WHAT'S INSIDE

2 Will Technology Reshape Our Cities?
Richard Bolan draws on modeling techniques, complexity theory, and reams of census data to determine ways in which technology influences the shape of urban areas.

5 Clicks vs. Trips
Kevin Krizek tries to unravel the relationship between information and communication technologies and household travel decisions to help transportation planners understand how urban areas may change as technology becomes more pervasive.

7 The Wireless Safety Net
Thomas Horan examines the intersection of the transportation, telecommunications, and organizational issues that surround the use of wireless communications in emergency management systems (EMS), particularly in rural areas.

10 Growing Companies, Growing Communities
Lee McNich is looking at how information and communication technologies—particularly Intelligent Transportation Systems—are used in a rural industry cluster in northwestern Minnesota.

14 The Well-worn Path
David Levinson has developed a model of network dynamics that suggests that transportation systems may be self-organizing networks with intrinsic hierarchies.

17 Making Connections
The State and Local Policy Program research team provides education and outreach to transportation professionals to ensure that the intersection of theory and practice is well marked and well understood.
Dear colleagues,

It’s the dream of every child on a long car trip. “Wouldn’t it be great,” the child says, “if we had one of those machines from Star Trek that just beams you to wherever you want to go?” Technology has not brought us that dramatic a change in how people move around—yet. But the impact of technological changes in the past decade or so on transportation has been enormous.

As part of the Sustainable Technologies Applied Research (STAR) initiative, researchers have looked at these changes from many angles and views. David Levinson uses complex modeling techniques to discover why road systems take the shape they do—and how that should affect transportation planning. Thomas Horan has studied how cellular phones have created a new, totally unplanned safety net on the highways—and the challenges this presents to rural emergency service providers. Richard Bolan and Kevin Krizek are examining how the shape of our cities may change as technology increasingly pervades our home and work life. My own research focuses on transportation networks and their importance to the economic life of rural areas as regions struggle to maintain and grow industry clusters.

The theme that cuts across all of this research is Places and Networks: New Hierarchies in Access and Activity. The lead phrase captures the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places. The second phrase connotes the changes that are occurring among and between networks and the dimensions (e.g., access, activity) that concern the STAR researchers.

What else links this research besides the obvious connection to technology? First, each of these projects looks at transportation networks as complex systems. Transportation involves many players, many linkages, and many hierarchies. How these factors work—or fail to work—together is important to know. Technology has the power to change transportation—to make it more efficient, less environmentally costly, and friendlier, and to encourage alternative means of transport. Yet, these technological changes have burst on the scene at a time when financial resources are scarce. Policymakers and transportation planners need the best information possible and a fuller understanding of how transportation systems function to determine how to spend scarce dollars.

A second—and equally important linkage—is that this research emanates from the State and Local Policy Program at the Humphrey Institute at the University of Minnesota. As an organization, we are committed to research rooted in the “real world.” Our mission encompasses both the creation of knowledge through research and the sharing of that knowledge with those who must make far-reaching decisions about community issues. I use the word “share” intentionally. Regular consultation and discussions with transportation planners and decision makers have greatly enhanced this and other research projects.

STAR is a six-year project of the Intelligent Transportation Systems (ITS) Institute of the University of Minnesota’s Center for Transportation Studies. The ITS Institute is a University Transportation Center (UTC) funded through the national Transportation Equity Act for the 21st Century (TEA–21).

This is the midpoint of the STAR project. As you will see in the articles that follow, we already have learned much about the technologies, networks, and hierarchies that influence transportation. Along the way, however, we’ve also discovered many new questions. We have three more years to ponder those.

Sincerely,

Lee W. Munnich, Jr.
Senior Fellow and Director
State and Local Policy Program
WILL TECHNOLOGY RESHAPE CITIES?
Research looks at who is located where and why

Richard Bolan’s examination of how technology will affect transportation and the shape of American cities began with a contradiction. “Camden, Maine, had declared itself the software capital of the United States,” says Bolan, an expert in planned social change who has been affiliated with the Humphrey Institute since 1985. It was a strong claim from a city of 5,200 located in the middle of one of the country’s most sparsely populated states. Yet Camden’s claim spoke to the notion that, with the advent of the Internet and other information technologies, traditional factors in economic development no longer mattered. Almost any business—especially those providing information services—could be located anywhere.

