Research Report
Research Project T9903, Task 89
ITS for Safety on Rural Roadways

The Contribution of ITS to Rural Safety:

A Look at Crashes in Washington State

by

Edward D. McCormack, Ph.D.
Research Engineer

Bill Legg
Assistant ITS Program Manager

Washington State Transportation Center (TRAC)
University of Washington, Box 354802
University District Building
1107 NE 45th Street, Suite 535
Seattle, Washington 98105-4631

Washington State Department of Transportation
Technical Monitor
Bill Legg
Assistant ITS Program Manager

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

January 1999

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 460.1	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE THE CONTRIBUTION OF ITS TO RURAL SAFETY: A LOOK AT CRASHES IN WASHINGTON STATE		5. REPORT DATE January 1999 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Edward D. McCormack, Bill Legg		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. T9903, Task 89
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, MS 7370 Olympia, Washington 98504-7370		13. TYPE OF REPORT AND PERIOD COVERED Research report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

Increasingly, transportation professionals are using technology, known as Intelligent Transportation Systems (ITS), to address transportation problems. This paper investigates the potential applications of ITS to safety issues on rural roadways in Washington. The most frequent type of rural crashes and their casual factors are identified from the state's Collision Report Form. The ability of ITS applications to reduce these types of crashes is then discussed.

In Washington State, the factors that contribute most to rural crashes is human behavior. Some ITS applications, such as speed warning systems, may be good solutions at known hazardous locations. However, most human behavioral issues, such as inattention or poor driver judgment, cannot be directly addressed by ITS application that are currently available.

In Washington, crashes due to some aspect of the roadside environment involved about one third of the vehicles. ITS offer a viable alternative to traditional engineering solutions for a number of these types of crashes by informing drivers about roadside hazards. ITS weather systems and traveler information systems in general, can indirectly improve rural safety by providing information about travel and roadway conditions. Rural intersections, work zones, and railroad crossings are other potentially hazardous areas where ITS may be useful.

The final factor that contributes to a small percentage of rural crashes is the vehicle and- ITS applications may help indirectly by making trucks more compliant with safety laws and by improving the efficiency of safety inspections.

ITS emergency notification systems also offer some safety benefits by mitigating some of the consequences of rural crashes.

For the WSDOT, a handful of ITS safety applications have been well enough tested that they can be aggressively used as tools to reduce rural crashes. However, many more ITS safety applications, although promising, still need to be fully documented and would be best applied in this state as a demonstration of future potential. Most of these applications would warn drivers about road and roadside hazards. The greatest benefit from ITS for rural safety may come from future applications that will address rural crashes caused by human behavior. These applications will evolve from a number of the large federal research projects that are under way and are still a number of years away from providing benefits on a wide scale. Given their potential impact on rural safety, WSDOT should monitor these projects closely.

17. KEY WORDS Rural accidents, rural travel, rural safety, ITS, Washington state	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	50	

DISCLAIMER

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EXECUTIVE SUMMARY

Increasingly, transportation professionals are using information processing, communications, and electronic technology, known as Intelligent Transportation Systems (ITS), to address transportation problems. One of the reasons that ITS are of interest to transportation professionals in Washington is that they have so many potential applications to safety issues. However, while the advantages of safety-oriented ITS in an urban setting are relatively well documented, the safety benefits of ITS on rural roadways is unclear. By using data from Washington State's Collision Report Form, this paper explores the contributions that ITS might make toward increasing rural roadway safety.

In Washington State, as in the other states, the factors that contribute most to rural crashes are related to human behavior. Principal among these causes are a driver's poor judgment, speeding, impairment due to drugs or alcohol, and sleeping or inattentiveness. Current ITS applications do not offer any broad or direct solutions to these problems. Some applications, such as automated speed warning systems, may be good solutions at known hazardous locations. Other human behavioral issues, such as inattention or poor driver judgment, cannot be directly solved by the ITS that are currently available to transportation professionals. Few ITS application can address impaired driving, but any ITS that improves overall safety should help these drivers avoid crashes. It is possible that current research into sophisticated in-vehicle systems such as a road departure warnings may someday produce ITS applications that help to mitigate the results of poor driver behavior, but these systems will most likely be implemented by the automobile industry rather than by transportation professionals.

In Washington State, between 1993 and 1996, crashes due to some aspect of the roadside environment involved about one third of the vehicles. ITS offer a viable alternative to traditional engineering solutions for some of these types of crashes by informing drivers about hazards. The most common factor in crashes linked to the roadside environment is weather. ITS weather systems, and traveler information systems in general, can indirectly improve rural safety by providing area-wide information about travel and roadway conditions. Other weather systems address specific hazardous locations and inform drivers about upcoming problems such as ice, dust, or high winds. Rural intersections, work zones, and railroad crossings are other potentially hazardous areas where ITS may be useful.

The final factor that contributes to a small percentage of rural crashes is the vehicle. This is another area in which transportation professionals currently have minimal direct impact. ITS applications may help indirectly by making trucks more compliant with safety laws and by improving the efficiency of commercial vehicle safety inspections.

ITS emergency notification systems also offer some safety benefits by mitigating some of the consequences of rural crashes. Currently, these systems include roadside call boxes or cellular phone-based systems within a vehicle.

For WSDOT staff the use of ITS for rural safety is best guided by the Advanced Technology Policy with its three levels of implementation. A handful of ITS safety applications are so well tested that they can be aggressively pursued as tools to reduce rural crashes. However, many more ITS safety applications, while promising, still need to be fully documented and are best used as demonstration applications of future potential. Most of these applications involve warning drivers about road and roadside hazards. The greatest benefit from ITS for rural safety may come from future applications that will address rural crashes caused by human behavior. These applications will evolve from a number of the large federal research projects that are underway and are still a number of years away from providing benefits on a wide scale. Given their potential impact on rural safety, WSDOT should monitor applications of these projects.

The main task for WSDOT staff interested in implementing ITS for rural safety is to keep aware of rapidly changing ITS technology. Fortunately, a variety of good sources of information are available including the Internet, ITS publications, and staff from WSDOT's Advanced Technology Branch.

INTRODUCTION

In Washington State, policy requires that staff "aggressively pursue, demonstrate, and monitor the application of advanced technology to transportation systems" (1). This technology, applied as Intelligent Transportation Systems (ITS), has become a viable alternative to more traditional engineering approaches, in part because of increased federal support but also because ITS has been shown to be effective. Nationally, a commonly stated goal for using ITS is to increase safety for travelers. Because more than 40,000 people are killed on the roads in this country each year, improving roadway safety is a pervasive component of most transportation professionals' jobs (2). The growth of interest in ITS, combined with a continuous need to improve roadway safety, suggests that many transportation engineers and planners in Washington may want to be aware of the potential safety benefits of ITS.

