Simulations reveal potential for up to 17% energy savings through traffic congestion controls

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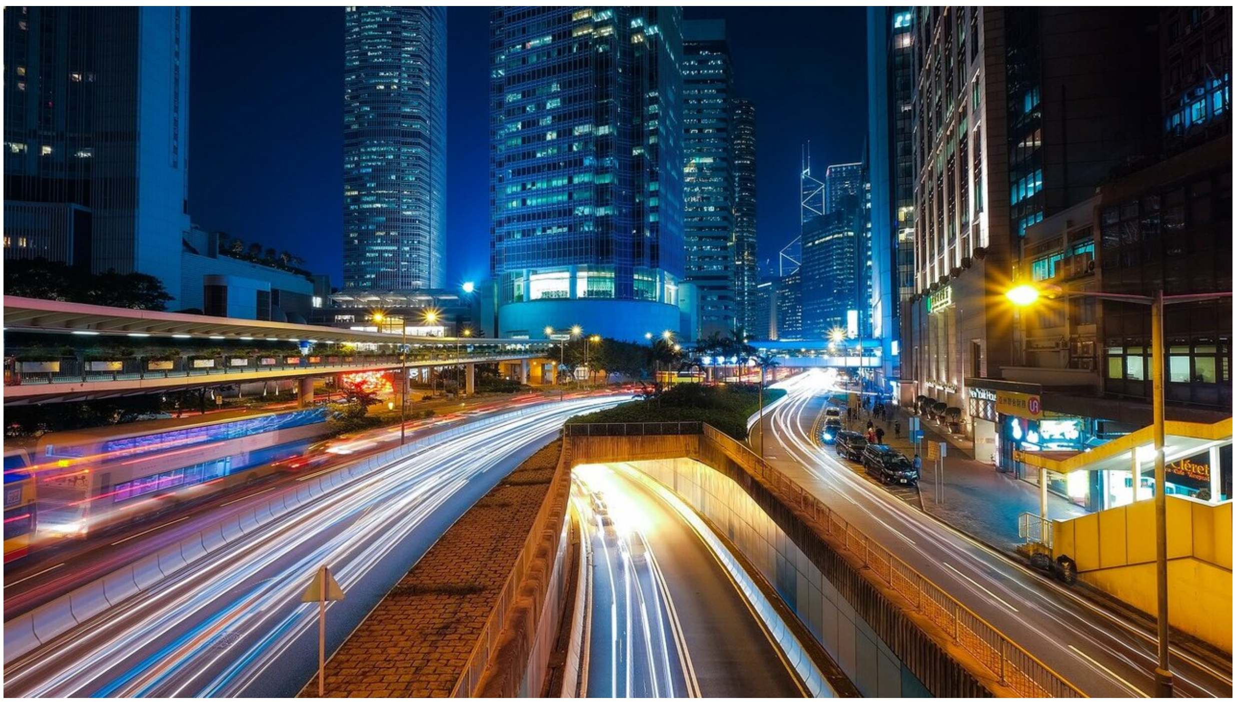

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Inching forward in bumper-to-bumper traffic, drivers bemoan the years of their lives sacrificed in bad commutes. Even with the pandemic dramatically reducing the volume of traffic, Americans still lost an average of 26 hours last year to road congestion. In a typical year, U.S.

drivers spend closer to 46 hours stuck behind the wheel—which can add up to thousands of hours in the course of a lifetime.

Traffic jams not only waste time and more than 3.3 billion gallons of fuel each year, but they also translate into 8.8 billion hours of lost productivity and surges in polluting emissions. Recent research by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), in partnership with Oak Ridge National Laboratory (ORNL), reveals the potential to untangle traffic snarls through a combination of next-generation sensors and controls with high-performance computing, analytics, and machine learning. These innovative congestion-combatting strategies target reducing vehicle energy consumption by up to 20% and recovering as much as $100 billion in lost productivity in the next 10 years.

