California AHMCT Program
University of California at Davis
California Department of Transportation

NEEDS ASSESSMENT AND COST/BENEFIT ANALYSIS OF THE ROADVIEW ADVANCED SNOWPLOW TECHNOLOGY SYSTEM*

Eli Cuelho[1] & David Kack[1]

AHMCT Research Report
UCD-ARR-02-06-30-02

WTI Final Report of Contract RTA65A0078

June 30, 2002

Affiliations:
1. Western Transportation Institute, College of Engineering, Montana State University, Bozeman, Montana 59717-3910

* This report has been prepared in cooperation with the State of California, Business and Transportation Agency, Department of Transportation and is based on work supported by Contract Number RTA 65A0078 through the Advanced Highway Maintenance and Construction Technology Research Center at the University of California at Davis.

Technical Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/CA/NT-2002/08-A		

4. Title and Subtitle Needs Assessment and Cost/Benefit Analysis of the RoadView Advanced Snowplow Technology System	5. Report Date June 30, 2002
	6. Performing Organization Code
7. Author(s): Eli Cuelho and David Kack	8. Performing Organization Report No. UCD-ARR-02-06-30-02
9. Performing Organization Name and Address Western Transportation Institute College of Engineering Bozeman, Montana 59717-3910	10. Work Unit No. (TRAIS)
	11. Contract or Grant
12. Sponsoring Agency Name and Address California Department of Transportation P.O. Box 942873, MS#83	13. Type of Report and Period Covered Final Report July 2000 - June 2002
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The goal of this project was to determine the feasibility of implementing Advanced Vehicle Control and Safety Systems to enhance snow removal activities, and to assess potential benefits associated with utilizing Intelligent Vehicle (IV) technologies in conventional snowplows. The RoadView™ Advanced Snowplow (ASP) technology was developed by the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California – Davis and the University of California- Berkeley's Partners for Advanced Transit and Highways (PATH) Center. The system was designed to assist snowplow operators and improve the safety and efficiency of snow removal operations. As follow-on research, this evaluation was designed to assess the magnitude of the challenges involved with clearing roadways of snow and ice, and to provide a needs assessment and a discussion of factors that could be utilized in a cost/benefit analysis of the RoadView™ system.

The analyses focused on data gathered primarily from four western states: Idaho, Montana, North Dakota and Wyoming. The three main factors to be considered in the needs assessment and potential cost/benefit analysis were safety, mobility, and operational issues. Both quantitative and qualitative data were collected from participating Departments of Transportation, with a survey distributed to snowplow operators in the four designated states. The survey was designed to gain further insight into perceived problems with limited-visibility snow removal operations, and to examine current methods being used by snowplow operators to improve their spatial and situational awareness during low-visibility conditions.

Results indicated the three methods most used by snowplow operators to maintain their lane position are visual, and that operators have a high perceived usefulness of technology that would assist in detecting obstacles and provide lane position information. The cost/benefit analysis indicated that RoadView™ would be most beneficial on roadways with high traffic volumes associated with significant road closures due to winter weather conditions.

17. Key Words	18. Distribution Statement
Intelligent Vehicle, snowplow, reduced visibility, needs assessment, cost/benefit analysis	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

20. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	122	N/A

Form DOT F 1700.7 (8-72)
(PF V2.1, 6/30/92)

Reproduction of completed page authorized

ABSTRACT

The goal of the RoadView™ project is to determine the feasibility of implementing an advanced snowplow control system to improve the safety and efficiency of snow removal operations, and to assess potential costs and benefits associated with combining conventional snowplow operations with Intelligent Vehicle (IV) technologies. The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California – Davis and the University of California- Berkeley's Partners for Advanced Transit and Highways (PATH) Center originally developed the RoadView™ Advanced Snowplow (ASP) technology. As follow-on research, this evaluation was designed to determine the magnitude of the challenges faced by snowplow operators while attempting to clear roadways of snow and ice, particularly during low visibility conditions. Both a needs assessment and a discussion of variables that could be used in a cost/benefit analysis of the RoadView™ system are provided, along with a detailed analysis of responses to a survey administered to snowplow operators.

The analyses focused on data gathered primarily from four western states: Idaho, Montana, North Dakota and Wyoming. The three main factors to be considered in the needs assessment and potential cost/benefit analysis were safety, mobility, and operational issues. Both quantitative and qualitative data were collected from participating Departments of Transportation, including a survey distributed to snowplow operators in the four designated states. The survey was designed to gain further insight into perceived problems with limited visibility snow-removal operations, and to examine current methods being used by snowplow operators to improve their spatial and situational awareness during low-visibility conditions.

Results indicated the three methods most used by snowplow operators to maintain their lane position are visual, and that operators have a high perceived usefulness of technology that would assist in detecting obstacles and provide lane position information. The cost/benefit analysis indicated that RoadView™ would be most beneficial on roadways with high traffic volumes associated with significant road closures due to winter weather conditions.

EXECUTIVE SUMMARY

Project Overview

The purpose of this research project was to determine the need for the RoadView™ system[1] and to discuss variables that could be used in a cost/benefit analysis of the technology. Previous demonstrations have shown the potential success of RoadView deployments, although such demonstrations are limited in terms of the number of advanced technology-equipped vehicles and the amount of time these vehicles have been in operation. Theoretically, the technology utilized in the RoadView project is expected to increase safety by reducing erratic snowplow movements, run-off-the-road incidents and lane departures, snowplow accidents, damage to other vehicles and the infrastructure, and injuries to snowplow operators or other vehicle occupants. Increasing the speed or efficiency of snow removal tasks may potentially reduce road closures and travel delays, thereby improving both the operational aspects of snow removal activities and the mobility of motorists during adverse winter weather.

The needs assessment portion of this project discussed possible measures of effectiveness for the RoadView system and potential benefits that may be realized from more extensive implementation and deployment of the technology. Data for the study were gathered primarily from four states: Idaho, Montana, North Dakota and Wyoming. Additional data collected as part of a RoadView evaluation in the Donner Pass area of California were included as supplemental information.

Quantitative data on winter weather-related accidents, as well as the frequency and duration of winter road closures, were collected for descriptive purposes and to enhance the needs assessment. The qualitative data collected via the snowplow operator survey were used to determine 1) equipment and route characteristics; 2) perceived problems with limited visibility snow-removal operations; and 3) current methods used to position the snowplow on the roadway during typical snowplow operations, and particularly during periods of limited visibility.

Summary of Conclusions

Results of the snowplow operator survey provided beneficial information regarding difficulties encountered while conducting operations in low visibility conditions, current practices and operational concerns, and receptivity to advanced technology. During an average snowstorm, for example, snowplow operators estimated they typically lost sight of the roadway between one and six times, for roughly four to five seconds per event. In terms of current operations, the three visual cues that snowplow operators relied on most frequently to maintain their position on the roadway included judging their distance from: guardrails, mileposts/delineators, and the centerline. When asked to assess the potential usefulness of

---

[1] RoadView is a trademark (U.S. registration number 2,830,001) of the AHMCT Research Center at the University of California – Davis. For the remainder of this preface, the trademark symbol will be omitted.

advanced technologies, operators gave the highest ratings to those that would provide lane position information and obstacle detection capabilities. On the other hand, operators reportedly felt that there would be weather conditions in which snowplow operations should be suspended, regardless of the availability of advanced snowplow technology.

Quantitative data confirmed the incidence of snowplow-related accidents, both with and without the involvement of other vehicles, along those roadways selected as study sites. Roadway closures due to severe winter weather also were documented, which resulted in unspecified delays to travelers. Intuitively, any technology assumed capable of reducing accident-related costs or injuries likely would be perceived as beneficial. Furthermore, technology that has the potential to shorten or eliminate road closures would have intuitive appeal. The task of assessing the need for advanced technology for which empirical data are unavailable was problematic. Thus, the difficulties of trying to establish the accident– or delay-reducing capabilities of the RoadView system are discussed in detail. The perceived usefulness and potential benefits of the advanced technology are documented, based on the responses to the snowplow operator survey.

For the cost/benefit analysis, similar difficulties were encountered due to the lack of empirical data to measure system benefits. Five scenarios that correspond to the designated study sites were used to illustrate how benefit/cost ratios for the RoadView system could be calculated. It must be emphasized that until sufficient data have been collected to substantiate and quantify the benefits of the advanced snowplow technology, such examples are hypothetical and should not be considered statistical estimates of system effectiveness. Due to the lack of empirical data, the benefit/cost ratios were calculated using what were believed to be conservative estimates of potential benefits associated with the RoadView system. Of the five scenarios, only one produced a benefit/cost ratio greater than 1.0 (i.e., signifying benefits that outweighed the costs of the system). Overall, it appears that the potential cost-effectiveness of the RoadView system would be increased in areas with high traffic volumes and high probabilities of road closures due to winter weather, or in areas that have experienced a large number of snowplow-related accidents in the past.

Recommendations for Further Research and Development

Within the confines of the survey, snowplow operators were asked to assess the perceived usefulness of advanced technologies without the benefit of direct exposure to or previous experience with the RoadView system. Visual or "hands on" demonstrations of the technology would provide more accurate and realistic perceptions of the usefulness of the technology. Without actual experience, particularly in adverse weather conditions, the operators' perceptions of the technology must be considered highly subjective, based on purely hypothetical situations. The snowplow operators' ability and willingness to use RoadView technology as the primary means of guidance, and the system's effectiveness at reducing snowplow accidents and run-off-the-road incidents can be determined only through practical experience or extensive field tests over a multi-year period.

As discussed previously, the results of the cost/benefit analysis are limited by the lack of objective data regarding the effectiveness of the RoadView system. The Donner Pass area of I-

80 in California is believed to be a likely candidate for a full-scale deployment of RoadView technology in the future. In addition, a similar advanced snowplow system has been deployed in the Thompson Pass area near Valdez, Alaska, which could provide data for further analyses. Cost data may need to be revised if additional field-testing and experimentation reduce the in-vehicle and/or in-road costs associated with the RoadView system. It is possible that other technological advances will be available for comparison, as well. For instance, Minnesota has experimented with using Differential Global Positioning Satellite (DGPS) technology for providing enhanced lane awareness information to snowplow operators. In general, however, the costs and benefits associated with the RoadView advanced snowplow technology can be rigorously evaluated only after increased deployment and operational testing of the system provide the requisite empirical data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DISCLAIMER/DISCLOSURE

ALTERNATE FORMAT

Persons with disabilities who need an alternative accessible format of this information, or who require some other reasonable accommodation to participate, should contact Kate Laughery, Western Transportation Institute, PO Box 173910, Montana State University – Bozeman, Bozeman, MT 59717-3910, telephone: (406) 994-6114, fax: (406) 994-1697. For the hearing impaired, call (406) 994-4331.

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	**Definition**
AADT	Average Annual Daily Traffic
ADTT	Average Daily Truck Traffic
AHMCT	Advanced Highway Maintenance and Construction Technology
ANSI	American National Standards Institute
ASP	Advanced Snowplow
AVCSS	Advanced Vehicle Control and Safety Systems
Caltrans	California State Department of Transportation
CWS	Collision Warning System
DGPS	Differential Global Positioning System
DOT	Department of Transportation
GPS	Global Positioning System
HUD	Head-Up Display
I-80	Interstate 80
I-90	Interstate 90
I-94	Interstate 94
ITS	Intelligent Transportation Systems
IV	Intelligent Vehicle
IVI	Intelligent Vehicle Initiative
MNDOT	Minnesota Department of Transportation
MOE	Measure of Effectiveness
MSU	Montana State University
NA	Not Answered
PATH	Partners for Advanced Transit and Highways
Std. Dev.	Standard Deviation
UCD	University of California-Davis
US-12	United States Highway 12
WTI	Western Transportation Institute

ACKNOWLEDGEMENTS

The authors thank the Departments of Transportation in Idaho, Montana, North Dakota and Wyoming for their participation and support. In addition, the authors acknowledge the district engineers, section supervisors and maintenance chiefs in each of the states who helped in distributing nearly 2,000 surveys. The authors would also like to acknowledge the dedicated efforts of the Undergraduate and Graduate students working at the Western Transportation Institute who provided instrumental assistance in the completion of this research.

CHAPTER ONE: INTRODUCTION

Keeping roads open and passable in the winter is a fundamental public safety task, the importance of which is emphasized by newspaper articles with headlines, such as "Storm Paralyzes Upper Midwest". The details of this particular article describe the magnitude of the problem. "Minnesota snowplow crews parked their rigs Tuesday because they couldn't keep up with blowing, drifting snow that closed schools for thousands of youngsters from the Plains to the upper Great Lakes." (1).

In addition to being an inconvenience to travelers, the economic impact of a major snowstorm can be significant. A study conducted for the Salt Institute estimated that impassible roadways in a twelve-state Midwest region would cost $526.4 million per day in federal, state and local taxes. In addition, it was estimated that such a storm would cost $1.4 billion per day in unearned wages and $600 million per day in lost retail sales (2).

Further, a major snowstorm has the potential to increase the number and severity of motor vehicle accidents. Researchers have explored the relationship between adverse weather and safety and found a significant decrease in crash rates after snow removal and deicing activities (3). Studies also have found that the number and rate of highway fatalities and injuries increase on snowy days (4).

Recent projects have focused on utilizing and evaluating technology to allow snowplow operators to continue to work in reduced-visibility situations (5,6,7,8,9,10). By utilizing a variety of technologies, it is hoped that snowplow operators will be able to continue clearing roads in low visibility conditions, thereby keeping roadways open and reducing the economic impact of a storm. The RoadView™ system[2] was initiated in response to these concerns, as a means to facilitate snowplow operations in inclement weather.

Purpose of the Study

A demonstration of the advanced snowplow lateral guidance and obstacle detection system was conducted as an initial step in creating a wholesale design (9). Although the evaluation completed as part of the demonstration was limited in scope, it concluded that the technology was useful in terms of providing snowplow operators with greater lane/roadway awareness during low visibility plowing operations. As follow-on research, the current project was designed to further document the need for such deployments and consider the potential benefits and costs associated with the advanced technology.

The needs assessment and examples of cost/benefit analyses utilized data gathered primarily from four western states: Idaho, Montana, North Dakota and Wyoming. The three main factors considered in the analyses were safety, mobility, and operational issues. Both quantitative and qualitative data were collected to examine such factors as snowplow-related accidents, road

---

[2] RoadView is a trademark (U.S. registration number 2,830,001) of the AHMCT Research Center at the University of California – Davis. For the remainder of this report, the trademark symbol will be omitted.

closures and other travel delays, and opinions of snowplow operators regarding current practices and potential benefits of technological advances. The survey, which was distributed to snowplow operators in the designated four states, was designed to gain further insight into perceived problems with limited visibility snow removal operations, and to examine current methods used by snowplow operators to improve their spatial and situational awareness during low visibility conditions.

Report Overview

Chapter 2 outlines the methodology used to collect and analyze the data used in this research effort. The quantitative data that were collected included snowplow-related accident information, road closure and travel delay figures, and weather data. The qualitative data analysis utilized responses to surveys distributed to snowplow operators in Idaho, Montana, North Dakota and Wyoming.

Chapter 3 provides the results of the analyses of both the quantitative and qualitative data that were gathered.

Chapter 4 discusses the needs assessment of the RoadView system, as well as the limitations of this phase of the analysis.

Chapter 5 includes an examination of potential variables that could be used in a cost/benefit analysis of RoadView technology. Previous demonstration projects have documented the in-vehicle and in-road costs of comparable technology, which were used to estimate the total "system acquisition" costs of the RoadView system. Empirical data to quantify system benefits were unavailable; therefore, five scenarios were utilized to compare total costs to the benefits that may be associated with the deployment of RoadView-equipped snowplows.

Chapter 6 provides conclusions, implications, and recommendations for future research.

Appendix A includes a list of the individuals contacted in a potential study sample of 13 states and two Canadian provinces, as well as the dates on which the contacts were made.

Appendix B provides a copy of the snowplow operator survey instrument administered to appropriate maintenance personnel in the Departments of Transportation in the four states that comprised the final sample.

Appendix C includes the statistical analysis of survey results, as well as documentation of any written comments or suggestions made by the snowplow operators.

Appendix D describes the chi-squared analysis and provides the results of chi-squared tests performed on data received from the snowplow operator surveys.

CHAPTER TWO: METHODOLOGY

To determine the need for advanced snowplow technology, and to identify the possible benefits of the RoadView Advanced Snowplow system, it was first necessary to determine which variables were of interest, along with their respective measure(s) of effectiveness and source(s) of data. Second, a system for collecting pertinent data from each of the designated information sources was established.

Measures of Effectiveness and Data Sources

Previous research concluded that the frequency and duration of road closures, motor vehicle accidents, and snowplow accidents would most likely be influenced by the implementation of advanced snowplow technologies (3,4,6). Similarly, the Salt Institute (11) identified the following factors for use in determining the potential benefits of winter maintenance activities:

- reduced property damage,
- reduced personal injury,
- improved emergency response,
- improved public security,
- improved public mobility,
- sustained economic activity, and
- enhanced perception of the competence of public administration.

For purposes of this study, the need for and potential benefits of the advanced technology were to be evaluated on the basis of three main factors: safety, mobility and operations (Table 1). An evaluation of the RoadView system's effect on safety would focus on the frequency and severity of snowplow-only accidents, collisions between snowplows and other motor vehicles, and run-off-the-road incidents involving snowplows. Data pertaining to these measures of effectiveness, as well as associated cost estimates, were to be obtained from traffic accident reports, snowplow maintenance budgets or maintenance logs, and a survey of snowplow operators.

Mobility would be measured in terms of delays to the traveling public from road closures during adverse winter weather conditions. A reduction in either the frequency or duration of road closures would be considered a positive effect on mobility. Information from highway maintenance logs was to be used to examine this variable.

Because snowplow operations affect both the safety and mobility of the motoring public, variables related to the effectiveness and efficiency of snowplow operations were key to the evaluation. In particular, snowplow operations during low-visibility conditions were of interest in this analysis. The snowplow operator survey would provide information about current plowing practices, as well as operators' perceptions and opinions regarding factors affecting reduced-visibility situations, and potential benefits of the RoadView system's advanced technologies.

Table 1: Evaluation Factors, Measures of Effectiveness and Sources of Data

Factors	Measures of Effectiveness	Sources of data
Safety	Snowplow-only accidents	• Traffic accident reports • Snowplow operator survey • Snowplow maintenance budgets or logs
	Snowplow vs. motor vehicle accidents	• Traffic accident reports • Snowplow maintenance budgets or logs • Snowplow operator survey
	Run-off-the-road snowplow incidents	• Snowplow maintenance budgets or logs • Snowplow operator survey
Mobility	Frequency and duration of road closures	• Maintenance/road closure logs
Operations	Causes of reduced visibility conditions	• Snowplow operator survey
	Current lane awareness methods	• Snowplow operator survey
	Perceived usefulness	• Snowplow operator survey

<u>Identification of Study Sites</u>

Thirteen states and two Canadian provinces located in the northwest were identified as having a significant stake in snowplow operations. Once initial contact was made with a representative of each location, it became apparent that previous data collection efforts were inconsistent or nonexistent with respect to snowplow-only accidents, run-off-the-road incidents and road closures, all of which were necessary elements for the intended analyses. Based on the availability and perceived reliability of the requisite historical data, a subset of the following four states was chosen as the study sample: Idaho, Montana, North Dakota and Wyoming. (Appendix A includes a list of individuals contacted within each of the thirteen states and two Canadian provinces, as well as the dates on which contacts were made.)

Specific roadway sections were identified for the quantitative data analysis, based on the following selection criteria:

- roadways with high traffic volumes and significant truck traffic,
- roadways in areas prone to low-visibility conditions,
- roadways with documented winter road condition-related accidents,
- roadways with limited route alternatives, and
- roadways with a history of closures due to factors that could be affected by advanced snowplow technologies.

The designated roadway in each of the four states is identified in Table 2, along with descriptive information and traffic volume data. The data collected for each of these areas included snowfall amounts, the frequency and duration of winter road closures, snowplow-only accidents, snowplow vs. motor vehicle accidents, and snowplow run-off-the-road incidents. In addition, data from a previous evaluation of advanced snowplow technologies that focused on the Donner Pass area of California (9) were included in this phase of the study.

Table 2: Selected Road Segments for Data Collection

	Mile Post	# of Lanes	Grade (%)	AADT	ADTT
California Donner Pass (I-80)	5-9	5	5-6	44,500	3,000
Idaho US 12 (Lolo Pass to Lowell)	98-174	2	6	990	240
Montana Homestake Pass (I-90)	241-227	4	6	7,060	1,595
North Dakota I-94 (near Bismarck)	159-190	4	0	7,000	1,660
Wyoming I-80 (near Laramie)	317-329	4	7-8	8,000	4,800

Snowplow Operator Survey

To augment the quantitative data, a snowplow operator survey was used to collect qualitative information related to operational issues, particularly snowplow operations in low-visibility conditions.

Survey Design

The survey used for this research project was based on previous research conducted by McGehee and Raby (8) that specifically concerned the interface design of a lane awareness system for snowplows. The survey focused on the following topics:

- operator experience,
- snow removal equipment characteristics,
- snowplow route characteristics,
- additional snow removal techniques,
- low-visibility operations and issues, and
- snowplow operator demographic information.

The survey provided essential information for the needs assessment and other discussions. In addition to highlighting the challenges faced by snowplow operators, the survey was used to document current methods that snowplow operators use to determine their position on the road, as well as to quantify their opinions regarding the potential usefulness of RoadView or other advanced snowplow technologies. (A copy of the survey instrument is provided in Appendix B.)

Survey Distribution

Surveys were distributed to snowplow operators employed by the Maintenance Divisions of the Departments of Transportation in Idaho, Montana, North Dakota and Wyoming. A predetermined number of survey packets was sent to the respective Maintenance Supervisors to be distributed to the appropriate individuals within their Departments. Each packet contained a postage-paid return envelope, the survey instrument, and an incentive drawing card to help boost response rates, as described below.

Two snowplow operators from each of the four States were randomly selected for a cash incentive of $50 each. The Maintenance Supervisor from the state with the highest response rate received an incentive, as well. The Montana Department of Transportation was unable to participate in the incentive program due to internal regulations. Table 3 details the response rate for each participating state, and for the total sample. The fact that over 50 percent of the individuals targeted for inclusion returned their questionnaires is noteworthy.

Table 3: Snowplow Operator Survey Response Rates

State	Surveys Distributed	Surveys Returned	Response Rate
Idaho	383	299	78.1%
Montana	646	221	34.2%
North Dakota	338	235	69.5%
Wyoming	398	237	59.5%
Totals	**1,765**	**992**	**56.2%**

CHAPTER THREE: DATA ANALYSES

The results presented in this chapter are divided into two primary sections, the quantitative analysis and the qualitative analysis.

Quantitative Analysis

Snowfall accumulations for the selected study locations were collected for 1996-2000 (Table 4) because previous research showed a correlation between snowfall amounts and road closures (9). Unfortunately, it was not possible to gather sufficient data on road closures to perform a similar correlation analysis in this study, as discussed below.

Table 4: Annual Snowfall Accumulations (inches) for Selected Roadways (1996-2000)

	1996	**1997**	**1998**	**1999**	**2000**	**Average**
Donner Pass, CA (I-80)	438.3	419.5	576.2	418.7	N/A	406.0*
Lolo Pass, ID (US 12)	235.0	122.2	133.2	134.8	129.0	150.8
Homestake Pass (I-90)	125.5	79.4	69.3	42.2	59.9	75.4
Bismarck, ND (I-94)	103.1	66.3	41.3	46.8	50.0	61.5
Laramie, WY (I-80)	55.3	75.1	42.8	42.0	62.0	55.4

***This is an average based 25 years of data (9)**

Because road closures have a significant impact on mobility, information on the frequency and duration of closures due to severe winter weather was felt to be an important variable for this study. As shown in Table 5, however, annual data regarding the duration of road closures were available for only one of the five selected roadways. Furthermore, the frequency of road closures at three of the designated sites was extremely small, which called into question the advisability of using this variable in the cost/benefit analysis of the RoadView system. It should be noted that Lolo Pass in Idaho (US 12) has been closed in the past, but the closures were due to avalanches and forest fires, not as a result of conditions that would be affected by advanced snowplow technologies. The remaining numbers indicate few closures, except on Donner Pass and the I-80 area near Laramie, Wyoming.

Table 5: Road Closure Information for Selected Roadways (1998-2001)

	1998		1999		2000		2001	
	# of Closures	Total Hours	# of Closures	Total Hours	# of Closures	Total Hours	# of Closures	Total Hours
Donner Pass, CA (I-80)	38	No Data	19	No Data	8	31.1	21	29.7
Lolo Pass, ID (US 12)	0	No Data	0	No Data	0	No Data	0	No Data
Homestake Pass (I-90)	0	No Data	1	No Data	0	No Data	3	No Data
Bismarck, ND (I-94)	1	No Data	3	No Data	3	No Data	3	No Data
Laramie, WY (I-80)	8	47.3	4	7.5	16	86.2	6	30.7

Data on snowplow-only accidents were intended for inclusion in both the needs assessment and the cost/benefit analysis. Although accident data were expected to be readily available for the target areas, two of the five sites had no data regarding accidents involving only snowplows, as shown in Table 6. Furthermore, annual totals of snowplow-only accidents were quite small, which limited the feasibility of using this variable (at least at these designated locations) in subsequent analyses.

