

Catalyst



Accelerating the pace of transportation innovation

AUGUST 2020

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Monitoring system provides decade of data from I-35W bridge

On August 1, 2007, the I-35W Saint Anthony Falls Bridge collapsed in Minneapolis. Its replacement, open to traffic just over a year later, was instrumented with more than 500 sensors to record the new structure's behavior and evaluate the effectiveness of different monitoring strategies. A 10-year review of the bridge's monitoring system is now available from U of M researchers.

Monitoring continued on page 6

Changes on tap for Catalyst newsletter, CTS website

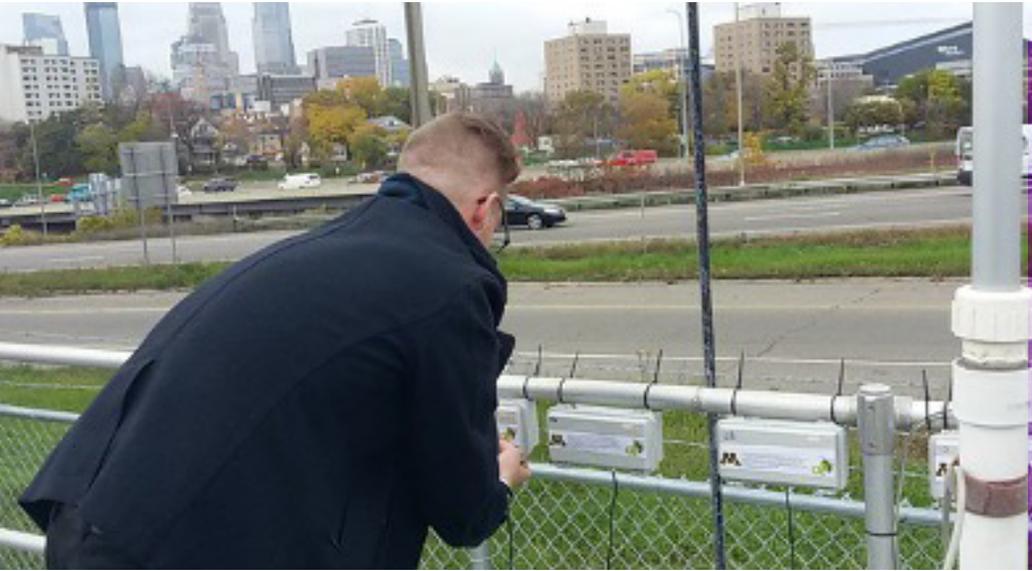
Last year CTS assessed the effectiveness of our communications mechanisms, including *Catalyst*, our website, and social media. We collected data—thank you for your survey responses!—and reviewed the latest communications trends.

In response, we landed on a set of adjustments. Beginning in September, we will move to a digital-first approach in which new stories will be published weekly on our website. This will allow for more timeliness and searchability, as well as a more robust social media presence. We will not publish a newsletter in September.

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Link between air quality, happiness could guide infrastructure decisions



Researchers used small sensors to monitor air quality.

By connecting measures of happiness to transportation, researchers are developing new metrics that can help cities prioritize infrastructure investments. In a new study, a research team that included Humphrey School of Public Affairs professor Yingling Fan found that air quality appears to be linked with a variety of emotional well-being (EWB) outcomes.

“As cities seek to evolve and become more livable, new metrics may help them achieve their desired goals,” Fan says. “Understanding how local air quality, neighborhood infrastructure, and well-being are connected could help cities identify strategies and investments for improving public health. It may also identify disparities across neighborhoods to pinpoint those at higher risk for low emotional well-being.”

To determine whether neighborhood air quality and happiness are linked, researchers first needed better ways to measure them. Traditionally, air pollution has been measured using expensive, bulky, and sparsely located monitors, and EWB data relied on the memories of study participants.

In this project, researchers used low-cost sensors developed in recent years to assess exposure to fine particulate matter (PM_{2.5}) from regional sources such as power plants in six Twin Cities neighborhoods. They also used air-quality modeling to estimate traffic-related nitrogen oxides (NO_x).

To measure happiness, the Daymica™ smartphone app was used to collect data from residents of the six study neighborhoods. The app tracked the residents’ movements for seven consecutive days; residents later annotated the data with assessments of their emotional well-being. Data included happiness, tiredness, stress, sadness, and pain.