So far, the majority of ITS applications and the resulting documentation have focused on urban areas. The use of ITS in rural environments, including applications to safety, has been less frequent and lacks documentation. This paper is intended to fill part of this gap by providing a background for transportation professionals in WSDOT and other public agencies who may want to consider ITS for addressing safety on rural roadways.

This paper is based on four years of data from the State of Washington Police Traffic Collision Report form. These data, which were modified to represent each vehicle in a crash, were explored to determine the factors that contributed to each vehicle's involvement in a crash. These factors were then used as a framework for evaluating ITS applications that might reduce different types of rural crashes in

Washington State. From this process, conclusions were drawn about the overall feasibility of applying ITS to solve rural road safety problems.

THE ADVANTAGES OF ITS

Why does Intelligent Transportation Systems technology have the potential to address rural safety problems? ITS technology applies information processing, communications, and electronics to transportation problems (3). More fundamentally, ITS are about information that helps travelers make safe decisions (4). Relevant for most transportation professionals is that ITS can sometimes be applied to safety problems as an alternative solution, one that may be more cost effective than traditional engineering approaches.

ITS can address safety problems both directly and through indirect improvements in other systems. A number of categories of ITS applications are recognized by the Federal Highway Administration (FHWA) (5). One category, traveler safety and security, focuses directly on safety. Examples of ITS safety improvements in this category could be an ice warning sign that flashes when a road surface temperature drops below freezing or an electronic message sign that warns motorists of hazardous road conditions. The FHWA also recognizes that whereas other program areas do not directly address safety, they may still touch upon safety issues. For example, a traveler information system or a roadside video camera linked to a Web page is not necessarily designed to address a specify type of rural crash but can increase rural safety because drivers informed of hazardous road conditions may drive less or more safely. This paper distinguishes between direct and indirect ITS safety applications.

ITS, SAFETY AND RURAL ROADS: OTHER STUDIES

ITS are based on recent advances in technology. As a result, only a few rural ITS applications have been in place long enough for a detailed appraisal, and solid data on the feasibility of ITS for rural safety are hard to find. However, a few studies do give some indication of the value of ITS.

In 1996, the FHWA sponsored a review of the benefits of ITS at locations across the country (6). One area evaluated was advanced rural transportation systems (ARTS). The ARTS category is open-ended and includes a number of different ITS applications such as travel information systems, traffic management systems, commercial vehicle systems, and vehicle control technologies. Because of the broad nature of ARTS, the study provided, in essence, an overview of the possible benefits of ITS in rural areas. The study concluded that a reduced number of vehicle crashes could be one benefit of rural ITS. This benefit would be the result of either systems that informed travelers of potential hazards or application of advanced vehicle control systems. In addition, some reduction in fatalities could result from systems that reduced notification times after an accident had occurred. Unfortunately, these conclusions about safety benefits were based on only a few measured cases and were for the most part derived from anecdotal information or predictions based on analysis and simulation.

A more recent FHWA overview of ITS benefits mirrored some of the conclusions of the previous report, noting that ITS can improve safety in rural areas with vehicle control systems and by providing emergency notification (7). Other rural safety benefits identified were weather information systems and rail grade crossing systems that warned drivers of approaching trains.

A Canadian study of the costs and benefits of many different ITS projects looked at rural safety projects (8). Although the study found a positive cost to benefit ratio for almost all ITS projects, the rural safety projects (a portable system that informed motorists of disruptions due to construction and a device warning of conflicts at a railroad crossing) had among the lowest ratios (1 to 1.1). However, the author suggested that since the study was based on conservative costs and since the safety benefits were seriously underestimated, the real cost to benefit ratio for the ITS safety studies could range from 1 to 30 to as high as 1 to 150.

A study of the feasibility of ITS in rural California looked at specific accident types and locations (9). The report suggested that several short-term ITS applications oriented toward reducing vehicles speeds (a speed warning system and automated speed enforcement) had "great" potential to increase rural safety. The authors also noted that promising future rural safety systems might involve in-vehicle driver monitoring systems and perhaps would have to come from vehicle manufacturers.

A 1997 FHWA sponsored assessment of information needs for rural travelers solicited information through interviews, surveys, and focus groups (10). The resulting report identified six rural information needs for general travelers of which four related to safety. These safety needs were the ability to call for help, warnings of hazards ahead, drowsy driver and run off the road alert signals, and advisories about safe maximum speeds. The report suggested that proven ITS technology exists to support basic ITS safety information needs with significant innovations coming in the future. However, the report also noted development of rural communication systems that can effectively address some of these information needs is a major challenge.

A strategic plan to implement ITS in Washington suggested another perspective from which to view the safety benefits of rural ITS (11). This plan noted that a rural ITS program might not have a measurable cost to benefit ratio but should be evaluated in terms of criticality. In other words, the benefit of a rural system "could be critical to a person's survival," or may have a minimal effect on total statewide travel but could greatly affect a few travelers. This viewpoint suggests that the prevention of a few injuries or fatalities may warrant a rural ITS application even if the standard cost to benefit approach indicates otherwise. However, such projects would be difficult to fund under Washington's current priority-based funding system.

These studies all indicated that specific ITS applications do have the potential to address particular safety problems on rural roadways. Most of the studies also highlighted the fact that the success of an ITS application is often dependent on communication technology. What is not clear from these studies is what role ITS may play in addressing a variety of types of crashes on rural roads. The next section of this paper focuses on the most frequent types of rural crashes in Washington and the potential for ITS applications to reduce the number of these crashes.

RURAL ROADWAYS AND CRASHES

In Washington State, all highways are considered rural unless they are within an area that has been designated urban. Urban areas include towns or cities with a population of 50,000 or more. They include those that the Bureau of the Census designates as urban, plus other urban areas designated by state and local officials.

These urban areas are a small proportion of Washington's total area; over 96 percent of Washington is rural. Because most of state land is rural, so are most of the state roadways; 85 percent (5,997 miles) of the total state highway mileage is rural. The majority of these roads are principal arterials. In terms of travel, 11.2 million annual vehicle miles are on rural roads and 15.9 are on urban roads. Much of the annual vehicle mileage is on Interstate even though the Interstate is only a small percentage of the state's road system.

On Washington's state highways, between 1993 and 1996, 18,300 rural and 44,800 urban crashes per year were reported on the Police Traffic Collision Report form. In terms of exposure rates, urban accidents (2.1 accidents per million miles of travel) were almost twice as frequent as rural accidents (1.2 accidents per million miles of travel). However, whereas rural accidents were fewer in number and lower in overall exposure rates, they were more often fatal than urban crashes (Table 1).

