In an effort to reduce dangerous right-angle crashes at rural intersections, the Minnesota Department of Transportation (MnDOT) has deployed dynamic warning signs at approximately 52 sites throughout the state. Using sensor technologies, these signs provide real-time traffic information to motorists at non-signalized intersections where cross traffic does not stop, warning drivers on the minor road when it is unsafe to enter the intersection. However, a number of sign-related complaints have been received from local road users.

Team identifies design alternatives for warning signs at rural intersections

For years, automated vehicles (AVs) have been the subject of research, testing, and avid speculation. And while the technology is developing rapidly, AV-focused policies are much further behind.

With this in mind, CTS hosted a two-day Strategic Visioning Workshop for Automated Vehicles in Minnesota on June 25 and 26. The event convened about 100 representatives from across the public, private, academic, and nonprofit sectors to define and advance an agenda related to the future of AVs in Minnesota.

Strategic visioning workshop explores future of automated vehicles in Minnesota

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New performance measures identify truck delays and bottlenecks

Twin Cities businesses need a reliable and accessible freight network to compete in the Upper Midwest and beyond. However, many of the metro’s roadways are clogged with traffic during peak periods, disrupting truck schedules.

In a recent project, U of M researchers developed new performance measures to identify more clearly the extent of system impediments for freight vehicles during peak periods in select corridors. The study, sponsored by the Minnesota Department of Transportation (MnDOT), builds on previous research that identified area bottlenecks.

“In this and the previous study, we examined increasingly more detailed and specific data to learn just where and when congestion and delays develop within the roadway system,” says principal investigator Chen-Fu Liao, senior research associate in the Department of Mechanical Engineering. “Now, with knowledge of problematic locations and times of day, it will be possible to approach mitigation with a greater probability of success.”

For the study, the research team worked with stakeholders to prioritize a list of Twin Cities metro area (TCMA) freight corridors that have data coverage in the National Performance Measure Research Dataset (NPMRDS). (The dataset includes travel-time data from probe vehicles at five-minute intervals for all National Highway System facilities.) Researchers obtained 24 months of NPMRDS data covering the selected corridors, along with GIS-based data and other travel-time sources. They then used their data analysis framework to generate measures of truck mobility, reliability, and delay at the corridor level.

“The precise tools and metrics revealed important information about truck mobility on different kinds of roadways, truck reliability on corridors during AM and PM peak periods, and the exact locations and extent of the delays within the TCMA highway system,” Liao says.

For example, truck congestion/delay measures revealed that the top five TCMA corridors with significant congestion had an average total delay on a regular weekday of more than 3,000 hours in the AM and PM peak periods, with the PM delays notably greater (see table below). Also, in the AM peak, eight additional interchanges had average daily delays of over 300 hours per mile. In the PM peak, nine interchanges and eight segments showed significant congestion.

All reliability measures indicated that truck travel time in the PM peak period is less reliable than in the AM peak period. Roadways with signalized or unsignalized intersections were less reliable for truck traffic than freeways. The truck mobility analysis found that roadways with intersections have higher travel times, particularly on county roads in the AM and PM peak periods.

“This research provided tools and metrics with levels of precision we didn’t have before concerning truck congestion,” says Andrew Andrusko, principal transportation planner with MnDOT’s Office of Freight and Commercial Vehicle Operations. “We needed the results of this research project to be able to take the next steps toward future investment in addressing freight bottlenecks and other strategic remedies.”

### AM Peak

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<tr>
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### PM Peak

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The top five congested AM and PM peak corridors in the Twin Cities metropolitan area, with the average total daily delay for trucks for those periods.
High-occupancy toll (HOT) lanes are one of the many tools available to help manage traffic demand on congested urban freeways. When managing HOT lanes, roadway engineers must decide whether to allow open HOT-lane access at most points or to close access and only permit drivers to enter or exit these lanes from select ramps and access points.

A new software tool developed by researchers at the Minnesota Traffic Observatory (MTO) allows MnDOT’s Regional Transportation Management Center (RTMC) to better design HOT-lane access for a good balance between service to the driving public and safety of the facility. The tool assumes an open design and produces safety and mobility performance measures along the HOT-lane facility. Given the desired balance, the tool also helps engineers design the optimal location of restricted access sections.