The neighborhoods—four in Minneapolis and one each in the suburbs of Blaine and Brooklyn Center—varied in terms of median household income and access to light rail. The study period was from October 2016 to April 2017.

The researchers found that, at least in the case of fine particulate matter, air quality and happiness appear to be linked. “We discovered that higher concentrations of fine particulate matter

led to lower emotional well-being scores of positive emotions, and higher scores for all the negative emotions such as tiredness, stress, sadness, and pain,” says Dr. Raj Lal with the Georgia Institute of Technology, the lead author of a paper summarizing the study.

The study didn’t find a link between traffic-related nitrogen oxides and any of the well-being outcomes. “Our data shows a near-zero relationship between emotional well-being and NO_x, but we believe this is because there were low NO_x levels throughout the study neighborhoods,” Lal explains.

The neighborhoods with lower household incomes tended to have higher PM_{2.5} concentrations than those with higher socioeconomic status, raising environmental justice concerns, Lal notes. Simulated NO_x levels from vehicles were significantly higher in the urban neighborhoods than in the suburban ones, which was expected given higher average traffic counts in the urban areas. Close proximity to light rail had no observable impact on average observed PM_{2.5} or simulated traffic-related NO_x.

The study findings, and the novel methods that the team introduced, could be used to guide policies in Minneapolis and other cities with similar neighborhood characteristics. “Now, cities can see that local interventions, such as travel demand management policies reducing single-occupancy vehicle travel, may offer not just air quality improvements but also improved well-being,” Fan says.

The project was funded by the National Science Foundation. Findings are published in the journal *Environmental Health Insights*.

CTS to build ecosystem for study of connected and automated vehicles



CTS has secured funding to begin assembling a connected and automated vehicle (CAV) ecosystem for use in research, education, and engagement. The funding allows for the purchase of a highway-speed automated vehicle, the lease of a second highway-speed vehicle, and the lease of a shuttle-type transit vehicle.

The funding, from 13 partners, includes a major contribution from the U's Office of the Vice President for Research. "The investment builds on researchers' substantial body of work in this critical field and lays the groundwork for the University of Minnesota to become a national leader," says Chris Cramer, the U's vice president for research. "Moreover, the opportunity to partner with key Minnesota industries that are also investing in this technology has the potential to make us a true innovation leader, positively impacting Minnesota's economy."

While many prior efforts to create CAV research centers at different universities have focused exclusively on technical aspects, CTS will leverage the University's prior work in vehicle automation to answer the next generation of both technical and societal questions. Since 2012, 25 projects related to connected and automated vehicles have been conducted by 30 researchers at the University of Minnesota, with a total

value of \$6.4 million.

CTS is currently working with stakeholders to develop a strategic research plan. The plan builds on what was learned from a series of focus groups and interviews about University researchers' interests, and it aligns those interests with external market dynamics. The following research categories are emerging as potential niche areas where the University of Minnesota's CAV research program would be unique:

- **CAVs and vulnerable road users:** This includes building an understanding of how CAVs will detect and identify vulnerable road users such as bicyclists, pedestrians, and riders of micromobility vehicles (e.g., electric scooters and e-bikes). Additionally, research will explore how vulnerable road users will interact with CAVs, and how to design CAVs to provide a safe and enjoyable experience for all road users.
- **CAVs and variable weather conditions:** Many CAV research deployments have been conducted in areas with reliable weather conditions. Coping with extreme weather will be critical for taking CAVs from the lab into the city and an important first step in developing CAVs that can be deployed at scale. Research includes understanding

how to sense obstacles in heavy rain or snow and how to control vehicles in low-traction road conditions.

- **Public perception and trust of CAVs:** For full integration into society, humans must trust the safety of the CAVs being designed. This focus area emphasizes the importance of understanding how to build trust in CAVs and how to design CAVs that humans can trust.

The CAV program will also include an education and workforce development component. Minnesota companies are at the frontier of CAV-related industries and are looking for creative ideas and human talent.

"By bringing multiple departments, units, and colleges together, U of M students will be able to learn and excel in various areas of autonomous vehicles," says Laurie McGinnis, CTS director. "This will benefit the University, the state, and businesses." Statewide engagement and outreach will also be offered through the CAV program.

CTS is currently exploring arrangements with private- and public-sector partners. This includes scoping the final technical specifications for the U's highway-speed test vehicle and investigating vendor options for the lease of a shuttle-type transit vehicle.

