Rural Safety Initiative, a May 2004 General Accounting Office report found that human behavior, roadway environment, vehicles and medical care after a crash were the key factors that contributed to rural roadway fatalities.

As shown in Figure 2 below, a number of crash factors demonstrate a greater probability for causing fatalities when the collision occurs on a rural road (ratings above the dashed line). Many of these factors can be grouped into the following categories:

- Passing/Lane position
- Speed
- Animals in the Roadway
- Roadway environment (design features, weather conditions, etc.)

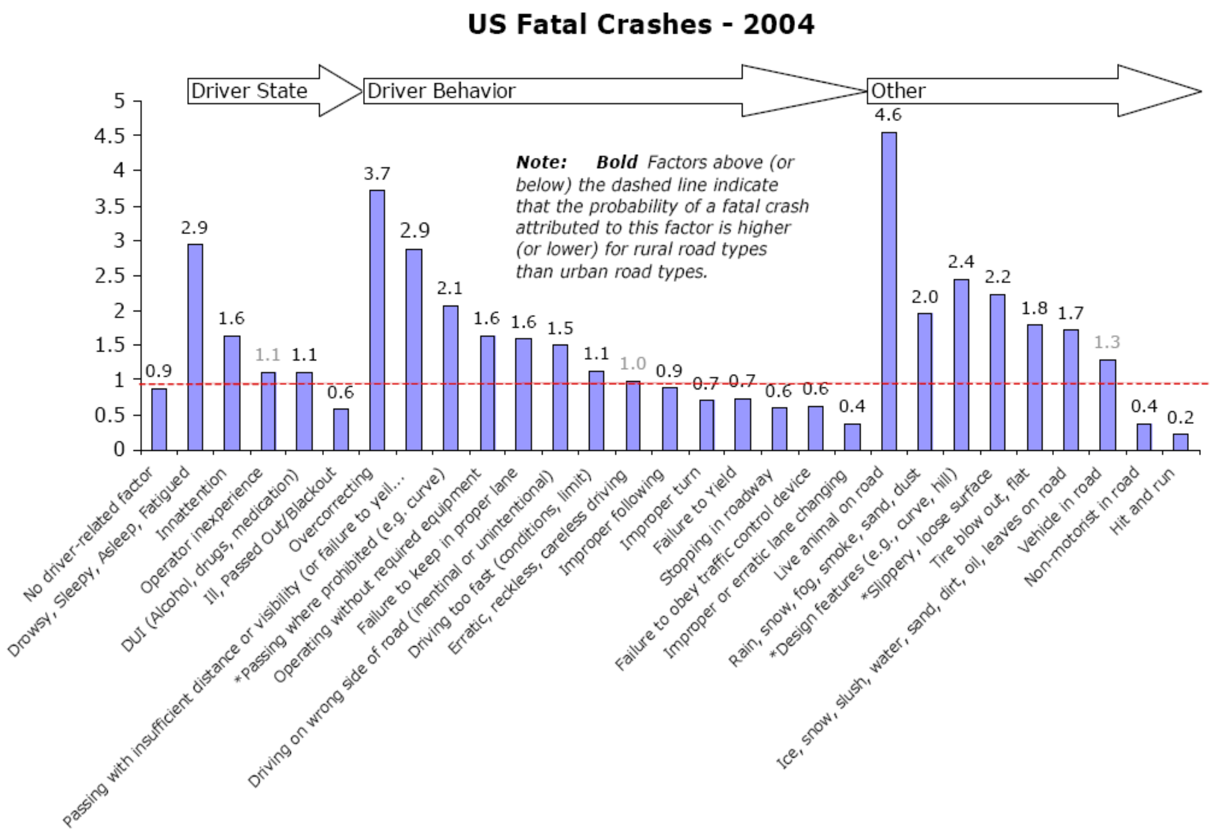

Figure 2: U. S. Fatal Crashes with contributing factors [5]

Crash Factors in Northwest Passage States

The literature further indicates that states in the Northwest Passage region, many of which have extensive rural areas, exhibit high rates of crash fatalities. For example, almost 25% of all nationwide rural ice/frost fatal crashes occurred in Northwest Passage states. Further, the percentage of fatal crashes with lane departure as a factor meets or *exceeds* the national average of 58% in all of the North/West Passage states:

- Montana: 74%
- Wyoming: 74%
- South Dakota: 74%
- Idaho 62%
- Washington: 60%
- Minnesota: 60%
- North Dakota: 58%
- Wisconsin: 58%

Use Case Identification

The research team reviewed numerous sources to identify VII use cases that were potentially applicable to addressing transportation challenges in the rural environment. Researchers identified and reviewed two rural area VII studies: the Automated Highway System (AHS) study conducted by WTI for the Yellowstone area (see "Previous Research" in Background section) and an AHS study conducted by the California Department of Transportation (Caltrans) District 1. Further, the team accumulated rural use cases from the following sources:

- WTI (Rural examples from previous research projects)
- Idaho Department of Transportation ("Rural VII Opportunities and Challenges")
- Iteris ("Enabling VII-based Rural Applications")
- USDOT ("VII Concept of Operations")

The rural use cases from each of these sources are included in Appendix 1.

USE CASE ANALYSIS

The research team reviewed the use cases identified in the literature review for their applicability to rural environments and for issues related to implementation in rural areas.

Rural Transportation Challenges

Researchers analyzed the use cases for their capabilities to address the unique transportation challenges that are common in rural areas, including:

- Long distances between destinations
- High speeds of travel
- High percentage of commercial vehicles
- Presence of some drivers who are unfamiliar with the surroundings or with driving on rural roads
- Few alternative routes
- Severe weather conditions
- Long emergency response times
- Higher fatality rates than urban areas

Rural Technical Challenges

Researchers also evaluated the use cases for their functionality within the infrastructure and resources typically available in rural locations:

- Compatibility with available vehicle fleets, such as Emergency Medical Services (EMS) vehicle fleets, highway maintenance vehicles, public safety vehicles, Rental vehicle fleets, rural transit and school bus fleets, and commercial fleets.
- Functionality of the VII technologies with existing infrastructure and equipment in rural environments, in order to leverage resources and reduce costs. Examples of roadside equipment that exist in rural environments are: Automated Gate Closures, Automatic Traffic Recorders (ATR), Closed Circuit Television (CCTV) cameras, Dynamic Message Signs (DMS), Extinguishable Message Sign (EMS), Highway Advisory Radio (HAR), Intersections, Lighting structures, Rest Areas, RWIS, Variable Speed Limit Sign, and Weigh in Motion (WIM)/Weigh Stations.
- Flexibility of VII technologies, such as the ability to disseminate the VII information to more than one system, and the ability to use portable equipment that can be moved to different hot spots in a region.

Use Case Definition

Researchers identified potential use cases and applications using vehicle to infrastructure (V2I), vehicle to vehicle (V2V), vehicle to driver (V2D), and wide area network (WAN) technologies.

They classified the promising rural use cases according to the categories included in the USDOT RITA IntelliDrive Initiative: Safety, Mobility, Environmental, and Convenience. (Complete classification list included as Appendix 2).

Given the importance of safety issues in rural areas, researchers focused on defining use cases in the Safety category. Use cases selected for potential inclusion in a rural demonstration are summarized below.

Speed Related Crashes

Speed related crashes include those in which a driver is traveling above the speed limit or traveling faster than is safe considering conditions and road geometry.

- Probes for Advisory/Variable Speed Limit: By recording historical and real-time data on actual speeds of vehicles on a roadway, a determination could be made of safe speed in a variety of conditions.
- Augmented Speed Enforcement: Vehicle speed information for a corridor monitored in real time may assist enforcement for speeding violations.
- Speed Limit Assistant: Drivers are informed that they are exceeding the speed limit. Speed information could be transmitted by roadside nodes or by use of an in-vehicle map database.
- Vehicle Based Road Condition Warning (V2V): Information such as antilock brake or traction control actuation is passed between vehicles.
- V2V Road Feature Notification (V2V): Information on local road features such as curves and appropriate speeds is passed between vehicles. This information does not require a roadway map database.

