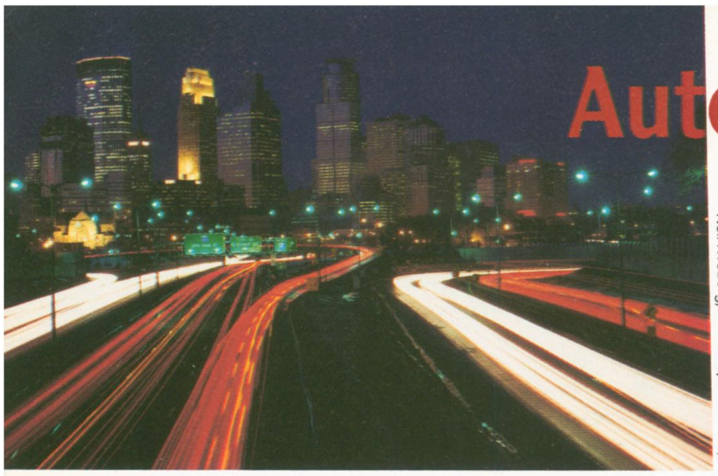


Neil Kveberg/Minn. Dept. of Transp.

Auto(-matic) Commute

Technology revolutionizes the ride to work

By ELIZABETH PENNISI

Hosaka/Nissan Motor Co.

Minnesota's IVHS effort, Guidestar, will smooth traffic in the Twin Cities (upper left). Japan's "Personal Vehicle System" (right) drives itself.

The day may come when computer viruses, not potholes, will be the bane of progressive transportation departments. Slowly, almost imperceptibly, engineers once preoccupied with laying out roadways and figuring out the best place to site a traffic signal are turning to high-tech devices and relying on computers to reduce congestion in the streets. Although their vision of transportation in the 21st century may seem like science fiction, the guardians of our highways expect to spend billions of dollars trying to make this fiction a reality.

And, oh, what a reality they foresee. Cars will drive themselves, sometimes at high speeds, and compute new routes to bypass congestion as it develops. People who prefer not to carpool can travel in one-person vehicles that link together for expressway travel. A bus that gets behind schedule will simply reset traffic lights so it can catch up. Signposts at bus stops will tell waiting passengers when the bus will arrive and suggest alternative transportation should delays occur.

For long-distance driving, cruise controls will warn a sleepy driver and slow a car down as it comes up on a slower-moving vehicle. Cars will zip through toll booths, their passage noted by sensors that electronically debit the driver's account (SN: 1/25/92, p.63), and trucks will weigh their loads without stopping.

Though it may take decades before this reality comes about — if, indeed, it does — innovative researchers have already begun applying sensor, computer, telecommunication and robotics technologies to all aspects of transportation. "Smart" devices are appearing on test vehicles and, in some cases, consumer cars all over the world. New devices on roads are smartening up highways. Some help drivers navigate and avoid congestion. Others help transportation agencies monitor and control traffic flow.

These advances represent the first steps by public agencies and private companies to evolve Intelligent Vehicle-Highway Systems (IVHS). Promoters of IVHS expect development will occur in three stages. Increasingly, cars will contain warning and assistance devices, but in this initial stage "the driver still maintains control of the car," says Michael J. Cassidy, a civil engineer from Purdue University in West Lafayette, Ind. Cassidy summarized IVHS research in January at the annual meeting of the National Research Council's Transportation Research Board, in Washington, D.C. In the next step, drivers will relinquish control upon entering certain restricted-access roads, such as HOV (high-occupancy vehicle) lanes. There, drivers will switch to automatic pilot.

Finally, fully automated cars will drive themselves everywhere, and cars, trains and buses will be fully integrated. "We have the opportunity to blur the distinctions between the modes," says Brian W. Clymer, head of the Federal Transit Administration in Washington, D.C. "The user should eventually perceive a seamless, coordinated surface transportation system."

About a year ago, various parties interested in IVHS formed IVHS America to act as a national advisory council. Seemingly prepared to spend a lot of money on IVHS, Congress has called for this Washington-based organization of companies and public agencies to devise a strategic plan by the end of 1992 for the nationwide implementation of IVHS in the decades ahead. During the next 30 years, the United States will invest \$350 billion in IVHS, predicts James Costantino, executive director of IVHS America. That figure makes the IVHS program larger than many others the federal government has funded. The 10-year Apollo program cost \$23 billion, for example, while the 35-year-old interstate highway program has cost about \$130 billion, Costantino says. But IVHS will be different in that some 65 percent of its funding will come from the private sector, he estimates.