“But there also are voices running counter to that,” says Bolan. “Their idea is that those who will benefit most from advanced telecommunications are places that are already rich in information technologies.”

As part of the Sustainable Technologies Applied Research (STAR) project, Bolan is in the middle of a six-year study of the impact of telecommunications on urban spatial structure and its subsequent impact on urban transportation demand and intelligent transportation systems. The study’s focus on innovation and its diffusion through the economy grows from the assumption that employment centers, telecommunications infrastructure, and transportation infrastructure are the building blocks of urban form. Bolan is drawing on modeling techniques, complexity theory, and reams of census data to determine ways in which technology influences the shape of urban areas. Bolan’s work examines the location of businesses and the location patterns of information workers. A related project led by Humphrey Institute assistant professor and researcher Kevin Krizek focuses on how information technologies are changing personal travel habits. (See related article on page 5.)

Examining the cross-currents of information technology

In the seven years from 1994 to 2001, the U.S. economy was inundated with innovation. The relationships between companies and their vendors and customers changed dramatically as new technologies allowed everything from online ordering to instant price comparisons to inventory management systems through which vendors could see when a company needed more of a product. “We’re looking at the ways in which telecommunications has affected economic activity,” says Bolan. “We’re trying to ferret out the cross-currents.”

Bolan’s research rests on several assumptions. First, that the innovations in technology do result in changes in urban spatial form. Second, that the rate of adoption of a new technology influences the rate of change. Finally, he believes the “theory of positive externalities” applies as technologies move into the economy. That is, as more people go online or embrace other technologies, the value of the technology increases. Thus, Bolan expects that existing centers of particular industries will benefit most from advances in telecommunications. “The real centers
of benefit are places like Los Angeles, New York, Chicago—places that are the centers of the entertainment industry, which has seen huge advances in technology. Other centers of benefit might be cities like Atlanta, Phoenix, and Salt Lake City. Not all the clustering caused by innovation is around traditional high-tech centers like Silicon Valley and Boston,” Bolan says.

The potential effects on transportation demand are significant. While telecommunications may replace some trips (sending an e-mail instead of postal delivery of a letter), advances in telecommunications also could lead to greater transportation demand, changes in commuting patterns, and changes in urban structure resulting from new location decisions.

**Two examples: An old economy firm and the new information worker**

While much attention has focused on dot-com and other high-technology companies, advanced telecommunications also have penetrated so-called “old economy” firms. Bolan’s case study of General Mills Corporation, completed in 2002, found that this multinational food product company was thoroughly infused with advanced information technology. The corporation produces a wide range of processed food products from cereal to frozen dinners and operates in Canada, China, Europe, Latin America, and Asia, as well as the United States. Information technology enhances the company’s operations in many ways. General Mills uses electronic data interchange to track inventory and order raw materials. It has dedicated Internet lines for financial institutions and suppliers. The company relies on videoconferencing to reduce travel expenses and increase communications. It hosts multiple Internet sites for consumer information and e-commerce. Voice mail and e-mail are ubiquitous.

Despite this heavy investment in telecommunications, plant location decisions still hinge on more traditional criteria, such as financing, the tax climate, and proximity to highways, rail lines, and airports. It is not that telecommunications are unimportant, says Bolan, “however, there may well be an assumption that the telecommunications systems already are in place.” In the second portion of the study, Bolan is examining the location patterns of information workers. He defines an information worker more broadly than the stereotype of a software engineer or systems analyst. Informed by the work of Humphrey Institute scholar and professor Ann Markusen, Bolan views information workers as anyone who “uses
information as a commodity.” Under this definition, information workers would include lawyers, bankers, social workers, medical workers, and educators, among others. These information workers account for 15 to 16 percent of the labor force, Bolan says.