Road Departure Crashes

- Mayday Relay: When a vehicle is in a crash, an automated message is sent to other vehicles for relay to a roadside node. In the limited market penetration case the message may appear on a display in a vehicle near the scene, which can use another type of communication system to call for help. Fleet vehicles often have some form of communication system.
- Curve Speed Warning: A driver is warned when the speed at which he is traveling exceeds the appropriate speed for road geometry. Road geometry information could be transmitted by roadside nodes or by use of an in-vehicle map database.
- Animal Warning/Wildlife Crossing Data Collection: The driver pushes a button that indicates an animal in the roadway. This information is passed to approaching vehicles and is stored in a database to recode wildlife crossing areas.
- Probe for Weather: Vehicles record road condition information and pass information on hazards to approaching vehicles.

- In Vehicle Sign Override: Certain vehicles, such as public safety and maintenance vehicles, interface with DMS and override them with a temporary message such as “Snow Plow Ahead”, “Wide Load Ahead”, “Paint Crew Ahead”, “Accident ahead”, or “Workers in Roadway”.

Intersection Related Crashes

- Emergency Vehicle Signal Preemption: Emergency vehicles override signals and allow safer and quicker passage through intersections.
- Stop Sign Violation Warning: An in-vehicle map database is updated by a roadside node with information on locations of intersections and stop signs. An in-vehicle warning is given if a stop sign is ignored.
- Highway/Rail Collision Warning: An in-vehicle map database would be updated by a roadside node with information on locations of railway intersections. An in-vehicle warning is given if the vehicle must come to a stop and if the crossing arm is down.

Work zone Warning

- In-vehicle Warning of Workzones and Appropriate Speeds. The system could interface with a smart Workzone to provide vehicle speed information and Workzone intrusion alarms.

In Vehicle Signage

- Roadside signage is displayed in-vehicle tailored to the driver and vehicle type. Sign information is transmitted by roadside nodes or by use of an in-vehicle map database.

NORTH/WEST PASSAGE MEETING

The research team presented the findings of the literature review and use case analysis, as well as a preliminary demonstration concept, at the North/West Pooled Fund annual meeting on March 10, 2009. Participants included representatives from the departments of transportation in the North/West Passage corridor states: Washington, Idaho, Montana, Wyoming, North Dakota, South Dakota, Minnesota, and Wisconsin.

The meeting provided an opportunity for stakeholders to provide initial feedback on the concept, based on their own needs and experience. The recommendations offered by participants played an important role in refining the scope of the demonstration project, by helping the team to develop a system that would:

- Incorporate use cases with the highest potential benefits to users,
- Function within the infrastructure and resources available in the North/West Pooled Fund states, and
- Fill the most critical gaps in rural VII research.

Through this forum, the research team also identified stakeholders who provided ongoing technical guidance throughout the development of the system concept.

RURAL VII DEMONSTRATION DEVELOPMENT

This section summarizes the concept of operations for the IntelliDrive^{SM} Rural Risk Warning System (IRRWS), which was designed specifically as a solution to problems in the rural environment. For the purposes of demonstration, the system is presented in the context of a potential deployment on the rural highways surrounding and passing through the greater Yellowstone region in Montana, Wyoming and Idaho.

The overarching goal of the research team was to create a system that would be used by the entire traveling public. Even though VII technology is currently focused on technologies added to vehicle fleets, this system has the potential to provide benefit to all travelers within the area where it is deployed.

From a design perspective, the research team also strove to develop a system based on existing research, well defined transportation problems in rural areas and integrated use of existing technology. This system could be implemented in the near term by integrating existing commercial products, software and networks. While the details remain to be defined, the system fits into the vision of the National ITS Infrastructure.

This concept of operation provides:

- The Risk Warning concept,
- A description of system users,
- An overview of the system design,
- Proposed location, equipment, infrastructure and operational environment,
- Operational scenarios, and
- Summary of impacts and benefits.

This concept of operations and system description is intended as a starting place for discussions between stakeholders, researchers, implementers and equipment vendors for the funding, creation, implementation, and use of such a system.

Risk Warning Concept

As the majority of roadway crashes are caused by a driver's behavior, a safety system that effectively changes driver behavior will have the most impact. The one element that most defines behavior is a driver's perception of roadway risk. Drivers use caution and pay attention to the roadway when they feel that they are in danger. If drivers are better informed or reminded of actual roadway risk, many incidents that are caused by un-noticed risk events or by driver distraction could be averted. Better communication of roadway risk is the basis of the IntelliDrive^{SM} Rural Risk Warning System.

Currently, roadway risk is communicated to drivers on an ad-hoc basis. There are highway advisories posted to websites or disseminated by radio or occasionally portable message signs. What is needed is a system that can warn a driver in the vehicle several seconds before the risk event and allow the driver to respond appropriately.

The IntelliDrive[SM] Rural Risk Warning System is an attempt at integrating current communications and networking technology with an effective human machine interface that can give drivers crucial extra seconds before a risk event puts them in danger.

Risk Warning is a method to make drivers more aware of unforeseen roadway risks or to remind them that they are driving in a risky environment. Studies have shown that the driver is responsible for 90% of fatal crashes. There are many approaches that deal with making the roadway safer but no single integrated system to affect driver's behavior due to roadway risk.

The Rural Risk Warning System will use factors from three areas to create a metric of actual driving risk:

- Human Factors,
- Geo-Referenced Roadway Data,
- Real Time Sensing.

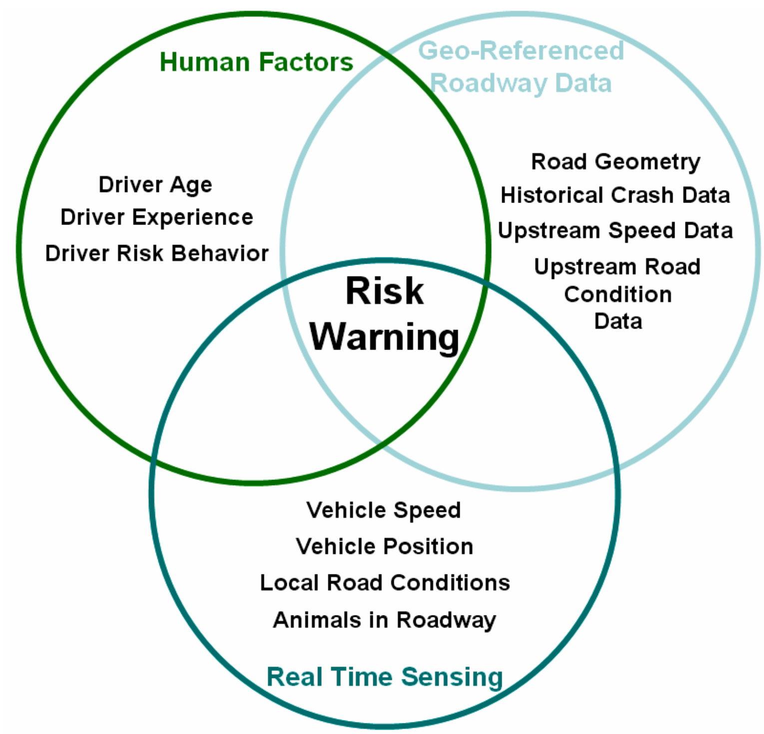

Figure 3: Risk Warning Concept

Integrated Risk Warning System Benefits

By integrating risk factors into a common format and interface to the driver, the Rural Risk Warning System will give critical additional seconds of warning before an incident will or would occur. A common, well studied interface will warn of present risk and record roadway conditions for dissemination to the general public by web and infrastructure based displays. The data collected can also be used by agencies to make corrections to hot spot areas that are identified by persistent risk events.

