If connected and automated vehicle (CAV) technology will significantly change how we travel, then it’s also bound to impact the work of those who design our roadways, operate our transportation systems, and enforce traffic laws.

“As more vehicles with these capabilities enter the national fleet, transportation professionals will need to expand the scope of their work to maximize the benefits of this technology and

**Drones, automated vehicles could fill needs for ‘last-mile’ delivery**

E-commerce has changed expectations dramatically. When shoppers make decisions, they often ask two questions: Is it available right now, and how soon can I get it? For the freight industry and supply-chain planners, this means finding a way to satisfy a market that seems to want it all.

In a project sponsored by the Minnesota Freight Advisory Committee (MFAC), U of M researcher

**Automated vehicle workshop helps practitioners prepare for the road ahead**

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**Delivery** continued on page 7

**Workshop** continued on page 6
New researcher studies the traffic impacts of automated vehicles

When Raphael Stern was a doctoral candidate, he didn’t just study automated vehicles—he got behind the wheel to test their impacts. Stern brings this expertise to the U of M this year as a new assistant professor in the Department of Civil, Environmental, and Geo-Engineering. His primary research interests are automated vehicles and how they can be used for traffic control and estimation. Other interests include transportation cyber-physical systems and smart and resilient cities.

Prior to joining the U, Stern was a postdoctoral scholar at the Technical University of Munich. Stern completed his graduate studies in the Department of Civil and Environmental Engineering and the Coordinated Science Laboratory at the University of Illinois at Urbana-Champaign. Read more about his plans and interests below.

Tell us about your plans for research and teaching.

We’re currently at a point where technology has the potential to transform how we think about transportation. This includes the emergence of automated vehicles on our roadways, improved sensing capabilities from cameras using deep neural networks, and the ability to analyze large amounts of mobility data in real time to better understand travel patterns and predict future travel demand.

My research interests are in understanding how these technologies, and specifically vehicle automation, can be leveraged to get the most out of our existing infrastructure. My teaching interests align closely with this since the next generation of transportation engineers will not only need to be well versed in traditional traffic flow theory and civil engineering techniques, but also be computationally literate and capable of applying the new computational techniques that will soon be more prevalent in transportation engineering.

What are some highlights from your recent work?

While fully automated vehicles may soon be approved for at least limited operation on our streets, adaptive cruise control (ACC) is commercially available now. ACC is a form of radar-assisted cruise control that represents the first step toward an automated future.

Recently, I’ve been interested in getting a better understanding of how ACC vehicles—which will soon be ubiquitous on our roads—will impact traffic flow. For this, I’ve done some work to test commercially available ACC vehicles to understand how they follow a leading vehicle and whether they amplify or dissipate small disturbances in the traffic flow (e.g., sudden braking). This work has important implications not only for traffic flow, but also for traffic safety, since changing the driving behavior of even just a small number of vehicles in the traffic flow could dramatically alter how shock waves propagate, for example.

Experiments I conducted in 2016 demonstrated how a single AV in a stream of 21 human-piloted vehicles could dampen stop-and-go traffic waves. In the tests, the lone AV increased the total throughput of the road by 14 percent, decreased the total number of braking events by 98 percent, and decreased average fuel consumption of the entire experimental fleet by up to 39 percent.

What are the implications of your work for Minnesota?

The emergence of partially automated vehicles on Minnesota roads over the next several years will mean large changes in terms of traffic flow and safety, as well as new best practices for traffic management. My research addresses these questions to understand how we can expect traffic flow to change and how best to prepare for the transition to automation to ensure that Minnesota is ready for the next era in transportation and mobility.
Register for the Freight and Logistics Symposium

Registration is now available for the 2019 Freight and Logistics Symposium, scheduled for Friday, December 6, from 7:30 a.m. to noon at the Delta Hotels Minneapolis Northeast. This annual event is designed to bring together members of the private sector and government to discuss current issues in the freight and logistics industry and to share public and private initiatives intended to strengthen the freight transportation system.

This year’s symposium will explore how the public and private sectors can and should respond to natural disasters that cause disruptions in the freight system. Jeffrey Dorko, assistant administrator for logistics at FEMA’s Office of Response and Recovery, will give the keynote presentation.

The event will also feature a panel discussion focused on how public-private partnerships could be leveraged to improve disaster response. In addition, representatives from the MnDOT Office of Sustainability and the North Jersey Transportation Planning Authority will share their perspectives on planning for and responding to natural disasters.

