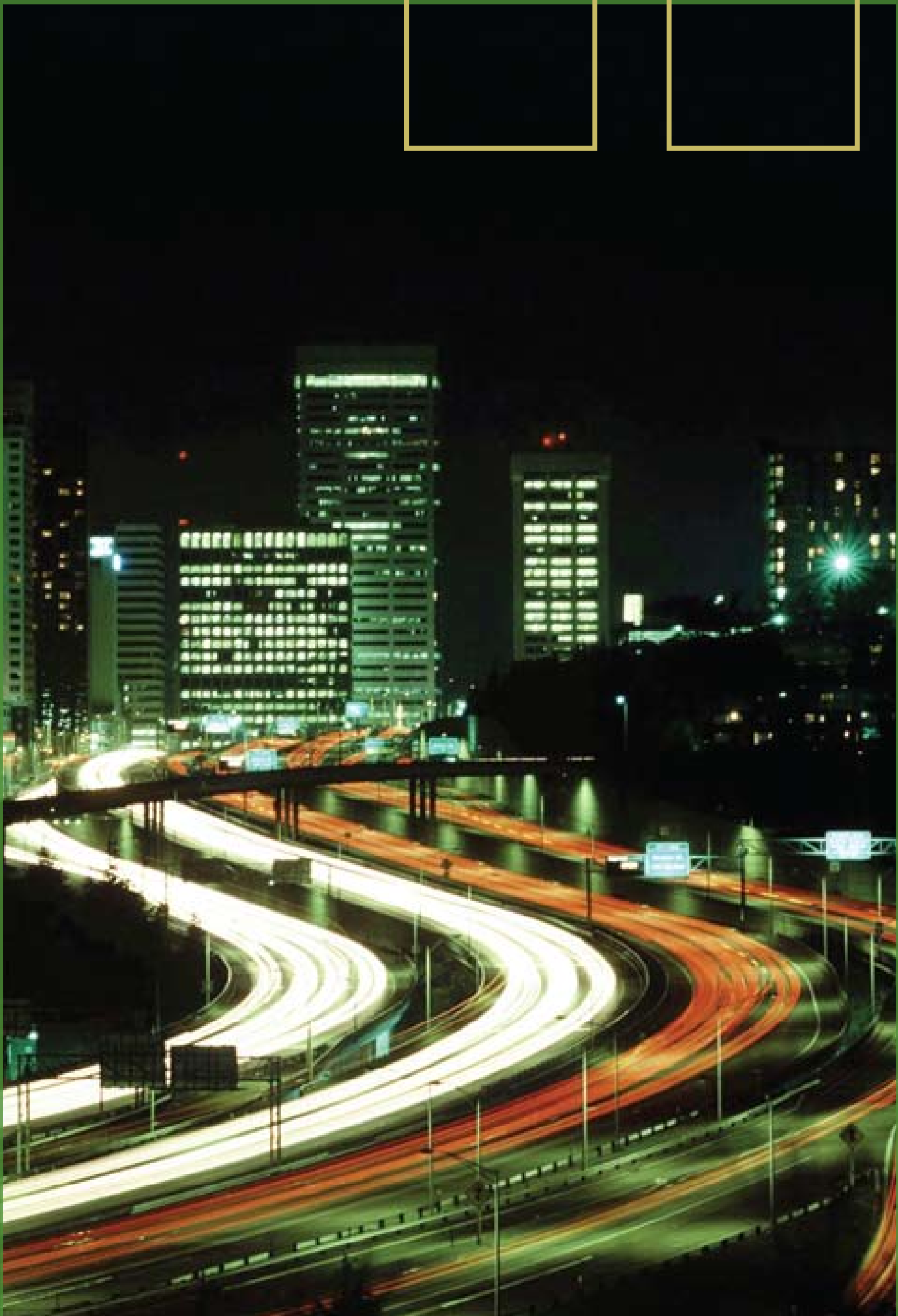

IntelliDrive℠ and the Open Road

By Greg Krueger, P.E.; Lee T. Mixon, P.E.; and J. Kyle Garrett

As long as there have been roads, there has been traffic. The first roads weren't much more than paths through a field or forest, made recognizable by the wear and tear of traffic. Improving the path by laying stones in the ruts or logs across a stream made it a road. Almost as soon as the road was built, it might have had to be repaired. An incident between two parties trying to pass each other could close the road to any other travelers. A rainstorm could turn the surface to muck.

