Places and Networks:

THE CHANGING LANDSCAPE OF TRANSPORTATION AND TECHNOLOGY

Final summary report of the STAR–TEA 21 project

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WHAT'S INSIDE

Friends:

Over the past six years, researchers from the University of Minnesota have studied the many ways in which transportation and technology intersect. Technology, of course, stops for no one, especially researchers, and as we have been studying advances in transportation technology, more have been achieved. Wireless communications have become ubiquitous and software that allows sharing of complex data across organizations is influencing transportation, safety, and public policy. Moreover, modeling techniques—specifically agent-based modeling—have grown more refined, allowing researchers to explore how the decisions of individual travelers affect larger systems.

Our work has explored these intersections from many perspectives. Thomas Horan is studying how intelligent transportation systems can help police, ambulance, and other public safety providers communicate more accurately and save lives. Richard Bolan is using agent-based modeling to predict how high-technology workers will influence city form—and therefore, transportation needs—through their choices about work and home location. Agent-based modeling also plays a part in David Levinson's studies of travel demand. Kevin Krizek has continued his work exploring whether and how the Internet will replace travel demand. My research has examined the potential loss of privacy related to advanced transportation technologies and the public policy issues surrounding privacy.

This new body work grew out of projects conducted earlier in the STAR–TEA 21 grant period, on topics as far ranging as the unanticipated safety net created by cellular phones to the potential impact of transportation technologies on economic development. Our research has shown the enormous potential for social good in new technologies: the ability to reduce congestion, to create smarter roads that help people travel more efficiently and in a more environmentally sound way, to respond to emergencies faster and more efficiently in order to save lives. Technologies also raise other issues. How do we pay for them and who pays? How do public entities work with private innovators who create new technologies? What do we lose in terms of privacy and freedom as we implement technological advances?

Our research has convinced each of us of how complex and layered the intersections of transportation and technology are. Transportation involves millions of decisionmakers—and it's these individual agents that policymakers need to anticipate. It also encompasses a vast array of linkages and hierarchies, public and private, transportation-oriented and technological.

One of the most exciting aspects of this research project has been the opportunity to explore these issues from a variety of perspectives—engineering, social policy, economics—and to share our work with those who are creating new transportation technologies and making policy decisions. We always have been committed to keeping our research rooted in real problems and to sharing it through symposia, academic papers, and articles.

While this is our final report on work done under the STAR–TEA 21 grant, it is not the end of our work on transportation technologies. There are too many questions left to explore. We will keep you posted.

Sincerely,

Lee W. Munnich, Jr.
Senior fellow and director
State and Local Policy Program

CITY SHAPERS

Modeling technique helps predict where information workers will spread

Technology—and the workers who create and use it—can reshape a city. Look no further than Alpharetta, Georgia, for proof. Located about 25 miles north of Atlanta, Alpharetta had a population of 3,000 in 1980. Many residents moved to Alpharetta because they could easily commute into the city. Then, companies began to move, too, attracted by a combination of open land, freeway access, and an educated population. By 1990, the population topped 13,000; by 2000, it was near 35,000; and today, Alpharetta has a population of more than 40,000—on its way to a predicted 53,000 by 2025.

Employment in Alpharetta has increased at an even faster rate. Alpharetta businesses currently employ about 120,000 people, many of them working in sprawling office parks near the North Point Mall. Companies settling in Alpharetta include big-name technology firms, like AT&T, Hewlett-Packard, ADP, and Lucent Technologies. But local businesses also include smaller, biotech companies, such as Inhibitex, which develops products to control viral and fungal infections, and AtheroGenics, a pharmaceutical firm developing treatments for chronic inflammatory diseases.

Planning for this type of economic growth and its impact on urban form and transportation demands requires a deep understanding of what is driving growth, an understanding that newer methods of analysis and modeling make possible, says Richard Bolan, professor of planning and public affairs at the University of Minnesota's Humphrey Institute of Public Affairs. Bolan, an expert in planned social change who has been affiliated with the Humphrey Institute since 1985, has been studying the movements of so-called information workers as a way to analyze urban form and its impact on transportation demand and intelligent transportation systems. Such edge cities as Alpharetta are among those areas in which information workers tend to cluster, says Bolan, who is using a new agent-based modeling system to track and predict where information workers will live and work in the future—a potentially vital tool in spatial and transportation planning.

Agent-based modeling is especially useful in this research, says Bolan, because information workers are not evenly distributed throughout the economy. Their impact might be overlooked in transportation and urban planning analyses that focus on more traditional sources of data, such as employment sectors. Agent-based modeling allows researchers to simulate the decision-making processes of many independent agents—agents that more closely mimic the decision making and behavior of real people in that they interact and compete with each other in ways that resemble human behavior.

The models allow researchers to see how complex interactions might lead to patterns over time. In addition, they give researchers the ability to change assumptions about both larger economic factors (population growth, demographics) as well as individual decision making (how many people will choose a certain occupation) and see how small changes in those factors might lead to larger changes in patterns. Bolan's work rests on the assumption that technology and information workers will have a significant effect on urban spatial form in the 21st century.

