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## Models shape the flow of traffic thoughts

*Researchers are using technology to reduce traffic congestion.*

February 11, 2002

A few miles from the traffic snarl of downtown Boston, a computer is running DynaMIT, a custom-built program that models the flow of traffic. The screen displays a number of small, color-coded boxes representing vehicles, which are streaming across a network of city streets and highways like ants en route to their nest.

Ben Akiva, professor of civil and environmental engineering at the Massachusetts Institute of Technology and the director of the plushly furnished Intelligent Transportation Systems lab on campus, is using DynaMIT to better understand and improve traffic flow in some of the most congested metropolitan areas in the United States. And beyond established industrial economies, traffic congestion has become a major problem for developing countries as well.

Today, drivers all over the world are spending more time than ever in traffic jams. Commuters in large U.S. cities are spending approximately half of their daily travel time in rush-hour traffic, according to a study commissioned by the Texas Transportation Institute, the official research agency for the Texas Department of Transportation and the Railroad Commission of Texas. And this situation is likely to get worse as urban populations continue to grow beyond the capacity of today's most advanced transportation infrastructures.

As a result, engineers, physicists, and mathematicians are combining their disciplines to solve current and forecasted traffic problems. It's a task that's nearly as difficult as forecasting weather--both are dynamic systems that involve a large number of variables, making predictions very difficult.

### Model Drivers

Researchers use three approaches to model traffic flow: a macroview, which encompasses large geographic areas, like New York City or Los Angeles; a microview, which looks at small neighborhoods of approximately 20 square blocks; and a hybrid model, which combines the two. The three methods complement one another, as no single model is capable of solving all the traffic problems of modern society. And most importantly, there's plenty of room for healthy debate.

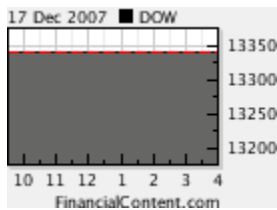
MIT's DynaMIT software uses the hybrid approach to traffic modeling. It combines the focus on driver behavior found in the microview approach with the macroview's focus on how interconnected traffic systems influence one another.

Thanks to increasingly accurate traffic simulators, researchers can now test and deploy new technologies to improve traffic flow, like traffic-congestion sensors embedded in roadways and new platforms for delivering real-time traffic data.

Despite these small advances, however, traffic congestion is getting worse. This has inspired a rash of innovative efforts to solve the problem. Some researchers have suggested deploying vehicles that run on autopilot and are guided by sensors and magnets embedded in the road. Others have proposed new models of traffic flow, based upon theories used to describe phenomena

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in the world of physics.

A group of physicists led by Dirk Helbing, currently a professor at the Dresden University of Technology in Germany, and Boris Kerner, a researcher at DaimlerChrysler, say traffic-flow patterns can be better understood by applying the principles of chaos theory. This macro theory holds that complex systems that have no apparent order actually follow some basic rules. In his field research, Mr. Kerner noticed that tiny fluctuations in traffic, like a driver slowing to let another car merge, could lead to unexpected results, like massive gridlock.

Not everyone agrees with Mr. Kerner's model, however. Alexander Skabardonis, a professor of civil engineering at the University of California at Berkeley's Institute of Transportation Studies, works with both models and says the chaos model's basic premise, that sudden unexplained changes in the flow of traffic cause bottlenecks, is wrong. "There is usually some cause, like drivers changing speeds near merger lanes," says Mr. Skabardonis, "that one can identify as the source of a change in traffic flow."

Most engineers say the best way to deal with gridlock is to give drivers up-to-the-minute traffic information. University researchers worldwide have obtained encouraging results from models that simulate the actions of drivers who are better informed about traffic conditions.

For example, Hani Mahmassani, a professor of civil engineering at the University of Texas at Austin, has developed a computer program that predicts how drivers will respond to control mechanisms like electronic tolls and ramp metering. He sees promise in intelligent transport systems, in which technologies like sensors and cameras are used to collect traffic information, which is then sent to drivers in real time by communications devices like radios, wireless phones, and billboards.

Mr. Mahmassani says his traffic simulations, which run on standard workstations, are able to analyze fairly large traffic networks. Like the DynaMIT model, his model is a hybrid, and his research has been focused primarily on diagnosing and solving traffic congestion in metropolitan areas.

More recently, Mr. Mahmassani has been applying his models to study how the flow of traffic changes when drivers get up-to-the-minute information in their cars. It is just one of three existing methods and tools used to influence traffic flow: dynamic pricing (like adding electronic toll collection and charging single drivers to use high-occupancy vehicle lanes), traffic control (for instance, traffic signals and ramp metering), and traffic information (which is provided to the driver).

Mr. Mahmassani also says there is something to the chaos model, and is incorporating its approach into his simulations. "From a microscopic aspect, look at short-term fluctuations and variability in a system that is very complex. On a macroscopic level, it's far easier to see patterns," he says. "You have a self-organizing system, where people are making decisions on their own, but certain patterns emerge."

#### Road Sage

Efforts to understand, model, and predict the flow of traffic can be traced back to Robert Herman, whom many consider to be the father of modern traffic science. While working as a physicist at General Motors Research Laboratory in the '50s, he developed algorithms that detailed driver interactions on a freeway. These algorithms formed the basis of Herman's hydrodynamic theory of traffic flow, which proposes that two-lane traffic behaves much like water flowing in a stream. To explain multilane traffic behavior, Herman, together with Ilya Prigogine, a Nobel Prize winner in chemistry, expanded upon his earlier concepts and developed a new model based on a kinetic theory of vehicular traffic. This theory--which evolved from hydrodynamic principles--proposes that traffic behaves much like how molecules move in gas. Later, researchers turned to chaos theory to model entire traffic systems.

While the science of understanding traffic flow is still young, many engineers and researchers are optimistic that insights from research like that of MIT's

Mr. Akiva will one day help smooth the morning commute in the most congested areas of the country--perhaps making it as painless as a trip to the grocery store. (But don't hold your breath).

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