“While open access can greatly increase mobility by permitting vehicles to access the HOT lane as quickly as they are able after entering the freeway, there may be some safety concerns with allowing lane changes at any point,” says John Hourdos, MTO director. “HOT lanes tend to have lower densities and higher speeds, so vehicles crossing the lane boundary must negotiate a speed change, which can cause the vehicles approaching from behind to form a shockwave that can lead to a crash.”

In the Minneapolis–Saint Paul metropolitan area, two major freeways currently include designated HOT lanes, and several more are planned or under construction. Until recently, drivers could only enter or exit HOT lanes from select ramps and access points. MnDOT now prefers open-access HOT lanes for the increased options they offer road users but needed a way to monitor and predict the incidence of shockwaves and the safety and mobility problems they create.

The researchers leveraged and integrated findings from three previous studies to create the new software system. It draws on historical data to identify patterns of traffic demand over time and generate predictions of points in the HOT lanes at which shifts from open to closed access will offer the most benefit. The program is designed to integrate smoothly with the RTMC’s current software and data capabilities and includes a module for access design, a module for generating data, and a web application.

“This tool delivered to MnDOT is calibrated for the Twin Cities,” Hourdos says. “It takes real-time data and diagrams each location separately for lane changes and reaction time. It took theoretical ideas and made them usable.”

The new tool has been embraced quickly by engineers at the RTMC, who plan to use the software to report HOT-lane performance and to create analyses and recommendations for changing specific locations from open access to closed access.

“Prior to this project we didn’t have a tool to assist us in designing HOT-lane access,” says Brian Kary, director of traffic operations at the RTMC. “There is a lot of debate around the country surrounding high-occupancy designs. This tool helps us develop designs and monitor existing corridors.”

The MnDOT-sponsored project also offers benefits for the broader transportation community, in which experts debate the relative merits of open- and closed-access HOT-lane designs. “With MnPASS, MnDOT has adopted the approach of an open design for HOT-lane access,” Kary says. “This software allows us to evaluate the performance of the MnPASS open design, which not only benefits MnDOT but helps to inform the national discussion on HOT-lane design.”
Advances in connected and automated vehicle technologies have resulted in new vehicle applications, such as cooperative adaptive cruise control (CACC). Using CACC, cars can follow each other more closely, with braking and accelerating done cooperatively and synchronously. Previous studies have shown significant increases in throughput as a result. The impact on larger networks as a whole, however, is unclear.

To address this information need, a research team developed a simulation model that allows users to predict the more regional, network-wide impacts of CACC on traffic congestion. “Our mesoscopic simulation model lets us analyze congestion not just on the lanes with CACC, but also on nearby arterials and other roads,” says Michael Levin, assistant professor in the Department of Civil, Environmental, and Geo-Engineering.

To test their new model, the team calculated the impacts from implementation of CACC-exclusive lanes on two networks in Texas. One was a 28-mile corridor of I-35 near Austin, with 220 nodes, 95 zones, and 315 links; all vehicles were assumed equipped with CACC. Results indicate that CACC reduced travel times by more than 50 percent, Levin says.

The other network studied was Round Rock, with 2,744 nodes, 716 zones, and 4,236 links. The modeling assumed all freeway links had one lane converted into a CACC-managed lane. This reduced freeway capacity for non-connected vehicles; connected vehicles (CVs) could choose to use either regular lanes or the CACC lane. Market penetration of connected vehicles was assumed at 50 percent. “The model found the CACC lanes would have significantly higher speeds and significantly higher reliability,” Levin says.

A surprising result for Round Rock, he notes, is that with the CACC implementation, average travel times for all vehicles were higher than without the CACC lane. Non-CV demand for arterial roads increased because of the reduction in available lanes on freeways, and CV demand rose on arterials connecting freeways. “In addition, even though connected vehicles had better travel times and higher speeds than non-connected vehicles, CACC still increased CVs’ overall travel times due to changing congestion patterns elsewhere in the network,” he says.

The team’s results also indicate that adding CACC lanes at low CV market penetrations is likely to cause congestion. “At 15 to 25 percent market penetration, CVs create enough demand to increase congestion for non-CVs,” he says. “Network analyses should be used to determine at which market penetrations, and at which locations, CACC lanes should be deployed to reduce city network travel times. Our model can be used in conjunction with microsimulation to analyze route choice on regional networks.”

