VIRGINIA SMART TRAVEL LABORATORY
INNOVATION IN TRANSPORTATION

Road building and lane expansion have been routine solutions to roadway congestion for decades. Yet pouring more and more concrete is expensive and often only marginally beneficial—a reality clear to transportation professionals, elected officials and ordinary citizens alike.

The need for innovative approaches to surface transportation issues—like managing congestion—prompted a dynamic partnership between the Virginia Department of Transportation (VDOT) and the University of Virginia (UVA) Center for Transportation. In 1997 they created the Smart Travel Lab, a state-of-the-art facility that supports research and education in the rapidly emerging area of intelligent transportation systems—or ITS.

ITS involves applying cutting-edge technologies in such diverse areas as information processing, communications, electronics and computer systems to existing transportation infrastructure. "ITS is a radical break in the long-standing transportation paradigm, promising cost-effective, ecologically aware, efficient and safe solutions to traffic management and control," explains Dr. Brian Smith, who co-directs the lab alongside Dr. Catherine McGhee.

Adds McGhee: "Like all state transportation agencies, VDOT's primary responsibility is no longer building and maintaining roadways. Today, facilitating mobility is VDOT's overriding mission. VDOT's ITS initiative, known as the Smart Travel Program, supports this effort."

Located in Thornton Hall at U.Va.'s School of Engineering and Applied Science, the Smart Travel Lab receives a continuous flow of real-time data and video from four traffic control systems across the state. Access to this data, which is subsequently archived by the lab, as well as the management software used in the traffic control systems, makes it possible for lab researchers to provide significant technical support to VDOT's Smart Travel Program.

"The fact that problem solving can occur in the lab without necessarily interrupting VDOT's daily traffic management operations is very a appealing aspect of VDOT and UVa's partnership," notes McGhee.

And, this arrangement fully supports the Smart Travel Laboratory's exciting, on-going research programs, which investigate such areas as data collection, management and analysis, safety impacts of ITS, forecasting, simulation, traffic flow theory, and other applied ITS technologies.

“VDOT has seen a tremendous return on the relatively small upfront investment necessary to create the lab,” says McGhee. “Clearly, VDOT and UVa’s joint commitment to ITS research already has resulted in improved travel conditions in Virginia,” she adds. Smith and McGhee believe that the nation’s roadways also will benefit from this unique partnership as Smart Travel Lab initiatives drive the development and implementation of new ITS technologies across the country.

NUMBERS, NUMBERS EVERYWHERE: TRAFFIC DATA COLLECTION, QUALITY AND USEFULNESS

Continuous, accurate information is the key to successful ITS endeavors. But current data collection mechanisms—mainly point sensors embedded in a road’s surface—are expensive to install and maintain and are prone to failure. Plus, most roadways are not instrumented with point-sensor systems. Consequently, detailed and useful data is lacking, making it difficult for traffic engineers to glean a thorough understanding of current roadway and travel conditions.

“Our challenge is to find ways of using existing infrastructure to collect better and more comprehensive data at a fraction of the cost,” explains Smith.

The Smart Travel Lab is investigating ways to tap into the extensive wireless communications infrastructure in order to track travelers as they move throughout a network. “If we can figure out how to derive traffic information using geolocation technology (e.g., GPS), departments of transportation (DOTs) can save literally billions of dollars and at the same time, receive significantly better traffic information than is available today,” says Smith.

The Smart Travel Lab is currently working on a Federal Highway Administration (FHA) - and VDOT-funded technology demonstration project in the Hampton Roads region with a wireless location technology firm that has developed a system. “DOTs won’t be willing to invest in wireless technology until it is proven to work. Explains Smith: “The lab’s role in this demonstration project is to evaluate the data for its quality and usefulness.”

The lab is also taking the lead in exploring the statistical sampling of the infinite numbers of traveler location data points generated through wireless location technologies in order to achieve an accurate regional traffic picture. “This is an area the private sector hasn’t considered,” says Smith. “Our goal is to publish the basic research, which will prompt companies to incorporate it into their products.”

Another novel concept in data collection involves integrating existing closed circuit television systems, which are typically used to monitor freeways and intersections for supporting incident management, with video image vehicle detection systems, which are capable of measuring traffic conditions such as flow rate and average speed.

Smart Travel Lab researchers proved the integration feasible after working out technical challenges associated with camera positioning and calibration, and subsequently designed a prototype called Autotrack.

Today, the lab is preparing Autotrack for field implementation, also in Hampton roads. According to Smith Autotrack has the potential to save the Hampton Roads Smart Traffic Center over $1 million in point-sensor construction costs.

NOT ANOTHER RED LIGHT! TRAFFIC SIGNAL OPTIMIZATION

Optimizing traffic signal timing is among the most cost-effective ways of improving mobility—objective number one for state departments of transportation (DOTs). Plus, doing so allays commuting-related stress and reduces fuel consumption and automobile emissions.