Complete program information and registration is available at cts.umn.edu/events/freight.

Unifying intersection control data paves way for smarter traffic signals

Traffic signals have come a long way, evolving from the simple time-based signals of the 1950s to the current dynamic systems that allow for real-time adjustment to traffic conditions. As a result, the data used for intersection control have become increasingly complex and important to transportation agencies, researchers, and private companies involved in developing models and technology. However, a standardized and universal format for the data has not yet been developed.

To remedy this data challenge, U of M researchers compiled intersection control information from traffic signal control professionals throughout Minnesota. This information was used to propose a unified code of Intersection Control Information (ICI) for developing future traffic models and technology systems.

“Historically, the availability of traffic signal control information and data formats has varied across jurisdictions,” says John Hourdos, director of the U of M’s Minnesota Traffic Observatory. “Using Central Traffic Signal Control Systems (CTSCS) can support recent trends toward more dynamic traffic models and controls, as well as advances in automated intelligent vehicles.”

Signal optimization experts at the Minnesota Department of Transportation (MnDOT) are also eager to use CTSCS for managing traffic near construction zones more strategically and effectively in order to combat the frequent and often severe disruption of traffic these zones can cause.

“A unified set of intersection control information is valuable for developing a regional signal timing database to model construction project impacts and provide standardized information for use with connected vehicle technologies,” says Kevin Schwartz, a signal optimization engineer with MnDOT Metro Traffic Engineering.

The MnDOT-sponsored project focused on three main objectives. First, researchers worked to collect intersection control information from all Twin Cities metro-area jurisdictions and automate the importation of this information into each jurisdiction’s CTSCS applications, including MnDOT’s construction design tools.

Next, they identified the most inclusive format to represent all required information. Finally, researchers designed a regional database of unified intersection control information and proposed methods for importing and exporting data between the central database and applications used by local jurisdictions.

A key component of the research project was surveying and conducting in-depth interviews with traffic professionals who work with traffic signal data. “Identifying the needs of different stakeholder groups allowed us to produce an organized, comprehensive format for intersection control information,” Hourdos says.

As a result of this project, MnDOT now has the full range of intersection signal control data used across the state. Researchers determined these data can be imported, stored, and delivered through a cloud-based method.

“With these findings, we can begin to consider projects that use CTSCS to mitigate construction-related traffic delays and support intelligent vehicle technologies,” Schwartz says.
While fully automated vehicles may be the future of transportation, key pieces of the underlying technology are available to consumers on some new vehicles today. One example is adaptive cruise control (ACC), which adjusts a vehicle’s speed to follow the vehicle ahead of it at a desired distance. This partial automation creates opportunities to improve safety and manage traffic flow, but also raises concerns about system resiliency and cyberattacks.

In a recent study, U of M researchers developed an analytical method that would allow vehicles using cooperative ACC to detect erroneous or malicious data and then react by changing the use of the system. (Cars using cooperative ACC, or CACC, follow each other closely and brake and accelerate cooperatively and synchronously.) The project was led by Michael Levin, assistant professor in the Department of Civil, Environmental, and Geo-Engineering, and Rajesh Rajamani, professor in the Department of Mechanical Engineering.

“Malicious actors could hack vehicle communications to incorrectly report position, speed, or accelerations to cause a collision,” Rajamani says. “Sensor faults can also be a serious source of problems for many intelligent transportation systems. To prevent these problems, system resiliency is essential.”

The researchers developed an estimation algorithm that can detect cyberattacks on a CACC system while monitoring the health of the radar sensor. Their simulation results show that the estimation system was able to detect either a cyberattack or a fault in the radar. “By comparing the two data sources, the system achieves resiliency under cyberattacks,” Rajamani says.

The researchers looked at two other aspects of vehicle connectivity that could provide near-term impacts. First, they studied whether position reports from connected vehicles could provide sufficient data for traffic management and operations.

“We found that even if the market penetration of connected vehicles is limited, it’s possible to estimate traffic flows and densities for specific spaces and times,” Levin says. “This means the basic messages from CACC communications could supplement or potentially replace other traffic data-gathering tools, such as loop detectors and video detectors.” Loop detectors need to be embedded in pavement and video detectors should be installed on high buildings—and both are difficult to maintain.

