APPENDIX H
Arizona DOT Training and Evaluation Survey
Snowplow Lane Awareness System
OPERATOR INTERFACE DESIGN AND EVALUATION

Arizona Training and Evaluation Survey

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Background

In early March 2001, the University of Iowa sent a two-page survey to active snowplow drivers assigned to Department of Transportation (DOT) maintenance garages near Flagstaff, Arizona (AZ). The survey was distributed to individuals who had received training on the 3M™ Lane Awareness System (LAS). A total of 16 out of 17 surveys were completed and returned.

The survey had 32 items organized into five separate sections. In the first section, seven questions addressed drivers’ training with the 3M System and other systems; in the second, 13 questions evaluated their actual experience with the 3M System. A third section focused on drivers’ trust and confidence in the system (five questions), and the fourth section asked for suggestions on how to improve the system (four questions). The last three questions asked about the safety benefits of such systems.

In addition to this survey, supervisor(s) at the AZ DOT asked the same drivers to complete an ADOT Snowplow Training and Evaluation Survey. The ADOT survey was initially designed to evaluate another lane awareness system. However, since drivers completed it with respect to the 3M Lane Awareness System and we received a copy of their completed surveys, we have included some of the findings in this summary.

Training & Use of Lane Awareness System(s)

In this section, drivers described the amount and type of training they received on the 3M System and on other comparable systems.

Training on the 3M System took place between November 2000 and February 2001. More specifically, seven Snowplow Team Leader Activity Reports provided to us by the Arizona DOT indicate that training sessions occurred on November 10 and December 25, 2000, and on a number of days in January (17, 27, 29, 31), 2001. The last was on
February 6, 2001. Except for one session that started at 19:00 and ended at 07:00, all took place during the day, starting at 07:00 and ending as late as 19:00, in some cases.

Sixteen drivers from a total of seven AZ DOT maintenance garages participated in training. They reported an average of 6.4 years of experience operating snowplows (range of 1 to 13 years). During training, drivers spent an average of 3.6 hours operating the 3M Lane Awareness System (0 to 16 hours range). When they completed the survey in March, a little less than half (44%) had used the system after their initial training; only three drivers (19%) had used it more than five times. These three ‘experienced’ drivers had spent between 40 to 150 hours operating the system. The other 13 drivers spent only an average of 1.97 hours on the system after they were trained (the range was 0 to 16 hours). Thus, except for three drivers, the experience level with the system was low, consisting of a few hours of training and at most a few hours afterwards.

The proportion of time drivers spent using the system in low-visibility conditions was of particular interest. Three drivers reported experiencing conditions of less than 100 feet forward visibility eight times or more during the three-month period. However, due to the wording of the question, it was difficult to determine if drivers were indicating the number of outings with low visibility or simply the number of low-visibility events (which could have all occurred during one outing). One driver reported encountering low-visibility conditions at least eight or more times even though he never had an opportunity to use the system after his initial training. In other words, most drivers (at least 75%) received training on and used the 3M System in fair-weather conditions. This was corroborated by the Team Leader Activity Reports, which indicated that visibility was ‘over 500 feet’ in all but one instance.

On November 10th, training occurred at night in zero visibility, windy and snowy conditions. Operators faced whiteout conditions and were able to use the system to help them find the road and stay out of the way of oncoming traffic. Weather information from the reports suggests that in other training sessions prior to and including January 27, snow or wind was encountered on two days and ice on one, the roadway was usually
covered with snow, and drivers were involved in plowing and sanding activities. For the remaining three training days (January 29 onward), the weather was clear, the pavement dry, and drivers did not perform plowing or sanding activities.

To anchor drivers’ opinions about the 3M System, we also asked about their experiences with other lane awareness systems. Almost every one (93%) had used the California Department of Transportation (CALTRANS) system before; no one had tried the Minnesota system. While we did not ask drivers how many hours they had spent using the CALTRANS system, we did ask which of the two systems they preferred and why. Drivers liked both systems—43% preferred CALTRANS while 57% favored 3M. The advantages listed for the CALTRANS system included the visual display (ability to see the curves in the road) and the collision warning capabilities. Where the 3M System was preferred, drivers indicated that they liked the seat component and the fact that it relieved them of the need to look at the visual components. Three people simply indicated that the 3M was the ‘better, easier, and simpler system.’ Overall, drivers found both systems attractive, but indicated a slight preference for the 3M System.