Smartphone-based coaching for new teen drivers may offer long-term benefits



More than five years ago, U of M researchers studied a group of new teen drivers to gauge the effects of real-time, in-vehicle coaching with their innovative Teen Driver Support System (TDSS) smartphone application. Now, a follow-up study offers new understanding about the system's long-term effectiveness in reducing risky driving behavior.

"We wanted to build on the original TDSS study, in which we deployed a novel technology to 300 Minnesota teen drivers in their first year of independent licensure," says Nichole Morris, director of the U's HumanFIRST Laboratory and the project's principal investigator. "Through that study, we were able to show the value of a low-cost technology for teens in their most vulnerable year of driving."

In the original study, teens were divided into three groups: TDSS, TDSS+, and a control group. Drivers in the TDSS group received real-time visual and auditory feedback about risky behavior through a smartphone mounted on their vehicle's dashboard. The TDSS+ group received nearly identical in-vehicle feedback, but the system also notified drivers' parents of detected risky behavior. The control group received no coaching. Results at the time indicated an overall safety benefit of TDSS, demonstrating that

in-vehicle monitoring and feedback, especially when coupled with parental notifications, was a meaningful intervention to reduce the frequency of risky driving behaviors.

In the new five-year follow-up investigation funded by the Minnesota Local Road Research Board, researchers aimed to establish the TDSS's long-term outcomes. To do so, the team contacted participants from the original 2013 study, successfully recruiting 150 people into the follow-up study. These individuals provided information about their driving history, behaviors, and attitudes and granted researchers permission to request their crash and citation records. Researchers also performed a new analysis of the 150 participants' original driving performances and divided them into low-, moderate-, and high-risk behavior categories.

"Once the participants were divided into risk categories based on the original study data, we were able to see clear differences in distributions across those categories for the three experimental groups," Morris says. "Namely, the control group had the highest proportion of high-risk events and the TDSS with parental alerts group had the lowest."

Following their re-examination of the original study data, researchers used state traffic citation and crash record data

to examine the relationship between early risky driving and long-term safety outcomes such as traffic violations and crashes. Findings show that young drivers in the moderate- and high-risk groups for almost all risky measurements were significantly more likely to have a ticket five years later than those in the low-risk group.

The sample size of crashes among these drivers was too small to determine if the TDSS intervention had any impact on crash rates. However, Morris says that sampling the participants again in an additional five years could improve researchers' ability to capture differences in crash outcomes across the three experimental groups.

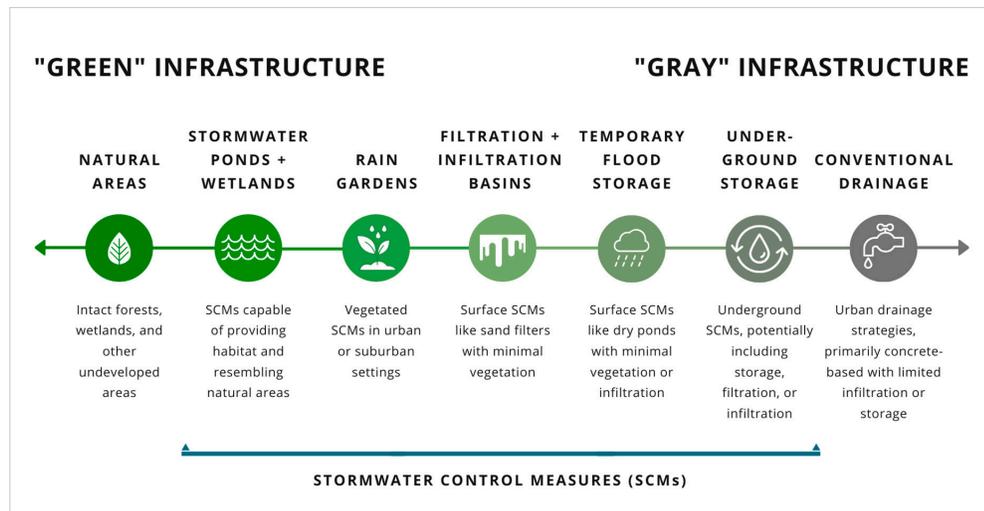
Overall, study results indicate that the TDSS provided reliable detections of risky behaviors under different driving conditions—and that such behaviors may serve as sensitive indicators for the risks of later involvement in a traffic violation event. "These findings suggest that the use of real-time, in-vehicle coaching systems such as the TDSS may be effective for improving the safety of younger drivers, in both short- and long-term metrics for risky driving," Morris says.