"What we are creating is not so much a precise prediction of the future," says Bolan, "but a set of future scenarios based upon changing assumptions." For his study, Bolan is looking at the distribution of information workers—anyone who uses information as a commodity—in four metropolitan areas: Atlanta, Phoenix, Denver, and the Twin Cities of Minneapolis and St. Paul.

In developing his model, Bolan determined that not all information workers are equally significant in terms of the built environment and transportation patterns. He divided information workers into three categories. Intermediate producers create and market intermediate products for others to use. Examples include software engineers or biomedical researchers. Primary users use information in the service of a client, such as bankers, lawyers, business managers, even school teachers. Secondary users include those whose main job is to assist a primary user, such as secretaries or data entry workers. These workers tend to follow primary users in terms of their work location. Non-information workers—everyone from carpenters to retail clerks—are scattered throughout urban areas and do not seem to have as concentrated an impact on urban form, Bolan says. Employees who could be classified as information workers made up about 20 percent of the workforce in 2000, and their numbers are rising quickly.

Freeway flyers

Information workers have a particularly strong impact on transportation systems because they tend to be clustered in terms of where they work, but not where they live. The concentration of information workers is highest in central business districts (downtowns) and suburban edge cities with strong freeway connections. Information workers also tend to commute longer distances from home to work. For example, the Atlanta area, with its high concentration of information workers, has the longest commutes in the nation—34 miles daily, according to 2000 figures from the Texas Transportation Institute.

While it might seem likely that technologically savvy workers would be more inclined to take advantage of telecommuting, that is not the case with most information workers, says Bolan. Intermediate producers tend to work on projects that require extensive collaboration. The creative nature of their work often requires that they work around others to share ideas. "They need face-to-face contact," says Bolan. Primary users do not collaborate as much as intermediate producers but they work for other people who want to meet with them at an office. "Most primary users serve clients, and they can't usually do that from home," he says.

"The best promise for telecommuting is with secondary users," he says. They tend not to have decision-making roles or client contact, giving them more opportunities to work away from the office.

For these driving and driven information workers, the appeal of edge cities, like Alpharetta, is obvious. Freeway interchanges become quick-access meeting points where workers can connect with each other at office parks, conference centers, or convention hotels.

Moreover, because information workers often live farther away from their workplaces than other workers, locating offices along main arteries gives employees the option to come to work easily from several directions.

Simulating the future

To figure out how technological changes could affect the internal geography of cities, Bolan developed a model to assess how information workers might pattern themselves in urban areas over time. The model is based on complexity theory, an idea that started in biology but has wide implications for social sciences and urban planning. Complexity theory argues that the world is a sequence of events in which small occurrences can have a big impact. Human endeavors—based on the decisions of many individuals, each of whom is acting on the information they have at hand—approach chaos but fall into "self-organizing" patterns.

Using the agent-based model and data from the University's Integrated Public Use Microdata Series (IPUMS), Bolan's simulation shows how cities might develop as information workers distribute and re-distribute themselves across the urban landscape. Running a version of the simulation on his computer at the Humphrey Institute, Bolan watches as clumps grow around freeway interchanges and in urban cores, showing increases in employment and traffic. Information workers spread out in a very controlled way, he says. Noted technology corridors, like Route 128 near Boston and the Silicon Valley, demonstrate the employment patterns of information workers. Similar technology clusters appear in many cities, so where policy leaders place highways can shape how the economy of a region takes form, says Bolan.

Bolan is continuing to refine the agent-based model for tracking information workers. "Agent-based modeling is still in its infancy, but there's a lot going on," he says. "It's a very important method of analyzing information workers because they operate at the individual level. They are not corporations or group entities; they are individuals."

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VIRTUAL TRAVELERS

As Internet use rises, impact on travel remains unclear

The potential of the Internet and other communications technologies to reduce travel demand and congestion is real. With increased access to the Internet, more people are capable of working, shopping, banking, even socializing without leaving home. But having the ability to perform necessary tasks electronically and actually doing them that way are two different questions, and statistics about information and communication technologies (ICT) and transportation tell a different, more complicated story, says Kevin Krizek, an assistant professor of transportation and land use planning at the Humphrey Institute, whose expertise includes travel behavior analysis.

In two recent studies, Krizek examined how Internet use and other technologies might reduce non-work related travel, specifically the kinds of errands that put people on the road when they might not need to be there. Clearly, the potential to reduce travel through ICT use exists. Between 1995 and 2003, the number of homes in the United States with Internet access skyrocketed. In 1995, fewer than 20 percent of U.S. households had an Internet connection. By 2000, 46 percent had access, and by 2003, 65 percent of households were connected to the World Wide Web. In addition to increased access, over the past decade, consumers have seen an explosion in the number and type of activities that can be done online. At the same time, security has improved. Today, it is possible to conduct nearly all of your financial transactions without ever entering a bank and to do most kinds of shopping—from groceries to clothing to furniture—without leaving home.