**Drivers’ Experience with the Lane Awareness System(s)**

The University of Iowa survey asked drivers to rank various aspects of the 3M System on a 7-point Liepert scale. Drivers first rated the lane awareness system on its user-friendliness and usefulness. Most found the system very ‘easy to use’ (average ranking of 6). This concurred with the rankings for ease of use in the ADOT Snowplow Training & Evaluation Survey, where the average rating was 8.8 on a 10-point scale (1=not at all to 10=completely). Drivers also indicated that they found the system ‘satisfying,’ as opposed to ‘frustrating’ (average ranking of 5.5), and quite ‘flexible’ (average ranking of 5.5). Still positive, but with a lower mean ranking was their assessment of how ‘intuitive’ the system was. They reported that it was better than average (average ranking of 5.1), but did not consider it to be ‘extremely intuitive.’
Of the three warnings available (i.e., visual scale display, peripheral flashing lights, and seat vibration), the seat vibration was by far the preferred warning. Drivers rated seat vibration ‘extremely useful’ (average ranking of 6.2 on the University of Iowa survey) and reported that this feature significantly increased their perceived level of safety, as indicated by an average ranking of 9.1 out of 10 on the ADOT survey. Comments in the Team Leader Activity Reports echoed these findings. Drivers indicated that they liked this component because it allowed them to keep looking forward to the road. They also liked being able to adjust the intensity of the vibration (11 out of 16 respondents).

Drivers’ responses to the other two warning modes were mixed. On the University of Iowa survey, drivers gave a higher mean ranking (5.6 out of 7) to the visual scale display for its usefulness in helping them maintain their lane position. However, on the ADOT survey, they indicated that the peripheral flashing lights were better than the visual scale (8.4 vs. 7.6 out of 10) at increasing their level of safety. One explanation of these results may be that the visual scale display was useful in providing information about lane position while the ‘peripheral flashing lights’ acted better as a warning. This explanation is corroborated by the fact that the majority (11 out of 16 respondents) reported being able to continue looking forward when the lights were flashing.

An additional item on the ADOT survey indicates that drivers may have been confused as to which system they were reviewing in filling it out. As mentioned earlier, this survey was originally intended to evaluate the CALTRANS system. The CALTRANS system includes a collision warning system, whereas the 3M System does not. The additional question asked about the ability of the collision warning system to improve drivers’ level of safety. At least 11 respondents rated this non-existent feature on the 3M System, giving it an average ranking of 8.9 out of 10.

The University of Iowa survey asked respondents which warnings they considered to be the ‘most’ and ‘least’ annoying, and which they would eliminate if they had to choose between them. The majority (10 out of 16) did not consider any of the warnings to be annoying—no one warning emerged as most annoying. Seat vibration was the least
annoying (6 out of 16) and would be the last one eliminated, followed by the visual display. If one of the warnings had to be eliminated, drivers suggested it should be the peripheral flashing lights (8 out of 16), but an almost equal number felt that all three should be retained (7 out of 16).

In general, drivers’ experience with the system was positive. Apparently, the 3M System did not prompt any driver to an erroneous action or judgment (14 out of 16 respondents), and most had no difficulties with the system (12 out of 16 respondents). Drivers indicated that, in general, the LAS made them ‘much more’ aware of their lane position—they ranked this item highly, with an average ranking of 5.9. In addition, respondents felt that the warnings enabled them, or would enable them, to respond quickly to a lane departure (average ranking of 5.8). The ADOT survey also reflected drivers’ general satisfaction with the system. Drivers rated the display and warnings an average of 8.6 (1=not at all to 10=completely) in terms of being clear and easy to understand. They also felt that the lane awareness system provided them with enough information to be useful (average ranking of 8.6) and that the system responded quickly enough to be useful (average ranking of 8.9).

Drivers did not seem to think, however, that the 3M System would reduce their workload significantly and thereby help them to allocate more resources to other tasks, such as radio communications (average 4.4). They indicated that the system might help them a little (average 4.8) to spend more time looking for stopped vehicles or objects in the roadway. They also felt that it augmented their traditional outside visual cues (average ranking of 4.9). Overall, drivers felt that the system was useful but would not ultimately impact their workload (average ranking of 4.3).

Drivers' Trust and Confidence in the 3M System

Drivers seemed to trust the lane awareness system and expressed confidence in its capabilities. On a Liepert scale of 1(not at all) to 10 (completely), drivers ranked most of the trust items an average of 7 or above. The highest mean ranking (average 7.5)
reflected drivers’ confidence in their ability to stay in the lane with the 3M System compared to without it. Similarly, they believed that the system could help them maintain their lane position better than their own abilities alone (average ranking of 7.1). They also trusted the system to provide them with accurate and reliable information (average ranking of 7.2). The lowest rating was in response to whether drivers felt they could rely solely on the 3M System (average 6.9). However, it appears that drivers considered the 3M System to be a reliable tool able to augment their own abilities and current equipment. Of those who had difficulty trusting the system, only one person indicated that this was due to a deficiency in the system (i.e., no ability to foresee the turns in the roadway). Others attributed their lack of trust to the system’s novelty, to the fact that no system is foolproof, and to their feeling that they had not had sufficient experience with the system to judge its reliability and accuracy.