“We’re exploring how these workers pattern themselves within a metro area,” says Bolan. He chose four cities to study: Atlanta, Phoenix, Denver, and the Twin Cities of Minneapolis and St. Paul. In addition to examining trends in the location of information workers among the different cities, Bolan is looking at the spatial distribution of these workers within each of the cities. Using data from the Census Bureau Transportation Planning Package, Bolan will compare worker locations between 1990 and 2000.

“We’re expecting to see information workers clustered in certain areas, whereas non-information workers will be more dispersed,” says Bolan. One reason for this pattern is the continuing reshaping of central business districts. “Downtowns” formerly had a diverse character, with retail, industrial, and other commercial workers all going there for their jobs. “Now central business districts are centers for information workers,” says Bolan. In addition to their concentration in downtowns, information workers also tend to congregate in so-called edge cities, second- and third-ring suburbs with easy access to highways and often to an airport.

**No predictions, just tendencies**

As he begins to analyze the data on information worker location, Bolan will draw on complexity theory, an idea with great potential for application in intelligent transportation systems, he says. Complexity theory argues that “the world is a sequence of events in which small events can have a big impact,” says Bolan. “We live on the edge of chaos but don’t fall into it because of our capacity for self-organization.” While complexity theorists say you cannot predict the future, “you can get a feel for tendencies,” says Bolan.

Bolan hopes his research will help transportation planners understand the varied scenarios that could develop as information technologies continue to be adopted. These technologies will certainly affect urban form and the transportation infrastructure needed for cities to grow and develop.

“We have a big agenda,” Bolan says.

---

Professor Emeritus Richard Bolan
Hubert H. Humphrey Institute of Public Affairs
University of Minnesota
Phone: (612) 625-0128
E-mail: dbolan@hhh.umn.edu
CLEKS VS. TRIPS

The complicated relationship between travel and technology

Back at the dawn of the Internet age—say, 1980—futurists predicted that as telecommunications improved, people would stay home more. We could work from home, shop from home, bank from home. One author predicted that telecommunications might eliminate all mundane travel. We could save time and energy, reduce air pollution, and eliminate traffic. It hasn’t happened yet, but don’t blame technology. People could travel less—they just don’t.

The relationship between information and communication technologies and household travel decisions is more complicated than futurists could have imagined. Unraveling that relationship to help transportation planners understand how urban areas may change as technology becomes pervasive is at the core of Kevin Krizek’s research. Krizek, an assistant professor at the Humphrey Institute, is collecting and analyzing data on household travel decisions in three cities: Seattle, Pittsburgh, and the Kansas City metropolitan area. The urban areas differ from one another in degree of technology use and in congestion levels. Krizek hopes that by examining such different cities he will get a clearer picture of how telecommunications will affect travel under a variety of circumstances.

“We want to stratify the sample to understand how travel behavior is related to both technology use and congestion,” says Krizek.

A wired world

Information and communication technologies—the Internet, personal digital assistants, cell phones, and other devices—have become part of even the simplest transactions. A shopper at the supermarket calls home on his cell phone to make sure he’s buying the correct brand of laundry detergent. Before buying a new car, a potential buyer looks online to see where she can find the best price on the model she wants. Then, she drives 50 miles to check out the car. A retiree with wanderlust checks the Internet for cheap, last-minute fares to Rome and books the tickets and accommodations from her apartment in St. Paul.

“At one point, we thought that e-commerce could replace a lot of physical travel and therefore we’d eliminate our congestion woes,” says Krizek. “The emerging thought is that information technologies are not replacing household travel but are complementing it.”

Krizek joined the STAR project team in 2001. His earlier research has focused on transportation demand management, travel behavior (including pedestrian and bicycle travel), neighborhood accessibility, and sustainable development.

The first step in his study of technology and household travel was an extensive review of earlier studies into the influence of technology on household decisions. Earlier research found that many kinds of household activities could be replaced by telecommunications. These include basic tasks like working from home and telecommuting, shopping online, and banking by phone or Internet, as well as discretionary tasks like distance education or tele-entertainment, among others. Generally, activi-
ties could be divided into subsistence activities, such as commuting for work, maintenance, such as grocery shopping or banking, and leisure, researchers found.