Time and technology haven't fundamentally changed these challenges, though engineering has enabled us to build more and bigger roadways as traffic has increased, an increase that includes a 37 percent jump in U.S. urban lane-miles and a 53 percent rise in urban interstate lane-miles between 1980 and 2000.[1]

As the road network has become more complex, we've added new traffic controls. Advances in intelligent transportation systems (ITS) over the past 15 years have vastly improved our ability to monitor traffic, adapt our controls to make the most of installed capacity, and improve flow around crashes and construction.

We've both planned more effectively for, and responded more quickly to, traffic incidents. As incidents have become more severe, we've added new safety features to both roadways and vehicles. Incident-response plans coordinated across agencies and jurisdictions have continued to reduce incident-response and -clearance times.

Despite better planning and more sophisticated technologies, congestion and delays are increasing, and the annual number of traffic fatalities in the U.S., rather than decreasing, is more or less stable. We have to ask ourselves, why?

In addition, we've developed more accurate and timely weather forecasts. Although we still can't do anything to control the weather itself, we've added new ways to prepare for and respond to road weather conditions while working to keep material and labor costs from overwhelming us. We have timely access to more information about road weather conditions than ever before.

Despite better planning and more sophisticated technologies, however, congestion and delays are increasing, and the annual number of traffic fatalities in the U.S., rather than decreasing, is more or less stable. We have to ask ourselves, why?

Multi-Dimensional Complexity

It may be helpful to remember that the more things change, the more they stay the same. As builders and operators of the transportation infrastructure, we're caught in a perpetual cycle of volume and capacity, complexity and control, flow and safety, with the occasional act of God thrown in for good measure.

How far will this go? How will we find the capacity we need? We could have flying cars and tollways in the sky and still find them congested. What kind of controls could possibly deal with the multi-dimensional complexity that's already challenging our ability to keep up? Can you even imagine a fender-bender at 8,000 feet? Will global climate change throw us new challenges? And how will we pay for it all?

It's a system, and every change we make to improve things will be met and dissipated by other changes within the system. ITS does help close the gap: There are new types of traffic sensors that are cheaper to deploy and maintain than previous models, and we have more of them. We have better cameras, at lower costs, too. And we have faster communications networks, larger databases, and more sophisticated performance measures. But we're still not quite keeping up. We need a new perspective. Infrastructure alone won't solve the problem.

So how do we break this cycle? How do we go beyond just tweaking the system to actually changing it?

In truth, transportation agencies have been trying to do it all from the outside and will never get ahead by working solely on the infrastructure. It's time to make the traffic—the vehicles themselves—part of the solution instead of the problem.

To some extent, vehicles have always been part of the solution. No one wants to be stuck in traffic. Drivers will use the best information and opportunities they have to work themselves out of a jam. And traffic managers have done the best they can to provide the best information. Just imagine, though, how things might change if we had direct communication and cooperation between the vehicles and the infrastructure. IntelliDrive℠ (formerly Vehicle Infrastructure Integration or VII) allows that change to be realized.

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The IntelliDrive℠ Concept

IntelliDrive℠ is both a technological and an institutional concept. Institutionally, IntelliDrive℠ is a set of cooperative efforts between federal, state, and local agencies; automotive manufacturers and suppliers; telecommunication, information, and engineering service providers; and the trade associations and research groups that support them. The participation of such a diverse group of stakeholders is itself recognition of the need for cooperation in solving our traffic mobility and safety challenges.

IntelliDrive℠ technologies. As a set of technologies, IntelliDrive℠ requires cooperation and integration between vehicles, communications networks, and application services. In this construct, the vehicles serve as both probe-data collectors and driver interfaces. With probe data, the idea is that vehicles are or can carry sensors within the traffic flow. Rather than detect traffic conditions from outside the flow, as we do with traditional fixed-position detectors, the detector (the vehicle and/or probe) in this case is placed within the flow. (See the sidebar "IntelliDrive℠ and Tolling" for more on probe data.) A communications network, meanwhile, allows communication between the vehicles and the providers of information services. Lastly, application services gather data from across the network and provide information to one another and to driver interfaces in vehicles.

