White Paper

Mn/DOT Driver Acceptance: IVI FOT Evaluation Report

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EXECUTIVE SUMMARY

This white paper provides findings from surveys and interviews for the evaluation of driver acceptance as a component of Battelle's independent evaluation of the Mn/DOT Intelligent Vehicle Initiative (IVI) Field Operational Test (FOT), sponsored by the U.S. Department of Transportation (USDOT). The overall objective of this white paper is to report on the perspective and experiences of drivers and their supervisors regarding the feasibility and benefits of advanced safety systems for specialty vehicles. During the winter months of 2001-2002, Mn/DOT tested technologies designed to provide operators of snowplows, ambulances, and a state patrol car a means to maintain desired lane position and avoid collisions with obstacles during periods of low visibility. The technologies that constitute the Intelligent Vehicle Safety Systems (IVSS) include the side- and forward-looking radars (and associated collision warning system); head-up display; a GPS-based lane departure warning system that included a visual, audible, and haptic alarm; and magnetic lateral guidance that was a backup to the primary, GIS-based lane-keeping system that was activated only upon the deterioration or loss of the GPS signal.

The evaluation of driver acceptance addressed elements of the following four evaluation objectives associated with Goal Area 2: Assess Impacts on Driver Acceptance, as presented in the Mn/DOT IVI Evaluation Plan:

- <u>Objective 2.1</u>. Determine the vehicle operator perceptions of the usability of the IVSS technologies.
- <u>Objective 2.2</u>. Determine perceived effects of the IVSS technologies on operator training requirements, job satisfaction, stress, workload, and fatigue.
- <u>Objective 2.3</u>. Determine perceived effects of the IVSS technologies on the driver in terms of behavior risk modifications and changes in driver vigilance.
- <u>Objective 2.4</u>. Determine perceptions of product quality, value and maturity and establish customer willingness to pay.

Findings and conclusions from this evaluation of driver acceptance must be interpreted in light of both unusually mild winter weather that afforded very few low-visibility driving "events" for which the IVSS was primarily designed, and technologies that were not always functioning to specification. These issues affected driver acceptance and are discussed in this report.

Data Collection Procedures

Members of the Battelle evaluation team met with many of the specialty vehicle operators in the two group-training sessions held in late 2001 and outlined plans for the evaluation. Initial baseline interviews were conducted with 12 drivers and 4 supervisors in December 2001, followed by the first Internet survey of 18 drivers in January 2002. The objective was to obtain background information on the drivers and to assess their expectations for the performance and likely benefits of IVSS in their specialty vehicles. In April 2002, after about three months of driving using the new technologies, a second Internet survey (13 drivers) and in-person interviews (12 drivers and 3 supervisors) were conducted to evaluate their experiences with the technologies and any changes in perceptions. Findings from both the surveys and interviews are integrated in this report to give an overall picture of drivers' and supervisors' perspectives on the technologies and their experiences with them. In addition, results from the analysis of the three different driver groups are aggregated where they are similar and discussed separately where they are significantly different. To maintain confidentiality, individual driver identity is not revealed.

Analysis and Findings

Background. Several background questions were asked of the drivers to gain a better understanding of what their thoughts and perceptions of these IVI safety technologies were before they had any significant contact with them. The drivers[1] selected for this FOT were very experienced, with reported experience ranging from 10 to 36 years. Only 11% of the drivers reported they never had taken evasive maneuvers such as hard braking or sudden lane changes to avoid an accident. Therefore, we would expect that these technologies would be viewed as beneficial, and should help reduce the need for sudden evasive driving maneuvers, especially under low visibility conditions. Before the start of this evaluation, drivers were aware of problems[2] with the performance of the technologies. Nevertheless, 83% of the drivers said they expected collision avoidance[3] and lane-keeping would likely be useful to them in their driving. This indicated that drivers were willing to give the technologies a fair test and were hopeful they would experience their intended benefits.

Driver Perceptions of Usefulness. Even though the kind of low visibility weather conditions (e.g., blowing snow, heavy fog) under which these technologies were designed to be used were rare during the evaluation period, and notwithstanding technical problems with the IVSS, the drivers tried out all aspects of the system under actual operating conditions, including several low visibility conditions. Insights into their perceptions are based both on responses to the Internet survey and in-person interviews. Although there were variations in the drivers' initial perceptions of the benefits of the collision avoidance and lane-keeping systems, some drivers tended to be skeptical of these benefits after having actual driving experience with systems in which the problems had not been fully resolved. This reaction should be expected. Moreover, some thought these systems could interfere with driving tasks and impact driving workload. Comparative survey results are highlighted in Table ES-1.

In general we see at the end of the evaluation period (second survey) the drivers reported reduced agreement with the potential benefits (collision avoidance and stress/fatigue reduction) of the systems and greater concerns about the technology interference with driving tasks and increased distraction and effort associated with the use of the IVSS technologies, compared with their

[1] Approximately 32 drivers were eligible to be involved in this FOT. See Table 2 of the report for details on the distribution of participants across vehicle types and surveys/interviews.
[2] These technical problems, related to loss of DGPS signal in certain geographic areas and configuration of the equipment in the vehicles, are discussed further in the white paper.
[3] In the interviews and surveys the term "collision avoidance" was used to describe the feature of the vehicle's driver assist system that gave warnings of potential front or side collisions. This feature in the Mn/DOT vehicles is more accurately a "collision warning system." We report the terminology as it was actually used in the evaluation with the recognition that the drivers fully understood its function as a warning system.

expectations entering into this evaluation (first survey). Also as a generalization, drivers are somewhat more positive regarding the benefits associated with lane-keeping versus collision avoidance. Although less than half the drivers said they wanted either of these systems to be kept on their vehicles in the future, more expressed a desire to keep lane-keeping compared with collision avoidance. Many of the drivers found that the IVI systems were helpful in snowy and low visibility conditions when they were working properly, but they were concerned about having them work consistently and reliably.

Table ES-1. Change in Driver Perceptions Between the First and Second Survey

Vehicle Operator Survey Questions	Percent of Operators Who Agree* First Survey: 18	Second Survey: 13
Perception of Benefits		
Collision avoidance will/does reduce the number of accidents or near-accident situations.	62%	15%
Lane-keeping will/does reduce the number of accidents or near-accident situations.	67%	31%
Collision avoidance will/does reduce the stress and fatigue of driving.	44%	8%
Lane-keeping will/does reduce the stress and fatigue of driving.	44%	15%
I would like the **collision avoidance** system to be kept and maintained on my vehicle in the future.		31%
I would like the **lane-keeping** system to be kept and maintained on my vehicle in the future.		46%
Expressed Concerns		
I am concerned that **collision avoidance** will/does interfere with my driving tasks.	39%	61%
I am concerned that **lane-keeping** will/does interfere with my driving tasks.	28%	46%
I am concerned that **collision avoidance** increases the amount of effort it takes to drive a vehicle.	28%	54%
I am concerned that **lane-keeping** increases the amount of effort it takes to drive a vehicle.	28%	46%
These systems create an added distraction.	39%	
• **Collision avoidance** system		77%
• **Lane-keeping** system		54%
General Perceptions		
I would be better off driving without these types of high tech systems.	6%	8%
High tech systems really do not help the experienced driver avoid front-end collisions.	11%	31%

* The bar charts show the sum of the percent of drivers who "agree" plus the percent who "strongly agree." Readers are cautioned to keep in mind that these percentages are based on small numbers of driver respondents.

In the in-person interviews drivers reported on the specific aspects of the systems that they liked or that were frustrating to them. The snowplow operators liked knowing where they were positioned with respect to the roadside when snow covered the road. Drivers in general thought the IVSS offered great potential in increased confidence and reduced stress of driving in low visibility conditions, though few expected measurable productivity benefits. Some drivers discussed such issues as glare and reflections off the head-up display (HUD) combiner, vibrations and lack of clarity in seeing road detail using the HUD, problems with night vision, and apparent false readings presented by the collision avoidance system. These kinds of issues caused some drivers to stop using the systems, or to only use them for testing purposes under good driving conditions.

When asked whether they would be better off driving *without* these types of high technology systems in their vehicles, 39% disagreed in both the first and second surveys and less than 10% agreed. Over half the respondents in each survey were undecided on this question, which suggests their abiding willingness to give the technologies a chance to prove themselves. Many felt, because of weather and technical constraints, that they hadn't had adequate opportunity to experience the real benefits of these technologies, and they looked forward to that opportunity, once the bugs could be worked out.

Driving Behavior. Half of the respondents on the initial survey said they expected their driving would change as a result of having both the collision avoidance and lane-keeping systems on their vehicle. Though they weren't asked to say specifically how their driving might change, this response indicates there is clear potential for underlying changes in driving habits. On the second survey, 46% of the drivers said that their driving had not changed as a result of the collision avoidance system, and 70% of the drivers said it had not changed as a result of the lane-keeping system. Drivers interviewed in-person mentioned they thought these safety technologies would make them more alert, more relaxed, and probably more careful about safely managing such driving tasks as following distance. This suggests they didn't think they might engage in more risky driving behaviors under the assumption that the technologies would keep them out of trouble.

Perceived Mental Workload. Mental workload refers to the amount of mental effort, concentration, or focus that drivers think it takes to perform their driving tasks. There was general consensus among these drivers that the level of workload is quite high when operating their vehicles under the worst winter driving conditions without any IVSS technologies, and that this workload level is reduced by the IVSS technologies. However, the average reduction in workload actually *experienced* by these drivers (second survey) was about half as much as they *expected* (first survey). A few drivers reported an increase in workload and others reported no reduction in workload at all due to the IVSS, but on average drivers indicate that the level of mental workload is reduced somewhat by these systems.

Perceived Liability. Citing liability concerns, ambulance operators said they were reluctant to use the technologies when a patient's life was at risk in an emergency driving situation. Both the ambulance and snowplow driver groups were split 50-50 on their perception of the overall safety benefits of the IVSS, with 38% agreeing that they provided a safety benefit, and 38% disagreeing overall, with no clear differences between the two driver groups.

Supervisors' Perspective on the IVSS. Overall, supervisors would like to see these kinds of systems on their vehicles if their reliability increases and if the costs can come down. They all thought the systems' test should run another year to gain greater exposure to the kinds of conditions in which they are designed to help drivers.

Conclusions

This evaluation of driver acceptance was hampered by both the lack of low visibility weather "events" and the initial performance problems experienced with some of the IVI technology systems in each of the three specialty vehicle categories. Because of these factors, driver perceptions measured by these surveys and interviews appear to have reflected the particular circumstances of the test along with the actual functionality and safety benefits they were able to experience from the technologies. Nevertheless, drivers and supervisors remained generally optimistic that, if the technology problems can be resolved, the IVSS technologies hold significant potential to enhance driver confidence and performance while operating specialty vehicles under very difficult driving conditions. The participants in this test agreed that the technical problems with the IVSS needed to be fixed and more evaluation time under adverse weather conditions was needed to confirm and quantify benefits.

1.0 INTRODUCTION

1.1 Background on IVI Field Operational Tests

The United States Department of Transportation (USDOT) established the Intelligent Vehicle Initiative (IVI) as a major component of the Intelligent Transportation System (ITS) program. The intent of the IVI is to improve the safety and efficiency of motor vehicle operations significantly by reducing the probability of motor vehicle crashes. These safety improvements could also show secondary benefits such as increased transportation mobility, productivity, or other operational improvements.

In 1999, USDOT entered into cooperative agreements with four partnerships to conduct Generation 0 Field Operational Tests (FOTs) of advanced intelligent vehicle safety systems (IVSS). These systems are expected to begin production preparations before the end of fiscal year 2003. Although the scope of the IVI Generation 0 FOT program included light passenger vehicles and transit vehicles, USDOT selected one FOT involving specialty vehicles and three FOTs involving commercial trucks. The Minnesota Department of Transportation (Mn/DOT). was selected to conduct the specialty vehicle FOT. The USDOT selected a Battelle-led team to work with each partner to perform an independent evaluation of the technologies being tested.

Mn/DOT deployed IVSS technologies designed to provide operators of snowplows, ambulances, and state patrol cars drivers a means to maintain desired lane position and avoid collisions with obstacles during periods of low visibility. Key among these technologies was vision enhancement, lateral guidance, and collision warning systems. The primary evaluation goal of the FOT was to determine the potential safety benefits of IVSS. Specifically, how many crashes, injuries, and fatalities could be avoided if all such vehicles were equipped with these technologies? It was also important to understand how these technologies affected driver performance. For example, did drivers drive more safely? And, how did these technologies affect driver stress level and workload? The secondary goals of these evaluations included the estimation of other benefits (mobility, efficiency, productivity, and environmental quality), evaluation of system performance, and assessments of other factors that affect development and deployment of these technologies. These factors included user acceptance, product maturity, manufacturability, and institutional and legal issues.

These were the original goals of the Mn/DOT FOT. However, the IVSS being tested in the Mn/DOT FOT are designed for use in snow accompanied by low visibility conditions. Thus, such conditions were necessary to achieve the goals and objectives of the Mn/DOT FOT as well as its independent evaluation by Battelle. However, the winter of 2001-2002 in the area of the test corridor turned out to be unusually warm and relatively devoid of snow. During the period of the FOT, December 21, 2001 – March 31, 2002, there were only two snowfalls of significance. Furthermore, according to measurements made by the Mn/DOT FOT partnership, there was no occasion during the FOT in which the visibility was very low (defined as less than 100 meters) and there were only 15 minutes when visibility was in the 100 to 199 meter range. Thus, in the words of Mn/DOT project management: "At no time during the FOT were any of the specialty (vehicle) operators exposed for *sustained* periods to the kind of conditions for which the DAS (Driver Assistive System) was designed."

Recognizing that the original evaluation objectives could not be met due to the mild winter weather, FHWA modified the evaluation Statement of Work to direct that "Battelle will prepare a Project Report that describes each system tested and details the evaluation plan and test plans developed." They also directed Battelle to prepare this white paper on driver acceptance based on feedback received during driver interviews and surveys.

1.2 The Mn/DOT IVI FOT

The Mn/DOT IVI FOT was conducted by a partnership including state and local government, industry, and the University of Minnesota. Table 1 lists the partnership organizations and their roles. URS/BRW Provided administrative and program management support to Mn/DOT on the project.

Table 1. Roles of the Mn/DOT FOT Partners

ORGANIZATION	ROLE
Mn/DOT Office of Advanced Transportation Systems (OATS)	Overall project manager as caretaker of Minnesota Guidestar Program. Facilitated contracts preparation and approval.
University of Minnesota (Intelligent Vehicle Laboratory, Human Factors Research Laboratory, and the Department of Applied Economics)	Technical lead & system integrator. Human factors support & evaluation. Benefit-cost analysis.
Mn/DOT - District 8	Provided 2 snowplows with operators. Resident district for magnetic tape installation. Provided office space in Hutchinson Area Transportation Systems (HATS) building.
Mn/DOT - Metro Division	Provided 1 snowplow with operators.
Minnesota State Patrol	Provided 1 state patrol car with operator.
McLeod County	Provided 1 snowplow with operators.
Hutchinson Health Care	Provided 1 ambulance with operators.
3M Corporation's ITS Project Office	Provided magnetic lateral guidance tape and sensor technologies.
Altra Technologies, Inc. (ATI)	Provided side-looking radar system.

The Mn/DOT IVI effort was focused on improving mobility and reducing the number and severity of specialty vehicle (especially snowplow) crashes with other vehicles and roadside equipment such as guardrails and traffic control devices. Such crashes sometimes occur under low-visibility conditions caused by fog, rain, blinding snow, and darkness. Specific goals of the FOT included:

- Reducing the number and severity of specialty vehicle collisions as well as rear-end collisions involving the public's vehicles hitting the backs of snowplows,
- Improving the productivity and efficiency of snowplow and emergency vehicle operations, and
- Successfully integrating systems and technologies tested in earlier Mn/DOT projects.

Overall, the Mn/DOT FOT proposed to build upon and to extend several ITS technologies investigated in past and ongoing efforts in the state of Minnesota. The purpose of the FOT was to establish safety benefits. The IVSS were focused on providing specialty vehicle drivers with assistance during low-visibility conditions. In the FOT there were four snowplows, one state patrol automobile, and one ambulance equipped with the technologies, as well as an infrastructure to support them. A number of distinct yet related systems were integrated into the IVSS using on-board processing.

The FOT was conducted from December 22, 2001 to March 31, 2002. During the FOT, the test vehicles operated on their usual state and county highway routes. The primary test road for the FOT was a 45-mile section of Minnesota Trunk Highway 7 (TH-7) that runs east-west between the I-494 beltway in Minnetonka (a community on the western side of Minneapolis) and the City of Hutchinson. There was also a 4-mile section of McLeod County Road 7 extending northeast from Hutchinson that was included in the FOT.

1.3 Organization of This Document

This paper is divided into four sections. Section 2 describes the approach that we took to evaluating driver acceptance and discusses the data collection procedures. Section 3 presents the analysis of the data collected and highlights findings from the evaluation as they relate to each of the outcomes discussed in Section 2. Section 4 provides the evaluator's conclusions on what we learned from drivers and supervisors concerning their acceptance of the IVSS.

2.0 APPROACH

2.1 Evaluation Goals and Driver Acceptance Objectives

The U.S. DOT originally suggested five goal areas:

Goal 1: Achieve an in-depth understanding of the benefits of IVI technologies
Goal 2: Assess driver acceptance of IVSS
Goal 3: Assess system performance
Goal 4: Assess product maturity for deployment
Goal 5: Address institutional and legal issues that might impact deployment

Because the benefits of the IVI technologies fall into five different categories (safety, mobility, efficiency, productivity, and environment), Goal 1 was divided into five separate sub-goals, corresponding to benefit categories. As noted in 1.1 above, weather conditions limited the opportunities to evaluate the IVSS technologies under the conditions for which they were designed (i.e., limited visibility). As a result, FHWA determined that Battelle's efforts should focus on two activities: (1) documenting the evaluation methods and lessons learned, and (2) performing an assessment of the drivers' acceptance of IVSS. This report presents findings related to the second goal. The methodologies and partial analyses completed for the original goals are available in a separate document (report in preparation on the *Mn/DOT Intelligent Vehicle Initiative Field Operational Test Evaluation Methods and Lessons Learned*, Battelle, 2003).

