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Intelligent Vehicle Initiative
Specialty Vehicle Field Operational Test

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The objectives of this assessment are; to estimate the potential benefits of the Driver Assist System (DAS) for winter maintenance activities; to assess and describe the potential market for the DAS technologies as well as the approximate price point at which the system would be commercially viable, and; to determine where, geographically, DAS technology would be most cost-effective.

The findings presented in this report are based on information that was gathered through an extensive literature review and a series of interviews conducted with state and county maintenance engineers and supervisors, equipment vendors, system integrators, equipment procurement personnel, and individuals involved in various aspects of risk management for transportation agencies. The expected benefits of DAS on winter maintenance vehicles include the reduction in travel times, less disruption to routine travel behavior and improved safety for the traveling public during and immediately following winter weather events. Winter weather events have a substantial impact on traveler safety, economic activity, and transportation maintenance costs.

The functional objective of the DAS is to provide snowplow operators a means to operate snowplows during periods of low visibility. The study assesses the issue of visibility from the perspective of both snowplow operators and maintenance engineers.

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Evaluation Report Volume 2:
Benefit Analysis
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Specialty Vehicle Field Operational Test

FINAL REPORT

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EXECUTIVE SUMMARY

A primary goal of the Federal Highway Administration's (FHWA) Intelligent Vehicle Initiative program is to "accelerate deployment of advanced technologies which enhance safety by providing a substantial level of understanding of risks of all types including, but not limited to, marketing, operating, crash, and liability risks, thus reducing deployment risks." Toward this end, the objectives of this assessment are to estimate the potential benefits of a Driver Assist System (DAS) for winter maintenance activities, to assess and describe the potential market for the DAS technologies as well as the approximate price point at which the system would be commercially viable and to determine where geographically DAS technology would be most cost-effective.

The findings presented in this report are based on information that was gathered through an extensive literature review and a series of interviews. Interviews were conducted with state and county maintenance engineers and supervisors, equipment vendors, system integrators, equipment procurement personnel, and individuals involved in various aspects of risk management for transportation agencies.

POTENTIAL SAFETY AND MONETARY BENEFITS OF THE DRIVER ASSIST SYSTEM FOR WINTER MAINTENANCE VEHICLES

The expected benefits of a DAS on winter maintenance vehicles include the reduction in travel times, less disruption to routine travel behavior, and improved safety for the traveling public during and immediately following winter weather events. The impact of winter weather on traveler safety, public agency budgets, and regional economies is well documented. As part of this assessment, a literature review of related studies and reports was performed. Estimated impacts of winter weather on surface transportation are as follows:

Safety: The FHWA estimates that adverse weather conditions cause 7,000 traffic fatalities and 450,000 injuries annually.

Maintenance Costs: State and local transportation agencies spend approximately $1.8 billion annually on snow and ice control.

Economic Impact: The FHWA estimates that a one-day highway shutdown caused by snow in a major metropolitan area would cost $15 million to $76 million in lost time, productivity, and wages.

Because winter weather events have a substantial impact on traveler safety, economic activity, and transportation maintenance costs, even incremental improvements to the efficiency of snowplow operations will potentially yield significant economic and safety benefits.

THE MARKET FOR DRIVER ASSIST SYSTEMS ON WINTER MAINTENANCE VEHICLES

The functional objective of the DAS is to provide snowplow operators a means to operate snowplows during periods of low visibility. Ultimately, the success of the DAS will depend on the value placed on it by those responsible for procurement of snowplow equipment. The study assesses the issue of visibility from the perspective of both snowplow operators and maintenance engineers.

Montana State University's Western Transportation Institute (WTI) recently completed a survey of 992 snowplow operators from Wyoming, Montana, North Dakota, and Idaho; all states with relatively frequent occurrence of blizzard conditions. One of the objectives of the survey was to assess the challenges faced while clearing rural roadways of snow and ice. The report summarizes responses to survey questions related to visibility.

WTI's survey of snowplow operators suggests that low visibility is an issue for snowplow operators in these states. Over half (58%) of the survey respondents indicated that during the worst snowstorm of the last winter season, they could recall having lost complete sight of the roadway and shoulders in front of their snowplow more than ten times, and 20% of the respondents indicated it was for a period of more than 21 seconds. During an average snowstorm almost 30% of the drivers indicated they lost sight of the roadway and shoulders between four and six times. **The majority (83%) of the operators indicated that if a device existed that would allow drivers to determine lane position while plowing, it would be very useful.**

Interviews were also conducted with maintenance personnel, snowplow equipment vendors, and system integrators to develop a better understanding of the snowplow equipment market and to assess how the functionality of the DAS would be received by those that make procurement decisions.

Each year, an estimated 12,000 snowplows are purchased in the United States. Reported costs for fully equipped vehicles range from $85,000 to $140,000. Maintenance engineers and supervisors from various regions within the Snow Belt were interviewed to gather their impressions on the potential for DAS technology. Differences in the perception of the DAS can be attributed, in part, to the wind conditions and traffic characteristics of the regions being maintained. Noting that there are differences within each of the following categories, the response summaries are broken down by the characteristics of the various regions: infrequent low visibility, frequent low visibility-lower traffic volumes, and frequent low visibility-higher traffic volumes.

