Greater Yellowstone Rural ITS Priority Corridor
Rural Automated Highway Systems Case Study

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Prepared by:

Russell Gomke, Research Associate
Western Transportation Institute
416 Cobleigh Hall
Montana State University-Bozeman
Bozeman, MT 59715
Phone: (406) 994-6010
Fax: (406) 994-1697
E-mail: RussG@coe.montana.edu

Stephen Albert, Director
Western Transportation Institute
416 Cobleigh Hall
Montana State University-Bozeman
Bozeman, MT 59715
Phone: (406) 994-6126
Fax: (406) 994-1697
E-mail: SteveA@coe.montana.edu

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ABSTRACT

The use of Automated Highway Systems (AHS) technology has been proposed as a mitigating application to vehicle collisions in rural areas. The application of AHS in the urban environment is being tested and evaluated to reduce traffic congestion with secondary consideration to safety. Typically, recurring congestion is not a problem in the rural environment, while increasing traveler safety is a primary concern. Automated Highway Systems have the potential to address safety issues in the rural environment by providing the driver with critical collision warning and avoidance information.

The purpose of this study was to address the feasibility, applicability and institutional issues of deploying AHS components in the Greater Yellowstone Corridor. To accomplish the project objectives a systematic research approach was developed to assess the safety challenges and infrastructure deficiencies of the Greater Yellowstone Corridor. The primary tasks consisted of a transportation system inventory, an accident analysis, an AHS countermeasure assessment and a benefit-cost evaluation.

The research yielded several spot location applications with the potential to positively effect the safety challenges of the Greater Yellowstone Corridor. Potential technologies are friction/ice detection warning system, animal-vehicle collision warning, intersection collision warning and advanced horizontal curve warning. These are all near-term applications. Benefit-cost evaluations have indicated several multi-mile sections of highway in the Greater Yellowstone corridor where far-term countermeasures are applicable and feasible. Far-term applications include longitudinal and lateral warning and guidance. However, these applications require appropriate vehicle fleet penetration before any true benefits can be quantified. Market penetration may be facilitated by fleet vehicle deployment.

The work performed for this project is only the first phase. Funding will be pursued to develop some of the near-term applications into field operational tests. The sites identified in this report are estimated to have the greatest potential for improving safety in the Greater Yellowstone corridor.

INTRODUCTION

The intent of this study was to recommend applications and consider implications of Advanced Vehicle Control Safety Systems (AVCSS) in a rural environment. This study focused on developing an applicable AVCSS for the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) corridor that would ultimately increase safety and improve operation of the GYRITS corridor.

Initial activities by the National Automated Highway System Consortium (NAHSC) have focused on urbanized areas. However, a need exists to investigate the applicability of advanced transportation technology and AHS in rural settings. AHS applications have primarily focused on problems associated with urban traffic congestion; secondary considerations have related to safety, air quality and energy conservation. These areas are also of concern to the rural transportation provider; however, the primary focus of the rural transportation provider is improved safety.

There are many safety benefits potentially realized through the application of AHS technologies to the existing transportation infrastructure, particularly through advanced driver warnings. It is estimated that if a driver were warned of an impending collision one half second earlier, 50 percent of rear-end and cross-road crashes and 30 percent of head-on crashes could be avoided. If an additional second is provided to the driver, 90 percent of all crashes could be avoided. Experts estimate that advanced transportation technologies will potentially save 11,500 lives, 442,000 injuries, and $22 billion in property damage nationally by 2010. [1]

The selected corridor represents a vital transportation link for the trucking industry, connecting the Northwest and Canada with Intermountain and Southwest markets. Approximately 20 percent of the traffic traversing the GYRITS corridor is commercial. [2] Commercial vehicles use this route to transport goods between the aforementioned markets and markets within the corridor (e.g., mining, forestry, and agricultural industries). Because much of the corridor is two-lane highway, many dangerous passing situations result involving large trucks, recreational vehicles, tourists and slow-moving farm machinery. Poor sight distance, limited by the winding road and canyon walls, exacerbates the danger.

The corridor presents an environment filled with unique challenges that must be confronted when developing a viable transportation system. The corridor receives about 80 to 90 inches of snow in a typical winter. Temperatures can reach 65 degrees below zero (Fahrenheit) and a 40 to 50 degree temperature shift from day to night is not unusual. Winter conditions typically last about eight months. However, it has been known to snow in the higher elevations in the summer months.

The corridor encompasses migration routes and habitat for deer, elk, bison and moose. Periodically, these animals can be found on the roadway, presenting a potential animal-vehicle conflict. Over a recent three-year period, 367 animal-vehicle collisions were reported. Non-reported animal-vehicle collisions likely increase this number substantially.

Because much of the corridor abuts mountain ranges, many sections of the corridor are not covered by cellular phone service. The canyon walls also preclude the reception of AM or FM radio band signals throughout much of the corridor.

The combination of varied, often undesirable driving conditions with wildlife, unfamiliar drivers, a diverse traffic stream and a lack of communication infrastructure indicates an immediate and growing need for increased focus on safety. The problems experienced in the

GYRITS corridor are common to many rural environments. Hence, it is an ideal location to showcase field operational demonstrations of advanced technologies.