Table 6: Annual Snowplow-only Accident Data for Selected Roadways (1996-2001)

	1996-97	**1997-98**	**1998-99**	**1999-00**	**2000-01**
Donner Pass, CA (I-80)	16	17	18	No data	No data
Lolo Pass, ID (US 12)	14	10	4	8	No data
Homestake Pass (I-90)	No data	No data	No data	No data	No data
Bismarck, ND (I-94)	4	2	3	3	3
Laramie, WY (I-80)	No data	No data	No data	No data	No data

The limited availability of data on snowplow-only accidents may be due to federal reporting requirements. Specifically, Rule D.16 of the American National Standards Institute (ANSI) states that accidents involving working snowplows are not to be counted statistically in crash databases unless they involve another motor vehicle in transport. Other vehicles performing a "non-transportation function" also are excluded from accident databases due to D.16. According to one expert, the exclusion of snowplow-only accidents is probably the most frequently discussed issue concerning ANSI D.16 (12). This ruling left the decision to record accidents involving only snowplows up to individual DOT's for internal use or contracted research.

Due to the lack of data on snowplow-only accidents for the sites selected in this study, accident statistics from research conducted by Booz•Allen & Hamilton (5) were included to more fully assess the magnitude of the problem. The data from Booz•Allen & Hamilton, included accidents related to snowplows being rear-ended by other vehicles, sideswipes, collisions with fixed objects, and sliding off the road. As summarized in Table 7, these data illustrate similar problems in terms of the limited availability of snowplow-related accident data, or low accident frequencies, in some of the participating states. No information regarding the severity of these accidents is provided, either in terms of injuries or accident-related costs. Sliding-off-the-road incidents, for example, which were included in the tabulations, may have had only minor consequences.

Table 7: Snowplow-related Accident Totals (Source: Booz•Allen & Hamilton, 1999)

	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Minnesota	160	76	149	207	No data	No data
Montana	No data	No data	No data	No data	18	19
North Dakota	33	24	27	43	17	22
South Dakota	90	45	92	128	54	46
Washington	2	5	14	16	3	10
Wisconsin	No data	51	No data	No data	No data	No data
Total	285	201	282	394	92	97
Annual Avg.	71.25	40.20	70.50	98.50	23.00	24.25

The research by Booz•Allen & Hamilton concluded that adverse weather, reduced visibility and snow-covered or icy road pavement conditions contributed to a high number of snowplow-related accidents (5). Given that snowplows typically are deployed when snow, ice, or other winter conditions pose a threat to motorists, these findings appear intuitively obvious.

Given the fact that detailed data on many snowplow-only accidents are not collected and/or identified as such, it is difficult to determine the actual costs associated with snowplow accidents. Research by Parsons, Brinckerhoff, Quade & Douglas, Inc. found that an average of 131 accidents involving snowplows and other motor vehicles occurred in Minnesota each year, resulting in an annual damage cost to the snowplows of approximately $450,000 per year (7). This figure equates to approximately $2,450 per accident, or $542 per year, per snowplow.

Obviously, winter weather conditions contribute to motor vehicle accidents, in general. These accidents typically are reported as "weather-related" if they occurred while the surface of the roadway was covered with snow, slush, ice and/or compacted snow, frost, or any combination thereof. Table 8 provides a four-year average for total motor vehicle accidents and winter weather-related accidents in the targeted areas.

Table 8: Total and Winter Weather-related Motor Vehicle Accidents for Selected Roadways

	All accidents	Winter weather-related accidents	% related to winter weather
Donner Pass, CA (I-80)	224	115	51.3
Lolo Pass, ID (US 12)	44	10	22.7
Homestake Pass (I-90)	69	39	56.5
Bismarck, ND (I-94)	68	28	41.2
Laramie, WY (I-80)	134	89	66.4
Total	**539**	**281**	**52.1**

Further analysis of the accident data revealed that approximately 1 percent of all accidents in the above areas were fatal crashes, 27 percent were injury accidents, and the remaining 72 percent were classified as property damage only accidents. These percentages were similar for all of the designated roadways.

The extent to which the implementation of the RoadView technology could be expected to measurably reduce the frequency or severity of winter weather-related motor vehicle accidents is unknown. Previous research found a significant decrease in crash rates following snow removal and deicing activities (3) and, in theory, if RoadView increases the operational efficiency of snowplows during low visibility conditions, motorists might be afforded safer road conditions. The effectiveness of the RoadView system, however, should be evaluated on the basis of a comparison between accident rates on roadways that were plowed by RoadView-equipped snowplows versus those that were plowed by conventional snowplows. Confounding influences (e.g., storm characteristics, roadway geometrics, traffic volume, operator experience, and so forth) would need to be controlled to establish comparability between the treatment and comparison groups. Given the difficulties associated with establishing the analytical framework necessary for such an evaluation, it is extremely unlikely that an effect on motor vehicle crashes attributable solely to the advanced technology could be substantiated.

More importantly, the extent to which RoadView increases the efficiency of snow removal operations has yet to be determined. There are a number of hypothetical situations in which the advanced technology could be credited with increasing the efficiency of snowplow operations. For example, the system may prevent instances when a snowplow runs so far off the road that assistance is required before the plow can continue operating. Secondly, the system may enable an operator to continue plowing when it would not have been possible otherwise, due to severe weather conditions. Lastly, advanced technology may allow an operator to increase his speed, thereby enabling him to plow greater distances or make more frequent passes on the same roadway section. Empirical testing, once again, is needed to document these improvements.

In actuality, many of the benefits of the RoadView system may be realized in terms of decreased workload or reduced stress (i.e., increased confidence or feelings of safety) for the snowplow operator. Although the guidance and warning systems may result in a reduction in accidents or incidents involving snowplows, the relatively low frequencies of snowplow-related accidents or run-off-the-road incidents suggest that operators are reasonably successful at maintaining their position on the roadway and avoiding collisions without the benefit of advanced technology. Nevertheless, the damage estimates from previous research (7) illustrate the economic impact of snowplow-related crashes on DOT Maintenance budgets.

Qualitative Data Analyses: Snowplow operator survey

In analyzing the results of the snowplow operator survey, descriptive statistics (e.g., percentages, means, standard deviations, and medians) were calculated on the basis of the total number of responses to a particular question, not the total number of surveys returned. An “NA” represents the quantity “Not Answered” for a particular question based on the number of surveys returned for each state and the total of all four states. Relevant comments for each section are included, along with summarized results. (A statistical examination of the survey data can be found in Appendix C, which also contains the written comments provided by the snowplow operators.)

In addition to descriptive statistics, chi-squared tests were performed. The chi-squared test compares the actual, or observed, frequencies in each cell in a table to the frequencies one would expect if there were no relationship between the two designated variables in the population from which the sample is drawn. If the observed values are sufficiently different from the expected values, the null hypothesis can be rejected and a statistically significant relationship said to exist between the two variables. It should be noted that a chi-squared test was deemed to be invalid if ten percent or more of the cells in a given table had a count of less than five ($n<5$), or if any of the cells had a count of zero ($n=0$). (Table D-1 in Appendix D provides an overview of the chi-squared test results.) The chi squared helps show differences with respect to the various Departments of Transportation plowing philosophies, and may further highlight differences in responses based on geography.

Demographic Information

This section of the survey included six questions to provide demographic information on the snowplow operators. This information was used in the chi-squared analyses to determine if there were significant differences among groups of respondents in terms of their answers to the survey questions.

Of the 992 survey respondents, 299 worked for the Idaho DOT, 221 worked for the Montana DOT, 235 worked for the North Dakota DOT, and 237 worked for the Wyoming DOT.

The mean age of operators was 45.1 years, with a standard deviation of 9.2 years and median age of 46 years. In relation to gender, 97.5 percent of the respondents indicated that they were male, with the remaining 2.5 percent being female. The mean level of experience of the operators was 12.2 years, with a standard deviation of 9.3 years and median experience level of 10.0 years.

Operators also were queried as to their level of education. It was believed that those with a higher level of education might be more receptive to advanced snowplow technologies. As shown in Table 20, just over half of the respondents were high school graduates or had a GED, while nearly 40 percent had some college or a two-year degree.

Table 9: Educational Level of Respondents

	# of responses	% of total responses
No high school	12	1.2
Some high school, but did not graduate	19	1.9
High school graduate or GED	510	51.9
Some college or 2-year degree	392	39.9
4-year college graduate	41	4.2
More than 4-year college degree	9	0.9

The final demographic question asked the operators to rate their level of computer experience on a 5-point scale with "1" being "no experience" and "5" being "advanced." The mean score was 2.5 with a standard deviation of 1.0, meaning that overall they had between beginning and average level of computer experience. A chi-squared analysis indicated that operators from Idaho had the highest level of computer experience, while those in North Dakota had a significantly lower level of computer experience.

Equipment Characteristics

Previous research showed a lack of standardization in the placement of equipment in snowplows, and found that operators generally are required to drive more than one type or model of snowplow (6). Thus, the first question regarding equipment characteristics asked survey participants to indicate the number of different models or types of snowplows they drove during the 2001-2002 winter season. The results, as shown in Table 10, indicate that the majority of operators drove two or more snowplow models during the past winter. Only 18 percent of respondents indicated that they drove only one model/type of snowplow during the 2001-2002 winter season.

Table 10: Number of Snowplow Models Driven by Operators

# of models	# of responses	% of total
One (1)	144	17.9
Two (2)	256	31.8
Three (3)	211	26.2
Four (4) or more	194	24.1

Information regarding the make and model of the vehicle, year of manufacture and axle type was requested, also. Many respondents interchanged the vehicle make and model, making interpretation of these responses difficult. Because this information was not considered critical to the analysis, the responses pertaining to truck model are not shown. As indicated in Table 11, the majority of the snowplows used in the study locations came from four manufacturers: GMC, Mack, Ford and International, with International comprising nearly one-third of all of the plows used by the operators who responded to this survey.

Table 11: Snowplow Manufacturers

Make	# of responses	% of total
AutoCar	44	4.5
Chevy	36	7.2
Ford	164	16.9
Freightliner	13	1.3
GMC	120	12.3
GMC/Volvo	41	4.2
GMC/White	11	1.6
International	322	33.2
Mack	157	16.2
Sterling	48	5.0
Other	13	1.3

Operators also were asked to identify the year of manufacture for the plow they used most frequently (Table12). As shown, most plows used on a frequent basis are no more than 10 years old. In fact, over 50 percent of the snowplows were manufactured in 1995 or later.

Table 12: Snowplows' Year of Manufacture

Vehicle year	# of responses	% of total
1979 or earlier	2	0.2
1980-84	20	2.1
1985-89	109	11.4
1990-94	303	31.7
1995-99	358	37.5
2000 or newer	163	17.1

Within this section, snowplow operators also were asked about typical plow configurations. Specifically, this question was included to gain insight as to the type and number of plow systems used, due to the fact that these systems can contribute to reduced-visibility situations, and increase the workload of the operator. Table 13 provides the mean percent of use of each of the various plow types/systems. These results indicate that operators typically used at least two systems, the plow and a material spreader. Wing plows have been known to increase the workload of operators because they extend further from the plow, thereby necessitating increased attention from the operator. In addition, 65 percent of operators indicated they drove a dual-axle snowplow, while the remaining 35 percent drove a single-axle plow.

Table 13: Snowplow Types/Systems in Use

Plow type or system	Average % of use
Front-mounted one-way plow	37.9
Front-mounted two-way plow	72.8
Front-mounted V-plow	2.8
Front-mounted snow blower	5.2
Under-body ice blade or plow	6.3
Left wing plow	2.9
Right wing plow	23.8
Material spreader	80.9

Route Characteristics

Operators who are required to plow multiple routes may be at a disadvantage compared to those who are assigned only one route, in that they spend less time (and accumulate less experience) on any particular roadway during a given period. Over time, however, this effect likely would diminish as exposure to each roadway is increased. The highest percentage of operators (33.7%) plowed two routes during an average storm, followed by operators who plowed three, four, and one route(s). Ten percent of operators responded that they plow five or more routes during an average snowstorm. A chi-squared analysis indicated that there was a difference in the number of routes driven between the various Departments of Transportation. Operators in Idaho drove either one or two routes during an average snowstorm, while those in Montana drove a higher number of routes (four or five) during an average storm.

Responses to the question of route length revealed that the mean route length was 85.4 lane miles, with a standard deviation of 64.9 lane miles, and the median length was 68.0 lane miles. The route lengths also varied between the respondents' state of residence. The chi-squared analysis indicated that snowplow operators in Idaho drove shorter primary routes (i.e., an average of 75 lane miles) during the 2001-2002 winter season, while a significantly higher proportion of operators in Montana drove routes with an average of 105 lane miles.

Each type of roadway typically presents different challenges to snowplow operators. For example, Interstates and state highways generally have higher amounts of traffic, including truck traffic. Two-lane undivided roads have smaller shoulders, and less room for clearance between the plows and other vehicles. Based on the mean and median length of roadway types, the three types of roadways driven most frequently by snowplow operators were: two-lane undivided highways, two-lane divided interstates, and two-lane divided highways, respectively.

The magnitude and severity of reduced visibility situations can be measured, in part, by the frequency of low visibility events, and the speed of the vehicle during periods of reduced visibility. In general, it would be more serious for a snowplow operator to lose sight of the road for 10 seconds when traveling at 50 mph, than when traveling 20 mph. That is, at the higher rate of speed, a greater distance will be covered, thereby increasing exposure to other vehicles or road hazards, and reducing the opportunity to take corrective actions. The greater the amount of time spent on the road, the greater the potential for encountering reduced visibility conditions during winter storms or periods of high winds. Table 14 shows the average and maximum driving times; and average, minimum, and maximum plowing speeds during the 2001-2002 winter season.

Table 14: Operational Hours and Speeds of Snowplow Operators

	Mean	Std. Dev.	Median
Average driving time (hours)	7.7	2.1	8.0
Maximum driving time (hours)	11.5	4.0	12.0
Average speed while plowing (mph)	34.7	5.9	35.0
Minimum speed while plowing (mph)	16.7	9.2	15.0
Maximum speed while plowing (mph)	42.9	7.8	45.0

The final question in this section asked if operators ever “backplow” or “back drag” as part of their typical operations, meaning operating the vehicle in reverse with the plows down. It was believed that the frequency of this maneuver may help determine the need for rearward looking obstacle detection systems. However, less than ten percent of the operators responded affirmatively to this question.

Visibility Issues

Questions related to visibility issues comprised the majority of the survey. These questions were intended to provide essential data for the needs assessment and assist in defining the potential benefits of advanced snowplow technology. This section focused on the following areas: conditions/sources of poor visibility, factors related to safe snowplow operation, methods for maintaining lane position, accidents/incidents aggravated by low-visibility conditions, and receptivity to technology that could aid in dealing with low-visibility situations. Each of these areas is described separately in the following subsections.

Conditions/Sources of Poor Visibility

The first question related to visibility asked snowplow operators to rank the usefulness of certain types of mirrors during snowplow operations. A five-point scale was used, with “1” being “completely useless” and “5” being “very useful.” The responses, as shown in Table 15, indicate that the operators believe that most of the mirror types are very useful in their operations, with the left-mounted rear-view mirror being rated the most useful.

Table 15: Usefulness of Mirror Placements on Snowplows

	Mean	Std. Dev.
Left-mounted rear-view mirror	4.8	0.6
Left-mounted small convex mirror	4.2	1.1
Right-mounted rear-view mirror	4.6	0.9
Right-mounted small convex mirror	4.2	1.1
Left front fender mirror	3.4	1.6
Right front fender mirror	3.9	1.5
Wing plow mirror	3.7	1.5

Three operators commented that the mirrors only work well when you can see out of the cab. Another operator stated that mirrors often ice-up and are useless unless the operator stops the vehicle to clean them. This individual also noted that the mirrors are heated, but the heaters don't work very well.

To determine the potential effectiveness of advanced snowplow technology in reduced visibility conditions, the factors that contribute to such situations must be identified. Question 10 asked operators to rank how often a specific item contributed to low-visibility situations, using a five-point scale with 1" indicating the item "never causes poor visibility" and "5" indicating the item "always causes poor visibility." Table 16 shows the mean value for items within each of three categories: weather conditions, plowing equipment and driving conditions.

The results showed that, in terms of weather conditions, a combination of falling and blowing snow, or blowing snow only, are perceived as having a greater effect on visibility than does falling snow. Snowplow operations typically, though not always, are suspended during the most severe winter driving conditions. Operators had comments on additional weather conditions that lead to poor-visibility, with the five other most frequently mentioned conditions including: fog (n=194); blowback (i.e., plowing into the wind)(n=124); high winds (n=30); freezing fog/rain/snow (n=31); and nighttime conditions (n=26).

Table 16: Factors that Contribute to Poor Visibility in Snowplows

	Mean	**Std. Dev.**	**Rank**
Weather Conditions			
Falling snow	3.5	0.9	5
Falling & blowing snow	4.4	0.7	1
Blowing snow	4.3	0.8	2
Plowing Equipment			
Plow size	2.5	1.1	9
Plow type	2.8	1.2	8-tie
Vehicle lights	2.9	1.2	7
Driving Conditions			
Meeting passenger vehicles	2.8	1.0	8-tie
Meeting trucks or buses	3.7	1.0	4
Being passed by passenger vehicles	3.0	1.1	6
Being passed by trucks or buses	4.1	1.0	3

The operators indicated that the plow equipment, itself, typically causes fewer reduced visibility situations than does the weather. As part of the question related to the effect plowing equipment has on reduced-visibility situations, operators were asked to describe the placement of the snowplow's lights, with regard to their contribution to visibility problems. Most operators indicated three light positions that they believed increased visibility problems: above the plow on the hood (n=132), fender-mounted (n=59), and too high on the truck (n=28).

When asked to identify other plowing equipment that contributes to poor visibility, operators indicated poor wipers (n=37), poor defrosters (n=27) and ice or snow on windows and/or lights (n=24). This sentiment was also echoed in the general comments provided by the operators. Of the 290 general comments, 167 pertained to problems with the lights, windows, mirrors, windshield wipers, or some combination of these factors.

The driving conditions faced by snowplow operators also contribute to poor visibility situations. After weather and equipment problems, operators ranked being passed by trucks or buses as the third highest factor causing poor visibility conditions, followed in fourth place by meeting trucks or buses. A total of 43 operators commented that either meeting or being passed by other vehicles could create a "snow cloud" that causes a temporary reduction in visibility.

Finally, conditions inside the plow contribute to poor visibility, as well. As noted above, the defrosting system in the plow cannot always keep the windows clear of condensation and ice/snow. Question 12 asked the operators if the windows of their snowplow ever "iced up" and reduced their ability to see outside the vehicle. Eighty-six percent responded that the windows iced up an average of 35 percent of the time (mean), with the median response being 30 percent of the time.

Factors Related to Safe Snowplow Operations

The potential usefulness of the advanced snowplow technology is determined, to a large extent, by the factors that influence safe snowplow operation. Operators were asked to rank five factors in relation to their importance for the safe operation of a snowplow. Each of these factors has the potential to be affected by the advanced snowplow technology, because the RoadView system provides lane awareness information, as well as radar that can detect obstacles to the front, rear and sides of the snowplow. The factors were ranked using a five-point scale, with "1" being "not at all important" and "5" being "very important." Table 17 displays the scores and the rank ordering of the five factors.

Table 17: Factors Related to Safe Snowplow Operation

	Mean	Std. Dev.	Rank
Ability to continuously see the roadway in front of your vehicle	4.79	0.6	2
Ability to see a vehicle my vehicle is approaching	4.78	0.6	3
Ability to see a vehicle approaching from behind	4.32	0.9	5
Ability to determine your lane position at all times	4.70	0.7	4
Ability to see large obstacles (such as stranded cars)	4.84	0.5	1

Snowplow operators felt strongly that all of the five factors were important in terms of their ability to safely operate a snowplow. Although the comparability of the mean scores makes it difficult to draw meaningful conclusions regarding relative differences between the five factors, it appears that the ability to see large obstacles is the highest priority, while the ability to see vehicles approaching from behind is considered relatively least important.

Given the opportunity to identify factors beyond the five predetermined responses, snowplow operators revealed an additional ten factors. From these ten, the four most frequently named factors included: the ability to see wildlife (n=15); the ability to see the edge of the road (n=11); the ability to see outside/windows free of snow and condensation (n=11); and the ability to see people by the roadway (n=9).

Methods for Maintaining Lane Position

To assess how advanced snowplow technology may assist snowplow operators in maintaining their lane position, data was collected to determine current methods used to accomplish this task. Operators were asked to rank the usefulness of nine methods typically used to maintain their lane position. A rank of "1" meant the factor was "completely useless" in maintaining lane position, while a "5" meant the factor was "very useful" in assisting the operator in this capacity.

As shown in Table 18, judging the distance from guardrails ranked the highest, followed by judging the distance from mileposts/delineators. Mileposts and delineators are perhaps the most "available" visual cues for snowplow operators because guardrails are positioned less frequently than mileposts and delineators.

Table 18: Current Methods Used to Maintain Lane Position

	Mean	**Std. Dev.**	**Rank**
Feeling the crown of the road	2.7	1.3	7
Feeling the rumble strips on the shoulder	3.5	1.5	5
Feeling the slope of the shoulder	3.7	1.3	4
Judging the distance from mileposts/delineators	4.0	1.1	2
Judging the distance from fence lines	2.1	1.2	9
Judging the distance from grass lines	2.9	1.4	6
Judging the distance from the center line	3.8	1.1	3
Judging the distance from guardrails	4.1	1.0	1
Following other vehicles' tracks	2.3	1.2	8

In the comments section, operators identified a total of 23 other methods they utilize to maintain their lane position in reduced visibility conditions. The six most popular methods included: knowing the road (n=51), slowing down (n=37), judging your position by seeing lines on the roadway (n=36), judging your distance from snow banks/snow berms (n=25), and using the feel/sound of the road (n=11). General comments made by the operators also discussed the need for operators to know their routes and maintain safe speeds.

A chi-squared analysis indicated that there were significant differences in the perceived usefulness of the above techniques, based on the operators' affiliations with the respective Departments of Transportation. For example, operators from North Dakota believed that feeling the crown of the road was much more useful than did the operators from Idaho. Further, operators from North Dakota and Montana responded that feeling the rumble strips on the shoulder was more useful than did the operators from Wyoming, while Idaho operators were evenly split on the usefulness of feeling rumble strips to help maintain their lane position. Table 19 shows how operators from the four Departments of Transportation rated the usefulness of each method for helping maintain their lane position while plowing in poor visibility conditions. A "+" indicates a significantly higher ranking of usefulness, while a "–" indicates a significantly lower ranking of usefulness. If the column is left blank, it means the operators' responses were comparable to the mean of the perceived usefulness of that method. In all likelihood, some of these differences simply reflect statewide variations in the extent to which certain safety improvements, such as rumble strips or roadside delineators, are utilized.

Table 19: Comparative Usefulness of Methods to Maintain Lane Position

	ID	**MT**	**ND**	**WY**
Feeling the crown of the road	-		+	
Feeling the rumble strips on the shoulder		+	+	-
Judging the distance from mileposts/delineators			-	
Judging the distance from fence lines	+	-		
Judging the distance from grass lines			+	-
Judging the distance from the center line			+	
Judging the distance from guardrails	+	+	-	
Following other vehicles' tracks		-	+	

<u>Accidents and Incidents Aggravated by Low-Visibility Situations</u>

Crossing into other lanes of traffic is one problem exacerbated by poor visibility conditions. Snowplow operators were asked to rank the seriousness of having a snowplow accidentally cross into the oncoming lane. Using a five-point scale with "1" being "not at all serious" and "5" being "very serious," the mean response was 4.2 with a standard deviation of 1.1. Operators commented that their answers were dependent, in large part, on the amount of traffic on the road they were plowing.

The frequency and duration of reduced visibility situations faced by snowplow operators would impact both the perceived need for and potential benefits of the advanced technology. Question 17 asked snowplow operators to quantify the number and duration of loss-of-visibility events during the worst snowstorm they could remember. Figures 1 and 2 show the number and duration of these events, respectively.