Another way to look at rural roadways and safety is in terms of the number of fatalities. In the period from 1993 to 1996, in spite of the greater number of miles traveled in urban areas, an average of 183 fatal accidents per year occurred on rural state roadways as opposed to an average of 97 per year on urban state roadways. Clearly, rural crashes in Washington State are more often fatal.

Table 1: Statewide Crashes per Million Miles of Travel 1993-1996

Severity	Rural	Urban
Property Damage Only	7.09	11.35
Injury Crash	5.37	9.47
Fatal Crash	.17	.06

Source: WSDOT Data Office

The most frequent contributing causes of crashes on rural state roadways in Washington are shown in Table 2. The table includes both rural highways under WSDOT's jurisdiction and other rural roads in the state.

From 1993 to 1996, exceeding safe speed contributed to almost a third of all crashes on state highways in rural Washington. Next in frequency were crashes due to the driver's inattention or the driver being asleep. Similar in frequency were crashes due to alcohol impairment and failure to yield.

The table also indicates that the types of crashes on rural highways were similar they happened under WSDOT's or under other agency's jurisdictions. As a result, the general findings from this paper, while focused on WSDOT's roads, should be usable by professionals from other transportation agencies in Washington.

Table 2: Principal Rural Crash Causes: 1993-1996

Contributing Cause	Percent of All Crashes	
	State Highways	Other Rural Roads
Exceeding safe speed	32.5%	28.7%
Inattention or asleep	14.8%	13.0%
Under influence of alcohol	9.6%	12.9%
Failure to yield	8.9%	10.1%

ACCIDENT FACTORS

The fundamental concept behind most ITS applications is the use of technology to provide information. A safety-oriented ITS application would give drivers information that would help them avoid a crash or in some cases provide information that would mitigate the consequences of a crash. Recognizing that the driver is the basic element in preventing crashes, the analysis treated each driver (and vehicle) separately ¾ even in a multi-vehicle crash. This allowed different types of ITS information to be matched with the proper contributing factors in a crash. For example, a frequent type of crash in Washington is a rear-end accident in which one vehicle crashes into a vehicle stopped at sign or signal. If the moving vehicle slid on ice, ITS technology such as automatic ice warning signs might have made the driver more cautious. But the same ITS technology would have been less effective to a stopped vehicle that was not at fault. Separating the crashes into individual vehicles permitted this type of distinction.

Determining what ITS application might reduce crashes required a framework in which to link the effects of ITS applications to causes of crashes. For this paper, this framework was based on a detailed analysis of accident factors in Indiana (12). In the study, all crashes were attributed to some combination of three factors: the driver, the road, or the vehicle. These categories also served as a useful framework for relating crashes in Washington to ITS applications because the appropriate ITS technology would differ, depending on the cause of the crash. The contributing causes in Washington were derived from a range of information collected from the collision report forms. This information was used to determine the contributing causes (including primary and secondary) of a crash but not the type of crash. For example, a vehicle running off the road and hitting a fixed object was the most frequent type of rural crash, but the contributing causes of this type of collision ranged from snow on the roadway to impaired drivers to exceeding the speed limit. The process of assigning contributing causes is discussed in the sections below.

DRIVER

Driver factors were defined as any contributing causes or vehicle actions that could mainly be attributed to human actions. These included variables in the collision that corresponded to

- the driver under the influence of alcohol or drugs
- the driver's inattention or being asleep
- the driver exceeding the speed limit or exceeding reasonable safe speed for conditions
- a driver's judgment error in improperly passing, losing control while passing, following too close, failing to signal, making an improper turn, or choosing an improper parking location
- the driver disregarding a signal, stop sign, or warning sign
- physical illness of the driver
- a driver's foot slipping off the brake or clutch.

ROAD ENVIRONMENT

Road environment factors involved both the roadway itself and the area beside the roadway. The factors included road conditions, weather, or other conditions outside of the vehicle. In the collision reports these factors included variables such as

- ice or snow on the roadway
- colliding with an animal or a crash due to avoiding animals
- actions to avoid pedestrians or objects in roadways
- weather or atmospheric conditions such as a dust storm, smoke, fog, wind, or the blinding sun
- a bridge or road washed out
- mud, hazardous material, or water on the roadway
- a crash due to a previous accident in the roadway
- a crash at a railroad crossing
- a crash in a work zone (a construction area).

VEHICLE

The final category included any crash related to equipment or vehicle problems. These included variables in the collision reports that indicated

- a citation for the driver operating defective equipment
- headlights not on or failure to dim
- a vehicle losing loads or the load shifting
- trailers striking other vehicles, jackknifing, or overturning
- the hood opening
- the failure of a tow chain or a crash due to towing.

FACTOR ASSIGNMENT

The data for each vehicle involved in a crash were sorted by the criteria above and were assigned contributing factors. Because a crash could involve a combination of multiple causes, a number of vehicles involved in a crash were assigned multiple factors.

For example, a vehicle in a crash that involved alcohol and icy surfaces would be assigned both human and road environment factors.

Figure 1 shows a breakdown of factors. These factors are dependent on the assumptions made above and are subject to interpretation of contributing causes as determined by the police officer investigating the crash. Thus, these percents are not intended to be a numerically precise examination of crash causes. Rather, they form a framework from which to link ITS and safety.

For more than 40 percent of all crashes the contributing cause was assigned to driver alone. This involvement of the driver as a contributing cause rises to over 60 percent if crashes with multiple factors are included. The road environment alone was a factor in 11 percent of crashes and was implicated in about 30 percent of all crashes. Vehicles were the minority contributing factor in crashes, being a sole factor in 2 percent of crashes and involved in about 8 percent of all crashes.

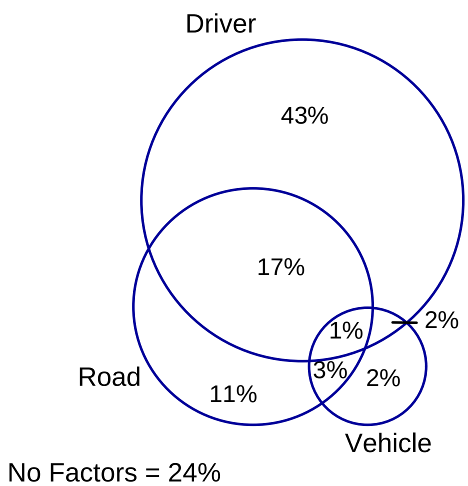

Figure 1: Crash Factors on Washington's Rural State Highways

Of the vehicles in the accident reports, 24 percent could not be assigned a contributing crash factor. There were several reasons for this. One is that some crashes were not investigated by a law enforcement official and were self-reported by those involved. This category included 12 percent of all the crashes on the state highways. (Few of these self-reported crashes involved injury crashes and none involved fatalities). These reports did not have information on contributing causes, and it was impossible to assign a crash factor. A second reason is that in some instances the driver of the vehicle was not at fault. Roughly a third of the vehicles with no crash factors were struck by (as opposed to striking) another vehicle. Finally, a handful of accident reports were missing information and could not be assigned a contributing cause.