PROJECT GOALS AND OBJECTIVES

The goal of this project is to enhance the quality of life for rural residents and travelers through more safe and efficient movements of goods and people using judicious applications of advanced vehicle control technologies. An evolutionary deployment process will be followed, which allows transportation system users and providers to gradually realize the tangible benefits of deploying advanced vehicle control technologies.

The rural community is faced with many unique challenges and opportunities to develop sustainable transportation systems that address the needs of the rural traveler. Some of the rural transportation needs are in vast contrast to the urban transportation needs. Urban problems encompass congestion, mobility, air quality, noise, safety, and energy issues. While rural areas struggle with many of these same issues, they have a rural-specific focus that differs. Rural safety issues are the highest priority. Two-lane rural highways are the backbone of the rural transportation network. These roads carry local traffic as well as commercial vehicles, transit vehicles, school buses, recreational traffic and commuter traffic destined for metropolitan areas. Rural roads account for 80 percent of the nation's total mileage. Only 40 percent of the national vehicle-miles traveled occur in rural areas. However, rural areas account for 58 percent of the accidents causing fatalities. [3]

CORRIDOR ROADWAYS

The corridor contains several roadways; a description of each roadway follows. In the northern portion of the corridor, U.S. 191 originates in Bozeman, Montana and continues south for fifty miles through the Gallatin Canyon following the Gallatin River. The Gallatin Canyon hosts a wealth of industries such as logging, recreation and tourism. Big Sky Ski and Summer Resort lies 35 miles from Bozeman, Montana, north of U.S. 191, offering abundant summer and winter recreational activities. U.S. 191 also travels through the Gallatin National Forest, which is used extensively by recreational travelers and commercial vehicles supporting the timber industry. Continuing south, U.S. 191 leaves Gallatin Canyon and enters Yellowstone National Park (YNP), home to thousands of elk, deer, moose and bison. YNP is also the location of an increasing number of year-round tourists. Between 1988 and 1992, annual visitation to YNP increased 40 percent, to total more than 3 million. [4] U.S. 191 terminates at West Yellowstone, Montana.

U.S. 20 originates at West Yellowstone, Montana and continues southwesterly to Idaho Falls, Idaho. U.S. 20 crosses Targhee Pass and the Continental Divide at an elevation of 7,072 feet. Every year, this pass delays travelers due to snow and other winter-related driving difficulties. U.S. 20 passes through Targhee National Forest, enters east central Idaho and terminates at Idaho Falls, Idaho.

U.S. 89, beginning in Livingston, Montana (for this study) presents driving conditions similar to U.S. 191. The primary difference is that U.S. 89 does not directly traverse the foothills of Paradise Valley, but rather crosses semi-flat terrain. Approximately 53 miles before U.S. 89 enters Yellowstone National Park, it passes through the Gallatin National Forest. It then continues though Yellowstone National Park and enters the Bridger-Teton National Forest in Wyoming. U.S. 89 continues through Grand Teton National Park and the recreational community of Jackson, Wyoming. U.S. 89 passes through either national park or national forest areas continually to the western Wyoming border.

Near the Wyoming border, at Alpine Junction, U.S. 26 begins. It enters Idaho and continues on to the study's final destination in Idaho Falls, Idaho.

RURAL AHS VISION

Automated Highway Systems (AHS), according to the National Automated Highway Systems Consortium (NAHSC), "will safely operate properly equipped vehicles under automated control on properly equipped lanes." [5] This is the long-term goal of the NAHSC. However, before this goal can be achieved, AHS will have to be incrementally deployed. For AHS to successfully evolve, the system must present clear and obvious advantages and benefits to the users. If no tangible benefits can be presented, then potential users will likely be unwilling to invest in AHS. This will be particularly true if capital costs are significant. The evolutionary approach will allow users to gradually use and accept AHS technology. With staged successes, users will be able to segmentally experience AHS and develop confidence in AHS safety and reliability.

This incremental approach will permit rural agencies the necessary time to fund and develop advanced technology applications to their transportation system. Generally, rural transportation providers operate with limited resources. Typical characteristics of rural transportation providers are:

- fewer finical resources which to operate;
- more lane-miles per capita to operate and maintain;
- smaller personnel base; and
- wider variety of weather extremes, particularly in the GYRITS corridor.

Rural highways were built to provide high-speed, long-distance travel to all vehicle types. The rural driving environment is unique from the urban driving environment in that rural highways posses the following characteristics:

- longer trips, often through unfamiliar areas;
- 78 percent of rural trips greater than 150 miles are for pleasure [6];
- areas of irregular terrain and road alignment, many times the irregular terrain dictates a less than desirable geometric road design;
- higher traffic speeds coupled with lower traffic volumes;
- longer trips, resulting in inattention, disorientation or fatigued conditions and lengthening driver reaction times;
- more motor vehicle fatalities and higher fatality rates;
- more older drivers, the average age is 45.8 and 18 percent of rural drivers are over 64 years of age [3];
- more severe effects of bad weather;

- more miles of unlit roadways;
- unexpected hazards, such as animals and slow-moving vehicles (farm machinery);
- fewer alternative routes; and
- generally more roadside obstructions and limited clear zones, particularly scenic areas.

For this rural case study, the AHS definition has been tailored to more adequately define the needs of the rural traveler and the evolutionary deployment vision. This case study has defined AHS to be "any application that assists the driver with avoiding any type of impending collision through the use of collision avoidance technology." This includes any type of audio or visual warning that will provide the driver with a few more seconds of reaction time. This concept best suits the rural environment due to the limited right-of-way and funding. On rural two-lane, limited access highways, dedicated AHS lanes are not a feasible option.