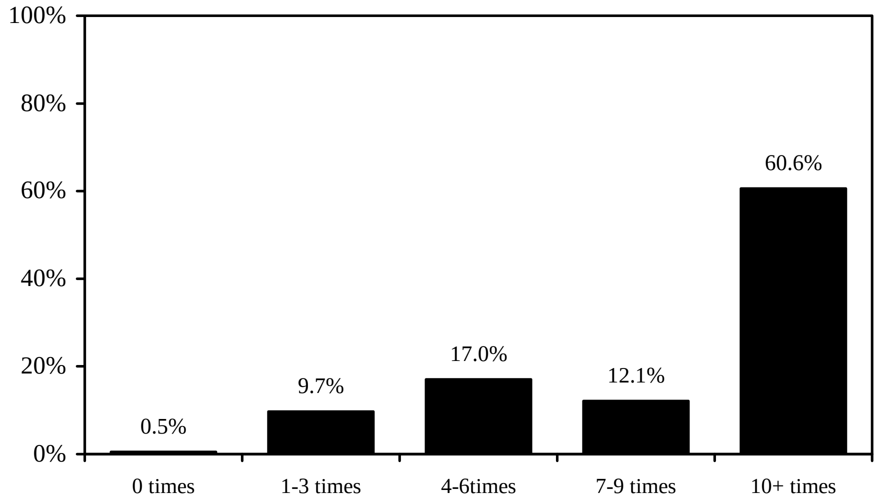

Figure 1: Number of Loss-of-Visibility Events – Worst Storm Scenario

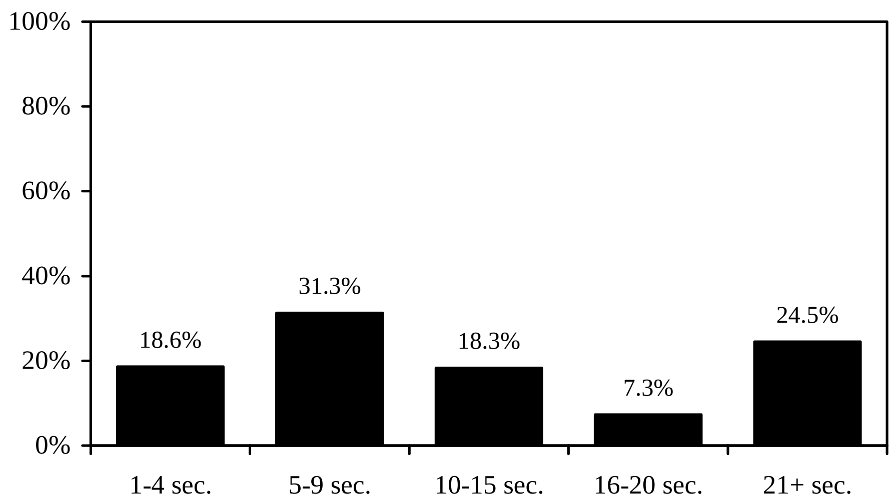

Figure 2: Duration of loss-of-visibility events – worst storm scenario

Question 18 asked operators to estimate the frequency and duration of reduced visibility situations during an average snowstorm. Figures 3 and 4 depict the number and duration of these events, respectively. In terms of the number of loss of visibility events, over 60 percent of the operators reported 10 or more incidents of this type during the worst storm scenario, compared to 14 percent who reported 10 or more incidents during an average snowstorm. The most frequent response was one to three loss-of-visibility events during an average storm, which was selected by over 40 percent of the snowplow operators.

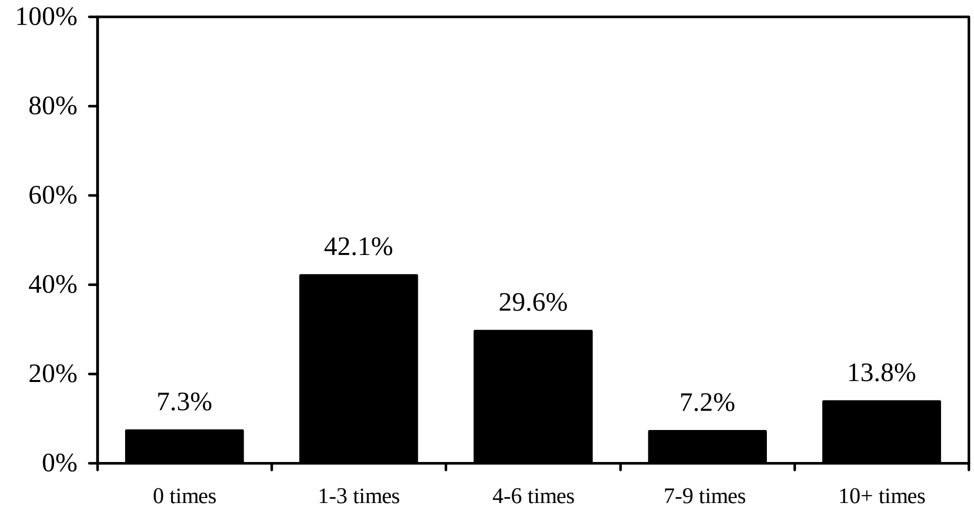

Figure 3: Number of loss-of-visibility events – average storm scenario

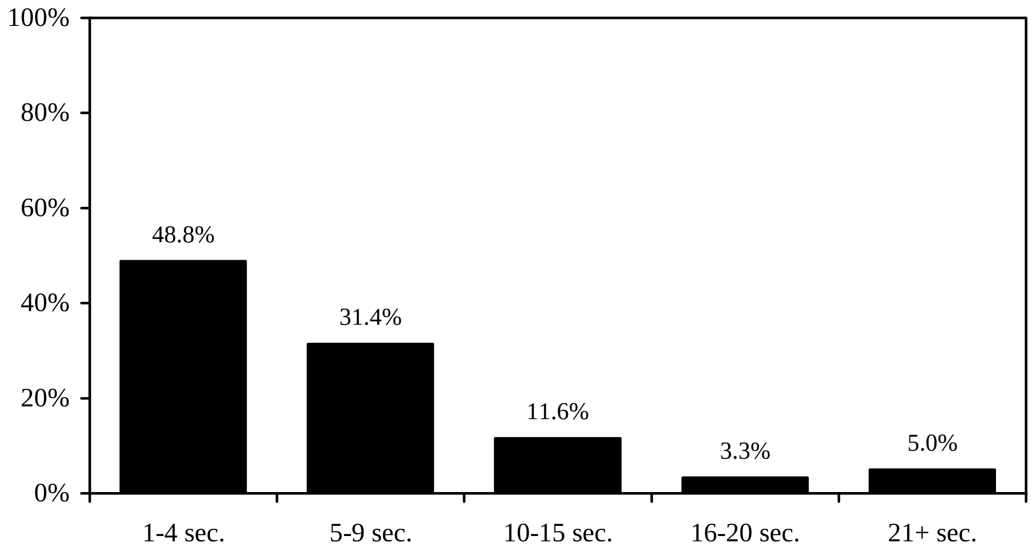

Figure 4: Duration of loss-of-visibility events – average storm scenario

The duration of loss-of-visibility events varied between the worst storm and average storm situations, also. During the worst storm scenario, operators were somewhat more consistent in terms of estimating the length of time they encountered loss of visibility. The range of responses in each time category varied from 7 percent (16-20 seconds) to 31 percent (5-9 seconds). Responses pertaining to an average snowstorm varied from 3 percent (16-20 seconds) to 49 percent (1-4 seconds). Over 80 percent, however, reported that the loss of visibility events during an average snowstorm lasted less than 10 seconds, compared to roughly 50 percent who responded comparably for the worst storm situation.

In analyzing the number and duration of loss-of-visibility events during an average snowstorm, the chi-squared analysis indicated a difference among the operators from the four states. Respondents from North Dakota indicated a higher number of events during an average storm, while those from Idaho indicated significantly fewer loss-of-visibility events. Respondents from Wyoming indicated a longer duration of loss-of-visibility events than did those respondents from the other three states.

A concern when confronted with reduced visibility conditions is that vehicles on the roadway, including snowplows, might have to stop, thereby increasing the potential for an accident. Question 19 asked if the operator ever had to stop during the 2001-2002 winter season because they could no longer determine their lane position. While the majority (53 percent) did not have to stop, 27 percent had to stop between one and four times, and just over 10 percent had to stop between five and nine times, because they could not determine their position on the roadway. A number of operators commented that they believed that they could not stop on the roadway for fear of causing an accident. A chi-squared analysis indicated that operators from Idaho stopped significantly more often than did those from the other states.

Low visibility conditions also increase the risk of snowplows running off the roadway. The consequences of running off the road can include major damage to the snowplow, damage to the infrastructure, or injury to the snowplow operator. Just over 15 percent of the operators responded that they had run off the road during the 2001-2002 winter season. However, data were not collected to ascertain the seriousness of these incidents in terms of the length of time the snowplow was out of operation, or if assistance was needed to get the vehicle back in operation (e.g., being pulled-out of the snow by another snowplow or a tow truck).

As a result of running off the road, seven percent of the operators responded that they struck one or two objects this past winter season. Those who struck an object were asked to identify what they hit. Ten different objects were listed, with the top three being mileposts/delineators (n=55), guardrails (n=37), and curbs (n=10).

Receptivity to Advanced Snowplow Technologies

In analyzing the challenges faced by operators, the survey asked specific questions about technology that might assist them in their snowplow operations. Questions 22 through 25 queried the operators on how useful they thought additional technologies would be in assisting them with their various duties. The operators were not provided any visual representation of the technologies and the questions were kept general. For instance, operators were asked to respond (on a scale of 1 to 5) to this statement: "If the technology existed that could tell you your lane position while plowing, how useful would it be to you?" A score of "1" indicated the operator believed the technology would be "not at all useful" while a "5" was "very useful."

Operators responded most positively to technology that would assist them with maintaining their lane position, and with detecting obstacles in front of the vehicle (Table 20). The responses indicated that technology to detect obstacles to the side and to the rear of the vehicle would be relatively less useful to them. These data closely match the responses provided in Table 17 regarding the influence of certain factors related to safe snowplow operations.

Table 20: Perceived Usefulness of RoadView Technology

	Mean	Std. Dev.	Rank
Provide lane position information	4.22	1.1	2
Detect obstacles in front of your vehicle	4.24	1.1	1
Detect obstacles behind your vehicle	3.57	1.3	3
Detect obstacles to the side of your vehicle	3.48	1.3	4

It was of interest to determine what factors might influence the perceived usefulness of advanced snowplow technology. It was anticipated that those operators who plow the greatest number of routes would have a higher perception of the technology's usefulness because they conceivably would be less familiar with their routes. However, the chi-squared test indicated that those operators who plow only one route had the highest perception of the system's usefulness. The chi-squared test between route length and perceived usefulness was invalid.

Further chi-squared tests indicated that operators from North Dakota thought that technology to provide lane position information would be more useful than did operators from Idaho. A chi-squared test regarding the usefulness of technology to detect obstacles from behind showed similar results, in that operators from North Dakota perceived this to be more useful than did the operators from the other states, while operators from Idaho indicated it to be the least useful technology among the choices available. A final difference shown by a chi-squared test indicated that operators from North Dakota and Wyoming thought technology to detect obstacles to the side of the vehicle would be more useful, than did the operators from Idaho and Montana.

In a further attempt to determine the perceived usefulness of advanced snowplow technology, snowplow operators were asked for their level of agreement with two statements. The first statement (Question 27) was: "There are times, due to weather conditions, that snowplow operations should be suspended." The second statement (Question 28) was: "Even if a system were in place that would be able to display the position of the snowplow on the road in poor visibility, there would still be weather conditions in which snowplow operations should be suspended." Both questions utilized a five-point scale where "1" indicated "strongly agree" and "5" indicated "strongly disagree". Table 21 shows the descriptive statistics for the responses to these two statements.

Table 21: Perceived Need to Suspend Snowplow Operations under Certain Weather Conditions

	Mean	Std. Dev.
Suspend due to weather	2.2	1.5
Suspend due to weather even with technology	2.3	1.4

A chi-squared analysis indicated that there was a significant relationship between the two questions. That is, the operators were in similar agreement with both statements, indicating that that did not feel advanced technology would affect decisions to suspend snowplow operations due to weather conditions. Although the operators perceived the technology to be potentially useful, as evidenced by responses to previous questions, they reportedly believed that there would still be weather conditions in which plowing operations should be suspended. Further, respondents from North Dakota more "strongly agreed" with both statements than did those operators from the other states. Conversely, operators from Idaho more strongly disagreed with both statements than did operators from the other three states.

Additional Chi-squared Analyses

In addition to the chi-squared results noted in the previous sections, there were chi-squared tests that indicated relationships between other variables. The majority of these relationships concerned the perceived usefulness of various methods that operators employed to help them maintain their lane position.

It was hypothesized that operators who had found it necessary to stop most frequently during the past winter season would indicate that "feeling the crown of the road" would be a less useful method for maintaining their lane position. As expected, those operators who had had to stop 16 times or more during the season found this method to be the least useful in terms of maintaining their lane position. However, the chi-squared test showed that operators who had to stop between 10-15 times during the 2001-2002 winter season believed that feeling the crown of the road was more useful than did operators who did not have to stop at all.

Several variables were related to how useful operators believed feeling the rumble strips on the road would be in helping them maintain their lane position. The first relationship indicated that operators who drove five or more routes during a snowstorm found this method most useful, while operators driving one route found this method to be less useful. Operators driving more routes may be less familiar with their roadways and, therefore, must rely on the rumble strips to help them maintain their awareness of lane position.

It was believed that operators who felt the use of rumble strips was an effective strategy would perceive the advanced technology to be less useful; however, the chi-squared test found the opposite to be true. The test revealed that operators who rated rumble strips as the most useful also responded that utilizing technology to help maintain their lane position would be more useful than did other operators.

Those operators who indicated that feeling rumble strips was the most useful method for establishing their lane position more strongly agreed with the statement that there were times, due to weather, that plowing operations should be suspended. This finding contradicted what was expected; if rumble strips were considered very useful in maintaining lane position, it was assumed that there would be less need to suspend plowing operations due to weather conditions because low visibility conditions would not affect the operator's ability to utilize this non-visual cue. The operators who believed that rumble strips were useful more strongly agreed with the statement that, even with advanced technology, there would be times that plowing should be suspended because of severe weather conditions. This indicates that these operators were consistent in their opinion that there were weather conditions in which snowplow operations should be suspended, either with or without the advanced snowplow technology.

Snowplow operators who indicated that judging their distance from mileposts and delineators was relatively less useful for determining their lane position were more strongly in agreement that, even with advanced technology, there would be times that snowplow operations should be suspended due to weather. Perhaps these operators have not determined a method thus far that they believe is useful in maintaining their lane position, and still do not believe technology will be able to assist them with this task.

Those who indicated that judging their distance from a grass line was a highly useful method for maintaining lane position, also tended to more strongly agree that there are times that plowing operations should be suspended due to weather. This finding is intuitive in that during severe winter weather, grass lines would become less visible and, therefore, operators who use this method would be less able to maintain their position in heavier snow conditions. Similarly, a relationship was shown by chi-squared tests that indicated snowplow operators who felt that following other vehicles' tracks was more useful for maintaining their lane position, more strongly agreed that there were times that snowplow operations should be suspended due to weather, with or without advanced technology.

The number of times an operator lost sight of the roadway during an average storm was related to a number of factors. Operators who have not lost sight of the roadway thought technology to detect obstacles from behind would be less useful. Operators who lost sight of the roadway the most, during an average snowstorm, believe that a technology that would detect obstacles from the side would be more useful than operators who lost sight of the road fewer times. As was expected, those operators who lost sight of the roadway more frequently, more strongly agreed that there were times, due to weather conditions, that snowplow operations should be suspended. A chi-squared test revealed similar results in that operators who lost sight of the roadway more often during an average storm also more strongly agreed that even with technology, there would be times due to weather that snowplow operations should be suspended.

A chi-squared test indicated that operators with a higher level of computer experience perceived a higher level of usefulness of technology that would detect obstacles from the side. This was the only chi-squared test that indicated a significant relationship with an operator's level of computer experience.

CHAPTER FOUR: NEEDS ASSESSMENT

A needs assessment represents an attempt to identify and quantify, if possible, the potential benefits of a given accident countermeasure or safety improvement. This task often provides the justification for funding decisions and, as such, is a valuable tool for Departments of Transportation. In this instance, the improvement under consideration is an advanced snowplow technology, referred to as the RoadView system. Based on previous research, RoadView and similar advanced snowplow technologies have been found to assist snowplow operators in determining their lane position, as well as providing a warning of objects and/or obstacles in front of and behind the vehicle (5,6,7,8,9,10). Research in Minnesota (5,7) focused on accidents and their related costs as the basis for continuing research efforts on this topic, and two studies were conducted in Iowa that focused on the operational aspects of plowing snow (6,8). The present study was designed to combine these two approaches in order to provide a detailed investigation into various issues associated with snowplow operations in low-visibility situations, and to consider variables that might be used to measure system effectiveness and assess possible benefits associated with the technology.

Analytical Considerations and Limitations

Identification of the potential benefits of the RoadView system focused on data related to: 1) snowplow-related accidents and run-off-the-road incidents, 2) delays to motorists; and 3) perceptions and opinions of snowplow operators and other maintenance personnel.

Data on accidents and incidents involving snowplows, as well as information on winter road closures, were used to describe the magnitude of problems that might be mitigated with the implementation of the RoadView system. Quantitative data confirmed the incidence of snowplow-related accidents, both with and without the involvement of other vehicles, on those roadways selected as study sites and statewide (Tables 6 and 7, respectively). Roadway closures due to severe winter weather also were documented, resulting in unspecified delays to travelers (Table 5). Intuitively, any technology assumed capable of reducing accident-related costs or injuries would be perceived as beneficial. Furthermore, technology that has the potential to shorten or eliminate road closures would have appeal. As emphasized elsewhere throughout this document, the ability of the RoadView system to reduce accidents or road closures remains undetermined at this point.

Moreover, in assessing whether or not a need exists for advanced snowplow technology, it was difficult to determine an appropriate threshold for each of the factors described above. In other words, at what point does each measure of effectiveness become a meaningful indication of need? How many snowplow-related accidents per year, for example, would have to be reported in order to establish a need for advanced technology? How many winter road closures? How many hours of delay due to road closures? Does the fact that snowplow operators perceive the proposed technology to be highly useful constitute a need? There are no objective criteria for determining appropriate thresholds, and, often times answers to these kinds of questions, by themselves, cannot establish whether the system is needed. Information concerning benefits to be accrued must be compared to the costs associated with the system in order to calculate the net value of the technology, as described in Chapter Six of this report. Only then can a safety improvement program or technology be judged relative to other budgeted or proposed projects to establish funding priorities. Wider-scale deployment and field testing of the RoadView technology are necessary in order to collect empirical data to assess the system's effectiveness and quantify its benefits so that objective decisions can be made regarding the need for and cost-effectiveness of the system.

Given that empirical data were not available to evaluate system effectiveness as part of this research, it was necessary to incorporate other, more subjective, information into the needs assessment. Responses to the snowplow operator survey were used to more broadly define the potential need for the advanced snowplow technology. For example, operators were asked to assess the potential usefulness of technology that would assist them in various aspects of snowplow operations. The survey responses regarding the perceived usefulness of the system became surrogate measures of the technology's potential benefits. It was not possible, however, to meaningfully assign monetary values to these potential benefits, which were based on hypothetical examples of the system's technological capabilities.

Results

The results of the operator survey highlighted several issues that may have implications regarding the need for advanced snowplow technology. (See Chapter Three for a more detailed discussion of the survey results). One of the RoadView system's two primary purposes is to provide lane-positioning information to snowplow operators. When asked what methods operators currently use to maintain their position on the roadway, their three highest ranked choices involved judging their distance from the following roadside features: guardrails, mileposts and delineators, and the centerline. In fact, eight of the fifteen most commonly used methods for maintaining lane position involved visual cues. By definition, these methods all rely on the operator's ability to see out of the vehicle, which may be severely hampered by a number of factors, as discussed below.

Weather conditions, as expected, were ranked highest in terms of factors that contribute to poor visibility. In addition, certain driving conditions (e.g., meeting or being passed by other vehicles) can exacerbate the situation. Whereas these things cannot be controlled, there were other factors that might be addressed through design modifications or routine maintenance and repair. Specifically, three different placements of the vehicle's lights were believed to create visibility problems, and numerous comments on the survey described problems caused by wipers and defrosters that did not function properly.

The importance of maintaining their lane position was ranked fourth out of five factors related to safe snowplow operation, although the mean rankings were extremely close for all five choices. Operators acknowledged that road configuration and traffic volume determine, to a large extent, the risks involved with crossing into another lane of travel. Similarly, run-off-the-road incidents increase during low visibility conditions, which potentially cause damage to the snowplow or the infrastructure, as well as injury to the snowplow operator. Survey responses described the magnitude of this problem, as well as provided information regarding what, if any, objects were struck when the snowplow left the road.

Operators were asked to rank the usefulness of technologies that would assist with four specific tasks, the first of which was providing lane position information. The remaining three tasks dealt with detecting obstacles to the front, rear, and side of the vehicle, respectively. It should be reemphasized that the operators had only a general, written description of each technology (e.g., "If the technology existed that could tell you your lane position while plowing, how useful would it be to you?"). The operators indicated that technology with the ability to detect obstacles in front of their vehicle would be most useful, followed closely by technology to assist with lane position awareness (Table 20).

As alluded to in the previous paragraph, the RoadView system's second major purpose is to warn snowplow operators of obstacles around the vehicle. Detection of obstacles in front of the snowplow was considered the most useful feature of the system, whereas detection of objects to the rear or to the side of the vehicle were relatively less important. When asked to rate a list of factors as to their relative importance to the safe operation of a plow, operators responded similarly in terms of their ability to see obstacles to the rear and side of the vehicle. These two factors were viewed as less important than obstacles in front of the vehicle, or than the vehicle's position in the roadway.

Lastly, the frequency and duration of loss-of-visibility events may be considered relevant to the needs assessment. During an average snowstorm, operators estimated they typically lost sight of the roadway once every two hours, with each occurrence lasting four seconds or less. This finding was similar to results obtained by McGehee and Raby (6) when they surveyed snowplow operators in Iowa and Minnesota. Loss-of-sight occurrences did not happen frequently or for extended periods of time, but these events can cause stress for snowplow operators, as can snow removal activities, in general. Perhaps more importantly, such instances can affect the efficiency of snowplow operations. During reduced visibility conditions, operators may have to significantly reduce their speed or stop their vehicle altogether. Either action potentially affects the mobility of travelers, and could have safety implications for both the snowplow operators and other motorists on the roadway.

Conclusions and Implications

This research identified ways in which advanced snowplow technologies may benefit snowplow operations, but operational testing on a wider scale and for extended periods of time are needed to establish the effectiveness of the system. To date, advanced snowplow technologies have been utilized predominantly in "proof of concept" or "proof of technology" research. Minnesota and California have had early successes in demonstrating that certain technologies can provide lane position and obstacle detection warnings to snowplow operators. Ultimately, however, deployment of the technology in real world situations will be necessary to provide quantifiable data on system benefits associated with reductions in accidents or delays.

There is evidence to support the continued research on and operational testing of advanced snowplow technologies. Historical data confirm snowplow-only and snowplow vs. motor vehicle accidents on designated roadways in this research effort, although the true magnitude of the problem may be underestimated, given the reporting limitations associated with ANSI's Rule D.16 (12). Reductions in mobility caused by winter road closures also were documented. The ability of an advanced snowplow system to directly impact these factors has not been determined, but should be investigated.

The results of the snowplow operator survey revealed the extent to which operators rely on their ability to see obstacles and vehicles in front of the snowplows and to utilize visual cues to maintain their lane position. Given the variety of circumstances in which visibility is severely restricted, advanced technology to assist operators by providing lane position information and obstacle warnings has obvious utility. The added potential benefit of reducing operator workload and stress was not addressed specifically in this study, but should be examined in future research efforts.

As stated previously, in order to determine the feasibility of widespread use of RoadView or other advanced snowplow technologies, it is important to consider the costs, as well as the potential benefits, of the system. A discussion of variables that could be used in a cost/benefit analysis of RoadView is included in the next chapter, along with cost/benefit scenarios using the five designated study sites.

CHAPTER FIVE: COST/BENEFIT ANALYSIS

For the cost/benefit analysis, an attempt was made to quantify the benefits of the RoadView system in terms of safety and mobility. For purposes of this analysis, the economic benefits associated with improved safety were related strictly to reductions in the number of snowplow-only accidents. Benefits associated with increased mobility were related solely to decreases in the time associated with road closures due to winter weather. Other benefits of the advanced technology may be related to increased effectiveness and efficiency of snowplow operations, which, in turn, may increase both mobility and safety. No attempt was made to quantify these variables for use in the calculations.

