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Vehicle-Based Lane Departure Warning Systems Shown Effective in Simulator Testing

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TECHNICAL SUMMARY

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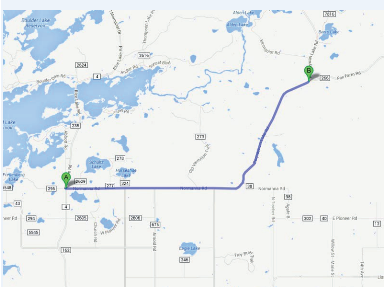
LRRB PROJECT COST:
$100,000



The St. Louis County roadway was one of two roadways modeled for use in the simulated routes.

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What Was the Need?

A run-off-road crash occurs when a single vehicle leaves the roadway on the left or right, resulting in a rollover, collision with an object or collision with another vehicle. These crashes account for about half of all roadway fatalities in the United States. In 2013, 387 individuals were killed in traffic crashes in Minnesota alone, and nearly 49 percent of those fatalities can be attributed to run-off-road crashes. In fact, this number could be higher as some crashes may not be properly reported as a roadway departure. The majority of these crashes occurred on a rural two-lane roadway.

This study provides feedback on drivers' behavioral response to a haptic-based lane departure warning system to reduce the severity of run-off-road events. Results showed a decrease in the severity of such events.

One potential tool to address this problem is an in-vehicle lane departure warning system. Using a GPS or highway infrastructure sensors, an LDWS tracks the vehicle's orientation and position relative to the lane boundary and issues a timely visual, auditory and/or haptic (tactile) warning to alert the driver that the vehicle is leaving the lane.

Minnesota transportation agencies need to be involved with the development of an LDWS since adopting these systems might require infrastructure changes and affect future roadway development.

What Was Our Goal?

The goals of this project were to determine how drivers respond to an LDWS and the extent to which they might rely on the warning information.

What Did We Do?

To safely simulate a realistic driving experience, the research team used a portable driving simulator with a haptic-based feedback system: Warnings were administered through vibrations on either the right or left side of the seat pan, depending on the direction of the lane departure.

Sixty study participants were divided evenly into three experimental conditions corresponding to different system reliability levels to see how these levels affected behavior. Participants received warnings on 100 percent, 90 percent or 70 percent of the occasions they drifted from the lane.

Researchers used rural roadway centerline data collected in the MnDOT-funded project [Development of a Digital Highway Framework to Facilitate Crash Avoidance] to create two sample roadways for the simulations. The speed limit was 55 mph, and each roadway took about 12 minutes to traverse.

Each participant group performed three sets of drives: one set of baseline drives with no LDWS and two sets of drives with the LDWS. Each set of drives consisted of four routes—both directions on each of the two roadways. On each route, participants encountered 10 wind-induced run-off-road events comparable to a 55 mph crosswind sustained for four seconds. During these drives, participants engaged in a secondary task

continued

> *"MnDOT wanted to know what kind of lane departure warning systems are effective, such as haptic vs. audible vs. visual, as well as what kind of system reliability would inspire the most trust in the driver."*
>
> **—Victor Lund,**
> Traffic Engineer,
> St. Louis County

> *"It's not surprising that participants reported false positives or false alarms during the experiment since striking an optimal balance between false or early alarms and missed or late alerts is difficult to achieve with all in-vehicle warning devices."*
>
> **—Alice Ton,**
> Assistant Scientist,
> University of Minnesota
> HumanFIRST Program

The HumanFIRST portable driving simulator includes three 32-inch high-definition displays, rearview mirror displays and vehicle controls. Vibrating motors installed in the left and right sides of the seat pan provide lane departure warnings. Drivers performed a secondary, distracting task via an 8-inch touch screen LCD on the right side, 25 degrees below the driver's horizontal line of sight.

performed on a touch screen that involved a visual search, target matching, working memory and response input.

The experiment measured:

- **Total time out of lane:** the overall duration of a single lane departure.
- **Maximum lane deviation:** the greatest distance traveled outside of the lane markings.
- **Driver workload:** an assessment of mental demand, physical demand, temporal demand, effort, performance and frustration.
- **Trust in the LDWS:** a measure determined via an open-ended questionnaire.

Additional variables were included in the study design, including road geometry, distraction, age, sex and personality traits, to help the researchers better understand the relationship between reliability levels, total time out of lane and maximum lane deviation.

What Did We Learn?

The study demonstrated that a haptic-based LDWS offers a promising means to reduce the severity of run-off-road events. Using the LDWS led to significant reductions in the total time spent out of lane and maximum lane deviation, even at the 70 percent system reliability level.

Reducing speed also reduced lane deviations. Participants who were engaged in the secondary distraction were more likely to travel far out of lane. The additional interaction demonstrated between velocity and curves to predict maximum lane deviation severity highlights the fatal combination of distracted drivers who enter a curve at an unsafe speed.

Subjects indicated trust in the system, but there was no indication of overreliance on it: Driving performance for those who drove without the LDWS after they had been exposed to it did not decrease. Notably, at all three reliability levels, many participants reported that the system provided false alarms.

What's Next?

The research report recommends that further studies use an increased sample size to better understand how drivers adapt to an LDWS, including their potential overreliance on the system. Future iterations of the LDWS should look to reduce false alarm rates while maintaining a level of reliability that facilitates users' trust in the system.

This Technical Summary pertains to the LRRB-produced Report 2015-35, "Human Factors of Vehicle-Based Lane Departure Warning Systems," published June 2015. The full report can be accessed at mndot.gov/research/TS/2015/201535.pdf.

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