Use of the Internet for banking and shopping has increased, Krizek notes. In 2003, more than half of all Americans had shopped online. According to the federal Economics and Statistics Administration, Internet sales grew at a rate of 28.5 percent a year during the past few years—five times more than the overall growth rate in retail shopping. Online banking has experienced similar increases. One poll found that 38 percent of Americans do at least some of their banking through the Internet.

Despite the marked increase in the availability of services through technology, people are not driving less, says Krizek. Reducing travel is not often a goal of ICT users, particularly with regard to shopping. Many Internet users are seeking more in-depth information, price comparisons, or particular vendors. A German study found that while 74 percent of computer users made fewer shopping trips, the remaining 26 percent made more. Other surveys have found that online shopping from home increases the frequency of shopping trips and trip chaining.

"The longstanding hope has been that ICT will substitute travel, reducing road congestion and pollution," says Krizek. "Despite increases in ICT use, there seem to be preferences for store shopping and human bank tellers and a fear of online transactions that may limit the future potential of ICT to replace physical trips. Still, while the degree of trip substitution is relative, any measurable reduction in congestion would be a success."

Who substitutes and why?

In two studies, Krizek has explored the attributes of people who might substitute ICT use for travel in two non-work areas: banking and shopping. His rationale for studying these areas is that shopping and banking trips, unlike work-related travel, are more under the control of the person doing the traveling. However, measuring how much ICT use substitutes for travel or merely supplements and modifies it is difficult, says Krizek. If a person uses the Internet to save time on one errand, then does another one instead, the substitution has not reduced travel demand. To isolate how much travel substitution is occurring, Krizek and his fellow researchers asked individuals in three urban areas to think, not only about their general travel patterns and ICT use, but also about the last transaction they conducted and whether they would or would not substitute the travel with ICT use. "From this we hoped to shed light on what factors influence substitutions and also on what type of person is more likely to substitute travel with ICT," says Krizek.

The survey samples were chosen from three urban areas representing communities with high and low levels of technology infrastructure and high and low levels of congestion. The cities chosen were Seattle (high tech/high congestion), Kansas City (high tech/low congestion) and Pittsburgh (low tech/low congestion). A total of 2,400 households were mailed surveys, and about one-third of those households responded.

The survey asked respondents to rate which trips from home they would be most and least likely to substitute with ICT. Interestingly, the top three categories of non-work trips most and least likely to substitute are the same: grocery shopping, non-grocery shopping, and banking. "We are caught in crossfire," says Krizek. "While one person might enjoy shopping online, another might consider the pleasure of in-store shopping irreplaceable." This may suggest important market segments, Krizek says.

While banking represents a relatively small number of trips—fewer than two percent of the total—it is a trip people are more willing to substitute and, indeed, ICT has become a common way to bank. Again, the ways in which substitution is occurring are complex. For instance, among those who use online banking, only 28 percent would have visited the bank at that time had banking via the web not been available—apparently a direct

savings on travel. However, for many financial transactions, it appears that online banking is replacing the U.S. mail (74.6 percent), which is not a trip replacement since the mail will be delivered anyway. "Online banking is mostly substituting for other kinds of in-home ways to bank," says Krizek.

The use of automatic teller machines (ATMs) presents an even more complex view of travel substitution. Going to the ATM involves a physical trip, though it may be a shorter trip than going to the bank or one that can be combined with other trips. The survey asked respondents about their last ATM trip, and 50 percent said they would have gone to the bank if no ATM were available. Another 20 percent reported they would have waited until their next trip to the bank and 28 percent said they would have cashed their check somewhere other than at the bank. A follow-up question found that the main effect of ATMs may be an increase in total banking, rather than substitution. Of those surveyed, 23 percent said that had no ATM been available they would have visited the bank every time they went to the ATM; 51 percent would have visited the bank fewer times than they used an ATM but more often than they currently do; 25 percent said they would continue to visit the bank as often as they do now if there were no ATM option.

"Responses to the survey suggest that without certain ICT options, more physical trips would occur. The key question is, how many," says Krizek. Another key question is, by whom? The survey offered an opportunity for Krizek and his fellow researchers to create a profile of individuals most likely to substitute ICT use for travel. Survey respondents were categorized based on four dimensions: socio-demographic; technology ownership and availability (such as Internet, cell phone, ATM card); frequency of trips and other behavioral indicators; and attitudes toward technology, traffic, and shopping. These responses led researchers to score respondents based on four factors labeled pro-technology, anti-travel, concerned about Internet security, and outgoing/gregarious.

From this, they determined that people most likely to substitute shopping or banking trips with ICT are younger, more educated, have Internet access at home, and tend to have attitudes that are pro-technology and introverted. "Interestingly, not owning a cell phone seems to increase the likelihood that a person would substitute ICT use for travel," says Krizek.

So what about those not willing to substitute? Krizek's research found a variety of factors led people to prefer to travel, despite potential or real congestion. In terms of online banking, more than half (58 percent) felt their errands needed to be done in person. Another 21 percent said they were doing other errands and combined their banking trips with other activities. Finally, 19 percent did not trust the security of the Internet. With non-grocery shopping, reasons for not using ICT were myriad. Many wanted to touch the goods they were going to buy (44 percent), some needed to get the goods immediately (28 percent), and others worried about Internet security (13 percent). "Physically going to the store continues to have insurmountable advantages over online shopping—at least for now," says Krizek.