Quantification of the system's potential benefits was problematic, due to a lack of empirical data. Advanced snowplow technologies have been used in demonstrations or "proof of concept" research, but have not been deployed in sufficient numbers or for a sufficient length of time to enable a rigorous evaluation of the system's effectiveness. Thus, estimates of reductions in the frequency of snowplow-related accidents and the occurrence and duration of road closures were arbitrary. As discussed elsewhere in this report, previous demonstrations have concluded that the technology was useful in terms of providing snowplow operators with greater lane/roadway awareness during low visibility plowing operations (9), but estimates of the accident-reduction capabilities of the system, or the system's effect on road closures are unavailable. Thus, the results of the cost/benefit analysis should be interpreted with caution.

Overview of Analytical Technique

To perform the cost/benefit analysis, an equation was used to calculate the annualized benefits and costs associated with full deployment of the RoadView system and produce a benefit/cost ratio.

The costs associated with the advanced technology system include both in-vehicle and in-road elements. The in-vehicle costs of the RoadView system include the sensors, monitors and support systems that allow the technology to provide lane positioning information and obstacle detection to the snowplow operator. The in-road costs are those associated with placing magnets in the roadway which, when read by sensors in the vehicle, provide lane position information.

The total system cost can be calculated by adding the in-road costs with the in-vehicle costs. The resulting total can then be divided by the expected useful life of the system to provide an annualized system cost. Finally, annual maintenance costs are added to calculate the total annual cost for the RoadView system.

It is hypothesized that full implementation of the RoadView system will produce certain benefits. Possible benefits include a reduction in the duration of road closures and a reduction in the frequency or severity of snowplow-only accidents. The monetary savings associated with these benefits are annualized, also. Finally, the annualized benefits can be divided by the annualized costs to calculate a benefit/cost ratio. If the ratio is greater than 1.0, the RoadView system would be considered cost effective.

A simplified summary of the calculations used to produce the benefit/cost ratios is provided below:

Costs	
In-road costs	$ I-R
In-vehicle costs	+ $ I-V
Total RoadView system initial purchase costs	$ Tot Cost
Annualized cost (Total cost/N yrs. + maintenance)	$ COST
Benefits	
Reduction of road closure duration (annual hours gained)	$ CD
Reduction of snowplow-only accidents (annual number)	+ $ SP
Annualized benefits from the RoadView system	$ BENE
Annual gain (loss)	$ COST-BENE
Benefit/Cost Ratio	BENE/COST

To illustrate the potential costs and benefits associated with implementing the RoadView system, five scenarios were analyzed. These scenarios pertain to the five areas that were targeted for data collection, as identified in Chapter 2. The roadways represented in the scenarios have individual characteristics that distinguish them from one another, including variations in traffic volume, the number of lanes, road grade, and the frequency of road closures due to winter weather conditions. By reviewing the scenarios, the factors that influence the benefit cost/ratio can be examined more fully.

Parameters Used in the Analysis

As previously discussed, the expected benefits of the RoadView system include increased safety and mobility. It is assumed that implementation of the RoadView technology will reduce the number and duration of road closures, as well as reduce the number of snowplow-only accidents. Operational benefits are anticipated, as well, but measures of the efficiency of plowing operations were not included in the analysis.

To calculate the economic benefits associated with the implementation of the RoadView system, the following data were used in each scenario: snowplow-only accident statistics, Average Annual Daily Traffic (AADT) and Average Daily Truck Traffic (ADTT), and the aggregate duration of road closures. The data used in Scenarios 1-4 were collected as part of this study, while the data utilized in Scenario 5 were collected by Ravani, et al. (9).

The benefits of the RoadView system were quantified using the following factors:

- Travel delay cost for automobiles of $12.20 per hour[3]
- Travel delay cost for commercial vehicles of $25.30 per hour[3]
- Cost of damage to snowplows per accident of $2,450[4]

The costs associated with the RoadView system pertain to placing magnets in the roadway (in-road costs), as well as outfitting the snowplow with the necessary radars, sensors, and control units (in-vehicle costs). Previous research identified the following costs associated with the RoadView project (14):

- In-vehicle costs = $30,000 per snowplow (includes installation)
- In-road costs = $18,000 per lane mile (includes installation)
- Maintenance costs = $500 per year per snowplow
- In-vehicle and in-road equipment life expectancy = 5 years

The scenarios and the formula utilized constant dollars (i.e., not adjusted for inflation) and were rounded to the nearest ten dollars ($10.00). It was assumed that the number of hours associated with road closures due to winter weather would be reduced by 5 percent. An average of 4 hours per closure was used for the purposes of the scenarios. It was further assumed that snowplow-only accidents would be reduced by 15 percent. Finally, the number of snowplows to be equipped with the RoadView system for deployment on each roadway was established on the basis of the number of miles and lane-miles to be plowed. Because of the cost associated with equipping the plows, it was assumed that a minimal number of plows would be equipped for each area, and used primarily for that specific roadway. Because plows are often part of a "gang plowing" operation, two plows were used for all but one of the scenarios. Four plows were used in the Idaho scenario because of the high number of lane miles for this example.

---

[3] Texas Transportation Institute (13)

[4] Parsons, Brinckerhoff, Quade & Douglas, Inc. (7)

Scenario #1: US-12 in Idaho (Between Lolo Pass and Lowell, Idaho)

The section of US-12 used in this analysis begins at the Lolo Pass, located on the Montana – Idaho border, and flows to the southwest, to the town of Lowell, Idaho. The majority of this section of roadway follows along the Lochsa River. As described previously (Table 3), this roadway segment consists of 76 miles of two-lane highway.

In-road costs (152 lane miles)	$ 2,736,000
In-vehicle costs (4 snowplows)	120,000
Total RoadView system initial purchase costs	$ 2,856,000
Annualized cost (including maintenance)	$ 573,200
Reduction of road closure duration[1]	$ 0
Reduction of snowplow-only accidents[2]	3,310
Annualized benefits from the RoadView system	$ 3,310
Annual gain (loss)	($ 569,890)
Benefit/Cost Ratio	0.006

Assumptions:

[1]Although Lolo Pass was closed during the five-year timeframe examined in this study, the closures were due to forest fires and avalanche conditions, factors that would not be affected by RoadView technology. Thus, there could be no reduction in this variable.

[2]Snowplow only accidents would be reduced from 9 to 7.65 (15% reduction)

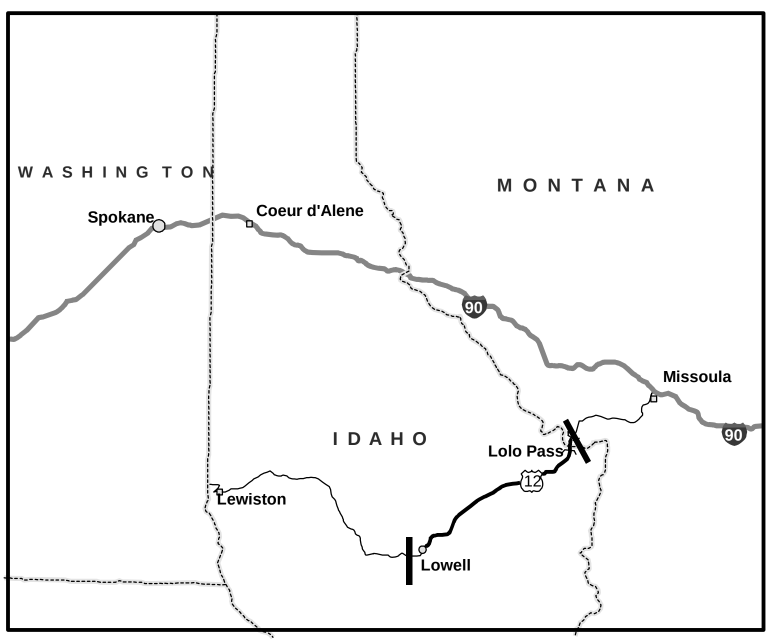

Figure 5: Idaho (US-12) Scenario Site

Scenario #2: Homestake Pass on I-90 near Butte, Montana

Homestake Pass is located on Interstate 90 approximately seven miles southeast of Butte, Montana. Interstate 90 is a major East-West road, connecting the West Coast to the Midwest. The area considered in this analysis consists of 14 miles of four-lane Interstate highway.

In-road costs (56 lane miles)	$ 1,008,000
In-vehicle costs (2 snowplows)	60,000
Total RoadView system initial purchase costs	$ 1,068,000
Annualized cost (including maintenance)	$ 214,600
Reduction of road closure duration[1]	$ 1,780
Reduction of snowplow-only accidents[2]	1,470
Annualized benefits from the RoadView system	$ 3,250
Annual gain (loss)	($ 211,350)
Benefit/Cost Ratio	0.015

Assumptions:

[1]Reduction in closures equals 0.4 hours per year (5% reduction).

[2]Snowplow-only accidents would be reduced from 4 to 3.4 (15% reduction).

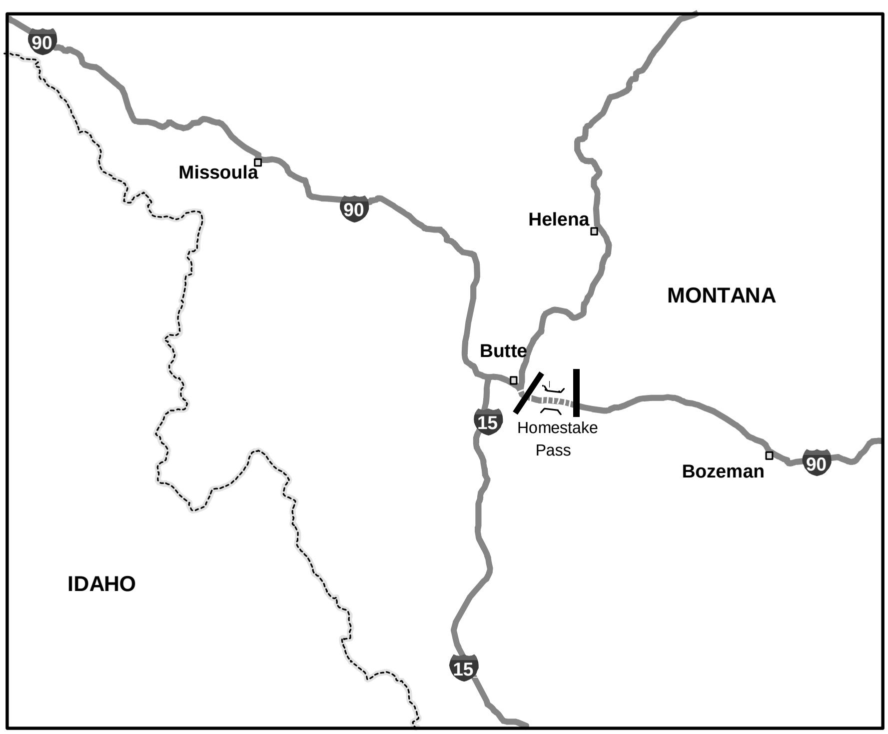

Figure 6: Montana (I-90) Scenario Site

Scenario #3: I-94 in North Dakota near Bismarck

Interstate 94 runs the entire length of the State of North Dakota, approximately 360 miles. I-94 enters the State in the east at Fargo (the largest city in the State), and continues west through Bismarck (the Capital) and then into Montana. As described in Table 3, the targeted 31-mile section of I-94 consists of four-lane Interstate highway between Bismarck and Driscoll, North Dakota.

In-road costs (124 lane miles)	$ 2,232,000
In-vehicle costs (2 snowplows)	60,000
Total RoadView system initial purchase costs	$ 2,292,000
Annualized cost (including maintenance)	$ 459,400
Reduction of road closure duration[1]	$ 2,230
Reduction of snowplow-only accidents[2]	1,100
Annualized benefits from the RoadView system	$ 3,330
Annual gain (loss)	($ 456,070)
Benefit/Cost Ratio	0.007

Assumptions:

[1]Reduction in closures equals 0.5 hours per year (5% reduction).

[2]Snowplow-only accidents would be reduced from 3 to 2.55 per year (15% reduction).

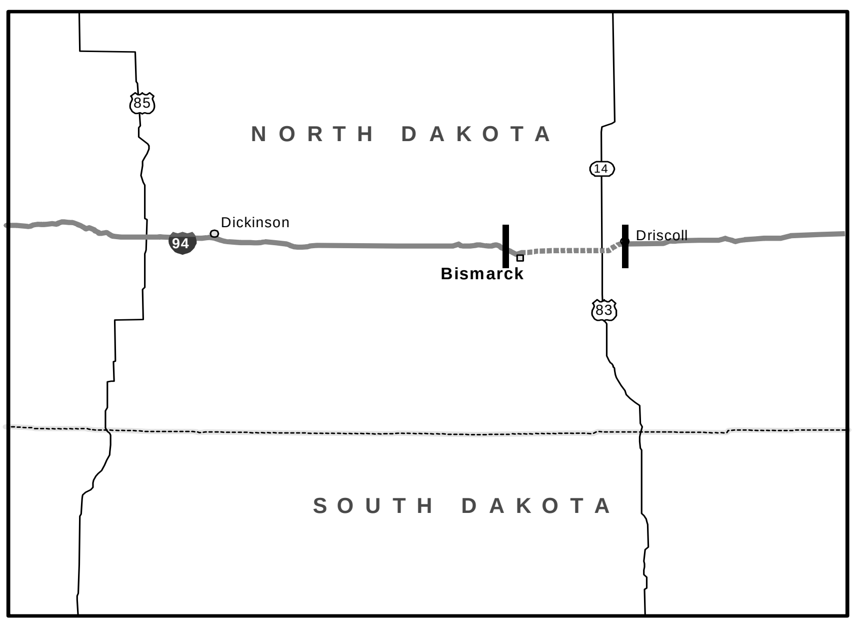

Figure 7: North Dakota (I-94) Scenario Site

Scenario #4: I-80 in Wyoming near Laramie

Interstate 80 runs the entire length of the State of Wyoming, approximately 400 miles. I-80 enters the State in the east near Cheyenne (the Capital and largest city in the State), and continues west into Utah. The targeted 12-mile section of I-80 consists of four-lane Interstate highway, near Laramie, Wyoming extending eastward to milepost 329.

In-road costs (48 lane miles)	$ 864,000
In-vehicle costs (2 snowplows)	60,000
Total RoadView system initial purchase costs	$ 924,000
Annualized cost (including maintenance)	$ 185,800
Reduction of road closure duration[1]	$ 11,370
Reduction of snowplow-only accidents[2]	1,470
Annualized benefits from the RoadView system	$ 12,840
Annual gain (loss)	($172,960)
Benefit/Cost Ratio	0.069

Assumptions:

[1] Reduction in closures equals 1.7 hours per year (5% reduction).

[2]Snowplow-only accidents would be reduced from 4 to 3.4 per year (15% reduction).

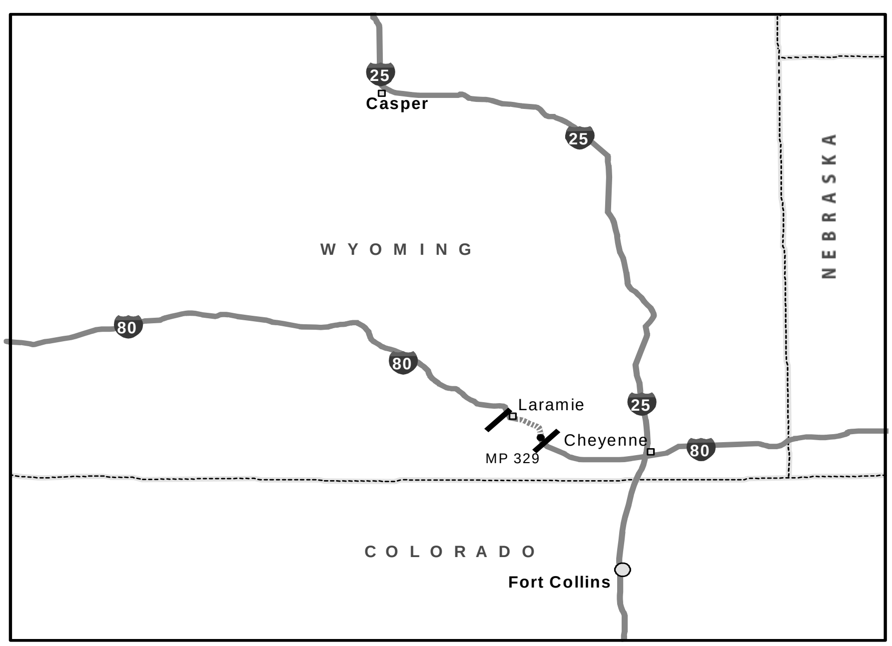

Figure 8: Wyoming (I-80) Scenario Site

Scenario #5: Donner Pass, California

Donner Pass is located on Interstate 80, to the west/southwest of Reno, Nevada. Although magnets were placed in just one lane for previous research (9), it was assumed that all lanes would receive magnets for purposes of this scenario. The targeted section includes approximately four miles of Interstate highway, part two-lane and part three-lane in configuration.

In-road costs (20 lane miles)	$ 360,000
In-vehicle costs (2 snowplows)	60,000
Total RoadView system initial purchase costs	$ 420,000
Annualized cost (including maintenance)	$ 85,000
Reduction of road closure duration[1]	$ 106,740
Reduction of snowplow-only accidents[2]	6,250
Annualized benefits from the RoadView system	$ 112,990
Annual gain (loss)	$ 27,990
Benefit/Cost Ratio	1.33

Assumptions:

[1]Reduction in closures equals 4.4 hours per year (5% reduction).

[2]Snowplow-only accidents would be reduced from 17 to 14.45 per year (15% reduction).

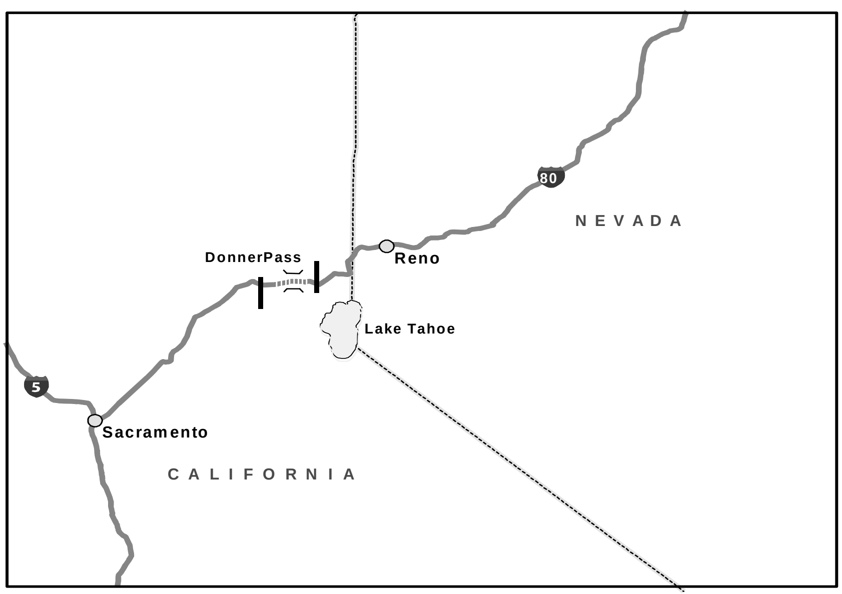

Figure 9: California (I-80) Scenario Site

Conclusions and Implications

The RoadView system was found to be cost-effective in only one of the five scenarios, the Donner Pass area in California. Several characteristics that distinguished this site from the other locations should be highlighted. First, this location experienced the highest frequency of snowplow-related accidents (Table 6) among the study sites, as well as the highest four-year average of winter road closures (Table 5). In fact, road closures at this site were six to ten times more frequent than at the other four locations. The AADT at Donner Pass was approximately six times greater than at the remaining sites, with ADTT figures ranking second only behind the designated roadway in Wyoming (Table 2). Thus, it appears that the RoadView system may have the greatest impact on roadways that have a history of numerous winter road closures, with high volumes of automobile and truck traffic. Roadways with high accident experience (i.e., crashes involving only snowplows or snowplows vs. other motor vehicles) also should be considered for deployment of vehicles equipped with advanced snowplow technologies in order to maximize the opportunity to detect and measure the system's effect on snowplow-related crash and injury rates.

To further illustrate the impact that road closures, traffic volume and the length of road have on the benefit/cost ratio, a "break-even" curve was created for each scenario. The break-even curve is defined as having a benefit/cost ratio of 1.0 at any point along its length. Points lying to the right of the curve have a benefit/cost ratio of greater than 1.0, while points to the left of the curve would have a benefit/cost ratio of less than 1.0. Break-even curves were individually calculated for each of the five scenarios. The values for annual system costs, snowplow-only accident costs, and the percent of ADTT remain the same as in the scenarios shown earlier. To create the break-even curves, the number of road closures and AADT were manipulated until the benefit/cost ratio was equal to 1.0. Distinct curves for each of the five scenarios are shown in Figure 10. In addition, corresponding values of actual road closures and AADT are also shown for each site. It is important to note that the data point for each scenario should be compared only against its distinct break-even curve.

From the analysis, it was found that the length of the roadway to be instrumented, the number of closures and AADT are the three most significant factors in determining whether the RoadView system would be cost effective in a particular area. The number of snowplow only accidents had less effect on the analysis because of relatively small cost of these incidents. Therefore, benefits realized from deployment are realized mostly through delay savings to the traveling public and, to a much lesser extent, snowplow only accidents. Bear in mind that this analysis was based on assumed estimates of benefit to be derived from the RoadView system. The California scenario, with only 20 lane-miles of roadway to be instrumented had $85,000 of annual costs to cover before the break-even point was reached, while the Idaho scenario, with 76 lane-miles of roadway had $573,200 of annual costs to cover before the RoadView system would break-even.

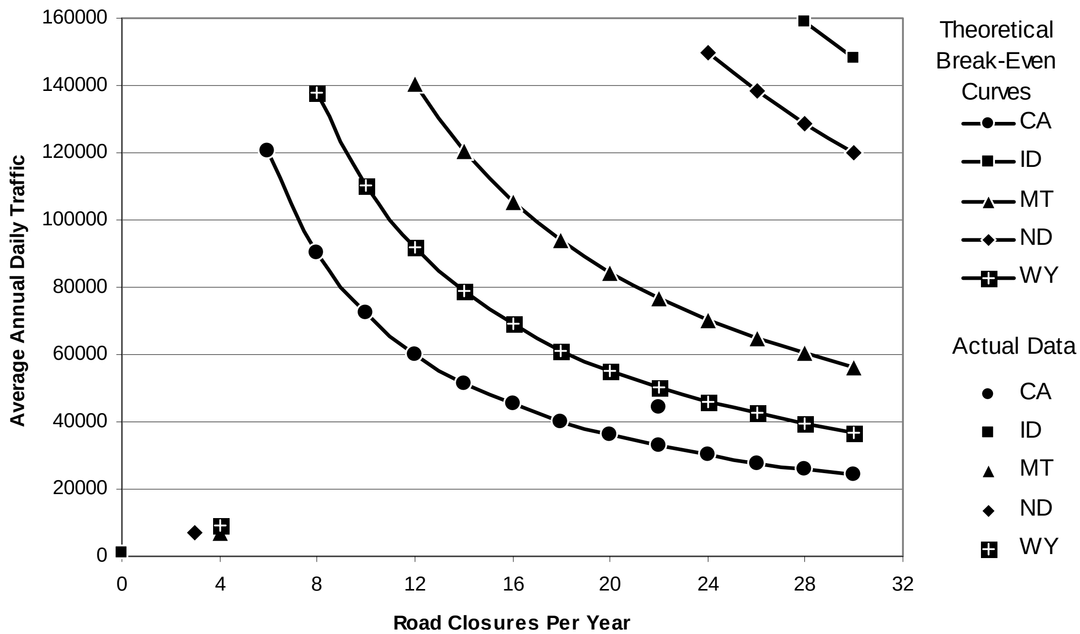

Figure 10: Break-even Analysis of RoadView System

At this stage of development, the costs associated with the RoadView system are extensive. Installation of the magnets is currently estimated to cost $18,000 per lane mile (14), which some Departments of Transportation may find prohibitive. It may be possible, however, to utilize the magnets in other safety improvement programs, thereby spreading the costs between projects or responsible agencies. Further testing or system modifications may reduce costs, as well, as could wholesale manufacture and product distribution. It is anticipated that the equipment costs might be reduced by up to 20 percent in a full-scale production/deployment scenario (14). The useful life of the in-road portion of the system (i.e., the magnets) is estimated to be at least five years; however, this estimate will depend, largely, on the frequency of resurfacing activities on any given roadway. Extending the useful life of the RoadView components would increase the benefit/cost ratio, because the system costs could be amortized over a longer period of time. Assuming the estimates of system benefits used in the scenarios were reasonable, the costs currently associated with the advanced snowplow technology would have to be reduced significantly in order to make the system cost-effective. Once again, however, these results must be interpreted with caution because of the arbitrary estimates of system effectiveness used in the calculations.