The NREL team created a series of simulations (or a "digital twin") of Chattanooga, Tennessee, traffic conditions using real-time data collected via a wide range of sensor devices. The simulations help identify which controls—in the form of traffic signal programming, alternative routing, speed harmonization, ramp metering, dynamic speed limits, and more—can deliver the greatest energy efficiency, while optimizing travel time, highway speed, and safety. The resulting information can be used by urban planners, technology developers, automakers, and fleet operators to develop systems and equipment that will streamline commutes and deliveries.

"Chattanooga provided an ideal microcosm of conditions and opportunities to work with an exceptional roster of municipal and state partners," said NREL's Vehicle Technologies Laboratory Program Manager John Farrell. "Eventually, the plan is to apply these solutions to larger metropolitan areas and regional corridors across the country."

Sensors were used to continuously collect data from more than 500 sources including automated cameras, traffic signals, on-board GPS devices, radar detectors, and weather stations. This information fed into simulation, modeling, and select machine-learning activities headed up by NREL researchers for the ORNL-led project.

The NREL team has developed state-of-the-art techniques and tools to identify and quantify energy lost to traffic congestion and evaluate and validate mitigation strategies. By pairing data from multiple sources with high-fidelity machine learning, NREL researchers can estimate energy use and energy loss, determine where and why systems are losing energy, and model realistic reactions to changes in conditions and controls. This provides a scientific basis for strategies to improve traffic flow, which the team can then assess through simulations and validate through field studies.

For the Chattanooga project, the NREL team created a method for estimating and visualizing real-time and historic traffic volume, speed, and energy consumption, making it possible to pinpoint areas with the greatest potential for energy savings through application of congestion relief strategies. The team also developed machine-learning techniques to help evaluate traffic signal performance while collaborating with ORNL researchers on other machine learning and artificial intelligence strategies.

NREL's analyses looked beyond data, using machine learning, data from GPS devices and vehicle sensors, and visual analytics to examine the underlying causes of congestion. For example, the team discovered that traffic signals along one major corridor had not been timed to optimize lighter, off-peak midday traffic flow, which resulted in a high incidence of delays due to excessive stops at red lights.

The team revealed that the same corridor could act as a strategic area for reducing energy consumption, with a simulation model of the corridor indicating that optimized traffic signal settings had the potential to reduce energy consumption at that location by as much as 17%. Researchers then recommended to Chattanooga Department of Transportation engineers specific improvements to four signal controllers along the corridor. Real-world results showed as much as a 16% decrease in fuel use for vehicles on that stretch of road—almost meeting the target of 20% reductions—through the deployment of very limited strategies.

"Optimizing the control of the traffic systems could help save significant amounts of energy and reduce mobility-related emissions in the real world," said Qichao Wang, NREL postdoctoral researcher and lead for the traffic control effort in this project.

The real-time data crunching required to produce these complex, large-scale simulations relied on high-performance computing on the Eagle supercomputer at NREL. This computer can carry out 8 million-billion calculations per second, allowing researchers to complete in hours, minutes, or seconds computations that would have previously taken days, weeks, or even months.

"The intersection of high-performance computing, high-fidelity data, machine learning, and transportation research can deliver powerful results, far beyond what has been possible in the past with legacy technology," said Juliette Ugirumurera, NREL computational scientist and co-lead of the laboratory's project team.

More than 11 billion tons of freight are transported across U.S. highways each year, amounting to more than $32 billion worth of goods each day. This gives commercial freight carriers even greater motivation than individual drivers to avoid wasting fuel and money in traffic congestion. Researchers have recently started working with regional and national carriers in Georgia and Tennessee to explore how to most effectively tailor the simulations and controls to trucking fleets.

"Up until now, our city-scale prototype has focused more tightly on passenger vehicles and individual travel patterns," said Wesley Jones, NREL scientific computing group manager and co-lead of the laboratory's project team. "As we expand our research to examine freight operations, we'll also take a broader look at the regional and national routes they travel."

Eventually, it is anticipated that these technologies for passenger and freight transportation will be applied across the country, with additional sensors and control equipment integrated in infrastructure and connected and autonomous vehicles.

Provided by National Renewable Energy Laboratory

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