Drivers’ Suggestions for Improving the 3M System

Most drivers seemed to be satisfied with the system and offered few suggestions for improvement. Eight respondents (out of 13) submitted no suggestions on either the University of Iowa or ADOT survey. The improvement most often mentioned was adding a feature to the visual display that would allow drivers to predict curves and turns in the roadway (a current capability of the CALTRANS system). One respondent remarked that having this capability was more important than being able to see that the vehicle is drifting away from the centerline (i.e., the magnetic tape). Other recommendations included further simplifying the visual display and positioning the display head-up on the windshield rather than down and to the right as it currently appears.

Suggestions for improving the warnings and radar capabilities included adding auditory warnings and the ability to detect both oncoming traffic and vehicles approaching from behind. Perhaps because of their prior experience with CALTRANS, two drivers also indicated they would like to have collision warning capabilities. A technical suggestion was made that the sensor be positioned higher on the vehicle, but it was not clear whether
the respondent was referring to the sensor for the CALTRANS collision warning system or the magnetic sensor of the 3M System.

Safety Benefits

In both surveys, drivers were asked about the safety benefits of LAS. On the ADOT Snowplow Training and Evaluation Survey, drivers indicated that the system had a very high potential of improving their safety, giving an average ranking of 9.2 on a scale of 1 (not at all) to 10 (completely). They felt similarly about the system’s ability to improve motorists’ safety (average ranking of 9.1). The University of Iowa survey responses were similar—on a scale of 1(not at all) to 7 (completely), drivers rated the 3M System’s ability to improve their safety an average of 5.8. They also indicated that the system had good potential for improving their efficiency (average rating of 5.7); this item on the ADOT survey received an average ranking of 8.4 out of 10.
3M LANE AWARENESS SYSTEM
TRAINING & EVALUATION SURVEY

In the 2000-2001 winter season, a group of Arizona DOT snowplow operators received training with the 3M Lane Awareness System. Afterwards, we asked them to complete a short survey summarizing their experiences with the system. The following pages are a summary of their answers. We include the survey questions, along with a brief overview of summary statistics. We have also listed answers to open-ended questions.

YOUR TRAINING WITH THE SYSTEM

1. When did you receive training on the 3M system?

2. How many hours did you spend operating the 3M system on that day?
   Total: 16 respondents
   Range: 0 to 16 hours
   Average: 3.6 hours

3. How many times have you used the 3M system since your initial training?
   None 9
   Once 2
   2 to 4 times 2
   5 to 7 times 1
   8 to 10 times 1
   More than 10 times 1

4. How many hours total, outside of your initial training, have you spent using the 3M system?
   Total: 16 respondents
   Range: 0 to 150 hours
   Average: 17.2 hours

5. How frequently did you use the 3M system in low-visibility conditions (i.e., less than 100 feet)?
   None 11
   Once 1
   2 to 4 times 1
   5 to 7 times 0
   8 to 10 times 2
   More than 10 times 1

6. In addition to the 3M system, have you used any of the following lane awareness or tracking systems?
   CALTRANS 14
   Univ. of Minnesota (head-up display) 0
   Did not use either Go to item #8 1
   Other(s), which one(s)? 0

7. If you have used other lane awareness or tracking systems, which system did you prefer and why?
   CALTRANS 5
   Univ. of Minnesota (head-up display) 0
   3M system 7
   Other 0
   CALTRANS and 3M System 2
Question 7 continued…

Why did you prefer this system?

CALTRANS
◊ When cornering it shows the curve in the highway
◊ Collision warning, bars
◊ The visuals were easier to watch
◊ Better graphics

3M System
◊ Better visibility and don’t have to look at screen
◊ Better, easier, simpler system (3 respondents)
◊ Because of the arrow

YOUR EXPERIENCE WITH THE SYSTEM

For the following questions, circle the number that best represents your experience with the 3M system.

8. Did you find the 3M system to be:
   a. easy or difficult to use

   ![Graph]

   Total: 16 respondents
   Average: 6

   b. satisfying or frustrating

   ![Graph]

   Total: 16 respondents
   Average: 5.5

   c. flexible or rigid

   ![Graph]

   Total: 16 respondents
   Average: 5.5

9. How intuitive was it to use the 3M system?

   ![Graph]

   Total: 16 respondents
   Average: 5.1
10. Did the 3M system make you less or more aware of your lane position?