The team’s work was published in a paper titled “Dynamic traffic assignment of cooperative adaptive cruise control” in the Transportation Research Part C 90 (2018) 114–133. Lead author was Christopher Melson (Louisiana State University); co-authors were Levin, Britton Hammit (University of Wyoming), and Stephen D. Boyles (University of Texas at Austin). The work was sponsored by the Data-Supported Transportation Operations & Planning Center and the National Science Foundation.
To address this issue, U of M human factors researchers studied the current sign to identify what features or layouts may be problematic and propose safe and efficient alternatives. “We directed special emphasis to the most vulnerable driver populations, such as older drivers and novice teenage drivers,” says Nichole Morris, director of the HumanFIRST Laboratory and the study’s principal investigator. The study was sponsored by MnDOT.

The research team first surveyed Minnesota county engineers regarding their experiences, perceptions, and complaints or comments from local road users. “In addition to the largely negative feedback from drivers, we learned that many county engineers incorrectly interpreted how the system functions—a number of them were not sure how the fail-safe/inoperable mode works,” Morris says.

Through iterative usability studies, researchers then examined alternative designs to produce three sets of sign options for a driving simulation study. The simulation study, with 120 participants, evaluated the safety effectiveness and efficiency of the sign options among teen drivers, middle-aged drivers, and older drivers.

The results indicate an overall safety benefit of sign deployment. “All the sign options except for one enhanced drivers’ gap-acceptance performance,” Morris says. “At intersections with inadequate sight distance, gap acceptance tended to be significantly better.”

The warning system’s benefits varied among the three age groups: middle-aged drivers demonstrated the most potential for safer gap acceptance; teenage drivers did not appear to be significantly assisted by the warning system, despite their self-reporting that the sign assisted them; older drivers tended to have a significantly reduced risk of accepting an unsafe gap but were also less efficient in using the system (they waited longer and rejected safe gaps more frequently).

The signs might simultaneously incur potential risks for drivers. “For example, the risk of stop-sign violations was found to be the greatest when the system was turned off due to a malfunction,” Morris says. Drivers also tended to check traffic much less often with the presence of the warning system.

After reviewing the study results, researchers identified an alternative sign design for future field tests that may demonstrate comparable safety benefits to the original sign with fewer potential risks. Specifically, certain design elements—an action word or icon—were recommended for consideration in follow-up field evaluations and future implementations.

“Intersection warning systems are an important tool for MnDOT as we push toward having zero deaths due to traffic crashes,” says Ray Starr, acting state traffic engineer with the Office of Traffic Engineering. “This study provides valuable information that is helping MnDOT consider any design changes for future versions of the warning system.” The findings may also have a broader implication for the design, development, and implementation of effective intersection countermeasures on rural, urban, and suburban roadways, Morris adds.
to AVs in the state. The workshop was sponsored by CTS, the McKnight Foundation, the Minnesota Department of Transportation, Hennepin County, and the Metropolitan Council.

In addition to featuring presentations by AV experts and transportation practitioners from around the country (see related article on page 7), the workshop engaged participants in the development of an action plan for Minnesota that focuses on deployment. This included outlining a vision, prioritizing strategies, and identifying champions to lead key plan elements.

One of the workshop’s first activities was a facilitated discussion in which participants explored the benefits to Minnesota of being a leader in AV advancement, potential challenges, partners needed for success, and big moves that could provide the greatest benefit in moving forward. Themes that emerged from the discussion included:

• AVs could help reduce the cost of transportation, increase access to jobs, address the equity gap, and attract a talented workforce.

• Our cold-weather climate presents unique challenges for AV technology, but it could also position us as a testing ground.

• To bring maximum benefits, we need to define our metrics around human-centered outcomes.

• Important partners include the private and public sectors, general public, freight industry, organized labor, builders/contractors, elected officials, and travel/tourism industry.

• Big moves could include establishing an AV corridor to demonstrate the technology in a controlled environment and distinguishing ourselves by focusing on people rather than just technology.

Participants also worked in small groups to create a vision for the state of AV deployment in Minnesota 10 years from now, including the progress that will be needed in key areas to make that vision a reality.

Based on those discussions, attendees collaboratively developed 18 proposed strategies in the areas of people mobility, freight mobility, traffic operations and safety, and planning, environment, and economic development. Each draft strategy includes suggested action steps, champions, partners, and timeframes. Examples include defining the problems AVs could help solve, developing AV freight pilot projects, educating the public about functions and limitations of AV technologies, and integrating the full cost of transportation into decision making.