The evaluation of driver acceptance addressed elements of the following four evaluation objectives associated with Goal 2: Assess Impacts on Driver Acceptance, as presented in the Mn/DOT IVI Evaluation Plan (Battelle Memorial Institute, 2001, p. 38):

- Objective 2.1. Determine the vehicle operator perceptions of the usability of the IVSS technologies.
- Objective 2.2. Determine perceived effects of the IVSS technologies on operator training requirements, job satisfaction, stress, workload, and fatigue.
- Objective 2.3. Determine perceived effects of the IVSS technologies on the driver in terms of behavior risk modifications and changes in driver vigilance.
- Objective 2.4. Determine perceptions of product quality, value and maturity and establish customer[4] willingness to pay.

Additional information on relevant driving experience and experience with computers and other "high tech" vehicle control or information systems was obtained in order to explore background factors and driver characteristics that might help explain the degree of observed driver acceptance.

2.2 Overview of Approach

Evaluation methods included in-person interviews with drivers and their supervisors and Internet-based surveys of the drivers. These were used to gather baseline information before the drivers had significant experience with the new IVSS technologies and later after they had experience with the technologies under the winter conditions for which they were designed. These data collection procedures are discussed in more detail in Section 2.

An objective of the initial baseline Internet survey (18 drivers) was to assess driver expectations for the use of the safety technologies and to ask drivers about their experiences with early versions of the technologies. It was known at the outset that there had been significant technical problems with the performance of the GPS in particular that resulted in incorrect or unusable

[4] The relevant customer regarding issues of willingness to pay or invest in the IVI technology is not the driver, but rather management. In this instance, interviews with selected supervisors from the major driving groups offer some insight into issues of perceived product maturity, suitability, value, and willingness to pay.

displays of roadway information that could not be corrected prior to the start of the Field Operational Test (FOT). The final Internet survey (13 drivers) sought to identify changes in driver perceptions based on their experiences with the IVSS. The baseline driver interviews (12 drivers) and final interviews (12 drivers) supplement the objective data collected in the surveys with a more open-ended, subjective discussion of expectations, experiences, and issues with the technologies. In addition to the data collected from the drivers, baseline and final interviews were conducted with selected supervisors (4 in the first interview and 3 in the second interview) in order to obtain their perspective on these safety systems. Findings from all these data are integrated in this report.[5]

As we learned from the driver and supervisor in-person interviews conducted in December 2001, early problems with the technologies appeared to cause some drivers to have reduced expectations regarding the potential to experience benefits from these systems at the outset of the evaluation. The final Internet survey and interviews sought to evaluate whether and how driver attitudes, perceptions, and behaviors with regard to each of the IVSS technologies changed as the drivers gained experience using the technologies and to the extent that the bugs were worked out.

Three other factors are known to have had an impact on driver responses and observations obtained from the surveys and interviews.

1. Drivers who participated in the surveys and interviews were operating very different vehicles under different conditions, associated both with the vehicle type and with the geographic areas in which they operate. For example, snowplows operating in more rural environments encounter very different driving conditions from snowplows operating closer to the city, in "urban corridors," and snowplows may operate very differently and under different conditions from ambulances or state patrol cars. Notwithstanding these differences, however, there was substantial agreement among the drivers on many of the topics covered in this evaluation. Where significant differences occurred in driver responses, these are discussed separately.

2. As was true for the entire IVI evaluation, the generally mild weather conditions that occurred between the baseline data collection and the final data collection approximately three months later significantly limited driver opportunity to experience the use and benefits of these safety systems. The evaluation timeframe provided at most two short instances of the kind of low visibility driving conditions that were considered essential to test the merits of the systems and offer the drivers sufficient opportunity to arrive at their sense of IVSS utility and potential benefit.

3. The technologies themselves were not fully debugged by the end of the second survey. This meant that the drivers were not able to report on a set of technologies that were performing up to their design specifications.

[5] Information that could reveal a driver's identity has been removed from this report, as all drivers were assured of confidentiality in the surveys and interviews.

Data collected at the initial and final time points allow for descriptive analysis of data on driver expectations, perceptions, and experiences at those time points, and also allow for a comparative assessment of any changes in responses and perceptions over the time period covered by this evaluation. Data from the same or similar questions asked at both points in time are analyzed to determine any changes in perception over time. Changes in perceptions are examined for groups of drivers (group averages for example) and at the individual level for the ten drivers who participated in both the first and second Internet surveys (to examine any changes in responses by the same person at both time points). In addition, where possible, comparisons between the survey responses and the objective systems data are provided as a way to discern how accurately drivers monitor their behavior and the accuracy of their perceptions of the system's performance.

This evaluation was conducted in parallel with a similar but independent evaluation conducted by the University of Minnesota (2002). Evaluators from both teams met periodically to discuss and coordinate plans for surveying and interviewing drivers, both to enhance the quality and comparability of the two evaluations, and to minimize the burden on the drivers to meet with the evaluators and respond to questions.

2.3 Conceptual Model

Figure 1 presents a conceptual model that illustrates sets of factors expected to influence how specialty vehicle drivers might be affected by the IVSS technologies. These factors were examined in the driver and supervisor surveys and interviews, and they include driver background, driver expectations about the IVSS, external conditions affecting the use of IVSS, and how these interact to influence driver perceptions and experiences with the IVSS. The first step (Baseline Perspective) is to take account of pre-existing experience and perspectives that can directly impact the outcomes of interest, as well as influence these outcomes through their indirect effects on driver expectations about the new technologies, their experiences and reactions while using the technologies, and their attitudes towards the technologies' benefits. These baseline conditions include training, driving experience, level of comfort with any kind of new technology, and the extent to which their organization and fellow drivers support or criticize the technologies.

Taken together, these conditions and factors directly affect the likelihood there will be driver trust that the technologies even have the *potential* to offer benefits. Another key set of conditions affecting the outcomes include whether the technologies work as they are supposed to and whether the external driving conditions and environment are conducive to a successful outcome. In the case of this evaluation, we know that some aspects of the technologies were not functioning correctly, or at all, and we also know that the needed low visibility weather conditions that were critical for an adequate test of the intended use of the technologies were almost non-existent during the evaluation period. In spite of these problems, most of the drivers were willing to put the technologies to the test where they could, and they were quite willing to share their experiences and opinions with us.

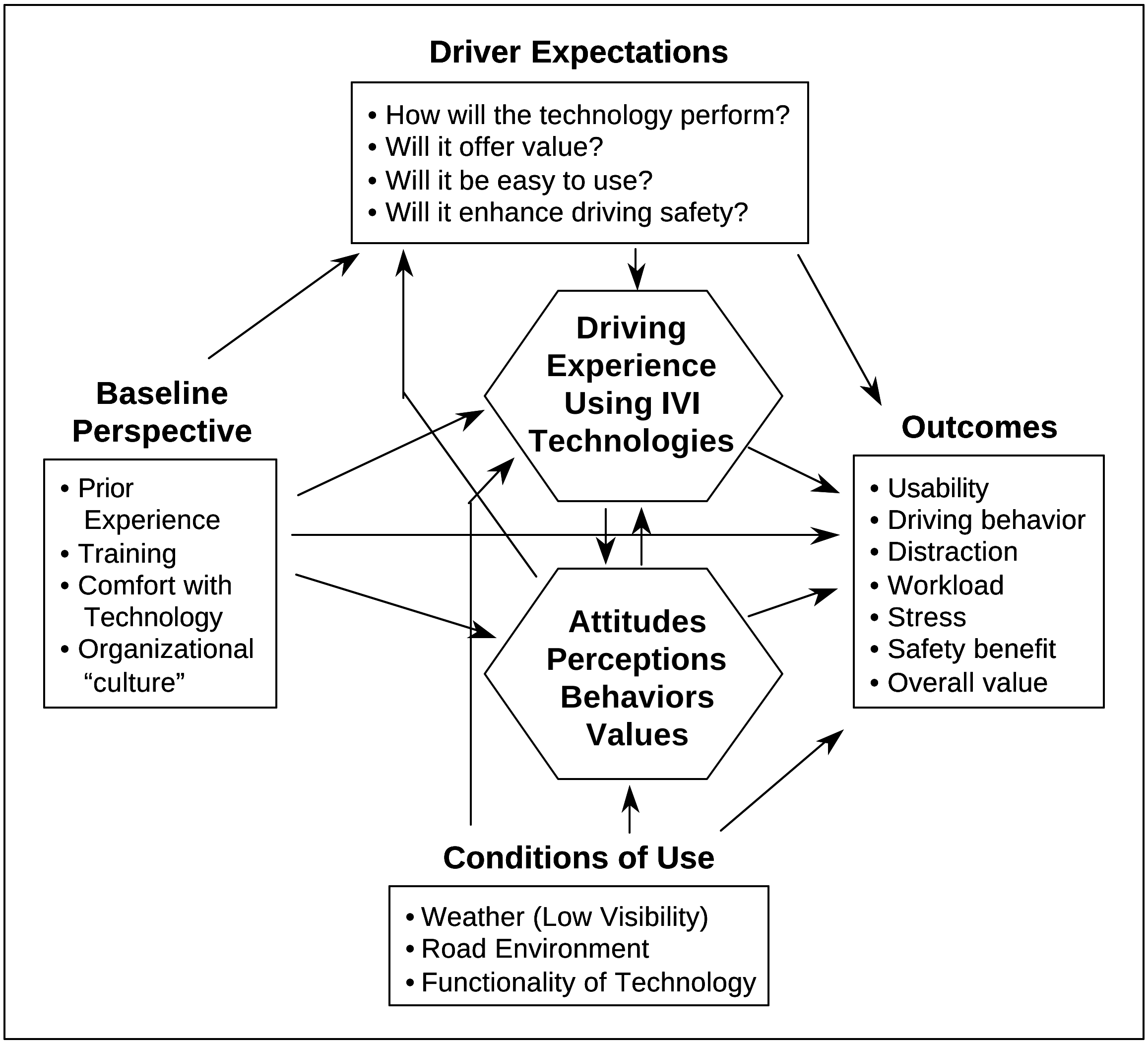

Figure 1. Factors Affecting Driver Acceptance of IVSS Technology

2.4 Data Collection Procedures

Several alternative strategies for collecting data from the drivers were considered, including written surveys, telephone and in-person interviews, and Internet surveys. In-person interviews were implemented because they provided a means of gathering attitudes, opinions, and anecdotal information not easily gathered by other instruments. We selected the Internet approach for the surveys because we felt this would be of interest to the drivers and would motivate them to complete the survey, as well as provide a manageable approach with the expectation of a high participation rate. The purposes of these interviews and surveys are shown in Table 2 in the order in which they were administered.

Table 2. Mn/DOT Interviews and Surveys

Data Collection Method	Dates of Implementation	Purpose
First Interview	Dec. 12 – 13, 2001	Gather baseline driver and supervisor attitudes, perceptions and expectations of the systems.
First Survey	Jan. 7 – 27, 2002	Gather baseline information from the drivers on their experiences with technology and their expectations of the systems.
Second Survey	April 2 – 11, 2002	Gather information after deployment of the IVSS technologies regarding driver uses of these systems, effects on driving behavior, and perceptions of benefits.
Second Interview	April 11, 2002	Gather qualitative information on driver and supervisor acceptance of IVSS, and an understanding of any changes in their attitudes and perceptions.

2.4.1 Interviews

Interviews were arranged with the cooperation and active support of Mn/DOT management. For each interview, arrangements were made to talk to as many of the drivers as possible. Most of the drivers were interviewed, except for a number of alternate ambulance drivers and the backup state patrol driver. Interviews were conducted with one participant at a time, and they lasted about 40 minutes each. The discussions were guided by a discussion protocol that listed all of the questions of interest, but the actual discussions were relatively free-flowing and informal. One member of the evaluation team led the discussion while the other took notes. Participants were assured that their names would not be used in any reports, and the resulting discussions were candid and open. Interviews with both the drivers and supervisors were conducted in convenient locations in three garages or the Hutchinson Hospital, although the protocol questions were different for each of these two groups of participants, and the protocols are included in Appendix C.

2.4.2 Surveys

Internet connections were accessible to each driver through his or her supervisor at their truck station, and this was a relatively low cost, efficient approach to implementing the survey and collecting data from the drivers. The intent was to achieve 100% driver participation in the survey, and the Internet approach was judged to offer the best chance of achieving a high response rate.

Battelle had already developed an Internet survey framework, and it was a straightforward matter to tailor a survey for this IVI FOT, using a set of questions designed for this purpose. The survey was prepared and pre-tested by Mn/DOT using approximately a dozen specialty vehicle drivers who were not affiliated with the Field Operational Test (FOT). Their feedback and comments were used to improve the question wording and the survey presentation over the

Internet. The final survey version was made available to the FOT drivers, who were notified to take the survey and given instructions on how to log onto their station computers.

Survey returns were monitored on a regular basis, and drivers were reminded by Mn/DOT management several times of the importance of completing the survey. It is unclear how many drivers were actually available to take the survey, because there remained some uncertainty regarding how many ambulance drivers would actually end up participating in this IVI program, there was some turnover in the drivers participating in the survey, and a few drivers were unavailable to take the survey. For the final Internet survey, only those drivers who had used the systems during a snow event were asked to complete the survey. It was difficult to arrange interviews with all the ambulance drivers, so only those drivers who had used the equipment participated in the final survey and the interviews.

Two state patrolmen participated in the FOT, a primary patrolman assigned to the equipped state patrol car and a back-up patrolman trained in the operation of the equipment who was slated to use the equipped vehicle only when the primary patrolman was not available to perform his duties. The primary patrolman was able to perform his duties throughout the evaluation period, so the back-up patrolman never gained experience with the systems and therefore had no need to participate in the surveys or interviews. The driver participation for each data collection event is shown in Table 3. When interpreting percentages in the tables and figures, readers need to keep in mind that the results presented in this white paper are based on small numbers of drivers.

Table 3. Participants in Internet Surveys and Interviews

Driver/ Operator Group and Supervisors	Eligible to Participate*	First Internet Survey	Second Internet Survey**	First In-Person Interview	Second In-Person Interview
Snowplow	10	6	8	8	8
Ambulance	15	11	4	3	3
State Patrol	2	1	1	1	1
Supervisors	5	n/a	n/a	4	3
Totals:	**32**	**18**	**13**	**16**	**15**

* The number of eligible drivers and supervisors is estimated to give the reader a sense of the response rate to the surveys and interviews. See the text for further explanation of eligibility. Also, 10 of the drivers/operators responded to each of the Internet surveys, and the rest responded to only the first or second survey. “n/a” = not applicable.

** Only operators who had actual driving experience using the IVSS were asked to complete the second survey.

Findings from both the surveys and interviews are integrated in this report to give an overall picture of drivers’ and supervisors’ perspectives on the technologies and their experiences with them.

2.5 Analysis Approach

The approach to data analysis has several components. The detailed data that describe responses to each of the two Internet driver surveys are presented in Appendix A. The important findings from these data will be highlighted in the subsections of this report. By comparing the two cross-sections, or snapshots, of the driver responses to the various questions at these two different points in time, we can draw inferences about how the drivers, namely the snowplow, ambulance and state patrol car operators, responded before and after they had experience with the IVSS technologies. This is one way to assess changes in perceptions and behaviors for the outcomes of interest (as illustrated in Figure 1).

Also, because ten of the drivers of both the snowplows and ambulances participated in both of the Internet surveys, we were able to examine how individuals actually changed their answers, and hence their perceptions, to comparable questions asked in both surveys. These ten participants constituted a mini-panel that allowed for additional understanding of changes in perceptions and behavior. Changes observed in a panel can be attributed more directly to the effects of the IVSS technologies because individual characteristics of the participants were the same (i.e., held constant) in both surveys (because the participants were the same individuals in each survey).

As explained in detail in the Mn/DOT IVI Evaluation Plan (2001), the snowplow operator groups, ambulance operators, and state patrol car operator covered a mix of different routes that ranged from rural to urban. The 3 Mn/DOT snowplows operated in the Hutchinson, Shakopee, and Eden Prairie sub-areas from west to east along the TH-7 test corridor. Each Mn/DOT snowplow cleared a section that was roughly one-third of the length of that corridor. The McLeod County snowplow operated on county roads that straddled TH-7. The ambulance operated along the entire length of the TH-7 test corridor and the state patrol car along most of its length. Along the test corridor, the geography, road characteristics, traffic, population densities, and even weather varied. This exposed the operators to potentially very different road and snow conditions, as well as differences in one of the safety technologies in place for this FOT: the presence or absence of the magnetic strips installed in selected areas.

The rural areas are subject to more blowing, drifting snow conditions with a lot of variability in roadside conditions, compared with the urban corridors that have characteristics that help define road boundaries even in very low visibility conditions. We expected these differences to influence the experiences of these operators and their perceptions of the benefits of the IVI safety technologies. For example, the Eden Prairie snowplow operated where there was a jersey wall dividing the TH-7 corridor; with that visual cue, the lane-keeping technology was relatively less important and collision avoidance was more important. Alternatively, the Hutchinson snowplow operated in more open conditions with blowing snow where lane-keeping had more importance. The ambulance and state patrol car had the greatest variety in their routes. However, given that we only interviewed a pair of drivers at each of these locations, the small numbers of responses did not allow for meaningful analysis of these kinds of effects from the survey and interview data. However, we report suggestive findings where possible.