Total: 16 respondents
Average: 5.9

11. Of the warnings you experienced, rank the usefulness of each warning in helping you maintain your lane position.

◊ visual scale display:

Total: 16 respondents
Average: 5.6

◊ peripheral flashing lights:

Total: 16 respondents
Average: 4.8

12. Did the warnings provided by the 3M system enable you to respond quickly to a lane departure?

Total: 16 respondents
Average: 5.8

13. Did the 3M system help you spend less or more time looking for stopped vehicles or objects in the roadway?

Total: 16 respondents
Average: 4.8
14. Did the 3M system allow you to spend less or more time doing other tasks (e.g., radio communications)?

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Total: 16 respondents
Average: 4.4

15. Compared to not having the 3M system, did you feel that having it reduced your workload?

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Total: 16 respondents
Average: 4.3

16. When using the 3M system, did you feel it augmented your traditional outside visual cues?

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Total: 16 respondents
Average: 4.9

17. Were you able to adjust the intensity of the seat vibration to your liking?

Yes | 11
No, Would you make it: | 5
◊ Less intense | 2
◊ More intense | 1
◊ No answer | 2

18. When the peripheral flashing lights were flashing, did you look at them directly or did you continue to look forward?

Looked at them directly | 2
Looked forward | 11
Other: | 3
◊ Did not notice | 2
◊ Both | 1

19. Did the 3M system ever prompt you to make a wrong action or an error in judgment?

No | 14
Yes. If so, what were they? | 2
◊ When it malfunctions | 1
◊ In the turns-could not predict on the screen | 1

20. Did you encounter any difficulties or problems with the 3M system?

Did not answer | 1
No | 12
Yes. If so, what were they? | 3
◊ Collision avoidance system inoperative at time of test | 2
◊ Could not see turns | 1
YOUR TRUST & CONFIDENCE IN THE SYSTEM

21. To what extent did you rely on the 3M system?

![Bar chart showing reliance on the 3M system]

Total: 16 respondents
Average: 6.9

22. How much did you trust the 3M system in providing you with accurate and reliable information?

![Bar chart showing trust in the 3M system]

Total: 16 respondents
Average: 7.2

23. Overall, rate the degree to which you trusted the 3M system to help you maintain lane position, compared to trusting your own abilities.

![Bar chart showing trust in lane maintaining]

Total: 16 respondents
Average: 7.1

24. If you had difficulty trusting the system, what were the reasons?

Could not foresee the turns in the road: 2
Not enough time to get used to system: 1
Being tested hasn’t proved itself, radar went out: 1
No system is fool proof: 1
New to me: 1
System breakdown: 1
None: 2

25. Overall, rate the degree of self-confidence you had in your ability to stay in the lane when using the 3M system, compared to when you do not have it.

![Bar chart showing self-confidence]

Total: 16 respondents
Average: 7.5

YOUR SUGGESTIONS TO IMPROVE THE SYSTEM

26. Of all the warnings available on the 3M system (i.e., visual display, peripheral flashing lights, and seat vibration):

◊ Which one was most annoying?

Peripheral flashing lights: 2
Seat vibration: 2
Visual display: 2
None: 10
Which one was least annoying?

- Peripheral flashing lights: 1
- Seat vibration: 6
- Visual display: 2
- None: 7

27. If you could, what would you change about the 3M system?

- Ability to predict turns & curves in roadway by adding them to visual display: 2
- Better graphics – mile marker readings: 1
- Continue to simplify display on monitor: 1
- Put magnets in road paint: 1
- None: 8

28. If you had to eliminate one of the warnings, which one would you choose?

- Peripheral flashing lights: 8
- Seat vibration: 1
- Visual display: 0
- None: 7

29. If you could add options to the 3M system, what would you add?

- Ability to predict curves by adding it to visual display: 3
- Collision warning: 2
- H.U.D.: 1
- Perhaps an audio warning: 1
- Need more training to get know system better: 1
- None: 4

30. Rate the potential for the 3M system to improve YOUR SAFETY:

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Total: 16 respondents  
Average: 5.8

31. Rate the potential for the 3M system to improve YOUR EFFICIENCY in snow removal operations:

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Total: 16 respondents  
Average: 5.7

32. Any additional comments or suggestions:

- The peripheral lights didn’t do much because it was a clear day, it might be better at night.
- Add a rear radar for traffic coming from rear.
- Need for computer to see curves before you are shown that you’re off the tape.
- None (5 respondents)
Date