Green stormwater infrastructure: tradeoffs and maintenance

Using “green” infrastructure is a useful strategy for handling city stormwater, which may contain deicers and other contaminants from streets and sidewalks. Choosing the right method and ensuring it doesn’t cause unforeseen damage, however, is another matter.

Green stormwater infrastructure (GSI) is a departure from more traditional, “gray” infrastructure in that it integrates natural functions of the environment. Used correctly, it can effectively utilize plants, microbes, and soil properties to trap or degrade pollutants, prevent soil erosion, and reduce stormwater volume. Since the early 2000s, GSI has steadily grown more prevalent as climate-change-altered precipitation patterns and increased land development force cities to rethink how they manage stormwater.

GSI must be used mindfully, however; there’s more than one method, each with specific strengths, weaknesses, maintenance requirements, and sometimes even social costs. A 2020 paper published in the journal *Water*



Researchers offer a framework for choosing stormwater control measures.

the authors write, “it is easy to overlook potential trade-offs and unintended consequences that may accompany infrastructural attempts to address flooding and urban water quality issues.”

The specific GSI method being used has to fit the environment. Infiltration systems, for example, can filter and sequester large volumes of excess

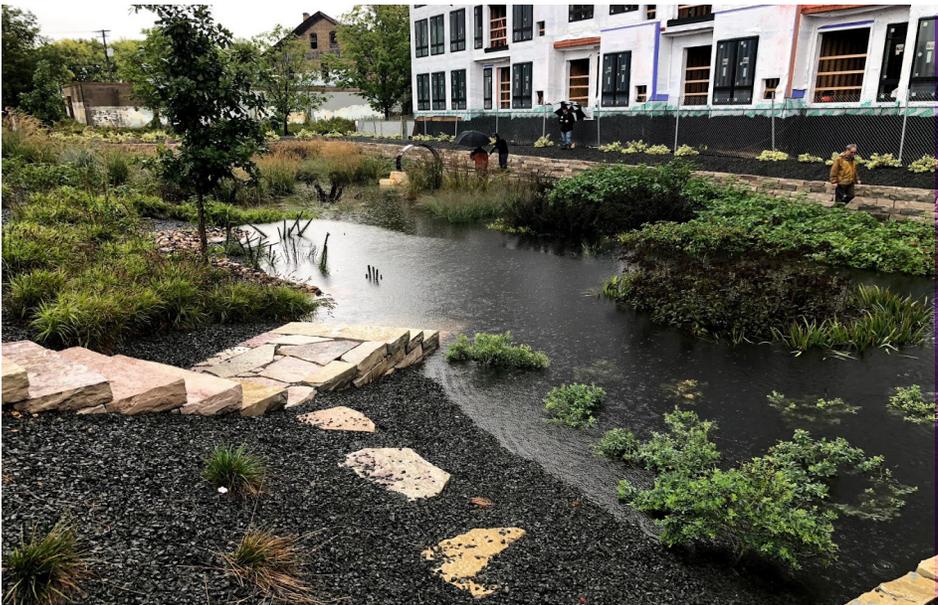
than others, such as nitrates or chloride.

Maintenance is another often overlooked aspect of GSI. Filtration systems are enhanced with media to retain dissolved contaminants and can “clean” stormwater runoff, but they require regular maintenance. Even strategies seen as low maintenance or “passive” require upkeep; the sediment that collects in stormwater ponds after rain events needs to be dredged on a regular basis so that the ponds don’t release their sequestered pollutants back into the environment.

“There’s so much about maintenance we don’t understand,” says Vinicius Taguchi, a Ph.D. candidate in civil engineering (advised by Professor John Gulliver) and the lead author of the paper. “If you’re not building it properly, if you’re not maintaining it properly, are you still doing some good?”

The final factor that the paper considers is the social impact of GSI. Installing “green” infrastructure, even something as simple as trees, can raise property values and rents—essentially a form of gentrification. Lower-income communities may also lack the funds to keep up their GSI, leading to defunct infrastructure that causes more problems than it solves.