Yet Smart Travel Lab researcher Dr. Brian Park explains that optimization programs currently used by DOTs often do not reflect actual traffic conditions because they rely on such parameters as traffic flow while failing to consider stochastic parameters such as individual driver behavior and day-to-day traffic variations.

VDOT looked to the Smart Travel Lab to evaluate several signal timing optimization programs using stochastic and microscopic simulation models that Park has calibrated and validated with the lab's archived real-time data and additional field data. "The model is only meaningful if it is calibrated to accurately represent traffic conditions, and then validated," says Park, who developed guidelines for calibration and validation in the lab.

Explains Park:"Once that is done, the model offers a risk-free test environment for the evaluation of not only signal timing plans, but also such scenarios as adding bus bays or blocking a road lane for construction."

Park's initial research evaluated signal timing for a segment of Route 50 in Northern Virginia. Park found out that the current VDOT procedure effectively improves traffic performance. However, he recommended that the timing plan be updated before it gets obsolete. Park also notes that advances in computation technology make evaluation of a network of roads feasible as well.

"Because microscopic simulation is presented as a 3-D animation, it is becoming an important support tool for decision-making," notes Park. "For example, it's easy for citizens at a public hearing to understand and compare proposals that will affect traffic by watching a simulation versus studying graphs and charts."

Another signal timing optimization technology the Smart Travel Lab is investigating involves using the Lab's archived data and computer processing to identify times of day when changes in expected traffic conditions warrant an adjustment in the signal timing plan.

“Many signal systems currently operate using the time-of-day approach,” explains Park. “But determining the ‘break point’ between one timing plan to another is a time-consuming, manual process, which is based on limited data and performed infrequently.”

Lab researchers are developing a computer program that performs statistical analysis of archived data, from which appropriate break points are then automatically identified. Traffic engineers can then decide whether to change the timing intervals or timing plans within each interval. Notes Park, “Even slight adjustments in break points—say a mere 15 minutes—can mean all the difference to the system’s operating efficiency.”

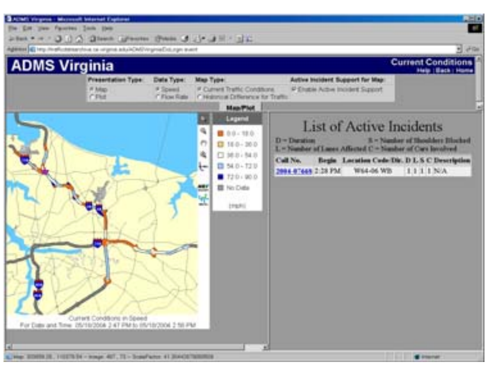
COMMUNICATION BREAKTHROUGHS: PREVENTING CASCADING FAILURES

In 1998 police, fire, emergency medical service, and transportation officials from Maryland, Virginia, and the District of Columbia, as well as several federal agencies, responded to a suicide attempt off the Woodrow Wilson Bridge. The bridge, which is under the jurisdiction of multiple law enforcement agencies, was shut down for more than 5 hours, creating traffic tie-ups as far as 20 miles away. The reason: an inability between agencies to quickly communicate and share information.

To prevent such cascading failures of the system, several agencies in the Washington, DC metropolitan area—including VDOT—initiated the development of CapWIN, a wireless integrated mobile data communications network to support public safety and transportation agencies. Such a system should improve emergency response time and traffic incident detection and recovery.

The Smart Travel Lab has supported CapWIN since its inception by conducting various preliminary studies. Today, the lab is focused on developing an application for visualizing information provided by CapWIN participants.

According to Marc Evans, who oversees the Smart Travel Lab’s CapWIN initiatives, “everybody wants everything” when it comes to sharing information between agencies. “The idea that law enforcement officers potentially can access not only first incident information, but also supportive information—perhaps ensuing traffic flow forecasts or optimal rerouting—is incredibly exciting for them,” illustrates Evans.



But designing and deploying such a communication bridge is exceedingly complex. Evans describes some of the requirements vital to the traffic incident management tool currently being developed at the Smart Travel Lab: “The application must accommodate multiple user platforms with different visualization capabilities, different processing capabilities, different storage capabilities and different bandwidth or communication capabilities.”

“This way, depending on the platform—be it a wireless LAN or palm pilot—the same information can be accessible—graphically on a map, textually as a description, temporally through a time-bar mechanism, organizationally via a Windows-type chart,” explains Evans.

Systems engineer Dr. Bill Scherer is working on another aspect vital to CapWIN's success—system-wide security. "Each of the participating agencies need to be able to monitor the general health of each other's system, thereby assuring the data's overall reliability," explains Scherer.

Scherer's prototype design automatically accesses the state of the participating agency's individual security systems as healthy, suspicious, or sick and boils these individual assessments down to an overall system "health score". Ultimately, a Web-based interface will enable CapWIN agencies to monitor the system's health score, as well as that of the network's individual members, giving them a heads-up to possible security concerns that may require action.