The results of the in-person interviews with both the drivers and supervisors offer a more in-depth look at the issues and perceptions of these participants than was possible in a multiple choice kind of Internet survey. Insights from the interviews were used to augment and help interpret the survey results. Where individual statements offer useful illustrations of findings, they will be provided in this report. The interviews with the supervisors adds a different perspective from that of the drivers, offering further insight into how the organization is likely to view the IVSS technologies and their suitability for more extensive use and fleet deployment.

Although the driver surveys and interviews are the primary source of data for evaluating driver acceptance, a limited amount of relevant on-board driving data were used to provide context for the survey and interview data. Specifically, these data documented the amount of time the system was available to each driver as well as the amount of time each driver spent with the system activated and with the volume control turned on.

3.0 ANALYSIS AND FINDINGS

The analysis and findings from both the surveys and interviews are presented in this section. Because of the small number of respondents, it is not possible to draw statistically significant conclusions from comparisons between the three different driver groups or within the driver groups. The results presented here primarily reflect summarized responses for groups of drivers and supervisors. Where interesting differences in patterns of responses are observed for the subgroups, those will be noted herein, as long as the analysis does not compromise the identity of individual respondents. For questions repeated in the "before" and "after" data collection periods, the patterns of responses are presented to illustrate any changes in driver perceptions that may be caused by their use of the technologies during the evaluation test period.

Figure 2 shows the total amount of driving time for each driver for which the data acquisition system was collecting on-board driving data. This time should generally coincide with the amount of driving time each driver had access to the IVSS – in all weather conditions. This time is divided into two categories: System Off time and System On time. No attempt was made to determine whether the System On time was recorded under adverse weather conditions. Instead, this information is provided as background. It shows that most of the drivers have at least some experience operating their vehicles with the IVSS system activated. The duration of this experience ranges from a few minutes to approximately 21 hours. Overall, the system was turned on approximately 25% of the time it was available to the drivers. Five snow plow drivers had the most experience (between 5 and 21 hours each). Only two ambulance drivers had more than one hour of driving experience with the system on. (Specific vehicles have not been identified in figures 2 and 7 in order to protect the identity of the drivers). Additional information on driving times under different visibility conditions will be available in Battelle's final evaluation methods report (Battelle 2003).

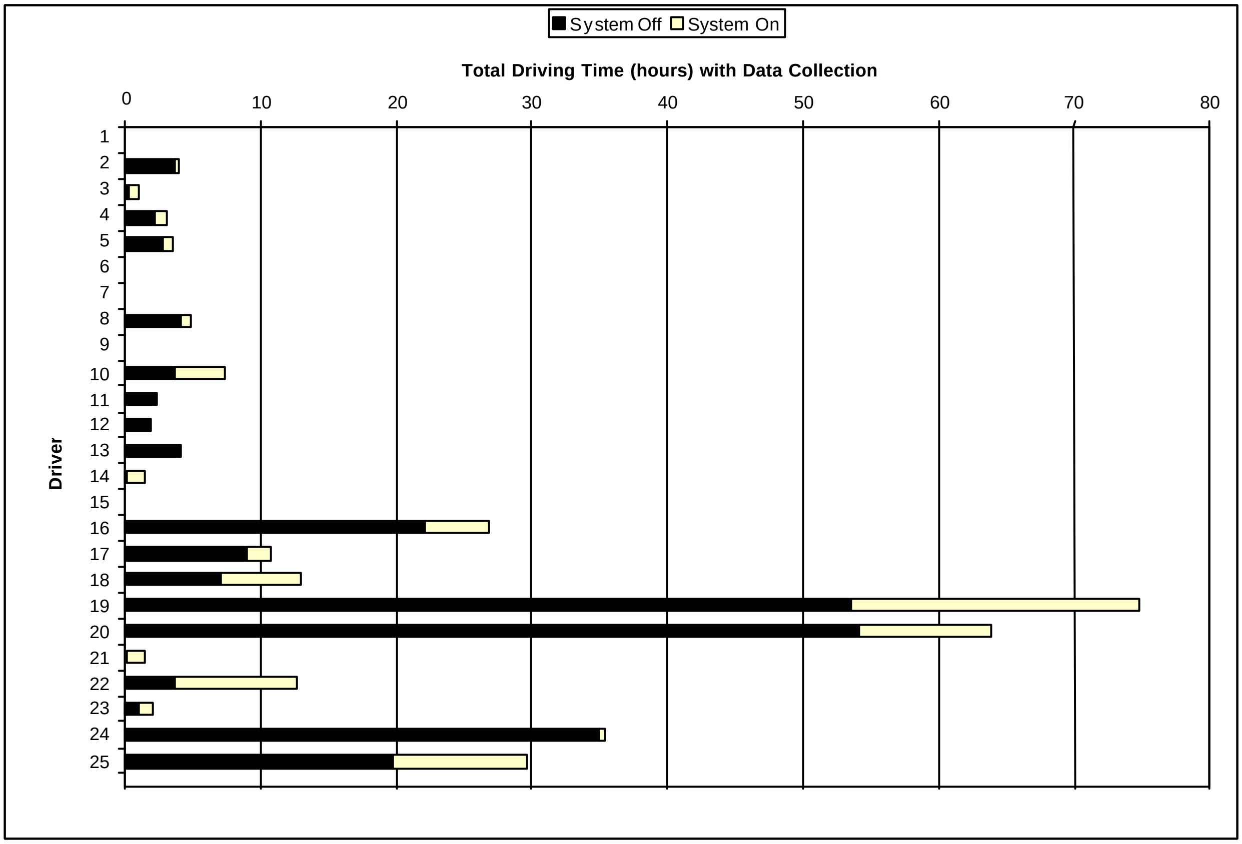

Figure 2. Driving Time with System Off and System On – by Driver

3.1 Driver Background

Several background questions were asked of the drivers to gain a better understanding of what their thoughts and perceptions of these IVI safety technologies were before they had any significant contact with them. These questions and the associated responses are represented in Table A-1 in Appendix A. They include questions about how often a driver has had to take evasive maneuvers to avoid a front-end crash, how satisfied they are with their vehicle's overall performance, and their general expectation of whether the new IVSS technologies are likely to be useful to them in their driving. The answers to these questions operate as a baseline or benchmark against which we can better interpret their answers to other questions regarding their perceptions of the specific IVSS technologies, their expectations for their function and value, and their reports of what they think after they have experience with them.

> **Snowplow Operator:** "If it [IVSS] works well, it will be the best thing since sliced bread. ... Any help the driver can get is good."

As shown in Figure 3, which represents all drivers, only 11% of the drivers in the first Internet survey report they never have taken evasive maneuvers such as hard braking or sudden lane changes to avoid an accident. On the other hand, very few drivers (6%) report they have done this "frequently." The majority is about evenly split between reporting such maneuvers as taking place "occasionally" or "rarely." The IVSS technologies are designed to assist drivers with warnings of vehicles and obstacles in their path under poor visibility conditions, and should be able to help reduce the need for such sudden, evasive driving maneuvers. The ambulance and snowplow operators reported similar patterns of the frequency of evasive maneuvers. While we might expect that drivers who report taking more evasive maneuvers would be more likely to also anticipate receiving greater benefit from the IVSS technologies, this is apparently not the case. Instead, drivers seemed to prefer to wait to see how the technologies actually perform before expressing the benefits they thought they *might* gain from using them. While these are very experienced operators, they were optimistic on balance that the new technologies offered valuable potential to help them in their driving jobs.

Another background question asked of the drivers was how satisfied they are with their vehicle's overall performance. We wanted a sense of whether the responses to questions about the IVSS technologies might be affected by whether or not the driver was satisfied with the performance aspects of his or her vehicle. The results show that almost 95% of the drivers say they are somewhat or very satisfied with the performance of their vehicle, suggesting this is unlikely to be an issue for these drivers in evaluating the benefits of the new safety technologies.

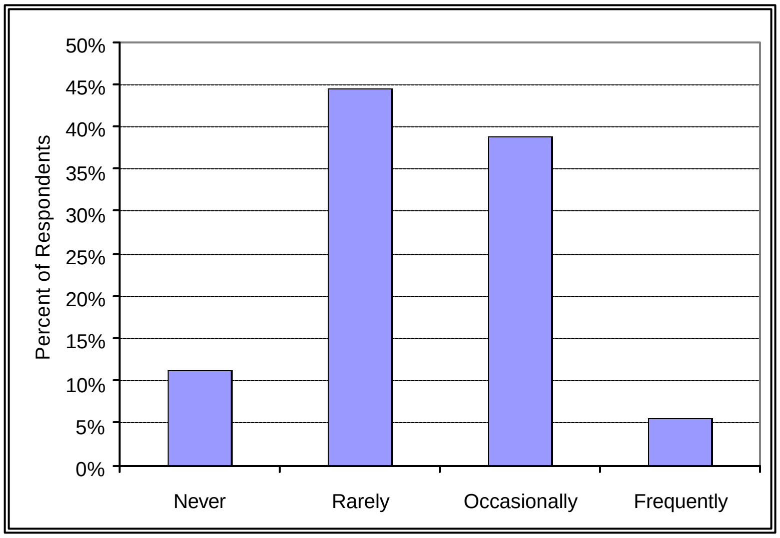

Figure 3. Frequency of Taking Evasive Maneuvers Under Poor Driving Conditions (First Internet Survey)

> **Expectations:** The great majority of drivers (83%) expected the collision avoidance and lane-keeping technologies to be useful in their driving.

Drivers were asked whether they expect the collision avoidance and lane-keeping technology systems are likely to be useful to them in their driving or likely to create problems, or alternatively whether the drivers felt indifferent on this matter. During the in-person interviews, some drivers said they were unsure whether they expected to experience productivity benefits from the IVSS technologies.

However, they were optimistic that the technologies could prove useful under various conditions, assuming they were functioning properly and reliably. Responses to this question on the Internet survey reflect this willingness on their part to view the technologies in a positive light and test their efficacy in practice. The great majority (83%) reported that they thought these technologies would be useful. The operators who thought the technologies are likely to create problems (2 snowplow drivers) did not provide any additional comments at the end of the survey that might help explain their concerns. Other drivers who said they thought the technologies would be useful to them also expressed concerns that the GPS satellites cut in and out numerous times, and that at night the HUD is too dark and external lights reflect off it "making it impossible to see things like jersey walls." The suggestion was made to put down magnetic tape in the pockets of poor GPS reception.

Additional driver background questions raised in the in-person interviews revealed that this was a very experienced group of drivers, with reported experience ranging from 10 to 36 years. Computer use by these drivers varied, from those who used computers frequently to those who only used them at work when needed. The drivers agreed that the IVI systems were the first high-tech systems to be introduced to their vehicles beyond the computerized systems integrated into the snowplows for treating winter road surfaces. Driving experience, comfort with computers and other technologies, and prior exposure to these specific kinds of technologies are all potentially relevant factors in trying to understand driver perceptions and reactions to the IVI safety technologies.

3.2 Objective 2.1: Use and Usefulness of IVSS

The first evaluation objective addresses the drivers' perceptions of the usability of the IVI safety technologies. Table A-2 shows the drivers' responses to the survey question that asked how often they had driven their vehicle *with each of the technologies operating properly* under adverse weather or low visibility conditions.[6] This question was asked in the first Internet survey (designated by S1) in terms of the number of times "up to now" and the second Internet survey (designated by S2) in terms of the number of times since January (i.e., since the first survey). Both sets of responses are shown in Table A-2 so that any change in driver response over time can be readily observed and interpreted comparatively. Many of the drivers had the opportunity to test drive some of these technologies, and given that there was at least one severe snow day early in the season prior to the formal start of the FOT, that may account for some of the experience indicated. The results in Table A-2 show that more than half of the drivers report having driven with each of the four technologies operating properly in their vehicle at least once, and many say they have driven with them four or more times, particularly in the second survey.

Looking at the two major driver groups (snowplow and ambulance) for the ten drivers who participated in both the first and second Internet surveys, we see that *none* of the ambulance drivers reported that they used any of these technologies during the test period with the technologies operating properly under low visibility or difficult driving conditions. While this could be interpreted to mean that either the technologies weren't operating properly, or that there were no low visibility opportunities when an ambulance was needed, the drivers in the final in-person interviews confirmed that the equipped ambulance was used infrequently, and in fact was the ambulance last to be chosen for emergency use. Ambulance operators commented that if they can't trust the technology 100 percent, then they are not going to put a patient's life at risk using it. They reported intermittent signal loss, unstable images on the head-up display, and bulky equipment that interfered with their driving and interaction with the medical personnel tending to patients in the vehicle. Conceptually they liked the idea and potential of the

[6] Note that low visibility conditions were very rare during the evaluation period, and in addition we know from the in-person interviews that the technologies functioned poorly or not at all some of the time and in some locations.

> **Ambulance Operators:** Liked the *potential* of the technology, but were concerned about liability issues when used in service.

technology, but so far in practice, they were unwilling to vest any of their driving and patient care responsibility onto an uncertain new system that presented too great a perceived liability risk for them.

All but one of the snowplow operators who participated in both surveys indicated an *increase* in driving experience with the technologies between the time of the first and second survey. The head-up display and lane departure warning were reported to have been used four or more times by all but one of the snowplow operators during the evaluation period, and most of these drivers had reported some prior experience with these technologies in the first survey. Figure 4 shows that usage by the 8 snowplow operators who completed the second Internet survey was much less for the side-looking radar, compared with the other three IVSS technology components.

Snowplow operator experience with the side-looking radar remained relatively low and essentially unchanged between the first and second surveys. These operators reported during the interviews that they tended to avoid using the side-looking radar capability. Some said that they didn't know their vehicle had this capability, or that they really didn't understand how to use it. Also, most of the snowplow operators used their vehicles on two-lane roads that afforded little opportunity to test this system component.

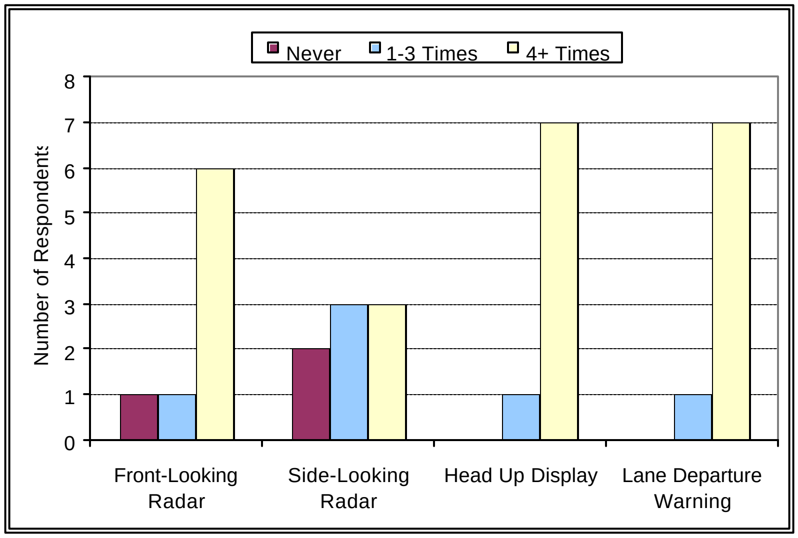

Figure 4. Snowplow Operators' Reported Driving Experience with IVSS Under Low Visibility Conditions During Test Period (Second Survey)

Table A-4 shows the results from a number of questions concerning the usability of the collision avoidance system and the lane-keeping system. To simplify the discussion, the presentation of the results is split into the two separate systems. One obvious similarity across both systems and the two different surveys over the course of the test is that the majority of the drivers do not express strong opinions ("strongly disagree" or "strongly agree") regarding the perceived value and usability of these systems; rather, they seem to gravitate to the more moderate attitudes of "agree", "disagree" or "neither agree nor disagree".

3.2.1 Use of the Collision Avoidance System

Drivers were asked to consider forward and side radar, vehicle and roadside object display on the HUD, and warning lights, sounds and symbols when responding to a series of questions about the collision avoidance system.

In the first survey, when drivers were asked whether they were concerned that the collision avoidance system *could* interfere with their driving tasks, their responses were split 50-50, with almost a quarter of the drivers uncertain. Several months later, when asked in the second survey whether these systems *did* interfere with their driving tasks, almost two-thirds said they did (61% agree or strongly agree, Table A-4). Primarily those who were uncertain before the test tended to express some concern after having some experience with these systems. One of the issues mentioned during the in-person interviews was the size and positioning of the bulky image projector placed close to the driver's head. Other issues relevant to the collision avoidance system included the following from the interviews:

Collision Avoidance System: After using the system, drivers were *more likely* to say it interferes with their driving tasks and *less likely* to be confident in its crash avoidance benefits.

- A decision was made not to display traffic approaching in the on-coming lane on the HUD. However, snowplow operators said that on-coming traffic is one of the more critical safety concerns for them when plowing under low visibility conditions, in part because they often have to cross the center line to avoid parked or stranded vehicles and in part because other traffic doesn't know where the center line is located under snowy conditions. Snowplow operators prefer to pull over closer to the road shoulder to give on-coming traffic more room to safely pass.

- The forward-looking radar can't detect snowdrifts that constitute a major hazard to snowplow operators, which means that the full potential performance benefit from the IVSS technologies is reduced. Another driver commented that the radar also can't distinguish snow or ice on the road, so it doesn't help them decide where to apply sand and/or salt (although that is neither a design feature nor a safety concern of IVSS).

- Some drivers liked how they could accurately plow the road shoulder when operating under low visibility conditions, but others said they were not able to bring themselves to fully trust the system. They would test it out under good visibility, find problems and errors, and therefore were reluctant to use it under high risk driving conditions.

There was strong agreement in the first survey among almost all the drivers (89% agreed or strongly agreed) that they expected it *would be* easy to learn how to use this system. However, in the second survey fewer agreed (61%) that it *had been* easy to learn in practice. In the second set of in-person interviews drivers varied a lot in describing the amount and value of the training they had received. Some said training was sufficient and useful, while others said they wished they had received more training, and there was a general preference for a one-on-one, hands-on approach to learning these systems.