Risk Warning Metrics and Display

To communicate risk, a metric and method of display must be created. The research team proposes using a metric of risk from 0-6, with zero corresponding to safety or no risk and 6 corresponding to immediate danger or the greatest risk.

Table 1: Risk Warning Levels and Meaning

Risk	Meaning	Proposed action
Less than 1	Low Roadway Risk	No action needed
1-2	Normal Roadway Risk	Maintain normal attention to roadway
2-3	Elevated Roadway Risk	Heighten vigilance
3-4	Moderate Roadway Risk	Travel with high concern and reduced speeds
4-5	High Roadway Risk	Avoid travel or take added precautions (chains, etc)
5-6	Extreme Roadway Risk	Only emergency travel should be attempted

The risk metric will be based on real time and historical data. The metric will be updated at least twice per second. The metric will be calculated to "look ahead" of the present vehicle position. A warning for a risk event in the future will be presented to the driver within the time needed by that individual driver to react and maintain safety.

Risk displays will be color coded in two methods. The first method will be used as an indicator to motorists or displayed on a web page to show the immediate risk metric. A color code based on the familiar logic of traffic signals will be used, with green for safety, yellow for caution and red for danger.

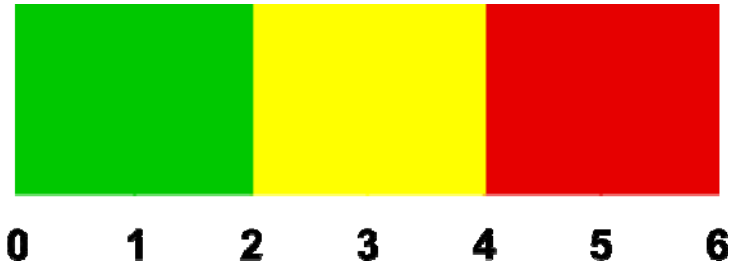

Figure 4: Risk Warning Colors for Risk Levels 0-6

The second method of color codes will be used to show trends such as risk for a vehicle on a route on a web display. This method will not be used for real time planning or as an indicator in a vehicle. This method of color coding will use gradients from green to yellow and yellow to red. The trend colors have the same meaning as the indicator colors: green for safety, yellow for caution and red for danger.

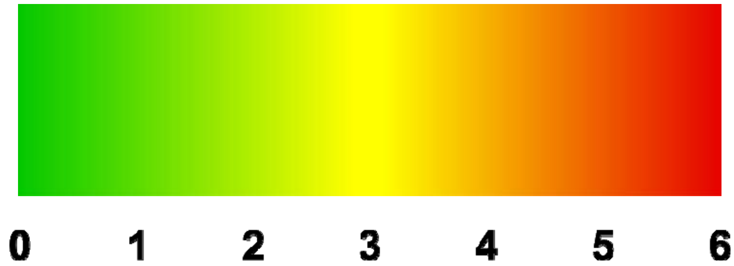

Figure 5: Risk Warning Colors for Risk Trends

System Users

The research team developed the IntelliDrive^{SM} Rural Risk Warning System (IRRWS) with three major groups of users in mind:

- In-vehicle system users
- Fleet operator system users
- Public system users

In Vehicle System User

Vehicles equipped with the IRRWS would receive location specific warnings in real-time, based on the metrics described in the previous section. A conceptual illustration of the in-vehicle interface is shown in Figure 6.

Figure 6: Example of an In-Vehicle Risk Display

Fleet Operator System Users

Fleet operators could use the system to monitor roadway risk for their vehicles, in order to enhance safety, track progress, estimate travel and arrival times, and other operational tasks. Examples of fleet users include:

- Highway Maintenance
- Transit/School Bus/Para-Transit
- Public Safety
- Emergency Medical Services
- Trucking and other Commercial Fleets
- Rental Fleets

An example of a web-based display for fleet operators is shown in Figure 7.

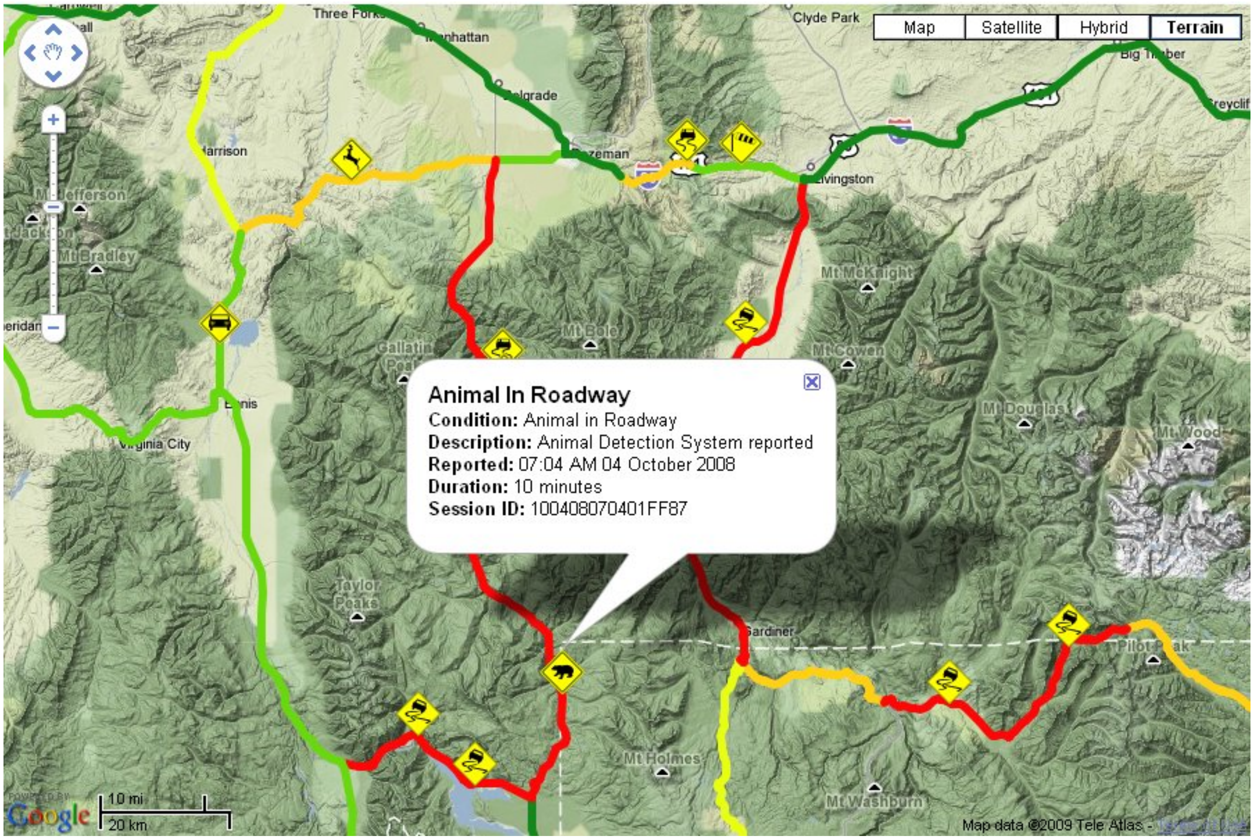

Figure 7: Sample Web-based display for fleet operators

Public System Users

The traveling public could directly benefit from the IRRWS in at least two respects. For pre-travel planning and route selection, drivers could access a web-based risk display of their planned route, as displayed in Figure 8.