Near-term rural strategies will consist of collision avoidance technologies applied at spot locations where there are a statistically high number of recurring accidents. Information will be communicated to the driver via roadside dynamic message signs or warning sign beacon mountings.

Long-term rural solutions consist of collision avoidance/driver assistance technology implemented in the vehicle. This will allow infrastructure to vehicle communication and vehicle to vehicle communication, resulting in a "smart" highway system.

THE SYSTEM

The system conceived for this project and used in the benefit-cost analysis assumes four incremental service levels. The service levels are:

0. **Spot Application**: locations where accidents are statistically over-represented will be implemented with technology to warning the driver of hazards via the infrastructure and dynamic messages.
0. **Information Assistance**: dangers warnings will be relayed to the driver via the vehicle.
0. **Control Assistance**: the vehicle warnings will be relayed to the driver and in the event the driver does not respond the vehicle will temporally assume control.
0. **Full Automation**: in this instance the vehicle is fully autonomous.

Information Assistance, Control Assistance and Full Automation have three primary functions that assist with collision avoidance. These three functions are (1) longitudinal collision warning/guidance, (2) lateral collision warning/guidance and (3) intersection collision warning.

Longitudinal Collision Warning/Guidance

The longitudinal warning function is designed to detect when a vehicle is traveling too fast for an oncoming roadway segment. The longitudinal warning system utilizes a vehicle's dynamic state and performance data in conjunction with current pavement condition and roadway geometric alignment data to calculate a maximum safe speed. If a vehicle is exceeding the maximum safe speed, the vehicle will alert the driver of the danger so that he/she may take appropriate action to avoid a crash. In the case of Control Assistance, a vehicle may automatically decelerate to a safe operating speed. The longitudinal warning function also detects slow-moving and fixed objects at a sufficient distance to allow the driver to stop or safely maneuver around the object. Once again, Control Assistance may intervene if a driver does not react or if the distance is to short to permit a driver adequate reaction time.

Lateral Collision Warning/Guidance

The lateral warning system is designed to detect when a vehicle is departing a travel lane. The lateral warning system utilizes data about the dynamic state of a vehicle in conjunction with information about an oncoming roadway geometric alignment to determine if a vehicle's current position and orientation will likely lead to a lane departure. If the likelihood of lane departure exceeds a particular threshold, an audio or visual alarm alerts the driver of danger to avoid an accident. In the case of Control Assistance, a limited amount of steering torque will be applied to reposition the vehicle in the center of the driving lane.

Intersection Collision Warning

The intersection warning system is designed to detect the presence of vehicles on major roadways and relay the information to vehicles waiting to cross on minor roadways. Sensors or loop detectors placed on either side of the intersection in the major road determine when crossing, left turn or right turn maneuvers are safe. The American Association of State Highway and Transportation Officials (AASHTO) provides safe distance values for all three maneuvers (i.e., crossing, left turn, right turn). Safe crossing information is relayed to the driver through stop sign-mounted beacons or through in-vehicle displays.

DEPLOYMENT VISION

Limited quantification of AHS benefits and slow market penetration (i.e., vehicles equipped with advanced vehicle control systems) makes it difficult to clearly envision AHS deployment. However, it is recommended that AHS development in this corridor be incremental. Incremental deployment has been the "rule of thumb" for all AHS deployments. Most rural agencies will have to incrementally build an AHS infrastructure due to limited annual financial resources. This approach is referred to as "open architecture" - the use of incremental deployment with flexible design and regional tailorability. An open architecture allows rural transportation providers to segment installation, remaining open to adapt evolving technologies yet tailor it to their specific needs.

Unlike in urban areas, the element driving rural AHS is safety. Recurring congestion is generally not a problem in rural environments. This section does not determine the feasibility of implementing advanced vehicle control systems at the technical or institutional level, but instead proposes a near-term and long-term deployment vision.

AHS BENEFITS

Automated Highway Systems (AHS) have the potential to address several different types of safety problems. AHS may be considered the tool of the future for engineers attempting to add to the safety and operation of a roadway where other traditional or conventional safety applications have fallen short. Unlike conventional safety applications, the goal of AHS is to achieve safety benefits through dynamic crash prevention countermeasures. Automated Highway Systems will provide dynamic warning and vehicle control information based on current roadway, traffic and environmental conditions.

Improving safety and security is the ultimate goal of this effort. Approximately 90 percent of traffic accidents result from human error, generally related to fatigue, inattentive driving and excessive speed. [3] Automated Highway Systems will assist the driver and help reduce/eliminate human error accidents. In the GYRITS corridor, it is expected that collision avoidance systems with Information Assistance will help reduce the frequency of accidents while the advancement to Control Assistance will help reduce the rate and severity of crashes. If fully automated vehicles were provided on rural two-lane uncontrolled access highways, crashes could be eliminated. With an evolutionary deployment AHS can provide the rural traveler with:

- safer travel;
- more efficient travel;
- environmental benefits;
- additional mobility for the aging rural population; and
- reduced insurance rates due to the reduction in accident frequency and severity.

