Get lots of sleep—but not behind the wheel

Many of us would never drive after drinking, but we’re not as hesitant about getting behind the wheel after being awake for too long or not getting enough sleep. It turns out that can be just as dangerous as driving while impaired by alcohol or drugs.

Unlike impairment, however, drowsy driving isn’t easily observable, and there are no tools to detect it. Because of such factors, it’s believed to be underreported and to have a much greater impact than we think.

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Reusing wastewater at Minnesota’s truck stations could help conserve state’s water resources

U of M researchers provided a comprehensive and practical evaluation of what the Minnesota Department of Transportation (MnDOT) would need to do to develop wastewater reuse systems for its truck stations and rest areas. Two MnDOT truck facilities will soon become more eco-friendly as a result of the findings.

“The great success of this project arises from its close examination and evaluation of all

Wastewater continued on page 6
Taconite-based mixtures show further promise for repairing potholes

Minnesota road crews may soon have a better way to battle potholes, as U of M researchers work to further refine an innovative, quick pothole repair method for both concrete and asphalt pavements. The new repair method is based on a plentiful Minnesota material—taconite—that can be applied fairly quickly and shows promise as a cost-competitive, long-term solution for potholes.

“A fast, durable pothole repair that can be conducted in cold or wet weather remains an elusive and prized technology,” says Lawrence Zanko, a senior research fellow with the U of M’s Duluth Natural Resources Research Institute. “We have been working to develop a rapid patch using the readily available, iron-containing materials of northern Minnesota taconite mining.”

In the project, funded by the Minnesota Local Road Research Board, Zanko’s team continued to improve taconite repair methods to simplify mixing procedures, avoid the need for expensive and large specialized equipment, and speed up patching activity.

This project builds on a 2016 effort funded by MnDOT that found taconite mixtures and microwave machinery could make potholes repairs in roughly 15 minutes that last for 6 to 12 months. Goals of the recent study included improving the earlier non-microwave taconite pothole patch methods, conducting field testing, and examining inexpensive mixing equipment that would be easy to use in the field.

Taconite pothole repairs were tested on local roads, state roads, parking lots, and an airport taxiway; researchers revisited all repair sites to inspect repair performance periodically. The method to place the taconite patches was also improved during this project. Previous taconite patching mixtures required mixing two packaged dry ingredients by hand with a liquid activator in a 5-gallon bucket; the new mixture is just two ingredients and can be blended in a special 15-gallon mixing barrel known as a “Mega Hippo.”

Researchers found that the improved taconite repairs set well in both asphalt and concrete and performed well for a year or more of observation. The method seems to be more durable than typical “throw-and-go” and cold-mix options for pothole repair, offering local agencies an asphalt- and cement-free option that uses plentiful local materials and costs less than mastic or hot-mix asphalt repairs.

The mixture was found to set more slowly in cold temperatures than warm, and better in deep repairs than in shallow. Fieldwork identified operating temperatures that allowed taconite patches to be placed in cool to cold (subfreezing) fall conditions—and site repairs were drivable in 30 minutes.

Next, researchers will further refine mixing methods and application to increase the material quantities workable by local crews and speed up repair activities. Researchers aim for repairs that can accept traffic in 10 to 15 minutes or less under moderate to warm temperature conditions. “This highlights the importance of having an efficient mixing and placement system that is a good match for the repair product’s quicker set time,” Zanko says.

“This research looks promising, but it’s early,” says Perry Collins, MnDOT assistant district engineer in MnDOT District 1. “Time will tell how it will perform in comparison to a hot-mix operation or mastic.”

Researchers demonstrate the “Mega Hippo” mixing barrel.
Waymo and Uber have started trials of shared autonomous vehicle (SAV) service in several US cities. Without the expense of drivers, autonomous service could one day make the cost of a ride so low that people choose SAVs for their daily transportation needs instead of owning a vehicle.

As a result, the efficiency of SAV systems, particularly in terms of matching shared vehicles to customers, could become highly important. To shed light on the challenges and possibilities, U of M researchers developed a dispatch model that would provide optimal throughput for SAVs. The research was led by Michael Levin, an assistant professor in the Department of Civil, Environmental, and Geo-Engineering, and funded by CTS.