Two-thirds of the drivers in the first survey (62%) said they expect that the collision avoidance system *would* reduce the number of accidents or near-accident situations, but then on the second survey almost two-thirds (62%) of the drivers said that they were uncertain whether this system *does* reduce accidents (i.e., they neither agreed nor disagreed), and only 15% agreed that they thought it does. These results indicate that the drivers started out optimistic about the possible safety benefits but then became less sure of the possible benefits after using the collision avoidance system during the test period. Interviews with these drivers suggest that they believe in the potential of these systems to increase safety, but they remain uncertain because of the system performance issues noted earlier.

When asked in general whether high tech systems help experienced drivers avoid front-end collisions, close to half of these drivers agree that they do. Uncertainty on this issue declined somewhat between the first and second survey, and after gaining some experience with the systems, more drivers agreed that such systems *don't* help avoid collisions (31% versus 11%); that is, they were less convinced that high tech systems are helpful in avoiding collisions. The main advantage reported in the interviews is that the system allows drivers to get out and clear roads when they otherwise might not be able or authorized to get out, and it gives drivers more confidence in the worst visibility conditions, assuming it is functioning properly. Ambulance operators, on the other hand, say they are pretty much obligated to be out in an emergency, regardless of the conditions.

3.2.2 Use of the Lane-keeping System

When answering a series of questions about the IVSS lane-keeping system, drivers were asked to consider GPS, 3M magnetic tape, the HUD, and warning lights, sounds, vibrations and symbols. Many of the usability questions on the two surveys were asked with regard to both the collision avoidance system and the lane-keeping system in order to provide separate and comparable measures for both of these systems.

Ease of learning to use systems: Drivers overwhelmingly said that both the collision avoidance system and the lane-keeping systems were easy to learn to use.

Drivers are apparently less concerned with the lane-keeping system possibly interfering with their driving tasks than with the collision avoidance system causing such problems. On the first Internet survey (Table A-4), half of all the respondents disagreed that they had such a concern and another 22% neither agreed nor disagreed, while less than one-third of the drivers (28%) agreed or strongly agreed that they were concerned about this. In the second survey and after having gained some experience with the lane-keeping system, driver opinions had shifted somewhat toward more drivers saying they that they feel that it does actually does interfere, and most of those were the snowplow operators. On balance in the second survey, fewer drivers were undecided, with the rest split evenly between 46% feeling that lane-keeping is not interfering with their driving and 46% saying that it does.

As was the case with the collision avoidance system, drivers clearly felt that it is easy to learn to use the lane-keeping system, with 94% of drivers (17 of 18) on the first survey expecting that it would be easy to learn to use and 77% (10 of 13) on the second survey agreeing that in fact it had been easy to learn. Some said they didn't have any formal operational training in the use of these systems (there was group training in a classroom setting), but they had their questions answered by representatives of the University of Minnesota. Some reported having short one-on-one training sessions in the cab, and others said they only received a quick overview. Reportedly, replacement drivers received less training than the regular drivers on the use of these systems. Operator preferences for learning these new technology systems include hands-on training, ride-alongs, and one-on-one training. A few indicated that they didn't have any manuals in their vehicle that describe how to use these systems.

There was strong agreement on the initial survey that lane-keeping would reduce the number of accidents or near-accident situations (67% agreed they expected it would), but 28% were unsure, neither agreeing nor disagreeing. We presumed, as with a number of these usability issues, that the drivers likely wanted to gain more experience before they felt they could express a firm opinion. One driver who was neutral on whether either the collision avoidance system or the lane-keeping system would reduce accident situations commented that "it will be very beneficial in rating the system after we have driven in poor visibility conditions while using the system."

By the time of the second survey, almost half (46%) of the drivers indicated that they were uncertain about the accident-reducing potential of these systems, with the remaining half more inclined to agree that it would (31% versus 23%). However, the optimism expressed in the first survey had declined by the second survey. Part of the problem, as has already been noted, is that there were very few low visibility events that could put this potential benefit to the test, and furthermore, with accidents being relatively rare, it would be hard to determine in a short period of time whether these systems really had the ability to reduce the number of accidents, even if they were working properly at all times.

The lane departure warning system provides the driver with three different types of warnings, including seat vibration, audible warning, and visual warning. Data showing the drivers' perceptions of the usefulness of these three types of warning are shown in Table A-3 and in Figures 5 and 6. In both surveys, drivers were asked how useful each of these components of the overall warning system is likely to be in indicating lane departure under marginal driving conditions. The results, as indicated for both surveys, suggest that drivers think the seat vibration warning will be the most useful of the three (78% and 46%, respectively, said "very useful"), and the audible warning least useful (39% said "very useful" on the initial survey and 31% said "not at all useful" on the final survey). Visual warnings fall in between these two in perceived usefulness (56% and 38% said "very useful" but a significant percent of respondents also said "useful").

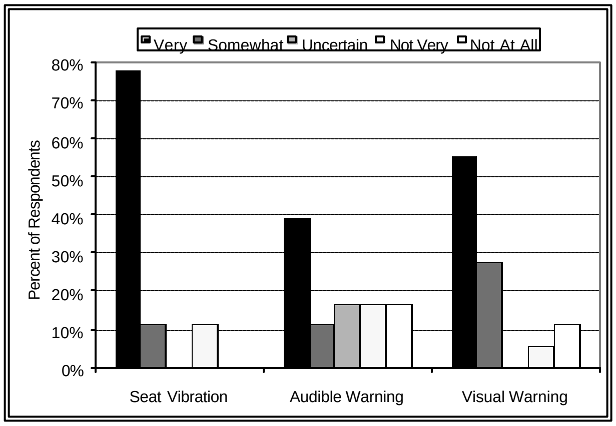

Figure 5. Perceived Usefulness of Three Lane Departure Warning Alerts: 1st Survey

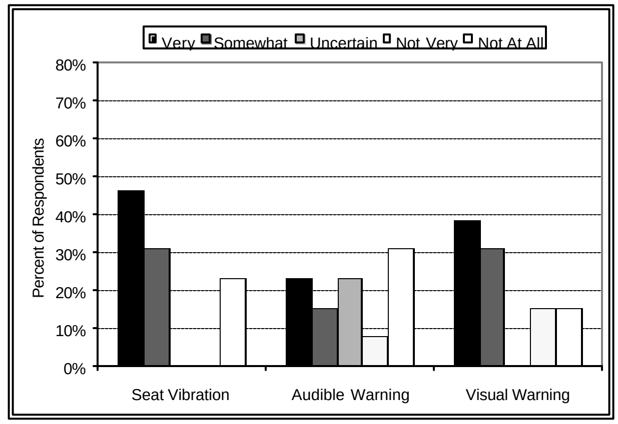

Figure 6. Perceived Usefulness of Three Lane Departure Warning Alerts: 2nd Survey

The interesting findings here are that there was no uncertainty about preferences for seat vibration or visual warnings—drivers either found them useful or not useful, but there was uncertainty of opinion on the audible warning system. Also, the number of respondents saying "not at all useful" increased somewhat for each of the three in the second survey compared to the first. We know from the in-person discussions with drivers that the audible warning turns off the truck radio when the warning is issued, which the drivers dislike. They have tried to turn down the volume of the warning and would disable its ability to interfere with their radio if they could do so. They reported that the seat vibration does the best job of getting their attention. Some drivers seemed to have their favorite warning system, rating one of them "very useful" and the others "not at all useful." Finally, 6 drivers (33%) in the first survey said they thought all three systems would be "very useful." Only 3 drivers (23%) in the second survey expressed that same opinion. Every single driver in each of the two surveys reported that at least one of these three warning systems was "useful" or "very useful."

> **Lane Departure Warning Systems:** *Every* driver said that at least one of the three warning systems was "useful" or "very useful."

Figure 7 shows the amount of time each driver was operating his vehicle with the system turned on. The time is divided into two categories: Volume off (volume level zero) and volume on (volume level 1 through 11). Only three drivers had any significant driving experience with the volume turned on. The significant issue is that nearly all of the other drivers chose not to turn on the audible alarm. These findings are consistent with the drivers' express concerns about using the audible alarm.

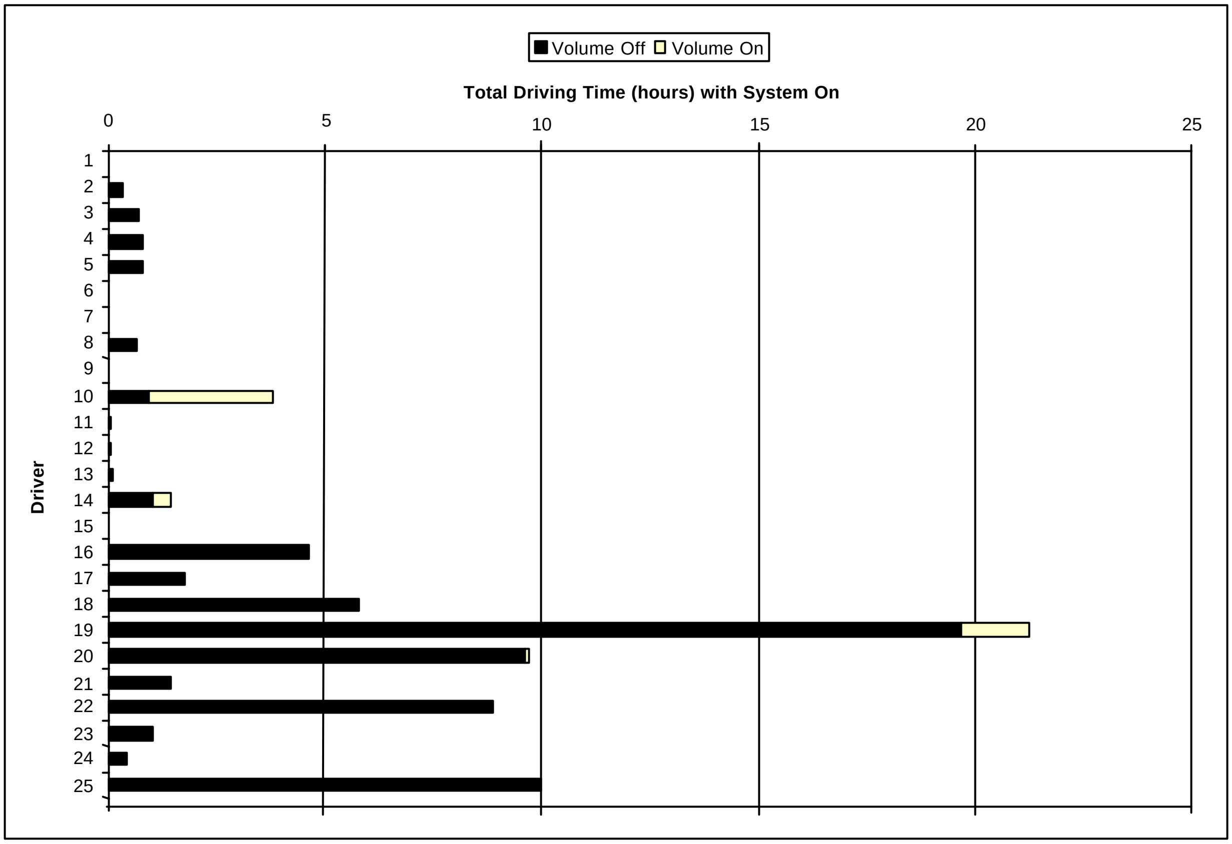

Figure 7. Driving Times with Volume Off and Volume On While System Was Turned On – by Driver

A backup method of vehicle lane positioning was the roadway magnetic tape/sensor-based system. The guidance that this system provided was displayed only when the GPS correction signal deteriorated in quality or was lost. If that occurred when the specialty vehicle happened to be on one of the two roadway sections that had the magnetic tape installed, the magnetic tape/sensor system provided local positioning information in the form of lateral displacement of the vehicle from the lane's center. The magnetic tape was installed on a total 12 miles of roadway located in the operating areas of the Hutchinson and McLeod County snowplows. The magnetic lateral guidance would be available until GPS signal quality was restored for the primary lane-keeping system.[7] Table 4 illustrates that only two of the vehicles (both snowplows) had magnetic lateral guidance for more

Table 4. Magnetic Lateral Guidance Usage

Vehicle	Provided by Magnetometer (seconds)	
	Left Sensor	Right Sensor
Ambulance	0	41.9
Patrol Car	0	82.3
Eden Prairie	0	0
Hutchinson	130.2	710.5
McLeod	470.4	0
Shakopee	0	0

[7] The ambulance and patrol car had only one magnetometer, which was on the right side of the bumper. The snowplows had two magnetometers, one on each side of the bumper, which would have been different distances

from the magnetic tape and thus could produce differences between right and left readings if the numerical sensor value dropped at one of them. The McLeod County snowplow's right sensor always displayed "error".

than 1-½ minutes total. Drivers said little about this component of the IVSS but it seemed to work reasonably well for the few who had an opportunity to use it.

3.3 Perceived Effects on Driver Distraction

An important issue in this evaluation is whether adding new technologies to the vehicle also serves to increase the potential distractions for the driver. If this were to happen, then technologies intended to increase truck safety may turn out to compromise it. This general survey question (Table A-4), regarding whether drivers think these safety technologies create an added distraction in their vehicle, was asked on the initial survey, and 39% of the respondents said that they do, while 34% said they do not. The rest (28%) were undecided, neither agreeing nor disagreeing. On average, the snowplow operators were somewhat more concerned with the distraction potential for these systems than the ambulance operators in response to this initial baseline question.

In the second survey the question regarding driver distraction was asked separately with respect to the collision avoidance system and the lane-keeping system (Table A-4, Figure 8). In a ratio of about 3 to 1, drivers said that they find the collision avoidance system distracting (46% "agree" and 31% "strongly agree"). Almost a quarter of the drivers (23%) strongly agreed that the lane-keeping system also was distracting, but 38% disagreed. No one expressed strong disagreement in this regard. Figure 8 illustrates the degree of concern that drivers expressed regarding the distraction effects of these IVSS technologies based on their limited driving experience with them. By the second survey, concern with the distraction effects of the collision avoidance system was equally expressed by both the ambulance operators and the snowplow operators.

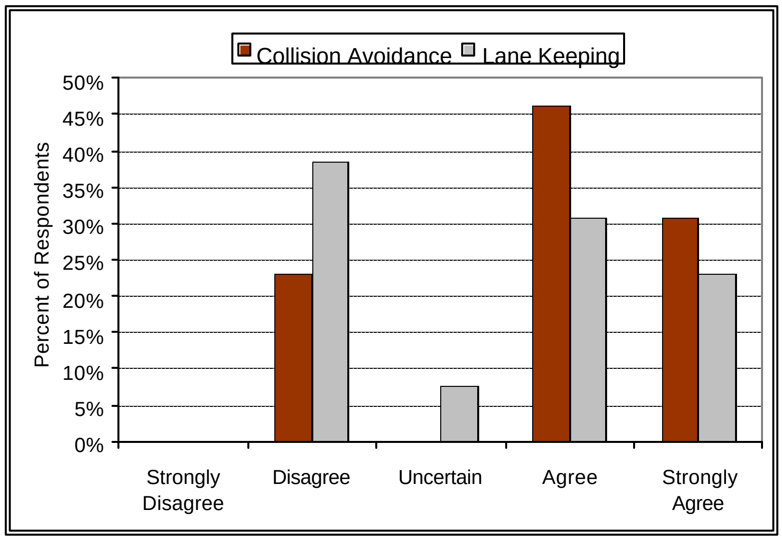

Figure 8. Second Survey: "The Collision Avoidance / Lane-keeping System is Distracting in My Driving"

Although there was no specific question in the in-person interview protocol that addressed driver distraction per se, drivers commented on a variety of aspects of these systems that they found distracting or bothersome. These comments are offered here to illustrate some specific aspects of these systems that, if they could be modified, could enhance driver experience and response.

Examples from the interviews, in the drivers' own words, include the following comments (paraphrased):

- *It is bothersome looking through the combiner. It is not as clear as it is without it, especially under low visibility conditions. Reflections are also bad off the combiner under certain lighting conditions, such as headlight glare at night, and the frame causes a blind spot. I find I'm frequently trying to look around it to verify what's there.*

- *My truck vibrates a lot, so whenever I get the combiner adjusted right, it just vibrates back out of position. I usually put up the combiner and didn't use it under high-risk conditions because it wasn't worth the stress.*

- *The lines representing the sides of the road on the HUD often don't line up with the actual sides of the road. It is especially bad on curves in the road.*

- *Not having my sun visor available on sunny days was a problem [Note: the visor was removed in some vehicles to accommodate the HUD.].*

- *Sometimes I would get a lane departure warning for no good reason.*

- *This test equipment is too big and bulky. I'm concerned about hitting my head on it, or having it block my view and creating a safety risk.*

- *I have to keep adjusting the offset to plow uneven shoulders. Having to try to reset the offset and drive at the same time was too distracting, and stopping frequently to reset was not feasible. This was sufficiently irritating that I would just turn off the system.*

> **Lane Departure Driver Comment—2nd Survey:** "When driving at night in the wee hours the sound alert is enough to take 10 years off your life, although it does keep you awake."

- *The GPS system would just go out in some sections of road. While this became predictable, it was still annoying.*

- *I found it discouraging to use the HUD, so toward the end of the test period I just stopped using it. When it was out of line, so were the lane departure warnings associated with it, so this was distracting. Then sometimes the lane departure warnings didn't activate when they clearly should have. I could drive 6 feet to the left of road center and still get no alarm.*

- *It was often hard to identify what objects were displayed on the HUD, and sometimes it gave false signals that something was there when it actually wasn't.*

- *The audio alarm was annoying because it interfered with the truck radio, and some of the visual alarms shine in your eyes.*

- *I saw the side pillar lights, but I never really knew what they meant or how they worked. Sometimes the lights flashed for no reason, so I disregarded them.*

3.4 Objective 2.2: Perceived IVSS Effects on Workload and Stress

The second evaluation objective is concerned with determining the impact of the IVSS technologies on various job aspects, including the drivers' perceptions of mental workload, perceived fatigue, job stress, and job satisfaction.