- In areas where low visibility is rarely a concern, the DAS technology would not get high priority, would be deployed on a limited basis, and purchase would depend largely on affordability.

- In low traffic volume areas where low visibility conditions occur frequently, the DAS would not alter winter maintenance patterns, but would be considered quite valuable on those occasions when winter maintenance vehicles assist in emergency rescue.

- In high traffic volume areas with frequent low visibility conditions, snowplow operations are likely to continue through poor travel conditions. The DAS would allow the snowplows to operate at higher speeds, improving the efficiency of snow removal. The DAS would also improve snowplow driver safety.

THE IMPACT OF SNOW AND WIND ON VISIBILITY

Frequent occurrence of low-visibility during winter weather events is, perhaps, the best single predictor of where the DAS would be highly valued. Visibility, however, is not a category that is tracked by the National Weather Service. The interview results of this study indicate that visibility is affected as much by wind (at the road surface) as it is by the amount of precipitation.

Figure A illustrates areas in which average winter wind is equal to or greater than 9.8 MPH and average snowfall is equal to or greater than 18 inches.

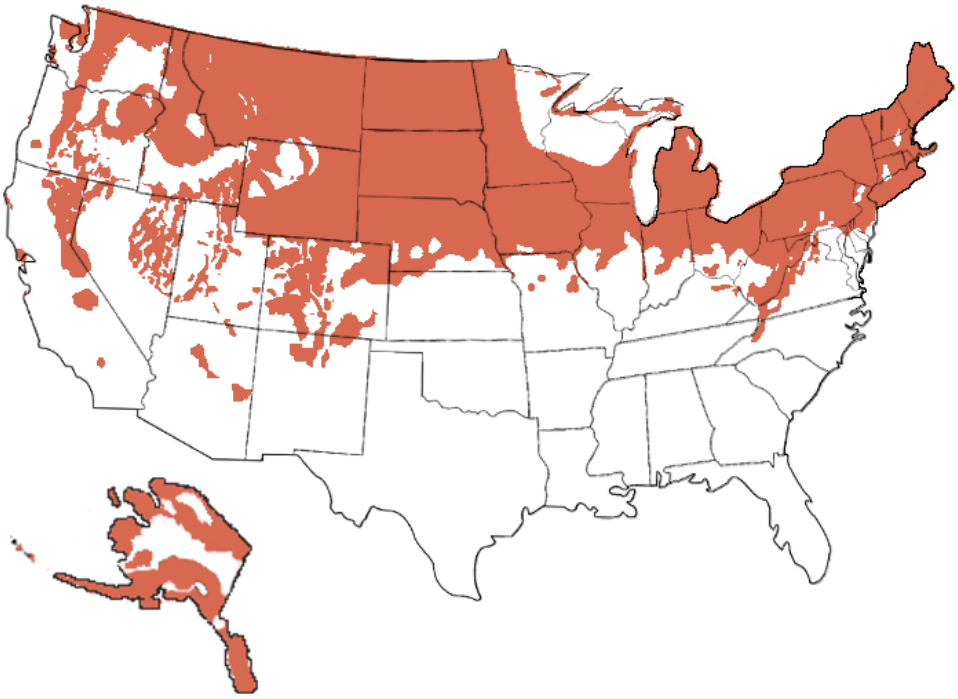

Figure A. Combined Winter Wind (average > 9.8 MPH) and Snowfall (> 24"Annually)

The areas shown in red would likely benefit the most from snowplows equipped with the DAS. Within these areas, transportation agencies responsible for the maintenance of high volume roads would be the best candidates for early deployment.

CHAPTER 1
INTRODUCTION

A primary goal of the FHWA's Intelligent Vehicle Initiative program is to "accelerate deployment of advanced technologies which enhance safety by providing a substantial level of understanding of risks of all types including, but not limited to, marketing, operating, crash, and liability risks, thus reducing deployment risks."

The objective of this component of the study is to provide context for and expand upon the quantitative findings of the field operational test evaluation. More specifically, the objectives of this assessment are to:

- Estimate the potential benefits of the Driver Assist System (DAS) for winter maintenance activities
- Assess and describe the potential market for the DAS technologies currently being tested on winter maintenance vehicles and public safety vehicles
- Determine the price point at which the system, as tested, would be considered an attractive option by those involved in the procurement of snowplows and snowplow equipment
- Describe how weather affects visibility and where the DAS technology would be most useful.

The report is organized into the following sections:

2.0 Potential Benefits of the Technology

If successful, one of the primary benefits of the DAS will be to improve the efficiency of winter road maintenance activities. This section examines how winter weather affects the surface transportation system. It is an overview of the impact of winter weather on traveler safety, the cost of maintenance activities, and in a broader sense, the impact on the economy.

Source: Literature review and agency interviews.

