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A Few Cars Controlled By Computer Can Keep Rest of Traffic Flowing

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You're trying to get away for a summer weekend, but instead you're sitting and fuming in stop-and-go traffic. Drivers are hitting their brakes for no apparent reason, causing everyone behind them to do the same. Soon what had been a smoothly if lethargically flowing stream of traffic looks like a bunched-up caterpillar. You also see drivers changing lanes erratically, causing the same ripple effect. You're sure the highway could handle this volume if only the other drivers weren't idiots.

Guess what? You're right.

L. Craig Davis is too polite to put it that way, preferring to couch his findings in more positive terms. But in a study published in the June issue of the journal *Physical Review E*, the physicist at University of Michigan, Ann Arbor, concludes that many traffic jams could be prevented if a mere one in five vehicles on the road used the new technology of adaptive cruise control rather than being piloted by their human driver alone. In other words, flesh-and-blood drivers make avoidable traffic-jam-causing moves that a computer does not.


"It's a very interesting result," says civil engineer Hani Mahmassani of the University of Maryland, College Park. "With ACC, by eliminating the spacing you need because of driver reaction time, you can get four times more volume on a road by letting vehicles follow each other closely at high speed."

Prof. Davis is the latest physicist to weigh in on a subject that has long been dominated by traffic engineers and "operations research" scientists. A little more than a decade ago, scientists realized that vehicles behave like molecules in a gas. In the most notorious similarity, cars ahead of you that stop or merely slow down can cause a compression wave -- a patch where the cars are jam-packed -- to propagate backward until it reaches you. The wave can persist for hours after the initial bunch of cars hit their brakes, with the result that drivers who never saw that deceleration are totally clueless about why they aren't moving. An estimated 75% of traffic jams are like this, having no visible cause.

In both traffic and gases, tiny perturbations can have effects out of all proportion to their size. In the state called "synchronized flow," traffic is moving, sometimes at a good clip, but it's so dense that the vehicles are in synch like cars in a train. Synchronized flow is, in physics-speak, in unstable equilibrium: The slightest change, such as a driver changing lanes and forcing others to brake, tips the system into a new state. The result is stop-and-go traffic, a true jam.

Physicists are exploring whether adaptive cruise control can prevent this. In ACC, a radar sensor gauges the distance between cars, automatically adjusting speed to maintain a safe distance. Because ACC, which has become standard on some luxury vehicles, can adapt instantly if the lead car brakes (humans take about 0.75 second to react), cars can tailgate safely. ACC can therefore pack more cars into a mile of highway, increasing a road's de facto capacity.

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But it can do more, Prof. Davis finds. Packed cars are a traffic jam waiting to happen. "When you have dense traffic at highway speeds," he says, "if someone brakes, the flow can break down. That doesn't happen with ACC," because the ACC vehicle never actually stops unless a car in front comes to a complete halt. "Perturbations due to changes in the lead vehicle's velocity do not cause jams," he says. Instead, by refraining from excessive braking, an ACC car simply gets closer to the car in front of it. The dreaded compression wave never forms.

It isn't even necessary for all vehicles to be driven by these smart systems. On single-lane roads with high-speed traffic, if a mere 20% of vehicles used adaptive cruise control, traffic jams could be eliminated altogether, Prof. Davis concludes from his computer simulation. Put another way, even if fully 80% of vehicles had an idiot at the wheel, there would still be no traffic jams. The fact that jams still exist means that not even 20% of drivers are minimally competent. But you already suspected that, didn't you?

Human drivers have a tendency to brake harder than the car in front of them did, erring on the side of safety. That can make a bad situation worse, says Prof. Davis. But "ACC eliminates the tendency to overbrake. It smoothes out the overreactions, correcting for bad drivers."

A little of that goes a long way. Remember the last time you were zipping along a highway in light traffic, approaching an on ramp and thinking that the highway could easily handle the merging traffic? Yet the flow seized up, or at best tipped into the dreaded synchronized flow. "Braking at merges can create those shock waves," says Prof. Mahmassani.

But if half the cars in the lane receiving the mergers are driven by ACC, the average velocity at the merge drops but traffic keeps moving, Prof. Davis finds. "When half the vehicles in the receiving lane have ACC, there is a region of reduced speed, but no jam," he says.

A single additional vehicle driven by adaptive cruise control could spell the difference between moving traffic and a traffic jam. Put another way, in some situations it's possible to prevent a traffic jam if only a single driver refrains from dumb moves. You know who you are.

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