Table A-7 shows driver perceptions of workload and stress based on both surveys. Drivers were asked whether they were concerned that the collision avoidance system would increase the amount of effort it takes to drive their vehicle. This provides a general measure of the perceived workload impact of the technology. On the initial survey, 28% of the drivers agreed or strongly agreed that they are concerned that the collision avoidance system increases their workload, while 44% indicated they were not concerned about this. Almost a third of the respondents were unsure. By the time of the second survey, 54% of the drivers indicated that they agreed that an increase in effort due to the collision avoidance system was a concern for them, while those not concerned had dropped to 23%. These results suggest that drivers perceive that the collision avoidance system increases their workload as they gained experience with it, rather than reducing the level of effort.

Workload Impacts: Drivers perceive that both the collision avoidance system and the lane-keeping system are resulting in *increased* driving workload.

Drivers were split evenly on the first survey regarding their perception that the lane-keeping system increases their driving effort (39% disagreeing versus 28% agreeing). A third of the respondents were unsure, neither agreeing nor disagreeing, and no respondents held strong opinions on this. These results are virtually the same as for the collision avoidance system on this issue of likely impact on driving effort. On the second interview, the percentage of drivers who disagreed was the same (38%), while those who agreed had increased to 46%, leaving only 15% neutral. As with the perceived effect of the collision avoidance system, these drivers say that they are experiencing an increase in effort due to the lane-keeping system.

Workload Impacts: Drivers believe that these systems would reduce workload and stress if they were working properly, but they don't, making it a "chore" to use them.

Table A-7 also shows driver responses to the questions on system effects on stress and fatigue. More respondents on the initial survey agreed than disagreed that the collision avoidance system would reduce the stress and fatigue of driving (44% versus 28%). About a quarter of the drivers were unsure, which is a reasonable response at this point before they had much experience driving with the systems under particularly stressful low visibility driving conditions. By the second survey, only 8% of the drivers indicated that the collision avoidance system actually does reduce stress and fatigue while 77% of the drivers indicated their disagreement with this statement. Disagreeing that the systems reduce stress does not necessarily mean that drivers think the systems lead to an increase in stress and fatigue however, so we asked about this. Table A-8 indicates that 8 of the 10 drivers who had disagreed said they thought the collision avoidance system would actually *increase* the stress and fatigue of driving, with four

Stress and Fatigue: 1 out of 13 drivers in the second survey said they experienced a *decrease* in stress and fatigue due to the collision avoidance system; 8 experienced an *increase*.

saying they experienced a medium to large increase. Some of the specific factors that drivers report being related to stress and fatigue included vibrations in the HUD screen display, difficulty seeing the road ahead clearly through the combiner (especially in difficult lighting conditions or night driving that caused reflections off the combiner), the combiner frame blocking their view of a part of the road ahead, or a HUD screen that was too dark for good night viewing. These kinds of issues caused some drivers to stop using the systems, or to only use them for testing purposes under good conditions.

Responses regarding the likely effect of lane-keeping on the reduction of driving stress and fatigue were also very similar to the perceived effects of the collision avoidance system. Drivers said in the first survey that they expected the lane-keeping system would help reduce the stress and fatigue of driving (44% agreed, 28% disagreed, and 28% were undecided, Table A-7). However, by the second survey only 15% agreed that the lane-keeping system actually does reduce stress while 54% disagreed with the possible reduction, leaving about one-third neutral on the subject. Experience with this aspect of the IVI systems seems to have caused a lack of faith in its ability to reduce stress and fatigue. Of the 7 drivers who disagreed that lane-keeping would reduce stress and fatigue, 5 of them said they actually experienced a medium to large increase.

Mental workload refers to the amount of mental effort it takes a driver to perform his or her driving tasks. Drivers were asked to think in terms of their level of concentration, amount of mental effort, or degree of mental focus, and to rate their assessment of the mental workload required under various driving conditions using the Overall Workload scale (Vidulich and Tsang, 1987), a unidimensional scale that ranges from 0 to 10, where 0 means no mental workload, 1 means very low mental workload, and 10 means the highest mental workload. Tables A-9 and A-10 show the results of the Mental Workload assessment. This workload scale was used because it has been shown to be highly sensitive and comparable to other multi-dimensional subjective workload measures, and is easy to employ and fit within the survey time and resource constraints (Hill, et al., 1992).

Using this scale, drivers provided ratings on the Internet surveys from 0 to 10 for a variety of driving scenarios to provide a means of comparison between the baseline and post-experience with the IVSS technologies. The goal of this assessment was to determine if drivers perceive the use of the IVSS as having an effect on their mental workload, either as a benefit to help reduce workload or as a hindrance resulting in increased workload. On each of the two surveys (**S1** and **S2**), drivers were asked to rate the level of mental workload under four different scenarios or driving conditions. The scenarios being compared are:

- **Scenario A**: Normal driving conditions when driving a personal automobile. This scenario provides a baseline for comparisons for the other three scenarios.
- **Scenario B**: Average winter driving conditions with good visibility and without the IVSS operating.
- **Scenario C**: Worst winter driving conditions with poor visibility without the IVSS operating.
- **Scenario D**: Worst driving conditions with poor visibility with the IVSS operating and functioning properly.

The results were compared across the four scenarios within the first and second surveys, and results were compared between the first and second surveys. We anticipated that drivers would likely say that driving their personal automobile under normal condition (scenario "A") requires less effort and mental workload than driving their work vehicle (ambulance, state patrol car, or snowplow) under each of the other scenarios. Driving a snowplow in the winter should be much more mentally demanding than driving a personal automobile under normal conditions, for example. Figure 9 shows the results from the four driving scenario questions across each of the two Internet surveys for all participants. We see that reported workload is in fact least, on average, for scenario "A" in both surveys, higher for scenario "B" (work vehicle, winter conditions, good visibility, no IVSS technologies), and the highest for scenario "C" (work vehicle, worst winter conditions, poor visibility, no IVSS technologies). Under each of these three scenarios, the average workload rating was somewhat less in the second survey compared to the first.

The range of responses across all of the participants in each Internet survey is shown by the vertical line that shows the lowest and highest workload rating given for each of the scenarios on each survey. A longer line represents less consensus on the workload value (i.e., large variation in individual responses to the question) and a shorter line more consensus. The greatest consensus, as shown in Figure 9, is for an average workload under the worst conditions without the IVSS technology (scenario "C") with average values on the two surveys between 8 and 9 on the ten-point workload scale. The average difference between the workload ratings for driving their vehicle under good conditions versus bad winter conditions without the new technologies is substantial, as one would expect. This difference reflects drivers' perceptions that, in bad driving conditions, the workload they experience increases almost 70% over driving their vehicle under good conditions.

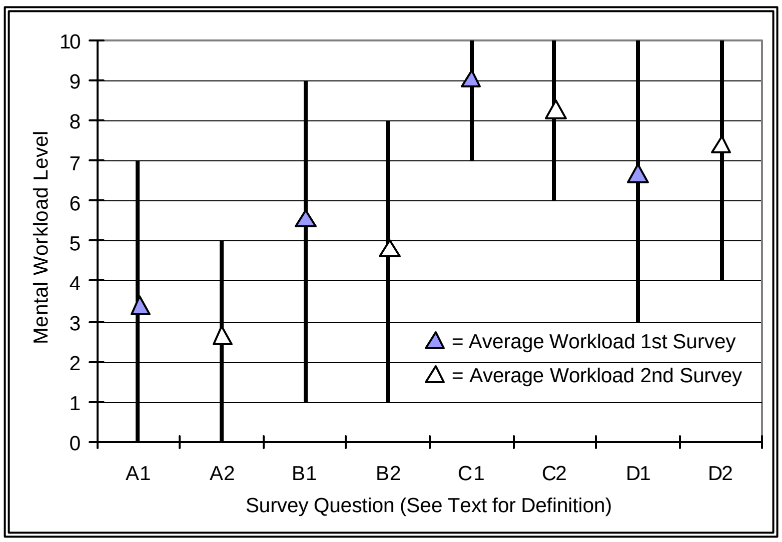

Figure 9. Reported Level of Mental Workload (High, Low, Average) Under Various Conditions Before and After Exposure to IVSS

Finally, we asked drivers to rate the level of mental workload when driving their vehicle under the same bad weather and road conditions but this time with the new technologies installed and functioning properly in their vehicles (Scenario "D"). Under these conditions, the estimate of workload dropped back down to an average rating of 6.6 in the first survey and 7.4 in the second survey, or drops in the workload index of 27% and 13% respectively. We can interpret this to mean that in the first (baseline) survey, drivers expected that the IVSS technologies would reduce mental workload by about 27% below the comparable level without the technologies, but not quite down to the level experienced driving their vehicles under good winter driving

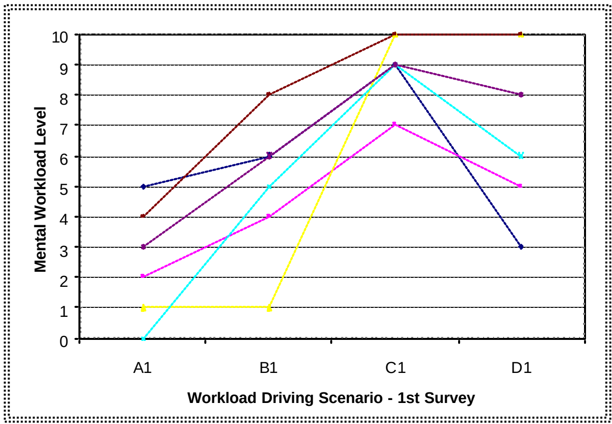

Figure 10. Level of Mental Workload Reported by Snowplow Operators, First Survey

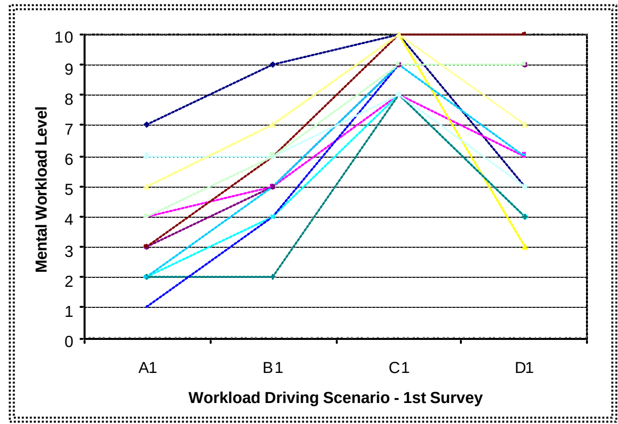

Figure 11. Level of Mental Workload Reported by Ambulance Operators and State Patrol Driver, First Survey

conditions. After having some experience with the technologies, the results from the second survey suggest that the drop (improvement) in workload is actually about one-half what they had expected it would be.

Further insight may be gained by looking at these workload rating scores driver by driver, within the main driver groups (snowplow, ambulance and state patrol[8]), and for the two survey periods. This comparison allows us to look at how each driver adjusted his or her rating under the different scenarios and across the two surveys.[9] Figure 10 shows the mental workload ratings for the six snowplow drivers who participated in the initial Internet survey and Figure 11 shows comparable ratings for the eleven ambulance drivers and the state patrol driver in the same survey.

IVI's Perceived Effect on Mental Workload: Drivers *experienced* a reduction in mental workload due to the IVI technologies in the second survey, but only about half the benefit they *anticipated* in the first survey. A few drivers reported an *increase* in workload.

In the first survey, all the drivers either lowered their estimate of workload between the with-technology and without-technology scenarios ("C" to "D"), or, in the case of 6 of the drivers, indicated no expected difference in workload due to the new technologies. The fact that six drivers expect no reduction in mental workload due to the IVSS technologies (i.e., no workload benefit) probably reflects the uncertainty we have seen expressed in response to many of the other questions due to the early stage of the technology deployment, lack of driver trust in their performance, and the lack of accumulated driver experience with them. As can be seen in Tables A-9 and Figures 10 and 11, some drivers expected a more substantial reduction in workload effort due to the IVSS technologies in poor visibility conditions than did others, and many expected to experience significantly lowered workload. Five of the 18 drivers in the first survey indicated they expected the IVSS

[8] Note that there was only one state patrol driver who participated in these surveys and interviews.
[9] A problem with using an average value across all drivers is that a value of "5" for one driver may not be the same as a "5" for another driver. Also, the average masks the fact that some drivers may see no benefit or even a reduction in benefit due to the IVI technologies, while others report substantial benefits. Therefore, it is useful to examine how individual drivers adjusted their workload ratings under each of the scenarios.

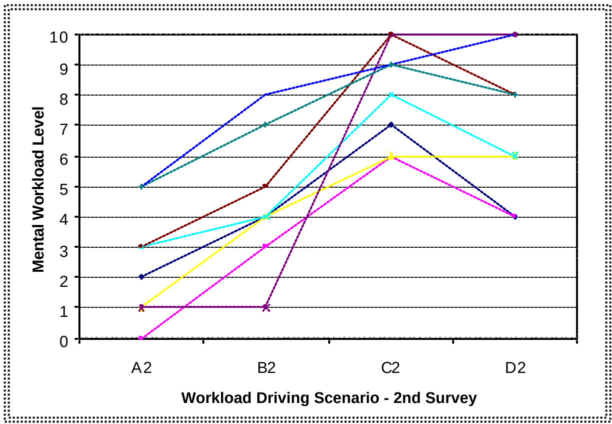

Figure 12. Level of Mental Workload Reported by Snowplow Operators, Second Survey

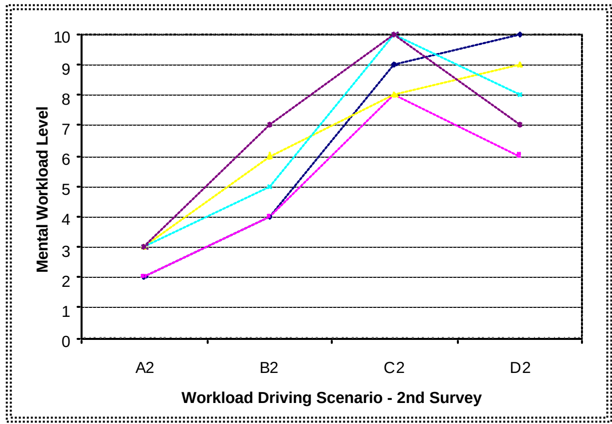

Figure 13. Level of Mental Workload Reported by Ambulance Operators and State Patrol Driver, Second Survey

technologies to result in a mental workload level at or lower than the level they indicated for driving their work vehicle in average winter conditions with good visibility and no IVSS technologies operating.

As can be seen in Figures 12 and 13 and Table A-10, 3 drivers increased their estimate of workload experienced between scenario "C" and scenario "D" in the second Internet survey, 8 lowered their rating, and 2 rated the two scenarios at the same workload level.

The findings from the ***first survey*** of mental workload (baseline, estimated workload) can be summarized as follows:

- There is a lot of variation in how drivers rate the level of mental workload required for driving under normal conditions in their own personal automobile. The ratings varied between "0" (no mental workload) to "7" on a scale from zero to ten, reflecting a lack of consensus on how much workload is involved in driving a personal car under normal conditions. This points to the importance of looking at individual changes in rating workload under the three other test conditions to better understand relative differences in ratings, driver by driver.

- There was equally as much variation in the reported level of workload when driving their work vehicle in average winter conditions with good visibility and no IVSS technologies. The level of workload under this scenario as reported in the first survey was equal to (2 cases), or higher than (16 cases) the level experienced when driving their personal automobile. This is a reasonable finding, indicating that operating an ambulance or snowplow, for example, takes more effort and concentration than operating an automobile.

- Comparing average winter driving in their work vehicle with the worst winter driving condition (without the IVSS technologies operating), we see that every driver in both surveys reported an expected increase in workload. This is very consistent with discussions in the in-person interviews. Snowplow operators reported that driving their snowplow, even under "normal" conditions demanded intense concentration, and that it was particularly stressful under low visibility conditions. Ambulance operators described the intensity of their job in terms of the high degree of responsibility they felt for their patients under all emergency conditions. We would therefore expect that these drivers would report greater workload under difficult driving conditions.

- One-third of the drivers in the first survey indicated they expected to experience no workload reduction benefits from the IVSS technologies (workload ratings with the technologies stayed the same as for the worst conditions without the technologies). But the remaining twelve drivers indicated they expected to see a reduction in the level of mental workload due to the technologies. None of the drivers expected workload to increase with the IVSS technologies. This is a key to understanding the potential workload benefits of the IVSS technologies; namely, will they lead to anticipate a reduced workload in terms of mental effort and concentration? Drivers mostly said they thought they would.

The findings from the ***second survey*** of mental workload (estimated workload based on limited experience during the evaluation period) can be summarized as follows:

- The results for the first two driving scenarios (Scenario A is normal conditions in the driver's personal automobile; Scenario B is driving his or her work vehicle under average winter driving conditions) are similar to those for the first survey. There was variation across drivers for each of these scenarios, and drivers generally reported an increase in workload under Scenario B compared with Scenario A.

- Scenario C (worst winter driving, low visibility, no IVSS technologies operating) demands the highest level of workload and concentration, and drivers' experience during this test period lines up with their expectations prior to the test period (second survey compared with the first survey).