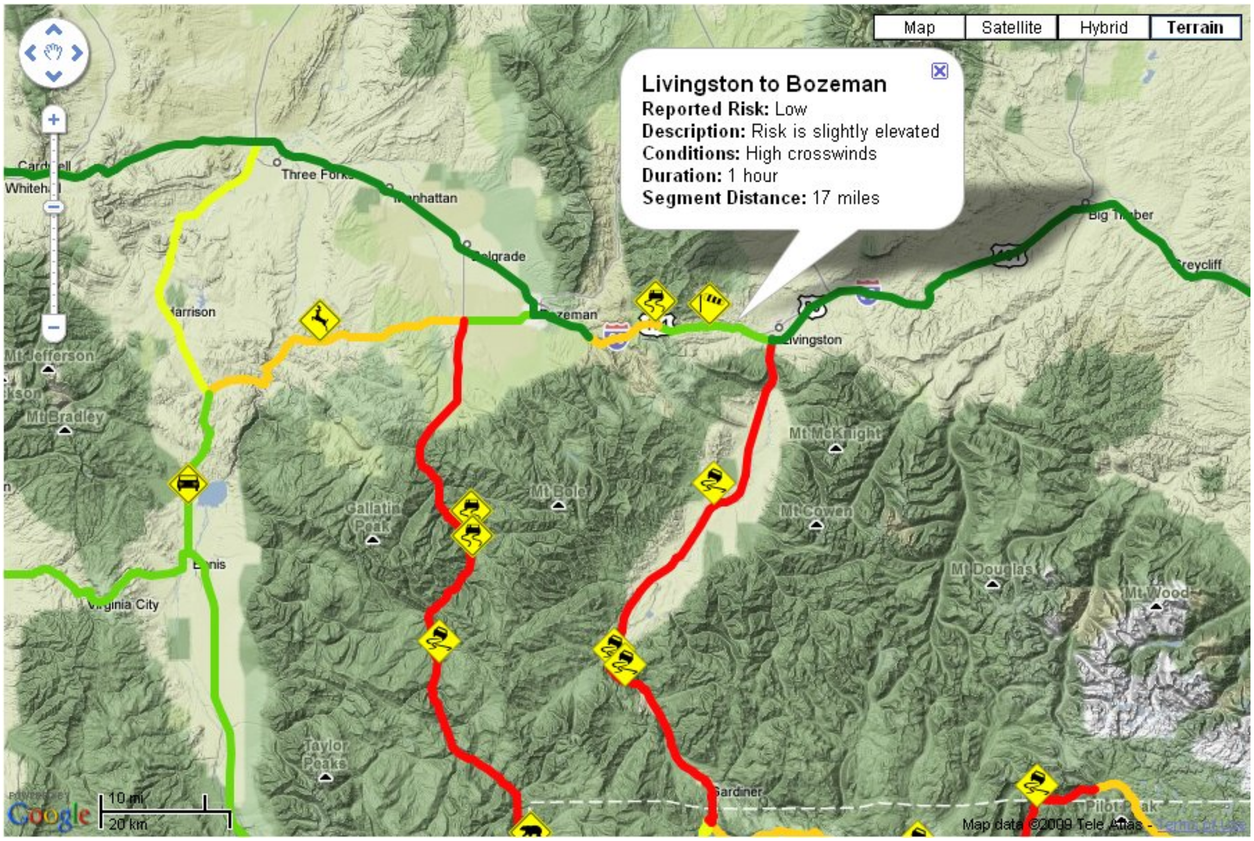

Figure 8: Example of a Web-based Display for Safe Route Planning

During their trip, travelers who use receive road condition information from traveler information systems (such as Dynamic Message Signs) will benefit from the updated information gathered and disseminated from the IRRWS.

System Technical Design Overview

The Rural Risk Warning system is composed of an integration of equipment in vehicles, on the roadside and at a management center. In the vehicle there are sensors, communication systems and a human interface. On the roadside there are sensors, communication systems and infrastructure based displays. At the management center there are computer servers, which interface to other data sources and serve the public web interface and the private fleet management web interface. The system makes use of the existing IntelliDrive[SM]/VII architecture.

A conceptual diagram of how vehicles exchange information with the roadside systems is displayed in Figure 9. It also displays a vision of how drivers can manage safety risks: if they receive timely warnings of hazardous road conditions, they can respond by adjusting their driving behavior or choosing an alternate route.

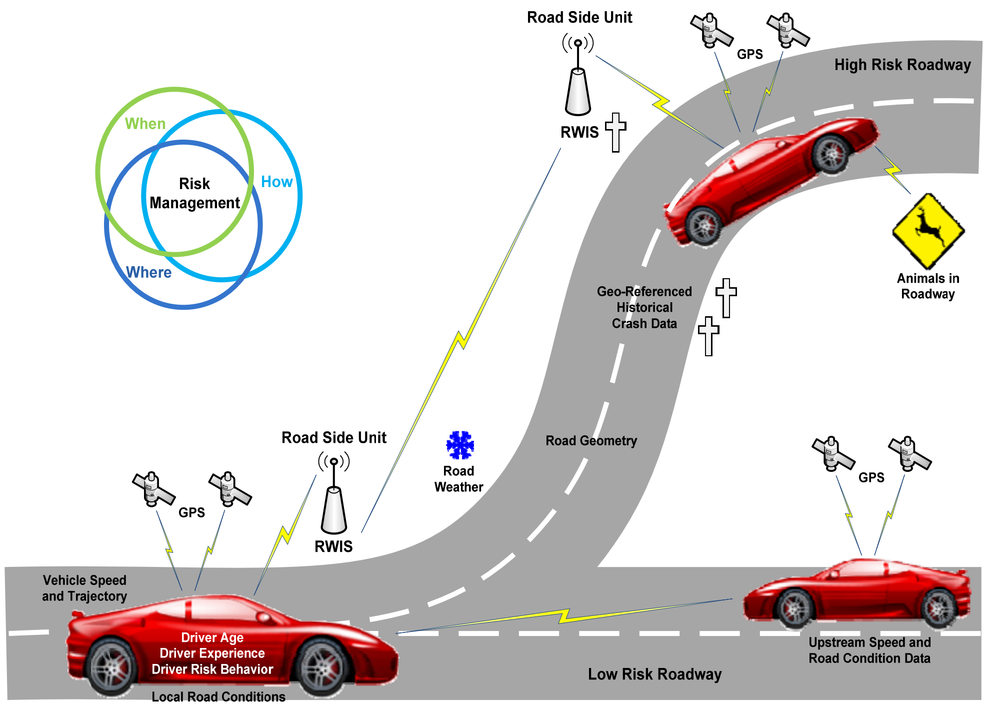

Figure 9: IRRWS Communication Concept

The system integrates a range of advanced communication technologies. Communication paths among system elements are displayed in Figure 10.

