MINNESOTA, USA INTELLIGENT VEHICLE INITIATIVE

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Abstract

In November, 1999, the United States Department of Transportation Federal Highway Administration (FHWA) awarded a major Intelligent Vehicle Initiative (IVI) grant to the Minnesota Department of Transportation (MnDOT). Minnesota's project was a three-year Generation '0' Specialty Vehicle Field Operational Test of technology providing lateral guidance and collision avoidance warnings to drivers in low visibility conditions. In addition to MnDOT and FHWA, there were a variety of other public and private partners participating in the project. Active operational testing was conducted over the winter of 2001-2002.

The intent of the project was to identify the safety and operational impacts of the technology, to guide future decisions regarding installation on specialized vehicles, and to encourage the development and appropriate deployment of such systems on all vehicle platforms. The technologies were tested in four snowplows, a State Patrol squad car, and an ambulance on a fifty-mile rural highway. A key aspect of the project was optimization of driver interfaces from a human factors perspective. This paper provides an overview of the project including technologies and evaluation approach. The deadline for submission of this paper does not allow the evaluation results to be presented in this text. However, the project results will be described at the symposium presentation.

Background

In Minnesota, approximately one of every five accidents on state roads is related to weather. Poor visibility is a contributing factor in accidents during adverse weather and also causes significant travel delays. Mn/DOT spends over $30 million annually on snow and ice operations to address pavement conditions. However, until recently, the issue of driver visibility could not be directly addressed, other than to advise motorists to keep their windshields clean.

Drivers responsible for public safety (ambulances, police squads, snowplows, etc.) must be able to operate under poor visibility conditions. Responding to accidents, rescuing stranded travelers, and keeping the roads open are all mission-critical endeavours. These specialty vehicles themselves are involved in significant numbers of accidents involving personal injury, vehicle and property damage. For example, Mn/DOT's 800 snowplows annually are involved in approximately 140 accidents with other vehicles, cause millions of dollars in damage to property (vehicles, guardrails, signs, mailboxes, etc.) and receive extensive damage to the plows themselves. Furthermore, these accidents result in additional delays for motorists. When weather conditions become extreme, even these specialty vehicles must be pulled out of operation and roads closed, creating substantial economic loss, decreased mobility, and threats to public safety.

Run-off-the-road vehicles and lane change crashes represent a significant number of the nation's highway crashes. Nationally, one third

(15,000/year) of all fatalities on highways involve, single vehicle road departure (1). One in five crashes (1.2 million/year) is reported as a single vehicle road departure. One of every 25 crashes (200,000/year) is caused by lane change/merge.

A driver-assistive system is needed that will help keep vehicles in their lane and warn drivers of approaching obstacles, both fixed and moving. For several years, Mn/DOT has worked closely with the University of Minnesota to develop automated and assistive systems for heavy-duty vehicles that improve safety. Several past and on-going field-tests with University and other partners have produced successive generations of technology.

Field Operational Test Concept

The Minnesota's IVI field operational test identified four goals for the field operational test:

1) Develop a fully-integrated driver-assistive technology solution.
2) Refine the system for various vehicle types.
3) Test the system in a real-world environment
4) Conduct a comprehensive evaluation of benefits, costs, and deployment potential.

The project developed a "Generation 0" system that is ready for widespread deployment; the evaluation identifies marketplace potential and barriers to implementation. The technology will eventually be applicable to light passenger vehicles in addition to specialty vehicles.

The project included a number of public and private partners including the University of Minnesota, 3M, Altra Technologies, International Truck and Engine, the Minnesota Department of Public Safety-Minnesota State Patrol, McLeod County, and the City of Hutchinson/Hutchinson Ambulance.

The field operational test took place on fifty miles of State Trunk Highway 7 between Hutchinson and Minnetonka, Minnesota as well as on some adjacent county roads. Highway 7 is typical of many rural, mostly two-lane roads in Minnesota, and experience relatively heavy truck and commuter traffic along with blowing and drifting snow. Numerous safety and operational problems related to roadway conditions and driver behavior on Highway 7 have been documented that are directly relevant to the technologies being employed in the project.

System Technology

The driver-assistive system consists of several components:

Collision Warning System – This system uses radar around the vehicle to detect and inform the driver of approaching obstacles. Radar detectors are mounted on the front, sides and rear of the vehicle

Vehicle Guidance and Driver Interface – Developed by the University of Minnesota, this system uses a windshield Heads Up Display (HUD), Differential GPS, and digital mapping/geospatial database of the corridor to project an image of lane boundaries (colored paint striping) and fixed roadside features (guardrails, signposts, etc.) allowing the driver to "see" the roadway. This display incorporates the outputs of the crash warning system; graphical icons change in size and shape to represent the status of approaching objects that pose a threat.