Even so, federal support has mushroomed. The Federal Highway Administration spent \$2.3 million in 1990 and \$20 million in 1991, according to Congress' General Accounting Office (GAO). This fiscal year the Department of Transportation alone plans to spend \$94 million on IVHS. In addition, as part of the Intermodal Surface Transportation Efficiency Act of 1991, Congress promised to appropriate \$660 million more toward IVHS during the next six years. "We accept that we cannot pave our way out of traffic congestion," says Tom Horan, of the GAO. "Something else is needed."

That something else includes improved navigational tools and more accurate and timely monitoring of roadway congestion. At first, navigational and monitoring systems will simply provide information; then they will issue advisories for drivers; finally, they will coordinate driving on a citywide basis to smooth traffic flow. Such systems require navigational devices that can determine a car's location and a data communication system between travelers and traffic control centers. Eventually, computers will coordinate rush hour, directing commuters not only to less congested roads, but also to buses or trains should those transportation modes offer a faster commute. "Through the appropriate implementation, we can improve road efficiency," says Cassidy.

So far, a \$30 million pilot project outside New York City seems to bear out that assumption. Over the past 15 years, INformation FOR Motorists (IN-

FORM), has helped manage a 40-mile-long highway and parallel and connecting roads on Long Island. The ramp meters, traffic monitors, and signs with variable messages help keep traffic flowing in that congested area by tracking car density and speed, informing drivers of delays ahead and directing drivers to alternative routes, says Steven A. Smith of JHK & Associates, an engineering firm in Riverside, Calif.

Ordinarily, 5 to 10 percent of drivers caught in heavy traffic will switch to an alternate route, but the INFORM instructions prompt 40 to 70 percent more drivers to leave one highway and try a different road, Smith reported in January at the Transportation Research Board meeting. By themselves, variable message signs translate into a savings of at least 300,000 vehicle-hours a year on these roads, and the whole system could save 10 times as much driving time, he adds.

In England, a private company has taken a more personalized approach to smoothing traffic flow. About 2,000 London-area drivers keep watch on congestion with Trafficmaster, an oversized pager with a small, built-in computer screen. Drivers can move this portable unit between cars and take it inside, so they can check on traffic before leaving the house or office, says David K. Martell of General Logistics PLC, which developed the system.

General Logistics installed 250 infrared sensors – one every two miles – along the main highways within a 35-mile radius of London. Mounted above traffic, the sensors send out two beams 10 feet apart that register when a car passes through. A microprocessor inside the sensor then computes the average speed of vehicles. If that speed falls below a certain threshold, "the unit automatically calls us," Martell explains.

The location of the congestion is then displayed on a map on the driver's pager. According to Martell, his system provides more timely and accurate information than do radio reports, which in London rely on people calling in or on police patrol reports. After operating the system for more than a year, "we've proved that the system is reliable," says Martell. "It has enabled [drivers] to use motorways more effectively." During 1992, the company will put in sensors along another 1,000 miles.

Though not as advanced as Trafficmaster, a navigational system called Travtek will make its experimental debut this spring in Orlando, Fla. One hundred rental cars will come with a color display providing information about traffic jams as they develop and giving the location of restaurants, hotels, government offices and entertainment centers.

Monitoring and guiding traffic effectively represents one tack in IVHS; smart vehicles represents another. To develop smart vehicles, scientists and engineers control a car's sideways and forward motions. In some cases, they have integrated these controls with other technologies to create cars that drive themselves.

For example, Wei-Bin Zhang and his colleagues at the University of California, Berkeley, have developed a guidance system that relies on magnets and magnetic sensors to keep a vehicle straight. The Berkeley team has installed 4-inch-long magnets 1 meter apart down the center of a lane at a test facility in Richmond, Calif. Magnetometers mounted on a test vehicle's front bumper sense when the car drifts to one side, and a computer in the car guides it back to center. Tests with the car moving at about 35 miles per hour showed that this guidance system kept the vehicle in line, allowing it to drift less than a foot to either side of center.

Ted Chira-Chavala of the Berkeley group envisions these magnetic guidance systems appearing first along HOV lanes. The sensors will not control steering but simply warn the driver when the car drifts near the edge of the lane or when the road begins to curve. During a second phase, all cars on these lanes will have magnetic sensors that direct steering and let the driver relax, but drivers will still change lanes manually. Finally, he hopes to see fully automated cars along HOV lanes.