The sheets we received were for the following dates:
- November 10 – 19:00 to 07:00 (12 hours)
- December 18 – 09:00 to 09:30 (0.5 hour)
- December 25 – 07:00 to 19:00 (12 hours)
- January 26 – 19:00 to 07:00 (12 hours)
- January 27 – 07:00 to 19:00 (12 hours)
- January 29 – 07:00 to 12:00 (5 hours)
- January 30 – 9:00 to 9:45  
  9:35 to 10:30  
  10:25 to 10:55  
  11:00 to 11:40  
  11:15 to 11:45  
  11:40 to 12:15  
  12:00 to 13:00  
  13:00 to 13:30 (approximately 4.5 hours)
- January 31 – 09:45 to 10:10  
  10:10 to 10:35  
  10:30 to 11:00 (1.4 hours)

Trainees & Organization

According to the list of names, approximately 15 drivers from a total of 7 maintenance garages received training during the period listed.¹

Overall, drivers reported an average of 6.4 years of snowplow experience, with a range of 1 to 13 years. They averaged 21.2 hours experience on the test plow, with a range of 25 minutes to 120 hours.²

Overall satisfaction with driver-assistance / guidance systems (10 = best, 1 = worst)

a. Ease of use of automated systems

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Total: 18 respondents
Average: 8.8
Median & Mode: 9

¹ One of these drivers completed the survey on three separate occasions after three different training sessions raising the number of completed surveys to 18.
² Although the average number of hours on the test plow was 21.2, the median was 4 hours and the mode 30 minutes.
b. Potential to improve YOUR safety

Total: 18 respondents
Average: 9.2
Median & Mode: 10


c. Potential to improve motorists’ safety

Total: 18 respondents
Average: 9.1
Median & Mode: 10

d. Potential to improve your efficiency

Total: 18 respondents
Average: 8.4
Median & Mode: 9
Lane Position Indication Screen:

Did this feature increase your level of safety?

Total: 18 respondents
Average: 8.6
Median: 9
Mode: 10

How often did you look at the display screen?

Drivers indicated that they had looked at the screen an average of 6.9 times, with a median and mode of 8 times. However, the data suggests that drivers may have misunderstood the question and ranked their answers using the 1 to 10 rating scales rather than simply stating the number of times they looked at the screen. It is therefore very difficult to interpret the results of this question.

Lane Departure Warning – Alarm Lights

Did this feature increase your level of safety?

Total: 16 respondents
Average: 8.4
Median: 9.5
Mode: 10
Lane Departure Warning – Vibrating Seat

1 to 10 Scale - Did this feature increase your level of safety?

Total: 18 respondents
Average: 9.1
Median & Mode: 10

Lane Departure Warning – Screen Display

1 to 10 Scale - Did this feature increase your level of safety?

Total: 18 respondents
Average: 7.6
Median: 8
Mode: 10

Collision Warning System

1 to 10 Scale - Did this feature increase your level of safety?

Total: 11 respondents
Average: 8.9
Median & Mode: 10
Displays and Warnings

Were these features clear and easy to understand?

Total: 18 respondents
Average: 8.6
Median: 9
Mode: 10

Did the system provide enough information to be useful?

Total: 18 respondents
Average: 8.6
Median & Mode: 9

Was the system response fast enough to be useful?

Total: 18 respondents
Average: 8.9
Median: 9
Mode: 10
Comments and Recommendations:

1. Were there any systems problems when you were operating the vehicle? (Describe):
   ◊ None (14 respondents)
   ◊ Collision avoidance radar was inoperative (3 respondents)
   ◊ Car passed on right side, yet the collision warning did not work.

2. Did the systems ever prompt you to make a wrong move or error in judgment? (Explain):
   ◊ None (18 respondents)
   ◊ Not to my knowledge.
   ◊ The feature on plow truck help you from making wrong moves.

3. What comments or suggestions would you make to improve any feature’s usefulness?
   ◊ None (8 respondents)
   ◊ Encountered white-out conditions and we used the system to find the road.
   ◊ The system needs something to indicate an oncoming traffic.
   ◊ Put the sensor higher on the truck.
   ◊ The collision warning system needs to be fixed to have all the safety features.
   ◊ The VORAD system needs to be repaired for further safety during whiteout conditions.
   ◊ When there is a turn or an increase or decrease in grade.
   ◊ The screen is still a little busy or cluttered. It needs to be simplified even further. A distinct improvement over screen in CALTRANS truck.
   ◊ Put display on a head-up reflected on windshield.
   ◊ Would be nice to use during snow conditions to get feel for actual effectiveness.