The 2020 paper offers a framework for the GSI decision-making process,

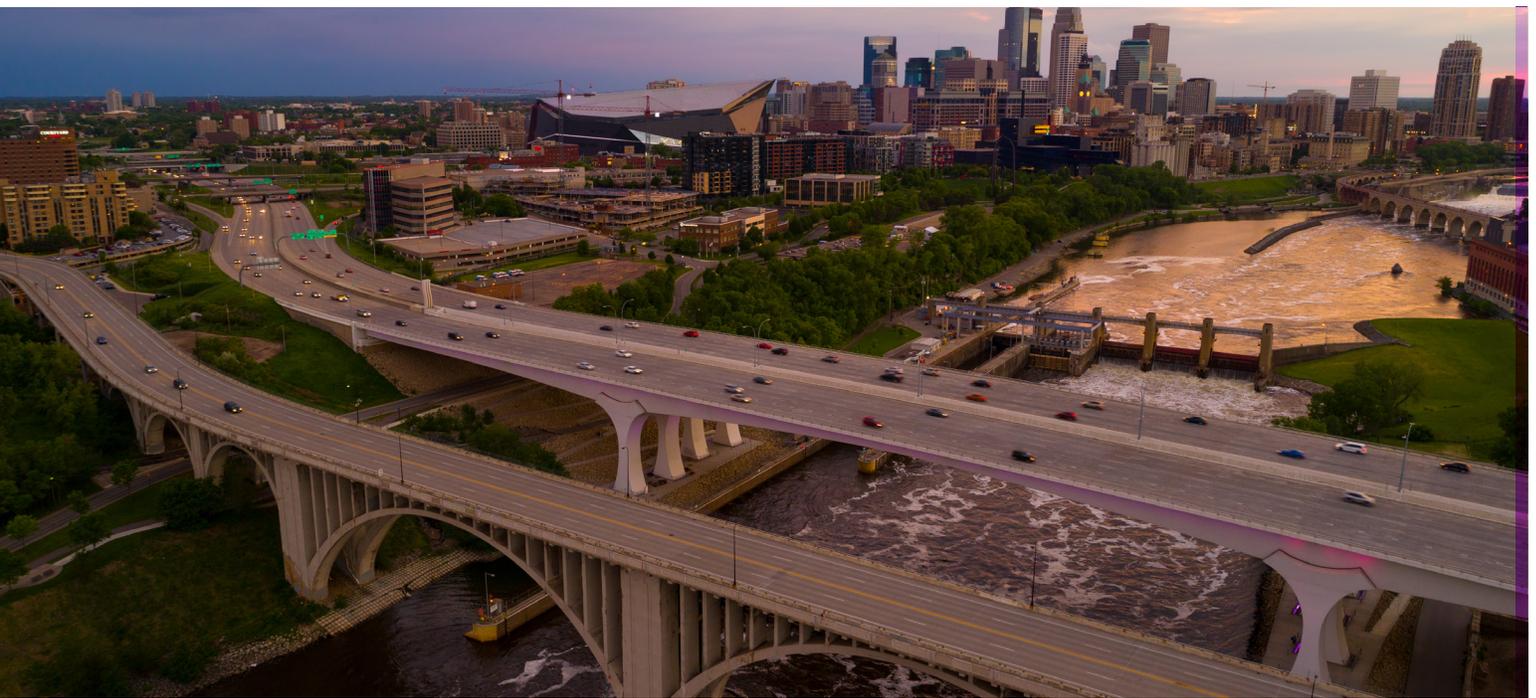


Rain gardens can serve as a “green” stormwater treatments.

outlines some of the more common challenges associated with GSI and offers a framework for how to handle them.

“Due to the growing interest in GSI,”

stormwater into the water table. However, the soil has to be the right composition, and certain pollutants—such as organics—are easier to filter out



"The measurements collected over the 10 years of monitoring, with the aid of material tests, truck tests, and finite element modeling, provide insight regarding the relative strengths of the instrumentation systems and potential considerations for future system deployments," says Lauren Linderman, assistant professor in the Department of Civil, Environmental, and Geo-Engineering (CEGE) and the project's principal investigator.

The continuous operation of the I-35W bridge monitoring system makes it one of the longest-lived in the country. The system incorporates many sensor types, including strain, temperature, and acceleration and displacement sensors, and has generated a uniquely large data set. "This data set offers an unmatched opportunity to evaluate long-term monitoring approaches," Linderman says.

