Method pinpoints ‘hot spots’ for bus emissions

U of M researchers have developed a way to identify the exact location of “hot spots” for air pollutants created by transit buses—work that could be used to create new strategies for addressing emission hot spots in the future.

The research team, led by Professor David Kittelson of the Department of Mechanical Engineering, began by collecting data using two different instrumented buses, one with a standard diesel engine and automatic transmission and another with a hybrid engine and selectively enabled start-stop technology (both model year 2013). Nitrogen oxide (NO\textsubscript{X}) emissions and GPS data were recorded for each bus during spring, summer, and fall on three different routes representing a wide range of driving conditions: an inner city route with frequent stops and slow speeds, a medium-
In Minnesota, the combination of traffic and extreme weather can turn small pavement problems into big potholes. To make progress in the seemingly unending task of pothole repair, U of M researchers are designing durable patches and repairs that are quick to apply and less costly for maintenance budgets.

“The goal of pothole repair is to mend the road surface in a way that lasts and is relatively inexpensive,” says Lawrence Zanko, a senior research fellow at the University of Minnesota Duluth’s Natural Resources Research Institute (NRRI). “Maintenance departments are realizing that the traditional method of ‘throw and go’ cold patch is quite ineffective and therefore costly in terms of both materials and labor.”

In a new report, researchers present two improved options for pothole repair that are ideally suited to Minnesota’s cold and wet conditions. The first approach is a fast-setting, taconite-based compound, which was found to be especially well-suited for rigid and relatively deep repairs in concrete pavements. The second approach uses a vehicle-based microwave heating system with taconite materials for in-place pothole and pavement repair; this technology proved very effective for repairing potholes in asphalt pavement at all temperatures, including very cold temperatures.

The research was part of a broader effort by the Minnesota Department of Transportation (MnDOT) to evaluate current practices, materials, and policies for pavement patching and repair. “There are more ways to patch than just sitting in the back of a truck and throwing bituminous mix into holes,” says Sue Lodahl, MnDOT assistant state maintenance engineer. “Some work better with concrete, some with bituminous. These taconite-based mixes can make durable patches.”

Full-depth replacement of potholes is expensive and time-consuming. Careful cleaning and filling with hot-mix asphalt can work, but in winter is impractical or even impossible. The new taconite options could help agencies overcome these obstacles.

“Because the microwave equipment heats the existing pavement to the point that the pavement itself becomes part of the repair, we get an excellent bond,” says Zanko, the study’s principal investigator. “This makes the technology superior to most other methods for repairing potholes in asphalt pavements, especially during the winter. Plus, we also demonstrated that an effective repair compound can be made almost entirely from inexpensive and easily-available recycled materials for a significant cost savings compared to typical repair compounds that rely on specialized asphalt formulations.”

To fully assess these technologies, the research team conducted comparative field-testing and in-place analysis of a variety of repair methods and materials. Many taconite-based repairs lasted three years, Zanko reports, and though some cracked, the repairs remained in place.

“Our findings indicate that these two repair options have the potential to save maintenance departments thousands of dollars in labor costs annually, reduce traffic disruption caused by the frequent repair of repeatedly failing patches, and add efficiency and longevity to repairs,” he says.

The final report includes two fact sheets on the new repair methods that maintenance agencies can use as part of their toolkit of options for repairing potholes and other pavement failures.

In addition, a new licensing agreement was recently finalized with a company interested in NRRI’s patented pothole/pavement repair compound. The agreement was in part influenced by work performed during the project, Zanko says.

In new work funded by the Minnesota Local Road Research Board, researchers will refine the taconite-based repair compound and develop and field-test a low-cost mechanized system that can efficiently mix and place the repair compound in larger quantities while minimizing or eliminating direct contact and hand-mixing by maintenance personnel, Zanko says.
Starting this fall, the annual CTS Transportation Research Conference will be a one-day event on the U of M east bank campus. As in past years, the conference will convene researchers and practitioners from Minnesota and the Upper Midwest to highlight new learning, emerging ideas, and the latest innovations in transportation. Sessions will also touch on implementation efforts and engagement activities.

The conference will be held November 3 at the Commons Hotel. The opening plenary and luncheon presentations are described below; the full program and registration information are available at cts.umn.edu/events/conference. Contact Maddie Grover at cceconf5@umn.edu or 612-624-4938 with questions.

Please plan to join us for a day of discovery and innovation!

OPENING SESSION: Creating Sustainable, Livable, Forward-Compatible Cities for Economic Resilience
Cities at different stages of development all grapple with managing the traditional challenges of transportation, infrastructure financing, housing, and environmental sustainability. These complexities are compounded by rapidly changing modes of operation, new and disruptive technologies, and changing expectations and demands from citizens and business. What innovations are taking place in cities, and how can government, business, and nonprofit leaders utilize this wave of change to shape a quality of life that is improved and not compromised? How can they work together—instead of at cross-purposes?