For each of these activities, telecommunications could have a variety of effects. The telecommunication could be a substitute for travel, such as working at home instead of commuting. The telecommunication also could modify travel in terms of time or location. For instance, a telecommuter might do his grocery shopping at noon on Tuesday instead of noon on Saturday, changing the time of the trip and probably avoiding congestion. Similarly, the woman who looked for a car online might end up traveling longer distances to buy a vehicle than she would have without information gleaned from the Internet. Finally, telecommunications devices can generate travel that otherwise might not have occurred. While using the Internet for other purposes, a consumer might see an advertisement for laptop computers at a great price and immediately head to his local electronics store. Or, a rare book fan might discover many previously hard-to-find volumes over the Internet and generate a truckload of trips for the local UPS driver.

"It's important for people to understand the role that technology could play," says Krizek. "I think some people may be looking for it to ameliorate our congestion woes. The benefits of technology may be overstated."

**Getting travel behavior data**

As he enters the second phase of the research, Krizek is conducting an extensive survey of several thousand households in Seattle, Pittsburgh, and the Kansas City metropolitan area. The questionnaire asks people about their use of technology for banking, shopping, and entertainment. It also asks about attitudes toward technology and various travel issues, such as congestion and walking as a travel option. He believes that understanding the demographics of who uses telecommunications and how will provide important insight into transportation issues.

"There are a lot of things we have to figure out," says Krizek. "One study found, for instance, that you can take a family out of the suburbs, but you can’t take the suburbs out of the family. That is, if a family moves from the suburbs into the city, they will take just as many trips using their car. The trips may be shorter, but the habit of driving is very hard to change."

The surveys were sent in May 2003, and Krizek expects to be analyzing this data this fall. He outlines several scenarios of the potential impact of information technologies on household activities. In some cases, information technology may directly replace certain trips. He also believes the Internet and other technologies may be prompting more purchases and, therefore, may be prompting more travel. This could include both short trips to the local mall and longer trips for leisure travel. "The good deals people can get on airline tickets through the web may well be instigating travel," says Krizek. In addition, the availability of products through the Internet has forced bricks-and-mortar retailers to change their approach to customers. Bookstores, for example, have remade themselves as coffeehouses and neighborhood gathering spots as well as places to buy books. The success of these bookstore hangouts speaks to one of the limitations of communication technologies.

"Much of the social interaction we require is invaluable and cannot be adequately served electronically," says Krizek. "For example, renting a movie is not a substitute for going to the theater because the two are not usually considered equivalent experiences."

Because information and communication technologies have been changing and developing so rapidly in the past decade, research into this area is scarce, says Susan Handy, a professor of planning at the University of California-Davis. "The Internet potentially is changing our daily travel in all kinds of significant ways, yet few studies have attempted to document these changes," says Handy. "This study will increase our understanding of these changes and provide a stronger basis for formulating transportation policy now and in the future."

**Assistant Professor Kevin Krizek**

Hubert H. Humphrey Institute of Public Affairs
University of Minnesota
Phone: (612) 625-7318
E-mail: kkrizek@hhh.umn.edu

---

**PLACES AND NETWORKS**
THE WIRELESS SAFETY NET

With cell phones everywhere, emergency response systems change to adapt

It happens hundreds of times every day all over the country: A car crashes and a passerby or the crash victims dial 9-1-1 with a cellular telephone. The caller may be excited or disoriented or injured, so police must piece together the information they gather to dispatch an ambulance and other emergency teams. Unlike calls received from landline telephones, with calls from cell phones, dispatchers sometimes have difficulty pinpointing the caller's location. Emergency workers hope they will get to the right place soon enough.

Cellular phones have created a new safety net on the highways. In the past 10 years, wireless telephone use has exploded. Today, the more than 120 million cell phone users in the United States place more than 140,000 emergency calls a day. While this has created stresses on local emergency response systems—largely in the form of a flood of calls reporting the same accident—it also has had the beneficial effect of driving down the response time to emergencies. In the past decade, notification time for fatal crashes has dropped by 30 percent. This new safety net saves lives, yet the policy implications of the use of wireless technologies in emergency management systems are little understood, especially as they operate in rural areas.