INSTITUTIONAL ISSUES

Probably the most prohibiting aspect of deploying an Automated Highway System (AHS) is the challenges presented to the state and local transportation providers. These two entities will likely inherit responsibilities related to maintaining and deploying AHS on the infrastructure within their jurisdictions. Furthermore, any testing or evaluating of AHS will likely be performed on state and local right-of-way. When the transportation network encompasses multiple jurisdictions, as this project does, the challenges are greater.

It is important that this study investigate the impacts of institutional issues as they apply to the rural community, and specifically, the GYRITS corridor. This section investigates the general issues and concerns that affect the successful development of AHS in the GYRITS corridor. Typical questions and concerns are:

- How will agencies procure AHS?
- Who will pay capital startup costs?
- Who will maintain and operate the system?
- Who will absorb possible liability claims?
- How are privacy issues dealt with?
- How will local agencies handle the technical demands?
- How is user acceptance established?
- Will the system be reliable?
- How will the new technology integrate with current state strategic plans?

- How will AHS affect the environment?
- Could public-private partnerships be successful?

Once these concerns have been isolated, they can be manageably addressed through outreach efforts to local governmental agencies and public stakeholders. Ultimately, both groups will be AHS users. Champions can be identified from each group who can help facilitate the maturation of AHS in pursuit of the AHS long-term goals and vision. Some public agencies are hesitant to get involved; the envisioned AHS system may be perceived as too futuristic. This is especially true in rural environments where agencies typically mitigate roadway problems using "low-tech, low-risk" solutions. Involving the rural transportation providers early in the planning, testing and evaluation phases will help promote the effectiveness of AHS, develop champions and achieve user buy-in. An incremental deployment strategy will help demonstrate early, visible, quantifiable safety benefits for potential users.

GENERAL ISSUES

AHS is a long-term, futuristic concept with the objective of developing autonomous vehicles, particularly in urban regions. Much of the technological know-how to make this futuristic concept a reality exists today. Near-term applications can be augmented to synergistically attain the ultimate AHS goal.

Challenges that may impede the deployment of AHS are institutional in nature. These include:

- legal implications;
- public acceptance;
- procurement procedures;
- funding;
- operation and maintenance responsibility;
- privacy issues;
- environmental impacts;
- societal issues and
- jurisdictional coordination.

All of these issues are concurrent problems in the rural and urban environments. However, some of these issues pose a greater challenge in the rural environment, creating disinterest and disincentive to commit agency resources.

Legal Issues

The legal concerns of the urban and rural environment are quite comparable when approaching the issue from the transportation provider perspective. The salient concerns of the transportation providers are how to mitigate the impeding legal ramifications of transferring vehicle control from the driver to the infrastructure. The goal of AHS is to assist and eventually remove the driver from the decision making process. Consequently, some party other than the driver may be responsible if an accident occurs.

Liability

One of the principal concerns transportation providers have when installing safety hardware on their roadway is liability. The governing laws are typically known as tort liability laws. The definition of tort liability is:

- **Tort –** A civil wrong or injury committed to a person or a person's property. It is an act or a failure to act that gives rise to a legal obligation, enforceable by a civil court, to pay money damages to those who suffer damage. [7]
- **Liability –** An obligation by law to be responsible for an activity or action. A liability is a court-enforceable duty of a person or entity (city, township, state, or private corporation). [7]

There are two categories of tort law: (1) injury law and (2) damage law. Most tort laws are developed and enforced at the state level, with differing sets of governing laws. Most states have tort compensations limits. Idaho, Montana and Wyoming all have tort limits that cap the amount of compensation per claim against the state. These limits are as follows:

- **Montana** $750,000 per claim and $1.5 million per occurrence.
- **Idaho** $500,000 per occurrence.
- **Wyoming** $250,000 per claim and $500,000 per occurrence.

State and local transportation providers are responsible for providing "reasonably safe highways". Most courts use the following definition of this responsibility:

> "Persons using highways, streets and sidewalks are entitled to have them maintained in a reasonably safe conditions for travel. One traveling on a highway is entitled to assume that his way is reasonably safe, and although a person is required to use reasonable care for his own safety, he is neither required nor expected to search for obstructions or dangers." [7]

Most transportation providers are concerned with areas termed "high-risk." High-risk areas typically have a potential for high frequencies of accidents. The following items are considered high-risk:

- work zones;
- signs, signals and pavement markings;
- clear zones;
- structures;
- guard rails; and
- intersections.

Transportation providers may consider AHS high-risk, particularly during the initial stages of demonstration and evaluation. During the initial development of AHS, much of the technology will be infrastructure based, placing much of the responsibility on the local transportation provider. As AHS matures and becomes more regional in scope, AHS technologies will shift from infrastructure based to vehicle based, reducing the responsibility of the transportation provider.

AHS is intended to enhance highway safety; thus liability claims in the aggregate should reduce. Legal issues may be mitigated at the legislative level by adjusting tort liability compensation levels or instituting individual state "sovereign immunity" laws that protect transportation providers from unreasonable liability claims.

Public Acceptance

Public acceptance may prove to be more of a barrier in the rural environment than in the urban environment. It is human nature to resist change and fear what is not fully understood. Historically, urban areas have been at the forefront, demonstrating and deploying components of advanced transportation technologies. Consequently, urban users have been exposed to new transportation technologies and may be more adaptable to the continued growth of AHS.

Rural transportation providers have been more reluctant to expand their transportation "toolbox" to include AHS applications, due to lack of financial and technical resources. The rural driver may be resistant without education and quantifiable, tangible travel and safety benefits.