WHAT TO EXPECT AND WHAT TO DO: TRAFFIC FORECASTING

Commuters caught in traffic want to know more than merely the cause and location of the tie-up. They want to know how resulting traffic conditions will evolve in the next 15, 30 or 45 minutes. Smart Travel Lab researchers envision a day when commuters can tune in to local traffic reports to get this type of advanced traveler information.

"We're exploring the development of sophisticated forecasting models, similar to weather models, that will predict how current traffic conditions will evolve over the short term based on historical data," says Smith. Knowing what will likely happen next is particularly useful to traffic engineers, who can use predictive information to support traffic control and management, especially during abnormal traffic flow, including accidents.

The Lab's extensive archived traffic data are what makes traffic forecasting potentially feasible. "The premise behind forecasting models is that whatever happens next, will probably follow a pattern similar to what has happened in the past under similar conditions," Smith explains.

Smith illustrates the idea using this simple example: "If snow is predicted, do you bother to go to the grocery store at 7:00 pm for bread and milk? Probably not. Because it's your experience that bread and milk are sold out before 7:00 pm when snow is in the forecast."

According to Smith the challenge for researchers is how to capture the current condition of a regional traffic system in a mathematical set of measures, which is needed for matching the current traffic scenario with similar historical scenarios. Also, researchers must find a way to quickly search and analyze huge amounts of archived data to identify similar traffic conditions.

"We need to describe the speed, volume, density, weather conditions, the existence of incidents, and so on over hundreds of roads. So, the way the condition of a road is described can get huge fast and the harder the research problem becomes," explains Smith. The lab anticipates resolving many issues through statistical techniques such as nonparametric regression, research funded by the National Science Foundation.

Despite the overwhelming task facing forecasting researchers, the Smart Travel Lab already has had some success. Says Smith: "We can predict the demand for travel over certain roadways for an hour within 10 percent accuracy," a capability of particular interest to such groups as the American Trucking Association. "The trucking industry will rely on traffic forecasting to improve dispatch scheduling and routing. For them, avoiding congestion means saving money," says Smith.

FINDING NEW USES FOR ARCHIVED MOBILITY DATA

Vast amounts of archived statewide traffic data compelled the Smart Travel Lab to ask "What next?" The answer came as a $1 million Federal Highway Administration grant awarded to VDOT to develop new systems for assessing this mobility data and developing applications for its use.

"The lab already has consolidated the state's numerous sources of traffic data into the Mobility Data Store. Now we must determine what types of information the various stakeholders would find useful—be it VDOT, city planning organizations, businesses, or citizens. Also we must figure out how exactly to extract that information through a prototype system," explains Smith, who notes that this effort will require sophisticated, cutting-edge technology not used by other departments of transportation.

A current Smart Travel Lab data analysis effort that illuminates the usefulness and novelty of mobility data applications involves software that plots data obtained from police accident reports on a regional map. Doing so efficiently and effectively captures 5-years worth of accident data through a 3-dimensional graphic. Intersections and road segments with high densities of accidents are instantaneously identifiable by elevations on the map's surface. Says Smith: "This information is useful both to engineers who want to correct the problem and decision-makers who need to prioritize spending."

Smart Travel Lab researchers envision VDOT engineers using mobility data to measure the operational performance of its traffic control systems and to support transportation planning. "Analyzing mobility data also can be used to reduce traffic-generated pollution or plan evacuations should a hurricane threaten a region," notes McGhee.

Ultimately, the archived mobility data will be readily available through the Internet, providing stakeholders the information they need to solve their own problems without duplicating data collection and analysis efforts.

TOOLS FOR TOMORROW: MANAGING CHANGE

Veteran transportation professionals have experienced some significant growing pains thanks to the industry shift toward ITS-based traffic control systems. Smith is not surprised. "That's what happens with innovation. When concrete roads made their debut, civil engineers needed to learn about that type of material and its applications. It's no different today with innovations in information-driven traffic systems."

Smith believes that the ITS experience garnered through the Smart Travel Lab can support the industry transition—as does the Federal Highway Administration. In fact at its request, the Smart Travel Lab is currently developing a "how to" manual for designing ITS-based traffic control systems to be used by transportation professionals.

The lab also recently completed a guidance document on managing change, another issue transportation professionals will need to sort out as traffic control systems continue to evolve. Explains Smith: “New equipment will be necessary, features will be added, things will go wrong, and so forth—small changes can have big consequences because ITS-based systems are complex and linked in many ways.”

Smith also notes how the Smart Travel Lab’s applied projects, such as the guidance documents, indirectly support the profession. “Doing applied work keeps Smart Travel Lab researchers grounded. So even our theoretical research is within a context that professionals will one day find useful to their jobs.”

FOR MORE INFORMATION		
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