3.0 Visibility from the Perspective of the Operator

The functional objective of the DAS is to provide snowplow operators a means to operate snowplows during periods of low visibility. In assessing the potential benefits of the DAS for winter maintenance, this study begins by gauging the issue of visibility from the perspective of the end user. Montana State University's Western Transportation Institute recently completed a survey of snowplow operators from the states of Wyoming, Montana, North Dakota, and Idaho. One of the objectives of the survey was to assess the challenges faced while clearing rural roadways of snow and ice. This section summarizes responses to survey questions related to visibility. (The following section incorporates the perspective of state transportation agency district maintenance supervisors and county engineers on the issue of visibility.)

Source: Western Transportation Institute's Snowplow Operators Survey.

4.0 The Snowplow Equipment Market

Ultimately, the success of the DAS will depend on the value placed on it by those responsible for procurement of snowplow equipment. Interviews were conducted with fourteen maintenance engineers, maintenance supervisors, equipment engineers, snowplow equipment vendors, and system integrators to develop a better understanding of the snowplow equipment market and to assess how the functionality of the DAS would be received by those that make procurement decisions.

Source: Maintenance personnel and equipment vendor interviews

5.0 The Impact of Snow (Presence and Type) and Surface Level Wind on Visibility

Visibility is not a weather condition that is tracked over time. Through the interviews, maintenance personnel have indicated that the frequency and strength of the wind, and the characteristics of the snow have as much if not more impact on visibility than do snowfall amounts. This section summarizes their comments and identifies where in North America visibility would be expected to be an issue based on the presence of strong winds and significant snowfall during the winter months.

Source: Maintenance personnel interviews and literature review.

6.0 Marketing Factors for the Driver Assist System

Snowplow equipment vendors, a system developer, and firms involved in manufacturing and marketing global positioning systems for winter maintenance vehicles were interviewed to identify the factors that would be considered in determining the market potential of the DAS technology. This section summarizes their responses.

Source: *Equipment vendor interviews*.

7.0 Conclusion

The report concludes with a summary of findings and a suggested strategy for future deployment efforts.

CHAPTER 2
POTENTIAL BENEFITS OF THE TECHNOLOGY

Driver Assist Systems will potentially improve the efficiency of snow removal operations by allowing snowplows to operate during periods of low visibility. The primary benefits include the reduction in travel times, less disruption to routine travel behavior and improved safety for the traveling public during and immediately following winter-weather events. Initially, other expected benefits included reductions in snowplow crashes and in property damage resulting from poor visibility. However, preliminary interviews with maintenance personnel suggest that the costs associated with snowplow crashes and the occurrence of property damage represent only a small percentage of the overall operating costs.

Because winter weather events have a substantial impact on traveler safety, economic activity, and transportation maintenance costs, even small improvements to the efficiency of snowplow operations will potentially yield significant economic and safety benefits.

2.1 TRAVELER SAFETY

The FHWA estimates that adverse weather conditions cause 7,000 traffic fatalities and 450,000 injuries annually [1]. The National Highway Traffic Safety Administration (NHTSA) reports that in 2000, 39% of all crashes reported to police occurred in reduced visibility conditions (including non-daylight and bad weather) [2]. NHTSA determined this using information from its Final Analysis Reporting System (FARS) and General Estimate System (GES) databases, which store samplings of information from police reports sent to the agency by each state. Without addressing causality, the agency also determined that 41% of all fatal crashes occur in reduced visibility conditions[2]. Considering that there is less traffic during nighttime and during periods of inclement weather, a disproportionate number of accidents occur in reduced visibility conditions.

Iowa State University compared crash rates on freeways in Iowa during storms and non-storm periods [3]. They examined traffic volume and crash data at seven interstate areas in Iowa and compared the data from defined winter storm events with data from winter non-storm times. The crash rate for the freeways during storm winter periods is 5.86 crashes per million-vehicle-kilometer (mvkm) traveled, compared with a crash rate of 0.41 crashes per mvkm traveled during non-storm hours. Over a three-year span, crash rates for the roads included in the study were 1,300 percent higher during the shorter duration winter storm events than the longer periods of clear weather.

2.2 ROAD MAINTENANCE COSTS

According to the FHWA, state and local transportation agencies spend approximately $1.8 billion annually on snow and ice control. Public funds spent on cleaning up after snowstorms is money that is often diverted from other uses such as education, law enforcement, and investment in infrastructure.

A study by Duane Smith of Iowa State University concluded that snow and ice control activities cost the Iowa Department of Transportation (Iowa DOT) $70,000 per hour [4]. He broke the costs into material ($35,000 per hour), labor ($19,000 per hour), and equipment ($16,000 per hour). These figures were based on Iowa DOT 1996 budget figures, and assume that the entire state of Iowa is involved in removal and treatment of snow during a winter storm.

Another study estimated that, in January of 2000, a particularly severe three-day storm in North Carolina (20" of snow) cost $15 million to clear roads [5]. This clean up included assistance from the National Guard. (Costs incurred by the National Guard during emergency deployment are reimbursed through their Public Assistance program. Seventy-five percent of the costs are covered through the federal budget and 25% from local sources.)