While Krizek's research seems to show little willingness on the part of consumers to substitute ICT use for travel, he points out the vast number of shopping and banking trips done every day and the potential for even a small change in behavior to affect travel demand and congestion. "Even a five percent decrease in non-work travel is substantial relative to the effect of other transportation policies," he says.

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SAVING TIME—AND LIVES

Technology offers new ways to improve emergency medical response

A car crashes in the night, somewhere along a rural highway in the resort area of north-central Minnesota. When a passenger or passerby calls 9-1-1, dispatchers at the regional dispatch center answer the call, and after questioning the caller about location and the severity of the accident, radio a State Patrol officer and contact an ambulance. If the victims are typical of those who called 9-1-1 in 2002, it will take about an hour from the time of the call until the victims arrive at a local hospital. Along the way, information about their situation will be transferred by voice from the dispatcher, the patrol officer, and the ambulance to doctors in the local emergency room.

While technology has made dispatching here faster than ever before, the advent of cell phones has meant some accidents are reported up to 20 times, stealing precious moments from dispatchers. Moreover, problems in individual response agencies, such as staff shortages at the ambulance services or outdated communications equipment at the hospital, can slow response even more. From beginning to end, the response requires several hand-offs between agencies and repetition of information, each with the potential to create delays.

Now consider another crash. This one occurs on a rural highway somewhere near Winchester, Virginia. Again, a passenger or passerby makes a cell phone call to report the incident. This time, however, the information is entered into a distributed database. Information includes not only what is provided by the caller, but also information on location provided by in-car global positioning. The data is instantly distributed through an Internet-like system that connects all possible responders: police, fire, ambulance, hospital. An Intelligent Message Broker—essentially a pre-programmed computer distribution system—makes sure all the right organizations receive the information they need about the incident and are updated as the victim is contacted reached, treated, and transported to the hospital.

Information technology has the potential to revamp how time- and information-critical public services are provided, says Thomas A. Horan, executive director of the Claremont Information and Technology Institute at Claremont Graduate University and a frequent collaborator with Humphrey Institute researchers. Many of these technologies already have been adopted by businesses, resulting in a marked increase in productivity in American companies. Since 2001, productivity has increased at a rate of 3.5 percent a year, more than twice the annual rate in the 1980s, according to the Federal Reserve Board. Much of this improvement has come about as companies have embraced information sharing and supply-chain management software.

Horan believes the same information technologies can be applied to public sector services, with similar results and even more vital outcomes. "EMS is a case where the adage 'time is money,' can be translated as 'time is lives,'" says Horan. Delays in responding to highway crashes have a direct impact on survival rates. This is particularly evident in rural areas where it takes longer for responders to get to victims. The average time between a crash and a victim's arrival at the hospital is 52 minutes in rural areas compared to only 34 minutes in urban areas. As a result, accidents on rural roads result in 60 percent of the traffic fatalities nationally. Rates are even higher in predominantly rural states, such as Maine (90 percent) and Montana (92 percent). In Minnesota, where Horan has studied EMS providers in a resort area, 73 percent of traffic fatalities occur on rural roads.

While time is vital to saving lives, having the correct information available to the right people is crucial to saving time. Responding to highway medical emergencies often requires several hand-offs between public and private entities, including the citizen making the call; a cellular provider; a dispatcher; various police, fire, and ambulance services; and one or more hospitals. Having the correct information about the accident's location, the closest services to it, data on the severity and nature of the accident, and biological data, such as the victim's blood type or allergies, could determine whether a victim survives or dies.

"The challenge for information and computer science is to devise new approaches and systems that facilitate rapid use of accurate information for EMS," says Horan. For the past three years, Horan and fellow researcher Benjamin L. Schooley have been developing a model for approaching time-critical information services. The model is rooted in the real-life experiences of EMS providers and is based on field visits, interviews, focus groups, and analysis of performance. The model highlights several dimensions of emergency response that present opportunities or challenges in applying information technology to improve services.

Anatomy of an emergency response

To understand how information technology could improve EMS response, it's important to think about four issues, says Horan. They include how and when information is passed from organization to organization in an emergency (time and information linkages), how well organizations are able to cooperate and share information, how emergency response works from end-to-end, and how well EMS operates in both normal and extreme conditions.

Traditionally, emergency response can be seen as a sequence of events, in which information is passed from one organization to another, says Horan. The key to an effective response is how accurately and quickly information is handed off. Technology already has improved many aspects of these time and information linkages. Cell phones, for example, have made it possible for motorists to report accidents more quickly—although sometimes too many motorists report the same accident. Vehicles with global positioning systems often can convey more accurate information about location to emergency dispatchers than an excited participant or witness. The serial and sequential manner in which information travels, with often time-consuming feedback loops, is one challenge for greater use of information technology in EMS response.