Previous studies have constructed simulations of SAV interactions with travelers on city networks. Those studies found that each SAV could replace between 3 and 11 personal vehicles. “This range is because the results are highly dependent on the passenger-to-vehicle matching technique used and the network topology,” Levin says.

Most vehicle-routing problems are complex and involve large numbers of potential customers, Levin explains, so most of the studies used a modeling technique that requires less time and data to produce feasible—but not necessarily optimal—solutions.

In this project, the research team analyzed the SAV dispatch problem using the concept of stability. Traffic networks are considered stable when the number of vehicles in the network, on average, remains bounded (does not grow to infinity). Inefficient signal timings or higher demand prevent stability.

For a fleet of SAVs, the number of vehicles in the network is constant but the number of waiting travelers could grow large if the fleet is too small to serve them. Other factors influencing stability include the additional congestion caused by SAV route patterns and trips without passengers. “Ideally, the dispatch strategy for SAVs would maintain stability for the largest number of travelers possible,” Levin says.

The researchers began by constructing a queueing model that represents the SAV system. They then analytically derived the demands that could be stabilized for any SAV system. “This analysis can determine the relationship between fleet size and demand,” Levin says.

Next, they analytically developed a maximum-pressure dispatch policy for SAVs and proved it has maximum stability. “Our strategy is guaranteed to serve at least as much demand as any other dispatch strategy,” he says.

The team has also completed numerical comparisons of the dispatch strategy to supplement the analytical results from this project.
Looking to the future of aerial mobility: flying cars for public transportation

Flying cars are typically regarded only as a fanciful staple of science fiction, but a recent graduate of the University of Minnesota believes they are closer to reality than we might think.

Zheyang Yuan earned master’s degrees in metropolitan design and architecture (advised by Professor Tom Fisher). As part of both degrees, Yuan began a project looking into the technology, infrastructure, public acceptance, and policy that will be necessary for electronic vertical takeoff and landing, or eVTOL, vehicles to become a viable form of public transportation.

“To safely introduce these fundamental changes to our transportation system,” Yuan says, “we need an orderly transition from experimental to commercial to the mainstream operation of eVTOLs.”

Around 80 different eVTOL models from various manufacturing companies currently exist in the US. The vehicles generally look and function similar to a scaled-up drone, with an electric battery powering one or more rotors. Depending on the model, they can fly 150–200 miles per hour, and they have a range of 50–200 miles. The models Yuan is interested in are autonomous and equipped with redundant sensors as required by the Federal Aviation Administration.

“Uber is the most ambitious in this field in the US,” Yuan says. The company plans to start demo flights for its Uber Air product in 2020 and limited commercial flights in 2023. Uber’s plans, however, are entirely urban, and Yuan thinks this strategy will have limitations.

“No individual company can afford to build the infrastructure network, or even a single component such as a ‘skyport’ building, that would be required to support this mode of travel,” she says. Uber’s initial budget for a single skyport—with all the necessary controls, landing pads, and user interfaces—is $65 million.

Affordability is also a public concern. In interviews with people of different physical abilities, ages, and incomes, Yuan found that “most of them can imagine the technology bringing more equity and mobility for the disabled, the elderly, and minority and rural communities—if it’s safe and affordable enough.”

Yuan’s project looks to the long term to solve the cost problem. With government help, she says, eVTOLs have the potential to eventually become a system of public transportation. She recommends shifting focus away from the cities—where public acceptance and regulations are likely to be messier—and instead focusing on the interface between cities and rural areas. Municipal airports could be retrofitted to function as skyports to save capital investment and make better use of underused public facilities.

“This new network would bridge rural areas with high unemployment and urban areas with unmet job vacancies,” Yuan says. “It could also revitalize rural areas by allowing urban companies to relocate from high-cost urban areas to areas with cheaper land and labor.”

None of this will happen quickly, however. Though the technology for eVTOLs is highly advanced, Yuan says, policy tends to move much slower. NASA is working on a five-year plan to develop a policy system for managing unmanned drones, and Yuan estimates it would take another five years for that policy system to be adapted to encompass passenger vehicles. From there, the technology could be used by bigger organizations like Mayo Clinic as a company vehicle, eventually transitioning into the public sphere by around 2040 as the system becomes more widespread and the cost of vehicles declines.