2.3 ECONOMIC IMPACT

The impact of winter weather related road closures on economic activity is much greater than the cost of snow removal to transportation agencies. Although some economic activities are only delayed by snowstorms, other activities are permanently lost. Lost days of operations for gas stations, restaurants and the loss of wages (and payroll taxes) for those that are temporarily put out of work, are typically not recaptured and can have a significant ripple effect on an entire regional economy.

The FHWA estimates that a one-day highway shutdown caused by snow in a major metropolitan area would cost between $15 million to $76 million in lost time, productivity and wages [6].

Consumer economist Mike Walden of North Carolina State University estimated that a major winter storm in North Carolina costs businesses $164 million per day in lost sales and economic activity throughout the state.

Standard and Poor's Data Resources Incorporated (DRI), in a study for the Salt Institute, estimated that a one-day shutdown of the entire province of Ontario due to a snowstorm would be $148 million (US) [7]. The losses included $80 million in lost wages, $34 million in lost taxes, and $34 million in lost retail sales. DRI used government statistics for hourly wages, taxes, and lost sales to estimate costs.

In another study, DRI examined the economic costs that would be incurred if all roads were closed in 12 states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New Your, New Jersey, Ohio, Pennsylvania, Virginia, and Wisconsin [8]. The study concluded that a complete closure would result in $518 million in lost taxes, $600 billion in lost retail sales, and $1.4 billion in unearned wages for each day. Individual state losses varied from $36 million per day (Iowa) to $325 million per day (New York). The lost wages alone are more than the annual cost of snow maintenance in the twelve states. These studies do not address the non-economic costs of road closure to travelers, such as lost time or health-related costs. While the shutdown of an entire state or province is unlikely, these studies illustrate the importance of maintaining open roads.

A more likely scenario is closure of a specific road due to winter weather. The Minnesota Department of Transportation estimates that a 3-hour winter weather related traffic delay on Interstate 90 in District 7 would incur economic costs to passenger vehicles and commercial trucks of between $36,385 and $77,911, depending on the volume of traffic [9]. To arrive at this cost estimate, Mn/DOT utilized a delay cost model developed by the Texas Transportation Institute, utilizing the observed Average Daily Traffic (ADT) and existing capacity.

2.4 LIABILITY

Winter maintenance activities can affect a state's liability in two distinct areas: 1) liability for maintaining snow and ice free roadways, and 2) vehicle liability. By improving the efficiency of snow removal and by improving the snowplow operator's ability to operate safely, it would be expected that the DAS technology would result in decreased exposure to both. However, it appears that the DAS technology would have little if any impact on costs related to liability.

First, there is the issue of keeping the roads clear.

- Minnesota State Statute 3.736, Subdivision 3D gives the state immunity from claims against the state for snow and/or ice on the roadway. The statute reads as follows:

- *"the legislature declares that the state and its employees are not liable for the following losses:*

- *...(d) a loss caused by snow or ice conditions on a highway or public sidewalk that does not abut a publicly owned building or a publicly owned parking lot, except when the condition is affirmatively caused by the negligent acts of a state employee."*

- The State of Michigan does not have a statute providing the same level of immunity. However, it does have a "natural accumulation doctrine" that is based on case-law history. In previous cases, it has been held that the state is not liable for snow or ice that has accumulated naturally.

Second is the liability related to snowplow operations. With a few exceptions, all Minnesota state-owned vehicles share a single insurance rate. Exceptions are made for fleets with higher claim rates. Mn/DOT's snowplow fleet does not fall into this exception category. Therefore, Mn/DOT pays the same premium for its snowplows as it does for their carpool vehicles. As a matter of practice, Mn/DOT pays for smaller property damage claims without formally filing claims with the statewide insurance pool. Although use of DAS may assist Mn/DOT in maintaining current insurance rates for winter maintenance vehicle, it would not result in better rates.

CHAPTER 3
VISIBILITY FROM THE PERSPECTIVE OF THE OPERATOR

Montana State University's Western Transportation Institute performed a needs assessment and cost:benefit analysis for the RoadView™ System. Similar in concept to the DAS, the RoadView™ System consists of lateral lane indication and forward collision warning systems. One of the objectives of the assessment was to determine the challenges faced while clearing rural roadways of snow and ice. A survey was distributed to snowplow operators from the Idaho DOT, Montana DOT, North Dakota DOT, and Wyoming DOT. There were 992 responses to the survey with at least 220 responding from each of the four states. The survey questions were broken down into four sections: 1) equipment characteristics, 2) route characteristics, 3) visibility issues, and 4) demographic information. The following is a brief summary of the demographic information and responses to questions regarding visibility.

As a whole, snowplow operators have considerable experience, are well educated and are computer literate. Respondents averaged 45 years in age and had twelve years experience as snowplow operators. Most of the operators (96%) had completed high school and more than 40% had further college education. Almost half of the respondents (47%) described themselves as having intermediate to advanced levels of computer experience.

