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LRRB
LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

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LRRB COST:
$80,902

TOTAL PROJECT COST:
$161,803

Researchers tested many curve warning sign progressions to determine which option drivers would most quickly understand.

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In-Vehicle Curve Speed Warning System for Rural Road Curves

Researchers developed and demonstrated the effectiveness of an in-vehicle curve speed warning system. The technology warns the driver of an imminent curve and the recommended speed to navigate the curve safely.

What Was the Need?

Vehicle lane departures at curves cause a significant portion of fatal crashes on rural Minnesota roads. Infrastructure-based methods such as standard curve warning signs and sensor-triggered dynamic warning displays are helpful; however, their cost is difficult to justify for low-traffic rural roads, even though that is where hazardous curves are most common.

One possible solution that could both offer adequate warning to drivers and avoid costly infrastructure changes is the use of in-vehicle technology to provide a timely curve speed warning to drivers. MnDOT along with Minnesota city and county agencies sought to learn about the feasibility of such an in-vehicle curve speed warning system.

What Was Our Goal?

The objective of this project was to develop and evaluate an in-vehicle dynamic curve speed warning system using a smartphone application (app). Researchers also sought to collect driver behavior data for use in future system development.

What Did We Do?

The project began with an extensive literature review into the visual, auditory and cognitive processes that underlie systems for in-vehicle- and infrastructure-based warnings and decision-making. Investigators considered standards and guidance on cognitive workload, display positions, auditory message design and visual design for safe vehicle operation and user satisfaction.

Researchers designed a curve speed warning interface, focusing on creating the most effective messages and warning format for delivering curve warning messages (visual, auditory, vibrational). They examined factors such as approach speeds, distances and time–distances from curves that would determine the most effective warnings. Through a usability study with 10 drivers, researchers collected feedback about several prototype warnings.

The interface was implemented into a smartphone app that researchers developed using knowledge gained from building the Teen Driver Support System (TDSS) app, which warns novice drivers about their speed and other driving behaviors. The TDSS was already capable of data collection and allowed unique warnings to be deployed based on GPS-provided locations. The new system allowed warnings to be initiated upon approach to identified curves, depending upon the speed and distance to the curve.

Finally, researchers designed an experimental trial and recruited participants to drive in a closed course pilot study using the curve speed warning app. The pilot study required in-depth feedback from drivers and tested warning timing thresholds, deviation from standard curve speed warnings, as well as drivers' impressions of levels of distraction or irritation, clarity of the warning, ease of use and trustworthiness of the system.

continued

"This in-vehicle warning system is potentially an inexpensive solution that could save lives on rural roads."

—Bradley Estochen,
Traffic Safety Engineer,
MnDOT Office of Traffic,
Safety and Technology

"While the system we developed was implemented as a smartphone app, the goal was to produce a warning strategy that could be deployed in other ways, such as integrated into a vehicle's built-in warning system."

—Brian Davis,
Research Fellow,
University of Minnesota
Department of
Mechanical Engineering

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The project's pilot study was conducted with recruited drivers on a closed course at the Minnesota Highway Safety and Research Center in St. Cloud, Minnesota, which offers multiple configurable driving courses and limited safety risk.

What Did We Learn?

Closed course testing showed that the prototype system, which functions on an Android smartphone, was effective in warning drivers to slow before a curve and that drivers were able to use the system without distraction.

Results from the literature review and usability studies conducted through the University of Minnesota's HumanFIRST Laboratory guided researchers to develop a system based upon optimum human usability factors. All aspects of the system were carefully investigated and tested:

- The system must be located just below or to the right and below the driver's line of vision to minimize distraction (such as in the upper dash area).
- Visual aspects of the warning are conveyed with simple icons rather than readable text: a diamond-shaped curve sign with the speed below, against a black background. The visual warning is a white, yellow or flashing red curve sign, depending upon the distance to the curve.
- An audible warning is conveyed through short, simple phrases, beginning with the context ("Curve ahead"), followed by the distance ("One-half mile") and then a command ("Reduce speed"). A computer-generated voice is used rather than a male or female voice.
- The optimum distance before the curve to activate the warning was determined through testing of three distances. Drivers in the pilot study indicated the distances that seemed best to hear and react to the warning.

What's Next?

Researchers selected the warning distances used in this experiment, but future work could develop a model for determining warning distances and timings for a given curve advisory speed and approach speed limit. The result would be a more automated method for assigning warning activation criteria for curves. Further research would also include field operational testing to assess the system's effectiveness and robustness on Minnesota's roadways.

This Technical Summary pertains to LRRB-produced Report 2018-12, "In-Vehicle Dynamic Curve-Speed Warnings at High-Risk Rural Curves," published March 2018. The full report can be accessed at mndot.gov/research/reports/2018/201812.pdf.