Title

Connected and Automated Vehicle Technology is Not Enough; it Must also be Collaborative

Authors
Patire, Anthony D., PhD
Dion, Francois, PhD
Bayen, Alexandre M., PhD

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POLICY BRIEF

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Connected and Automated Vehicle Technology is Not Enough; it Must also be Collaborative

Anthony D. Patire, Ph.D., Francois Dion, Ph.D., Alexandre M. Bayen, Ph.D.
Institute of Transportation Studies, University of California, Berkeley

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Issue

Connected and automated vehicles (CAVs) will revolutionize the way we travel; however, what impact this revolution will have on advancing broader societal goals is uncertain. To date, the private sector technology rollout has emphasized the automation side of CAVs and neglected the potentially transformative possibilities brought by a more collaborative notion of connectivity. This may have significant downsides from a broader societal perspective. For example, CAVs (including those on the road today) collect a vast amount of data gathered through onboard systems (e.g., radar, lidar, camera), however, this data is not typically shared with other vehicles, roadside infrastructure, or public transportation agencies. This lack of collaboration will likely make traffic worse and forfeit the opportunity to manage traffic at the systems-level, which is where significant gains can be made in terms of improving traffic flow and safety, reducing greenhouse gas emissions and vehicle energy use, and more.

A small but growing body of research and pilot demonstrations championed by the CIRCLES consortium[1] are showing that a collaborative CAV ecosystem can support strategies for creating a more efficient, safe, and environmentally sustainable transportation system. One strategy of particular interest is "flow smoothing" whereas data gathered by "downstream" vehicles is transmitted to "upstream" vehicles and used to adjust upstream vehicle speeds in a manner that smooths stop-and-go traffic waves and improves traffic flow along a corridor.

Key Research Findings

Traffic improves when vehicles collaborate, which has implications for greenhouse gas (GHG) emissions and air quality. Experiments along a circular track with more than 20 vehicles with human drivers revealed that traffic waves emerge naturally and consistently but can be dampened by controlling the speed of just a single vehicle in the flow[2]. This is possible in part due to the vehicles traveling in a closed circle, whereas the one "controller vehicle" sets its speed profile based on maintaining a safe following distance from the vehicle in front while making it easy for the vehicles behind to follow. One of these studies specifically examined the implications on vehicle emissions and found that reducing or eliminating stop-and-go may reduce carbon dioxide emissions by 15% and nitrogen oxide emissions by 73%[3]. If these results can be scaled, then controlling the speed of automated vehicles in general traffic (i.e., a mix of vehicles including those with human drivers as well as partially or fully automated vehicles) has the potential to dampen stop-and-go waves and deliver significant environmental benefits.

Collaborative flow smoothing requires high-quality real-time data. The availability of real-time downstream traffic information is needed to generate and communicate optimal speed profiles to upstream vehicles for the purposes of smoothing traffic and reducing the overall energy and emissions footprint of vehicles along a corridor. Typical online sources of downstream vehicle speeds are not lane-specific and have significant time delays. This is an issue because calculating a vehicle's trajectory based on obsolete data (i.e., reported traffic congestion that no longer exists) will produce erroneous, and in some cases dangerous results.

The key to high-quality data is having enough vehicles along a corridor sharing data in real-time. A recent real world field experiment led by UC Berkeley, called the MegaVanderTest, aimed to do just this. To date, the MegaVanderTest is the largest deployment of CAVs for the purpose of smoothing traffic flow along a corridor. Over the course of one week (from November 14 to 18, 2022), 100 vehicles equipped with adaptive cruise control systems modified by the CIRCLES research team were deployed on a 4.2-mile stretch of Interstate-24 MObility Technology Interstate Observation Network (I-24 MOTION) near Nashville, Tennessee, which is equipped with 276 pole-mounted high-resolution traffic cameras. These modified vehicle systems were able to produce sufficient traffic data to generate and follow optimized vehicle trajectories (i.e., vehicle paths with specified following distances and speeds). Data gathered from the instrumented vehicles and roadside infrastructure were extracted for analysis and evaluation of traffic performance measures.

The barrier to a collaborative CAV ecosystem can be overcome by building a market for it. This can be achieved by demonstrating the value of collaboration through larger-scale pilots and deployments. This may involve public sector support and incentives as well as private sector acceptance of the technology for integration with their products. Flow smoothing technology may also improve the driver experience and operations of managed lanes, bridges, or other specific facilities. Further work is required to match the goals of multiple agencies with viable target fleets or commuter populations that use these facilities.

Without collaboration, adaptive cruise control is likely to make traffic worse. Adaptive cruise control technologies commonly deployed in vehicles on the market today are not "string-stable"[4]. In other words, they are not able to prevent small traffic disturbances from amplifying into stop-and-go waves. The continued deployment of these technologies may make traffic worse, and increasingly unpleasant for those driving vehicles unequipped with the latest technologies. This is a missed opportunity since typical mid-tier vehicles (such as those used in the MegaVanderTest) come equipped with the ACC technology needed for flow smoothing, except for the ability to share data and collaborate.

More Information

This policy brief is drawn from the report "Pathways for CAV Technology Rollout" prepared by Anthony Patire, Francois Dion, and Alexandre Bayen of the University of California, Berkeley. The report can be found at www.ucits.org/research-project/rimi-5b-01. For more information about the findings presented in this brief, please contact Anthony Patire at adpat@berkeley.edu.

[1]The Congestion Impacts Reduction via CAV-in-the-loop Lagrangian Energy Smoothing (CIRCLES) project aims to reduce instabilities in traffic flow, called "phantom jams," that cause congestion and wasted energy. CIRCLES is led by UC Berkeley and the Institute of Transportation Studies (ITS) Berkeley, in coordination with Vanderbilt University, Temple University, Rutgers University-Camden, the Tennessee Department of Transportation, Toyota North America, and Nissan North America.

[2]R. E. Stern, S. Cui, M. L. D. Monache, R. Bhadani, M. Bunting, M. Churchill, N. Hamilton, R. Haulcy, H. Pohlmann, F. Wu, B. Piccoli, B. Seibold, J. Sprinkle and D. B. Work, "Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments," Transportation Research Part C: Emerging Technologies, vol. 89, pp. 205-221, 2018. https://doi.org/10.1016/j.trc.2018.02.005.

[3]R. E. Stern, Y. Chen, M. Churchill, F. Wu, M. L. D. Monache, B. Piccoli, B. Seibold, J. Sprinkle and D. B. Work, "Quantifying air quality benefits resulting from few autonomous vehicles stabilizing traffic," Transportation Research Part D: Transport and Environment, vol. 67, pp. 351-365, 2019. https://doi.org/10.1016/j.trd.2018.12.008.

[4]G. Gunter, C. Janssen, W. Barbour, R. E. Stern and D. B. Work, "Model-Based String Stability of Adaptive Cruise Control Systems Using Field Data," in IEEE Transactions on Intelligent Vehicles, vol. 5, no. 1, pp. 90-99, March 2020, doi: 10.1109/TIV.2019.2955368.

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