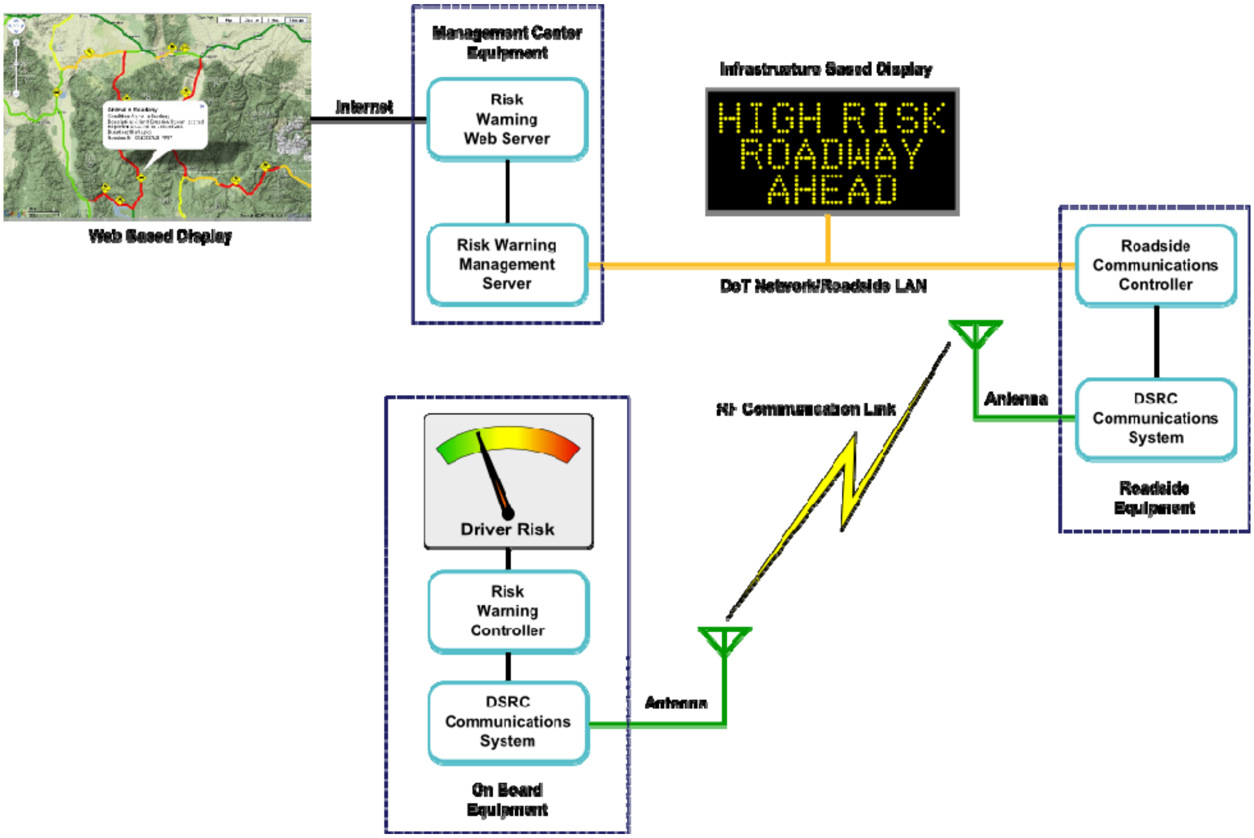

Figure 10: Risk Displays and Communication Paths

System Location

The risk warning system could be installed wherever there is need. The system is designed to work in extreme environments such as the north-west where weather is a problem for roadway safety.

Although the system is meant to solve rural safety problems it should be noted that the risk warning concept would fit well within an urban environment.

The location of the risk warning system should have several characteristics for a pilot project. The pilot location should have:

- A mix of roadway types with varied terrain,
- Roadways that provide alternative routes along well used corridors,
- A variety of safety challenges that would benefit by having the system in place, and
- Existing roadway sensors and ITS infrastructure.

For the purposes of the demonstration concept example, the following roadways would be included in a Yellowstone region deployment:

- US Interstate 15, from Idaho Falls, ID to Butte, MT

- US Interstate 90, from Butte, MT to the Park County MT Line
- US Highway 20, from Idaho Falls, ID to US89 Junction Yellowstone National Park
- US Highway 89, from US20 Junction Yellowstone National Park to Livingston MT
- US Highway 191, from West Yellowstone MT to Bozeman MT
- US Highway 287, from West Yellowstone MT to Three Forks, MT
- MT Highway 84, from Norris MT to Four Corners, MT
- MT Highway 87, from US 20 Junction to US 287 Junction
- US Highway 212, from Mammoth Hot Springs, WY to Cooke City, MT
- MT Highway 287, from Ennis MT to Twin Bridges, MT

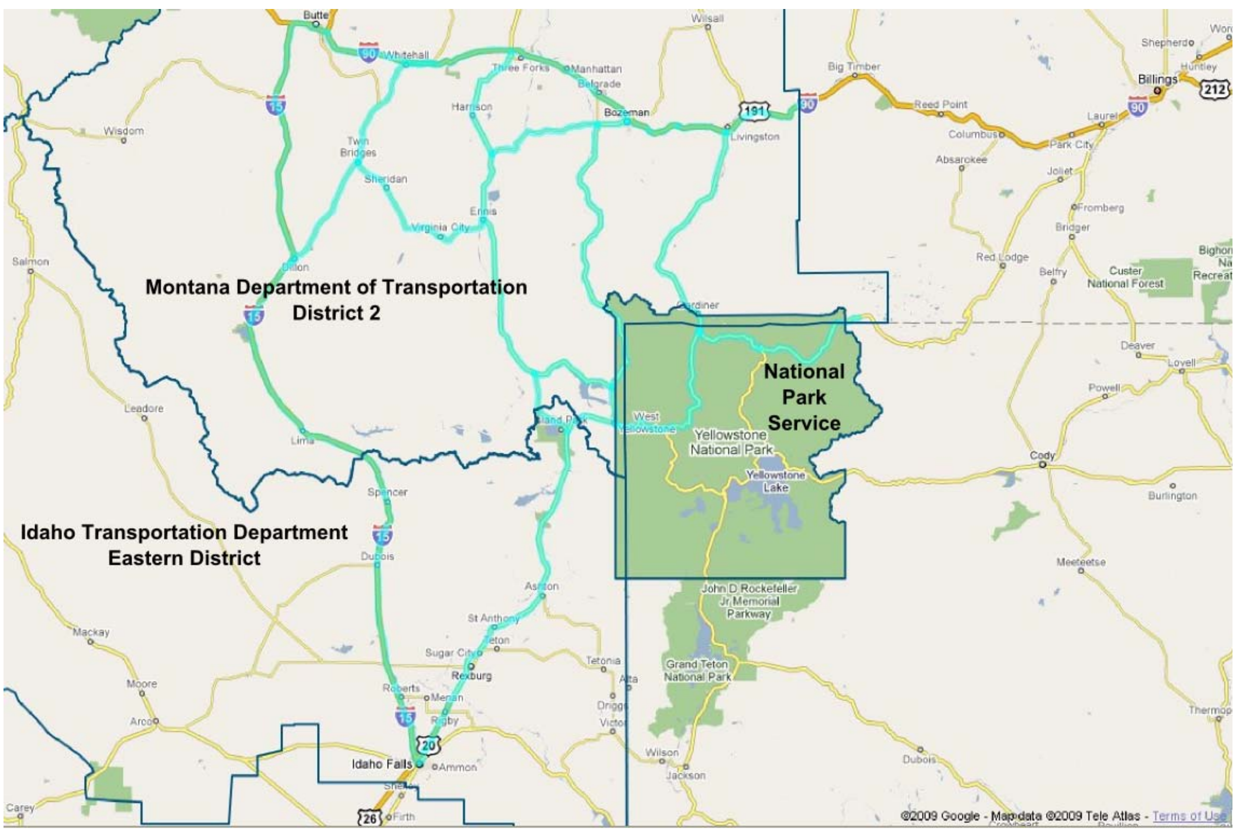

Figure 11: Project Extents and Transportation Agency Stakeholders

Risk Warning System Equipment

On-Board Equipment

The Rural Risk Warning System On-Board Equipment (OBE) consists of a computer, display, a DSRC radio, interface to vehicle systems, sensors, and optional auxiliary radio(s) for communication in a rural environment.

The computer contains the algorithm that calculates the risk warning metric based on parameters in an internal database containing maps and geo-referenced risk data, and real time information from vehicle sensors and from V2V and V2I communications. The computer also contains the software that interfaces with the vehicle systems, sensors and V2V and V2I communication systems. The computer drives the display and interfaces with any input devices such as key-fob transponder for access to driver data.

