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LRRB
LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

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TOTAL PROJECT COST:
$88,896

LRRB PROJECT COST:
$30,689

Snow may be cleared from wheel tracks but still cover lane markings, impeding the lane-finding function in AVs.

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

Impacts of Autonomous Vehicles on Minnesota Roads

What Was the Need?

Fully autonomous vehicles (AVs), though not quite road-ready, are progressing. However, vehicles that are partially autonomous—those that include adaptive cruise control, automated lane keeping and automated blind spot monitoring—are already on the roads.

As research into AV technology continues, practical questions arise about how these vehicles may impact traffic, infrastructure and maintenance operations. An AV's lane-keeping function, for example, depends on the visibility of lane markings, which may be covered with snow or may temporarily change in a work zone.

The Local Road Research Board (LRRB) and MnDOT wanted to begin exploring these operational implications, understanding that the ramifications of AVs to Minnesota's roads may change as the technology progresses.

As autonomous vehicle technology evolves, transportation agencies want to understand how road maintenance and traffic operations may also need to evolve. New research begins to identify potential needs and further questions for winter road maintenance, work zones and traffic flow.

What Was Our Goal?

This project sought to understand the operational and maintenance implications of AVs within the transportation system in the contexts of winter conditions, construction zones, and traffic flow and safety.

What Did We Do?

An AV purchased by the University of Minnesota's Center for Transportation Studies provided an opportunity for a series of experiments at test locations and on highways and local roads. The car was retrofitted with numerous sensors to perceive the surrounding environment, including distance and relative velocity of preceding vehicles. A Mobileye sensor identified lane markings. Software processed and fed the information to lateral and longitudinal control systems to steer and regulate speed, respectively, unless manually overridden.

The vehicle was first evaluated at the MnROAD testing facility to understand the vehicle's performance in ideal conditions and to ensure the systems were operating effectively. Driving the AV on local freeways with varying snow cover identified the vehicle's capability to stay in the lane's boundaries. Investigators manually drove when lane markings were covered but still gathered data measuring the detection quality of the lateral controller. An assessment of longitudinal control determined whether any level of active snowfall inhibited the detection of a preceding vehicle and how the vehicle performed in blowing snow when traveling behind a snowplow.

Next, light (greater than 40 mph), medium (20 to 40 mph) and heavy (less than 20 mph) traffic on local highways provided a testing ground to compare differences in speed, acceleration and following distance of manual and autonomous driving modes. Lastly, investigators tested the vehicle's autonomous mode at MnROAD in a variety of work zone configurations such as temporary or conflicting lane markings and cones or barrels placed at various spacings.

What Did We Learn?

The initial testing demonstrated the AV's excellent steering on straight roads but poor performance on curves. The vehicle's autonomous mode was good at matching a lead vehicle's speed but at slower speeds, the speed changes caused lurching. Researchers completely reworked the

continued

“Local transportation agencies and MnDOT need to understand the implications of autonomous vehicles on the daily operation of our roads. The results of this project will shape our ongoing inquiry as technology progresses.”

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

“In addition to informing the agencies on how roads can accommodate AVs, this research could also help vehicle manufacturers understand regional considerations for AVs such as winter driving.”

—Rajesh Rajamani,
Professor, University of Minnesota Department of Mechanical Engineering

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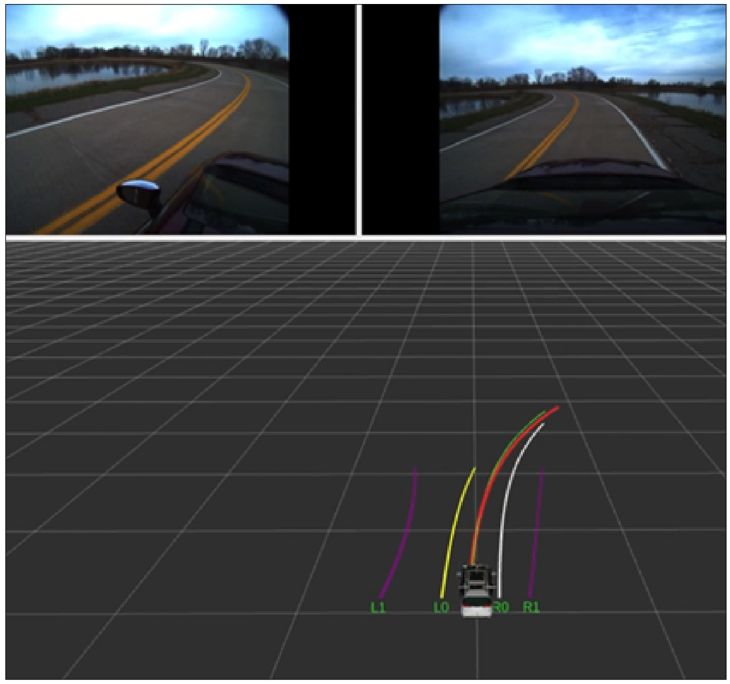

The AV steering controller performed poorly on sharp curves, as shown in this in-vehicle display. The road curves to the left (top photos) but the system estimated that the lane curves to the right (bottom photo, shown between the white and yellow lines).

longitudinal control software to operate more smoothly and effectively at all speeds for the remainder of the experiments.

In the evaluation of the AV’s winter driving performance, wet-only roads did not hinder lane marking detection ability. However, snow partially or fully impeding lane line visibility could significantly reduce lane detection and make autonomous lateral control very challenging. Unless other control methods that don’t rely on visibility of pavement markings are developed, researchers recommend that agencies clear snow from lane lines.

In light and medium traffic, the AV accelerated and decelerated with less magnitude than the preceding vehicle, indicating that autonomous driving results in decreased speed changes and improved traffic flow over manual driving. Despite the rapid stop-and-go behavior forced by heavy traffic, the AV consistently performed better than the preceding manually driven vehicle.

Work zone configurations presented significant navigation challenges for the AV. Cones placed so as not to visually impede lane markings did not impact detection, but cones placed on top of markings needed to be at least 6 feet apart. Barrels impacted detection slightly more in the same circumstances. With a sufficient density of cones or barrels, it is possible to make lane lines either hidden or visible. In autonomous mode, the vehicle did not detect temporary lane markings nor could it operate with conflicting markings. Early warning of an upcoming construction zone would allow AV drivers to transition to manual driving mode.

What’s Next?

The investigation into how AVs will interact with transportation infrastructure and the implications for traffic, operations and maintenance will necessarily continue as the level of automation increases in vehicles. An inquiry into local agency policies on how much snow is acceptable on the roads, for example, would inform whether different winter maintenance strategies may be necessary for AVs to operate in winter conditions.

Agencies may benefit from identifying strategies for construction zones that are compatible with AVs. A more complete understanding of the potential benefits of AVs for traffic improvements, including fewer rear-end crashes, smoothing traffic flow and accommodating more vehicles, could also help local transportation agencies and MnDOT integrate AVs into transportation networks.

This Technical Summary pertains to Report 2023-23, “Influence of Autonomous and Partially Autonomous Vehicles on Minnesota Roads,” published May 2023. More information is available at mdl.mndot.gov.