Another challenge is building cooperation and understanding among organizations, as Horan discovered in his observations in Minnesota. Collaboration technologies can be developed to enhance inter-organizational sharing of information, but "this does not negate the need to understand the unique and varying characteristics of organizations," says Horan. For example, Horan found significant cultural differences between police and transportation agencies. Police tended to be both more focused on service and more hierarchical; they operate around the clock, whereas transportation departments tend to keep business hours. Another factor affecting the collaboration and performance is that changes in one agency—such as staffing cutbacks or changes in scheduling of staff—can affect overall performance of the EMS system. Collecting and sharing performance data can improve services, as can multi-level linkages between EMS organizations, Horan found. However, organizations must be able and willing to make the necessary information available to others and they must agree on what kinds of performance data should be collected, how it should be evaluated, what kinds of metrics (goals) should be instituted, and how the information might be distributed.

The complexity of EMS response makes it important to look at the EMS process from end to end, says Horan, who gathered data on more than 20,000 mobile 9-1-1 calls from a rural area in Minnesota in the resort study. The calls produced 7,215 emergency responses to 3,325 crashes involving 71 deaths. "Our work in this areas has made it clear that a need exists for public agencies to first agree on how to measure performance across agencies, and then build performance tracking into new public information systems," says Horan.

Moreover, as new systems, such as the Virginia E-safety system, are developed, policymakers need to consider, not only the normal conditions under which EMS providers operate, but also the extreme conditions that would test any EMS system.

Extreme conditions might include everything from recurring events, such as a busy holiday weekend in a resort community, to natural disasters, like tornadoes or hurricanes, to unpredictable disasters—plane crashes, oil spills, terrorism. Using a model based on the data collected in Minnesota, Horan looked at regularly occurring spikes in emergencies and extrapolated that to a larger-scale disaster. Not surprisingly, in an extreme situation, the data found that delays in response increased significantly.

"The Virginia E-Safety network suggests that service-oriented architectures can be of great use in delivering time-critical information services to the public," says Horan. Technical solutions—in the form of computing standards for the collection, sharing, and evaluation of EMS performance data—are being developed. A parallel need exists to find ways to help organizations collaborate more fully. As Horan notes, "There is a need to device 'org-ware' as well as 'software.'"

Horan is optimistic. Researchers have interest in the topic. Funding, particularly from the National Science Foundation and the Department of Homeland Security, is available. Moreover, those involved in road safety are committed to improving emergency response.

Information for this article was drawn from "Time-Critical Information Services" by Thomas A. Horan and Benjamin L. Schooley published in Vol. 50, No. 3 of COMMUNICATIONS OF THE ACM (March 2007).

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PRIVACY IN THE BALANCE

Technology promises to help us move more safely, quickly, and efficiently. But at what cost to privacy?

Thirty years ago, when a government agency or private company collected information on its citizens or customers, the process was transparent and easy to avoid. You filled out a form. If you did not want to mention your age, your phone number, or that felony conviction lurking in your past, you left the information off. You cannot hide much now. Booking a hotel online, using a credit card or smart card, visiting websites, using a cell phone or global positioning technology, driving through a toll road—all of these activities can leave behind a trail of data that can be followed and used by anyone with access to it. The accumulation of data we leave behind can give others remarkable access to our private lives.

"Information constantly is collected, often without the knowledge of the individual," says Colin Bennett, a political scientist at the University of Victoria in British Columbia and an international expert on privacy issues. Information collection is the strength of many intelligent transportation systems, but the same information that can be used to make drivers and roads safer and more efficient also can rob individuals of their privacy rights. As a result, privacy issues have become increasingly important to transportation planners and policymakers, says Lee Munnich, director of the State and Local Policy Program at the Humphrey Institute at the University of Minnesota. Munnich and research assistant Adam Kokotovich developed a set of principles to guide information collection and distribution relating to transportation (see sidebar).

Unlike most developed nations, the United States does not have a comprehensive privacy policy, says Bennett. State and federal laws regulate privacy in many areas—government data, credit information, and health records, for example—but large areas of personal data are unregulated, and even in regulated areas gaps exist.

Travel and transportation long have required the collection of personal data: airline flights taken, train or bus trips booked, passport and credit card numbers. New technologies significantly increase the amount and kinds of data produced. Smart cards used for buses contain personal information. In-car safety systems, such as OnStar, indicate where a car is. New toll-road technologies involve transponders or automatic license-plate readers that give those with the data a clear picture of where a driver has been and when.

Fair principles, balanced risks

Most international privacy policies contain similar principles. "Basically, privacy policies require that information about others be treated in the way we would want information about ourselves to be treated," says Bennett. These typical principles include telling people why information is being collected, not using the information for secondary purposes, allowing individuals the chance to access or correct information about themselves, and keeping electronic and paper records secure.

"There are big benefits to intelligent transportation systems," says Munnich, "and many contain some risk to privacy. The question is how you minimize that risk and spread it evenly across society, so that you are not targeting one group over another for privacy risks."

