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Seeking to unravel mysteries like traffic jams and tailgating

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TRANSPORTATION HERE AND THERE

--Most of us hate traffic jams. Even the sight of a congested freeway brings up memories of breathing exhaust fumes as you bake in the sun, slowly going nowhere.

Michael Cassidy, however, seeks them out. A transportation engineer from the University of California, Berkeley, Cassidy is part of a small cadre of mathematicians and civil engineers dedicated to studying today's congestion in the hope of improving tomorrow's freeways.

In one study, conducted in 2002 and 2003, Cassidy staked out a notorious on-ramp on San Diego's I-805. He was interested in the phenomenon of "breakdown," which occurs when traffic flow suddenly congeals for no apparent reason, converting a minor bottleneck into a full-fledged jam.

At his San Diego study site, he discovered that rush-hour traffic would slowly build until the four-lane freeway was carrying about 170 cars per minute. At that point, traffic would start to back up, but the flow rate would remain high. For several minutes, nothing more would happen except that the back-up gradually got worse. Then, traffic flow would plummet by as much as 17 percent and stay low until the rush abates.

Such breakdowns have long puzzled transportation engineers, says Paul Nelson, an emeritus professor of computer science, nuclear engineering and mathematics at Texas A&M University. Obviously, drivers have gotten impatient and have somehow changed their behavior, to the detriment of everyone.

Dirk Helbing of Dresden University of Technology, Germany, believes that drivers behave in a more-or-less predictable manner, and that models can be made sophisticated enough to account for the normal range of individual behaviors. Typically, he says, modern models treat drivers as reacting like magnets to forces of attraction or repulsion. Thus, drivers are drawn into open spaces or faster moving lanes, but repelled from collisions.

How closely people are willing to follow the car in front of them is also taken into account, as is what Nelson calls "gap acceptance" - the minimum-sized opening into which drivers will change lanes. But trying to puzzle out all of the rules that govern this behavior remains one of the Holy Grails of transportation engineering.

But even the best of today's models aren't good enough to explain everything commuters take for granted. One big mystery is the "phantom" traffic jam that occurs when traffic piles up for no apparent reason. Sometimes it's simply because an obstruction such as a stalled vehicle has been removed and traffic has yet to get back up to speed. But often, such jams appear to occur spontaneously.

Nelson thinks that one of the culprits is statistical fluctuation not captured by the models. Perhaps a surge of vehicles all wants to enter the freeway at once, causing other drivers to overreact in a snowball effect that quickly ties up traffic.

But it's also the case that not all the rules of traffic behavior are understood. In his San Diego study, Cassidy appears to have found a new rule. Breakdown, he says, occurred with "uncanny reproducibility" when traffic in the freeway's right-hand lane began to back up beyond a critical limit - in this case, 16 cars. At that point, people started changing lanes in an effort to avoid the congestion. That spread the slowdown to the inner lanes. Wary drivers in the farthest left lane then reduced speed, and the breakdown was complete.

Knowing what causes the breakdown offered the opportunity to see whether anything could be done to correct it. The obvious solution is to meter the rate of oncoming traffic at the merger, but prior studies have shown that metering doesn't always work. Overly aggressive metering may well reduce freeway congestion, while failing to increase the number of cars getting through the bottleneck. That's because everyone's queued up on the on-ramp, grumbling about not being able to get on the highway.

What was needed at this on-ramp, Cassidy discovered, was a "smart" metering process, in which the rate at which cars were allowed on the freeway depended on the number of vehicles backed up in the right-hand lane. To cure breakdown once it occurred, the meter needed to restrict the rate of entry to about seven per minute. But as long as there were fewer than 16 vehicles backed up in the freeway's right-hand lane, the meter could allow cars to enter at nearly twice that rate without impeding flow.

This could be done automatically, Cassidy says, by wiring the meter to a traffic sensor in the freeway's right-hand lane. Another solution, he says, might be to install a sign that varies the speed limit in the right-hand lane, depending on the level of congestion. The sign would be posted far enough upstream of the merge that drivers would have time to change lanes to avoid the slow zone, thereby opening room for more vehicles to enter.

In another study, Cassidy examined stop-and-go driving on a Toronto freeway. Traditional theories attribute this irritating phenomenon to the way people follow the car in front of them, but Cassidy's study suggests that exit ramps may also play a role.

The problem, he says, arises when congestion from a downstream bottleneck reaches an exit ramp. Concerned about the slowdown, some drivers take the opportunity to exit. That opens space for drivers behind them to speed up, so they, thinking that the congestion is clearing, choose not to exit. Then traffic backs up again and the cycle repeats.

One way to solve this is by metering oncoming traffic at the on-ramp downstream of the exit. Even if the on-ramp isn't the source of the congestion, the rate of entry can be adjusted to damp out the oscillation, counteracting the stop-and-go phenomenon. The result might not be faster driving, but it would be safer and less irritating. "And it would reduce engine emissions and fuel consumption," Cassidy says.

Hani Mahmassani, professor and director of the Maryland Transportation Institute at the University of Maryland, has been taking an entirely different approach to reducing rush-hour congestion. Rather than studying individual bottlenecks, Mahmassani has developed a computer model that predicts congestion levels and traffic delays up to 30 minutes in advance. This can then be linked to signs advising drivers to choose the least-congested routes. Such systems, Mahmassani says, are already in use in Europe, where commuters are accustomed to signs telling them how long it takes to reach popular destinations by various routes.

One problem with giving such notices is that you don't want everyone to heed them. If they do, you've simply substituted one congestion problem for another. Typically, Mahmassani says, traffic flow can be substantially improved if 15 to 40 percent of drivers change their route. Even diverting as little as five percent of the traffic can produce noticeable improvement. Mahmassani therefore proposes "smart" signs that monitor the degree to which drivers respond and adjust their advice accordingly.

The first U.S. implementation of Mahmassani's system will be in Houston, where it will be used to route traffic away from highways that are flooded by the region's frequent heavy thunderstorms.

Looking to the future, he sees high-tech cars with onboard displays that can present traffic-flow information from the Internet. Similarly, telephone companies could beam updates to cell phones or hands-free devices, much as radio stations have made traffic reports a staple of their rush-hour broadcasts. These updates could even provide real-time video from strategically located cameras, so drivers can see exactly what awaits them. "The technology is already here," Mahmassani says. It's merely a matter of making use of it.

Transportation agencies, however, tend to be very conservative about making major changes, such as installing Mahmassani's smart signs.

Part of the problem is legal. Attorneys are fearful that if signs tell commuters what route to take, the city might be held liable if someone heeds that advice only to be killed in an accident.

Another problem is that traffic authorities are leery of experiments. Cassidy's on-ramp metering experiment was conducted on a small enough scale that most drivers probably never noticed them. The meter was already in place - he merely adjusted the timing of the red-light cycle for a few days. But larger-scale traffic experiments have a bad reputation. "Half the time, you make it worse," Nelson says. "And 90 percent of the time you're perceived as making it worse."

Because of that, Nelson feels that modeling will play a vital role in fine-tuning the freeways of the future, allowing transportation engineers to sort out good from bad ideas without inconveniencing commuters in the process. That, in turn, might help overcome the bureaucratic inertia of transportation authorities, overly locked into doing things the way they've always been done before.

Nelson hopes that Congress will continue providing funds for ever-better traffic models. "It's a very cost-effective way to determine the most effective way of accomplishing your goal," he says.

And the goal is one we all share. After all, at today's gas prices, who wants to waste fuel creeping along in stop-and-go-traffic?

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