ITS AND CRASHES

This section examines rural crashes, investigates their contributing factors, and discusses how these types of crashes might be reduced through the use of ITS applications. A distinction is made between ITS technologies that are usable by transportation professionals at the WSDOT or regional public agencies and those that are promising but may need to come from large federal programs or the private sector. Because this paper is analyzing drivers and vehicles involved in rural crashes and not each crash, a statement such as "5 percent of the crashes had drivers with drug or alcohol impairment" refers to 5 percent of all drivers involved in rural crashes– not 5 percent of all crashes. Also, in the sections below, the percentages of crashes for property damage only and severe crashes (an injury or fatality) are not discussed separately unless there was a notable difference between them.

NO CRASH FACTORS RECORDED

Incomplete or inaccurate accident reports represent an area in which ITS applications might indirectly improve safety by allowing better and more accurate reporting of crashes. This would help transportation engineers better identify and address recurring safety problems. In Washington, a system of total station surveying equipment placed in police cars permits accident investigation to be completed more quickly and addresses a common problem of correctly locating a crash to recording it in the accident reports (13). An additional benefit is that total station helps personnel clear the roadway more quickly. Another example of this type of system is the use in Minnesota of laptops and portable computers in police vehicles (5). This system is expected to reduce paperwork and to locate accident sites more accurately.

The increasing accuracy of global positioning systems, combined with new GIS and crash recording software, as well as powerful portable computers, suggests that law enforcement personnel will enjoy a continually improving ability to collect accurate data at crash scenes. One recent FHWA study evaluated a range of technologies for traffic accident reporting in four states (including a short test in Thurston County, Washington) (14). While the authors found that the tested systems needed polish and did not necessarily reduce the time required to complete an accident form, they concluded that, with training, such technology could reduce errors and omissions on the report forms.

DRIVER FACTORS

In Washington State, as well as nationally, the factor that contributes to the majority of crashes is driver behavior. In general, reducing crashes due to human behavior is not an area where state-level transportation engineers and planners directly focus their efforts. In addition, most ITS systems are not capable of preventing a crash due to poor judgement or perception on the part of drivers. However, current ITS technology can indirectly reduce the driver’s role in some crashes by warning drivers of situations that might warrant caution or increased vigilance. Some such ITS systems are discussed below.

Unsafe Speeds or Exceeding Safe Speeds

For the majority of vehicles (22 percent) involved in rural crashes in Washington, the assigned contributing cause was a driver either exceeding the safe speed or exceeding the speed limit.

Lower vehicle speed allows more time for actions, increases braking distance, and if there is a crash, reduces severity. One ITS solution that may cause drivers to lower speeds is a system that informs drivers of their speed, or informs drivers when their speed exceeds some "safe" limit. These systems are feasible at specific locations identified as hazardous. An example of this type of system is an application in Colorado at a curve with a history of truck accidents (5). The system uses radar linked to a variable message sign that alerts truckers when they are speeding. This system has proved to be successful by producing a notable reduction in truck speeds. A similar system in Seattle uses radar to detect vehicle speeds before a sharp curve (5). If a vehicle approaches at a speed that is too fast to safely make the curve, a beacon on a sign flashes a warning. This system uses widely available equipment. More sophisticated systems that classify vehicles on the basis of size and length and then suggest a safe speed are available. Another ITS system that indirectly addresses excessive speeds is a variable speed limit that can be changed in response to poor driving conditions. One such system with 13 variable message signs is installed over Snoqualmie Pass in Washington (15).

Most existing ITS applications that inform drivers about unsafe speeds can only be installed at fixed locations that have an accident history or that have been identified as hazardous. For example, in Washington, 40 percent of speed-related crashes occur on straight stretches of road, suggesting that driver behavior, not the road, may be the most important contributory factor. In these locations, fixed installation probably would not be effective. Reducing speed in these areas may depend more on education or enforcement. One promising enforcement tool in use in some states is a roadside photo camera with radar. Vehicles exceeding the speed limit are photographed and identified by their license plate, and a citation is then mailed to the registered owner (16). However, this type of system has an uncertain legal standing in this state.

Inattention or Sleeping

In Washington State, 9 percent of all crashes were attributed to drivers being either inattentive or asleep. While this contributing cause is sometimes used as a “catch all” factor on accident reports, it is still a recognized problem on the state’s rural roadways. At this time, few ITS applications that deal directly with this type of crash can be found. Most ITS solutions that may eventually address such problems will arrive through federal research programs, perhaps as a result of in-vehicle devices developed in conjunction with the automobile industry. For example, the National Highway Safety Administration (NHSTA) is currently exploring drowsy driver monitoring systems (17). Such systems sense driver performance by tracking how well the vehicle stays within lanes and other factors such as eye movements, steering wheel motion, and sideways movement. If the sensors detect a problem, the driver can be warned. Another potential ITS solution from NHSTA is a road departure warning system (17). These systems will either inform drivers that their vehicle has crossed the lane onto a shoulder or warn drivers that the vehicle is about to run onto the shoulder. Either system will be sophisticated and involve sensors in the vehicle, perhaps with roadway infrastructure. Such systems will most likely involve the automobile industry. Although they could eventually contribute greatly to rural safety, this type of system is not of immediate use to public transportation professionals trying to solve specific accident problems. In many cases, non-ITS solutions, such rumble strips on the shoulder, may be more cost effective.

Judgment Errors

Sixteen percent of the vehicles were in crashes that involved poor driver judgment, such as the failure to yield, improper passing, improper signaling, and U-turns. Few ITS applications that directly address drivers' judgment errors are currently available.

Judgment related crashes, that are not linked to impairment due to drugs or alcohol (covered in the next section), might involve driver inexperience or declining mental and physical ability related to aging. An examination of driver age in relation to judgment-related crashes in Washington found that these crashes were most common for younger drivers. The number of crashes in this category declined with age until about age 55, after which there was an increase in crashes. This trend matches national findings. NHTSA notes that "younger and older drivers share the distinction of having more crashes per mile driven than other age groups" (18).

An ITS tool that may address these type of problem but that is probably beyond the reach of most transportation professionals is technologically advanced driver training. This type of training could depend on computer-based techniques such as computer simulation. Such tools are used for military and flight training but have yet to be widely used for driver training.

For elderly drivers, computer-based techniques that enhance or improve their ability to receive roadside information may equally and indirectly address rural safety. NHTSA is examining advanced technology crash-avoidance counter-measures to determine which have the greatest safety potential for older drivers (19). Another project sponsored by the FHWA is using a computer-based system for developing and improving the design of roadside symbol signs for easier viewing by the elderly (19).