Procurement Procedures

Procurement of advanced transportation technologies presents another difference between urban and rural transportation providers. Most urban transportation systems have reached or exceeded their capacity; transportation providers have been searching for ways to enhance their transportation capacity with AHS applications. These urban agencies typically have large planning and procurement departments and financial resources.

Rural agencies generally have little to no financial resources dedicated to advanced transportation technologies. Rural transportation agencies have vast transportation networks to maintain with limited economic resources. Consequently, rural agencies seek low-cost, low-tech, and low-risk near-term solutions to provide an adequate level of service to their customers.

Funding

Most rural transportation providers operate on limited budgets with little to no funds set aside for the development of AHS. Many rural agencies rely on volunteers to perform public safety functions. Rural agencies' poor economy is explained through their vast highway system coupled with their low populations and consequent small tax base. Much of the federal funding allocated to states is a reflection of the state's population.

Rural areas may be an ideal testbed for the effectiveness of public/private partnerships. The current economy may not permit rural transportation providers to deploy AHS. The private sector may supplement through both financial resources and technical sophistication unavailable in the public sector.

Operation and Maintenance Responsibility

Operation and maintenance is another issue impacting rural transportation providers more than urban transportation providers, given current funding levels and technical support. It is speculated that private or federal agencies will be the primary participants in early AHS deployment efforts, especially during testing and evaluation. State agencies would assume operation and maintenance responsibilities once the system is functional. [8] The critical question is - will rural transportation agencies have the financial and technical resources to assume operation and maintenance responsibilities? Currently, they do not possess the financial or technical means; it is doubtful that the future will bring about significant change.

Privacy Issues

Privacy issues affect rural and urban transportation providers equally. Standards and guidelines should be developed defining the control and use of motorist-related data gathered through AHS. Standards and guidelines should address individual and vehicle identification, storage and access of the information, and any secondary uses of the information. Proper standards and guidelines will help to foster public acceptance.

Environmental Impacts

Generic issues within this category that affect both the rural and urban environment include air quality, energy and resource conservation. Aesthetic issues may capture more national attention in the rural environment given that most rural areas host many national parks, national forests and recreational centers.

Aesthetic issues may provide an even greater impact to this study due to the fact that it encompasses a treasure of natural resources, two national parks, several national forests and hundreds of campgrounds.

Societal Issues

Societal issues will impact both the rural and urban sectors to different degrees. Societal issues will impact community mobility, local economy, land use, social equity and other transportation issues. The gamut of impact will vary depending on community development goals or master plans.

Jurisdictional Coordination

Jurisdictional coordination poses a hurdle for both rural and urban transportation providers. Roadway jurisdiction is fragmented between state and local agencies. Any decision making process may involve governors, mayors, state legislatures, city councils, and local transportation coordinating committees. Furthermore, rural communities do not have Metropolitan Planning Organizations (MPO). Guidelines should be developed to mitigate jurisdictional conflicts and streamline coordination between the many agencies involved.

The roadway network for this study encompasses over 500 miles of roadway in three states and two national parks. The chore of uniting the multiple jurisdictions has thus far proven challenging. The Greater Yellowstone Steering Committee, who oversee the Greater Yellowstone Rural ITS Corridor project, may provide the multi-jurisdictional organizational structure needed to carry these initial AHS efforts to fruition. Thus, coordinating the Greater Yellowstone Rural ITS Corridor project and this study will help develop a seamless rural architecture and provide a tangible product.

PROJECT PARTNER CONCERNS

This study facilitated an early discussion of institutional issues of concern to the project partners. Surveys were distributed to provided partners with a forum to voice their concerns. The findings are summarized below.

Montana Department of Transportation (MDT)

The Montana Department of Transportation (MDT) was unable to respond to the questionnaire. However, MDT tends to be proactive and is investigating ways to guide snowplows through the GYRITS corridor in cooperation with 3M.

Idaho Department of Transportation (IDT)

The Idaho Department of Transportation (IDT) is interested in what AHS technology can do, but is hesitant to get directly involved. IDT may not completely understand the AHS concept. Further outreach and education may solicit IDT's participation.

Planning and Outreach

To implement AHS in Idaho, all state and local transportation providers need to be involved, including state and local police. IDT currently has a transportation improvement plan that includes advanced transportation systems; information related to specific applications was unavailable. The IDT planning office would monitor all AHS research-related activities on their highways. IDT favors an evolutionary approach to slowly achieve public support.

Demonstrating, Deployment and Operation

IDT's desire is that AHS deployment be simple and incremental. The effectiveness of the technology must be proven to the local transportation providers and users. The pursuit of advanced technologies such as AHS is part of Idaho's state transportation improvement plan. However, it is premature for them to begin deploying any AHS technologies. IDT is willing to train appropriate personnel to maintain and operate any AHS. If AHS deployment were made possible through the continuation of this study, IDT would be willing to operate and maintain the system.

Financing and Legal Issues

Currently, IDT is not willing to commit funds to deploy any advanced transportation technologies until the systems are thoroughly proven and cost-effective.

Wyoming Department of Transportation (WyDOT)

The Wyoming Department of Transportation (WyDOT), similar to IDT, has adopted a "wait-and-see" approach before committing to AHS. While WyDOT wants to remain an involved player in AHS and ITS activities, they are hesitant to demonstrate the benefits of AHS on their transportation system. Outreach efforts may encourage a more intimate involvement from WyDOT.