Magnetic Lateral Warning and Guidance System – Developed by 3M, this system (no longer commercially available) uses magnetic pavement marking tape that can take the place of regular lane striping. The tape can be either grooved in the existing pavement and secured with an adhesive, or underlayed during construction. A magnetic sensor on the vehicle detects the tape when within one meter proximity and indicates to the driver via the HUD the vehicle's position within the lane.

Other Driver Warning Devices – Other visual, audible and tactile warnings are provided for the vehicle drivers including a vibrating seat and audible alarm for lane departures and LED flashing lights for side-radar detected objects when the vehicle is changing lanes.

The DGPS and magnetic tape system both provide lateral guidance. The intent is to provide back-up technology in case of primary failure (for example, the loss of GPS signal in certain areas). For purposes of the project, and to control costs, only 8 of the 50 miles of TH 7 have the tape striping, in addition to 6 miles of a nearby County Road.

A key aspect of all projects was to design these systems such that they are useful and not burdensome to drivers. Drivers were extensively involved through outreach sessions, surveys, simulation studies and field-testing. The University of Minnesota has conducted human factors evaluations of various design solutions in both the lab and field to determine the optimal design. Ambient lighting conditions, positioning of displays and types of warnings are of particular interest. A specially developed in-vehicle camera system was developed to help monitor the responses of drivers to various situations and conditions. The camera system was part of a comprehensive automated on-board data-acquisition system that records road vehicle manoeuvres and driver actions. In addition, 6 roadside visibility stations were installed along the corridor to verify visibility and weather conditions.

Drivers in three Mn/DOT snowplows, one McLeod County snowplow, a State Patrol squad and a Hutchinson ambulance were included in the test. Both baseline information and test data was collected for the evaluation. Road maintenance supervisors, vehicle equipment supervisors, program administrators and policy-makers for the partnering organizations were solicited for input regarding system effectiveness, impacts, and implementation issues.

Evaluation Approach

The approach to evaluation developed for the project included the following goals and key questions:

Goal: Safety/Driver Performance

- Will the implementation of these technologies lead to a measurable increase in operator or public safety?
- How will the technology affect driver performance with respect to behaviours such as lane keeping, obstacle avoidance, headway, and reaction?
- How will the technology affect job satisfaction, workload, situational awareness, stress, and fatigue?

Goal: Fleet Productivity

- Will use of these technologies lead to an increase in the productivity and effectiveness of snowplow (and other) operations?
- How will the benefits compare to the costs?

Goal: Efficiency

- Are snowplow (and other) operations more efficient as a result of these technologies?

Goal: Driver Acceptance

- How do snowplow (and other) operators respond to the technologies?
- Do they understand the systems?
- What are the effects on driver stress, workload, and fatigue?
- How could the driver-vehicle interface be improved?

Goal: System Performance

- What is the expected reliability, accuracy, and maintainability of the IVI system?

Goal: Institutional/Legal/Societal Issues

- How will the integrated technologies impact current rules and policies; what are the key liabilities, organizational, and interagency issues?

Project Results

The operational test was completed on March 31, 2002. The winter season that the field operational test was conducted was an unusual one and will be written in the history books as one of the mildest winters on record for the Twin Cities as well as much of Minnesota. There were a number of records

that were broken, or very close to being broken since modern record keeping began in 1891.
November 2001 through February 2002 finished as the warmest November through February on record. The average temperature for November 2001 through February 2002 is 31.8° F. This tops the previous record November through February by over two degrees. February 2002 wound up being the fifth warmest February on record with an average temperature of 28.4° F. March came in "like a lion" with much colder than normal temperatures and produced snowfall events used to analyze the project.

Highest Average Temperatures on Record. (November – February for Twin Cities, Minnesota)

Rank	Year	Avg. Temp (° F)
1	2001-2002	31.8
2	1930-1931	29.5
3	1999-2000	27.8
4	1931-1932	27.0
5	1997-1998	26.5
6	1986-1987	26.4
7	1918-1919	26.3
8	1941-1942	26.0
9	1982-1983	25.9
10	1953-1954	25.9

To date the operational test area has received approximately 51.5" of snow. Obviously, this is a generalized estimate the entire 50-mile corridor has received. The gradual transition from a major metropolitan area to a rural setting presents opportunities to evaluate the technology in both an urban and rural setting.

During the operational test there were only two significant snow events that created limited visibility situations. The first event was a 3-5 inch snowfall with very high winds; this event lasted 12-18 hours. The second event was a 12-16 inch snowfall that lasted over 48 hours. These two events will be used to draw our conclusions from the operators and data retrieved from the lateral guidance and collision warning systems.

The project team has requested an extension of the project. Extending the project will allow the technology to be tested for one additional winter season and provide additional information so that scientifically valid conclusions can be ascertained.

Due to the paper submission deadline it was not feasible to present any evaluation findings in this manuscript. However, project results and preliminary evaluation findings will be presented at the presentation during the symposium.

References

(1) US DOT Intelligent Vehicle Initiative brochure #FHWA-OP-99-034