Gabe Klein, author of Start-Up City: Inspiring Private and Public Entrepreneurship, Getting Projects Done, and Having Fun (Island Press), will discuss the larger macro trends in society and address process innovation and governance. He will also share how city leaders are reorganizing their urban systems to be synergistic rather than at odds with one another and the cities’ goals. Klein has also led the Chicago and Washington, DC, transportation departments and served as vice president of Zipcar.

Following Klein’s presentation, a panel of experts will share perspectives on the implications for the future of transportation systems in Minnesota cities.

LUNCHEON: How to Promote and Prepare for Automated Driving
Automated or “self-driving” cars are becoming reality on our roadways—with potentially dramatic impacts on infrastructure, accessibility, land-use patterns, and much more.

Bryant Walker Smith, assistant professor in the School of Law at the University of South Carolina, will present steps that governments can take now to encourage the development, deployment, and use of automated driving systems. These steps build on a solid understanding of the technologies, applications, and existing legal infrastructure—and include key administrative, legal, and community strategies that focus as much on today’s problems as tomorrow’s solutions.

Smith is also an affiliate scholar at the Center for Internet and Society at Stanford Law School and chair of the Emerging Technology Law Committee of the Transportation Research Board.

READ CATALYST ONLINE for links to research reports and other resources.
Access to opportunities such as jobs and services is one of the main benefits of public transit. To ensure this benefit is maximized, transportation planners are increasingly seeking to distribute transportation resources as fairly as possible in order to provide a variety of options to commuters and increase their access to opportunities.

Typically, transportation accessibility is measured using the number of opportunities that can be reached within a given time threshold. For example, a planner might look at how many jobs residents of a socially disadvantaged neighborhood can reach within 45 minutes to see where improvements might be needed. However, these traditional accessibility measurements have a significant shortcoming.

“Research shows us that low-income and socially disadvantaged individuals are the most likely to be transit dependent and face barriers to accessing their desired destinations,” says David Levinson, a professor in the Department of Civil, Environmental and Geo-Engineering. “If we only look at time as a constraint on accessibility, we leave the crucial factor of financial access out of the equation. For low-income populations, transit fares can present a major barrier to accessibility, since fares can consume a large share of individuals’ budgets. As a result, planners and researchers may overestimate job accessibility, particularly for low-income riders.”

In recent research, Levinson and his co-authors developed a set of innovative accessibility measures that incorporate both travel time and transit fares. Then, they applied those measures to determine whether people living in socially disadvantaged neighborhoods—in this case, in Montreal, Canada—experienced the same levels of transit accessibility as those living in other neighborhoods. Finally, they compared the results of their new measurement with traditional accessibility measures that account only for travel time.

“We found that accessibility measures relying solely on travel time estimate a higher number of jobs than our measure,” says Levinson. “For the most socially disadvantaged residents, factoring in a single fare reduces job accessibility 50 percent; adding a monthly pass reduces it 30 percent.”

The study also found that public transit generally favors vulnerable populations in Montreal. “Low-income populations generally reside in the central city, near transit stations and job concentrations. Higher-income populations are concentrated in suburban areas, and suburban fares are much more expensive. So in this case, residents of socially disadvantaged areas have more equitable accessibility to jobs even when fare cost is included,” he explains.

The new accessibility measure offers several benefits for transportation planners, Levinson says. First, it will allow them to better explain to policymakers the number of jobs a resident can reach for a given cost, thereby allowing fare structures and hourly wages to be judged against the cost of commuting. In addition, it can help planners identify neighborhoods that need transportation benefits the most and provide broader insight for the transportation community into how combined measures of accessibility can be used to better understand the impact of transportation planning decisions.

This research was conducted as a collaboration between Levinson and the Transportation Research at McGill (TRAM) group, which is led by Ahmed El-Geneidy, associate professor at McGill University in Montreal and a former U of M researcher.

Adding transit costs to the accessibility equation offers a better gauge of transportation equity

Nominees sought for Research Partnership Award

CTS is seeking nominations for the 2017 Research Partnership Award. The award honors research projects within the CTS program that have resulted in significant impacts on transportation.

The award will be presented at the CTS annual awards ceremony on February 15.

Please submit your nomination by November 23. For more information or to submit a nomination, please visit cts.umn.edu/about/awards/rpa.
Mumble strips, bridges and waterways, surveying, pavement construction, and highway noise sampling are just a few of the topic areas explored by students in this year’s Summer Transportation Internship Program.

The program, offered jointly by CTS and the Minnesota Department of Transportation (MnDOT), allows U of M civil engineering undergrads to gain real-world experience in transportation and hone their professional skills.

The following students from the U of M’s Twin Cities and Duluth campuses participated in the 2016 program, working in these MnDOT offices:

- James Bolton, Bridge Office, Hydraulics Unit
- Logan Camilli, Office of Traffic, Safety and Technology
- Paul Fritton, Office of Environmental Stewardship
- Yousan Foo, Office of Materials and Road Research
- Chen Hu, Design Office, Metro Division
- Brittany Jurrens, Office of Land Management, Geodetic Unit
- Carlos Moreno-Gomez, Bridge Maintenance and Inspection Unit
- Metro Division
  - Shaluka Samarasena, North Area Management Unit, Metro Division
  - Joshua Tarr, Office of Traffic, Safety and Technology

Student highlights include working directly with MnDOT engineers on a variety of projects, taking field measurements, writing research reports, and offering guidance to local transportation agencies.