The visibility section of the survey was designed to assess visibility issues faced by the snowplow operators. Respondents were asked to estimate on a scale of 1 (never causes poor visibility) to 5 (always causes poor visibility) a series of weather conditions, driving conditions and equipment characteristics. "Snow in combination with wind" (mean score = 4.41) was identified as the greatest factor to poor visibility, followed by "blowing snow" (mean score = 4.26) and "being passed by trucks or buses" (mean score = 4.07). Eighty-six percent of the snowplow operators indicated that the windows of the snowplow iced up, causing reduced visibility at least once during the most recent winter season. The operators indicated that the most important factor when safely operating a snowplow is the ability to see large obstacles such as stranded vehicles. Overall, the operators indicated that the ability to continuously see the roadway in front of them, the ability to see a vehicle approaching from behind, and determining lane position at all times is very important for safely operating a snowplow.

Over half (58%) of the survey participants noted that during the worst snowstorm, they could recall having lost complete sight of the roadway and shoulders in front of their snowplow more than ten times and more than 200 participants indicated it was for a period of over 21 seconds. During an average snowstorm almost 30% of the drivers indicated they lost sight of the roadway and shoulders between four and six times. When asked about the duration of lost sight, the most common response (44%) was between one and four seconds. When asked how often the loss of visibility forced them to stop because they could not determine their position, 52% indicated never, followed by 25% that said they had to stop between one and four times.

The majority (83%) of the operators indicated that if a device existed that would allow drivers to determine lane position while plowing, it would be very useful. However, drivers generally agreed that such a device would not eliminate the need to pull plows under certain

conditions. Two-thirds (66%) of respondents agreed with the statement, “There are times, due to weather conditions, that snowplow operations should be suspended.” When asked to respond to the statement, “Even if there were a system in place that would be able to display the position of snowplow on the road, there would still be times, due to weather conditions, that snowplow operations should be suspended,” 62% agreed.

CHAPTER 4
THE SNOWPLOW EQUIPMENT MARKET

Each year, an estimated 12,000 snowplows are purchased in the United States. Reported costs for fully equipped vehicles range from $85,000 to $140,000. The single largest cost factor is axle configuration. Fully equipped, single-axle vehicles are typically less than $100,000. Tandem triple-axle configurations are at the other end of the range.

Most agencies procure snowplows and snowplow equipment through the bid process. Some agencies purchase truck chassis directly and contract separately with truck equipment houses to install the snowplow accessories (e.g. hydraulic systems, electronic controls, sand/salt spreaders, boxes, wing plows, and underbody grader blades) that make a heavy duty truck a snowplow. Other agencies develop specifications for fully equipped vehicles, making the truck vendors and equipment houses responsible for developing the final product. In either case, the equipment houses serve as general contractors of sorts, procuring the accessories identified in the agencies' specifications and installing the equipment on the vehicles.

Truck equipment houses and public agencies both indicate that it is rare to retrofit trucks with new accessories once the vehicles are in operation. The expected lifecycle of a snowplow is 12 to 15 years. (Assuming an average life span of 12 years, there are approximately 144,000 snowplows in operation throughout the United States.) Older plows are often resold to smaller local governments, typically cities with populations less than 3,000 and townships.

4.1 NEW TECHNOLOGIES USED IN WINTER MAINTENANCE

Global positioning system (GPS) technology is being used on snowplows and other fleet vehicles for a variety of purposes. In Wisconsin, counties conduct all maintenance activities on state routes and are reimbursed by the Wisconsin DOT accordingly. The Wisconsin DOT is currently funding the deployment of GPS on county maintenance vehicles on a pilot basis. GPS will be used to maintain more accurate records of hours of operation, number and location of lane miles plowed, and use of salt/sand on state routes. As one county engineer remarked, "if one agency is providing services to another (as is the case throughout Wisconsin), more accurate reporting is in the best interest of both parties." One county in Wisconsin is using the same system to develop a detailed Geographical Information System (GIS) database of roadway and roadside characteristics and county assets. GPS is also being used to more efficiently manage fleet routing and to improve the accuracy of National Pollutant Discharge Elimination System (NPDES) required salt usage reporting.

The two maintenance engineers that have used GPS on their maintenance fleets were generally more open to new technologies. They realized the potential benefits and functionality of GPS and sought out the technology before it was offered to them as an equipment option. They described early failures more positively, using terms such as "learning curve" and the "process of trial and error." They also spoke of the need for patience and the important role of the pilot project.

With a few notable exceptions (as described above), maintenance engineers and equipment vendors both gave the impression that public agencies have a tendency to be risk averse, particularly when it comes to investing in new technology. County engineers and district maintenance engineers are typically given discretion in how to allocate their limited equipment budgets. When developing specifications for snowplows, there is a clear choice between having additional equipment on the snowplows and having more plows. More than one maintenance engineer relayed accounts of bad experiences with new technologies that have failed. In addition to the added capital cost, agencies are also concerned about the complexity and cost associated with maintaining advanced equipment.

Most of the maintenance supervisors/engineers were at least somewhat familiar with the Field Operational Test and the functionality of the DAS (if not the specific technology) and were able to reflect on how it might be utilized in their particular regions. A concern shared by many of the respondents was the underlying management strategy of operating snowplows during periods of low visibility. Maintenance supervisors were concerned that clearing roads during periods of low visibility would lead to higher traffic volumes when driving conditions are poor, resulting in more rather than fewer crashes. There was, however, general agreement that the DAS technology would be beneficial when snowplows are used to assist public safety vehicles.