Planning and Outreach

WyDOT would be the principal agency involved in any planning and deployment of AHS. City involvement may be required if AHS is deployed within their jurisdiction. AHS could be adapted into Wyoming's state transportation plan if WyDOT views AHS as an agency goal or objective. In other words, if the system presents tangible benefits to all users, WyDOT would be interested in incorporating the technology into their transportation "toolbox." The Wyoming Department of Transportation (WyDOT) maintains roads in Wyoming and in Grand Teton National Park; both agencies coordinate and exchange information. However, communication between these two agencies could be improved.

Demonstrating, Deploying and Operation

WyDOT is not proactive in pursuing new and innovative technologies to solve their transportation problems. Limited financial resources may explain their hesitancy to stray from basic maintenance and familiar, conventional countermeasures. However, WyDOT does want to have some level involvement, but prefers to take a wait-and-see approach. WyDOT wants to witness tangible benefits before committing any resources.

Currently, WyDOT would not be willing to deploy AHS in their fleet vehicles. They would prefer to see the technology demonstrated first. WyDOT does not have adequate technical staffing to maintain and operate AHS. They are willing to train their employees if WyDOT deploys an AHS. WyDOT is willing to assume control of an AHS after a "successful" demonstration.

Financing and Legal Issues

WyDOT is willing to financially support AHS if tangible benefits are demonstrated and they decide to adopt the technology as part of their transportation "toolbox." WyDOT would encourage public-private partnerships that would help finance AHS. WyDOT's principal concerns involving technology are system reliability and privacy issues.

Yellowstone National Park (YNP)

Yellowstone National Park (YNP) is very proactive in seeking advanced transportation solutions. Resistance from Park management may be minimal depending on public reaction to AHS requirements and ecological impacts. YNP is ready to move forward toward developing and deploying AHS components for testing and demonstration.

Planning and Outreach

The Department of the Interior is the roadway authority; representing both Yellowstone National Park (YNP) and Grand Teton National Park. A fluent line of communication exists between the Park Managers and their staff.

A review process exists which requires both Park Managers to approve any AHS deployment initiatives. Any AHS proposals that have been accepted by Park management can readily be adapted to their transportation plans. Each of the two national parks have maintenance and planning divisions that would be responsible for monitoring the AHS planning and deployment process.

The Department of the Interior needs a better understanding of what AHS is and what it can do for them. Some of their questions may be answered in this report. However, additional outreach efforts may facilitate better user education and interest.

Demonstrating, Deploying and Operation

Yellowstone National Park would prefer to have a proactive role in the development of AHS. YNP is open to any advanced transportation technologies that will help improve the Park's visitor experience by reducing traffic congestion and reducing motor vehicle accidents.

YNP is very interested in participating in an AHS demonstration project and demonstrating the effectiveness of AHS in their fleet vehicles. They have over 700 vehicles; implementation would depend on system requirements.

If AHS can demonstrate tangible benefits and reliability, Yellowstone National Park would commit to controlling, operating and maintaining the system. Currently the Park maintains radio communication systems and numerous computer systems. With training, the Park's staff should be able to operate and maintain the advanced transportation system. It is premature to measure resistance to installing advanced transportation technologies and equipment in the right-of-way until a system is designed and elements such as location, unit size, and electrical and communication requirements are determined.

Lacking within the YNP jurisdiction is an adequate communication and electrical infrastructure.

Financing and Legal Issues

Yellowstone National Park has no barriers restricting them from fostering private-public partnerships. However, it is too early in the preplanning stage for YNP to predict any financial amount they would be willing to channel toward deploying AHS. It would depend on system reliability and capabilities.

ACCIDENT ANALYSIS

The fundamental objective of AHS is to address the limitations of human-based vehicle systems by:

- warning the driver of potential conflict, thus increasing the time for the driver to react;
- assisting the driver in potential collision situations by partially relieving the driver of the driving task; and
- providing autonomous vehicles.

To effectively determine where AHS technologies would produce the highest level of tangible benefits; traffic accidents for the GYRITS corridor were analyzed at spot locations (microanalysis) and roadway segments (macroanalysis). Safety is of paramount concern in the rural environment. By focusing this study on the safety applications of AHS, a greater acceptance can be achieved from the rural stakeholders. This section describes the accident analysis methodology and results.

To target high benefit areas, traffic accidents for the corridor were analyzed. A total of 2,538 accidents were analyzed for a three-year period: 1993 to 1995 for Montana and Idaho and 1994 to1996 for Wyoming. These accidents resulted in an economic impact to society of $131,242,436. Accidents within the city limits of Jackson, Wyoming and Livingston, Montana were ignored to focus on typical rural environments. The accidents that occurred within the city limits of these small cities paralleled accidents typical of large urban traffic centers caused by stop/go and merge/diverge traffic.

Accident rates were determined for each mile or half-mile segment along the corridor. It should be noted that Yellowstone National Park segments varied from 0 to 6 miles because of the node/sheet data format. High accident areas (i.e., locations in the corridor with a statistical over-representation of accidents when compared to the volume of traffic traversing the road) are referred to as “atypical” locations.

Severity rates were also determined for each mile or half-mile segment. Potential atypical accident locations were chosen on the basis of severity in addition to accident frequency.