Last, the researchers looked at traffic flow during the transition period when automated vehicles (AVs) using CACC will share the road with human-driven cars. Simulations of Round Rock, Texas, show that if a set of freeway lanes are converted to AV-only, those “platooning” lanes would have much higher speeds and reliability. When enough AVs use the platooning lanes, traffic congestion would decrease in the freeway corridor.

However, overall travel times would increase for both AVs and drivers, and congestion would rise in the city overall. “Because drivers have fewer available lanes on freeways, they switch to arterial roads,” Levin explains. “AVs also increase their use of arterials to connect to their uncongested platooning lanes.” (Read more about this research in the August 2018 CTS Catalyst.)

The project was one of five that received seed funding from CTS last year. CTS seed funding, awarded biennially, aims to help CTS Scholars develop expertise in emerging areas and foster strategic relationships that position them for future funding opportunities.

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for links to research reports and other resources.
When you see people riding a city bus, it seems logical to assume that every one of those passengers is being treated equally. But U of M researchers are exploring several aspects of our transportation systems that show just how their designs put women at a disadvantage.

Those disparities are basic features of transportation infrastructure, the researchers say in a series of articles posted by the Gender Policy Report, published by the Center on Women, Gender, and Public Policy at the Humphrey School of Public Affairs. The issues the researchers address primarily revolve around public transportation—such as buses and commuter trains—and bicycling.

Building on previous research by Humphrey School professor Yingling Fan, Ania McDonnell studies how transportation professionals can develop effective solutions in their own communities.

Women who ride on public transit report that they often feel unsafe while waiting at platforms or stops and are sometimes harassed, according to Fan's research. They also feel unsafe walking home from the bus or train stop, especially at night after working a late shift. Women who work low-income or hourly jobs are disproportionately affected and are less likely to have other transportation options available to them.

McDonnell, a Master of Public Policy candidate at the Humphrey School, believes public transportation service providers should have meaningful discussions with their diverse passengers to gain a better understanding of their safety concerns. “And they should take steps toward implementing policies that will address those needs so that women are not forced to find more costly or inefficient ways to reach their destinations safely,” she says.

Public transportation also fails to account for the ways that women typically move around. One example is “trip chaining,” in which a rider makes multiple stops for school or daycare, errands, and appointments. These caregiving tasks disproportionately fall to women regardless of their socioeconomic class, and they occupy a significant portion of the day, McDonnell says.

A related phenomenon, time poverty, often causes women to take part-time jobs closer to home, limiting their employment opportunities.

McDonnell says addressing these gender disparities will require federal, state, and local policies that address the different mobility needs of men and women. Collecting adequate data is also key to ensure that transportation systems are designed and built for all people.

The gender disparity in transportation extends to bicycling as well, says Humphrey School professor Greg Lindsey. Women are far less likely to bicycle than men, he says, and one major reason is that women are concerned about their safety while biking.

Recent research by Lindsey’s students for Hennepin County shows this concern is warranted. A field experiment they conducted yielded the unexpected result that vehicle drivers were significantly more likely to encroach—to pass closer than three feet—on a female cyclist than on male cyclists. Under Minnesota law, drivers are required to provide cyclists a berth of at least three feet.

The vast majority of drivers kept a safe distance from the cyclists. But of the 33 encroachments that occurred, 73 percent were on the female rider.

Lindsey says his study underscores the need for greater investment in safer facilities like protected bike lanes.

(Reprinted and adapted with permission from Humphrey School News, Aug. 8, 2019, and the Gender Policy Report.)
avoid or mitigate its risks," says U of M researcher Brian Davis. "We’re asking them to take on a new set of responsibilities and to do so competently and extremely quickly."

To help them prepare, Davis and fellow researcher Reed Johnson, both with the Department of Mechanical Engineering, created several training modules as part of a project sponsored by the Roadway Safety Institute. The training, Davis says, attempts to bridge the gap between the U of M’s CAV research and transportation professionals and practitioners interacting with technology in practice.

A two-day pilot workshop was held on the U of M campus in May for eight transportation professionals representing different public agencies. The workshop included both classroom-based lecture sessions and outdoor demonstrations with a Husky unmanned ground vehicle—an outdoor-ready robotic vehicle made by Clearpath Robotics.

Davis says he chose topics based on interest from project stakeholders and applicability to CAVs operating in northern climates like Minnesota’s.