The vehicle's onboard equipment (OBE) collects data from sensors throughout the vehicle to create probe-data messages to be sent to collectors on the network. The OBE can process

location data for navigation services and vehicle-based safety enhancement systems such as Cooperative Intersection Collision Avoidance Systems (CICAS). The OBE also serves as a network end point for receiving traveler information and transactional services, such as tolls, parking fees, and even restaurant drive-through payments, from the information services on the other end of the network.

IntelliDrive℠ can be implemented using a variety of wireless communication technologies between the vehicle and the wired infrastructure. While many demonstration systems have focused on dedicated short-range communications (DSRC), other prototypes have used networks based on Wi-Fi and other IEEE 802.11 wireless area network technologies or 900MHz radios. The selection from among alternative communication networks depends on the particular applications being implemented and their dependence on factors such as latency (time delay), bandwidth, and range. In practice, multiple networks may cover the same geographical region, and applications may access multiple networks.

Agency applications. The potential transportation agency applications for vehicle-generated probe data are both diverse and rich. In terms of traditional

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agency activities, probe data can benefit traffic management, incident response, road weather information, traveler information, and asset management.

Traffic data from IntelliDrive℠ probe vehicles can supplement traditional fixed-location vehicle detection station data and be commingled with other probe data. The resulting data set can provide a more detailed, continuous view of traffic conditions along all classes of roadways, from interstate freeways to rural county roads. Whereas traditional measures are generally limited to speed, volume, and lane occupancy, the high-resolution probe data available from IntelliDrive℠ can potentially identify and quantify queue formation and turbulence within the traffic flow, in addition to vehicle location, speed, and heading (direction of travel).

Traffic management systems that rely on fixed-location vehicle detection stations are limited in their ability to locate incidents on the roadway. IntelliDrive℠ probe data, however, can use vehicle speed and heading with other probe data, such as stability-control or antilock-brake activations, to pinpoint incidents. Better incident and traffic information would allow faster and more accurate dispatch and routing of emergency services.

Road weather information is currently limited to data provided by fixed-location environmental sensor stations (ESSs) and, to a lesser extent, specially instrumented winter maintenance vehicles. IntelliDrive℠-enabled vehicles, however, can provide weather observations from across the road network under all weather conditions. Most vehicles can provide direct measurement of ambient air temperature and pressure, and other weather data can be derived from other probe data. Precipitation indicators, for example, could include windshield wiper status, traction-control activation, and headlight status.

Traveler information services could then be expanded to significantly greater levels of detail. Reports on travel times and congestion could be provided for a greater number of routes. Navigation systems could provide realistic alternative routings around congestion and incidents to minimize travel times or distances. IntelliDrive℠-enabled vehicles would be able to receive messages and routing information relevant to their specific location and intended destination.

It may even be possible to obtain information about ride quality and road and bridge surface conditions from IntelliDrive℠ probe data. The IntelliDrive℠ probe-data standards include data sets such as longitudinal, lateral, and vertical accelerations, which could be used with other probe data to infer the relative roughness of the road surfaces on which the vehicle is traveling. Large vertical accelerations, perhaps in combination with traction- and stability-control activations, might be used to infer pothole locations, for example.

Michigan's DUAP Program

The Michigan Department of Transportation (MDOT), inspired by the potential for vehicles to be involved in gathering information about the operation and condition of roadways, has established the Data Use, Analysis, and Processing (DUAP) program to look specifically at IntelliDrive℠ applications for transportation agencies. The current phase of the DUAP program is developing prototype applications like those described above, using data from probe vehicles merged with data from traditional DOT sources.

Data acquisition. The DUAP program is using and pursuing multiple channels for probe vehicle data acquisition. For example, Chrysler LLC is providing basic probe data to DUAP from a fleet of employee-driven vehicles used primarily for gathering field diagnostic data under normal driving conditions. These anonymously detected data have enabled the program to demonstrate all the basic capabilities needed to gather and process probe data. DUAP can gather data from practically any probe-data source, including IntelliDrive℠ test beds, the MDOT's

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own fleet of maintenance and supervisory vehicles, and other commercial sources.

