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## TRAFFIC STOP, GO

**At about 2,000 cars per hour, per lane, flow gets gummed up**

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Stop-and-go traffic is a common occurrence as Elizabeth Duffy drives back and forth on Interstate 66 between her home in Capitol Hill and her job in Tysons Corner. "Sometimes it seems like it's congested for no reason. There's no accident, no police activity," Ms. Duffy says. Yet I-66 is like a parking lot. Then suddenly traffic starts moving - again for no apparent reason.

"[We] say 66 just blew its nose when traffic picks up like that," Ms. Duffy says.

So, why is it that Ms. Duffy and millions of other drivers sometimes just get stuck in heavy traffic on the Beltway, I-66 or elsewhere for no apparent reason?

"This is one of the most vexing phenomena in traffic," says Hani Mahmassani, professor of civil and environmental engineering and director of the Maryland Transportation Initiative at the University of Maryland.

"There is no 'perfect' theory to understand that yet," Mr. Mahmassani says.

What physicists and civil engineers do know is that when traffic increases - when the volume of cars reaches a critical point, somewhere between 1,850 and 2,000 per lane, per hour - there is a risk of greater instability in the traffic flow.

Each driver's behavior affects the whole traffic scene, Mr. Mahmassani says.

"When traffic is at a critical level, it just takes a few people, for whatever reason, to slow down, which will send shock waves down the road for miles," says Denos Gazis, author of "Traffic Theory," published by Kluwer Academic Publishers in 2002.

The sudden stop of the traffic flow is called a "breakdown" among traffic-flow theorists, Mr. Gazis says.

Exaggerated braking (for as little as just a few seconds) in cars up front can lead to complete stopping farther down the road. So, while some cars are

completely stopped several miles down the road, the person who started the breakdown, or chain reaction, by tapping the brakes a couple of times has barely slowed at all.

Nevertheless, the fact that high traffic volume is conducive to breakdowns doesn't explain why such breakdowns sometimes happen and sometimes don't when road conditions otherwise are exactly the same.

"We're still lacking a rigorous explanation as to why it happens," Mr. Mahmassani says.

When volume is low, on the other hand, traffic tends to be stable. Individual drivers have room to change lanes and drive at their desired speed without affecting each other significantly.

Physicists and engineers have used everything from chaos theory, which explains the unpredictability of traffic flow, to hydrodynamic theory, which explains the ripple effects of traffic breakdowns, to try to explain traffic.

However, nothing quite does it yet, Mr. Mahmassani says. This is where the human element comes in.

"The presence of humans makes this more complicated than many other systems," he says, referring to other physical systems that don't involve human behavior - for example, the flow of fluids in a pipe or channel.

Of course, human behavior is very difficult to predict, he says. Some people will brake, others accelerate; some will stay in one lane for dozens of miles, others zigzag constantly between lanes.

"We know there are aggressive and less aggressive drivers," says Pravin Varaiya, professor of electrical engineering and computer science at the University of California at Berkeley. "We don't have enough data on driver behavior yet."

One thing scientists do know is that humans will always keep a certain distance between cars to feel safe.

"We need to follow each other at a certain distance, or it increases the safety issues," Mr. Mahmassani says.

That distance puts the cap on the capacity of highway driving at about 2,200 cars per lane, per hour.

If computers - which don't have the inconvenient, and sometimes lifesaving, human characteristic of fear - drove our cars, capacity possibly could be increased to up to 5,000 cars per lane, per hour, Mr. Gazis says.

This idea has been presented on a theoretical level as the "automated highway," where drivers would relinquish control of their cars once on the highway. The car would be driven by a centralized computer that also would control the other cars on the highway.

However, Mr. Gazis and others doubt that this type of highway and technology will be realized soon.

"It could work if the highway was just infinite," Mr. Gazis says, "but when you start having exits and entrances, it becomes a difficult task."

Current technology and traffic engineering that helps the traffic flow include, in city traffic, lights that are timed to alleviate congestion. On highways, appropriate placement of exit and entrance ramps makes a big difference, Mr. Mahmassani says.

The decision on where exits and entrances are placed is up to the Department of Transportation (DOT) on a state level, Mr. Varaiya says.

Sometimes landowners and developers petition for entrances and exits to serve their developments. Most plans are subject to environmental review and occasionally citizen input, but the practice varies by state and region.

"It's always a trade-off. For the flow of traffic, you want the exits as far apart as possible," Mr. Varaiya says, "but if people have to drive a long way to get to the highway, then surface streets get clogged instead."

Ultimately, to understand traffic behavior better and to improve the traffic environment, most scientists agree that they have to use a combination of microscopic theory - modeling the individual driver's behavior - and macroscopic theory - modeling traffic as a whole.

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One thing upon which scientists - and the rest of us - can agree is that the number of cars on our roads increases by the day and few people like spending time on our increasingly clogged roads.

"The state DOTs and the Feds know that the golden age of building highways is over," Mr. Varaiya says. "We can't keep adding lanes."

In the past decade, congestion on California's highways has increased five times, but there has been hardly any increase in the number of highway lanes, Mr. Varaiya says.

Instead of building more highway lanes to increase traffic flow, scientists are focusing on such issues as how to deliver driver information about the best possible route, creating ramp metering to slow the influx of cars onto highways from surface streets, and installing more toll roads and lanes.

"You wouldn't market it as a penalty, but say, if you want to use this faster lane or road, you pay a price," Mr. Gazis says.

The most important aspect of improving traffic flow in Mr. Gazis' opinion would be to deliver customized information - through computers or a phone service - to allow each driver to pick the best route or mode of transportation on any given day.

"I would like to be able to get up in the morning and get immediate information," Mr. Gazis says.

"It might say you'd better go back to bed, because everything is jammed or your best bet is to park at Yankee Stadium and take the subway into

Manhattan."

It's important when delivering route information that all drivers don't receive the same travel solutions, Mr. Mahmassani says. If everyone is told to take the same surface streets because I-66 or the Beltway is clogged, neighborhood streets will get jammed.

"The key is to get different information to different users," Mr. Mahmassani says.

In the end, traffic-flow science is a cross-disciplinary field that includes social sciences, behavioral sciences, economics, physics, engineering and even anthropology, Mr. Mahmassani says.

It turns out human traffic behavior may be incorrigible.

"History has shown that we always allot a certain amount of time to transportation. If we don't spend that time commuting, we'll travel for other purposes, like shopping or recreation," Mr. Mahmassani says. "Even in ancient Rome, there was traffic congestion."

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