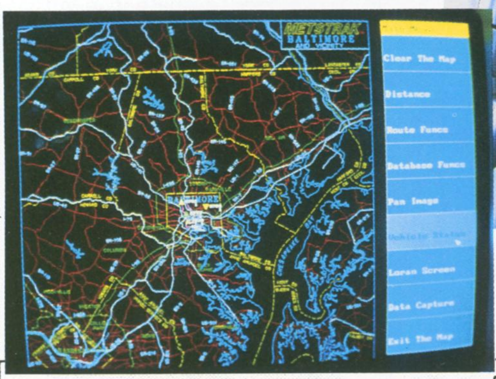
"Fully automated lateral control technology could result in very significant improvements in both the capacity and safety [of roads]," says Chira-Chavala. Based on traffic accident reports from Texas, California and Virginia, Chira-Chavala estimates that this automation will reduce accidents by 24 percent, including those resulting from cars changing lanes or running off the road.

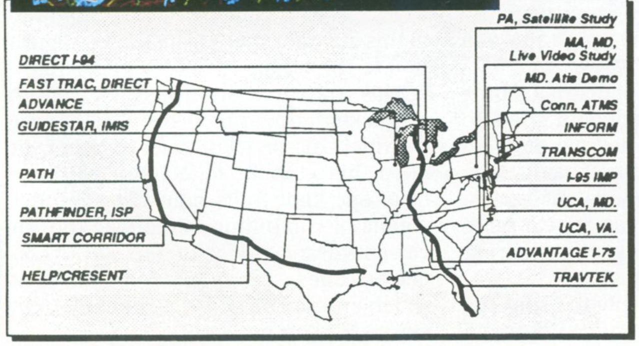
"If you have the system automated, we can get more cars per hour per lane," adds Andrew A. Frank, a mechanical engineer at the University of California, Davis. He thinks one could double the number of cars passing though a specific space per hour. "But the trick is to design a system so the driver can instantly recover [control]," he adds. In one scenario, about a dozen automated cars will move as a pack, or platoon. The front vehicle monitors the distance between it and the next platoon 300 feet ahead and adjusts its velocity accordingly. The rest of the platoon will follow its lead.

Frank and his colleagues designed a controller for steering, braking and accelerating an automated car that uses "fuzzy logic" – that is, the controller emulates a human's decision-making process and decides what to do based on the particular situation. The researchers wrote a computer program that modeled a pla-

Continued on p.187


Travtek


Blakeslee Lane Inc./Federal Transit Administration



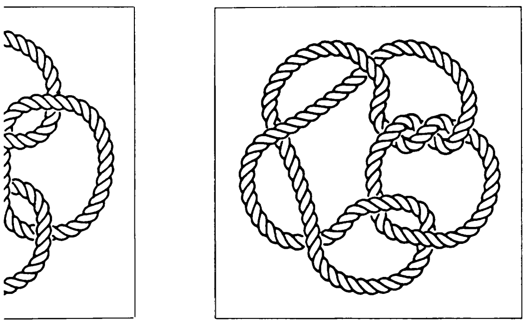
IVHS America

Though called by many names, IVHS projects are under way throughout the United States (see map). As part of IVHS, computer screens at traffic control centers monitor vehicle locations on roadways (left), and displays in cars guide drivers to their destinations and warn of traffic jams (above). Called Travtek, this in-car system will become available on a limited basis this spring in Orlando, Fla.

Initially, Vassiliev's approach seemed formidable and impractical. Many mathematicians who read his paper found his techniques very difficult to apply in practice and could see no guarantee that usable knot invariants would emerge from his work.

Birman and Lin, however, discovered a way of translating Vassiliev's scheme into a set of rules and a list of potential starting points. "That's what began to suggest that [Vassiliev's invariants] really looked like the knot invariants we already knew," Birman says.

News of this work brought Dror Bar-Natan, now at Harvard University but then a student at Princeton, into the picture. After several days of discussions with Bar-Natan, Birman and Lin proved that the Jones invariants and several related expressions are directly connected with Vassiliev's knot labels. Bar-Natan discovered simultaneously a remarkable link between his own work on Feynman diagrams – pictures used to



provide an intuitive interpretation of interactions between subatomic particles – and Vassiliev's original equations for computing invariants.

Although this research doesn't completely solve the problem of how to interpret the numerous knot invariants that mathematicians have discovered, it provides a familiar framework within which they can begin to tackle the problem. "It changes an old problem you didn't know how to do into a new, hard problem that's a lot of work," Birman says. "It's a beginning."