DUAP also draws on fixed data sources for baseline data quality checking. Data from vehicle detection stations serving a transportation management system can be absorbed by DUAP and used as a basis of comparison with probe vehicle counts and speeds. Likewise, data from ESSs used for road weather information systems can become the basis for quality checks of air temperatures and pressures received from probe vehicles.

The core data processing functions within DUAP locate the data on the road network, relate the data to other data nearby in time and space, and correlate the data with other traffic, weather, and asset conditions. In this process:

- Data locations based on latitude and longitude are mapped to linear references along the road network.
- Incoming data can be checked for quality and consistency against other probe and fixed data from similar sources.
- Individual probe vehicle speed, location, and heading are converted to traffic measures such as average speed, volume, and lane occupancy for integration with traditional traffic management systems. Travel times can be calculated from average segment speeds along routes, or from individual vehicles whose routes are identifiable within the system.

- Road weather conditions are correlated from probe vehicle observations such as wiper speed, air temperature, and air pressure.
- Probe data on vehicle acceleration and stability- and traction- control systems, when available, may be used to infer road surface conditions and provide ride-quality measures.
- Probe vehicle data and inferred observations may be combined into higher-level measures of effectiveness for DOT operations.

Supporting DOT operations. DUAP applications and presentations of probe vehicle and derived data are designed to support DOT operational needs. From that perspective, probe vehicle data are valuable because they can improve the efficiency, and reduce the

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cost, of obtaining information the DOT needs to fulfill its mission. Improved access to traffic and road condition information translate into improvements in safety, mobility, and asset management.

DUAP groups similar functions into application interfaces and presentations used by specific users or systems to meet a particular need. (Currently, the users are the staff of MDOT and partner agencies. Users of Michigan's roads will see the benefits of DUAP through MDOT's operational improvements.) The applications can then build on one another to fit other specific needs.

The most generalized end-user application in the DUAP suite is the map-based system browser. The user selects a time frame and the desired probe data to be displayed on a map. The spatial view of the data is controlled through the map interface using pan and zoom controls. The temporal view, meanwhile, is controlled through playback controls that can show data at a particular point in time or "animate" the display of data. This presentation gives the user great flexibility in browsing the available

data and can be used for display and analysis when no other appropriate tools are available.

Traffic information can be passed back to the traffic management systems in the Michigan ITS Center and other regional centers through interfaces complying with the National ITS Architecture. This allows data from the probe vehicle fleets to be synthesized into existing DOT systems with minimal disruption to operational systems and procedures. System operators can use existing interfaces and displays. Procedures for generating traveler information and messages can be based on access to IntelliDrive[SM]-enriched data and may be able to offer more specific guidance or to extend coverage to areas not previously instrumented.

Weather information obtained or derived from probe vehicle data can be made available to traffic management centers or passed to other weather data aggregation systems. On a regional or statewide basis, the information can be sent to a road weather information system for integration with data from fixed sensor stations. Outside of traditional DOT weather systems, the data may prove useful as an extension to existing meteorological mesonets (networks of automated weather stations that observe meteorological phenomena on the storm-system level).

Pavement and bridge condition information derived from probe vehicle data will be made available to the Michigan DOT's existing asset-management systems for integration with traditional condition data. The geographic scope and low latency of the vehicle probe data will allow for early evaluation of potentially abnormal surface conditions. More detailed and precise inspections could then be conducted as needed in locations indicated by the probe data.

An alert service can be configured to monitor any of the probe-data indicators to flag changes in conditions that may require operator analysis. For example, sudden local changes in the number of traction-control system activations might indicate that roads are becoming slippery and need treatment. The same techniques could be used to scan the roadway network for changes in traffic speeds or pavement surface conditions.

The "system health" dashboard displays measures of effectiveness derived from the more basic probe and derived data. Measures can be more consistent and continuous when they are based on a geographically extensive base of data with reduced latency. Traffic volumes and travel times, for example, can be compared in near real time with daily, weekly, and annual averages. Access to new data can also create opportunities for devising new measures and for applying measures to specific road segments and operating conditions.