Drugs or Alcohol

Driver impairment due to drugs or alcohol was a factor for 5 percent of all vehicles in rural accidents in Washington. These crashes tend to have greater severity and involved 30 percents of all vehicles in fatal crashes. ITS strategies to address this type of crash are now limited to in-vehicle devices such as simple coordination tests or in-vehicles breath analyzers. Such technology would most typically come from the private sector, but the courts can mandate the application of such technology. In Washington, new legislation allows the courts to require individuals with a history of impaired driving to install breath analyzers with ignition interlock in their vehicles (20).

Note that ITS techniques that benefit most drivers may also reduce the number of crashes involving impaired drivers. Impaired drivers are the same as unimpaired drivers except with slower reaction times and with worse judgment. Impaired drivers may be more prone to crashes, but they also may benefit more from ITS applications such as speed control signs or NHSTA's road departure warning system. Thus, other ITS safety applications may indirectly increase safety by reducing rural crashes by drug or alcohol impaired drivers.

Other Human Factors

Other reasons for rural crashes on Washington State Highways, such as the driver losing control while passing, physical illness of the driver, and the driver's foot slipping off the brake or clutch, can be linked to human factors. However, these crashes involve such a small percentage (less than 0.2%) of all vehicles that any ITS strategy focused on these factors would probably be inefficient.

ROAD FACTORS

For about 30 percent of the drivers in rural crashes, a contributing factor is the road and roadside environment. Transportation planners and engineers have traditionally been the most effective at preventing crashes due to roadside hazards and roadway conditions. This effectiveness extends to ITS applications. ITS systems can provide timely information to drivers about specific hazards they will encounter on the road ahead. This gives drivers an opportunity to proceed more cautiously or to simply forego a trip. Either situation will increase rural safety.

Weather

Weather has a notable impact on travelers by reducing roadway traction, visibility, and vehicle stability. In Washington State, between 1993 and 1996, about 20 percent of rural crashes were on roadway surfaces covered with snow or ice. Foggy conditions were implicated in another 2.4 percent of the rural crashes. Wind was a factor in a few crashes (less than 0.1 percent).

The use of technology to inform travelers about weather-related hazards is one of the most promising applications of ITS in rural areas and currently involves a number of approaches. Although large area weather forecasts are common, they typically have contained little information on road conditions. Weather reporting systems with information designed for travelers can reduce travel during bad conditions and encourage those that do travel at these times to be cautious. The FHWA's Advanced Rural Transportation Systems (ARTS) compendium lists a number of area-wide weather forecasting systems that provide traveler information (21). Among these are systems in Idaho and New York that link environmental sensors and visibility data to central computers and then to roadside variable message signs. A complex system in California (called Snow Wars) links weather radar, pavement sensors, and weather stations to a management center (22). The management center then provides traveler information via variable message signs, highway advisory radio, and a state highway information network. The state of Washington will be developing a similar statewide multi-element weather system.

Another type of ITS weather system focuses on specific locations and delivers traveler information when hazards occur at these spots. One example of this type of fixed system is ice detection sensors hooked to warning signs. Such a system was tested in Washington State and used ice sensors on a bridge linked to a beacon on an ice warning sign (5). This system was removed, in part, because of concerns about liability if an ice-related accident occurred during a system malfunction. This highlights the concern that that the perceived liability of such systems may create a cost that outweighs their benefit.

Fog and dust storms, while not contributing factors in a high percentage of rural crashes, often affect multiple vehicles. Fog, dust storms, and blowing snow can be detected and linked to roadside warning signs and other warning systems. One example of a dust storm system is in California on a section of Interstate prone to dust storms. The system includes small-scale weather forecasting equipment, closed-circuit television, and changeable message signs (22). This system is operated by a control center and informs drivers when conditions become hazardous for driving. Another system is on I-75 in Tennessee along a river (5). A control center gathers information from weather stations and visibility meters. When fog does occur, highway radio, variable message signs, and fixed signs with beacons provide information to drivers. The actual flow of traffic can be monitored by radar, and gates are available to close on-ramps. Other systems are simpler, such as one in South Carolina that uses visibility sensors and automatically turns on streetlights when conditions are foggy (5).

Wind gust detection systems, which can be hooked to warning signs or to a control center, are available. Such a system can be installed in areas where the forces of the wind are concentrated and are somewhat predictable. Washington State, for example, is installing wind gauges linked to warning signs on a bridge on I-90 with a history of truck blow-overs.

A relatively new application that holds promise to reduce weather-related crashes the intelligent road marker. This is similar to standard reflective lane delineators but with lights (LEDs), solar chargers, and sensors installed in the unit (23). The sensors can detect darkness, fog, ice, or surface water and activate the lights inside the marker. These lights are notably brighter than the reflectors used in standard delineators. Future models are expected be able to transmit and receive information and can be linked to traffic signals, pedestrian crossings, and can detect obstructed shoulders. One drawback of intelligent road markers is that their cost may restrict their usage to problem locations.

Another aspect of weather-related, rural safety is roadway maintenance. Several projects will apply technology to snowplows. For example, one study in California is developing a plow that uses technology to assist drivers. The plow includes a lane position indicator, lane departure warning, collision warning, and some vehicle automation (24).

In Washington, collisions with snowplows occur occasionally. ITS technologies that warn travelers about snowplows ahead may prevent this type of crash. This type of system could use automatic warning signs or have the plows carry a short range, portable radio (known as an electronic flare) to broadcast a warning message received over nearby vehicles' radios.

The ARTS compendium identifies sensors in snowplows and maintenance vehicles as a means of monitoring snow depth and assisting in vehicle and routing management (21). More efficient management of such equipment should resulting in more efficient snow removal, safer travel conditions for travelers, and fewer crashes. Other maintenance systems use sensors to detect when to optimize applications of anti- or de-icing fluids. For example, a test system in Utah uses atmospheric and pavement sensors to detect when anti- or de-icing fluids should be applied to an overpass (5).

Wildlife Collisions

Vehicles that hit animals (both domestic and wild) were involved in 4.8 percent of all rural accidents in Washington (but only 1.1 percent of them were severe). Other than traveler information that warn about seasonal migration problems, few ITS solutions currently address this problem. However, a windshield mounted infra-red vision system that is currently being offered as an option by one American automobile company may increase driver's ability to detect wildlife in the roads. In the future, in-vehicle systems may alert a driver or even brake a vehicle when an animal (or any other roadway obstruction) is detected (7). However, the use of all such systems will greatly depend on participation by the automobile industry.