- Whereas drivers in the first survey expected a substantial decline in workload due to the IVSS technologies, they reported a smaller decline on average based on (limited) actual experience (see Figure 9 and Figure 14: D1-C1 versus D2-C2). As shown in Figures 10 and 11 and Table A-10, four out of 13 operators said workload with the IVSS technologies either stayed the same or increased. The remaining operators reported a drop in workload compared with Scenario C, but the drop was less than expected—in fact about one-half as much as expected (in the first survey). We learned in the in-person interviews that some drivers found the IVSS technologies required more effort than they expected. However, two of the operators reported that workload using the IVSS dropped back down to the same level of workload as under Scenario "B"—average winter driving with good visibility. Note that drivers were asked to rate workload levels in Scenario D assuming that the new technologies were functioning properly—an assumption that was not always achieved.

To summarize the evaluation results with regard to driver perceptions of mental workload, we looked at the changes in average workload ratings given by the ten operators who participated in both surveys (see Figure 14). This figure compares the various scenarios and shows differences in number of points on the workload 11-point scale, based on operator responses to the different workload scenario questions. The first two bars in this chart show the impact of adverse weather on driver workload at the times of the two internet surveys. Specifically, they show how much more workload, on average, these drivers feel is caused by driving their specialty vehicles in the worst winter weather conditions with poor visibility without the benefits of IVSS (scenario "C") compared with driving under good conditions (scenario "B").

In both the first and second surveys, drivers said that average workload was increased by about 4 points on the 11-point rating scale due to bad weather alone. They clearly believe it takes significantly more effort and concentration to drive under those conditions compared with driving under normal weather and visibility conditions, and their opinions on this did not change between the first and second surveys. The next two bars in Figure 14 show the extent to which these 10 drivers perceive that IVSS can or does reduce the amount of mental workload required to drive their specialty vehicles in the worst conditions. In both surveys they said that IVSS helps reduce workload somewhat (between one and two rating points), but the perceived benefits of IVSS in this regard are somewhat less after they had some actual experience with the technologies than their expectations for its performance in the first survey. The last bar in Figure 14 shows the perceived change in workload after experience with the IVSS technology. The results suggest that these drivers thought that the level of mental workload required in bad weather conditions, with IVSS operating, was somewhat greater based on limited experience with it than they had anticipated it would be in the first survey, though the difference is very small.

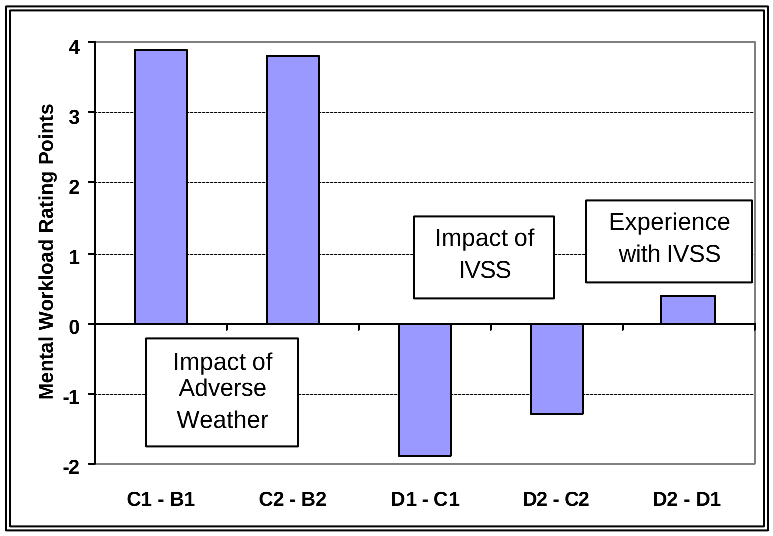

Figure 14. Effects of IVSS on Perceived Level of Mental Workload

3.5 Objective 2.3: Perceived IVSS Effects on Driving Behavior

The third objective of this evaluation is to assess the perceived effects of the IVSS technologies on driver behavior, including driving risk behaviors and driver vigilance. Questions related to this goal area were asked to determine if drivers changed the attention they paid to safety as a result of the technologies, if the drivers took more risks with the systems in place, if the IVI systems caused drivers to use or rely on them in unexpected ways, and if the presence of the systems caused driving behavior to change.

Table A-6 displays the survey question covering driver behavior. Half of the respondents on the initial survey (S1) said they expected their driving would change as a result of having both the collision avoidance and lane-keeping systems on their vehicle. Though they weren't asked to say specifically how their driving might change, this response indicates there is clear potential for underlying changes in driving habits. On the second survey (S2), drivers were asked whether their driving had actually changed as a result of having either of these two IVSS technologies on their vehicle. Forty-six percent of the drivers said that their driving had not changed as a result of the collision avoidance system, and fully 70% of the drivers said it had not changed as a result of the lane-keeping system, with almost a quarter of the drivers (23%) not sure if it had or not. Drivers interviewed in-person mentioned they thought these safety technologies would make them more alert, more relaxed, and probably more careful about safely managing such driving tasks as following distance, suggesting they didn't anticipate engaging in more risky behaviors under the assumption that the technologies would keep them out of trouble.

In the in-person interviews we asked the drivers to reflect on any productivity benefits they may have derived from these IVSS technologies. We were particularly interested to know whether these systems allowed the snowplow operators to operate their vehicles any faster under low visibility conditions or to go out or stay out when they otherwise might decide to stay at or return to their garage. The idea was to explore whether they could plow more miles or road in a given period of time with these technologies compared to without them. The general consensus was that the technology might give them the ability to operate somewhat faster under low visibility conditions than they otherwise could, but they pointed out that plowing at higher than normal speeds is not necessarily more effective and might add unacceptable safety risks independent of the better lane-keeping and collision avoidance capabilities afforded by the technologies.

One of those risks is the danger posed by others on the road who do not have similar technologies, such that driving faster, even if they could do it, would not be prudent. Another risk is that of damage to their vehicle from hitting a snowdrift, which is invisible to the forward-looking radar. There probably would be instances in which they could continue to operate under very poor visibility conditions that they would otherwise prefer to avoid. When conditions involve blowing snow, it simply may not be productive to be plowing, since the roads are quickly covered again. Also, as has already been noted, drivers said that any significant behavioral or performance changes have to be based on a reliable system that they can trust. Both the snowplow operators and the ambulance operators are concerned about the potential liability risks associated with changing their operating procedures based on these technologies.

3.6 Objective 2.4: Overall IVSS Safety Benefit and System Value

The fourth goal area is to understand drivers' perceptions of the overall functionality, safety performance, quality and value of the system, and to explore operator and supervisor recommendations for changes in the system and opinions on its future deployment. There were several questions on the survey that were pertinent to this goal area, and the results are reported here in terms of perceived safety benefit and overall value of the IVSS technologies.

3.6.1 Perceived Safety Benefit

Table A-11 shows the results of a question that asked drivers in the second survey, after they had some experience with the IVSS technologies, whether they thought these high tech vehicle systems increased their safety while driving. Both the ambulance and snowplow driver groups were split 50-50 on this, with 38% agreeing that it did, and 38% disagreeing overall, with no clear differences between the two driver groups. Those who said they thought the systems did not increase their safety tended to disagree or be undecided as to whether they thought they would be better off driving without these types of high technology systems. This can be interpreted to mean that they continue to perceive that there is potential for the IVSS technologies to be beneficial but, given the current technology problems, they are not perceived to have been performing up to their safety potential. Most of the drivers who said the systems increase their driving safety also said they think the systems are helpful for experienced drivers in avoiding front-end collisions.

In the in-person interviews drivers were asked to discuss whether the systems helped them avoid dangerous situations and/or caused them to simply feel safer performing their driving jobs. Drivers agreed that the systems help them when visibility is restricted by snow, slush on the windshield, or fog. Some remarked that they feel safer with the systems to supplement their own driving skills and experience, but other drivers did not feel confident that the system would consistently perform accurately and reliably. We also asked the operators to comment on how they think the public is likely to respond to these safety systems and whether their driving safety practices might be affected. The snowplow operators in particular were quite clear in their belief that the public will do what it wants regardless of the safety risks, and these IVSS technologies probably won't make any difference. They could inadvertently create a problem to the extent that they allow plows to be out in even worse conditions than at present, signaling to the public that it is okay to be on the road themselves when in fact they have no business driving under such conditions. One driver commented that it makes "no difference with most people. If they want to go, then they will go. They will pass plows and go on unplowed roads. They don't care."

3.6.2 Perceived System Value

Drivers were asked in both surveys whether they thought they would be better off driving without these types of high tech systems in their vehicles. Results from the first and second surveys are very similar, as shown in Table A-4. While just over one-third of the respondents (39% for both surveys) disagree that they would be better off driving without these types of high tech systems, over half (56% and 54%) were unsure, neither agreeing nor disagreeing. It makes sense that before they really had an opportunity to try out the safety systems, drivers would feel quite uncertain as to whether or not to expect to benefit from them. But even after exposure to these systems, drivers continued to express uncertainty about the systems' value in their driving. The large amount of uncertainty, however, suggests that many drivers would be willing to give the technologies the benefit of the doubt. This interpretation is supported by the in-person interviews, in which drivers said they

> **Perceived IVSS Value:** Drivers are not sure of its long-term value after this short test, but apparently willing to give it a good try.

wanted to have the chance to give the technologies a better test over another winter season after the bugs had been worked out.

When drivers were asked in the second survey if they would like to have the systems kept and maintained on their vehicles in the future (Table A-11), there was a wide diversity of opinion for both the collision avoidance system and the lane-keeping system. Driver response to the lane-keeping system was somewhat more positive than for the collision avoidance system, with 31% agreeing that they would want the collision avoidance system maintained on their vehicle and 46% agreeing that they would want lane-keeping on their vehicle. Those who disagreed for both technologies tended to disagree strongly, and they were fairly equally divided among both ambulance and snowplow drivers. When offered a chance to comment on their experiences with the collision avoidance system on the survey, fewer than half the drivers wrote in any comments. But those who did reiterated comments heard in the in-person interviews that "the system is not reliable, it restricts clear views of the road in front, it takes up too much space in the vehicle cab, and often didn't work correctly anyway." One driver commented that "it would have caused more accidents than anything."

The few comments on the lane-keeping system were similar. One driver said "the lane system does not show if there is a stop sign or stop lights ahead if it is a white out." Another told us that the "system did not work most of the time properly." In the in-person interviews, an ambulance driver commented that he thinks of the IVSS systems as another tool in the ambulance along with a number of other tools. He said "the best tools are hands and brains" and suggested drivers not rely too much on technology and lose their instincts. Another practical perspective voiced in the interviews is that it will be critical to consider the cost-benefit tradeoffs associated with these technologies, and whether drivers can expect to gain enough benefit to justify the costs of installing and maintaining the systems. These results indicate that at this early stage drivers have not yet fully accepted the systems and perceived them as valuable over the long term.

Bottom Line for the Drivers: These IVI systems have potential but they need improvements and more testing.

In-person interviews were also conducted with a few of the supervisors of the driver crews to gain their unique perspective. The supervisors' views on the system's operation were basically drawn from what they heard from their drivers, thus there were few insights from them outside of what the drivers provided. Only the supervisor at Hutchinson Ambulance was also a driver during the FOT. The supervisors would have considered the value of the IVSS in terms of enabling them to dispatch an equipped snowplow or ambulance under adverse weather conditions where they otherwise could not have, but that situation did not present itself during the FOT. The supervisors might also have commented on any maintenance requirements that were incurred by their garage, but during the FOT all IVSS repair or maintenance was handled by University of Minnesota personnel.

Supervisors felt that driver response to these new systems was strongly related to how technically sophisticated the drivers were and whether they were the personality type that welcomed an opportunity to try new ways of doing their job. Some drivers, particularly the younger drivers, liked the challenge and others felt they didn't need all these new "gizmos."

Overall, supervisors would like to see these kinds of systems on their specialty vehicles if the costs can come down and their reliability increase. They all thought the systems test should run another year to gain greater exposure to the kinds of conditions with which they are designed to help.

4.0 Conclusions

Surveys and interviews were conducted with most of the drivers of the three types of IVI specialty vehicles both prior to the onset of winter driving conditions and again three months after they had a chance to drive with the technologies operating on their vehicles. The objectives were to gain some understanding of operator expectations regarding the performance of these safety technologies, followed by their assessment of the benefits of using the technologies in marginal, low visibility winter driving conditions. The results of this component of the overall evaluation of the Mn/DOT IVI FOT program indicate that the vehicle operators and their supervisors were concerned with some performance problems with these technologies but supportive of such safety technology innovations and guardedly optimistic that these technologies would offer them tangible benefits, if they could be assured of their accuracy, convenience and reliability.

As is now well recognized, the mild winter conditions experienced during the driver evaluation period did not afford adequate opportunity to test and evaluate the full range of potential safety benefits of the technologies; nevertheless, this assessment of driver responses to the systems is comprehensive with regard to driver perceptions of the potential benefits of the systems, and in spite of the weather and technical problems, these drivers have contributed significantly to our understanding of the acceptability of the IVSS. The conclusions from this evaluation can be summarized as follows:

<u>Driver Expectations and Confidence</u>: The vehicle operators were widely aware at the start of this evaluation that there were technical problems with the performance of some of the core technologies. For example, the GPS was not functioning properly, there were “dead spots” on selected highway segments, and the equipment was sometimes not configured in ways that were comfortable for the operators. Nevertheless, the operators were willing to give the technologies a fair test and were hopeful that the benefits would outweigh the apparent drawbacks.

<u>Driver Experiences Using the IVSS Technologies</u>: Even though the kind of low visibility weather conditions, under which these technologies were designed to be used, were rare during the evaluation period, the drivers tried out all aspects of the IVSS under actual operating conditions, including several limited visibility conditions. Their reactions included the following:

- For both the collision avoidance system and the lane-keeping system, drivers who began feeling skeptical about IVSS benefits tended to become increasingly skeptical after having actual driving experience with them. Some comparative survey results are highlighted in Table 5, based on full results as shown in Appendix A.

Looking at these summary results in Table 5 we can see that, as a general conclusion for both the collision avoidance and lane-keeping systems, drivers tend to report at the end of the evaluation (dark bars in Table 5 representing responses to the second survey) greater concerns about technology interference with driving tasks, less confidence in the safety potential, less reduction in stress and fatigue, and increased distraction and mental effort associated with the use of the IVSS technologies, compared with their fairly low expectations entering into this evaluation (light bars in Table 5 representing responses to the first survey). Also as a generalization, drivers are somewhat more positive regarding the benefits associated with lane-keeping versus collision avoidance, with more expressing a desire to retain lane-keeping on their vehicle compared with collision avoidance.

The in-person interviews helped interpret these survey findings. Drivers reported on the specific aspects of the systems that were frustrating to them, such as glare and reflections off the combiner, vibrations and lack of clarity in seeing road detail using the HUD, problems with night vision, and apparent false readings presented by the collision avoidance system. These kinds of issues caused some drivers to stop using the systems, or to only use them for testing purposes under good driving conditions.

When asked whether they think they would be better off driving *without* these types of high technology systems in their vehicles, 39% disagreed in both the first and second surveys and less than 10% agreed. Over half the respondents in each survey were undecided on this question, which suggests their abiding willingness to give the technologies a chance to prove themselves. In spite of the problems they experienced, they are not willing to write off the possibility that they will offer benefits, once the bugs are worked out.

- Mental workload refers to the amount of mental effort, concentration, or focus that drivers think it takes to perform their driving tasks. There was general consensus among these drivers that the level of mental workload is quite high when operating their vehicles under the worst winter driving conditions without any IVSS technologies, and that this workload level is reduced somewhat by the IVSS technologies. However, the average reduction in workload actually *experienced* by these drivers (second survey) was about half as much as they *expected* (first survey). Among the 13 drivers in the second survey, 8 reported a decrease in workload, 3 reported an increase, and 2 reported no change in workload at all due to the IVSS. This difference in opinion is consistent with the range of driver perceptions of other aspects of the IVSS at this early stage of IVSS technology development, the lack of driver trust in technology performance, and the lack of accumulated driver experience with the IVSS.

- Citing liability concerns, ambulance operators said they were reluctant to use the technologies when a patient's life was at risk in an emergency driving situation. Both the ambulance and snowplow driver groups were split 50-50 on their perception of the overall safety benefits of the IVSS, with 38% agreeing that they provided a safety benefit, and 38% disagreeing overall, with no clear differences between the two driver groups.

Table 5. Change in Driver Perceptions Between the First and Second Survey

Vehicle Operator Survey Questions	Percent of Operators Who Agree* First Survey: 18	Percent of Operators Who Agree* Second Survey: 13
Perception of Benefits		
Collision avoidance will/does reduce the number of accidents or near-accident situations.	62%	15%
Lane-keeping will/does reduce the number of accidents or near-accident situations.	67%	31%
Collision avoidance will/does reduce the stress and fatigue of driving.	44%	8%
Lane-keeping will/does reduce the stress and fatigue of driving.	44%	15%
I would like the **collision avoidance** system to be kept and maintained on my vehicle in the future.		31%
I would like the **lane-keeping** system to be kept and maintained on my vehicle in the future.		46%
Expressed Concerns		
I am concerned that **collision avoidance** will/does interfere with my driving tasks.	39%	61%
I am concerned that **lane-keeping** will/does interfere with my driving tasks.	28%	46%
I am concerned that **collision avoidance** increases the amount of effort it takes to drive a vehicle.	28%	54%
I am concerned that **lane-keeping** increases the amount of effort it takes to drive a vehicle.	28%	46%
These systems create an added distraction.	39%	
• **Collision avoidanc**e system		77%
• **Lane-keeping** system		54%
General Perceptions		
I would be better off driving without these types of high tech systems.	6%	8%
High tech systems really do not help the experienced driver avoid front-end collisions.	11%	31%

* The bar charts show the sum of the percent of drivers who "agree" plus the percent who "strongly agree." Readers are cautioned to keep in mind that these percentages are based on small numbers of driver respondents.