Differences in the perception of DAS can be attributed, in part, to the wind conditions and traffic characteristics of the regions being maintained. Noting that there are differences within each of the following categories, the response summaries are broken down by the characteristics of the various regions: infrequent low visibility, frequent low visibility-lower traffic volumes, and frequent low visibility-higher traffic volumes.

Regions exhibiting infrequent low visibility include:

- Eau Claire County, Wisconsin
- Washington State DOT, South Central Region, Maintenance Area 1
- Mn/DOT District 2A Bemidji
- Mn/DOT District 1, Duluth.

Many of the maintenance engineers/supervisors indicated that visibility was not a major issue in their regions and that snowplows were rarely, if ever, taken out of operation due to whiteout conditions. Rolling terrain, mountains, heavy vegetation, or a combination thereof prevent blizzard conditions. DAS technology would be considered on a limited basis, perhaps used on one or two of their less protected or higher-volume routes. Because lack of visibility is not a major concern, DAS technology would not get high priority and deployment would depend largely on affordability.

Regions exhibiting frequent low visibility with lower traffic volumes include:

- Mn/DOT District 2B, Crookston
- North Dakota DOT, Grand Forks District
- Redwood County, Minnesota.

Whiteout conditions and blowing and drifting snow are recurring problems in the plains of western Minnesota and eastern North Dakota. Due to the rural nature of these areas and the limited road maintenance resources, poor winter driving conditions and road closures are expected. Lower maintenance fleet density in these rural areas makes the objective of maintaining clear roadways during periods of falling or blowing snow impractical. Rural districts and counties will not have vehicles out in extremely low visibility conditions, except to assist emergency vehicles. On occasion, Mn/DOT snowplows will clear routes for public safety vehicles when attempting to rescue stranded motorists or responding to medical emergencies. Field supervisor Dave Dallager of Mn/DOT District 2B and Gene Solberg of the Grand Forks District of the North Dakota DOT said that the DAS technologies would be beneficial in such cases. Dave added that deployment should be done in conjunction with public safety agencies.

Regions exhibiting frequent low visibility-higher traffic volumes include:

- Mn/DOT District 3B, St. Cloud
- Mn/DOT District 6A, Rochester.

Both of these districts are responsible for segments of Interstate with relatively high traffic volumes and frequent low visibility. District 3B is responsible for the maintenance of Interstate 94 from Maple Grove, in the Minneapolis/St. Paul metropolitan area, to the Todd County line, northwest of St. Cloud. District 6A is responsible for Interstate 90 from the Wisconsin State line to Interstate 35. Both Districts expressed a strong interest in the DAS technologies.

District 3B indicated that whiteout conditions occur occasionally, particularly north of St. Cloud, but only on two occasions (in the staff's memory) has the Interstate been pronounced closed. They make a distinction between pronouncing a segment closed and physically closing the Interstate. Without gates, it is not practical to entirely block access to the Interstate during inclement weather. If plows were to be pulled, the district would invariably be asked to clear routes for emergency vehicles. Therefore, snow removal operations continue through all driving conditions. The DAS system would allow the snowplows to operate at higher speeds, improving the efficiency of snow removal. During periods of heavy snowfall drivers are forced to slow to a pace that makes it difficult to maintain a clear road surface. The DAS would also improve safety. It was pointed out that the snowplow is often the most dangerous vehicle on the road during periods of low visibility.

CHAPTER 5
THE IMPACT OF SNOW AND WIND ON VISIBILITY

Visibility during winter weather events is affected as much by topography and existence/lack of vegetation as it is by the amount of precipitation. As an example, the Washington State DOT area maintenance supervisor responsible for I-90 Pass through the Cascades reports that, although there is a tremendous amount of snow (550" in 2001) and snow removal operations are ongoing virtually 24 hours a day during the winter months, visibility is not a major issue. Because the snow is heavy and the pass is protected by the surrounding mountain range, snow falls straight down. In contrast, the engineer for Redwood County Minnesota reports that even a 2" snowfall can lead to white out conditions in areas where there is no protection from the wind. In Northeastern North Dakota, with enough snow on the ground, a strong wind can cause white-out conditions on an otherwise clear day.

The largest issue in areas with extremely high snowfalls but little or no wind is often keeping ice from forming on the windshield and the headlights. For this problem, there is likely a much more cost-effective solution.

Figure 5.1 illustrates data that covers snowfall measurements from 1895 to the present. That data is from the National Climactic Data Center Climate of 2002 – February (http://1wf.ncdc.noaa.gov/img/climate/research/2002/feb/snowfall_std_mean.gif).