The risk display alerts the driver to changing conditions and gives spot warnings of current roadway risk events. The display will be well studied for effectiveness and not cause distraction from the driving task.

The DSRC radio will communicate with other vehicles and the infrastructure.

A physical interface will connect vehicle sensors and systems to the on-board risk warning system computer. The interface will pass data from traction control and antilock braking systems, environmental sensors, and indicate the use of seat belts, state of the headlights and windshield wipers. This information is stored in a geo-referenced database.

The system may have additional communication systems that perform tasks related to the rural environment.

Roadside Equipment

The Rural Risk Warning System Roadside Equipment (RSE) consists of units that contain a roadside communications controller, which in turn contains a computer, a DSRC radio, optional auxiliary radio(s), and an interface to a backbone or internet. The roadside component will also include infrastructure based risk displays. The system will leverage existing roadside sensors such as ATR, MVDS, RWIS, and WIM stations.

The roadside communications controller contains a computer with software that interfaces the V2I communications with other roadside sensors. The controller polls data services for risk events and updated roadway data which is stored in memory. Updated information is exchanged with vehicles from the vehicle's on-board database.

The DSRC radio will communicate risk data to vehicles. The controller may have additional communication systems that perform tasks related to the rural environment.

Infrastructure based displays will inform the traveling public, whose vehicles are not equipped with the system about risk events. The displays will most likely be DMS, but could also include EMS or other changeable or even static signage.

Existing roadside sensors will be accessed through public and private portals on the Internet or direct connection to the sensor's backbone.

Management Center Equipment

The Risk Warning Management Center will coexist with a Traffic Management Center (TMC) or a Regional Traffic Management Center (RTMC). The center would contain servers for databases of historical risk data, drivers' accumulated risk, current risk events, and risk trends of routes for fleet operators.

The center will also interface with existing roadside ITS nodes such as DMS, portable DMS, and RWIS either on a dedicated backbone or securely through the Internet.

The Risk Warning Management Center will contain displays that show current risk events and the state of the system.

Data from the Risk Warning Management Center will be formatted and displayed in real-time on a public web page. The page will show current risk events and historical risk for roadways.

The public web page will also appear in a format that is easily displayed on a mobile device such as an Internet enabled cell phone.

Operational Environment and Infrastructure

The IRRWS will be operational 24 hours a day, 7 days a week. All functions will be largely automated and require no intervention to display warnings in-vehicle, on infrastructure or on the web based displays. The system will continuously store and update risk events and disseminate them to vehicles using the system.

Management Center Infrastructure

Databases and Data Storage

A database storage system will exist at the management center that contains important information used by the system. The databases will contain geo-referenced real-time sensor data, roadway geometry and speed information, roadway event historical data, fleet vehicle information, and driver information for fleets such as driver risk metrics and demographics.

Data from the system will be made available to interested parties such as DOTs or Transportation Centers for planning and research.

Web Based Risk Display Server

The web based display server will be disseminated to public and private web pages used by the system.

A private secure network behind a firewall will ferry data from the management server and databases to the web server.

Management Center Personnel

For the most part the IRRWS will be automated. No direct user information will be needed to send messages to the vehicle fleet or infrastructure based displays. However, there is a need for monitoring of the system in case of faults or emergency situations that need to be disseminated to authorities.

The system is planned to be collocated with a regional or district TMC. Personnel performing normal tasks at a TMC can easily monitor the Risk Warning system for performance and important risk events. In fact, the risk warning system will augment existing road condition information systems.

Roadside Infrastructure

Roadside Communications Equipment

Roadside communications equipment links vehicles to the management server. The communications occurs over DSRC or possibly other communications methods such as WiMAX or IEEE 802.15.4. Whenever possible, roadside communication nodes will be collocated with existing roadside TMS to leverage existing power and communications infrastructure, such as CCTV, lighting structures, rest areas and weigh stations.

Roadside Sensors

The IRRWS will use existing roadside sensors and TMS such as:

- Automatic Traffic Recorders (ATR),
- Loop Detectors at Intersections,
- Microwave Vehicle Detectors (MVDS),
- RWIS, and
- Weigh in Motion (WIM).

The data from these sensors can be obtained from public portals, access to the DOT backbone, or communicated directly to vehicles to be relayed at a roadside communications node.

Infrastructure-Based Displays

For warnings displayed on roadside infrastructure, the system will primarily use existing Dynamic Message Signs (DMS) both fixed and portable, and Extinguishable Message Signs (EMS). Automated Highway Advisory Radios (HAR) could also provide warnings of roadway risk.

In the future, it is expected that the IRRWS will also have direct automated control of Automated Gate Closures and Variable Speed Limit Signs.

Fleet Operation Infrastructure

Fleet operators will have dedicated communications equipment on-site to communicate with vehicles in their fleet. Vehicles will be updated with risk events before the vehicles are dispatched, and information from vehicles will be downloaded upon the return of the vehicle to the yard.

Fleet operators will use a secure web interface on the Internet to input information and display accumulated risk and route risk for planning.

OPERATIONAL SCENARIOS

For purposes of illustration, the following operational scenarios describe potential functionality, uses, and benefits of the IRRWS if fully deployed as described in this report.

Construction Worker in a Fleet Vehicle

On a cold winter morning, a construction worker prepares to travel though the Gallatin Canyon from Bozeman to Big Sky to a construction site. As the user enters the vehicle and starts the engine, the IntelliDrive^{SM} Rural Risk Warning System boots and enables without any user intervention.

The system reads a transponder on the user's keychain and gets demographic data such as the user's age and driving experience level. This data is stored in internal memory for the duration of the trip and cleared when the system shuts down.

The IRRWS enables a Global Positioning System (GPS). The last saved position is used as an initial location to retrieve information from the internal map database. Upon getting a GPS fix, the location of the vehicle is updated in the internal map database. If the GPS does not get a fix or is inoperative, an error will be recorded and the driver will be warned that the system is inoperative.

Readings of important environmental variables are taken and stored in internal memory along with a location of the reading.

The system enables V2V, V2I and V2D communication system(s). The yard where the vehicle is stored is equipped with a communications node that exchanges information with the vehicle. Current conditions of the roadway and associated hazards are sent to the vehicle by a V2I communication and stored in the system's internal map database.

As the driver pulls onto the roadway, the system starts recording hazard conditions with a reference to their locations. Hazard information is transmitted to roadside nodes by a V2I exchange. The roadside nodes update a database at the management center so that data can be shared with all vehicles using the system and with the traveling public by web and infrastructure based displays. The system also communicates hazard information to other vehicles equipped with the system.

The system displays the current risk to the driver continuously as the vehicle travels along the roadway. If the system senses a condition that drastically increases risk, an additional message will be displayed in an effective manner, such as a heads-up display, to give the driver additional time to respond to the hazard.

The system acts as a "black box" and records risk for the route the vehicle travels. The system continuously records the risk level at the location of the vehicle and stores it in a historical database and updates an average value for the individual driver. Information is stored such that specific risk behavior such as speeding cannot be extracted from the recorded or average values.

The construction worker passes an area where animals are known to cross the roadway during the winter season. An animal detection system has been installed in the area and communicates the presence of animals in the roadway to the IRRWS in the vehicle. An icon appears in the head-up display warning of the animals in the roadway ahead. The driver slows to avoid the animal.

As the driver continues along the roadway the system records the presence of black ice and snow on the roadway. The system records these hazards and communicates them with other system equipped vehicles.

Although the driver is experienced in winter driving on a route that he travels daily, the system provides additional information and assistance with unexpected hazards, which help ensure his safe arrival at the construction site in Big Sky. The driver provided probe data to other vehicles on the roadway with drivers who may not have been as experienced.

When the vehicle returns to the parking lot at the end of the day, the system updates the fleet hazard map and records risk information for the driver.