“Public transit is not a short-term thing,” Yuan says, “but in this way, regions playing various roles in Greater Minnesota could function more effectively as a system.”

Aerial vehicles: mobility option during pandemic?

In this time of pandemic, the movement of medical supplies, hospital staff, and patients has become a priority, yet social distancing is essential. Given these factors, the potential of electronic vertical takeoff and landing (eVTOL) vehicles is taking on new significance.

The technology itself is relatively advanced, and companies worldwide are advocating for increased testing. Public acceptance and government policy, however, have been slow to progress. The pandemic, says Zheyang Yuan, a recent U of M graduate, presents two circumstances that might push forward development: an increased need for a fast, efficient medical courier system that doesn’t involve human contact, and the fact that everyone is indoors.
When people travel, they may be happy—or not—depending on the mode they use, trip duration, and other factors. A team of U researchers has created an interactive map that illustrates differences in travelers' happiness ratings on streets and roads in the Minneapolis–Saint Paul metro area.

“Happiness is increasingly seen as a gauge of an individual’s well-being, and this has many social implications,” says Professor Yingling Fan of the Humphrey School of Public Affairs, the principal investigator.

The Transportation Happiness Map is the latest effort led by Fan to explore happiness as a useful metric to assess transportation systems and guide policymaking, supplementing more common measures such as mobility and accessibility. The work was funded by CTS.

“Transportation is an emotional landscape people cannot avoid,” Fan says. “It is more than a means of getting from place to place. People spend significant time every day in transportation, and a significant amount of land area in our cities is dedicated to transportation-related facilities. Livable transportation solutions need to maximize both system efficiency and user experience.”

The map makes self-reported emotional experience data easily accessible through visualization. Users can select among 10 travel mode options (such as driving or biking), 7 time options, 8 emotion options (including stressed or tired), and two statistic options.

The data powering the map were collected using the Daynamica smartphone application. Daynamica is based on patented technology developed by a team of faculty and students led by Fan. It detects activities and trips in real time and allows users to annotate the detected data with information such as emotional experiences.

The team collected data from 398 residents from six neighborhoods in the region, including four urban and two suburban areas. Each resident contributed a week of trip data in 2016 or 2017.

“Right now we are all at home, so it’s easier to design those routes even across those dense urban areas,” she says. In other countries, there’s been a big push for increased testing of eVTOLs. In Norway and Spain, the Chinese company eHang has been granted operational permits by a handful of cities, she says, and the company recently released a video showcasing how its two-seat passenger autonomous aerial vehicles might be used to transport staff and medical supplies amid the COVID-19 pandemic.

In the US, companies are beginning to encourage more testing, but government policy and funding are still a barrier. A system of registration and remote identification for drones will need to be set up before companies can operate, and neither NASA nor the Federal Aviation Administration has indicated immediate plans to do so, Yuan says.

There are, however, intermediary steps moving forward in the US. Mayo Clinic announced April 2 that it will deploy autonomous ground vehicles for medical supply transport in Jacksonville, Florida.

“The biggest barrier,” Yuan says, “is cooperation among governments, the companies that design, manufacture, and operate this technology, and urban planners.”
aspects of industrial wastewater reuse in Minnesota, from regulation to the practical choice of technology MnDOT will be able to sustain in the future,” says Sara Heger, a research engineer with the U’s Water Resources Center and the principal investigator.

The need for this MnDOT-funded project was surprising but real: despite Minnesota’s abundance of water resources, 75 percent of the state’s water comes from aquifers used at increasingly unsustainable rates. Recycling wastewater would allow potable groundwater aquifers to be used more conservatively. Minnesota’s state agencies have been directed by executive orders to make efforts to save energy and water; since every MnDOT building uses water, the agency saw potential for water reuse.

MnDOT realized that developing a system of water recycling could create sustainable water resources for toilet flushing and vehicle washing at its 50 rest areas and 137 truck-washing stations and storage facilities. “In addition, we were interested in exploring how salt-laden wastewater might be recaptured for further use in winter road maintenance,” Heger says.