To explore the privacy implications of intelligent transportation systems, Munnich and Kokotovich looked at three recent applications of ITS and their privacy ramifications. They found that privacy issues can be complex and require a balance between what may be a public good and what is a private right.

Slowing teens down. Nationally, drivers aged 16 to 19 make up only 4.7 percent of drivers, but account for 11.3 percent of fatal crashes. The two major causes of these fatalities are speed and seatbelt use, according to Max Donath, director of the Intelligent Transportation System Institute at the University of Minnesota. ITS applications can reduce fatalities in three ways: forcing safer behaviors, telling drivers when they are taking unnecessary risks, and reporting behaviors to parents or law enforcement. For instance, interlocks can prevent a car from starting if alcohol is detected or seatbelts not in use are available. (New Mexico is using interlocks for first-time DWI offenders, and a dozen other states are considering similar laws.)

Other ITS systems would use global positioning and digital road maps to tell drivers (or their parents) when speed limits are being exceeded. These systems present many safety benefits, and when used with young drivers tend to have public support, even though they compromise the privacy of a selected group of individuals. However, when discussion turns to expanding these kinds of programs to include other groups—the elderly or all drivers—privacy concerns arise. Policymakers need to guard against "mission creep," says Kokotovich. Determining the appropriate scope of a policy and being clear with the public about its purposes, its limitations, and its effectiveness.

Stop means stop. By having electronic police watch for violations, ITS technology makes it easier to enforce traffic rules. However, the technologies that make it easier to spot bad drivers also generate large amounts of data—information that could be used for other purposes, potentially violating an individual's privacy rights. A recent Minneapolis program to discourage drivers from running red lights and reduce accidents at several busy intersections provides insight into the privacy trade-offs of some ITS applications, Munnich and Kokotovich say. From June 2005 to March 2006, the Minneapolis Police Department instituted its "Stop on Red" program. Cameras were set up at 12 accident-prone intersections. Back at police headquarters, an officer and a computer monitored the cameras for vehicles that ran a red light. Using the license plate number on the car and registration information to identify the owner, the officer issued 26,000 tickets—at $142 each—in less than a year. To mitigate privacy concerns, the police publicized the location of the intersections with cameras and allowed those receiving tickets to access a website to view their infraction. Nevertheless, citizens objected to the program, which was deemed unconstitutional by a Minnesota court because it assumed the driver of the vehicle was the vehicle's owner.

Not surprisingly, the Stop on Red program collected vast amounts of data on drivers and their cars—not only for the 26,000 tickets issued but also for 30,000 other incidents that did not generate tickets. Police plan to retain the data indefinitely in case of a lawsuit over a ticket. While police do not plan to use the information for other purposes, secondary uses of the data would be possible and might even have public benefit, both for police activities and other city business. Retaining the data indefinitely raises issues of data security, say Kokotovich and Munnich. Finally, the location of the cameras—largely in neighborhoods with significant populations of people of color—seems to indicate that some population groups carried a higher risk of having their privacy violated than others during the Stop on Red experiment.

Smart cars, smart roads. A third example of ITS generating privacy issues is the U.S. Department of Transportation's Vehicle Integration Infrastructure initiative (VII). VII supports vehicle-to-infrastructure and vehicle-to-vehicle communication for a variety of safety, traffic, and private applications. VII allows communication between drivers and the infrastructure: notice of accidents or poor road conditions, increased efficiency through traffic signals, electronic toll collection, warnings to drivers who are going too fast or changing lanes without caution, among many others. The technical possibilities of VII are impressive, but they also raise many privacy issues, which the coalition of stakeholders—transportation agencies, automotive manufacturers, automotive and ITS associations—is attempting to address. The coalition's privacy principles include a requirement that drivers be allowed to remain anonymous on the road. Much of the data collected through VII would not contain personal identifiers, but some data would, and there are possibilities that data could be used by police or others for surveillance.

New technologies and the ways we use them are blurring the distinctions between what's public and what's private. A phone call on a land-line made from home is private—or should be. A call taken on a cell phone in a crowded room cannot have the same assumption of privacy. "New technology consistently is challenging and rendering irrelevant our privacy assumptions," says Munnich. "Our point is not to say that there should be no privacy risks with new intelligent transportation systems; clearly, there are social benefits. Our point is that we should understand what the trade-offs are."

PRINCIPLES FOR PRIVACY

While laws and guidelines vary, several core principles are embedded in most privacy regulations.

Accountability. Organizations collecting information about individuals are responsible for its use and its protection.

Clarity. The purposes for which information is collected should be clear before it is gathered.

Transparency. People should know you are collecting data, and it should be done only with their consent. Moreover, organizations collecting data should be open about their policies and practices and should not maintain a secret information system.

Limited. Collect only the personal information that is needed. If birthdates, social security numbers, driver's license numbers, or other private data ate not needed, do not gather it.

Final. Once collected, information should only be used for the original purpose unless individuals agree to have it used for other purposes. In addition, information should be retained only as long as it is needed.

Accuracy. Personal information should be kept accurate, complete, and up-to-date.