CHAPTER SIX: SUMMARY AND RECOMMENDATIONS FOR FURTHER RESEARCH

The goal of this project was to determine the feasibility of implementing an advanced snowplow guidance and warning system to improve the safety and efficiency of snow removal operations, and to assess potential costs and benefits associated with combining conventional snowplow operations with Intelligent Vehicle (IV) technologies. The study was designed to determine the magnitude of the challenges faced by snowplow operators while they attempt to clear roadways of snow and ice, particularly during low visibility conditions. Both a needs assessment and a discussion of variables that could be used in a cost/benefit analysis of the RoadView system were provided, along with a detailed analysis of responses to a survey administered to snowplow operators. This study was not intended as an effectiveness evaluation of the system.

The quantitative and qualitative data that were collected for subsequent analyses were related to safety, mobility and operational issues. Previous demonstrations have shown the potential success of RoadView deployments, although such demonstrations were limited in terms of the number of vehicles equipped with the advanced technology and the amount of time these vehicles had been in operation. Theoretically, the technology utilized in the RoadView project is expected to increase safety by reducing erratic snowplow movements, run-off-the-road incidents and lane departures, snowplow accidents, damage to other vehicles and the infrastructure, and injuries to snowplow operators or other vehicle occupants. Increasing the speed or efficiency of snow removal tasks may reduce road closures and travel delays, thereby improving both the operational aspects of snow removal activities and the mobility of motorists during adverse winter weather.

Historical data confirmed the incidence of snowplow-related accidents, both with and without the involvement of other vehicles, along those roadways selected as study sites. Roadway closures due to severe winter weather also were documented, which resulted in unspecified delays to travelers. Presumably, any technology capable of reducing accident-related costs or injuries would be perceived as beneficial. Furthermore, technology that has the potential to shorten or eliminate road closures would have intuitive appeal. The task of determining the need for advanced technology without the benefit of empirical data was problematic. Therefore, subjective assessments of the perceived usefulness and potential benefits of the system, based on the responses to the snowplow operator survey, were used as additional measures or indications of the need for the technology.

The survey also provided information regarding difficulties encountered by snowplow operators while conducting operations in low visibility conditions, current practices and operational concerns, and the receptivity of operators to the advanced technology. During an average snowstorm, for example, snowplow operators estimated they typically lost sight of the roadway between one and six times, for roughly four to five seconds per event. In terms of current operations, the three visual cues that snowplow operators relied on most frequently to maintain their position on the roadway included judging their distance from: guardrails, mileposts/delineators, and the centerline. When asked to assess the potential usefulness of various advanced technologies, operators gave the highest ratings to those that would provide lane position information, followed by those that would provide obstacle detection capabilities.

Despite these high ranking of potential usefulness, operators felt that there would be weather conditions in which snowplow operations should be suspended, regardless of the availability of advanced snowplow technology.

As with the needs assessment, the cost/benefit analysis was limited by the lack of empirical data to measure system benefits. Five scenarios that corresponded to the designated study sites were used to illustrate how benefit/cost ratios for the RoadView system could be calculated. It must be emphasized that, until sufficient data have been collected to quantify the benefits of the advanced snowplow technology, such hypothetical examples should not be considered statistical estimates of system effectiveness and should be interpreted with caution. In response to these concerns, what were believed to be conservative estimates of potential benefits associated with the RoadView system were used in the calculations. In comparison, Parsons Brinkerhoff Quade & Douglas, Inc. (7) utilized benefit levels of 10, 20 and 30 percent for reducing the number of snowplow crashes with other motor vehicles and fixed objects, reducing delays to commercial vehicles, and increasing the productivity of snowplow operations.

Of the five scenarios, only one produced a benefit/cost ratio greater than 1.0 (i.e., signifying benefits that outweighed the costs of the system). Overall, it appears that the potential cost-effectiveness of the RoadView system would be increased in areas with high traffic volumes and high probabilities of road closures due to winter weather, or in areas that have experienced a large number of snowplow-related accidents in the past.

Recommendations for Further Research

Within the confines of the survey, snowplow operators were asked to assess the perceived usefulness of advanced technologies without the benefit of direct exposure to or previous experience with the RoadView system. Visual or "hands on" demonstrations of the technology would provide more accurate and realistic assessments of the usefulness of the technology. Without actual experience, particularly in adverse weather conditions, the operators' perceptions of the technology must be considered highly subjective, because they are based purely on hypothetical situations. The snowplow operators' ability and willingness to use RoadView technology as the primary means of guidance could be tested by utilizing driving simulators, or virtual reality scenarios that would give snowplow operators the ability to interact with the technology in a variety of conditions. This testing also could examine the expected operational benefits, such as increased plowing speeds, associated with the advanced snowplow technologies. Moreover, simulators or virtual reality tests could provide other vehicle operators, such as emergency response personnel or commercial vehicle operators, the opportunity to gain practical experience with the technology.

Ultimately, the system's effectiveness at reducing snowplow accidents and run-off-the-road incidents, as well as reducing the incidence or duration of road closures, can be determined only through more extensive deployment of technology-equipped vehicles over an extended period of time. The Donner Pass section of I-80 in California is believed to be a likely candidate for a full-scale deployment of RoadView technology in the future. In addition, a similar advanced snowplow system has been deployed in the Thompson Pass area near Valdez, Alaska, which could provide data for further analyses. It is possible that other technological advances will be available for comparison in the future, as well. For instance, Minnesota has experimented with using Differential Global Positioning Satellite (DGPS) technology to provide enhanced lane awareness information to snowplow operators. Other technologies should be examined whenever possible to investigate alternatives that might prove to be more cost-effective than the RoadView or comparable systems.

It will be extremely important for Departments of Transportation to establish appropriate data collection procedures so that reliable data on snowplow-related accidents, regardless of the involvement of other vehicles, are available and accessible for analysis. Similarly, information on run-off-the-road incidents or other operational problems should be recorded routinely, along with associated repair costs to the snowplows or roadway infrastructure. Such data are essential to evaluations of the RoadView system's effectiveness and subsequent cost/benefit analyses.

Periodic revisions to the cost data pertaining to RoadView or similar technologies will be required, assuming future modifications to the system, wholesale distribution, or other developments reduce the in-vehicle and/or in-road costs. In addition, the possibility of expanding the applications for the RoadView technology should be investigated (e.g., providing lane-positioning information to emergency response or commercial vehicles), which could result in in-road costs being shared by other agencies.

Previous research and the responses of the snowplow operators to the survey administered as part of this study strongly suggest that the potential benefits of the advanced snowplow technology are sufficient to justify further testing of the system. However, the results of the current analyses illustrate the limitations of attempting to assess the need for the technology, or calculate cost/benefit ratios, without empirical data to measure system effectiveness. It is strongly recommended that evaluations of the accident-reduction and delay-reduction capabilities of the technology, based on actual deployment of RoadView-equipped vehicles, be conducted as soon as sufficient data are available for analysis.

REFERENCES

1. *Bozeman Daily Chronicle*, Wednesday, November 28, 2001.

2. Salt Institute statement on Standard & Poor's DRI Study, Winter 1999. Available on-line at http://www.saltinstitute.org/pubstat/s-p-dri.htm.

3. Hanbali, Rashad M., "Economic Impact of Winter Road Maintenance on Road Users," *Transportation Research Record* 1442.

4. Knapp, Keith K., Smithson, Leland D., and Khattak, Aemal J., "The Mobility and Safety Impacts of Winter Storm Events in a Freeway Environment," *Mid-Continent Transportation Symposium 2000 Proceedings.*

5. Booz-Allen & Hamilton, Inc., "Evaluation of the Minnesota Department of Transportation's Intelligent Vehicle Initiative Snowplow Demonstration Project on Trunk Highway 19," Winter 1998-1999, Prepared for the Minnesota Department of Transportation, October 27, 1999.

6. McGehee, Daniel V., and Raby, Mireille, "Operator Interface Design Rational for the 3M™ Lane Awareness System for Snow Removal Operations". Draft Report, The University of Iowa, July 3, 2000.

7. Parsons Brinckerhoff Quade & Douglas, Inc., "Snow Plow Vehicle Case Study Summary Report," Submitted to the Minnesota Department of Transportation Office of Advanced Transportation Systems, September 21, 1998.

8. Raby, Mireille, McGehee, Daniel V., Nourse, Gary E., and Bartingale, Steve, "Operator Interface Design Of A Lane Awareness System For Snow Removal Operations.

9. Ravani, Bahram, et al, "Advanced Snowplow Development and Demonstration: Phase I: Driver Assistance," Advanced Highway Maintenance and Construction Technology (AHMCT) Research Report, UCD-ARR-99-06-30-03, June 30, 1999.

10. Ravani, Bahram, et al, "Development of an Advanced Snowplow Driver Assistance System (ASP-II)," Advanced Highway Maintenance and Construction Technology (AHMCT) Research Report, UCD-ARR-00-06-30-02, June 30, 2000.

11. Salt Institute "Risk Managers Are On The Snowfighting T-E-A-M." Available on-line at http://www.saltinstitute.org/risk.html.bak.

12. Personal conversation with Mr. Ken Hackman on June 12, 2002.

13. Texas Transportation Institute (TTI) "Benefit-Cost Spreadsheet," Available on-line at http://tti.tamu.edu/austin/research/b-c_spreadsheet_6-00.xls.

14. Correspondence with Mr. Kin Yen, University of California-Davis, and Mr. Stephen Owen, Arizona Department of Transportation.

APPENDIX A: INITIAL CONTACT INFORMATION

Alaska

Person Contacted (When):

- Frank Richards, Department Engineer, (2/01, 3/01, 4/01, 5/01, 6/01, +)
- Douglas Lewis, (6/01, 7/01, 9/01, +)
- Greg Patz, Chief of Section Maintenance and Operation, (6/01)
- Cling Adler, Jeff Ottesen, State ITS Manager, (5/01)

Data Received (Who):

- Most challenging roadways are Thompson Pass and Turnagain Pass (Frank Richards)
- Crash results for Thompson Pass (Douglas Lewis)
- Location description for Thompson Pass (AADT, ADTT, grade, chain requirements, & length of segment) (Douglas Lewis)
- Pass closures (Douglas Lewis)
- RoadView implementation overview (Clint Adler, Jeff Ottesen)

Arizona

Person Contacted (When):

- Daniel Russell, ADOT Flagstaff District Maintenance Superintendent, (2/01, 3/01, 4/01, 5/01, & 6/01)
- Crystal Phipps, Assistant to ADOT Flagstaff District Maintenance Superintendent
- Lt. Dan Wells, Arizona Department of Public Safety, Flagstaff Patrol District (6/01)
- Dennis Kiefer, ADOT Traffic Safety, Flagstaff District (3/01)
- John Harper, ADOT Flagstaff District Maintenance Engineer (6/01)

Data Received (Who):

- Most challenging roadways are I-40, I-17, & US-89 (all surrounding Flagstaff)
- Crashes, closures, and chain requirements (Daniel Russell) <Data wasn't broken out per year, was told that it was not possible for crashes and chains>
- AADT & ADTT (Dennis Kiefer)
- RoadView implementation overview (John Harper)

California

Person Contacted (When):

- Rob Marsh, (2/01)
- Jack Tonkin (2/01, 3/01)

Canada

Person Contacted (When):

- British Columbia: Mark Duncan (3/01)
- Manitoba: Dave Murray (3/01)

Data Received (Who):

- Most challenging roadway segments are HWY 37 Glacier Hwy and Bear Pass in NW BC (Dave Rider)

- Closures per year, snowfall, and location description; no reply on request for crashes/closures (Dave Rider)

Colorado

Person Contacted (When):

- Susan Maculah (2/01)
- Ed Rozgay (2/01)
- Lee Metzgler, Avalanche Forecast (2/01)
- Mark Mueller, Avalanche Forecast (2/01)
- Dennis McCoy, Maintenance Engineer (2/01)
- George Watley, Maintenance Foreman (2/01 & 3/01)
- Jeff Sneider, Maintenance Foreman (3/01, 4/01, 5/01, & 6/01)

Data Received (Who):

- Most challenging roadway segments are Vail Pass, Berthoud Pass, Wolf Creek Pass, and Rabbit Ears Pass (Susan Maculah)
- Pass descriptions (Ed Rozgay)
- Winter road closure log (Ed Rozgay)
- Crash data not available (CSP, CDOT-Ed Rozgay)
- Snowfall data (Mark Mueller)
- Crash data not available (George Watley & Jeff Sneider): <only provided estimates>

Idaho

Person Contacted (When):

- Jim Carpenter District 2 Engineer (5/01, 9/01, & 10/01)
- Johann Thompson District 6 Business Manager
- Lytle Gaskill District 4 Maintenance Engineer (5/01)
- Jim Hutchins District 6 Maintenance Engineer (5/01)
- Herb Drexler Maintenance Foreman (4/01)
- Cheryl Rost Safety and Risk Management (2/01, 3/01, 4/01, 5/01, & 10/01)
- Dave Jones State Maintenance Engineer (2/01, 10/01, & 1/02)
- Janet Kalin Forest Service (2/01)
- Pat Lightfield District 2 Maintenance Engineer (10/01)
- Cathy Koon Assistant to Jim Hutchins (6/01 & 7/01)

Data Received (Who):

- Most challenging roadway segments are Lolo Pass, Galena Summit, Monida Pass, and Henry's Lake Flat (Dave Jones)
- Operator contact list unavailable/no response (Johann Thompson)
- Snowfall data <Henry's Lake Flat> (Janet Kalin)
- Pass closure and crash data (Cathy Koon)
- Crash data (Cheryl Rost)
- Closure, location description, and chains (Pat Lightfield)
- Contact list unavailable (Herb Drexler)
- Snowfall data <statewide> (NOAA website)

Montana

Person Contacted (When):

- Doug Moeller, Bozeman District Engineer (5/01, 6/01, & 7/01)
- Roger Pearson, Duck Creek Section Maintenance Engineer (6/01)
- Don Woodland, Bozeman Pass Maintenance (6/01)
- Russ Rooney, Gallatin Canyon Maintenance (6/01)
- Russ McDonald, Big Sky Section Maintenance (7/01)
- Suella Chapman, Butte Radio Dispatch (8/01)
- Dan Bisom, State Traffic Engineer (7/01)
- Wayne O'Connell, Butte District Maintenance Engineer (7/01)
- Shane Stack, Lolo Pass Maintenance (7/01)
- George Schwartz, Lolo Pass Maintenance (7/01)
- Tesch Brandi, State Maintenance (1/02)
- Mike Bousliman, State Maintenance (1/02)

Data Received (Who):

- Most challenging roadway segments are Homestake Pass & Gallatin Canyon (Doug Moeller). Also looked at Lolo Pass (See IDAHO)
- AADT & ADTT for Homestake Pass and Gallatin Canyon (Dan Bisom)
- Chain-up's and crashes collected in person from the MDT log books (7/01 & 8/01) *recorded numbers were negligible
- Homestake Pass location description (Wayne O'Connell)
- Poor responses all around <got crashes for Gallatin Canyon from Russ Rooney> most data collected was anecdotal.
- Number of Operators by Section (Brandi Tesch)
-

Nevada

Person Contacted (When):

- Thor Dyson (2/01, 3/01)
- Wayne Allred (2/01, 3/01)

North Dakota

Person Contacted (When):

- Jerry Horner, Department Engineer (2/01, 5/01, 6/01, 7/01, 8/01, 11/01, & 01/02)
- Troy Gilbertson, Maintenance (6/01)
- Steve Chase, Safety Officer (6/01 & 7/01)
- Aarden Johnson, Risk Management (8/01 & 9/01)
- Kevin Levi, Maintenance (6/01)
- Jim Redding, Maintenance (6/01)
- Verna Kadrmas (1/02)

Data Received (Who):

- Most challenging roadway segments are I-29 Red River Valley, I-94 Bismarck/Valley City, and US-2 Minot (Jerry Horner)
- Red River Valley location description and closures, no chain law (Troy Gilbertson)

- Crashes per year for all of I-94 (Steve Chase) <not broken out by MP or year>
- Crash data <with type and cost> (Aarden Johnson)
- AADT & ADTT (Jerry Horner)
- Number of Operators by District (Verna Kadrmas)

Oregon

Person Contacted (When):
- Patrick Cooney (2/01)
- Doug Tindell (2/01, 3/01)

South Dakota

Person Contacted (When):
- Norm Humphrey (2/01)

Utah

Person Contacted (When):
- Lynn Bernhard, Department Engineer (3/01, 5/01, 6/01 & 7/01)

Data Received (Who):
- Most challenging roadway segments are I-80 Parley's Summit, US-6 Soldier's Summit, & South Hwy 210 Alta/Brighton (Lynn Bernhard)
- Discussed challenged areas and received soft data over the phone to include: Location Description, Chain law (activation), Closures, and Mileposts. No crash data. (Lynn Bernhard)

Washington

Person Contacted (When):
- Casey McGill, Olympic Region Maintenance Superintendent (2/01, 3/01, & 4/01)
- Sam Krahenbuhl, Snoqualmie Maintenance Superintendent Assistant (3/01)
- David Bowers, Roadway Maintenance Engineer (3/01)

Data Received (Who):
- Most challenging roadway segments are I-5 Tacoma Dome & SR-241 Rattlesnake Ridge (Casey McGill)
- Overall response to inquiries were negative as for visibility challenges to snow removal operations…..their challenges are more due to traffic.

Wyoming

Person Contacted (When):
- William Kirsch, Maintenance (3/01)
- Ron Chavez, Risk Management (10/01)
- Ken Schultz, Department Engineer (3/01, 6/01, 10/01, & 12/01)
- Tim McGary, Maintenance (2/01)
- Calvin Goddard, Maintenance (2/01)
- Ted Wells, Maintenance (2/01)

- Larry Konetkzi, Maintenance (2/01)
- Martin Kidner, Maintenance (2/01)
- Dee West, Highway Safety Supervisor (3/01, 10/01, & 12/01)

Data Received (Who):

- Most challenging roadway segments are I-80 Laramie/Cheyenne, Teton Pass, & I-80 Rock Springs/Rollins (Ken Schultz)
- Crashes unavailable (Ron Chavez)
- Crashes <cumulative> (Dee West)
- Location Descriptions (Maintenance)
- Operator contact list (Ken Schultz)

APPENDIX B: SNOWPLOW OPERATOR SURVEY

When distributed to the snowplow operators, this survey was on two 8 ½ by 14 sheets of paper, printed back-to-back

We are interested in finding out about your experiences with snowplow operations. Please answer each question to the best of your ability and as precisely as possible. If you have any comments or additional information you wish to provide, do not hesitate to write in the margins. Participation in this survey is strictly voluntary, and there is no penalty for not participating. All results are confidential, and no effort will be made to link individuals to a particular survey. **When finished, please return the completed survey in the postage paid return envelope along with the yellow card to enter the drawing for $50. Entries must be received by March 29,2002.**

Thank you for your time and taking part in this survey.

Section 1: Equipment characteristics

This section is designed to determine the type(s) of equipment you use in your snow removal operations.

1. How many different models/types of snowplow vehicles did you drive during the current (01-02) winter season? ________

2. What is the year, make, model and axle type of the snowplow vehicle you drove most frequently this (01-02) season?

Year_________ Model_______________________________

Make______________________________ Axle________________________________

3. During the current (01-02) season what percentage of time, on average, did you use each of these plows or systems? (*Circle the number that best represents the percentage of time you used the following equipment*)

a. Front-mounted, one-way plow	0%	10	20	30	40	50	60	70	80	90	100%
b. Front-mounted, two-way plow	0%	10	20	30	40	50	60	70	80	90	100%
c. Front-mounted V-plow	0%	10	20	30	40	50	60	70	80	90	100%
d. Front-mounted snowblower	0%	10	20	30	40	50	60	70	80	90	100%
e. Under-body ice blade or plow	0%	10	20	30	40	50	60	70	80	90	100%
f. Left wing plow	0%	10	20	30	40	50	60	70	80	90	100%
g. Right wing plow	0%	10	20	30	40	50	60	70	80	90	100%
h. Material spreader	0%	10	20	30	40	50	60	70	80	90	100%

Section 2: Route characteristics

This section is designed to determine the features of the route you plow.

4. In the current (01-02) season how many different routes did you plow during an average snowstorm?________

5. What was the approximate length of your primary route this season (*do not include deadhead miles*)

_________lane miles

6. Approximately how many lane miles of each type of roadway do you plow on your current primary route (*do not include deadheading*)

__________lane miles of ramps __________lane miles of two-lane divided interstate

__________lane miles of city streets __________lane miles multi-lane (3 or more) divided interstate

__________lane miles of two-lane undivided highways __________lane miles of two-lane divided highways

__________lane miles of other roadways (please describe)___________________________

7. During this winter season what was your:

a. Average driving time _________hours per shift

b. Maximum driving time _________ hours

c. Average speed while plowing _________ mph

d. Minimum speed while plowing _________ mph

e. Maximum speed while plowing _________ mph

8. As part of your snowplow operations do you ever "backplow" or "back drag"? (operating the vehicle in reverse with the plows down)

____ No

____Yes. If yes, approximately how many times during an average storm_____________

Section 3: Visibility Issues

9. How useful are the following types of mirrors during snowplow operations? (*Circle the number that best represents your answer*)

	Completely Useless				Very Useful	Do Not Use
a. Left-mounted rear-view mirror	1	2	3	4	5	____
b. Left-mounted, small convex mirror	1	2	3	4	5	____
c. Right-mounted rear-view mirror	1	2	3	4	5	____
d. Right-mounted, small convex mirror	1	2	3	4	5	____
e. Left front fender mirror	1	2	3	4	5	____
f. Right front fender mirror	1	2	3	4	5	____
g. Wing plow mirror	1	2	3	4	5	____
h. Other:______________________	1	2	3	4	5	____

10. Estimate how often you believe each of the following items contributes to poor visibility while you are conducting snowplow operations? (*Circle the number that best represents your answer*)

	Never causes poor visibility				Always causes poor visibility
Weather conditions:					
a. falling snow	1	2	3	4	5
b. falling and blowing snow	1	2	3	4	5
c. blowing snow	1	2	3	4	5
d. Other______________________________	1	2	3	4	5
Plowing equipment:					
e. plow size	1	2	3	4	5
f. plow type	1	2	3	4	5
g. vehicle lights	1	2	3	4	5

If the vehicle lights cause a visibility problem, please describe their placement on the snowplow

____

h. Other______________________________	1	2	3	4	5
Driving conditions:					
i. Meeting passenger vehicles	1	2	3	4	5
j. Meeting trucks or buses	1	2	3	4	5
k. Being passed by passenger vehicles	1	2	3	4	5
l. Being passed by trucks or buses	1	2	3	4	5
m. Other________________________	1	2	3	4	5

11. Describe any other weather conditions OR situations not listed in Question 10 that have caused visibility problems for you during snowplow operations.

____

____

____

12. During the current season did the windows of your snowplow vehicle ice up and reduce your visibility?

____ No

____ Yes. If yes, what percentage of the time? __________ percent.

13. How important are each of the following factors are in safely operating a snowplow vehicle? (*Circle the number that best represents your answer*)

	Not at all Important				Very Important
a.. Ability to continuously see the roadway in front of your vehicle	1	2	3	4	5
b. Ability to see a vehicle my vehicle is approaching	1	2	3	4	5
c. Ability to see a vehicle approaching from behind	1	2	3	4	5
d. Ability to determine your lane position at all times	1	2	3	4	5
e. Ability to see large obstacles (such as stranded cars)	1	2	3	4	5
f. Other______________________________________	1	2	3	4	5

14. How useful are the following methods in helping you maintain your lane position while plowing in poor visibility? (*Circle the number that best represents your answer*)

	Completely Useless				Very Useful
a. Feeling the crown of the road	1	2	3	4	5
b. Feeling the rumble strips on the shoulder	1	2	3	4	5
c. Feeling the slope of the shoulder	1	2	3	4	5
d. Judging the distance from mileposts/delineators	1	2	3	4	5
e. Judging the distance from fence lines	1	2	3	4	5
f. Judging the distance from grass lines	1	2	3	4	5
g. Judging the distance from the center line	1	2	3	4	5
h. Judging the distance from guardrails	1	2	3	4	5
i. Following other vehicles' tracks	1	2	3	4	5
j. Other________________________	1	2	3	4	5

15. Describe any methods not listed in Question 14 that you have found useful in maintaining your lane position in poor visibility.

____

____

____

16. Based on your experience, how serious of a problem do you believe it is to have snowplows accidentally cross into the oncoming lane? (*Circle the number that best represents your answer*)

Not at all serious				Very serious
1	2	3	4	5

17. During the WORST snowstorm you can remember, how often, and for how long, did you completely lose sight of the roadway and shoulders in front of your snowplow vehicle?

Number of times: ___0 ___1-3 ___4-6 ___7-9 ___10 or more

Average duration (seconds): ___1-4 ___5-9 ___10-15 ___16-20 ___21 or more

18. During an AVERAGE snowstorm, how often, and for how long, do you completely lose sight of the roadway and shoulders in front of your snowplow vehicle?