High accident and severity rates were used as indicators to target areas where accidents were occurring as the result of recurring contributing circumstances (i.e., accident trends). Areas experiencing accident trends were thought to have the best chance of maximizing benefits from AVCSS safety countermeasures.

Micro Accident Analysis

Accident rates were determined for each half-mile segment using a floating referencing system. Specifically, rates were determined on a half-mile basis, advancing along the route every tenth-mile. Additionally, severity rates were determined for each floating half-mile segment. Based on these rates, potential atypical accident locations were chosen for further study. These locations were analyzed to determine what, if any, accident trend(s) existed. Segments exhibiting trends were thought to have the best chance of maximizing benefits from AHS applications.

Accident Rates

Accident locations were identified as “atypical” if their accident rate showed a statistical over-representation of accidents. Over-representation was defined as being two standard deviations from the mean accident rate. Accident rates were determined for each half-mile segment using a rate per million vehicle-miles traveled (R/MVMT). Average annual daily traffic (AADT) from the nearest traffic counting station was estimated by averaging the AADT over the three-year timeframe. The accident rates for all segments were compared along each route. Routes were compared by alignment (i.e., level, rolling or mountainous). The objective of this analysis was to determine the best site for further research or operational testing and to quantify corridor challenges; not necessarily to determine the most accident-prone locations in the corridor.

Severity Rates

Severity rates were calculated in the same manner as the accident rates, except that accidents were weighted based on their severity. Fatalities were weighted by a factor of eight, injuries were weighted by a factor of three, and property damage only accidents were weighted by a factor of one. These weighting factors were taken from “Traffic and Highway Engineering.” [9] A factor of eight was used for fatalities instead of the suggested factor of 12 to prevent random singular fatalities from skewing the severity rates in particular half-mile segments. Severity rates did not yield significantly different results from the atypical locations identified by the accident rates.

Macro Accident Analysis

Accident data, collected from Idaho, Montana, Wyoming and Yellowstone National Park, was standardized and assimilated to allow for spatial representation using Geographic Information Systems (GIS). Accident data was depicted both at spot locations and continuously along the roadway depending on the frequency and characteristics of the accidents.

Before examining the accidents to determine geographic areas of focus, the corridor was separated into 18 major segments based on: changes in geometric alignment, city limits, mountainous areas, and state lines. Although state lines were assumed to be transparent, segments were broken along state lines for ease of analysis. The segment types included rural-flat, rural-mountainous, urban (within city limits), suburban (directly outside city limits until change in cross section), and semi-mountainous (only in Yellowstone National Park). The number of accidents for each accident trend, identified previously for half-mile locations, was determined for each of the 18 major segments. A geographic area was identified for focus if the area possessed two of the three following criteria:

- a high percentage of the accidents in the area had a common trend;
- a high number of the accidents in the area had the same common trend; and/or
- half-mile atypical locations existed with the same trend.

Stratified Accident Analysis

The previous accident analyses considered the entire accident sample when determining potential AHS deployment locations. Targeting smaller groups within this sample may actually help to accelerate NAHSC’s near-term deployment goals. Hence, two smaller groups were separated out for further analysis: (1) commercial vehicles and (2) in-state/out-of-state drivers.

Commercial Vehicles

Commercial vehicles or heavy vehicles were targeted because they provide a smaller market group and market penetration may be fostered more easily. Heavy vehicle accidents were sorted and stratified with the following objectives:

- to determine the characteristics of crashes involving heavy vehicles;
- to determine if heavy vehicles are over-represented in crashes in the corridor;
- to identify causal factors for heavy vehicles; and
- to link causal factors to trends.

With the stratified accident data, a microanalysis and macroanalysis were performed to characterize and geographically locate trends and challenges related to heavy vehicles.

Traveler Origin

Traveler origin information was examined to determine if accidents within the corridor were a product of unfamiliar out-of-state travelers or local residents. It was hypothesized that this information would be helpful in determining target groups for early operational testing and evaluation. Specifically, if the origin data indicated a statistical accident over-representation of either of the two aforementioned groups, this group could be isolated and targeted for various AVCSS applications.

The information presented here represents only vehicles involved in accidents within the corridor and does not represent the percent of total out-of-state/local travelers traversing the highways. The data was stratified by state and was only reduced to a macro level; the low frequency of accidents at most locations would not yield statistically valid findings in a microanalysis. The accident data from Idaho and Wyoming allowed for the determination of the causing party. Hence, each accident could be traced to a single in-state or out-of-state party; the proportion of in-state travelers and out-of-state travelers involved in an accident summed to one. Montana’s accident data did not reflect causing party information but rather accident involvement. Hence, the proportion of in-state travelers and out-of-state travelers summed too greater than one.

BENEFIT-COST ANALYSIS

This analysis considered system costs to local transportation providers; it was assumed that the costs for vehicle upgrades would be distributed to the consumer. Specifically, this analysis assumed transportation providers would only be responsible for the purchase and installation of the magnetic lateral warning and guidance systems discussed previously.

The benefit-cost analysis was performed on a regional basis to better determine the magnitude of AHS impacts in the GYRITS corridor. The benefit-cost analysis was also performed separately on each corridor section, where the roadway segments were separated and categorized by roadway type. The benefit-cost analysis consequently indicated the relative magnitude of benefits experienced along particular sections of roadway. The identification of relative impacts among corridor segments was intended to assist in the ranking of projects for field operational tests. The sites were analyzed and ranked only if a feasible countermeasure existed – either advanced or traditional.

