**Title**

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RESEARCH BRIEF

National Center for Sustainable Transportation

# An Adaptive Strategy for Connected Eco-Driving under Uncertain Traffic and Signal Conditions

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## Research Question

Connected and automated vehicle technology could bring about transformative reductions in traffic congestion, greenhouse gas emissions, air pollution, and energy consumption. Connected and automated vehicles can directly communicate with other vehicles and road infrastructure and use sensing technology and artificial intelligence to respond to traffic conditions and optimize fuel consumption.

An eco-approach and departure application for connected and automated vehicles has been widely studied as a means of calculating the most energy-efficient speed profile and guiding a vehicle through signalized intersections without unnecessary stops and starts. Simulations using this application on roads with fixed-timing traffic signals have produced 12% reductions in fuel consumption and greenhouse gas emissions. But real-world traffic conditions are much more complex, with the need to account for other vehicles queued at intersections, variable driving behavior by other drivers, and actuated traffic signals (those that respond to the presence of a vehicle or pedestrian). These uncertainties and the limited sensing range of automated vehicles create challenges for determining the most energy-efficient speed.

To account for this uncertainty, researchers from the University of California, Riverside's Center for Environmental Research and Technology propose a prediction-based, adaptive connected eco-driving strategy (Figure 1). The proposed strategy analyzes the possible upcoming traffic and signal

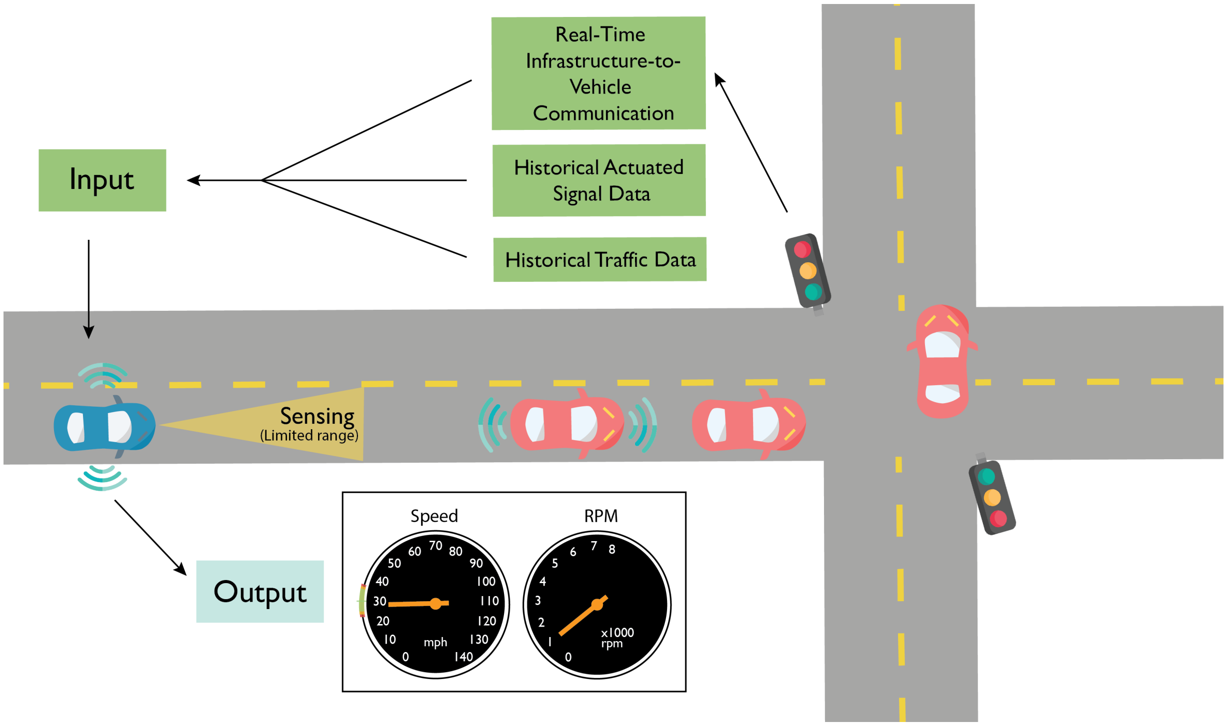


*Figure 1. An illustration of adaptive eco-driving under uncertain traffic and signal conditions. The target vehicle senses upcoming traffic conditions and receives information from road infrastructure, which is supplemented by historical traffic and actuated signal data, and adjusts speed accordingly.*

scenarios based on historical data and live information collected from communication and sensing devices, and then chooses the most energy-efficient speed. This approach can be extended to accommodate different vehicle powertrains and types of roadway infrastructure.

## Key Findings

**The adaptive eco-driving strategy can reduce fuel consumption and emissions under uncertain traffic conditions.** The proposed strategy is designed to optimize the energy consumption at the intersection considering preceding traffic and queues, using sensor detection and historical traffic data. For uncertain traffic conditions, simulation results show average energy savings of 9%. Simulations also indicate that energy consumption of a vehicle equipped with this adaptive strategy and a 100-meter–range sensor is equivalent to a vehicle with a conventional eco-approach and departure strategy and a 190-meter–range sensor. This suggests that the proposed strategy could nearly double the effective detection range in eco-driving.

**The adaptive eco-driving strategy can use historical traffic signal data to achieve even greater fuel savings at intersections with actuated signals.** Historical signal phase and timing data can be used to calculate the probability that a signal transfers from one state to another, which then determines the vehicle's optimal travel speed. Simulations conducted using real-world traffic signal data collected from an intersection in Carson, California show that the proposed method, relative to other baseline methods, can achieve 40% energy savings when the vehicle arrives in the red time and 8.5% energy savings when the vehicle arrives in the green time.

**Even when historical traffic signal data is unavailable, a hybrid reinforcement learning technique can reduce fuel consumption and travel time.** Researchers developed a hybrid reinforcement learning framework that would enable a vehicle to learn long-term driving strategies based solely on onboard sensor data. Microsimulation experiments show that a hybrid reinforcement learning-based vehicle using an eco-driving strategy can reduce energy consumption by 12–47% and travel time by 1–7% compared to baseline methods when traveling through a signalized intersection under mixed traffic conditions.

## Research Implications

Future directions for this work will include analyzing the performance of different types of vehicles, such as heavy-duty trucks, and testing a cooperative eco-driving strategy with multi-vehicle agents communicating in complex traffic networks. More refined micro-simulations and field experiments can also be conducted to analyze performance of adaptive eco-driving in more realistic situations.

## More Information

This research brief is drawn from "Developing an Adaptive Strategy for Connected Eco-Driving under Uncertain Traffic and Signal Conditions," a report from the National Center for Sustainable Transportation, authored by Peng Hao, Zhensong Wei, Zhengwei Bai, and Matthew Barth of the Center for Environmental Research and Technology, University of California, Riverside. The full report can be found on the NCST website at https://ncst.ucdavis.edu/project/developing-adaptive-strategy-connected-eco-driving-under-uncertain-traffic-conditions.

For more information about the findings presented in this brief, please contact Dr. Peng Hao at haop@cert.ucr.edu.




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