Project co-investigators were Carol Shield (CEGE professor) and Brock Hedegaard (civil engineering assistant professor, U of M Duluth). The project was sponsored by the Minnesota Department of Transportation.

"This project has given us more knowledge in how we may be able to better instrument bridges in the future if we find it necessary to monitor or investigate their behavior," says Ben Jilk,

principal engineer with MnDOT's Bridge Office. "It has also given us confidence that the design criteria we have been utilizing on bridges in Minnesota like the I-35W bridge is conservative with respect to the behavior observed."

The team's report documents the successes and challenges of the monitoring program. In particular, the researchers studied the effectiveness of different strain measurement techniques and sensor distributions.

Overall, the instrumentation survival rate was approximately 90 percent over the 10 years. "This is significant given the deployment duration, embedment of gages, and variety of sensor systems," Linderman says.

Researchers leveraged the monitoring system in different ways throughout the project. Some instrumentation, for example, helped the team calibrate the model used for behavior comparisons and validate design assumptions.

One key finding from the project is that seasonal and daily temperature variations have a big impact on the bridge's behavior. As a result, the instrumentation needed to measure temperature and its impacts are the most important for long-term monitoring.

"Currently, one cross-section is heavily instrumented to capture

temperature data, but behavior at this cross-section varied significantly from behavior near the piers," Linderman says. "For future bridge deployments, we recommend instrumenting more cross-sections, with fewer sensors, to get a more accurate representation of the temperature distribution throughout the structure. This could be essential as the temperature-dependent behavior starts to dominate the bridge's response, and the time-dependent effects slow down."

These large thermal stresses—in particular, those caused by low temperatures during morning rush hours—could lead to concerns about deck cracking.

"This bridge used a conservative design approach, so we believe its service life won't be affected," Linderman says. "Comparable bridges, however, could encounter issues. The insight gained from this study could be key for their design and life span."

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for links to research reports and other resources.

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In October, we'll roll out our new approach for *Catalyst*. We'll start sending a monthly email—called *Catalyst First Look*—compiling all recent posts from our website. We'll also launch a refreshed print *Catalyst* newsletter, published bimonthly, that features selected stories.

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beginning with making and prioritizing goals: deciding what needs to be fixed and ensuring that one solution will not cause greater problems elsewhere.

The final decision should take into account the varying strengths, weaknesses, and maintenance needs of

the strategy used, the researchers advise, and once the GSI is installed, it should be monitored and re-evaluated regularly to ensure it continues to be effective.

"We definitely want this to be a useful tool," Taguchi says. "Hopefully, people who read through this paper will have an

idea of how to think through this specific situation, or at least know that they need to have some questions for researchers with more experience."

Eugene Skok: leader in asphalt and paving



Eugene Skok, a leader in the pavement engineering profession, passed away on June 29. Skok was a civil engineer and former faculty member at the University of Minnesota. His pioneering research, under the supervision of Professor Miles Kersten, led to the development of an asphalt

pavement design procedure for the state of Minnesota, parts of which are still in use today.

Skok was instrumental in the planning and construction of the MnROAD test facility in the early 1990s. His career included positions with several organizations, such as the Minnesota Department of Transportation, the Asphalt Institute, and the Minnesota Asphalt Paving Association.

Skok's approachability and his willingness to invest time with others made him a great mentor to young pavement engineers and a model for established professionals. Skok

influenced many in the field through his years of teaching at the University and in the two-year program for technicians in civil engineering at St. Paul College.

"I took one pavement design class from Gene in 1987, and he became a dear friend, mentor, and boss," says Ann Johnson, president of Professional Engineering Services, Ltd. "Gene led by example and consistently demonstrated kind, thoughtful, and moral leadership for so many, including me."

In 2016, the U's Department of Civil, Environmental, and Geo- Engineering established the Eugene Skok Scholarship, funded through the proceeds of the National Road Research Alliance annual conference, to honor Skok's contributions to the pavement community. The scholarship benefits undergraduate students studying at the University with an interest in pavement engineering.

Skok received the Richard P. Braun Distinguished Service Award from CTS in 2009.

(Adapted in part from CEGE News.)

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2221 University Avenue S.E.
Minneapolis, MN 55414

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A publication of the Center for Transportation Studies
University of Minnesota

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