Number of times: ___0 ___1-3 ___4-6 ___7-9 ___10 or more

Average duration (seconds): ___1-4 ___5-9 ___10-15 ___16-20 ___21 or more

19. During this current winter season, did you ever have to stop because you could no longer determine your lane position?

____No

____Yes. If yes, number of times: ___1-4 ___5-9 ___10-15 ___16-20 ___21 or more

20. During the current winter season did you hit an object (for example, guardrail, post) because of poor visibility?

____No

____Yes. If yes, number of times: _______ What did you hit:_____________________________________

21. During the current winter have you ever run off the road because of poor visibility during snowplow operations?

____No

____Yes. If yes, number of times: ___1-4 ___5-9 ___10-15 ___16-20 ___21 or more

22. If the technology existed that could tell you your lane position while plowing, how useful would it be to you? (*Circle the number that best represents your answer*)

Not at all Useful				Very Useful
1	2	3	4	5

23. If there was a device that was able to detect obstacles in front of your vehicle while plowing, how useful would it be to you? (*Circle the number that best represents your answer*)

Not at all Useful				Very Useful
1	2	3	4	5

24. If there was a device that was able to detect obstacles behind your vehicle while plowing, how useful would it be to you? (*Circle the number that best represents your answer*)

Not at all Useful				Very Useful
1	2	3	4	5

25. If there was a device that was able to detect obstacles to the side of your vehicle while plowing, how useful would it be to you? (*Circle the number that best represents your answer*)

Not at all Useful				Very Useful
1	2	3	4	5

26. If there was a device that would allow you to determine your lane position while plowing, how would you like that information to be relayed/displayed to you? (C*heck all that apply*)

____Visually (for example, arrows to show if you are left or right of center)

____Auditory (for example, buzzer or bell sounds)

____Motion (for example, vibration in the driver's seat)

____Other:____

Indicate your level of agreement with the following statements:

27. There are times, due to weather conditions, that snowplow operations should be suspended.
(Circle the number that best represents your answer)

Strongly Agree		Neutral		Strongly Disagree
1	2	3	4	5

28. Even if a system were in place that would be able to display the position of the snowplow on the road in poor visibility, there would still be weather conditions in which snow plow operations should be suspended. (*Circle the number that best represents your answer*)

Strongly Agree		Neutral		Strongly Disagree
1	2	3	4	5

Section 4: Demographic Information

The following information is necessary to ensure that your responses are properly represented in this survey. **This information will only be used for the purposes of this survey.**

29. Which organization do you work for?

____Idaho DOT ____North Dakota DOT

____Montana DOT ____Wyoming DOT

____Other ____

30. What is your age?_______________ **31. What is your gender? ____Male ____Female**

32. How many years have you worked as a snowplow operator?__________

33. What is the highest grade or level of school you have completed?

____No high school ____Some college or 2-year degree

____Some high school, but did not graduate ____4-year college graduate

____High school graduate or GED ____more than 4-year college degree

34. How would you rate your experience level in the use of a computer?
(Circle the number that corresponds to your level)

No Experience		Intermediate		Advanced
1	2	3	4	5

Comments and suggestions

Please provide any comments or suggestions you may have for improving your ability to see from your vehicle and maintaining your lane position during low-visibility snowplow operations.

Thank you for your time in completing this survey. When finished, please return the completed survey in the postage paid envelope along with the yellow card to enter the drawing for $50.

<u>Entries must be RECEIVED by March 29, 2002</u>

APPENDIX C: ANALYSIS OF SURVEY RESULTS AND COMMENTS

Snowplow Operator Survey Results

Note that "NA" means "Not Answered". In analyzing the results, percentages, means, standard deviations, and medians are calculated based on the total number of responses to a particular question, not the total number of surveys returned.

Comments to specific survey questions are listed after the question in order of total responses. The lack of a number after a response indicates that only one (1) response was given. General comments and suggestions, at the end of this section, are grouped by category.

Section 1: Equipment characteristics

1. How many different models/types of snowplow vehicles did you drive during the current (01-02) winter season?

	One Vehicle	Two Vehicles	Three Vehicles	More than three	NA
Idaho DOT	47	69	68	54	61
Montana DOT	24	53	55	54	35
North Dakota DOT	36	70	49	30	50
Wyoming DOT	37	64	39	56	41
Total	144	256	211	194	187
%	17.89	31.80	26.21	24.10	---

2. What is the year, make, model and axle type of the snowplow vehicle you drove most frequently this (01-02) season?

Year

	1979 or earlier	1980-1984	1985-1989	1990-1994	1995-1999	2000 or newer	NA
Idaho DOT	0	0	28	79	136	47	9
Montana DOT	2	15	32	62	56	41	13
North Dakota DOT	0	0	23	100	71	32	9
Wyoming DOT	0	5	26	62	95	43	6
Total	2	20	109	303	358	163	37
%	0.20	2.10	11.41	31.73	37.49	17.07	---

Make

	Idaho DOT	Montana DOT	North Dakota DOT	Wyoming DOT	Total	%
AutoCar	34	4	0	6	44	4.54
Chevy	0	17	10	9	36	3.72
Ford	22	70	26	46	164	16.92
Freightliner	13	0	0	0	13	1.34
GMC	21	52	19	28	120	12.38
GMC/Volvo	14	19	5	3	41	4.23
GMC/White	11	0	0	0	11	1.15
International (IH)	18	15	165	124	322	33.23
Mack	157	0	0	0	157	16.20
Sterling	0	36	0	12	48	4.95
Other	3	1	5	4	13	1.34
Did not answer	6	7	5	5	23	---
Total	299	221	235	237	992	100.00

Model – No analysis provided as operators confused make and model.

Axle

	Single-Axle	Tandem-Axle	No Answer
Idaho DOT	91	188	20
Montana DOT	59	155	7
North Dakota DOT	107	116	12
Wyoming DOT	75	146	16
Total	332	605	55
%	35.43	64.57	---

3. During the current (01-02) season what percentage of time, on average, did you use each of these plows or systems?

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	NA
Front-mounted	One-way plow	289	82	31	18	16	27	11	14	29	61	137	277
Front-mounted	Two-way plow	80	57	31	21	17	34	23	31	55	120	413	110
Front-mounted	V-plow	450	43	8	2	1	9	0	2	0	0	11	466
Front-mounted	Snow blower	418	70	19	14	2	10	2	1	0	0	1	455
Under-body Ice blade or plow		434	41	17	7	8	18	3	1	2	0	8	453
Left wing plow		475	13	4	8	3	1	0	1	2	3	4	478
Right wing plow		312	108	31	21	15	30	13	22	25	28	41	346
Material spreader		24	15	28	31	22	53	17	38	55	79	477	153

	Mean % of use
a. Front-mounted one-way plow	37.9
b. Front-mounted two-way plow	72.8
c. Front-mounted V-plow	2.8
d. Front-mounted snow blower	5.2
e. Under-body ice blade or plow	6.3
f. Left wing plow	2.9
g. Right wing plow	23.8
h. Material spreader	80.9

Section 2: Route characteristics

4. In the current (01-02) season, how many different routes did you plow during an average snowstorm?

	One (1)	Two (2)	Three (3)	Four (4)	Five (5) or more	No Answer	Median
Idaho DOT	60	116	62	25	31	5	2.0
Montana DOT	15	55	61	47	40	3	3.0
North Dakota DOT	32	83	62	44	11	3	3.0
Wyoming DOT	41	75	52	34	29	6	2.0
Total	148	329	237	150	111	17	3.0
%	15.18	33.74	24.31	15.39	11.38	---	---

5. What was the approximate length of your primary route this season *(do not include deadhead miles)*

	N	Mean	Std. Dev.	Median
Idaho DOT	291	75.42	59.97	60.00
Montana DOT	210	104.81	88.40	76.00
North Dakota DOT	228	81.63	50.28	68.00
Wyoming DOT	226	83.83	53.84	74.50
Total	955	85.36	64.87	68.00

6. Approximately how many lane miles of each type of roadway do you plow on your current primary route (do not include deadheading)

Ramps

	N	Mean	Std. Dev.	Median
Idaho DOT	170	7.27	20.43	2.50
Montana DOT	123	13.57	25.57	4.00
North Dakota DOT	132	4.96	10.49	2.00
Wyoming DOT	142	5.78	15.26	2.00
Total	567	7.73	18.95	2.00

City streets

	N	Mean	Std. Dev.	Median
Idaho DOT	183	4.43	7.29	2.00
Montana DOT	142	6.69	12.34	2.00
North Dakota DOT	123	4.64	14.29	0.50
Wyoming DOT	135	3.96	12.30	1.00
Total	583	4.92	11.48	2.00

Two-lane undivided highways

	N	Mean	Std. Dev.	Median
Idaho DOT	255	59.95	128.81	48.00
Montana DOT	197	107.30	75.08	90.00
North Dakota DOT	195	69.02	49.35	60.00
Wyoming DOT	200	80.10	64.44	70.00
Total	847	77.81	90.23	60.00

Two-lane divided highways

	N	Mean	Std. Dev.	Median
Idaho DOT	134	17.57	34.91	0
Montana DOT	96	15.92	43.13	0
North Dakota DOT	123	26.45	38.69	1.00
Wyoming DOT	96	12.01	29.38	0
Total	449	18.46	37.08	0

Two-lane divided interstate

	N	Mean	Std. Dev.	Median
Idaho DOT	155	50.30	67.55	28.00
Montana DOT	113	79.05	100.94	31.00
North Dakota DOT	128	42.48	54.04	22.50
Wyoming DOT	135	67.91	72.87	50.00
Total	531	59.00	75.60	32.00

Multi-lane (3 or more) divided interstate

	N	Mean	Std. Dev.	Median
Idaho DOT	120	5.31	18.75	0
Montana DOT	90	5.37	27.81	0
North Dakota DOT	96	3.35	11.36	0
Wyoming DOT	93	3.39	9.01	0
Total	399	4.40	18.13	0

Other roadways

	N	Mean	Std. Dev.	Median
Idaho DOT	117	16.91	39.97	0
Montana DOT	90	24.58	44.05	3.50
North Dakota DOT	72	6.46	19.44	0
Wyoming DOT	78	18.97	47.16	0
Total	357	17.18	40.00	0

- 2-lane undivided roads with turn or passing lane (16)
- Secondary roads (16)
- Frontage - service roads (11)
- Undivided 5-lane (10)
- Undivided 4-lane (10)
- Gravel roads (7)
- Turn-outs (5)
- Undivided 2-lane (3)
- Undivided multi-lane (2)
- 4-lane to 6-lane roads (2)
- In-town & city streets (2)
- Rest area approaches

7. During this winter season what was your:

a. Average driving time

	N	Mean	Std. Dev.	Median
Idaho DOT	295	8.52	1.80	8.00
Montana DOT	217	7.08	1.82	8.00
North Dakota DOT	229	6.76	2.31	7.00
Wyoming DOT	233	7.94	1.90	8.00
Total	974	7.65	2.08	8.00

- Varies per storm

b. Maximum driving time

	N	Mean	Std. Dev.	Median
Idaho DOT	295	12.58	2.91	12.00
Montana DOT	217	11.14	4.34	12.00
North Dakota DOT	224	9.88	3.16	10.00
Wyoming DOT	225	11.94	4.95	12.00
Total	961	11.48	3.99	12.00

- Depends on storm (3)
- As many as needed (2)
- As many as it took to finish

c. Average speed while plowing

	N	Mean	Std. Dev.	Median
Idaho DOT	298	32.67	2.57	35.00
Montana DOT	221	34.09	5.25	35.00
North Dakota DOT	232	34.72	5.91	35.00
Wyoming DOT	236	37.63	6.16	35.00
Total	987	34.66	5.92	35.00

d. Minimum speed while plowing

	N	Mean	Std. Dev.	Median
Idaho DOT	296	14.15	8.97	11.00
Montana DOT	217	16.03	8.71	15.00
North Dakota DOT	232	18.88	7.44	20.00
Wyoming DOT	235	18.32	10.66	20.00
Total	980	16.69	9.22	15.00

- Depends on the weather
- 30 mph, 20 in fog

- Mph is determined by the difference in each storm (storm –powder –wet heavy) (visibility)

e. Maximum speed while plowing

	N	Mean	Std. Dev.	Median
Idaho DOT	297	40.48	6.97	40.00
Montana DOT	221	42.00	5.38	45.00
North Dakota DOT	230	42.64	7.08	42.50
Wyoming DOT	235	47.05	9.41	45.00
Total	983	42.90	7.75	45.00

8. As part of your snowplow operations do you ever "backplow" or "back drag" (*operating the vehicle in reverse with the plows down*)?
If yes, approximately how many times during an average storm.

	No	Yes	Mean	Std. Dev.
Idaho DOT	272	27	2.44	3.30
Montana DOT	207	14	2.21	2.58
North Dakota DOT	208	27	4.37	4.77
Wyoming DOT	213	24	3.09	2.63
Total	900	92	----	----
%	90.73	9.27	----	----

8. Areas that operators backplow or back drag

- On chain up areas " turn outs"
- We do reverse plow: going forward pushing to the left side or wind-rowing
- Yes- very minimal –cleaning R.R. tracks
- It depends on the situation
- When doing cleanup

Section 3: Visibility Issues

9. How useful are the following types of mirrors during snowplow operations?
(1=completely useless, 5= very useful)

	1	2	3	4	5	NA
a. Left-mounted rear-view mirror	11	5	29	83	847	17
b. Left-mounted, small convex mirror	35	58	144	172	519	64
c. Right-mounted rear-view mirror	21	37	54	110	746	24
d. Right-mounted, small convex mirror	40	52	124	193	517	66
e. Left front fender mirror	59	35	44	43	114	697
f. Right front fender mirror	50	21	33	64	193	631
g. Wing plow mirror	48	21	27	52	135	709
h. Other	6	1	3	4	24	954

	N	Mean	Std. Dev.	Median
a. Left-mounted rear-view mirror	975	4.79	0.62	5.00
b. Left-mounted, small convex mirror	928	4.17	1.13	5.00
c. Right-mounted rear-view mirror	968	4.57	0.92	5.00
d. Right-mounted, small convex mirror	926	4.18	1.13	5.00
e. Left front fender mirror	295	3.40	1.57	4.00
f. Right front fender mirror	361	3.91	1.45	5.00
g. Wing plow mirror	283	3.72	1.53	4.00
h. Other	38	4.05	1.50	5.00

9c. Right-mounted, rear-view mirror

- Good when you can see out of cab (2)
- Mirror ices up and is useless with out stopping to clean the are heated but don't work very well

9d. Right-mounted, small convex mirror

- Good when you can see out of cab

9f. Right front fender mirror

- Should be mandatory on vehicle 6" min dia.

9g. Wing plow mirror

- We need them

9h. Other mirrors

- Large convex mirrors (10)
- Heated mirrors (7)
- Underbody mirrors (2)
- Convex wing mirrors
- "Blind side" mirror

10. Estimate how often you believe each of the following items contributes to poor visibility while you are conducting snowplow operations?
(1=never causes poor visibility, 5=always causes poor visibility)

	1	2	3	4	5	NA
Weather Conditions						
a. Falling snow	4	92	456	297	131	12
b. Falling and blowing snow	0	7	94	369	515	7
c. Blowing snow	1	29	128	373	442	19
d. Other	4	6	41	44	139	758
Plowing Equipment						
e. Plow size	202	247	335	119	46	43
f. Plow type	153	207	315	193	83	41
g. Vehicle lights	147	192	296	195	113	49
h. Other	11	5	11	25	17	923
Driving Conditions						
i. Meeting passenger vehicles	80	325	354	145	67	21
j. Meeting trucks or buses	23	103	234	363	251	18
k. Being passed by passenger vehicles	70	293	326	176	103	24
l. Being passed by trucks or buses	31	61	138	318	425	19
m. Other	11	6	15	21	25	914

	N	Mean	Std. Dev.	Median
Weather Conditions				
a. Falling snow	980	3.47	0.85	3.00
b. Falling and blowing snow	985	4.41	0.69	5.00
c. Blowing snow	973	4.26	0.80	4.00
d. Other	234	4.32	0.96	5.00
Plowing Equipment				
e. Plow size	949	2.54	1.11	3.00
f. Plow type	951	2.84	1.18	3.00
g. Vehicle lights	943	2.93	1.23	3.00
h. Other	69	3.46	1.37	4.00
Driving Conditions				
i. Meeting passenger vehicles	971	2.79	1.03	3.00
j. Meeting trucks or buses	974	3.74	1.03	4.00
k. Being passed by passenger vehicles	968	2.95	1.09	3.00
l. Being passed by trucks or buses	973	4.07	1.05	4.00
m. Other	78	3.63	1.35	4.00

10d. Other weather conditions that contribute to poor visibility

- Fog (194)
- Blow back – plowing into the wind (124)
- High winds (30)
- Freezing fog/rain/snow (31)
- Nighttime conditions (26)
- Snow fog (19)
- Heavy wet snow fall (15)
- White outs (14)
- Blowing dirt/dust (11)
- Drifting snow (11)
- Sleet – rain and snow mix (8)
- Ground blizzard (8)
- Ice (5)
- Flat light conditions (3)
- Rain (2)
- Hail

10g. If the vehicle lights cause a visibility problem, describe their placement snowplow.

- Above plow on hood (132)
- Fender mount (59)
- Too high on the truck (28)
- On the grill (7)
- Fog lights mounted too low (5)
- Rain (2)

10h. Other plowing equipment that contributes to poor visibility

- Poor wipers (37)
- Poor defrosters (27)
- Ice and/or snow on windows, mirrors and/or lights (24)
- Fog lights not strong enough (7)
- Plow and plow flags (5)
- Color of lights (2)
- Equipment in Cab reducing visibility (2)

10m. Other driving conditions that contribute to poor visibility

- Snow cloud – caused by other vehicles (43)
- Other vehicles not dimming their lights (20)
- Plowing into a rising or setting sun (12)
- Train lights (4)
- Stopped or slow traffic (3)
- Snowmobile lights

11. Describe any other weather conditions OR situations not listed in Question 10 that have caused visibility problems for you during snowplow operations.

- Not enough delineators on roadway (3)
- Reflection of strobe lights on plow (2)
- Snowplow hood reducing visibility (2)
- Plow blocking lights (2)
- Poor lighting on back of truck when backing
- Glare off of back of other plows
- Lights going out due to vibrations
- Cracked or pitted windows or mirrors
- Stopping to let vehicles pass

12. During the current season did the windows of your snowplow vehicle ice up and reduce your visibility? If yes, what percentage of the time.

	No	Yes	Mean	Std. Dev.	Median
Idaho DOT	38	261	33.14	24.22	25.00
Montana DOT	38	183	35.57	24.84	30.00
North Dakota DOT	33	202	36.97	24.20	30.00
Wyoming DOT	29	208	34.80	24.89	30.00
Total	138	854	34.97	24.63	30.00
%	13.91	86.09	-----	-----	-----

- Depending upon temperature (3)
- Yes, lots (3)
- No, very little snow, weather this season (2)
- New 2002 bad
- Have heating element of some kind in windshield to prevent ice build up
- When windy from snow coming over plow
- Thermostat gets weak allowing motor to run too cool causing weak or poor defrost operation
- Yes- when if cold/heat and defroster don't put out enough
- If possible keep heat off of windshield. Window cleaner rather then deicer/ cleaner is very hazardous. Cleaner freezes

13. How important are each of the following factors in safely operating a snowplow vehicle?
(1=not at all important, 5=very important)

	1	2	3	4	5	NA
a. Ability to continuously see the roadway in front of your vehicle	1	10	40	93	842	6
b. Ability to see a vehicle my vehicle is approaching	1	12	35	108	828	8
c. Ability to see a vehicle approaching from behind	2	45	153	216	569	7
d. Ability to determine your lane position at all times	2	14	52	145	774	5
e. Ability to see large obstacles (such as stranded cars)	1	6	27	80	864	14
f. Other	3	3	5	11	91	879

	N	Mean	Std. Dev.	Median
a. Ability to continuously see the roadway in front of your vehicle	986	4.79	0.57	5.00
b. Ability to see a vehicle my vehicle is approaching	984	4.78	0.57	5.00
c. Ability to see a vehicle approaching from behind	985	4.32	0.91	5.00
d. Ability to determine your lane position at all times	987	4.70	0.65	5.00
e. Ability to see large obstacles (such as stranded cars)	978	4.84	0.49	5.00
f. Other	113	4.63	0.90	5.00

13f. Other factors important in safely operating a snowplow vehicle

- Ability to see wildlife (15)
- Ability to see edge of road (11)
- Ability to see outside – windows free of snow and condensation (11)
- Ability to see people by the roadway (9)
- Ability for other vehicles to see the plow (6)
- Ability to see delineators, signs, etc. (6)
- Ability to keep track (see) passing vehicles (4)
- Ability to see large snowdrifts (4)
- Easy access to plow controls and uniformity of same (2)
- Know where you are (2)

14. How useful are the following methods are in helping you maintain your lane position while plowing in poor visibility?
(1=completely useless, 5=very useful)

	1	2	3	4	5	NA
a. Feeling the crown of the road	225	258	235	110	141	23
b. Feeling the rumble strips on the shoulder	140	87	143	204	313	105
c. Feeling the slope of the shoulder	75	106	190	277	305	39
d. Judging the distance from mileposts/delineators	42	76	165	277	411	21
e. Judging the distance from fence lines	396	244	184	76	52	40
f. Judging the distance from grass lines	204	174	224	201	160	29
g. Judging the distance from the center line	44	90	190	297	340	31
h. Judging the distance from guardrails	23	52	166	296	431	24
i. Following other vehicles' tracks	303	245	220	99	68	57
j. Other	7	5	14	17	46	903

	N	Mean	Std. Dev.	Median
a. Feeling the crown of the road	969	2.67	1.34	3.00
b. Feeling the rumble strips on the shoulder	887	3.52	1.45	4.00
c. Feeling the slope of the shoulder	953	3.66	1.25	4.00
d. Judging the distance from mileposts/delineators	971	3.97	1.14	4.00
e. Judging the distance from fence lines	952	2.10	1.19	2.00
f. Judging the distance from grass lines	963	2.94	1.38	3.00
g. Judging the distance from the center line	961	3.83	1.14	4.00
h. Judging the distance from guardrails	968	4.10	1.02	4.00
i. Following other vehicles' tracks	935	2.34	1.23	2.00
j. Other	89	4.01	1.27	5.00

14b. Feeling the rumble strips on the shoulder
- Don't have them
- They are iced up and snow covered. They don't do any good, during snowstorm

14c. Feeling the slope of the shoulder
- I try not to do this as on my road your trouble
- You would be too late and off the road by then

14d. Judging the distance from mileposts/delineators

- Only 5 miles of my primary route has delineators

14e. Judging distance from center lines

- N/A they're buried give me a break can't see center line
- Very good if it is visible

14i. Following other vehicles' tracks

- Only works are long as other vehicle is in right lane

14j. Other methods for helping determine lane position while plowing in poor visibility.

- Knowing the road – familiarity with the route (51)
- Judging distance by seeing the lines on the roadway (36)
- Judging distance from snowbanks/snowberms (25)
- Plowing with 2 or more plows (9)
- Judging distance from ditch lines (4)
- Judging distance from windrow (3)
- Feeling the curvature of the road (2)

15. Describe any methods not listed in Question 14 that you have found useful in maintaining your lane position in poor visibility.

- Slowing down (37)
- Judging distance from shoulder (16)
- Using the feel and sound of the road (11)
- Feeling the edge of the road (9)
- Looking further down the road (9)
- Adjusting the vehicles lights (8)
- Luck/prayer (7)
- Judging distance from tree lines (6)
- Experience (6)
- Judging distance from power poles, telephone poles (4)
- Judging distance from fog lines (4)
- Following lights of other vehicles ahead (3)
- Following lane created by first pass (2)
- Communication with other drivers

16. Based on your experience, how serious of a problem do you believe it is to have snowplows accidentally cross into the oncoming lane?
(1=not at all serious, 5=very serious)

	1	2	3	4	5	NA
Idaho DOT	14	12	47	38	181	7
Montana DOT	8	19	30	34	122	8
North Dakota DOT	4	15	51	49	113	3
Wyoming DOT	3	16	45	40	125	8

	N	Mean	Std. Dev.	Median
Idaho DOT	292	4.33	1.15	5.00
Montana DOT	213	4.15	1.18	5.00
North Dakota DOT	232	4.09	1.06	4.00
Wyoming DOT	229	3.38	1.06	5.00
Total	966	4.16	1.11	5.00

- Doesn’t often happen in the area where I work but ya that but isn’t a good thing
- When plow digs into snow floor. Pushing you into on coming lane
- Depends if anyone is coming at you
- No traffic on my road section.
- Depends on how much the road is traveled
- We don’t have our units doing this but have more problem with traffic doing this to us
- Choice 5- depending on traffic numbers
- Choice 5**-** if it happens extremely serious –I don’t believe it happens often.

