Title
Automated Vehicle Technology Has the Potential to Smooth Traffic Flow and Reduce Greenhouse Gas Emissions

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Automated Vehicle Technology Has the Potential to Smooth Traffic Flow and Reduce Greenhouse Gas Emissions

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Issue

In an ideal world, all cars along a congested roadway would travel at the same constant average speed; however, this is hardly the case. As soon as one driver brakes, trailing cars must also brake to compensate, leading to "stop and go" traffic waves. This unnecessary braking and accelerating increases fuel consumption (and greenhouse gas emissions) by as much as 67 percent.[1] Fortunately, automated vehicles (AVs) — even Level 2 AVs[2] which are commercially available today — have the potential to mitigate this problem. By accelerating less than a human would, an AV with flow smoothing technology is able to smooth out a traffic wave, eventually leading to free-flowing traffic (See Figure 1).

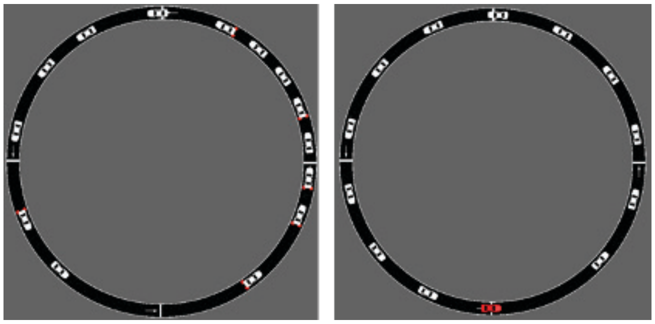

Figure 1 Left: Vehicles not equipped with flow smoothing technology will quickly form stop-and-go traffic waves caused by vehicles braking and then accelerating too much. Right: Introducing a flow-smoothing AV (red car) stabilizes vehicle speeds, primarily by maintaining a gap between the vehicle it is following.

To demonstrate the potential of flow smoothing on reducing greenhouse gas emissions, researchers at UC Berkeley used a calibrated model of the I-210 freeway in Los Angeles to simulate and measure the effect of deploying different percentages (10%, 20%, 30%) of flow-smoothing AVs on the average miles per gallon (MPG) of non-AVs in the traffic system.

Key Research Findings

Deploying flow-smoothing AVs can almost double the fuel economy of other cars on the road. As the proportion of flow-smoothing AVs increased in the simulation, so did the average fuel economy of all cars (Table 1). When the proportion of flow-smoothing AVs increased from zero to 30 percent, the fuel economy of non-AVs went from 19 MPG to 36 MPG. This almost doubling of fuel economy is broadly in line with the empirical results of other research that found fuel consumption decreased by 40 percent with flow smoothing AVs present.[3]

Flow smoothing provides net benefits even when induced demand is considered. When a roadway's traffic flow and average speed improve, more travelers may be enticed to use the roadway — a phenomenon referred to as induced demand. It is estimated that "every 10 percent increase in travel speeds is associated with a 6.4 percent increase in vehicles miles travelled (VMT)."[4] For example, when 30 percent of vehicles in the simulation were flow-smoothing AVs, overall vehicle speeds increased by 50 percent, which over time could increase VMT by at most about 30 percent due to induced demand. Still, the increase in VMT (and thus fuel consumption) would be far less than the near doubling in fuel savings achieved from flow smoothing in this scenario.

Proportion of Flow-smoothing AVs	0%	10%	20%	30%
Average MPG	19 ± 2	25 ± 2	34 ± 4	36 ± 0

Table 1. Fuel economy achieved by the simulated human drivers (non-AVs) as a function of the proportion of flow-smoothing AVs on the road.

Flow smoothing can be affected by how human drivers behave. As the proportion of aggressive drivers was increased in the traffic simulation, the positive effects of flow smoothing were attenuated. For example, with half of the drivers behaving aggressively (e.g., frequently changing lanes into smaller gaps between vehicles), the benefits of flow smoothing were almost eliminated. This finding highlights a central challenge of designing flow-smoothing controllers: traffic microsimulations have accurate enough human driver models to reproduce large-scale traffic phenomena such as traffic waves; however, the effectiveness of flow smoothing also depends on small-scale movements of individual cars (such as lane changes). To be more confident about the effectiveness of flow smoothing, additional analyses should be performed over a range of possible human driving scenarios.

Governmental action will likely be needed to deploy flow smoothing on a large scale. Auto manufacturers have little incentive to implement flow smoothing since consumers primarily benefit from other vehicles using flow smoothing, not from using flow smoothing themselves. A potential pathway for encouraging flow smoothing is through the Safer Affordable Fuel Efficient (SAFE) Vehicles Rule, which sets emissions standards for passenger vehicles and light trucks. Specifically, the benefits of flow smoothing technology could be captured as an off-cycle credit for reducing overall CO2 emissions. Off-cycle credits aim to reward auto manufacturers for technologies that reduce CO2 emissions but whose effect may not be captured in the standardized highway fuel economy tests on individual car models. Changes to the SAFE Vehicles Rule could award credit to auto manufacturers based on the measured impact of flow smoothing across the whole system. This approach may be especially enticing to automakers since commercially available Level 2 adaptive cruise control is already available and can be adapted into a flow smoothing technology.

Further Reading and More Information

This policy brief is drawn from the report "Using Automated Vehicles to Smooth Traffic Flow and Reduce Greenhouse Gas Emissions" authored by Sulaiman Almatrudi, Kanaad Parvate, Daniel Rothchild, Upadhi Vijay, Kathy Jang, and Alexandre Bayen with the University of California, Berkeley. For more information about, please contact Alexandre Bayen at bayen@berkeley.edu.

[1]Stern, R. E., Cui, S., Delle Monache, M. L., Bhadani, R., Bunting, M., Churchill, M., Hamilton, N., Pohlmann, H., Wu, F., Piccoli, B., et al. 2018. Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies* 89:205–221.

[2]The Society of Automotive Engineers (SAE) defines six levels of driving automation ranging from 0 (fully manual) to 5 (fully autonomous). Level 2 (Partial Driving Automation) is where the vehicle can control both steering and acceleration/deceleration. This is not considered self-driving because a human sits in the driver's seat and can take control of the car at any time. Examples include Tesla Autopilot and Cadillac Super Cruise systems. https://www.synopsys.com/automotive/autonomous-driving-levels.html

[3]Stern et al. Dissipation of stop-and-go waves.

[4]Cervero, R. 2003. Road expansion, urban growth, and induced travel: A path analysis. *Journal of the American Planning Association* 69(2):145–163.

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