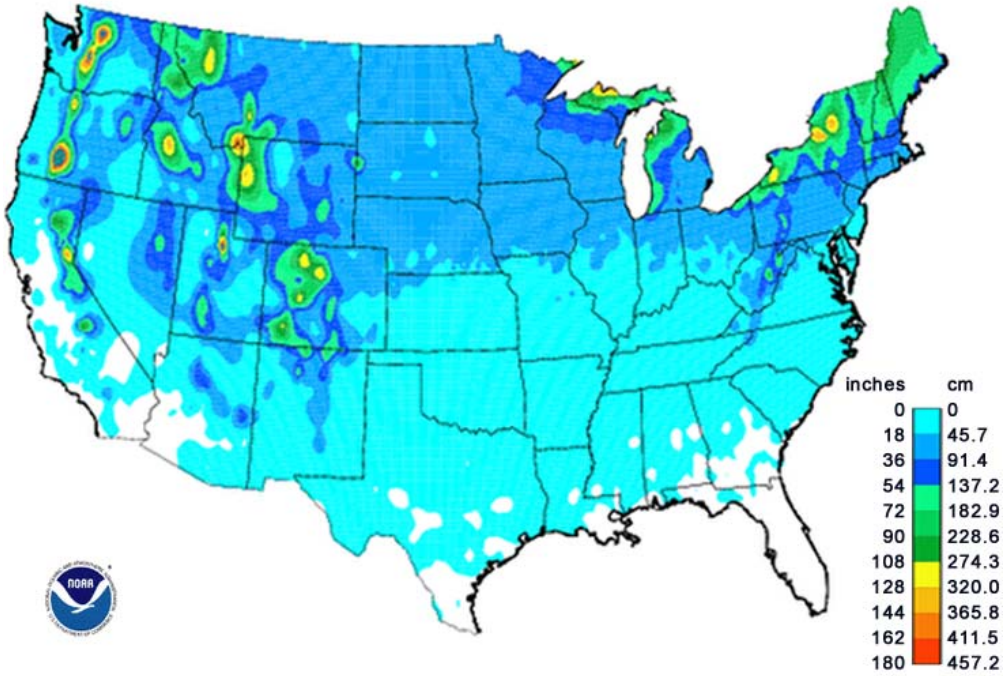

Figure 5.1 Average annual snowfall from August to February

Figure 5.2 illustrates data from the Wind Energy Resource Atlas of the United States, published by the National Renewable Energy Laboratory. Annual mean values/speeds are based on an average of the one-to-three hourly observation of wind speed in the period of record. Three thousand stations across US provided wind data. The data is a cumulative historical average. The data was gathered using a variety of techniques, and various lengths of time. Some data collection has been on-going since the 1930's.

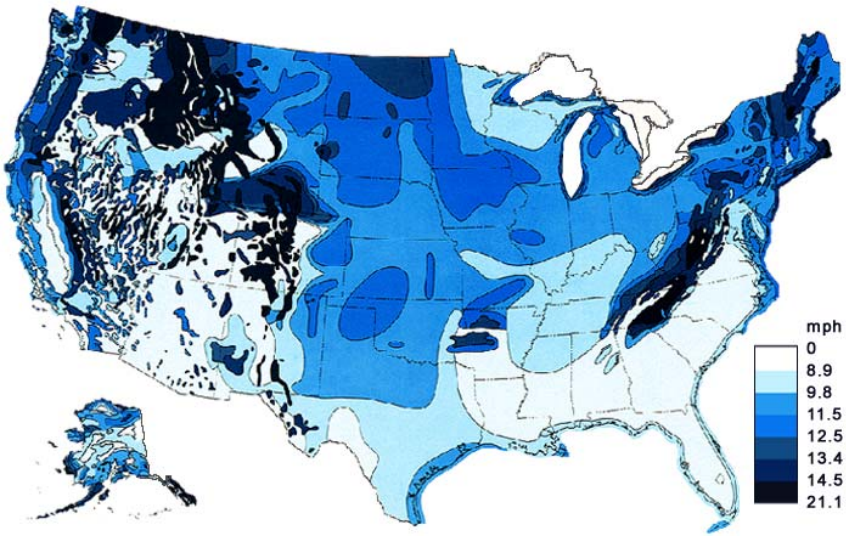

Figure 5.2 Average Annual Wind Speed in the Months of December, January, and February.

Figure 5.2 illustrates areas within the United States with average winter wind equal to or greater than 9.8 MPH and average snowfall equal to or greater than 18 inches. The areas shown in red would likely benefit the most from the DAS for snowplows. Within the red, maintenance districts and or counties that are responsible for high-volume roads would see the greatest benefits in terms of improving service. The interviews indicate that rural maintenance districts and counties are more apt to use the DAS on winter maintenance vehicles in support of emergency response activities.