Going forward, outcomes from the workshop will be used to help frame the direction for the future of AVs in Minnesota. Preliminary information has already been shared with the Governor’s Advisory Council on Connected and Automated Vehicles. A complete summary of the event, including the action plan and proposed strategies, will be available this fall on the CTS website.

The great transition

In the workshop’s opening presentation, Tim Papandreou, founder of City Innovate, shared his vision for the coming transition to an active, shared, electric, and automated transportation system. Key points from his presentation include:

• As AVs become commonplace, they’ll turn the entire transportation system on its head. City design will look different, as will freight movement and mobility management.

• Cities, states, and regions need to start thinking about transportation as a platform that’s part of a larger mobility ecosystem. Land use, street design, parking management, and performance metrics are key components.

• We need to develop a baseline for the true cost of transportation.

• Three new job types will be needed in the public sector: data scientists, behavioral scientists, and storytellers.

• Partnerships between government, industry, and academia are essential for success.

• The new system will be focused on people, not vehicles.

For more of Papandreou’s presentation, watch the full video recording at cts.umn.edu/events/2018/AVworkshop.
On the second day of the visioning workshop, attendees heard from a panel of experts who have experienced AV deployments in their jurisdictions. Panelists from public-sector agencies in Washington, Pennsylvania, and Texas shared their perspectives and offered advice based on their lessons learned.

What have you learned from AV deployments in your areas?
“Our biggest takeaway so far is to focus on collaboration,” said Kristina Holcomb, vice president of strategic planning and development at the Denton County Transportation Authority in Lewisville, Texas. “ Everyone has unique needs and resources. [The public sector has] funding opportunities those on the private side don’t have. But the private side can bring a level of expertise we don’t have.”

“It’s important to think about what the lived life with AVs will look like,” said Alexander Pazuchanics, assistant director of the Pittsburgh Department of Mobility and Infrastructure. “ The technology is incredibly disruptive in terms of societal norms and the ways cities and regions will operate. [We need to] acknowledge these transitions.”

“AV is not a silver bullet. We have to be careful to not become so enamored with the technology we forget the public policy perspective,” said Roger Millar, secretary of the Washington State Department of Transportation. “ People will think they can continue suburban development two hours from downtown because the commute will no longer be a problem. But what really is the technology doing for us? AVs have to blend with walking, biking, and mixed-use transportation.”

What has been the local response to AVs?
“The federal government named Pittsburgh one of 10 AV proving grounds,” explained Pazuchanics. “ When bicycle advocacy groups polled the general public, a majority was excited by the technology, as long as AVs obey speed limits and stop signs. I think [following the fatal Uber crash in] Arizona, that might be a different conversation.”

“There’s a fear of the unknown, so we’re focused on community education,” Holcomb said, regarding her agency’s pilot program with Drive.ai that is testing driverless vehicles in Frisco, Texas. “ We’ll have chaperones sitting in the passenger seat. They’ll help people on board and answer their questions.”

“[We’re setting] up what I call petting zoos, places where people can see this stuff in action,” Millar said. “ We propose local governments team with agencies and AV developers who could bring their technology into a low-speed urban environment where people could kick the tires.”

What advice would you give for how Minnesota should move forward?
“It will be critical to build a sustainable funding strategy to replace revenue losses from things like parking and the gas tax and changes in property tax evaluations,” Pazuchanics said. “ If not addressed up front, those revenues will be harder to extract further down the line.”

“Start small and focus on one market,” Holcomb suggested. “ Look at case studies [from] other cities. Look at lessons learned and apply them as you’re developing policies. Some cities had AV programs first and then the policies came in, and they didn’t allow for much out-of-the-box thinking. Make sure to form partnerships and have all the right players at the table.”

“You have to get the public health, social equity, environmental, and economic people involved,” Millar emphasized. “ AV is a means to an end, and the end is the economic prosperity and quality of life you want to have as a community.”

Experts share perspectives on AV deployment from around the country

Kristina Holcomb, Alexander Pazuchanics, and Roger Millar
Team identifies DESIGN ALTERNATIVES for warning signs at RURAL INTERSECTIONS.

NEW PERFORMANCE MEASURES identify TRUCK DELAYS and bottlenecks.

Software tool helps determine SAFE ACCESS POINTS for high-occupancy TOLL LANES.

Strategic visioning workshop explores future of automated vehicles in Minnesota.