Work Zones

Of all the vehicles involved in rural crashes in Washington, 3 percent were in construction areas. Between 1993 and 1996, 13 fatalities were associated with construction zones. A variety of ITS systems have been developed to address such situations. One simple approach is to use variable message signs at work sites. These signs are relatively inexpensive, can be altered via telephone, and are adaptable to changing work site conditions (5). A more complex portable system, developed by a vendor, includes variable message signs and highway advisory radio with real-time information on work zone conditions and detours (5).

Other ITS systems for work zones control drivers' speed by linking radar to warning signs and beacons. One system applied to a work zone by the Indiana DOT links electronic occupancy sensors to lane drop signs. As traffic volume increases, more signs are activated, smoothing the merging of vehicles (3). The National Cooperative Highway Research Program is funding another ITS test system that warns workers when lasers detect a vehicle has intruded into the work zone (25).

Indirectly, ITS traveler information systems may increase work zone safety by informing drivers about alternative routes and by permitting them to avoid construction areas.

Other Roadside Causes

Crashes due to other roadside hazards, such as washed out roads and bridges or water or debris on the roadway, were only a small percentage of all crashes (less than 0.1 percent). ITS applications focused directly on this type of crash may not be cost effective. However traveler information could easily contain information related to road conditions that covers many of these types of hazards.

About 0.7 percent of the crashes involved pedestrians or bicycles. In areas where a problem may exist some inexpensive, low technology systems can simply warn drivers of bicyclist or pedestrians ahead. The systems are activated by the pedestrian or bicyclist and are linked to a sign or flashing light that turns off after a set period of time. Examples of such self-activated systems include a "BICYCLES ON HIGHWAY" sign and beacon in Colorado and “PED/BICYCLE IN TUNNEL WHEN FLASHING” sign in Washington (5). A more complex system could use sensors in place of self-activation.

Even though some ITS applications may only affect a few drivers, they may still be justifiable for some roadside hazards because they may make a critical difference to those drivers. One example of this type of situation is railroad crossings. In Washington, in comparison to other types of rural crashes, relatively few crashes occur at railroad crossings. However, existing ITS that warn drivers of a train approaching or warn train operators of a vehicle on the track (21) may still be justifiable because of their criticality.

Another critical hazard is rural roadway intersections, where about one-quarter of all rural crashes occur in Washington. ITS can warn drivers about to cross an unsignalized intersection, particularly crossings at higher speed roads, about a dangerous situation. One example of such a system is a collision countermeasure system being evaluated by the FHWA and installed in Virginia (26). This system is designed as an alternative approach for rural intersections where the cost and traffic delays of a fully signalized intersection would be difficult to justify. The system uses sensors and flashing signs to warn a driver traveling on the major through road when a vehicle is prepared to enter the intersection. Drivers waiting to cross the through road are warned with an animated sign when traffic is approaching.

VEHICLE

This category included 2.9 percent of all vehicles involved in rural Washington crashes between 1993 and 1996. ITS strategies to address vehicle problems lie mainly within the realm of vehicle manufactures. However, some ITS applications may address safety problems related to trucks.

Trucks

In Washington, 6.7 percent of all vehicles involved in crashes are trucks over 10,000 pounds. Although the percentage is not high, such crashes tend to be more severe. Because weather conditions such as high winds or icy roads may have a greater impact on trucks than on other vehicles, ITS weather warning systems may have a correspondingly greater positive effect on trucks than on other vehicles. Spot locations that are particularly hazardous to trucks can be equipped with vehicle classification detectors linked to warning signs (as discussed in the section on speed, above). One interesting safety system in Oregon is located at a weigh station just before a steep downhill grade. The truck's weight is used to calculate a safe speed which is then flashed on a message sign for the truck's operator to read.

In addition, indirect rural safety improvements may come from Commercial Vehicle Operations (CVO) programs that improve regulatory compliance. These permit a state to automate portions of the vehicle inspection process and increase efficiency. They should ensure that safer vehicles are on the road. A number of CVO projects are under way in this country, and many have a safety component (3).

EMERGENCY NOTIFICATION

Any reduction in emergency service response times to crashes has been shown to reduce injury severity and fatalities (6). As a result, ITS technology oriented toward emergency notification holds promise for rural safety especially given the relatively high rate of fatalities on rural roads. Such ITS systems range from site-specific roadside call boxes to area-wide in-vehicle mayday systems. As with most ITS technology, the viability of emergency notification systems depends on the coverage and technology of communication networks.

Emergency call boxes have been installed in a number of areas across the country, including in Washington State (27). Call boxes are designed to address specific locations where notification problems occur. Studies of call boxes in urban areas suggest that in some areas they work well (27). Call boxes may also provide additional benefits as multi-purpose ITS data stations. For example, the California Department of Transportation has investigated the use of call boxes as traffic counting and hazardous weather detection stations (28). Call boxes have used both standard wired phone lines and wireless cellular. Unfortunately, in many rural areas both wired and cellular coverage is incomplete, reducing their usability. In some of these situations, the usability of call boxes can be extended by using repeater cells to relay a signal along a string of call boxes until a wired line or cellular coverage is reached.

In-vehicle mayday systems using cellular technology have been tested in Washington and other areas. This area-wide system allows drivers to request emergency assistance from their vehicles while an in-vehicle global positioning system relays their location. Such systems usually depend on vehicle manufacturers' installing these systems in vehicles. Because of current incomplete rural cellular coverage, mayday system may become more feasible if a wide area system, such as the Low Earth Orbiting Satellites (LEOS), is implemented.

A related mayday system uses in-vehicle sensors to detect when a collision has occurred and then automatically informs EMS providers where the crash is located (17). These systems may even relay information on the severity and type of crash. Although

NHTSA is performing an operational test of these systems, they probably will not see immediate application due to limited communication coverage and the fact that any widespread use would depend on the vehicle manufacturers' support.

CONCLUSION

How can ITS help transportation professionals in WSDOT and other public agencies improve roadway safety in rural areas? This paper addresses this question by relating the type of crashes on rural roads in Washington to existing and future ITS applications.

FINDINGS

This research split four years' worth of Washington rural crashes into single vehicles and then into contributing crash factors, which served as a framework for examining the potential contribution of ITS to rural safety. In Washington State, as in other states, the factor that most commonly contributes to rural accidents is driver behavior. This area can be difficult to address at the level on which most transportation professionals operate. As the president of the Institute of Transportation Engineers (ITE) noted, "The behavioral initiatives to combat (driver behavior) problems are not the things we traffic and transportation engineers typically deal with directly" (2). Some ITS applications, such as radar linked to speed warning signs, may be a good solution for transportation professionals who need to reduce the number of crashes linked to driver behavior at a particular location. Other ITS applications that inform drivers about unsafe situations such bad weather indirectly address driver behavior by providing information linked to area-wide hazards. Drivers can use this information to modify their behavior. Other human factor issues such as impaired drivers or poor driver judgment cannot be easily solved by ITS applications that are currently available to transportation professionals. It is probable that ongoing federal research into drowsy driver warning and road departure systems may someday produce ITS systems that help to mitigate the results of poor driver behavior, but these systems will most likely be implemented by the vehicle manufacturers.