The work progressed in three phases. First, researchers reviewed current wastewater reuse policies and regulations in Minnesota, wastewater reuse programs in other states, and international guidelines for wastewater reuse. They found that Minnesota’s wastewater regulation is complex—at least four agencies are involved—and that wastewater reuse systems will require a variance and, in some cases, additional permits from local agencies.

“We found that wastewater reuse systems have been successfully implemented in Minnesota,” Heger says. “However, the regulatory framework for water reuse needs to be simplified and streamlined to create a more effective permitting process.”

Next, the researchers sampled and collected data from 11 MnDOT truck-washing facilities to identify common contaminants. They found excessive levels of only one chemical (ethylene dichloride, a solvent), which MnDOT could reduce its use of. Across all samples, the critical contaminants to be removed for water reuse were organics and suspended solids. Excessive chlorides were not considered a contaminant since chloride-rich water could be reused as brine in winter road maintenance operations.

Finally, researchers evaluated existing wastewater treatment technologies and determined which method would be most cost-effective. They recommend a membrane bioreactor as the most effective and economical system for MnDOT.

“This innovative study’s findings will result in the implementation of wastewater reuse technology at MnDOT,” says Neile Reider, an administrative engineer with MnDOT’s Office of Maintenance. “The project promises to be a continuing success.”

Based on the study’s findings, MnDOT is installing pilot implementations at the Granite Falls and Buffalo truck stations. “At these two sites the washdown water from washing plow trucks will be reused to make brine, thereby reusing the salt that otherwise would have been wasted and sent to a wastewater treatment plant,” Heger says. Evaluation of the system’s treatment effectiveness and maintenance requirements will then be used to inform a broader-scale implementation of wastewater reuse systems for MnDOT.
To better understand and address the problems of drowsy driving, researchers at the U’s HumanFIRST Laboratory designed a study that aimed to find an objective test (or set of tests) that law enforcement officers could quickly and easily administer to identify fatigue during traffic stops. The Minnesota Department of Public Safety’s Office of Traffic Safety (OTS) helped secure two federal grants for the research team and provided guidance for the study’s design.

As part of the study, subjects stayed in the HumanFIRST research facility for 30 hours. They were not allowed any stimulants, and each subject was with a staff member at all times to help keep them awake. Every four hours, subjects participated in 30 minutes of driving and 30 minutes of fatigue assessment testing. During the other three hours, they played games, walked, and did other things to keep their minds and bodies active—they just weren’t allowed to sleep.

The driving took place in the HumanFIRST simulator, on a virtual stretch of I-35 between the Twin Cities and the Iowa border. Lab director Nichole Morris, the study’s principal investigator, said they kept it as boring as possible: “No crossroads, no traffic or buildings, a twilight sky.” Morris and her colleagues then watched to see whether the subjects were staying in their lane, obeying the speed limit, and staying on the road—and how these behaviors changed the longer the subjects were awake.

The fatigue assessment testing consisted of seven assessments that looked at the types of mental functions that might be affected by sleep deprivation. For example, participants would watch a screen and push a button as fast as they could when they spotted a circle. Another test involved responding only when they saw the letters P or Q and actively ignoring other letters. Generally, the more fatigued the subjects were, the worse they performed on the tests.

Some study findings were surprising to Morris and her team. For example, around the 26-hour mark, many participants reported visual illusions or hallucinations. Dr. Conrad Iber, a U of M professor of sleep medicine who worked on the study, said the illusions may have been dream activity.

Another surprise was how quickly fatigued drivers fell asleep at the wheel after they had just been walking around and feeling “refreshed.” At around 16 to 17 hours, perky participants would get into the driving simulator and fall asleep within five minutes. “The adage of ‘I feel sleepy, I’m going to go walk around and get some fresh air’ won’t save you,” Morris says. “No amount of walking around is a substitute for sleep.”

Overall, the project identified some promising possibilities for fatigue assessment tests, but there is more work to be done. For example, assessment results would need to be able to stand up in court, like breathalyzer and blood tests for drunk driving. But ultimately, this study is a step in the right direction to help make our roads safer.

(Adapted from a Minnesota Department of Public Safety blog post published in February 2020.)

FROM 2014–2018, more than 5,000 CRASHES in Minnesota involved drowsy drivers.

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