A component of the Sustainable Technologies Applied Research (STAR) initiative is to examine the intersection of the transportation, telecommunications, and organizational issues related to the use of wireless communications in emergency management systems. Thomas Horan, executive director of the Claremont Information and Technology Institute at the Claremont Graduate University in Claremont, California, and a transportation scholar who has been affiliated with the Humphrey Institute for more than a decade, directs the research in this area.

"No one planned this mobile safety net," says Horan, "and there hasn't been an appreciation for how this came to be so important. People did not think about it as part of the transportation system, though it is. We are asking questions like, where are gaps in coverage? Can the system accommodate continued growth in usage? There is a growing expectation on the part of the public for a rapid response in emergency situations. Yet no one has been taking a systems approach to the issue."

"Our goal is to understand this emerging system and how it is performing," continues Horan. "Often transportation systems and telecommunication systems are heavily planned. This one really grew out of strong consumer demand for the service."

In approaching the issue, Horan has employed the National Intelligent Transportation Systems Architecture as a framework to analyze how emergency response systems operate in rural Minnesota. This framework allows researchers to separate a complex, multi-part system into discrete layers. In this case, the layers include, transportation networks, communications networks, and institutions that develop the policies for and fund the systems used to provide emergency services. Horan also has explored complexity theory and how it might be used to "drill into these socio-technological issues," he says.

Social and physical scientists have embraced complexity theory as a way to understand how systems adapt and grow. As part of his research, Horan is developing a software program to analyze information about crashes. This program would use information like response times, crash locations, delay factors, and road type, among many other data elements, to provide performance information about emergency response systems.

"We're trying to get performance information from different angles of the system," says Horan. "The idea is to come up with a tool that can show you..."
where the problems are in each sector. We’re hoping to develop a new way of reporting about crashes and therefore a new way of managing emergency response.”

So far, Horan’s study has been conducted in rural Minnesota, particularly the areas around Virginia and Rochester, home of the Mayo Clinic. This next year, Horan will advance the study with an additional case study in Brainerd, a resort community that sees a population and traffic surge every summer.

The rural environment provides a rare opportunity to study how wireless emergency systems are developed. The potential for life-saving improvements in response time is great here. According to the Minnesota Department of Transportation, only 30 percent of the miles driven within the state of Minnesota are on rural roads, yet 73 percent of fatal crashes will occur in rural areas in 2003. In addition, half of the rural traffic fatalities happen before the victim arrives at the nearest hospital. Medical care during this “golden hour” immediately following a car accident is critical to reducing deaths and disabilities.

Other factors also led to the choice of Minnesota as a study area. First, the state has a history of aggressively pursuing intelligent transportation system initiatives. Minnesota Guidestar, the state’s Intelligent Transportation System program, has carried out a number of projects to provide traveler information and improve traffic control and incident management. Second, technological infrastructures are less developed in rural areas, which offers an opportunity to explore specific barriers to wireless emergency responses that do not exist in metropolitan areas. Finally, partnerships among emergency response providers—police, sheriffs, ambulance services, hospitals—tend to be less developed in rural areas.

Horan’s initial research involved several rounds of interviews with representatives of public and private organizations involved in the emergency management system, as well as site visits to the communities being studied. Organizations participating in the research include local and state police, fire departments, hospitals and ambulance services, the Minnesota Department of Transportation, city and county governments, and local economic development agencies. In addition to the interviews, data on relevant issues, such as current and future wireless communication requirements, 9-1-1 dispatching protocols, rural transportation and emergency medical services radio communications needs, and intelligent transportation systems planning, was reviewed.

Researchers found that challenges facing emergency response and emergency management systems in rural areas took three forms: technology issues, organizational issues, and policy issues. “Emergency response and emergency management is a complex system,” says Horan. “It’s comprised of many organizations and services that rely greatly upon technology. While there is no doubt that the technology exists to create a state-of-the-art emergency response and management system, major barriers exist to implementing and managing that technology.”