"Vassiliev's work provides a very good insight into the nature of knot invariants generally," says Louis H. Kauffman of the University of Illinois at Chicago. "It's entirely possible that all of the invariants we know are built of the building blocks coming out of Vassiliev's picture."

"It gives us another unifying principle for describing knot polynomials," Birman adds. "Instead of one explanation for knot polynomials, we are instead finding multiple explanations and interrelationships, each very beautiful and each opening new doors for investigation." □

Continued from p.185

toon containing vehicles of three sizes, then asked the computer to simulate the platoon's response to changes in wind and road gradient; emergency stops; and vehicles entering or leaving the pack. With the fuzzy logic controller, the cars seemed to handle these conditions just fine, Frank reported in August 1991 at the Second International Conference on Applications of Advanced Technologies in Transportation Engineering, held in Minneapolis.

Taking a step further toward automated autos, government engineers in Japan and that country's carmakers have built a "Personal Vehicle System" which looks like a Winnebago camper but does its own driving. It uses five TV cameras, with ultrasonic sensors as backups, to see where it is going and to avoid obstacles. Its computers contain maps of the test roads and can plan a route, then instruct the vehicle to drive to any destination on it – turning left or right as necessary – even in the rain or at night.

"I think in 30 years or so, we may see automated driving for freeway use," predicts Akio Hosaka of the Nissan Motor Co. in Kanagawa, Japan.

No doubt engineers will make cars smarter, but they must not make them too smart for the driver. People can process only so much information at one time, says King M. Roberts at the Federal Highway Administration in McLean, Va. They react only so fast to information they get and, for now, drivers must also concentrate on the road ahead. Those factors will limit the usefulness and safety of some navigational aids.

Roberts and his colleagues studied how well 126 young, middle-aged, and older drivers could maneuver along a computer-simulated 26-mile route. The participants used a variety of navigational systems in a range of driving conditions and complications. Three systems displayed maps on dashboard video screens: One showed the driver as an icon moving through a street map; a second added written instructions such as "turn right"; and the third contained arrows that lit up to tell a driver when to turn. Three other systems just talked to the drivers, giving them varying amounts of information. As a check, some drivers navigated with maps in current use today.

The testers could narrow the lanes on the road, create the effect of crosswinds on the vehicle and make the simulated gauges indicate trouble. In addition, they sometimes asked the driver to do simple math en route. During testing, the researchers kept track of speed, reaction time, heart rate, the car's position and, of course, crashes.

Drivers made more errors when they depended on visual aids than when they just listened to instructions. Also, those watching the dashboard screen drove more slowly and missed more warning signals on the dashboard, Roberts and his co-workers concluded in a May 1990 FHA Technical Report.

Establishing a wide margin of safety could result in automated highways packing in too few cars to help smooth traffic flow. For example, long distances between platoons of cars would decrease the chance of platoon pileups, but "such implementation might reduce capacity," says Purdue's Cassidy.

Driverless driving is just one of many aspects of an automated commute. To become reality, other issues need resolving: establishing standards for the vehicles, deciding who should manage and police the new highways, training traffic personnel and finding the money to pay for all the changes.

"The setting of standards is a particularly troublesome problem. There is a desire to have uniformity; on the other hand, you don't want to stifle innovation prematurely," says Thomas B. Deen with the Transportation Research Board.

Finally, liability questions will arise, because accidents will occur no matter how good the technology. "The deployment of IVHS could bring a shift of liability from the driver to the operator or the manufacturer," says Cassidy. Flawed driving may be minimized, but flaws in how the car is built or operated may still lead to crashes.

In addition, the single-commuter automobile represents just one type of transportation. IVHS should encompass buses, trains, and car pools – and that holistic approach requires coordination of other agencies, Clymer says. He envisions smart buses, with voice and data hookups to central traffic controllers and sensors that track passenger load or bus location. Commuters will carry hand-held communication devices that will route them to a bus, car pool, roadway or train, as congestion requires. "Ultimately [car-pool] matching will be done in real time with a moving vehicle traveling along a similar path," he adds.

All that integration will require tremendous improvements not only in data gathering and management, but also in people management. It requires the cooperation of a tremendous number of individuals and agencies. Up to now, however, IVHS has headed in as many different directions as there are interested people and parties. But its promoters want to change that.

"IVHS is well under way in the U.S. and is going to happen, whether we have a plan or whether we do anything collectively about it," says Deen. "But to make it more effective in a longer run, we believe a plan needs to be developed and needs to be used." □