The DUAP program will continue to expand the base of IntelliDrive[SM] data and interfaces for DOT applications. Additional data sources could include public, commercial, and private vehicle fleets providing telematics (data from and information services to vehicles over wireless communication networks); arterial and signal management systems; IntelliDrive[sm] test beds; and low-cost demonstrations of new probe-data gathering techniques within the DOT's maintenance and supervisory vehicle fleets. The program

IntelliDrive℠ and Tolling

As integrators of high technology held to the highest standard of customer service, the toll industry is a natural match with IntelliDrive℠.

Some argue that the toll industry, as opposed to tax-supported roads, has an added incentive, driven by users, to provide a better travel experience. One tool for achieving this goal is technology. IntelliDrive℠ is an example of such technology and offers a step change in transportation system and customer management. With it, vehicles and the road are no longer discrete elements. IntelliDrive℠ technology—the key one being 5.9 GHz DSRC—"connects"and enables cars to "talk" with other cars, the roadside, and traffic management centers to provide safety, mobility, and convenience services unavailable now.

Some of the basic elements of IntelliDrive℠ and their relevance to the toll industry include the following:

- Dedicated short-range communications (DSRC) systems are the open standards–based, interoperable platform underpinning IntelliDrive℠. DSRC has higher functionality than electronic toll collection (ETC), ranging from collision avoidance to toll collection. For tolling, DSRC's open standards are essentially new and mean that more than one vendor can supply hardware, thereby increasing competition and innovation. Also, from an investment standpoint, DSRC can save costs because it is designed for payment (ETC) *and* ITS applications via one hardware platform—no more stovepipe technology.
- Similar to today's reader, the IntelliDrive℠ **roadside unit** (RSU) identifies the vehicle, but it does much more, as well: RSUs can send and receive additional data for use in new information and safety applications.
- An IntelliDrive℠ onboard unit (OBU) can be as simple as a stand-alone 5.9GHz DSRC tag-like device meant for electronic payments only. This is available today. It will also come with more functionality, and, at some point, be integrated during a vehicle's manufacture. Once these latter OBUs become integrated, the toll operator will no longer have to incur the high costs of managing a tag base.
- **Probe data** constitute a lynchpin of the "data-transformed-into-information" system. They are anonymous data that a car's computer already generates that can now be read by the RSU and used to create a more accurate picture of roadway operating conditions than what is available to toll operators today. Probe data are rich, real-time data that an operator can use to better react to changing roadway conditions, and that can be turned into information sent back to drivers to improve their mobility.—*Timothy McGuckin, executive director, OmniAir Consortium, Inc.; mcguckin@omniair.org*

may also develop pilot applications for in-vehicle signage and messaging and expand demonstrations of integration with agency operations.

The Promise of IntelliDrive[sm]

IntelliDrive[sm] data archives will provide a tremendous information base for transportation planning. Minutely detailed models can be compared with actual conditions without the large costs associated with traditional field studies. Once the models are established, the wealth of data to be derived from IntelliDrive[sm] creates significant new opportunities for near real-time traffic modeling and simulation. With enough data at low latencies, it may become possible to perform near-term traffic forecasting.

This is the promise of IntelliDrive[sm]. Transportation agencies carry a tremendous responsibility to protect the traveling public, maintain the flow of traffic, and preserve the investment in the infrastructure. IntelliDrive[sm] provides near real-time monitoring from within the traffic streams, allows safety and congestion messages to be sent directly to drivers, and provides continuous monitoring of infrastructure conditions, all of which contribute to the more effective use of our transportation assets. IntelliDrive[sm] allows vehicles—the traffic itself—to be part of the traffic solution.

Greg Krueger, P.E., is program manager, intelligent transportation systems, for the Michigan Department of Transportation. He may be reached at kruegerg@michigan.gov.

Lee T. Mixon, P.E., is principal of Mixon Hill, Inc., which provides transportation management and technology solutions to the transportation industry and its agencies. The company's offices are located in Overland Park, Kans., and Lovettsville, Va. Mr. Mixon may be reached at lee.mixon@mixonhill.com.

J. Kyle Garrett is a senior systems engineer at Mixon Hill, Inc. He may be reached at j.kyle.garrett@mixonhill.com.

Endnote

1 Source: http://www.bts.gov/publications/national_transportation_statistics/2003/html/table_01_06.html.