Elderly Driver

On the same winter morning an elderly driver prepares to travel though the Gallatin Canyon from Big Sky to Bozeman. The driver had his vehicle equipped with the IntelliDrive^{SM} Rural Risk Warning System to get a discount on car insurance to offset increased cost due to the driver's age.

The system boots and reads the driver's information from the transponder on the user's keychain. It adjusts warning thresholds based on the driver's limited sight and hearing due to the age of the driver.

As the elderly driver travels toward Bozeman the system continuously updates the risk warning level.

As the construction vehicle traveling from Bozeman passes by, a short V2V exchange gives data from hazards along the roadway recorded by the construction vehicle's system. The on-board system records these hazards in the onboard map database.

One of the roadway hazards passed from the construction vehicle was the presence of animals on the roadway ahead. Approximately 8 seconds ahead of the area where animals were in the roadway minutes before, a heads-up display icon appears that warns the driver. Based on limited sight distance for an elderly driver, the system increased the warning time above the normal 5 seconds. The driver slows the vehicle's speed and easily avoids the animals crossing the roadway.

As the driver approaches Gallatin Gateway the system responds to an intersection that has elevated crash incidence. Due to the driver's decreased vision, a head-up icon appears suggesting reduction of speed due to an intersection. The driver slows to an appropriate speed through the intersection based on unperceived human factors and roadway crash data.

College Student in a Rental Vehicle

A college student from Arizona who is visiting a friend at Montana State starts out on a drive from Bozeman to Big Sky for a weekend of skiing. His rental car is equipped with the IntelliDrive^{SM} Rural Risk Warning System.

At the rental agency, the student is given an explanation of the system and a brochure explaining winter roadway safety in the rural northwest. The rental agency also explains a bonus program from which the student will receive a discount on the rental fees if he keeps the roadway risk below a specific threshold.

The driver's human factor information such as age and experience level is stored in the system by the rental agency for the duration of the rental agreement. Since the student is from the southwest, which is an area that does not experience similar severe winter weather, risk level will be elevated during travel on snowy roadways.

As the student drives to Big Sky, the system continuously updates the risk warning level. The system trains him in winter driving by raising the risk level when his speed is slightly above what is safe for roadway conditions.

As other IRRWS equipped vehicles traveling in the opposite direction pass the student's vehicle, the vehicles share data from hazards along the roadway.

After the student enters the Gallatin Canyon he gets in a line behind a vehicle traveling 10 miles an hour below the posted speed limit. As other cars pass the vehicle in front of him his confidence increases, so in a straightaway he puts on his blinker to signal intent and begins to pull into the other lane to pass the vehicle ahead.

The system looks ahead on the roadway map database and calculates the time required to pass the slow moving vehicle. Approximately 5 seconds ahead there is an area where trees shade the roadway and a patch of ice has formed in the opposite lane. The system immediately puts up a heads-up display icon showing "Ice on Roadway" directly in the driver's vision. He immediately slows down and pulls back behind the slow moving vehicle, averting a dangerous situation. The slow moving vehicle sees the aborted passing attempt and pulls over at the next pullout to let the line of cars pass by.

The student resumes a speed just below the posted speed limit based on his cautious approach to the roadway environment. The system looks ahead in the map database and finds a sharp curve in the roadway with spotty ice and snow. Although the driver is traveling below the speed limit, his speed is still not appropriate for the roadway geometry based on the icy conditions. The system posts a "slow for curve" warning on the heads-up display. The student slows the vehicle down and travels the curve safely.

The student arrives in Big Sky without a mishap and with better training about driving on winter roadways.

Fleet Operator

A fleet operator has equipped his vehicles with the IntelliDrive℠ Rural Risk Warning System for the safety benefit and a discount on his insurance. While his vehicles are traveling to jobs, the system records the risk level and downloads the data when the vehicle is parked at night.

The operator accesses information on the fleet safety through a secure website. The information is in the form of a map with routes highlighted with color-coding. Icons show locations of persistent hazards. The operator can review the past risk levels for the routes that his fleet has taken and current risk for routes in a real time display.

On this morning the operator is concerned about safety on a particular route. He checks the map and finds that conditions are below what he feels are safe for his vehicles. He has the choice of choosing another route or waiting to dispatch a vehicle until conditions are better.

Management Center

In the demonstration concept example, the management center exists in a regional TMC at the TRAIL Lab at the Western Transportation Institute, Montana State University. The lab is shared by MDT personnel, transportation researchers and local and state public safety officials when the situation warrants.

The center is automated so operators are not required to be on site 24 hours a day. Agencies can also view the IRRWS web sites when personnel are not on-site.

Maintenance Vehicle

Local transportation agencies equip snowplows and maintenance trucks that travel Gallatin Canyon with the IntelliDrive^{SM} Rural Risk Warning System. The system makes the real time sensing data from the network available to the operator of the vehicle. Conditions such as black ice or other hazards on the roadway are communicated directly to the system in the vehicle.

The user interface is more advanced in the maintenance vehicle. A map display is available and warnings are posted for locations other than where the vehicle is currently traveling. The drivers of the maintenance vehicles can choose to travel to the locations of hazards to provide assistance or eliminate risk factors entirely by correcting conditions such as black ice.

The system will also report failures directly to the maintenance crews.

Insurance Company

Insurance companies use the system to better define cost for risky or at risk drivers. As insurance companies already charge for approximate vehicle miles driven, it is a small change in philosophy to include vehicle miles driven at high risk.

Agreements with fleet operators allow the sharing of risk information from the system to the insurance agencies. Fleet vehicle drivers know that their driving performance is reported to the insurance company who could in turn increase cost to their employer. This encourages safe driving and changes of behavior.

As local insurance agencies get data on risks in their coverage area, they are willing to give discounts to customers for having added safety systems.

IMPACTS AND BENEFITS

If fully deployed, the Rural Risk Warning System is expected to have direct, positive impacts on all three types of users.

Drivers in system equipped vehicles will benefit from:

- Improved personal safety
- Lower insurance cost due to direct safety impact
- Efficient route planning and scheduling saves time and fuel

Fleet Operators who install the system in their vehicles can expect:

- Improved employee and equipment safety
- Lower insurance cost due to direct safety impact
- Efficient route planning and scheduling saves time and fuel

Public System Users who access the warnings through the internet will benefit from:

- Improved personal safety by safest route planning
- Lower insurance cost for area due to indirect safety benefit

In addition, the system and potential pilot deployment is expected to advance the development of IntelliDrive and related VII technologies on a national level by:

- Refining the development of the national IntelliDrive architecture
- Providing a model for deployment of VII in the rural environment, which can be replicated in other regions,
- Generating data on the safety benefits of VII deployment, which may encourage further deployment,
- Providing a testbed for field testing of novel applications of existing technologies, as well as emerging technologies from private vendors

NEXT STEPS

With the completion of this high level concept of operations and system design, the North/West Passage Pooled Fund states and WTI will look for opportunities to develop and deploy the proposed system.

In 2009, the Idaho Transportation Department (ITD) (on behalf of the North/West Passage Pooled Fund states) assembled a team of public and private partners to develop a more extensive model deployment proposal. On the public sector side, the team included the North/West Passage states and three universities: the University of Idaho, Montana State University and the University of Michigan. Private sector team members included IBM, Telcordia, Kapsch, Meridian Environmental, ACMS, Vaisala, Castle Rock Consultants, Sirius-XM, and Kimley-Horn and Associates. In addition, other data partners included the Idaho State Police, the Idaho Department of Health and Welfare, and the National Weather Service.

Using the concept developed by WTI in this document, the proposed Rural IntelliDrive(sm)^{SM} Model Deployment Program will create a communications backbone and traveler information system that keeps travelers connected to vital information along the major rural corridors that connect the North/West Passage states.