The president of ITE noted that, in terms of safety, roadside infrastructure is "where traffic and transportation engineers practice our magic"(2). This holds true for both traditional engineering approaches and ITS applications. In Washington State, crashes linked to some aspect of the road or roadside environment involve about 30 percent of the vehicles. ITS offer a viable alternative to traditional engineering solutions for some of these types of crashes by informing drivers about hazards. However, the ultimate success of ITS in this situation will still depend on drivers' proper reaction to the information.

The most common factor in crashes linked to the roadside environment is weather. Some ITS weather systems can indirectly address rural safety by providing area-wide information about travel and roadway conditions. Other weather systems address specific hazardous locations and inform drivers about upcoming problems such as ice or high winds. These are feasible tools for transportation professionals to use in dealing with rural safety. Rural intersections, work zones, and railroad crossings are other areas where ITS may be useful for dealing with specific safety hazards.

ITS traveler information systems may indirectly reduce the number of crashes linked to the roadside environment. They will do so by providing drivers the information necessary to react to hazards or by providing the impetus to avoid traveling all together.

The final factor that contributes to a small percentage of rural crashes is the vehicle. This is another area in which transportation professionals currently have minimal direct impact. As the ITE president noted, "vehicle failure is best reduced by legal and educational means" (2). ITS applications may help indirectly by making trucks more compliant with safety laws and by improving the efficiency of commercial vehicle safety inspections.

ITS emergency notification systems also offer some safety benefits by mitigating some of the consequences of rural crashes. These systems currently are roadside call boxes or cellular phone-based systems within a vehicle. However, widespread success of such systems is dependent on more complete communication coverage in rural areas.

The findings in this report are summarized Table 3. The table links rural safety issues with the appropriate ITS applications. The table also identifies whether these applications are available currently or will be available soon, are potential future application, and whether the application's feasibility will depend on the vehicle manufacturers.

Because ITS provides information, it is important to remember that communication technology plays a crucial role. Most rural areas, in comparison to urban areas, have limited access to communications systems, with a particular limitation on systems that allow two-way communication. More universally available communications technology, either through improved technology or through growth of existing systems, should have a notable impact on the feasibility of rural ITS. One proposed technology that holds considerable promise for rural ITS is satellite-based systems, such as LEOS, that would provide communication over a wide area (29, 30). This system would provide obvious benefits for mayday systems but could also be linked to positional systems to provide dynamic in-vehicle safety information that would better address crashes caused by driver-related factors. For example, such a system might inform individual drivers that they are exceeding safe speed for a curve just ahead.

Table 3: Summary of Findings

Contributing Crash Factors	Rural Safety Issue	% of Vehicles in Rural Crashes in Washington	Possible ITS Solutions
Human	Unsafe Speed or Exceeding Speed Limit	22 %	● Speed radar linked to warning sign (5) ● Variable speed limits (15) ● Photo enforcement system (16)
	Inattention or Sleeping	9 %	❍ 🚗 Driver monitoring system (17) ❍ 🚗 Roadway departure systems (18)
	Judgment Errors	16 %	● Computer-based driver training ● Compute designed roadway signs (19) ❍ 🚗 Crash avoidance countermeasure system for older drivers (19)
	Drug or Alcohol	5 %	● 🚗 Ignition interlock with breath analyzer (20)
	Other Human Factors	> 0.5 %	Few ITS applications
Road	Weather	23 %	● Area-wide weather warning systems (5, 21) ● Ice sensors linked to warning signs (5) ● Fog, dust or smoke warning systems (5, 21) ● Wind gust warning systems ● Intelligent road markers with weather sensors (23) ● Snow plow ahead warning systems (21) ❍ Snow plow management systems (21) ❍ Advanced technology snow plows (24) ● Automatic anti-icing and de-icing systems (5)
	Wildlife Collisions	5 %	● 🚗 Night vision systems ❍ 🚗 Roadway obstruction detection (7)
	Work Zone	3 %	● Adaptable variable message signs ● Portable work zone safety systems (3, 5) ● Work zone intrusion warnings (25)
	Other Road Hazards	> 0.1 %	Few ITS Applications
	Pedestrian or Bicycle Involvement	0.7 %	● Self- activated warning signs for roads and tunnels (5)
	Railroad Crossings	> 1 %	● Train conflict sensors and warning signs ❍ In-locomotive “vehicle in crossing” warning systems (21)
	Rural Intersections	28 %	● Approaching vehicle warning sensors and signs (26)
Vehicle	Truck (over 10,000 lb.) Involvement	7 %	● Truck classification detectors and warning signs at hazardous locations (5) ● Automated commercial vehicle inspection and enforcement programs (3)
Post-Crash	Emergency Notification		● New technology call boxes (27, 28) ❍ 🚗 In-vehicle mayday systems (17)
	Incomplete or Inaccurate Crash Reports		● Total stationing for crash reporting (13) ● Portable computers in police vehicles (5, 14) ● Crash reporting systems utilizing GPS and GIS software (5, 14)

● = Application feasible currently or in the near future
❍ = Potential future application
🚗 = Application from vehicle manufactures

ITS, WSDOT, AND RURAL SAFETY

Washington State is actively using ITS to address rural safety issues. For example, an extensive variable speed limit system on Snoqualmie pass and total station equipment used to record crashes are among the ITS applications in use. These and other ITS applications in Washington are guided by an Advanced Technology Policy designed to minimize the uncertainty and risk of deploying ITS (1). This policy has three levels of implementation for ITS.

Aggressively pursue the implementation of applications that have proven effective through research, demonstration projects, and broad scale development elsewhere.

Demonstrate applications supported by substantial research and an indication of strong demand but whose benefits have not yet been fully documented.

Monitor applications and projects nationwide that have the potential to create substantial benefits for travelers, shippers, and transportation agencies.

These levels of implementation can be related to the findings in this report. This forms a policy framework that can provide some general guidance to WSDOT planners and engineers who need to evaluate ITS applications for rural safety. The following section discusses this framework.

Aggressively Pursue

According to Washington's technology policy, proven and effective ITS policies should be aggressively pursued. In general, rural ITS technology is still too recent for many ITS application to be unequivocally pursued, especially as an alternative to traditional solutions to safety issues. However, this situation is changing as many rural ITS projects that have been demonstrated under federal programs are proving effective and are starting to see state (as opposed to federal level) funding and acceptance.