Supervisors' Perspective on the IVSS. Overall, supervisors would like to see these kinds of systems on their vehicles if the costs can come down and their reliability increase. They all thought the systems test should run another year to gain greater exposure to the kinds of conditions in which they are designed to help drivers.

Summary. This evaluation of driver acceptance was hampered by both the lack of low visibility weather “events” and problems with the design and performance of some of the IVSS technology systems. Because of these factors, driver perceptions measured by these surveys and interviews are more likely to reflect their frustrations and concerns with the circumstances of the test than with the actual functionality and safety benefits to be derived from the technologies. Nevertheless, in spite of all the problems, drivers and supervisors remained generally optimistic that the IVSS technologies hold significant potential to enhance driver confidence and performance operating specialty vehicles under very difficult driving conditions.

References

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APPENDIX A:

SURVEY DATA TABLES

Table A-1. Background Questions (First Survey)

Question	Response*	N = 18
Please think back over your driving experiences in low visibility or poor conditions. Estimate how often you have to take evasive maneuvers, such as braking hard, making sudden lane changes, or other actions, to avoid an accident because a vehicle pulled in front of you, stopped or slowed suddenly, or appeared suddenly in front of you?	Frequently	6%
	Occasionally	39%
	Rarely	44%
	Never	11%
How satisfied are you with your vehicle's performance overall, including handling, transmission, engine, braking—in other words, its total performance?	Very Dissatisfied	6%
	Somewhat Dissatisfied	0%
	Neither Satisfied nor Dissatisfied	0%
	Somewhat Satisfied	22%
	Very Satisfied	72%
In general, do you see these technology systems (collision avoidance and lane-keeping) as likely to be:	Useful to you in driving your vehicle?	83%
	Creating problems for you when driving your vehicle?	11%
	Not useful to you but not a problem either in driving your vehicle?	0%
	No answer	6%

* Responses to these and subsequent questions presented in Appendix A may not total 100% due to rounding error. In Tables A-1 to A-11, "N" refers to the number of cases (respondents) on which the percentages are based.

Table A-2. Driver Experience with IVSS (Both Surveys)

Question		Survey Number	Response (S1: N=18; S2: N=13)				
			Never	1 Time	2 Times	3 Times	4 or More Times
(Up to now/Since January), how many times have you driven your vehicle with each of these technologies operating properly in low visibility or difficult driving conditions, such as snow on the road, blowing snow, fog, rain, or night time?	Front-looking Radar	S1	44%	33%	6%	6%	11%
		S2	38%	0%	15%	0%	46%
	Side-looking Radar	S1	44%	33%	6%	6%	11%
		S2	46%	0%	23%	8%	23%
	Head-up Display	S1	44%	33%	6%	11%	6%
		S2	31%	0%	15%	0%	54%
	Lane Departure Warning	S1	39%	22%	11%	6%	22%
		S2	31%	0%	8%	8%	54%

Table A-3. Usefulness of Lane Departure Warning Systems (Both Surveys)

Question		Survey Number	Response (S1: N=18; S2: N=13)				
			Very Useful	Somewhat Useful	Uncertain (Neutral)	Not Very Useful	Not at all Useful
The lane departure warning system has three parts, seat vibration, audible warning, and visual warning on the HUD. How useful do you think each of these three warning systems will be to you in indicating lane departure under marginal driving conditions?	Seat Vibration	S1	78%	11%	0%	11%	0%
		S2	46%	31%	0%	0%	23%
	Audible Warning	S1	39%	11%	17%	17%	17%
		S2	23%	15%	23%	8%	31%
	Visual Warning	S1	56%	28%	0%	6%	11%
		S2	38%	31%	0%	15%	15%

Table A-4. Selected Driver Attitudes Regarding IVSS (Both Surveys)

Question		Survey Number	Response (S1: N=18; S2: N=13)					
			Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	No Answer
(I am concerned that the ____ can interfere/The ___ system interferes) with my driving tasks.	Collision avoidance system	S1	0%	39%	22%	33%	6%	0%
		S2	0%	31%	8%	38%	23%	0%
	Lane-keeping system	S1	0%	50%	22%	22%	6%	0%
		S2	8%	38%	8%	31%	15%	0%
(I expect it would be/It has been) easy for me to learn how to use the ____.	Collision avoidance system	S1	0%	6%	6%	78%	11%	0%
		S2	15%	23%	0%	46%	15%	0%
	Lane-keeping system	S1	0%	0%	6%	89%	6%	0%
		S2	0%	15%	8%	62%	15%	0%
(I expect that the ____would reduce/The ___system will reduce) the number of accidents or near-accident situations.	Collision avoidance system	S1	0%	11%	22%	56%	6%	6%
		S2	8%	15%	62%	15%	0%	0%
	Lane-keeping system	S1	0%	6%	28%	67%	0%	0%
		S2	0%	23%	46%	31%	0%	0%
High tech systems really do not help the experienced driver avoid front-end collisions.		S1	11%	39%	39%	11%	0%	0%
		S2	0%	46%	23%	31%	0%	0%
I would be better off driving without these types of high tech systems.		S1	6%	33%	56%	6%	0%	0%
		S2	8%	31%	54%	8%	0%	0%
These high tech vehicle safety systems create an added distraction in my vehicle.		S1	6%	28%	28%	28%	11%	0%
The ____ system is distracting to me in my driving.	Collision avoidance system	S2	0%	23%	0%	46%	31%	0%
	Lane-keeping system	S2	0%	38%	8%	31%	23%	0%

Table A-5. Perceived IVSS Effect on Accident Potential (Second Survey)

Question		Response (N=13)				
		No increase	Small increase	Medium increase	Large increase	Appropriately Skipped
In the question above, you disagreed with the statement that the ________reduces the number of accidents or near-accident situations. Please indicate here the degree to which an increase is experienced.	Collision avoidance system	8%	0%	8%	8%	77%
	Lane keeping system	8%	8%	8%	0%	77%

Table A-6. Perceived Effect of IVSS on Driving Behavior (Both Surveys)

Question		Survey Number	Response (S1: N=18; S2: N=13)				
			Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
(I expect that my driving will **not** change/My driving has **not** changed) as a result of having the _____ on my vehicle.	Collision avoidance system	S1	0%	50%	28%	17%	6%
		S2	8%	31%	15%	38%	8%
	Lane keeping system	S1	0%	50%	17%	28%	6%
		S2	0%	8%	23%	62%	8%

Table A-7. Perceived IVSS Effect on Driver Workload and Stress (Both Surveys)

Question		Survey Number	Response (S1: N=18; S2: N=13) Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	No Answer
I am concerned that the _____ increases the amount of effort it takes to drive a vehicle.	Collision avoidance system	S1	0%	44%	28%	22%	6%	0%
		S2	8%	15%	23%	31%	23%	0%
	Lane-keeping system	S1	0%	39%	33%	28%	0%	0%
		S2	0%	38%	15%	38%	8%	0%
(I expect that the _____ would reduce/The_____ reduces) the stress and fatigue of driving.	Collision avoidance system	S1	0%	28%	22%	44%	0%	6%
		S2	31%	46%	15%	8%	0%	0%
	Lane-keeping system	S1	0%	28%	28%	44%	0%	0%
		S2	15%	38%	31%	15%	0%	0%

Table A-8. Potential of IVSS to Decrease Workload and Stress (Second Survey)

Question		Response (N=13)				
		No Decrease	Small Decrease	Medium Decrease	Large Decrease	Appropriately Skipped
In the question above, you disagreed with the statement that the ________increases the amount of effort it takes to drive a vehicle. Please indicate here the degree to which a decrease in effort is experienced.	Collision avoidance system	15%	0%	0%	8%	77%
	Lane-keeping system	15%	15%	8%	0%	62%
Question		**Response** (N=13)				
		No Increase	**Small Increase**	**Medium Increase**	**Large Increase**	**Appropriately Skipped**
In the question above, you disagreed with the statement that the ________reduces the stress and fatigue of driving. Please indicate here the degree to which an increase is experienced.	Collision avoidance system	15%	31%	23%	8%	23%
	Lane-keeping system	8%	8%	31%	8%	46%

Table A-9. Perceived Mental Workload (First Survey)

	Estimate of mental workload under normal driving conditions when driving your own personal automobile?	Estimate of mental workload when driving your vehicle in average winter conditions with good visibility and without these new technologies?	Estimate of mental workload when driving your vehicle in the worst winter conditions with poor visibility and without these new technologies?	Estimate of mental workload when driving your vehicle in the worst winter conditions with poor visibility with these new technologies functioning properly?
1	5	7	10	7
2	2	5	9	6
3	7	9	10	5
4	1	5	9	6
5	5	6	9	3
6	2	4	7	5
7	4	5	8	6
8	4	6	9	9
9	5	7	10	3
10	3	6	9	8
11	1	1	10	10
12	3	5	9	9
13	1	4	9	9
14	2	4	8	4
15	4	8	10	10
16	3	6	10	10
17	6	6	8	5
18	2	2	8	4

Table A-10. Perceived Mental Workload (Second Survey)

	Estimate of mental workload under normal driving conditions when you drive your own personal automobile?	Estimate of mental workload when driving your vehicle in average winter conditions with good visibility and without these new technologies?	Estimate of mental workload when driving your vehicle in the worst winter conditions with poor visibility and without these new technologies?	Estimate of mental workload when driving your vehicle in the worst winter conditions with poor visibility with these new technologies functioning properly?
1	3	7	10	7
2	5	8	9	10
3	3	4	8	6
4	1	4	6	6
5	2	4	9	10
6	2	4	8	6
7	3	5	10	8
8	5	7	9	8
9	0	3	6	4
10	3	6	8	9
11	1	1	10	10
12	2	4	7	4
13	3	5	10	8

Table A-11. Desirability and Perceived Safety Benefits of IVSS (Second Survey)

Question		Response (N=13)				
		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I would like the _____ to be kept and maintained on my vehicle in the future.	Collision avoidance system	31%	8%	31%	31%	0%
	Lane keeping system	23%	8%	23%	31%	15%
These high tech vehicle systems increase my safety while driving.	S2	0%	38%	15%	38%	8%

APPENDIX B:

INITIAL AND FINAL DRIVER SURVEYS

Initial Driver Survey - Mn/DOT

1. Type your name here:

2. Select the type of vehicle you operate on the job:

Please Choose an Answer

- Please Choose an Answer
- Snowplow
- Ambulance
- Patrol car

3. How satisfied are you with your vehicle's performance overall, including handling, transmission, engine, braking—in other words, its total performance?

Please Choose an Answer

- Please Choose an Answer
- Very Dissatisfied
- Somewhat Dissatisfied
- Neither Satisfied nor Dissatisfied
- Somewhat Satisfied
- Very Satisfied

4. Up to now, how many times have you driven your vehicle with each of these four technologies operating properly in low visibility or difficult driving conditions, such as snow on the road, blowing snow, fog, rain, or night time?

	Choose one box for each of the 4 technologies.				
Front-looking radar	Never	1 time	2 times	3 times	4 or more times
Side-looking radar	Never	1 time	2 times	3 times	4 or more times
Heads Up Display	Never	1 time	2 times	3 times	4 or more times
Lane Departure Warning	Never	1 time	2 times	3 times	4 or more times

5. In general, do you see these technology systems (collision avoidance and lane keeping) as likely to be:

- Useful to you in driving your vehicle?
- Creating problems for you when driving your vehicle?
- Not useful to you but not a problem either in driving your vehicle?

Initial Driver Survey - Mn/DOT

6. Please think back over your driving experiences in low visibility or poor conditions. Estimate how often you have to take evasive maneuvers, such as braking hard, making sudden lane changes, or other actions, to avoid an accident because a vehicle pulled in front of you, stopped or slowed suddenly, or appeared suddenly in front of you?

Please Choose an Answer

- Please Choose an Answer
- Frequently
- Occasionally
- Rarely
- Never

7. The lane departure warning system has three parts, seat vibration, audible warning, and visual warning on the HUD. How useful do you think each of these three warning systems will be to you in indicating lane departure under marginal driving conditions?

	Choose one answer for each				
Seat vibration	Very Useful	Somewhat Useful	Uncertain (Neutral)	Not Very Useful	Not At All Useful
Audible warning	Very Useful	Somewhat Useful	Uncertain (Neutral)	Not Very Useful	Not At All Useful
Visual Warning	Very Useful	Somewhat Useful	Uncertain (Neutral)	Not Very Useful	Not At All Useful

Initial Driver Survey - Mn/DOT

8. In the next set of questions, we are asking you to answer some questions about the collision avoidance system.

When answering each part of Question 8, consider the entire collision avoidance system, including forward and side radar, vehicle and roadside object display on the HUD, and warning lights, sounds and symbols

Statement	Choose one answer for each				
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
8a. I am concerned that the collision avoidance system can interfere with my driving tasks.	○	○	○	○	○
8b. I expect it would be easy for me to learn how to use the collision avoidance system.	○	○	○	○	○
8c. I expect that my driving will **not** change as a result of having the collision avoidance system on my vehicle.	○	○	○	○	○
8d. I am concerned that the collision avoidance system increases the amount of effort it takes to drive a vehicle.	○	○	○	○	○
8e. I expect that the collision avoidance system would reduce the stress and fatigue of driving.	○	○	○	○	○
8f. I expect that the collision avoidance system would reduce the number of accidents or near-accident situations.	○	○	○	○	○

Initial Driver Survey - Mn/DOT

9. The second set of questions deals with the lane keeping system.

When answering each part of Question 9, consider the entire lane keeping system, including the GPS, 3M magnetic tape, the HUD, and warning lights, sounds, vibrations and symbols.

Statement	Choose one answer for each				
9a. I am concerned that the lane keeping system can interfere with my driving tasks.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
9b. I expect it would be easy for me to learn how to use the lane keeping system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
9c. I expect that my driving will **not** change as a result of having the lane keeping system on my vehicle.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
9d. I am concerned that the lane keeping system increases the amount of effort it takes to drive a vehicle.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
9e. I expect that the lane keeping system would reduce the stress and fatigue of driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
9f. I expect that the lane keeping system would reduce the number of accidents or near-accident situations.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

The following questions are about high-tech systems in general.

Statement	Choose one answer for each				
10. High tech systems really do **not** help the experienced driver avoid front-end collisions.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
11. I would be better off driving without these types of high tech systems.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
12. These high tech vehicle safety systems create an added distraction in my vehicle.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

Initial Driver Survey - Mn/DOT

"Mental workload" is the mental effort it takes for you to perform tasks. Think in terms of your level of concentration, amount of mental effort, or degree of mental focus.

On a mental workload scale of 0 to 10,

- *0 means no mental workload*
- *1 means very low mental workload*
- *10 means the highest mental workload.*

Please check a number between 0 and 10 that reflects your estimate of the level of mental workload under each of the following.

Statement	Choose one answer										
13. Normal driving conditions when you drive your own personal automobile?	0 No mental workload ○	1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 ○	10 Highest mental workload ○
14. When driving your (snowplow/ambulance/ patrol car) in average winter conditions with good visibility and **without** these new technologies?	0 No mental workload ○	1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 ○	10 Highest mental workload ○
15. When driving your (snowplow/ambulance/ patrol car) in the worst winter conditions with poor visibility and **without** these new technologies?	0 No mental workload ○	1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 ○	10 Highest mental workload ○
16. When driving your (snowplow/ ambulance/patrol car) in the worst winter conditions with poor visibility **with** these new technologies functioning properly?	0 No mental workload ○	1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○	8 ○	9 ○	10 Highest mental workload ○

Initial Driver Survey - Mn/DOT

You can call John Scharffbillig at (612) 670-0594 if you have any questions about this technology program or Jessica Sanford at (614) 424-4998 if you have specific questions regarding this survey.

We will be conducting a second survey in about two months from now to discuss your driving experiences.

Thank you for your participation!

Write any comments below. Note question numbers to which your comment(s) may apply (if you need to refer to questions from earlier in the survey, you may find entering comments easier by hitting the review button)**:**

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1. Type your name here:

2. Since January of this year, how many times have you driven your vehicle with each of these four technologies operating properly in low visibility or difficult driving conditions, such as snow on the road, blowing snow, fog, or heavy rain?

	Choose one box for each of the 4 technologies.				
Front-looking radar	Never	1 time	2 times	3 times	4 or more times
Side-looking radar	Never	1 time	2 times	3 times	4 or more times
Heads Up Display	Never	1 time	2 times	3 times	4 or more times
Lane Departure Warning	Never	1 time	2 times	3 times	4 or more times

3. The lane departure warning system has three parts, seat vibration, audible warning, and visual warning on the HUD. How useful do you think each of these three warning systems has been to you in indicating lane departure under marginal driving conditions?

	Choose one answer for each				
Seat vibration	Very Useful ○	Somewhat Useful ○	Uncertain (Neutral) ○	Not Very Useful ○	Not At All Useful ○
Audible warning	Very Useful ○	Somewhat Useful ○	Uncertain (Neutral) ○	Not Very Useful ○	Not At All Useful ○
Visual warning	Very Useful ○	Somewhat Useful ○	Uncertain (Neutral) ○	Not Very Useful ○	Not At All Useful ○

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4. Next, we would like you to answer some questions about the collision avoidance system.

When answering each part of Question 4, consider the entire collision avoidance system, including forward and side radar, vehicle and roadside object display on the HUD, and warning lights, sounds and symbols

Statement	Choose one answer for each				
4a. The collision avoidance system interferes with my driving tasks.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4b. It has been easy for me to learn how to use the collision avoidance system.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4c. My driving has **not** changed as a result of having the collision avoidance system on my vehicle.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
4d. The collision avoidance system increases the amount of effort it takes to drive a vehicle.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

4e. The collision avoidance system reduces the stress and fatigue of driving.	Strongly Disagree / Disagree / Neither Agree nor Disagree / Agree / Strongly Agree
4f. The collision avoidance system reduces the number of accidents or near-accident situations.	Strongly Disagree / Disagree / Neither Agree nor Disagree / Agree / Strongly Agree
4g. The collision avoidance system is distracting to me in my driving.	Strongly Disagree / Disagree / Neither Agree nor Disagree / Agree / Strongly Agree
4h. I would like the collision avoidance system to be kept and maintained on my vehicle in the future.	Strongly Disagree / Disagree / Neither Agree nor Disagree / Agree / Strongly Agree

Please note here any specific comments, pro or con, about your experiences with the collision avoidance system:

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4 continued.