17. During the WORST snowstorm you can remember, how often, and for how long, did you completely lose sight of the roadway and shoulders in front of your snowplow vehicle?

Number of times

	0	1-3	4-6	7-9	10 +	NA
Idaho DOT	1	38	43	34	173	10
Montana DOT	3	19	38	23	127	11
North Dakota DOT	1	14	47	40	127	6
Wyoming DOT	0	22	35	19	153	8
Total	5	93	163	116	580	35
%	0.52	9.72	17.03	12.12	60.61	---

Average duration (seconds)

	1-4	5-9	10-15	16-20	21 +	NA
Idaho DOT	57	73	50	25	74	20
Montana DOT	45	74	31	12	43	16
North Dakota DOT	41	89	46	12	31	16
Wyoming DOT	30	55	43	19	80	10
Total	173	291	170	68	228	62
%	18.60	31.29	18.28	7.31	24.52	---

- Could not see, pulled over and stopped off of road
- Sometimes almost constantly depends on wind drafting
- Had to walk in front of the truck so I could see my tracks
- Average duration: - life time
- Any longer than 6 sec, I would stop and wait to clear.

18. During an AVERAGE snowstorm, how often, and for how long, do you completely lose sight of the roadway and shoulders in front of your snowplow vehicle?

Number of times

	0	1-3	4-6	7-9	10 +	NA
Idaho DOT	33	141	80	13	23	9
Montana DOT	18	87	61	10	36	9
North Dakota DOT	5	85	74	22	43	6
Wyoming DOT	14	92	70	24	31	6
Total	70	405	285	69	133	30
%	7.28	42.10	29.62	7.17	13.83	---

Average duration (seconds)

	1-4	5-9	10-15	16-20	21 +	NA
Idaho DOT	130	76	30	6	13	44
Montana DOT	110	56	14	6	9	26
North Dakota DOT	107	75	25	2	10	16
Wyoming DOT	86	71	34	15	12	19
Total	433	278	103	29	44	105
%	48.82	31.34	11.61	3.27	4.96	11.84

19. During this current winter season, did you ever have to stop because you could no longer determine your lane position? (If yes, number of times)

	No	1-4	5-9	10-15	16-20	21 +	NA
Idaho DOT	119	94	38	16	9	15	8
Montana DOT	141	46	11	12	4	2	5
North Dakota DOT	140	49	25	10	1	4	6
Wyoming DOT	114	73	27	15	1	1	6
Total	514	262	101	53	15	22	25
%	53.15	27.09	10.44	5.48	1.55	2.27	---

- Cannot stop because you will get rear-ended, cause an accident (6)
- Very mild winter (2)
- Got struck
- Most times it is safer to just keep going

20. During the current winter season did you hit an object (for example, guardrail, post) because of poor visibility? If yes, number of times and what did you hit.

	No	1-2	3-4	5-9	10 +	NA
Idaho DOT	232	31	8	5	3	20
Montana DOT	197	10	5	1	0	8
North Dakota DOT	225	2	2	1	0	5
Wyoming DOT	183	24	13	5	7	5
Total	837	67	28	12	10	38
%	87.74	7.02	2.94	1.26	1.05	---

- Delineator/milepost (55)
- Guardrail (37)
- Curb (10)
- Concrete guardrail (8)
- Snowbank/snowberm (6)
- Bridge/underpass (6)
- Road signs (2)
- Rocks (2)

- Dead animals (2)
- Tree

21. During the current winter have you ever run off the road because of poor visibility during snowplow operations? (If yes, number of times)

	No	1-4	5-9	10-15	16-20	21 +	NA
Idaho DOT	235	53	4	1	0	1	5
Montana DOT	181	26	4	4	0	1	5
North Dakota DOT	220	11	0	0	0	1	3
Wyoming DOT	168	59	6	1	0	0	3
Total	804	149	14	6	0	3	16
%	82.38	15.27	1.43	0.61	0.00	0.31	---

- Not this winter, but hit heavy draft under one and shot across road
- In the post many, many times
- Yes- dropped front wheel off shoulder
- No- mild winter
- Not fully off the road ever this season
- Felt wheel leave shoulder, immediate correction (slow)

22. If the technology existed that could tell you your lane position while plowing, how useful would it be to you?
(1=not at all useful, 5=very useful)

	1	2	3	4	5	NA
Idaho DOT	16	33	31	50	163	6
Montana DOT	5	11	36	21	140	8
North Dakota DOT	2	9	37	45	137	5
Wyoming DOT	8	13	34	41	136	5

	N	Mean	Std. Dev.	Median
Idaho DOT	293	4.06	1.27	5.00
Montana DOT	213	4.31	1.07	5.00
North Dakota DOT	230	4.33	0.94	5.00
Wyoming DOT	232	4.22	1.11	5.00
Total	968	4.22	1.12	5.00

- Technology distracting
- Depends on how much of a distraction it would cause
- Very useful- if you could afford it

- If it was heads up display and could tell me with is 1' 2' ft Would not trust this It depends on if you are looking at the device all the time- we have other operations going on – sending/radio traffic wing operation
- Cost?
- Depends on lot of factors
- If you don't know where you re how can you know where you need to be?

23. If there was a device that was able to detect obstacles in front of your vehicle while plowing, how useful would it be to you?
(1=not at all useful, 5=very useful)

	1	2	3	4	5	NA
Idaho DOT	13	19	46	56	161	4
Montana DOT	4	15	31	36	129	6
North Dakota DOT	3	13	32	49	135	3
Wyoming DOT	3	13	31	46	141	3

	N	Mean	Std. Dev.	Median
Idaho DOT	295	4.13	1.16	5.00
Montana DOT	215	4.26	1.06	5.00
North Dakota DOT	232	4.29	0.99	5.00
Wyoming DOT	234	4.32	0.99	5.00
Total	976	4.24	1.06	5.00

- Very useful - if you could afford it
- Depends on how much of a distraction it would cause.
- That's mostly what we worry about –what or who we are going to run into!!
- You need to see what is happening in front of you
- As long as it could identify what object
- Unless it gives false alarms
- Anything that would increase safety to operators and others would be a plus
- How would it know if on object or snow or curve in road.
- If it was accurate and not some cheap pos. of junk I have used such device when I was driving a big truck
- Would not trust this neither
- Cost?
- Would like to try night vision glasses
- You need to pay attention: if you become too mesmerized to even know what might to ahead or too depends on device, what happens when an animals, or, person darts out in front of you?

24. If there was a device that was able to <u>detect obstacles behind</u> your vehicle while plowing, <u>how useful</u> would it be to you?
(1=not at all useful, 5=very useful)

	1	2	3	4	5	NA
Idaho DOT	29	69	80	48	72	1
Montana DOT	13	37	61	35	74	1
North Dakota DOT	6	24	42	38	124	1
Wyoming DOT	11	42	68	35	79	2

	N	Mean	Std. Dev.	Median
Idaho DOT	298	3.22	1.31	3.00
Montana DOT	220	3.55	1.27	3.00
North Dakota DOT	234	4.07	1.16	5.00
Wyoming DOT	235	3.55	1.25	3.00
Total	987	3.57	1.29	4.00

- Very useful when use of wing
- Pretend you're always in traffic use mirror!!!
- Especially if fast closing distance

25. If there was a device that was able to detect obstacles to the side of your vehicle while plowing, how useful would it be to you?
(1=not at all useful, 5=very useful)

	1	2	3	4	5	NA
Idaho DOT	27	60	60	65	82	5
Montana DOT	18	42	63	38	59	1
North Dakota DOT	12	40	58	36	88	1
Wyoming DOT	13	37	62	57	67	1

	N	Mean	Std. Dev.	Median
Idaho DOT	294	3.39	1.13	3.50
Montana DOT	220	3.35	1.28	3.00
North Dakota DOT	234	3.63	1.28	4.00
Wyoming DOT	236	3.54	1.21	4.00
Total	984	3.48	1.28	3.50

- On the right side
- Snow berms?, rock bluffs?, trees?, guard rail?
- There are all kinds of objects along sides of road fences telephone poles guardrail signs why worry we know these objects are there
- Depends on how much distraction it would be
- Extremely helpful if the object never moves or never leaves your side- be alert to the unexpected
- Not sure, interstates heavy traffic maybe

26. If there was a device that would allow you to determine your lane position while plowing, how would you like that information to be relayed/displayed to you?

	Visually	Auditory	Motion	Other
Idaho DOT	243	80	24	7
Montana DOT	180	65	23	10
North Dakota DOT	208	64	31	8
Wyoming DOT	195	77	26	9
Total	826	286	104	34
% of response	66.1	22.9	8.3	2.7

- Heads-up display (17)
- Computer screen or monitor (9)
- Pleasant voice (5)
- Red light or line to display shoulders (3)
- Camera or screen
- Infrared goggles
- Computer talking – eyes should be on road
- Auditory – as long as adjustable

Indicate your level of agreement with the following statements (27 & 28):

27. There are times, due to weather conditions, that snowplow operations should be suspended.
(1=strongly agree, 5=strongly disagree)

	1	2	3	4	5	NA
Idaho DOT	118	53	45	33	48	2
Montana DOT	101	37	36	18	26	3
North Dakota DOT	168	18	16	9	23	1
Wyoming DOT	123	29	25	22	35	3

	N	Mean	Std. Dev.	Median
Idaho DOT	297	2.46	1.50	2.00
Montana DOT	218	2.22	1.41	2.00
North Dakota DOT	234	1.72	1.32	1.00
Wyoming DOT	234	2.22	1.52	1.00
Total	983	2.18	1.47	1.00

- We have to keep plowing to keep the road open and sometime its not the safest thing to do but we don't
- Although I agree that there are times when we should not be out there it we are not the road would be closed and people would by stranded you can't close an interstate, an interstate closes itself
- Our job is to keep the road open even under hazards conditions if allowed to below shut will take longer to open. I do believe under certain condition it needs to be closed to public travel
- We close the road because of weather condition and don't drive when unsafe
- We are more of a blizzard than the storm
- Sometimes when a citizen just sees the snow plow going down the road they think they can go too, even if the road and closed. I've been in 2 very serious near fatal accidents because there was black ice and open roads.

28. Even if a system were in place that would be able to display the position of the snowplow on the road in poor visibility, there would still be weather conditions in which snowplow operations should be suspended.

(1=strongly agree, 5=strongly disagree)

	1	2	3	4	5	NA
Idaho DOT	109	50	58	35	41	6
Montana DOT	80	40	43	31	26	1
North Dakota DOT	154	34	16	12	16	3
Wyoming DOT	95	46	40	23	29	4

	N	Mean	Std. Dev.	Median
Idaho DOT	293	2.48	1.44	2.00
Montana DOT	220	2.47	1.41	2.00
North Dakota DOT	232	1.72	1.22	1.00
Wyoming DOT	233	2.33	1.41	2.00

Total	978	2.26	1.41	2.00

- If you can't see in front of you can't safely plow-right?
- If working in a closed road area no-no public-avalanche danger
- During blizzards people stay home leaving no one on roads, If condition are that serious, plow operator lives are at stake also.
- Reason if you could make a device that can tell you where the truck trailing the road way will it be able to stop if there was someone or truck car on the road up side down in poor visibility

Section 4: Demographic Information

29. Which organization do you work for?

	N	%
Idaho DOT	299	30.14
Montana DOT	221	22.28
North Dakota DOT	235	23.69
Wyoming DOT	237	23.89
No Answer	0	---
Total	992	100.00

30. What is your age?

	N	Mean	Std. Dev.	Median
Idaho DOT	295	45.45	9.09	46.00
Montana DOT	215	44.97	9.17	45.00
North Dakota DOT	232	46.59	9.27	48.00
Wyoming DOT	235	43.23	9.65	44.00
Total	977	45.12	9.25	46.00

31. What is your gender?

	Male	Female	No Answer
Idaho DOT	288	9	2
Montana DOT	214	3	4
North Dakota DOT	221	5	9

Wyoming DOT	226	7	4
Total	949	24	19
% of responses	97.5	2.5	---

32. How many years have you worked as a snowplow operator?

	N	Mean	Std. Dev.	Median
Idaho DOT	296	11.32	9.32	9.00
Montana DOT	220	11.87	10.00	10.00
North Dakota DOT	233	13.51	9.83	12.00
Wyoming DOT	235	12.59	8.99	11.00
Total	984	12.26	9.26	10.00

33. What is the highest grade or level of school you have completed?

	Idaho DOT	Montana DOT	North Dakota DOT	Wyoming DOT	%
No high school	2	5	3	2	1.22
Some high school, but did not graduate	5	4	3	7	1.93
High school graduate or GED	148	98	116	148	51.88
Some college or 2-year degree	133	99	95	65	39.88
4-year college graduate	5	12	14	10	4.17
More than 4-year college degree	2	1	2	4	0.92
No Answer	4	2	2	1	---
Total	299	221	235	237	100.00

34. How would you rate your experience level in the use of a computer?

(1=no experience, 5=advanced)

	1	2	3	4	5	NA
Idaho DOT	40	85	127	29	12	6
Montana DOT	21	67	104	20	6	3
North Dakota DOT	62	63	88	15	5	2
Wyoming DOT	42	53	119	17	3	3

	N	Mean	Std. Dev.	Median

Idaho DOT	293	2.62	0.98	3.00
Montana DOT	218	2.65	0.88	3.00
North Dakota DOT	233	2.30	1.00	2.00
Wyoming DOT	234	2.51	0.91	3.00
Total	978	2.52	0.96	3.00

Comments and suggestions

Please provide any comments or suggestions you may have for improving your ability to see from your vehicle and maintaining your lane position during low-visibility snowplow operations.

All comments are listed, and have not been corrected. The researchers did delete comments that did not pertain to the overall subjects presented in this survey.

Selected comments to 10g (If the vehicle lights cause a visibility problem, describe their placement snowplow)

1. Glare off of brightly colored plows
2. Have lights mounted as close to front as possible
3. Mounted side of hood just above plow- this is the best position I have found
4. Mounted too high causing reflection into the cab
5. Need to be able to adjust per driver
6. Need to be set as low as possible
7. The lights have to be mounted high to get over the plow and cause blinding visibility in snow storms
8. The lower the light on the truck the less reflection back on the window. The higher the lights are they gather too much reflector and only can see real short distance.
9. Got covered with snow need a wind tunnel elbow or something to blow snow off lights
10. If mounted too high or aimed incorrectly, falling snow just reflects light
11. If they are to high hard to see at night when snowing
12. Lights placement is ok. The problem is the light reflection back in your eyes driving at night in snow storms
13. More lights / higher above plow / better flashing lights and more of them
14. Mounted on front fenders- higher than the plow-lites are closer to eye-level causing more glare.
15. Need to be placed higher to shine down
16. Need yellow light to help cut through weather
17. Night driving with snow falling or blowing cause a white wall that you can not see through.
18. Placed too high on trucks & need better quality lights
19. Placement is where they have to be but amber lens covers would be very helpful
20. Reflects off plow and snow-need to find better placement
21. The lights cause a problem but it not cause height but the color they should be yellow not white light

22. Grill mounted lites-always get iced up
23. When the lights were on the top of cab visibility was a lot better than on front fenders
24. If lights are too high will shine back in your face
25. Need more lights on most trucks
26. Pencil lights have greatly improved visibility on my truck
27. The use of our fog lights is very beneficial

Window/mirror/wiper comments (50)

1. Heated Windshield wipers/ wires in glass for heated windows/ visibility is everything!
2. Heated Windshield wipers or windshield (other than defroster)
3. Heated wipers that work, fender mounted mirror on right side
4. Better ice control on windshield and on wipers
5. To see from the vehicle, heated windshield and or side windows would keep visibility available
6. Heated Wipers – Heated Glass
7. Heated Window, heated wipers, temperature gauges that work for air surface
8. Heated windshield and heated wipers that work
9. Heated windshield wipers, heated front windshields
10. Need better wipers to help keep snow off
11. Thermal heated windshield
12. I share a tandem axle truck with 2 other drivers, we all keep the rig clean and waxed when possible, also we clean our windshield real good let them dry then put rain x on real heavy and wipe on evenly and heavy it keep snow and ice build up down on window and wipe blades last 3 times longer. It helps with deice also will bead on windshield instead of smearing. Plowing with 2 or more plows helps to it keep traffic slow and behind plows.
13. Better windshield wipers and washers. Actually fix them when needed
14. Some way of keeping the windows from icing up and the wipers
15. I have problem with my wiper blades icing up
16. Better system, of keeping windows or wipers from icing. Same as above for lift and right mirror right shoulder need to lighted better may a cab lit pointed down toward
17. Heavy truck i.e. 10 wheeler, heated windshield wipers that wouldn’t ice up in hold up with snow, defrosters would won’t and still be able to keep feet warm, head its that wouldn’t build up with ice and snow.
18. Heated side windows on passenger side better windshield wipers and motors.
19. Heated windows on passenger side truck and big windows in front heated and better wipers. Blades and motors.
20. Heated windows on passenger side, better wipers, better wipers motor.
21. Wipers and windshield that don’t turn into blocks and ice.
22. Left windows and mirror sometimes when plowing blowing snow makes hard to see out.
23. Non-stick windshield
24. Heated windshield wipers
25. Heated remote control mirrors, heated windshield wipers
26. Heated mirrors, heated windshield.
27. For 20 degree or below run with a cold front window, it keeps the visibility good and presents, icing up on your front window.

28. Heated mirror
29. Heated mirror, heated windshield wipers
30. Heated windshield to prevent icing
31. Better mirrors with wider angle of visibility
32. D.O.T needs to find some new kind of windshield wipers that will not continuously ice up.
33. Better w/shields cleaning i.e. wipers / defrost
34. Air conditioning in the truck would help with interior moisture would make my life easier. I drive with a small squeeqy in my hands to clean off condensation. There is enough other things to be watching and worrying about without cleaning the windows all the time. Heated wipers might also help.
35. A better windshield wiper system
36. A better windshield wiper system
37. Better defrosters in our trucks, better windshield wiper. heavy duty
38. Air conditioning would help with the windows
39. Develop some type of wiper blade so ice doesn't build up on the blade during certain condition.
40. AC to remove moisture on inside of cab. Air movement in cab. Heated rear view mirror.
41. Air conditioning to provide dehumidifying for windows
42. Windshield wipers that will keep windshield clean, windshield wipers that will keep won't let snow stick to them
43. Some way of keeping snow off windshield
44. Some sort of defroster for right side windows and mirror.
45. All mirror need to be heated along with passenger windows needs to be heated
46. Would like to see heated windows on the right side of truck
47. Heated window on door of drivers side. Heated spot mirrors (large) on each fenders beside cab.
48. The windows on a 8yd int is to flat which causes your windows to ice up all the time.
49. Improved wiper system (windshield loads up with snow or slush and you drive with your head out the window till solves)
50. Better deicing of windshield and mirrors and better design is wiper and window cleaner use.

Snowplow lighting comments (41)

1. Stronger, brighter head lights and fog lights
2. Better wing mirrors, more lighting on wings, lights mounted higher
3. Moveable driving lights (electric, operator from cab)
4. Lights mounted to show right edge of roadway
5. Better lighting system
6. In rural areas very strong lights (aircraft landing lights) help a lot can't use them in traffic but work well in rural areas.
7. Snow plows need better lighting system to allow operation to see better at night and in fog
8. A better headlight system. The headlights we have are not ht enough to keep the snow off. And in a heavy snow storm at night you can not use bright lights. It actually reduces you visibility. At times I have had to shut the lights off, and use only the fog lights.
9. We need a better head lamp set up and fog lamps, cl means better light out put ahead and to the sides
10. Need true blue halogen headlights regular headlights do not shine as well as the blue ones do when I see traffic coming with blue lights I can see the ground in front of them 3 times better.
11. Better lights on truck
12. Better lights and ones that do not become snow covered or ice up
13. Better head lights, better fog lights, rights fender mirror to help with blind side of truck
14. Use a true blue lamps also head light position very important
15. Alternate light source, colored lights, ability to control and snow off lights that cause visibility problems of (glare back) i.e., over head cab lights
16. I believe that all snow plow vehicle should have adequate back-up lights on the rear of the vehicles. The only lights currently used are sanding lights which are useless for backing up at night. I feel this is a very important item for safety which is a major concern
17. Fog lights on both sides pointing ahead
18. Tail lights get covered with snow. This makes your turn signal lights not visible
19. Better lights to see with and, flashing lights to be seen by traveling public
20. Better lighting and positioning of lights on plows.
21. May be placing the headlamps in a better spot.
22. Keep snow from covering headlights and taillights there has to be a way of heating lens, or wind deflection to keep head lights taillights clean. Lowering headlights would also help.
23. Stronger lights, mounted lower
24. Better headlights system
25. Have they ever tried two sets of headlights one set on top and one set on front bumper
26. Some type of lights with colored lens that the operator can run from the cab. Could perhaps use a long set of bar lights mounted on the front top of cab in amber color that could easily adjusted.
27. Let's up put lights back on top at cab instead on front fenders
28. Better lighting system or try some different colored lights such fog lamps or lights with more direct projection
29. Better forward lighting maybe a high intensity fog light system would be helpful.
30. Make sure that the trucks are equipped with pencil beam lights
31. Better lights in a lower position
32. Pencil beam headlights work very well in poor visibility

33. We use high powered adjustable driving lights to determine where center or outside lines are on roadway
34. Light that will shine throw the snow and fog
35. Plows need better lighting so traveling public sees you better.
36. Get better lighting for the truck on the front and on the back so people can see you.
37. Better light might help some do not know the best for all storm what is works in one type is no good in a different one.
38. If there were a way to put lights on the plow that followed the truck not the plow angle (lower to the ground)
39. More fog lights and more light on back of truck so people can see you sometime the snow can built up on the back and cover your lights up.
40. Position lights lower but still high enough to clear plow height
41. Better lighting to see while plowing, better lighting so that the public can see you.

Lighting and window/mirror comments (31)

1. Brighter Headlights and Fog lights, maybe a heated right side passenger side window and windshield when plowing drifts and heavy snow when there is a slight or heavy wind snow accumulation on right side windshield and passenger side window leaving them completely useless. Have right and left side heated windows but right side increases in these solutions.
2. Better wiper/cleaning of windshields of ice and dirt. Better lighting.
3. Better light system, better wipers
4. Better lighting better visibility (windshield)
5. 2 fog lites each corner front, stacked above each other. A chemical deicer that can be applied through truck window washing system, a deicer that really works. I have found that heated wipers help a lot if you keep them repaired
6. They need to have a heated windshield and figure out how to mount head lights on plow's that will not vibrate off the snow plow
7. Heated wipers-anything that will help keep snow and ice off all windows surfaces and lights. More penetrating lights.
8. Heated wiper blades that work, heated headlights rings to keep headlights them icing up.
9. Heated windshield wipers mirror and some way of keeping lites clear of ice and snow
10. Design a "slick" windshield so ice and snow does not build up. Flat beam head lights like were used during WWII during black out periods. I have developed a method to make our snow plows tail lights visibility during plowing operation.
11. Heated wipers, heated mirrors, better lights that will cut three blowing snow.
12. Some sort of a device to keep the windshield from ice building up on the wipers blades and a better head light system
13. Yellow headlight help at night sometimes lower headlight also help but when you need them they are covered with snow. Being able to keep windows, windshield and mirror clear.
14. I'd like to see more powerful lights that charging system can still handle. Also how about something that will eliminate ice from windshield and wiper build up.
15. Better wipers –lower lights while plowing and yellow lights, better mirror on passenger side.
16. Improved head lamps (such as a brow over the top of headlamp) design windshield to clean better- mount wipers at top of windshield.
17. Heated windshield wipers, yellow headlight like they use in Europe and the far east.

18. Fog lights, lights on top of cab & above bumper both some condition lights work better. Better heating system to keep windows clean wind deflectors on hood.
19. Install an electric fan to circulate air in cab to help keep windows clear consider heated wiper blades to help eliminate ice build install flashing lights.
20. More lights, A.C.
21. Better lights, better heaters and defrosters (windshield fog up)
22. Better lighting on vehicles, A/C in trucks (helps keep windows clear under certain condition)
23. 6' or larger convex mirror even on RT FR fenders –2000 trucks don't have them . Change thermostat when engine heating problem occurs to insure proper operation of defrosters and deicing of side windows- including size windows defroster vents – led tail lights brighter light –less heat minimizes icing –create more visibility –halogens shine further- thank you for heated mirrors.
24. More enhanced lighting and clear windows and mirror
25. Better lights and positioning of them not to high or to low. May be some way to cut glare form on coming traffic, maybe some kind of heated wiper to stop ice and snow build up on them
26. The pencil beam light help-if there was a way to keep windshield clear, it would be a great asset
27. Need better lights and heated mirrors. Mirrors mounted by headlights work best for using plows windows work good but you half to see them at all times.
28. Some lower lights yellow lens on lights more mirrors on trucks. We only have 2 round convex mirror on 4 truck, none on motor grader and none on snow blower.
29. Remote control spot light would help power operated passenger window would also help.
30. Good wiper blades, good fog and head lights truck should have rear strobe lights for better visibility from the rear.
31. Better windshield defrosters- better forward lighting- lights mounted in a manner that they do not reflect off falling snow into plow drivers eyes.