Demonstrate Applications

Most of ITS rural safety applications discussed in this paper have undergone significant research and test applications, but their benefits have yet be fully proven and documented. Therefore, WSDOT staff should demonstrate and prove their feasibility in this state using smaller or more limited applications. If these applications are shown to be effective alternatives to traditional engineering approaches, they can then be aggressively pursued as part of WSDOT's safety program. The majority of the ITS projects that have been tested, but not fully proven, on rural roadways fit in the following categories:

- ITS that delivers information over a broad area about an area wide situation that may affect safety. An example of this type system is a weather information system. Once drivers receive this information from these ITS systems they can respond by driving cautiously, taking alternative routes, or foregoing that trip.
- ITS that delivers information to many drivers about a specific safety hazard at a specific location. An example of this type of ITS is a speed warning sign tied to roadside radar. Once drivers receive this warning they can respond by driving more cautiously.

Monitor Applications

WSDOT staff should be monitoring a number of ITS safety research programs. These mostly federal program, such as NHTSA's run-off-the road and drowsy driver warning systems, involve in-vehicle or automatic vehicle control systems and have considerable promise for addressing crashes caused by driver behavior. Such crashes caused by poor driver behavior at road locations that have not been specially identified as hazardous and is not really addressed by existing ITS tools. The ITS applications coming from these federal research programs may help fill this gap because they can directly prevent crashes due to human mistakes. For WSDOT, these applications not may not only reduce rural crashes but also have potential to free up resources for other safety projects. Some applications, such as roadway departure warning systems, may also affect WSDOT because they may require roadside infrastructure. Other ITS systems, such as variable speed limits, may eventually affect standards.

While Washington's Advanced Technology Policy provides guidance on implementing ITS, another challenge facing WSDOT staff is determining what rural ITS applications are available and worth considering for implementation. Fortunately, up-to-date information about ITS projects and programs is readily available on a number of ITS oriented Internet sites. Because many ITS applications are initially supported or demonstrated by the federal government, the FHWA's sites are often relevant. The addresses of relevant ITS Internet sites, along with some other sources of information, are listed in Appendix A. Publications are another source of information about ITS in general, and some major publications are listed in Appendix B.

Within the WSDOT, another information source concerning ITS is the Advanced Technology Branch (ATB). This branch is responsible for developing and deploying ITS, and their staff are available to assist WSDOT personnel in learning about and apply ITS. The Advanced Technology Branch is also involved in a number of pooled fund ITS studies. These are studies in which multiple states have "pooled" their funding to cooperatively install and test projects. Example of ITS studies with ATB participation include an automatic bridge de–icing system, and an area-wide weather information system. These studies provide an opportunity for WSDOT staff to monitor and demonstrate ITS rural safety projects without shouldering the entire cost and risk. More information on current pooled fund studies can be obtained through the ATB.

One perceived problem that may hinder WSDOT's use of ITS is liability. While concerns about legal issues are best passed along to the experts, one attorney well versed in this area indicated that ITS is not fundamentally different legally from existing vehicle and highway systems (31). ITS America has a legal committee, and its Internet page is a good source of general ITS legal information (32).

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APPPENDIX A
SOURCES OF INFORMATION ON ITS IN RURAL AREAS

This appendix lists sources that would be of use to WSDOT staff seeking additional information on ITS and safety in rural areas. Benefiting the technological orientation of ITS, many of the sources are Web pages.

ITS America http://www.itsa.org/rural.html	ITS America's Web site provides a wide range of ITS related information. There is a discussion area for rural topics.
The Rural Intelligent Transportation Systems (ITS) Free Press http://www.ruralits.org	This USDOT site is provided to facilitate the discussion of issues related to rural transportation and ITS. This Web page is a good starting point for obtaining ITS information focusing on rural applications and has educational information about rural ITS systems as well as links to a number of other ITS rural sites.
FHWA Advanced Rural Transportation Systems Compendium http://www.tfhrc.gov/its/newarts.htm	A Federal Highway Administration downloadable database of the Advanced Rural Transportation Systems Compendium. A number of the projects discussed have a safety component. A brief description of each project is included along with contact information.
Technology for Rural Transportation: Simple Solutions http://inform.enterprise.prog.org/	This Web site presents Technology for Rural Transportation: Simple Solutions. This project presents the results from a research effort to identify proven, low cost solutions to rural needs. Many have a safety element.
California PATH database http://www.nas.edu/trb/about/path1.html	The Web site to the California PATH database. This database is a large bibliographic database pertaining to ITS.

Intelligent Transportation Systems (ITS) Projects Book http://www.its.fhwa.dot.gov/cyberdocs/welcome.htm	The annual "Intelligent Transportation Systems (ITS) Projects Book" identifies ITS projects that have been partially or completely funded with federal money. This large document serves as a good source for tracking down contacts for ongoing ITS projects.
National Highway Traffic Safety Administration http://www-nrd.nhtsa.dot.gov	NHTSA has an active ITS program focusing on issues such as crashes due to running off the road and drowsy drivers. While many of the projects involve a high level of technology and are not the type of program directly usable by transportation professionals from public agencies, these projects may eventually have an impact on rural safety.
Arnold, James A. "Rural Versus Urban, A Communications Infrastructure Perspective" ITS America. Proceeding of the Annual Meeting of ITS America 6^{th}, Vol. 2, 1996, pp. 1045-1051.	A good overview of the important role that communication plays in ITS. There is a discussion of various communications technologies and their eventual impact on rural ITS.
National Work Zone Safety Information Clearinghouse http://tti.tamu.edu/clearinghouse/wzsafety/	The site for the National Work Zone Safety Information Clearinghouse includes information on technology as applied to work zone safety.
National Associations Working Group for ITS http://www.nawgits.com/icdn/	Created by the National Associations Working Group for ITS (NAWG), the ITS Cooperative Deployment Network (ICDN) is an Internet-based resource for transportation professionals.

National ITS Architecture http://www.odetics.com/itsarch/	A Web site for the Odetics Corporation, which concerns the national ITS architecture. This technically oriented page provides an overview of different types of ITS services and technologies that may someday be available. While not specifically rural, this site includes information on safety systems such as the warning devices for highway railroad intersections and post-crash emergency notification. For more information on the national ITS architecture, also visit the U.S. DOT's ITS web site at http://www.its.dot.gov/.

APPPENDIX B
MAJOR ITS PUBLICATIONS

ITS World Advanstar Communications, http://www.itsworld.com	This magazine is published eight times a year and concerns technology and applications for transportation systems.
ITS International Route One Publishing, http://www.itsinternational.com	This British magazine is published six times a year and focuses on international applications of the deployment of advanced technology for efficient surface transportation.
ITS Quarterly ITS America	A journal published four times a year as the forum for ITS America. The emphasis is on the social, legal, economic, and policy ramifications of ITS.
Traffic Technology International UK and International Press.	A British magazine published six times a year with an international emphasis and number of articles related to ITS.