“My favorite parts of the summer involved research and updating MnDOT policy,” says Joshua Tarr. “I never thought I would be doing such important work. My internship has shown me real-world application skills in the field of engineering [and] allowed me to create a clear path to landing a job.”

The internship also offered students the chance to further develop their general professional skills. According to the interns, the program helped them improve their communication skills, learn new software programs, troubleshoot problems and prioritize tasks, and interact effectively with MnDOT employees, city and county engineers, and individuals at consulting firms.

In addition to providing practical work experience, the program also exposed some interns to new areas of educational and career interest.

“This internship helped me to expand my understanding of civil engineering,” says Paul Fritton. “I now have a much greater interest in and appreciation for the work that environmental and water resources engineers do. I am looking forward to [taking] classes in fluid mechanics and water/wastewater treatment to help me learn more about where my interests lie and where my career path will lead me.”
Travel times are calculated using a detailed road network and speed data that reflect typical conditions for an 8 a.m. Wednesday morning departure. Additionally, the accessibility results for 8 a.m. are compared with accessibility results for 4 a.m. to estimate the impact of road and highway congestion on job accessibility.

Rankings are determined by a weighted average of accessibility, with a higher weight given to closer, easier-to-access jobs. Jobs reachable within 10 minutes are weighted most heavily, and jobs are given decreasing weights as travel time increases up to 60 minutes. Based on this measure, the research team calculated the 10 metropolitan areas with the greatest accessibility to jobs by auto (see sidebar).

A similar weighting approach was applied to calculate an average congestion impact for each metropolitan area. Based on this measure, the team calculated the 10 metropolitan areas where workers experience, on average, the greatest reduction in job access due to congestion (see sidebar).

“Rather than focusing on how congestion affects individual travelers, our approach quantifies the overall impact that congestion has on the potential for interaction within urban areas,” Owen explains.

“For example, the Minneapolis–St. Paul metro area ranked 12th in terms of job accessibility but 23rd in the reduction in job access due to congestion,” he says. “This suggests that job accessibility is influenced less by congestion here than in other cities.”

The report—Access Across America: Auto 2015—presents detailed accessibility and congestion impact values for each metropolitan area as well as block-level maps that illustrate the spatial patterns of accessibility within each area. It also includes a census tract-level map that shows accessibility patterns at a national scale. A separate publication, Access Across America: Auto 2015 Methodology, describes the data and methodology used in this evaluation.

The research was sponsored by the National Accessibility Evaluation Pooled-Fund Study, a multi-year effort led by the Minnesota Department of Transportation and supported by partners including the Federal Highway Administration and 10 state DOTs.
speed route with longer distances between stops, and an express route that required little braking. After 66 total days of testing, researchers accumulated nearly 13 gigabytes of data representing more than 1,200 trips along these routes.

Analyzing this immense amount of data produced a number of significant findings. First, researchers discovered that buses driving their routes often emit NO\textsubscript{X} emissions at much higher levels than during certification testing, particularly routes with frequent stops. On selected routes, bus stops resulted in 3.3 times the route-averaged NO\textsubscript{X} emissions.

“We believe this shows that the federal testing procedure does not accurately represent real-world driving conditions for in-use transit buses, which make up more than 7 percent of the heavy-duty vehicles this standard was intended for,” says Andrew Kotz, a graduate student on the research team.

In addition, researchers were able to pinpoint the conditions under which increased NO\textsubscript{X} emissions were most likely to occur. “Our results indicate that bus stops, cold starts, inclines, and accelerations had the most noticeable impact on elevated NO\textsubscript{X} emissions for the tested routes,” Kotz says.

The hot spot detection technique developed for this study (a Lagrangian spatial analysis) will provide a new lens with which to view emissions hot spots.

“The ability to pinpoint hot spot magnitude for individual vehicles during regular use was not possible before, because the models generalized vehicle emissions factors and provided insufficient spatial resolution,” explains Will Northrop, ME assistant professor and project co-investigator. “Identifying spatiotemporal hot spots can give researchers and vehicle manufacturers a better understanding on where to focus their emissions-reduction efforts and provide regulators with data for improved standards.”

Ultimately, the technique could be used for emissions analysis of larger data sets, such as networks of connected vehicles, Northrop says.

The project was funded by the U of M’s Initiative for Renewable Energy and the Environment and CTS.

The U of M researchers continue collaborations with Metro Transit and the transit bus engine manufacturer Cummins, and have added a 2015 model year bus to assess improvements made from the initial study. Preliminary data show substantial reductions in real-world driving NO\textsubscript{X} emissions.
New method pinpoints ‘HOT SPOTS’ FOR BUS EMISSIONS.
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RESEARCH CONFERENCE:
A day of discovery and innovation ON CAMPUS.
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Report illustrates access to jobs
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