Technology comments (31)

1. From some system I've seen, I would need to be able to see any traffic that could be in my way. I have a mountainous route with no visible lighting. During heavy storms at night, it is impossible to see detection equipment would be great. Liability reasons prevent the running in some heavy conditions.
2. If I could not see the road for an extended period of time, I would not like or trust a device to help me steer. A period of time would be extended periods of a whiteout for example.
3. Low level screen on dash to display positions
4. Anything that could show me where I am on the road would help a lot like a head up display that shows the centerline and shoulder or fog line.
5. The least amount of distraction and obstruction as possible
6. What about the question to detect obstacles in front of your plow very useful that is where you are going to most likely need a warming device alert. When you can't see for a second or two and just know you are going off the road that's ok, but an abandoned car (that would hurt)
7. A device show if you are left or right of center would be very useful. Also a device to detect vehicles in front of you.
8. Radar

9. G.P.S with monitor.
10. Some sort of night vision glass or goggles that allows us to see during storms.
11. If we used GPS system it would improve what we do. It would also aid in our safety as drivers. The military uses heads up display and even some vehicles have them.
12. Night sensor cameras
13. A device such as radar unit mounted in the cab that is easy to see that would guide us in these types of problem not being able to see is the biggest problem we face.
14. This was an open winter for us, very little snow. Blowing and drifting is a problem for us. Its possible to have a road blow in minutes after plowing. if a system is developed to determine lane position no bells whistles buzzers or other distractions, concentration is a vital function when plowing.
15. Infrared to help see someone walking or standing alone side roadway to help keep from hitting with snow or snowplow when it is still dark out. We start plowing at A.M till 10:00 pm
16. If you are going to put a GPS or other device on the truck for this I would like to see a projection on the windshield that shows the lanes of the road and your current position like a video game.
17. Road lines displayed on windshield – object or vehicles too
18. Any improvement that can be put to use in snow operatio for implanted no matter what the cost is implanted.
19. GPS accurate display on right center lower windshield
20. The sooner there is the equipment to be able to maintain lane position, should be bought at any cost.
21. These new ideas sound great if they help but will we ever see them in truck, highly unlikely. If we do by charge get then it will be low bid and will end up being a headache more than anything
22. If the idea is to someday use global positioning to tell just where you are at on the roadway, I am all for it.
23. If speed odometer and gauges were reflected on the windshield you would very seldom have to take year eye from them and would add in mirror use.
24. When gang- plowing the shadow vehicle should have a arrow board that tells the public that there are Z or z etc. plow's ahead and what lane to move into.
25. I think with the technology we have today we should be able to run infra-red camera's to see forward and penetrate snow fog. May have infra-red hoods should have warning system from the rear. I'm not sure visually would work homework constant warning beepers aren't the best thing either
26. Whatever is used, shouldn't take your eyes off the roadway!
27. A screen or monitor showing position of vehicle on roadway
28. I think that it is my job to know the roads I am plowing and what the road is like and the bad spots. I strongly disagree with any computers that tell you where you are on the road. It will be a waste of money. Just like the computer sanders and the liquid chloride.
29. We can't even keep our truck running much less something extra I do like the idea of knowing just where I'm at during a storm maybe I will see it in my life time but most safely items are talk –cost in all that seems to count good luck and I will be watching. How about something on the plow that sends a signal when it cross's the center line paint or shoulder paint.

30. Don't really know what would work best, but there is a real need to have something in place to help in bad condition.
31. Maybe an inforred system on sonar, something that the weather won't have any effect on.

Plow related comments (10)

1. I would like a plow that wouldn't throw the snow on windshield while plowing into wind
2. Better snow plows that are designed to plow pap snow and dig drifts. Not the computer designed junk being bought.
3. Size the vehicle to the person (large) to (small) make him or her comfortable, not cramped or uneasy & improve defrosting capability & increase vision & lumination. Leg room a must – good sound & acoustic am/fm – air –heat – air seals – large wiper blades – high power motion for wipers & heaters, larger mirrors.
4. I feel that if there was a way to keep snow from coming over the plow onto the windshield that this would greatly increase visibility
5. Better control of snow leaving exit side of snowplow, keeping snow from blowing over truck cab when traveling with passenger side winds.
6. I operate a reversible express plow, snow coming off right side of plow directly at windshield some kind of attachment to deflect snow away from windshield would be very helpful.
7. Wing on right side of truck causes visibility problem during interstate passing lane plowing operator – wing being in up position. truck used on interstate should not have wing attachment
8. Design the snowplow so you wouldn't get as much snow going back at you on your windshield while plowing. We put canvas mats to help and then do but we still get some back on the windshield
9. Should have question on types of plows my falls plow is a short plow and I have more problems than others with snow coming and blowing over the top of my plow
10. Horse power is as important as anything in plowing a low horse truck can be a hazard. Air deflection device for snow fog coming off of the plows.

Roadway comments (5)

1. Delineator both sides of two-way highway, yellow delineator on left shoulder, clear delineator on right shoulder
2. In certain situation there really isn't any way you just have to trust instinctively to where up wave, 3 look fog a snow pole or delineator to get your bearing try using flashing delineator every 199ft or so!
3. Better center line paint
4. This is North Dakota –we need more trees along the roads.
5. Right hand rumble strips

Multiple comments (61 total, 45 with lighting and/or window comments)

1. Use the best lighting, plow together as a team with good communication. Use the team method (gang plowing) and use the method we use. Keep bunched up until its safe to let them pass and let them pass in groups when ready.
2. Sometimes you have to look out side windows to gage your distance in heavy fog.

3. Sloped hood on truck to better see plow and have better visibility
4. Better lighting system, improved windshield wipers. Some type of display to see roadway.
5. Better light system, wiper system, heads up display system of some sort to see roadways
6. Thermal windshield i.e. heated, infrared camera
7. Yes closure should be done more often “ the public” has no common sense they’ve got to get where they’re going and always faster than condition deem they won’t even obey road closure signs. Forward warning sensors would be useful if they did not give false warning (cry wolf) rear would not be any help because people are going to hit you and you won’t be able to react. A lane position is only relative for “pass” on the run. Center (1st pass) fog line (2nd pass) shoulder (3rd pass)
8. Would like flashing/ stationary red lights on each corner of plow so at least on coming traffic has visibility of you. lights on running boards for traffic. Because most of the time traffic cannot see our strobe or wigways. Also would like red/ white reflective tape on rear of vehicle so traffic will know that is the end. Would also like signs in low visibility / blowing drifting snow with flashing lights.
9. Better headlights placements. More delineation (snow poles)
10. You should break it down into night an day driving, most of my trouble are at night. bright lights, falling snow. Strobe lights blinking questions 26 (visually) we all ready have to many to look for car, centerline, edge. auditory we have to many radios buzzer bells anything but this. My suggestions. Shock collar would work for some of these guys. keep up the good work, anything would really help.
11. One winter a few years ago lost my bearing my bearing and ran over a telephone pole. This winter was in a heavy snow storm with blowing snow condition on the interstate. The lights, fog lights, windows and wipers quickly become iced over and it was extremely difficult to see anything post the hood! I was posed by several semi truck which made it even more difficult one truck had big bright round fog lights which could see coming up behind me and of course pass me. I talked to him a second on the CB radio and he said he could see just fine! I wish we could have fog lights like that!
12. Better lites or brighter. Slowing down, taking your “time” helps a lot also!
13. Better lights and the placement of such lights! shop nose truck : we drive macks with to large of hoods : the older autocars are better plow truck’s (91-95 series) 30% more visibility : more glass –less support poles in cab-low profile sanders . Auto transmission just one less thing to do while plowing: the drivers to day (women and sneaker type don’t know how to shift!
14. Heated windshield glass-heated wipers, some times more hood lights plow designed for area plowing in. centerline road sensors would be great.
15. Headlights on all veh. At all times heated mirror and windshield on plows. Heated
16. headlights conversion plows. Use of yellow fog beans
17. Better heating system in sterling trucks. larger convex mirrors. more adequate lighting for wing plows heated windshield.
18. Heated windshield and mirror “ over cab plow lights studded/ winter front “ steering tires! Better visible strobe yellow lights- not 4-way alternate!!
19. Better seats with arm rest, fog lights, heated mirrors, heated windshield and wipers
20. Cover the top 1/8 of head lamp. Paint the top ½ of plow flat black.

21. Don't forget prayer it works. Four head lights two higher to clear plow when plow is up and adjusted for normal use and two set for left and right. Shoulders would be the best help. This would provide people lighting for plow drivers.
22. Seats with arm rests, heated windows
23. Fog lights, headlights reflector covers, better seats w/arm rests, heated windshield
24. Technology is pretty good right now- experience is the best factor not much can be done in serious storms
25. I wonder if some kind of extension (removable) could be added to the plow to direct the discharge of snow farther. That way in high cross wind situation the wind couldn't catch the snow and blow it across in front of the windshield. I also wonder about special headlight or maybe night glasses to help us see in a white out blizzard or in the darkness.
26. Heated windshield wipers of mirror would be a great asset. Better quality seats in truck would help for comfort of drivers
27. Heated mirror, the delineators are life savers, if it wasn't for those I know would have been in the ditch a lot well painted lines on the road also helps.
28. Different types of head lights maybe, different types of top or warning lights (strobes-color), determine if it is really necessary to be out plowing.
29. A right mirror for wing visibility. Plastic sewer pipe elbows mounted under headlights to blow snow off.
30. I believe a center line sensor system would be very useful- heated mirror, very useful –plow light to shine from left to right in front of plow – away to keep right side window clear of ices now possible top of cab mounted lights. A way to run a cold windshield when needed prevents snow meet =freeze cycle.
31. Yellow lights on all snowplows, yellow glasses for all plow drivers, educate public their transportation awareness program- hoe I do my job (T.A.P).
32. Extra driving lights for nighttime operation. Better designed plows that don't throw snow over the top into your windshield, more delineators with larger reflecting area.
33. Hoods on trucks could be painted black windshield could have electric elements similar to rear windows trucks should tapered hoods and no negative air flow scoop hoods should have debris deflectors
34. May be better plow to prevent snow fog coming over top or from ends and somethings better in form of wipers to keep windshield clean of ice and snow build up
35. Although beneficial, all the technology in the world does not make up for the ignorance of a handful of drivers. The hands-on plow operators should be able to decide what condition warrant what action not be ordered by a guy in a office watching a computer weather map.
36. On question 24 detect obstacles behind you would be good so you know when to pull over. That would save time if you wouldn't have to pull over unnecessary for traffic when there is none. Do not try to defeat mother nature just respect her for what she give us.
37. Keeping snow coming off the plow from blowing across the windshield be a big help tome. Also windshield get ice covered due to this condition.. a device in the truck to tell operator their position on the roadway would be very beneficial during poor visibility storms a device to detect obstacles in the roadway would be a valuable tool for all operator.
38. Make sure one has a good 1st of all.
39. The front of the plow should have an extended drift catcher to limit the snow being thrown over the top of the plow. More and bigger candle power lights could be used in the rights

condition to aid in brightening up the road way also fog lights, a good set should be mounted on each plow truck.

40. Better heat placement – double windows use the storm gates I realize this slows progress-but let us go out really free of traffic and do our jobs in any snow intense and use spotters in pickups for those that are still traveling out there yet.
41. Position the driver higher up in the vehicle with plow wall below the headlights. Better lighting (regular head lights send a wide spread beam and lights up a large area) possibility a spot type with heat to blow off the ice or snow buildup on headlights. I drove over the road semi truck prior to this job(Sept 24,2001-present) so my exp. plowing snow is limited but adverse weather conditions are nothing know.
42. Improve heating device, fans etc to keep windows clean. Watch the design of snowplow, some allow the snow to come over and directly into windshield that is the most difficult thing to deal with!
43. During low visibility any snow moving equipment should be removed from plowing operations. The law should be that no snowplow in operation should be passed. More and lashing lights should be placed on back of plow at bet two on each side.
44. Buying a snowplow (falls) that the operator like the best not getting the plows that are a cheaper bid. Plow that have a 12 foot cutting edge. Keep enough help hired to be able to plow in tandem's maybe a seeing age computer operated equipment to tell you the road way where you are, but all this computer equipment may not be a answer either –because we are having plenty of problem now.
45. Slow down. Use 4 way flashes. At night make sure your pencil beam driving lites are on. All lights are free of snow and ice
46. Slow down. At night we use Hella pencil lights that penetrate fog and snow very well. I use all lights available 4ways, sander light (amber and sander pattern spot) where possible plow with wind.
47. Reduce speed keep to the right or left depending on type of roadway being plowed. keep windows and mirror clean as possible drive by the seat of your pants
48. I don't believe detectors and sensors and other electronic gadgets would be much help their not reliable and are easily damaged. When it's all said done it takes people with experience, good judgment and a willingness to do the job.
49. There should be an option where age becomes a factor in some high stress jobs- I think plow drivers should be able to retire the same as law enforcement. Also when buying the truck they should look more to comfort and safety than the bottom line low bid.
50. Better quality of lights, more lights, and better location of lights, better plows , not always low bid. I would like to know more about your survey and the result!
51. Something needs to be done for the plow operator, because at 55 years of age your sight and reaction time has diminished. But at state wages he can't retire. Traffic is increasing and going faster, we are there in a risky situation, we need better lights , defrosters. It is interesting
52. I have seen first hand what snowplow can do to vehicles signs. Anytime the operator can't see is a deadly feeling. Any device that could improve your vision and sense would be worth its weight in gold. I want to go home every night and I'm sure every motorist would to. I am a public safety worker and it's not safe to drive –if you can't see (every one!)
53. Better lighting and road sensors

54. Better headlights system on high and low beams, plow built to push snow to the top to windshield – better lights for backing vehicle.
55. Better windshield, better ways to keep side windows clear, better lights, better ways to keep snow from coming over plow.
56. My air condition helps remove moisture in the cab, which reduces icing on my side windows and windshield. Using amber beams with no head lights help in blowing snow. Bug shields.
57. Keep cab lights very low. Keep your delineator in good repair
58. Sloped hoods on truck –when my plow is down. I can only see my wands on plow corners. Sloping windshield –help snow to blow over and not built up on hood and windshield
59. Driving ability, years of plowing snow, young drivers get into trouble. Stronger wiper system. Better lights. Even yellow help. After 20+ years you have seen and done it all. Come take a ride come bad, bad night. Thank you for this survey
60. Know the road and route you are plowing – air duet system with fan to blow, snow away from windshield before snow reaches the glass, would help keep glass from icing up as bad (exterior mounted)
61. A heads-up type display of center line and objects a head would be very useful. Lighting devices that could light up below the snow so it was not reflecting in your eyes.

General comments (61)

1. Slow down, some young drivers drove way too fast. Hood windshield deflectors help (bugshields). Delineation really helps. Knowing your road sections.
2. Just do your job and quit whining
3. Slow to a safe speed. Know capabilities of your equipment being very familiar with the road that you are maintaining.
4. Suspend plowing operation when throwing snow against the wind you not going to accomplish what you want. Wait till wind quits blowing and then move the snow off the road.
5. My feeling it doesn’t matter how prepared or advanced the equipment is you’ll never prevent the inevitable, traffic is always a problem and your always in there way. Until the traffic and truck slow down and drive responsibility snow plow are going to be targets in any situation.
6. This survey has provided good points for safe operation of snow plow
7. I have no problem
8. Having equipment that has been researched and specifically designed to provide maximum visibility to the operator. Teaching should be suspended and allowed the authority to do so.
9. I don’t know what to say to this except we have enough distractions while plowing why increase another, which could cause as accident
10. Like previously said as operator has many things to watch listen and feel while operating any equipment including snowplow. A person reacts to 3-4 scenarios; the resr is as called lutimatics why keep increasing something more to watch listen or feel; to me this puts more complication in what we need to watch listen and feel for; safety fist first.
11. This is a high wind area the only way we can make it better is find a way to shut the wind off
12. The traveling people need to get a high fine on the one they do not obey the laws
13. Let the foreman run his section
14. Close the road and fine and citations for all who run the road closed sign.
15. When there is bad visibility a snow plow creates a hazard the road should be closed to avoid running into other vehicles
16. Safety first, experience next.

17. More public awareness an the problem snow plow operators have seeing during low visibility condition, so the public can stay clean of plowing operations and assist in helping us know where we are at on roadways
18. More training for new person, operating snow removal, sanding roadway, spraying device etc. Ride with operator (experienced)
19. Stay alert even if the work is redundant
20. Believe that strong o.j.t training in the field in all condition and knowing your equip and route by heart is a tried and proven tool. Spend your time and money here and put the money to ward programs which support these program.
21. I really do not think this is much of a problem for myself!!!
22. If you can’t see the road, the traffic can’t see you and you shouldn’t be out there.
23. A lot of times, you can’t determine which lane you really are in. so experience is the key
24. Since I have worked for MT DOT we have not had a hard winter with a lot of snow.
25. Keep alert
26. During a white out nothing I can think of can help you see. I think it should be considered to close the road when visibility is zero. It’s a very helpless feeling when you cannot even see your plow in front of you.
27. Know the lay of the land and become familiar with the road you are plowing. Keep your speed at a safe level
28. When out plowing snow in the worst of weather condition, most plow operator are really careful of this truck and other vehicle around then, there are operation out then that don’t care about that public or then self. Then the one give every body a bad name as a state employee
29. I feel its best to regulate your speed the slower the safer. Try not to plow against the wind if possible this create snow fog, which is the most dangerous condition for accident. I believe very heavily in gang plowing with hwy patrol behind you.
30. There’s not much to be done for visibility when the weather as the main factors for seeing. Just don’t be on the roads in poor weather.
31. Snowplow operations should not be conducted during visibility problem you are more of a hazard than you are doing good.
32. I go by the crown of the road and watch for the yellow line in my left mirror
33. Plow as weather permits
34. If you don’t feel safe out there in low visibility pull off the road until the visibility gets better.
35. Technology will never replace operator experience or common sense. Snow and ice control operation should be discouraged during extreme condition and after dark. To give the traveling public a false sense of security will only encourage risk to both operator and the public. No travel advised and road closures mean just that.
36. Ability to see is always going to be a problem from storm to storm, each has then own characteristic some home lots of wind causing problem and some have no wind which can cause problem where snow just hangs in the causing visibility problems.
37. Because of the winter being so nice and think this was the wrong time to be taking a survey like this. On a average winter in North Dakota the answer may be also different
38. Operators need to adjust to all snowplowing conditions also traffic needs to realize we are doing our job and need to give us space to work and allow us to do our job.
39. Slow down, take your time and drive defensively

40. There is nothing now to help during strong winds and blowing snow just take it slow and try to feel the road or get off the road until condition get better. The speed of driving varies a lot with blowing snow the speed mark down is on good condition, blowing snow varies from 15-25 MPH
41. Had a very good winter not much snow
42. Every snow fall or snow storm varies a lot of condition change things one direction while plowing seems better than the other – depends on wind condition. if you could just stop the wind
43. For our situation in rural North Dakota do not believe it makes much sense to be out in a severe snow storm at all. You just do not accomplish your objective. It fills in behind you with in minutes of your pass.
44. I’ve found in the day and age you can’t even trust a co worker behind you to tell you if something is behind you and ready to hit the back of your truck. So I trust no one that I work with to tell me if and am about to be hit. So I say, you on your own when you are out in a storm or what even you had better have full contact of your truck your self.
45. Make public aware of our problem so as they don’t make our problems worse. Use public announcements to educate people about plow operation so as they will not do things that make things worse like crowd plows, drive into plow, drive into plow clouds stop in travel lanes, etc.
46. Lower speed
47. Never stop or you’ll get all disorientated
48. With our current equipment, we need to be more willing to close roads and suspend operations when condition approach 0 visibility. To continue operation in these conditions is not only dangerous but a waste of time and full as little or nothing can be accomplished, poor visibility is a very real and very serious problem. Lives are at stake.
49. There are times that it is not safe for you or the public to be there. We had one operator injured already due to staying out to long.
50. Know your roads – memorize landmarks, curves, hills, dips, bumps, everything slow down – never stop unless you can get away from road and turn off all lights or traffic will follow, run into you.
51. Help employees by stressing importance of working together – storm down –and work safe.
52. Be careful –people don’t look out for you
53. Being careful and aware of situation
54. I need to learn how to use a computer
55. Use of good common sense and stay calm
56. Better informed public concerns to snowplow operations
57. I feel if you can’t see in very poor visibility that we the plow operator are in a bad risk situation as the public therefore in my own personal opinion. I don’t know how anybody can be judge or trailed in error.
58. Instead of paper survey, people should be exposed to the application of being in or operating a snowplow. The people that make all the policies and rules will never be found near a snowplow during the conditions that exist during a storm. If problem occur you are at (fault)
59. Your initiative to solicit input and carry that out in this survey is very wise and much welcomed. Hope that it is probable that you won’t initiate any plans procedure or new equipment that is not tested thoroughly first by actual snow plow operators.
60. The traveling public seems to expected more service and are becoming worse drivers.

61. Slow down

APPENDIX D: CHI-SQUARED ANALYSIS

The demographic and traveler information data collected in the Snowplow Operator Survey were used to define the categories in the significance testing. Our analyses included significance testing based upon t-statistics to determine whether certain demographic and snowplow operator characteristic variables significantly influence the responses to various opinion-based questions. The chi-squared analysis is used to determine if differences in responses across groups are statistically significant at a predetermined level of probability. For this analysis, a 95% confidence interval was selected for reporting purposes. Thus, statistically significant differences in responses meant there was only five chances in a hundred that the variation between the categories was due to something other than actual differences in the groups being analyzed.

In order to use the chi-squared analysis on a data set, the data must meet the following requirements.

1. The sample must be randomly drawn from the population
2. Data must be reported in frequencies (**not** percentages)
3. Measured variable must be independent
4. Values on independent and dependent variables must be mutually exclusive
5. Observed frequencies cannot be too small

The chi-squared test operates by comparing the actual, or observed, frequencies in each cell in a table to the frequencies we would expect if there were no relationship at all between the two variables in the populations from which the sample is drawn. In other words, the chi-squared analysis compares what actually happened to what hypothetically would have happened if all other things were equal. If the actual results are sufficiently different from the predicted hypothesis results, we reject the hypothesis and claim that a statistically significant relationship exists between the two variables. This result represents a chi-squared difference in the tables on subsequent pages.

As shown in Table D-1, a shaded cell indicates that no differences were found using the chi-squared analysis. A blank cell indicates that no test was performed on the corresponding data. An “X” indicates that the test was invalid based on the criteria established earlier (10% of the cells in a given table had a count less than 5, or, any cells had counts of zero). A fully blacked out cell indicates that differences were found.

Table D-1: Chi-squared analysis

Question/Demographic	4. Number of routes	5. Approximate length of route	7.a. Average driving time	7.c. Average speed while plowing	19. Have to stop	20. Hit an object	21. Run off the road	22. Lane position	23. Front obstacle	24. Rear obstacle	25. Side obstacle	27. Suspension due to weather	28. Suspension w/technology	29. DOT	30. Age	32. Years of experience	33. Grade level	34. Computer experience
4. Number of routes							X											
5. Approximate length of route				X		X	X	X	X									
7.a. Average driving time				X	X	X	X	X	X	X	X	X	X	X				
7.c. Average speed while plowing					X	X	X	X	X	X	X			X	X	X	X	X
14.a. Feeling crown of the road			X	X			X										X	
14.b. Feeling rumble strips			X				X	X									X	
14.c. Feeling slope of the shoulder	X	X	X	X	X	X	X	X				X	X	X	X	X	X	
14.d. Judging distance from mileposts/delineators			X	X		X	X									X	X	
14.e. Judging distance from fence lines			X	X		X	X	X									X	
14.f. Judging distance from grass lines			X			X	X										X	
14.g. Judging distance from the center line		X	X	X		X	X	X								X	X	
14.h. Judging distance from guardrails		X	X	X	X	X	X	X							X	X	X	
14.i. Following other vehicles' tracks			X	X			X	X									X	
17. Worst storm # of times lost sight of road						X	X	X	X	X	X	X	X					
17. Worst storm duration of losing sight of road						X	X	X	X	X	X	X	X	X				
18. Avg. storm # of times lost sight of road							X	X	X									
18. Avg. storm duration of losing sight of road						X	X	X	X									
22. Lane position usefulness					X	X	X		X	X	X					X	X	X
23. Front obstacle detection					X	X	X			X	X					X	X	X
24. Rear obstacle detection						X	X									X	X	
25. Side obstacle detection							X										X	
27. Suspension due to weather							X									X	X	
28. Suspension due to weather with technology							X									X	X	
29. DOT						X										X	X	
34. Computer experience																X	X	

Passed test	
Invalid test	X
No test performed	
Difference	