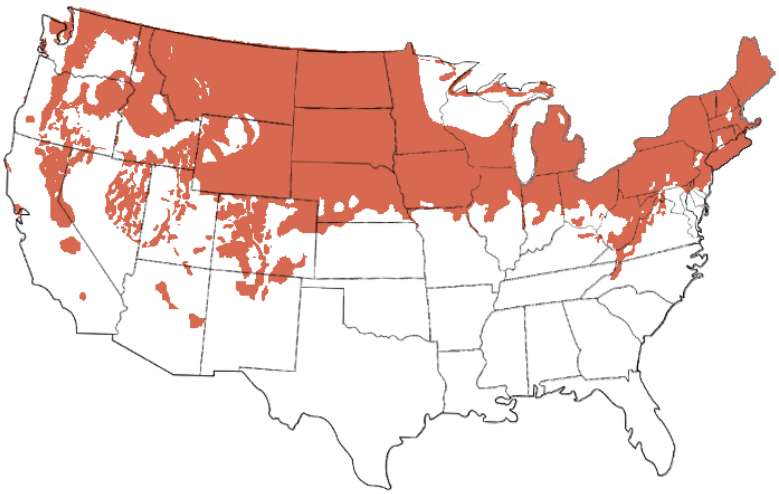

Figure 5.3 Average Winter Wind Equal to or Greater than 9.8 MPH and Average Snowfall Equal to or Greater than 18 Inches.

CHAPTER 6
MARKETING FACTORS FOR THE DRIVER ASSIST SYSTEM

Snowplow equipment vendors and firms involved in the development, manufacturing, and marketing of GPS for winter maintenance vehicles were interviewed to gain insight into how the DAS technology might be perceived by the private sector. The following factors were identified as those that would be considered when determining the market viability of the DAS technology.

Accuracy

The accuracy of the DAS will be a primary concern. To be effective, DAS must be accurate a vast majority of the time. One vendor likened it to an airplane's autopilot system. When these systems were first introduced, pilots were unwilling to use them. The DAS is certainly not as critical as an autopilot system. If there is system failure, snowplow operators have the option of ceasing operations. However, like the autopilot system, developing trust in navigational instruments such as the DAS often takes longer than what is originally anticipated.

Durability/Reliability

The snowplow operates in a very caustic environment. Equipment must be designed accordingly. In assessing the DAS as a product, a prospective manufacturer/vendor would want to clearly understand the ongoing operations and maintenance requirements. Questions to be answered would include:

- How frequently would the GPS unit require calibration and preventative maintenance?
- How often would system failure be anticipated?
- Would maintenance and repair require a service call by a technician with specialized skills or could it be done in house? If maintenance is to be done in house, are transportation agencies willing to take on maintenance responsibilities? How complex is the system? Would system production volumes be such that there would be a market for spare parts?

Product Costs/Ability to Assemble

Where the IVI Field Operational Test evaluates the concept of the DAS using a prototype, a prospective manufacturer/vendor would, instead, base its investment decision largely on production cost projections. The company that would take on the development and marketing of the system would have at least one of the technologies within their core competencies.

In this early stage of system development, it is not possible to project per unit production costs with any degree of certainty. The findings of past studies and input from maintenance professionals do, however, provide some insight into what price would be acceptable.

In 1996, Eric Anderson of Veridian was involved in a "proof of concept" study of GPS-based Automated Vehicle Location (AVL) system for fleet management. Among the findings of the

study was that the AVL systems tested would be acceptable at between 3% and 5% of the overall vehicle cost. Because DAS would provide safety benefits, he suggested that the system may be marketable at a rate as high as 10% of the overall vehicle costs.

When asked to estimate a price point at which the DAS technology would be considered a viable option, responses from county engineers and maintenance supervisors ranged from $2,000 per vehicle to $20,000 per vehicle. The average response was $10,000 per vehicle. Six of the twelve respondents were willing to project a cost. Most respondents expressed their estimates in ranges.

CHAPTER 7
CONCLUSION

Previous studies have shown that the impact of winter weather on traveler safety and the economy is great. Even incremental improvements in the efficiency of snow and ice removal would likely yield substantial benefits for the agencies responsible for winter maintenance as well as the regional economies affected by snowstorms.

There is less agreement and notable geographical differences in terms of how maintenance supervisors/engineers perceived how a DAS would affect safety. Several were concerned that clearing roads during periods of low visibility would lead to higher traffic volumes when driving conditions are poor, resulting in more, rather than fewer, crashes.

Perhaps the most important insight gained through this study is how a DAS would be perceived, valued, and utilized by winter maintenance personnel. Differences in the perception of DAS can be attributed, in part, to the visibility conditions and traffic characteristics of the regions being maintained. In regions with higher traffic volumes and frequent periods of low visibility, snowplow operations are rarely halted due to visibility. In these regions, the DAS would be used to improve the efficiency of winter maintenance activities as well as the safety of the snowplow operators. In regions with frequent low visibility and lower traffic volumes, DAS would be used when assisting public safety agencies with emergency response. It would not necessarily change winter maintenance operations. In regions where low visibility is infrequent, DAS is not considered high priority, would be deployed on a limited basis, and purchase decisions would be very sensitive to unit costs.

The regions that are most likely affected by low visibility during winter maintenance activities are illustrated in Figure 5.3. Maintenance engineers and supervisors that were willing to project a price at which the technology would be considered an attractive option, suggested, on average, $10,000 per vehicle. In addition to considering the potential demand and the projected price point of the system, prospective system developers/manufacturers will also judge the market viability of DAS based on the system's accuracy, durability/reliability, and production costs.

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