Assumptions

The objective of this analysis was not to determine the performance of AHS at the technical or institutional level. The analysis assumes that the technologies perform as anticipated and as indicated in the literature.

Safety benefits resulting from AHS were difficult to predict for two reasons: (1) system reliability is unproven and (2) success relies often on driver response. Accident reduction factors (ARFs) were adopted from previous research or were assumed by hypothesizing that a certain percentage, less than 100 percent, of human error accidents could be reduced.

For the regional analysis, it was assumed that AHS technologies would be helpful in mitigating the following types of accidents, categorized by longitudinal assistance, lateral assistance, intersection assistance and other.

- rear ends

Longitudinal Assistance

- animal-vehicle conflicts
- following too close
- motor vehicle parked along roadside
- head on collisions

Lateral Assistance

- sideswipes
- overturned (after leaving the roadway)
- ran off road
- struck another motor vehicle in transit
- struck fixed object
- struck guard rail
- struck ditch
- struck cut slope
- struck tree
- struck sign
- struck fill slope
- not in right lane
-
- disregard traffic control

Intersection Assistance

- failure too yield
- inattentive

Other

- traveling too fast for conditions
- fell asleep
- illegal lane change
- illegal backing maneuver
- fail to signal
- over corrected
- improper pass

The appropriate ARFs were applied to each functional classification to determine the reduction in accidents and ultimately the resulting benefits. The ARFs used in this analysis were adopted from Yokota, Tokuyama and Ueda. [10] It is important to remember that the ARFs and consequent benefits from AVCSS are theoretical values. Field operational testing is required to confirm the accuracy of the theoretical ARFs. The ARFs applied regionally by each evolutionary stage are summarized in Table 1. The ARFs applied at spot locations are summarized in Table 2. In each case, the ARF value represents the proportion that accidents are reduced. For example, an ARF of 0.20 indicates that accidents are predicted to reduce by 20 percent.

Table 1 – Regional Accident Reduction Factors

System	Accident Reduction Factors		
	Information Assistance	**Control Assistance**	**Full Automation**
Longitudinal Assistance	0.65	1.0*	1.0
Lateral Assistance	0.30	0.85	1.0
Intersection Assistance	0.75	0.90	1.0
Other	0.30	0.85	1.0

* 0.90 used for Animal-vehicle Collisions

Table 2 - Spot Location Accident Reduction Factors

System	Accident Reduction Factors
Friction/ice detection and warning systems	0.45
Static ice warning sign	0.23 [16]
Intersection crossing detection	0.50 [17]
Animal-vehicle collision warning system	0.20
Dynamic variable message sign (speed advisory)	0.75
Chevrons	0.25

The friction/ice detection and warning system accident reduction factor (0.45) was derived by assuming that half of the 90 percent human error accidents would be eliminated. [3] With this system, it is still largely to the driver to decide on an appropriate response. The intersection crossing detection system ARF (0.50) was adopted from an FHWA report 93-080. [11] The animal-vehicle collision warning system ARF (0.20) was assumed to be low; many vehicles may not be equipped with radar detection devices and the driver is once again responsible for the final response. The dynamic variable message sign (speed advisory) ARF (0.75) was assumed to be high; the system is proving very successful in field applications (i.e., Eisenhower Tunnel in Colorado). The ARFs for the traditional applications - warning signs (0.23) and chevrons (0.25) - were taken from Agent, Stamatiadis and Jones. [12]

CANDIDATE FIELD OPERATIONAL TESTS

Field operational tests (FOTs) encourage support for the deployment of advanced transportation technologies. Through field operational tests, “proof of technology” can be demonstrated. The proliferation of AHS will not emerge until components of AHS are successfully demonstrated. Through the successful demonstration of “showcase” projects, AHS can win the support of both transportation providers and users. Automated Highway Systems must demonstrate tangible safety benefits to support the theoretical accident reduction claims made by researchers.

This section recommends several areas for possible early field operational testing with low-level AVCSS technology. The intent of the recommended FOTs is to provide the driver with more information and more time to react. It is hypothesized that this additional information and time will help the driver avoid many collisions. Through the benefit-cost analysis, sites with the greatest potential were selected for AHS technology deployment in continuing efforts. The candidate sites include:

Friction/Ice Detection and Warning System

- Montana U.S. Highway 191, milepost 9.900 to 10.011 and 10.000 to 11.000;

Intersection Crossing Detection

- Idaho U.S. Highway 26, milepost 336.000 to 337.000;
- Idaho U.S. Highway 20, milepost 317.000 to 318.000 and 311.000 to 312.000;

Animal-Vehicle Collision Avoidance

- Wyoming U.S. Highway 89, milepost 160.000 to 161.000 and 189.000 to 190.000;

Horizontal Curve Speed Advisory

- Wyoming U.S. Highway 89, milepost 127.000 to 128.000.

These sites were estimated to have the greatest potential for improving safety in the GYRITS corridor through the deployment of AHS. However, before any of the above sites are designated as FOTs, further investigation of the police accident records, the site, and the transportation providers' perspectives needs to occur.

This analysis also helped identify segments of roadway within the corridor that would realize the greatest benefits from deployment of AVCSS, which is a reflection of accident trends in varying locations.

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