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LRRB
LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

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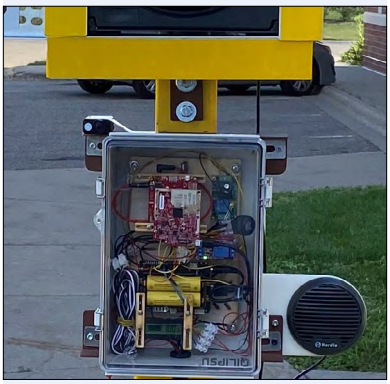
$240,793



Low-cost sensors and microprocessors allow algorithms to track oncoming vehicle trajectories.

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

# Developing Smart Signs for Traffic Control in Work Zones

## What Was the Need?

Providing traffic control in work zones is one of the highest risk jobs in the country. Flaggers are often considered the first line of defense against distracted, inattentive or aggressive motorists who may intrude into these work areas.

Making work zones safer is an important component of Minnesota's Toward Zero Deaths goal. Digital smart signs that are equipped with sensors and controlled remotely by workers have been developed and tested in work zones. Despite warning workers of potentially dangerous situations and alerting drivers to slow or stop, the signs have had varying levels of success due to operational complexities, cumbersome size and prohibitive cost.

*Work zone flaggers have a dangerous job as drivers may not heed temporary traffic directions. A new, cost-effective system that tracks an oncoming vehicle's trajectory can warn workers of an unsafe intrusion into the work zone and alert drivers to slow or stop.*

The Local Road Research Board was interested in exploring a portable and easy-to-use system that would alert both drivers and workers of a vehicle's unsafe approach to a work zone. In addition to the technical capabilities to detect potentially threatening vehicles, the system needed to account for the needs and preferences of the flaggers who were directing traffic.

## What Was Our Goal?

This project sought to develop an affordable, portable intrusion detection system that electronically monitors approaching vehicles to warn drivers who are unsafely approaching or entering a work zone.

## What Did We Do?

An initial design of the intrusion detection system was a modified Stop/Slow paddle that flaggers could rotate. The system included a vehicle trajectory tracking capability that used low-cost radar sensors, an embedded microprocessor and advanced algorithms to monitor a vehicle's position and speed to predict a potential intrusion. An audiovisual warning system sounded when unsafe driving was identified, and a camera captured the event and vehicle information. The weight of the electronics and accompanying battery necessitated mounting the unit on a rolling platform for ease of movement.

Roadway maintenance employees from MnDOT and Washington County provided feedback about the safety system, including its maneuverability and efficacy to direct traffic and alert both workers and drivers to potential intrusions.

This feedback prompted a redesign to a modified, remote-controlled traffic signal that would display a red ball for Stop, a flashing yellow ball for Yield and a solid yellow ball for Slow. According to the workers, the traffic signal colors could better communicate the desired driver behavior, and the remote-control capability would allow users to still be visible while located a safer distance away. The redesigned traffic signal was mounted on a rolling platform similar to the one used with the first prototype so that it could be disassembled for easy transport. The attached vehicle trajectory tracking system's sensors and algorithms were developed and tested to capture approaching vehicles and warn those detected of imminent intrusions.

The modified traffic signal design underwent usability testing in a driving simulator, which created realistic roadway contexts and configurations. Driving exercises took 36 participants through

*continued*

*"This research is an important step in finding an easy-to-use traffic control system for work zones that keeps not only the worker operating the system safe, but all staff within the work zone. Driver distraction continues to be a problem within work zones and this type of system may provide improved safety for the workers."*

**—Victor Lund,**
Traffic Engineer, St. Louis County Public Works

*"The intrusion detection system developed in this project using low-cost sensors is a significant advancement. Worker feedback on the proposed systems is invaluable to ensure future designs will meet their needs and expectations."*

**—Nichole Morris,**
Director, HumanFIRST Laboratory, University of Minnesota Department of Mechanical Engineering

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Driving simulator participants trusted, accepted and understood a flagger with a Stop/Slow paddle more than the prototype signal.

two work zones—one with a traditional flagger and one with the portable traffic signal and auditory alarm—to compare driver stopping behavior. Researchers assessed participants' understanding and acceptance of the prototype signal compared with a traditional flagger.

Based on the usability testing results, researchers again modified both the flagger's Stop/Slow paddle and the prototype design before conducting a second round of testing. An LED border that was added to the paddle flashed red when an intruding driver was detected, and an audio alarm sounded similar to the auditory warning of the traffic signal. To enhance the visibility of the prototype system, a yellow border was added around the signal, a sign with the message "Stop Here on Red" was attached to the signal, and a worker was positioned near the prototype similar to the location of the traditional flagger.

## What Did We Learn?

During the first round of testing, drivers had significantly more stop failures and late stops with the prototype signal than the traditional flagger, but were slightly less likely to remain stopped than with the traditional flagger. The modified flagger sign testing found drivers improved their stopping behavior and were less likely to fail to remain stopped with the enhanced lighted border and auditory alert, which outperformed the traffic signal alert system with enhanced conspicuity. While drivers were less likely to safely stop with both the original and modified traffic signal alert systems, they tended to perceive the modified traffic signal to have greater visibility, clarity of instruction and authority compared to the flagger, indicating continued need to support flaggers in their work to direct traffic.

Testing after modifying both systems showed the modified flagger with the alarm system promoted the safest driving performance. Modifications to the prototype signal did not significantly affect driver behavior or improve perception of that system. However, nearly all participants fully complied with the flagger system with the LED border and audiovisual alarm.

The vehicle trajectory tracking system, used in both the Stop/Slow paddle and the prototype signal, was successful in identifying all intruding test vehicles and providing warnings.

## What's Next?

A follow-up pilot study is underway to further modify the Stop/Slow flagger system to allow for remote operation. Researchers will focus on road worker acceptance and determine if the driver behavior in simulations extends to real-life settings. Further exploration could include methods to alert all workers within a work zone of an intruding vehicle.

*This Technical Summary pertains to Report 2023-26, "User-Centered Smart Traffic Sign Development Study," published June 2023. More information is available at* mdl.mndot.gov.