Safety. Appropriate safe-guards (electronic and otherwise) should be taken to keep data private.

Accessible. Individuals should have access to their personal information and have the ability to correct and amend data.

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THE HUMAN FACTOR

Agent-based modeling may help planners account for the imperfect person

A typical commuter's morning rushes by in a blur: breakfast, shower, get the kids off to school, pack up lunch and work papers, and away she goes. Somewhere along the way, a decision gets made about which route to take to work. That choice may be influenced by factors ranging from an intuitive sense that one route is faster than another to a radio traffic report to a desire to avoid congestion and take a slower, more aesthetic road to simple habit.

While many factors influence traffic patterns, traditional transportation models tend to ignore behaviors and choices made at the individual level, treating individual travelers as robots moving along prescribed tunnels with perfect knowledge of their options and the road system. It's not that planners don't care about drivers and their choices; until now, they simply lacked the computing power to account for individual agents.

"Transportation planning traditionally has involved modeling flows of traffic rather than individual travelers," says David M. Levinson, a professor at the University of Minnesota's Department of Civil Engineering and a researcher with the University's Intelligent Transportation Systems Institute. "This was fine in the 1950s when computing power was hard to come by. There have been attempts to update aggregate methods, but they don't get at individual behaviors."

Understanding individual decisions could significantly improve transportation forecasting models, says Levinson, allowing planners to consider such factors as what kinds of vehicles are on the road at various times of day and when more dangerous drivers tend to travel. This information could influence environmental or law enforcement policy as well as transportation planning.

This exploration of agent-based travel demand modeling grew out of Levinson's earlier studies of network dynamics, specifically the idea that transportation systems may be self-organizing networks in which hierarchies of roads emerge not solely as a result of planning decisions but also as a function of such factors as growth, induced demand, induced supply, and the underlying structure of networks. Levinson believes that complex networks, such as road systems, are made up of groups of subsystems that relate to each other in imperfectly known ways. Even systems that seem chaotic develop hierarchies and patterns over time. Creating models that more fully reflect the real-world travel decisions of individual drivers would improve planners' understanding of how complex transportation networks operate.

But how do drivers make decisions about their routes? Not with perfect information, as most aggregate models assume, says Lei Zhang, an assistant professor of transportation engineering at Oregon State University. Zhang received a Ph.D. from the University of Minnesota in 2006 and conducted his doctoral research under Levinson's supervision. "If you want to help drivers and help planners design better road networks, you have to recognize that people are not perfect and do not have a supercomputer to make their decisions," Zhang says. His thesis proposed a travel-demand model that incorporated more behavioral realism than earlier models. Transportation decisions, says Zhang, are "complex, constrained, multidimensional, and dynamic."

The decisions an individual traveler makes about which road to take to work or how to get to the store frequently involve four conscious or unconscious connected and continuous processes, which Zhang and Levinson have labeled SILK: Search, Information, Learning, Knowledge. Here's roughly how it works: An individual driver may search for alternative routes using information he already has—maps, previous knowledge of the area, media reports—from that he learns about various routes—how crowded they are, how many stop signs they have, whether those roads are pleasant to travel because of views or a sense that the driver is moving along briskly—and from that the driver will develop more knowledge about routes—"that was fast" or "I'll never try that back road again!"—and that knowledge becomes part of the heuristics, or rules of thumb, the driver uses in conducting his future route searches and travel decisions.

Each step in an individual's decision making can be influenced by a variety of factors: distance, time of day, unexpected incidents along the road, whether he travels alone or with others. Cost and benefit perceptions also are important. Some travelers choose the first likely route and rarely change their course after that initial choice is made, Zhang notes. Others try several routes to find out which they perceive is faster. Zhang translated these factors into a quantifiable model of driver behavior, using a series of if–then questions to represent drivers' choices and their likely assessment of the relative cost or gain to them as individuals of continuing to search for alternate routes.

Real-world information

To test the SILK theory and help develop the model, Zhang and Levinson gathered information about and observed real driving behavior. One effort involved 120 volunteer drivers who were asked to travel between two landmarks in the Twin Cities. (They started at the Gateway Center on the University campus and drove to the Cathedral in St. Paul about 10 miles away.) Because that section of the Twin Cities transportation network is essentially a grid, drivers had many choices—at least five possibilities along major city streets or a freeway. Using global positioning technology, researchers could measure route preference and speed. Researchers wanted to determine how drivers found their way on the network, how many trips it took them to find a preferred route, and how willing they were to try alternate routes.

Additional information used to develop the model and provide data for simulations came from 62 University engineering students. These students recorded the routes they have considered for three different types of trips. Interestingly, most often (48 percent of the time) drivers considered only one route for a trip; 31 percent of the time they considered two possible routes. Only 21 percent of the time did they consider more than two routes. The data provided information on 295 trips, with an average trip distance of 14 miles. While the sample size was relatively small, it provided enough information about the factors that went into route choices—access points and types of roads chosen, for example—to develop a model, says Zhang.