In question 4d, you disagreed with the statement that the collision avoidance system increases the amount of effort it takes to drive a vehicle.

Please indicate here the degree to which a decrease in effort is experienced.

- ○ No decrease (effort stays the same)
- ○ Small decrease in effort
- ○ Medium decrease in effort
- ○ Large decrease in effort

4 continued.

In question 4e, you disagreed with the statement that the collision avoidance system reduces the stress and fatigue of driving.

Please indicate here the degree to which an increase is experienced.

- ○ No increase
- ○ Small increase
- ○ Medium increase
- ○ Large increase

4 continued.

In question 4f, you disagreed with the statement that the collision avoidance system reduces the number of accidents or near-accident situations.

Please indicate here the degree to which an increase is experienced.

- ○ No increase
- ○ Smal increase
- ○ Medium increase
- ○ Large increase

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5. The second set of questions deals with the lane keeping system.

When answering each part of Question 5, consider the entire lane keeping system, including the GPS, 3M magnetic tape, the HUD, and warning lights, sounds, vibrations and symbols.

Statement	Choose one answer for each				
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
5a. The lane keeping system interferes with my driving tasks.	○	○	○	○	○
5b. It has been easy for me to learn how to use the lane keeping system.	○	○	○	○	○
5c. My driving has **not** changed as a result of having the lane keeping system on my vehicle.	○	○	○	○	○
5d. The lane keeping system increases the amount of effort it takes to drive a vehicle.	○	○	○	○	○

5e. The lane keeping system reduces the stress and fatigue of driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
5f. The lane keeping system reduces the number of accidents or near-accident situations.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
5g. The lane keeping system is distracting to me in my driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
5h. I would like the lane keeping system to be kept and maintained on my vehicle in the future.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

Please note here any specific comments, pro or con, about your experiences with the lane keeping system:

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5 continued.

In question 5d, you disagreed with the statement that the lane keeping system increases the amount of effort it takes to drive a vehicle.

Please indicate here the degree to which a decrease in effort is experienced.

- No decrease (effort stays the same)
- Small decrease in effort
- Medium decrease in effort
- Large decrease in effort

5 continued.

In question 5e, you disagreed with the statement that the lane keeping system reduces the stress and fatigue of driving.

Please indicate here the degree to which an increase is experienced.

- No increase
- Small increase
- Medium increase
- Large increase

5 continued.

In question 5f, you disagreed with the statement that the lane keeping system reduces the number of accidents or near-accident situations.

Please indicate here the degree to which an increase is experienced.

- No increase
- Smal increase
- Medium increase
- Large increase

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The following questions are about high-tech systems in general.

Statement	Choose one answer for each				
6. High tech systems really do **not** help the experienced driver avoid front-end collisions.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
7. I would be better off driving without these types of high tech systems.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○
8. These high tech vehicle systems increase my safety while driving.	Strongly Disagree ○	Disagree ○	Neither Agree nor Disagree ○	Agree ○	Strongly Agree ○

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"Mental workload" is the mental effort it takes for you to perform tasks. Think in terms of your level of concentration, amount of mental effort, or degree of mental focus.

On a mental workload scale of 0 to 10,

- *0 means no mental workload*
- *1 means very low mental workload*
- *10 means the highest mental workload.*

Please check a number between 0 and 10 that reflects your estimate of the level of mental workload under each of the following.

Statement	Choose one answer										
	0 No mental workload	1	2	3	4	5	6	7	8	9	10 Highest mental workload
9. Normal driving conditions when you drive your own personal automobile?	○	○	○	○	○	○	○	○	○	○	○
10. When driving your (snowplow/ambulance/ patrol car) in average winter conditions with good visibility and **without** these new technologies?	○	○	○	○	○	○	○	○	○	○	○

11. When driving your (snowplow/ambulance/ patrol car) in the worst winter conditions with poor visibility and **without** these new technologies?	0 No mental workload ◯ · 1 ◯ · 2 ◯ · 3 ◯ · 4 ◯ · 5 ◯ · 6 ◯ · 7 ◯ · 8 ◯ · 9 ◯ · 10 Highest mental workload ◯
12. When driving your (snowplow/ ambulance/patrol car) in the worst winter conditions with poor visibility **with** these new technologies functioning properly?	0 No mental workload ◯ · 1 ◯ · 2 ◯ · 3 ◯ · 4 ◯ · 5 ◯ · 6 ◯ · 7 ◯ · 8 ◯ · 9 ◯ · 10 Highest mental workload ◯

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You can call John Scharffbillig at (612) 670-0594 if you have any questions about this technology program or Jessica Sanford at (614) 424-4998 if you have questions specific to this survey.

Thank you for your participation!

Write any comments below, including problems experienced with these systems or suggestions for improving them, or any other observations you care to provide. Note question numbers to which your comment(s) may apply (if you need to refer to questions from earlier in the survey, you may find entering comments easier by hitting the review button)**:**

APPENDIX C:

DRIVER AND SUPERVISOR INTERVIEW PROTOCOLS

Initial Interviews for Snow Plow Drivers / Ambulance Drivers / Patrol Car Driver(s)
December 12-13, 2001

1. **Introductions**
    (1) Battelle's role as independent evaluator.
    (2) Coordinated with U Minn's evaluation.
    (3) Informal discussion, first in series of data collections.
    (4) How many years driving?
    (5) How long in this job?
    (6) Briefly describe your job.

2. **Ground rules**
    (1) All interviews confidential.
    (2) Purpose of the interview is to discuss expectations about safety technologies, experiences and comfort with other technologies, and understand drivers' perspectives on driving tasks.
    (3) Looking for objective feedback, both pros and cons of the technologies.

3. **Use of and comfort with technologies**
    (1) Do you use a computer as part of your work?
        (a) If so, describe how much experience/skill you have with computers.
        (b) Overall, how comfortable would you say you feel with high tech things?
        (c) In general, how comfortable do you think most of your fellow drivers are with high tech?
    (2) Do you use a computer at home?
    (3) Have you participated in any previous tests of any of these systems?
    (4) Is there other high tech gear in your vehicle?

4. **Exposure to date with IVI systems and orientation/training**
    (1) Have you participated in any orientations or training yet?
        (a) Simulator test or the test track trials?
        (b) On-site orientations or ride-alongs?
        (c) Other training?
        (d) Has the orientation/training been effective?
    (2) Will there be additional training and if so, when is it scheduled?
    (3) How do you personally like to learn how to use new systems like these?
        (a) Formal training?
        (b) Road experience?
        (c) Talk with other drivers?
        (d) Read the manual?
        (e) Trial and error?

5. **Initial reaction to new systems**
    (1) Have you had a chance to drive with these systems turned on yet?
        (a) What was that like?
        (b) Were the systems working properly?
        (c) What are your main likes? Dislikes? (Initial impressions)

6. **Understanding of system functions**
    (1) Are you familiar with the following system components?
        (a) Forward-looking and side-looking radars
        (b) Heads Up Display (HUD)
        (c) GPS
    (2) Are these the terms you use when you talk about these systems?
    (3) Discuss how these systems operate in your vehicle.
    (4) What kinds of warnings or feedback to you get from these components?
        (a) Do you prefer any of these warnings over others? Why?
        (b) Are they distracting?
        (c) Can they be confused with other system warnings in your vehicle?

7. **Are these systems more useful under certain conditions?**
    (1) Explore conditions such as snow on road, blowing snow, fog, night driving, other
    (2) How often do you experience these conditions?
    (3) Do you use the system (and is it useful) under normal driving conditions?

8. **Discuss potential productivity benefits**
    (1) Explore whether systems offer measurable productivity or efficiency benefits
        (a) More efficient plowing; faster travel times, quicker emergency response, etc.

9. **Discuss potential effects on driver workload**
    (1) What is it like to drive a snowplow, ambulance, or patrol car?
        (a) Explore level of concentration, mental effort, focus required
        (b) Explore whether job is perceived as stressful
    (2) Now talk about how the new systems might effect your job and workload

10. **Discuss range of likely driver responses to systems**
    (1) Every driver is different. People have different levels of experience, skills, and styles of driving. How do you expect these systems to work for you? How do you expect these systems to work for other drivers?
        (a) In what way do you think they may help?
        (b) In what ways might they not be so helpful?
    (2) Overall, how comfortable would you say drivers are going to be having these kinds of technologies in their vehicles?

11. Overall perspective on the systems at this time

(1) What are the most important advantages likely to be? Explore the following:
   (a) Safety (yourself and others on the road)
   (b) Driving comfort
   (c) Reduced stress of driving
   (d) More efficient/productive driving
   (e) Other?
(2) What are the disadvantages likely to be?
(3) How confident do you feel about relying on these systems?
   (a) What will it take for you to trust the information the system gives you?
(4) Considering what is helpful and what is not helpful together, what is your conclusion?
(5) Do you think these systems will allow you to operate in conditions you normally could not?
   (a) How often are you likely to encounter such conditions?
   (b) How are decisions made about whether to go out, or to recall your vehicle when conditions are very bad? Could these systems affect those decisions?
(6) Do you think these systems could in any way change your job? Or change the way you drive?

12. Wrap up

(1) Anything else you would like to say about these matters?
(2) Next steps:
   (a) Phone, written, or Internet surveys to evaluate your experiences
   (b) A final in-person interview at the end of the test (after March 30th)
(3) Discuss possible interviews after extreme events or driving maneuvers.

Final Interviews for Snow Plow Drivers / Ambulance Drivers / Patrol Car Driver(s)
April 11, 2002

1. **Introductions**
   (1) Review Battelle's role as independent evaluator.
   (2) Coordinated with U Minn's evaluation.
   (3) Informal discussion, second since January (last this year).
   (4) How many years driving? *[only if new interviewee]*
   (5) How long in this job? *[only if new interviewee]*
   (6) Briefly describe your job. *[only if new interviewee]*

2. **Ground rules**
   (1) All interviews confidential.
   (2) Purpose of the interview is to discuss your experiences with safety technologies
   (3) Looking for objective feedback, both pros and cons of the technologies.

3. **Use of the Internet for surveying**
   (1) Have you completed the recent Internet survey?
      (a) If so, did you like this way of answering questions?
      (b) Would another method be preferable for you?

4. **Exposure to date with IVI systems and orientation/training**
   (1) Have you received training or orientations for the use of these technologies?
      (a) On-site orientations or ride-alongs?
      (b) Other training?
      (c) Has the orientation/training been effective?
      (d) Any suggestions for improving driver training?
   (2) How do you personally like to learn how to use new systems like these?
      (a) Formal training?
      (b) Road experience?
      (c) Talk with other drivers?
      (d) Read the manual?
      (e) Trial and error?

5. **Use of the new technologies to date**
   (1) Since January, have you driven your vehicle in bad weather or poor visibility conditions (blowing snow, snow on the road, fog, or heavy rain)?
      (a) How many times?
      (b) Were the systems working properly?
      (c) What worked well? What didn't work so well?
      (d) What are your main likes? Dislikes?
   (2) (Snowplow Operators only)
      (a) Have you ever adjusted the lateral offset? If yes, why?
      (b) What is the most common offset distance you use?
      (c) How often do you specify this offset distance?

(3) Experience with the HUD
  (a) How often and under what conditions (medium, low, no visibility) do you use the HUD?
  (b) Did you ever totally disable the systems? If so, why? Under what conditions?
  (c) Did you sometimes just fold up the HUD combiner so that you didn't have to look through it? If so, why? Under what conditions?

(4) Discuss alerts you get from the systems:
  (a) HUD: How often do you find that objects change to red boxes on the HUD?
  (b) When that happens, do you think it reflects a safety-critical situation? Or how often is this just a nuisance alert?
  (c) During "normal" driving situations, do you find that the lane-keeping alert occurs when you think there is no good reason for a warning? If so, how often does this happen? Under what conditions? What seems to be the cause?
  (d) Do you get warnings from the side-collision radar when you are quite sure there is no vehicle in the lane next to you?

6. Discuss potential productivity and safety benefits

(1) Explore whether systems offer measurable productivity or efficiency benefits
  (a) More efficient plowing; faster travel times, quicker emergency response, etc.

(2) Explore safety benefits experienced by the driver
  (a) Avoid dangerous situations; reduce perceived risk of driving in bad weather; just feel safer driving with the technologies than without.
  (b) Do you think these systems allow you to perform your job about as well under low visibility conditions as you can under "normal" driving conditions?
  (c) Can you perform your job with these systems in some conditions that you otherwise could not do without them? Describe.

7. Discuss potential effects on driver workload

(1) Drivers have told us before how stressful the driving job can be. Now that you have some experience with these systems, how you think they effect your job, stress and workload?

8. Discuss range of driver responses to systems

(1) Every driver is different. People have different levels of experience, skills, and styles of driving. How have these systems worked for you? How have they worked for other drivers?
  (a) In what ways have they helped?
  (b) In what ways have they not been so helpful?

(2) Overall, how comfortable would you say drivers are having these kinds of technologies in their vehicles?

9. Overall perspective on the systems at this time

(1) What are the most important advantages? Explore the following:
   (a) Safety (yourself and others on the road)
   (b) Driving comfort
   (c) Reduced stress of driving
   (d) More efficient/productive driving
   (e) Other?
(2) What are the disadvantages?
(3) How confident do you feel about relying on these systems?
   (a) Would you say that your trust in the systems and the information the systems give you has increased or decreased, now that you have had some experience?
(4) Considering what is helpful and what is not helpful together, what is your conclusion?
(5) Do you think these systems could in any way change the way you drive?

10. Reactions of the public

(1) Do you think the public perceives changes due to your use of these technologies that changes how they drive? If so, how?
(2) Can/does the public drive more as a result? More safely?

11. Wrap up

(1) Anything else you would like to say about these matters?
(2) Thanks for sharing your thoughts with us about these technologies.

Final Interview for Managers/Operators/Dispatchers
April 11, 2002

1. **Introductions and objectives**
   (1) Review Battelle's role as independent evaluator
   (2) Coordinated with U Minn's evaluation
   (3) All interviews confidential
   (4) Purpose of the interview is to discuss experiences with safety technologies from a management perspective
   (5) Informal discussion, looking for candid feedback, both pro and con
   (6) Second interview since January (last this year)

2. **Reaction to new vehicle safety systems (discuss three types)**
   (1) What are your thoughts about forward-looking, side-looking and rear-looking radar, the parts of the **collision warning** system?
      (a) How well has this system been working for (*org. name*) so far?
      (b) Has (*org. name*) provided training for drivers in using the radar?
      (c) In your opinion, how effective has the training been?
      (d) How do your drivers seem to respond to this system?
      (e) How do you and others in management like this system?
      (f) Are the forward-looking, side-looking, and rear-looking radar systems creating any problems for you (maintenance, getting the job done, driver reactions, etc.)?
      (g) In your opinion, what is the outlook for the future of forward-looking, side-looking, and rear-looking radar systems in (*org. name*)'s fleet? Would you recommend further investments in this system for the fleet?

   (2) What are your thoughts about the **vehicle positioning** system (GPS)?
      (a) How well has this system been working for (*org. name*) so far?
      (b) Has (*org. name*) provided training for drivers in using the system?
      (c) In your opinion, how effective has the training been?
      (d) How do your drivers seem to respond to this system?
      (e) How do you and others in management like this system?
      (f) Are the vehicle positioning systems creating any problems for you (maintenance, getting the job done, driver reactions, etc.)?
      (g) In your opinion, what is the outlook for the future of vehicle positioning systems in (*org. name*)'s fleet? Would you recommend further investments in this system for the fleet?

   (3) What are your thoughts about **lane-keeping** systems?
      (a) How well has this system been working for (*org. name*) so far?
      (b) Has (*org. name*) provided training for drivers in using the system?
      (c) In your opinion, how effective has the training been?
      (d) How do your drivers seem to respond to this system?
      (e) How do you and others in management like this system?
      (f) Are the lane-keeping systems creating any problems for you (maintenance, getting the job done, driver reactions, etc.)?
      (g) In your opinion, what is the outlook for the future of lane-keeping systems in (*org. name*)'s fleet? Would you recommend further investments in this system for the fleet?

3. Perceptions of advantage / disadvantage of these systems

(1) What are the most helpful things about having these systems installed on (*org. name*) vehicles?

(2) Are there any disadvantages? If so what are they?

(3) Considering what is helpful and what is not helpful together, what is your conclusion? Do you think these systems help your drivers drive more safely or are they not worthwhile to your organization?

(4) Do you think these systems in any way impact or change your job? For example, do they impact training requirements for maintenance or other jobs? Management responsibilities? Other?

(5) Do you think these systems should be deployed in the entire MNDOT fleet?

(6) Do you expect to see measurable safety benefits across the fleet from installing these systems? If so, over what time frame?

(7) Every driver is different. People have different levels of experience and different styles of driving. In your opinion, do you find that these systems work for your drivers differently depending on factors such as driver experience, driving "style", or comfort with "high tech"?

  (a) Describe your experiences.

(8) Overall, how comfortable would you say you are having these kinds of technologies installed in the (*org. name*) fleet?

(9) Do these systems allow vehicles to go out in weather in which they would normally not be able to?

(10) Do you think it is a good idea for vehicles to go out in weather in which they would not normally be able to?

4. Wrap up

(1) Anything else you would like to say about these matters?