“Our primary goal was to develop foundational technical literacy when it comes to some of these CAV technologies,” Davis says. “Ideally, this will provide participants with a context when discussing these technologies with researchers, vendors, implementers, and other professionals.”

According to Davis, other related courses for professionals generally focus on system-level overviews or policy considerations of CAV networks. The U of M workshop chose to focus on lower-level enabling technologies for CAVs including GPS/GNSS, LIDAR, computer vision, and navigation algorithms. “We think that focusing on foundational knowledge will help transportation professionals by providing context when dealing with these technologies in the course of their work,” he says.

One participant, Major Sean Meagher with the Minnesota State Patrol, says his agency works closely with MnDOT’s CAV-X Office and monitors current events and industry trends.

“CAV technology will have a tremendous impact on traffic safety in the future,” Meagher says. “In Minnesota, on average 350 to 400 people die each year on our roadways. Almost all, if not all, are due to human contributing factors. CAV technology will certainly have a positive impact on lowering traffic fatalities in the coming decades.”

Workshop participant Rick West, Otter Tail County Public Works director, says that from a practitioner point of view, he appreciated learning how the technologies interrelate. Although he has no first-hand CAV experience yet, he’s been part of research projects dealing with dynamic in-vehicle warning technology for horizontal curves and high-accuracy mapping of local road pavement edges for future vehicle guidance.

“Being responsible for local roads and bridges, I believe that we will be involved at some point in providing quality pavement markings and highly accurate GPS-referenced infrastructure location data to help guide these vehicles,” West says.

Because response to the workshops was overwhelmingly positive, Davis hopes to incorporate participant feedback and offer additional workshops in the future.
Frank Douma studied these trends, their implications, and how the industry is responding. His white paper focuses on activities that most experts feel are likely to be of the highest impact: what it takes to get customers’ orders the “last mile” to their doors.

“In the ongoing effort by MFAC to better understand freight movement, the committee chose this topic to explore how consumer demand—in this case, e-commerce—is driving change in freight movements,” says Ron Dvorak, MFAC chair. “The shifting market expectation is creating a new paradigm with major infrastructure implications, and this paper provides the committee a lens to better focus planning guidance.”

The last mile is the final step of the delivery process and can actually range from several blocks to several miles, says Douma, the director of the Humphrey School’s State and Local Policy Program. The “first mile,” from the shipper to warehouses or distribution centers, can raise similar issues, especially in states like Minnesota where manufacturers can be spread widely across small towns or rural areas.

The exact nature of the issues and challenges can vary. “For example, while a transportation planner may be concerned about possible congestion impacts resulting from increases in delivery vehicle traffic, a small carrier may be concerned about its very existence: whether and how it should try to compete against, or collaborate with, a company like Amazon as it moves toward the use of drones,” Douma says.

A number of emerging innovations and technologies are driving this changing landscape, including vehicle automation. “Traditionally, humans have covered this last mile, whether they were professional delivery drivers or consumers bringing home the goods,” he says. “Now, technology is emerging that can substitute for both methods.”

This technology can come in many different forms: automated vehicles, small drones delivering individual packages from a larger vehicle, or smaller self-driving boxes that are able to safely maneuver in dense environments. Such advances are still five to ten years out, Douma says, and considerable opportunity remains for existing lower-tech solutions.

In the meantime, “Changes at distribution centers and warehouses are likely even more central to the greater and faster deliveries the market is calling for,” Douma says. New robotic and other technologies are making it possible for parcels to be sorted, shipped, and tracked to their destination faster and at lower cost.

Many of these changes in freight transportation are taking place outside of Minnesota, but changes are happening in this state as well, offering significant opportunities.

“A limitation, however, concerns our rural broadband and highways,” he says. “The sensors, robots, and all of the other technologies will rely, to some extent, on the growth of the internet of things and other connectivity. To the extent that this connectivity does not exist, particularly in smaller towns and rural areas, potential benefits and competitive advantages could be lost.”

**25 PERCENT of customers would be willing to pay extra for same-day and instant delivery.**

— McKinsey and Company
Drones, automated vehicles could fill needs for ‘last-mile’ delivery.

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POLICIES, DATA needed to address GENDER DISPARITIES in transportation.

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UNIFYING INTERSECTION CONTROL DATA paves the way for SMARTER TRAFFIC SIGNALS.

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AUTOMATED VEHICLE workshop helps PRACTITIONERS prepare for the road ahead.