The technological underbelly

What would a state-of-the-art wireless system look like for rural areas? Interviewees indicated that it would require full cellular coverage, a system that would ensure the emergency call went to the correct Public Service Answering Point, and would involve a way of locating, through global positioning or other systems, the exact location of the caller. That information then would be seamlessly forwarded to the emergency response team. While the technology to accomplish this exists, cost and other factors have prevented full deployment in rural areas. Only 10 percent of cell phones in use have the global positioning chip, says Horan.

Of the 119 Public Service Answering Points (PSAPs) in Minnesota, 40 percent comply with Phase 0 or Phase 1 standards of the Federal Communications Commission’s (FCC) wireless 9-1-1 rules. These rules require that when an emergency call is placed, dispatchers can determine the location of the nearest cell tower base station and the cell phone number from which the call was placed. According to Horan, emergency services providers indicated that cellular coverage
is not yet complete in Minnesota and that 9-1-1 calls occasionally are routed to the incorrect PSAP. This creates delays in responding to the emergency and often requires responders to use their general sense of the area and whatever directions they have been given to locate the accident victims.

There have been delays in updating PSAPs to accept calls with global positioning data in compliance with the FCC's Phase 2 rules. The high cost of implementing upgrades is the main reason rural areas have been slow to add them, says Horan. Minnesota has a large number of PSAPs, and outfitting each of them has been expensive. Other technological improvements that would reduce response times include upgrading data backup capabilities, adding dedicated wireless trunk lines to PSAPs, and upgrading technology to allow for the acceptance of both wireless and wire line calls rather than retrofitting existing wire line systems. Nationally, 80 percent of PSAPs do not have full data backup capabilities, resulting in a high percentage of calls being lost. Again, cost often is listed as a reason to put off the improvements. "Another issue was that PSAP decision makers often are not aware of new, lower-cost technical solutions," says Horan. "They often rely on vendors, who may push high-cost, long-term solutions."

Organizing for a better response

Responding to an accident always crosses organizational lines: the police or State Patrol may be the first called to a scene, an ambulance almost always is required, a helicopter may be needed to transport the patient, and the hospital must be alerted that accident victims are en-route. In addition, the Minnesota Department of Transportation is involved in road maintenance and transportation improvement programs that can affect emergency response. These organizations have varying cultures and approaches, which may make partnerships more difficult.

"Because these partnerships include both public and private organizations, they encounter both barriers and synergies to creating an effective emergency response system," says Horan. For instance, in one of the study areas, the Mayo Clinic purchased the Gold Cross Ambulance Service, which served the Rochester area. Money shortages had prevented the ambulance service from making technological upgrades. It essentially could not keep up with the hospital, yet it provided a vital service to the community and to the Mayo Clinic.

Horan cautions that, while Mayo was able to play a valuable role in this case, the general picture emerging from the research is one where "private sector resources may be too strained to provide seamless services in rural areas, particularly under crisis conditions."

But money is not the only barrier. No single administrative structure or distribution of roles seems to work best. Organizations had widely varying perspectives on the optimal distribution of responsibilities. Public-private partnerships pose particular challenges and may result in a lack of trust among organizations. For example, recognizing the potential positive effects of cellular technology in emergencies, the Minnesota Department of Transportation Communication Technology Office proposed that government agencies receive a priority access service during a large-scale disaster, such as a tornado. However, carriers opposed the idea because it would lower consumer call completion rates.

Other barriers exist within organizations themselves. Training employees to use new technology can be time-consuming and challenging for small organizations. In addition, some employees resist adopting new technologies because they fear they will depend too much on a technology that could fail in an emergency.

The work ahead

Over the next three years, Horan will develop and refine a software "proof of concept" for organizing and reporting crash data. The ultimate goal is to understand "end to end" performance of the rural EMS system, so that weak links can be identified and overall service provided.

In addition to working with Minnesota communities to test the system, Horan will consult with stakeholders in other parts of the country to get a "reality check" on whether the tool is collecting and analyzing data in the most useful manner. He and his team of researchers also plan to assess the ability of systems to function during "extreme" events as well as during periods of rapid cell phone growth.

"This is a rare opportunity to look at an emerging system," says Horan. "Our goal is to keep the emphasis on the performances of the transportation and telecommunication systems so services can be better and responses quicker."