The applications to be developed and deployed will focus on several key areas:

- Driver safety information, warnings and alerts that are location specific, updated in real-time, and displayed in the vehicle
- Information on nearby tourism services and attractions that is disseminated directly to the vehicle
- Commercial carrier transactions (such as weight and security clearances) that can be conducted automatically and electronically
- Information relay from vehicle to vehicle to roadside devices, allowing the relay of a May Day message from a disabled vehicle, or the immediate relay of a road hazard from the first vehicle that encounters it
- Probe data collection that allows Traffic Operation Centers to receive data from vehicles, and use it to plan incident management or update 511 systems

The team has completed a preliminary proposal and is working to identify and secure national funding partners.

APPENDIX 1: RURAL USE CASES

WTI Rural Examples

Use Case/Application	V2I	V2V	V2D	WAN	Notes
Animal Warning	X	X			
Bicycle Pedestrian Warning			X		
Curve Speed Warning	X				"Roadway Departure"
Downgrade Speed Management	X			X	Warning on a steep grade based on truck weight that is individualized for specific vehicles.
Electronic Brake Light Warning		X			
In Vehicle Sign Override	X				System overrides DMS message (Chain Control/Watch for Plows/Wide Load Ahead/Paint Crew Ahead)
Intersection Collision Avoidance System	X	X			Cooperative system
Point of Interest Notification	X			X	Info on local area and services
Probe for Travel Times	X			X	
Seasonal Corridor Management	X			X	
Smart Bridges	X			X	Minimize damage to bridge based on vehicle weight/geometry
Special Events Congestion Management	X			X	
Speed Limit Assistant	X			X	"Roadway Departure"
Tourist Information	X			X	
Vehicle Probe (Weather /Travel Time/VSL)	X			X	
Vehicle Based Road Condition Warning		X			"Roadway Departure"
V2V Road Feature Notification		X			"Roadway Departure"

Idaho Department of Transportation, Rural Use Case Examples

(Rural VII Opportunities and Challenges: Robert Koeberlein, Mobility Services Engineer, Idaho Transportation Department)

Use Case/Application	V2I	V2V	V2D	WAN	Notes
Traffic Signal Violation Warning	X				DGPS
Stop Sign Violation Warning	X				DGPS
Driver Assistance at Intersections	X				DGPS
Curve Speed Warning	X				
In-Vehicle Signage	X			X	
Traffic Signal Optimization	X			X	
Ramp Metering	X			X	
Traveler Information	X			X	
Corridor Management	X			X	
Roadway Maintenance	X			X	
Electronic Toll Collection	X			X	
Electronic Payment	X			X	
Remote Diagnostics and Warranty Management	X			X	
Exchange Road Weather Observations (traction control, ABS, wipers).		X			
Exchange Electronic Map Updates		X			
Rear end Collision Warning		X			
Relay Vehicle to Infrastructure data messages		X			
Relay Mayday messages (air bags deployed, roll over, high deceleration rate)		X			

Iteris Rural Use Case Examples

(Enabling VII-based Rural Applications: Jeff Brummond, Principal Systems Architect, Iteris, Inc.)

Use Case/Application	V2I	V2V	V2D	WAN	Notes
Limited Height Warning Low Bridge – Alternative Routing	X			X	
Access Control Gates Commercial Vehicle Clearance Border Crossing	X			X	
Weigh Station Clearance	X			X	
Highway / Rail Collision Warning	X				
Incident Notification via Relay	X	X		X	
Work Zone Information	X				
Curve Speed Warning (Rollover Warning	X	X			
Stop Sign Violation Warning	X				
Intersection Collision Warning	X				
Traffic Signal Violation Warning	X				
Speed Limit Assistant	X				
Wrong Way Driver Warning	X			X	
Weather Information (Icy Bridge)	X				
Lane Departure Warning (internal to vehicle)					
Visibility Enhancer		X			
Cooperative Forward Collision Warning		X			
Cooperative Glare Reduction		X			
Emergency Electronic Brake Warning		X			
Emergency Vehicle Approaching Warning		X			
Lane Change Warning		X			
Post Crash Incident Warning		X			

Pre-Crash Sensing		**X**			
Road Condition Warning to Other Vehicles		**X**			
Incident Notification via Relay		**X**			
Wildlife Crossing Information / Warning	**X**	**X**			
Passing Vehicles on Two Lane Road		**X**			
Approaching Top of Single Lane Hill		**X**			

USDOT VII Concept of Operations Use Cases

The VII concept of operations has a list of use cases that are suggested for "day one" in the implementation of a VII system.

Use Case/Application	V2I	V2V	V2D	WAN	Notes
Emergency Brake Warning	X				
Traffic Signal Violation Warning		X		X	DGPS
Stop Sign Violation Warning		X		X	DGPS
Curve Speed Warning					
In-Vehicle Signage: Local Notifications	X			X	
Traffic Information: Traveler Information	X			X	
Electronic Payments: Gasoline Purchases	X			X	
Electronic Payments: Parking Fees	X			X	
Electronic Payments: Toll Roads	X			X	
In-Vehicle Signage: Regional Road Advisories	X			X	
Traffic Information: Vehicle Route Redirection	X			X	
Roadway Condition: Weather	X			X	
Roadway Condition: Potholes	X			X	
Traffic Management: Corridor Management	X			X	
Traffic Management: Ramp Metering	X			X	
Traffic Management: Signal Timing Optimization	X			X	
Traffic Management: Winter Maintenance	X			X	

APPENDIX 2: CLASSIFIED RURAL USE CASES

[Use cases classified by application categories included in the USDOT/RITA IntelliDrive Initiative]

Safety		
	Speed Related Crashes	
		Probes for Advisory/Variable Speed Limit
		Augmented Speed Enforcement
		Speed Limit Assistant
		Vehicle Based Road Condition Warning (V2V)
		V2V Road Feature Notification (V2V)
	Road Departure Crashes	
		Mayday Relay
		Curve Speed Warning
		Animal Warning/Wildlife Crossing Collection
		Probe for Weather
		In Vehicle Sign Override
	Intersection Related Crashes	
		Emergency Vehicle Signal Preemption
		Stop Sign Violation Warning
		Highway/Rail Collision Warning
		Work zone Warning
		In Vehicle Signage
Mobility/Accessibility		
		In-Vehicle Roadway Weather Images
		Seasonal Corridor Management

	Special Events Congestion Management
	Infrastructure Based Traffic Management – Probes
	Pot Hole Detection
	Automatic Vehicle Location
	Hazardous Materials Shipment
	Transit System Analysis and Planning
	Transit Dynamic Scheduling and Planning
Environmental	
	Green Light Optimal Speed Advisory
Convenience/Economy	
	Traveler information
	Transit Traveler Information
	Point of Interest Notification

REFERENCES

---

1 RITA Intelligent Transportation Systems. IntelliDrive[SM] Initiative Overview. http://www.its-.dot.gov/intellidrive/intellidrive_overview.htm (accessed January 24, 2008).

2 RITA Intelligent Transportation Systems. Major Initiatives. http://www.its.dot.gov/-newinit_index.htm (accessed January 24, 2008).

3 Vehicle Infrastructure Integration. VII Vehicle Infrastructure Integration Overview. http://www.vehicle-infrastructure.org/vii-overview/ (accessed January 24, 2008).

4 RITA Intelligent Transportation Systems, Major Initiatives, Last accessed January 24, 2008, http://www.its.dot.gov/newinit_index.htm

5 Ward, Nicholas, "The Culture of Traffic Safety in Rural America." Chapter in *Improving Traffic Safety Culture in the United States: The Journey Forward*. Washington, D.C.: AAA Foundation for Traffic Safety (2007): pages 241-256.