"Most models assume drivers are considering every possible route at the same time," he says. "Yet, in reality, a driver only would consider two or at the most three routes before making a choice. Clearly, they are using some kind of cognitive heuristics. The data also showed that people tend to stay with their current choices. They don't want to change, even if they might save time."

A new kind of model

The information gathering confirmed behaviors that most drivers would observe in themselves and others. "Overall, people look for the shortest distance on major routes," Levinson says. But some drivers will choose to take a longer route because it's more scenic or because they don't like traffic. These "stop and smell the roses" drivers tend to have an overall beneficial effect on transportation networks. Traffic flows more smoothly because they avoid major highways.

With the data gathered on real-world drivers and the if–then assumptions developed into equations, Zhang conducted several computer simulations of the traffic-demand model using the Twin Cities road network as a background. The simulations found that the transportation systems flowed best when some, but not all, travelers searched extensively for alternate routes. If all drivers continued searching for routes, the system overall would be in flux so much that overall travel times would rise. "We found empirical evidence that people are inefficient, but they use cost-effective heuristics in deciding which routes to take," Zhang says. Generally, the travel saving in terms of time needs to be 10 percent before people will switch routes.

Zhang further tested the model by applying it to a transportation question that has baffled policymakers in the Twin Cities for some time: whether using freeway ramp meters encourages or discourages drivers from using major highways, possibly contributing to congestion. Ramp meters have been used to manage freeways in the Twin Cities since the late 1960s. They have been controversial more recently as congestion has increased and longer wait-times at meters—sometimes as much as 20 minutes—have frustrated drivers. Ramp meters were turned off for two months in the Twin Cities in 2000 as part of a test of their effectiveness. Using the agent-based travel-demand model, Zhang simulated turning meters back on after they had been off for awhile. In the simulation, only a small number of drivers—about 2,000—immediately changed their routes in response to the meters coming on. However, the changes those drivers made resulted in more drivers making changes in later iterations of the simulation. After 46 iterations—the equivalent of nine weeks of commuting—the system as a whole has returned to an equilibrium.

Future applications

Agent-based models have a variety of potential applications in transportation planning. A similar approach could be used to study who uses mass transit, why, and how to better serve those people, says Levinson. Another possible realm of research would involve studying why people choose to live or work where they do. Another student at the University is using agent-based modeling to study trip distributions.

Zhang also is gathering data in Oregon to supplement and refine the travel-demand model he developed at Minnesota. "I want to focus on what really occurs in the city," Zhang says. "Planners need to use models, and whenever you create a model you have to start with assumptions. I think agent-based models are more in line with observations of drivers and are more consistent. If you are starting with better assumptions, you can get even more rigorous models and better traffic operations."

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What Lies Ahead

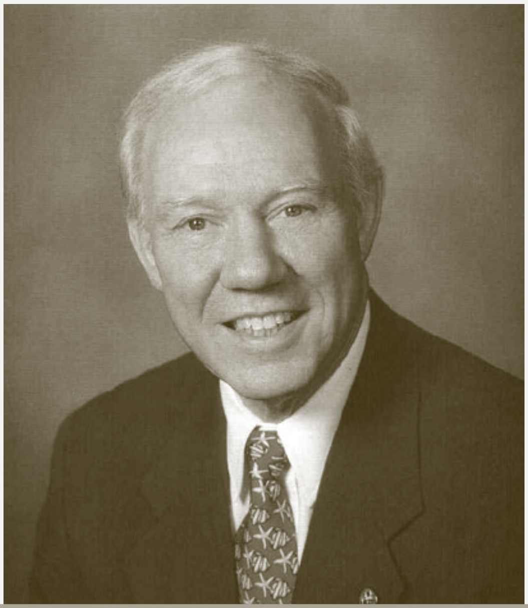
"TechPlan: Transportation Planning and Policy Applications of ITS-Related Technologies" (TechPlan) is the State and Local Policy Program's research program funded by SAFETEA-LU, through the Intelligent Transportation Systems Institute at the Center for Transportation Studies. The overall objective of TechPlan is to investigate and propose policies that will take advantage of the increased presence of intelligent transportation systems (ITS) and ITS-related information and communication technologies (ICT) for planning of transportation and related infrastructure. The work will include analysis of skills and challenges related to planning and managing regional and local transportation and infrastructure systems from a technological perspective, including identification of opportunities for training, both for professionals and those seeking graduate degrees in the field.

TechPlan is a research, education, and outreach program that addresses the ITS Institute's high-priority transportation application area of societal issues related to ITS technologies. The research projects identified here address using ITS or ITS-related ICT in the planning, operations, maintenance, or assessment of transportation and related infrastructure systems. Specifically, these projects will being work in the following areas:

- The Role of Social Networks and ICT on Destination Choice
- ITS and EMS System Data Integration for Safety and Crisis Information and Decision-making Systems
- Implications for ITS in School Travel
- ITS and Privacy Issues

Funding requested in this round will support initial research into each of these areas, as well as support functions that include:

- Peer review and comment on each proposal;
- Planning for an interim roundtable; and
- Coordination of the projects to ensure timely reporting, review, and completion.



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