Thomas Horan
Executive Director
Claremont Information and Technology Institute
Phone: (909) 607-9302
E-mail: tom.horan@cgu.edu
Information and communication technologies are reshaping businesses worldwide. From Internet-driven supply-chain management tools to robotics on the manufacturing floor to advanced marketing strategies that allow even small firms to go global, the computer, cell phones, sensors, and a myriad of other technologies are making individual companies more efficient and productive. Yet, the rapid development and uneven deployment of these technologies—including technologies that drive Intelligent Transportation Systems (ITS)—has prompted questions about how communities will prosper in the future.

“While these technologies open doors for new strategic models at the firm level, little is known about their impact on regional economies,” says Lee Munnich, director of the State and Local Policy Program at the Humphrey Institute and lead researcher on the Sustainable Technologies and Applied Research (STAR) project. Regional economies often are driven by the presence of industry clusters—groups of companies making a similar product or components for that product that congregate naturally in a specific region. Examples of industry clusters abound, ranging from shoemakers in northern Italy to biotech firms in Boston. Strong industry clusters often lead to strong regional economies.

Munnich is working to determine how information and communication technologies, with a focus on ITS, are used in a rural industry cluster. For the study, Munnich and Humphrey Institute graduate research assistant James Lehnhoff chose the recreational vehicle industry in northwestern Minnesota. This industry cluster consists of two major manufacturers of snowmobiles, all-terrain vehicles, jet skis, and other recreational vehicles. The two large manufacturers—Polaris and Arctic Cat—are supplied and served by a variety of smaller companies operating within the region.

The cluster is an important part of the economy in northwestern Minnesota, says John Ostrem, president of the Northwest Minnesota Foundation, a community development organization. Ostrem considers Munnich’s research a source of new, practical insight into how the region can become stronger economically. “There are lots of ways to do economic development,” says Ostrem. “We don’t think trying to attract industries from outside is the answer. We’d like to build on the businesses we have.”

The northwest Minnesota cluster offers several advantages for analysis. First, it’s successful despite being located in the most sparsely populated section of Minnesota. In addition, the cluster has characteristics of a classic industry cluster: a strong manufacturing base, internal cooperation and competition among producers, local supply networks, and a significant overall economic impact on the region. Finally, it provides a chance to study an industry that is facing increasing competition from foreign and domestic markets and is therefore strongly motivated to seek out innovations and efficiencies.

In addition to providing information about how the cluster functions today, Munnich’s research will explore future uses of ITS in a rural industry cluster and its potential impact on a regional economy.
“What we’re doing is looking at the economic development aspects of transportation,” says Munnich. “We’re seeing how it can be used to improve a regional economy.”

Munnich’s study has involved consultation with experts in rural industry clusters and extensive interviews with representatives of the companies operating within the cluster. These corporations provided Munnich with detailed information about how they communicate with customers and suppliers, how they link suppliers and customers through transportation and communication networks, how they move goods, how the cost of transportation affects the firm’s location, how transportation needs have changed over time, and what changes in communication and transportation strategies they anticipate in the future.

“Transportation is a huge issue for this industry cluster,” says Munnich. “It’s located in a very sparsely populated area. There are no interstate highways. The weather conditions can be horrible and have a severe effect on transportation. We’re trying to discover to what extent technology improvements affect the cluster and what improvements likely will be needed for the future.”

Industry clusters and the diamond of advantage

Competition from low-cost producers in the 1970s and 1980s and its effect on traditional industrial centers prompted academic inquiry into industry clusters. While some regionally based industries struggled, others remained strong. Early studies found that successful clusters tended to reward constant innovation in product and process. Harvard Business School Professor Michael Porter provided a basis for examining industry clusters in his book, The Competitive Advantage of Nations. Porter theorized that successful clusters could be explained in terms of a set of characteristics that affects the entire cluster and that drives innovation, resulting in competitive advantage. Porter called this set of characteristics the “diamond of advantage” and it provides a framework from which Munnich has approached his study of a rural industry cluster. The four primary characteristics are:

**FACTOR CONDITIONS.** These include regional advantages, such as human capital, physical resources, local specialized skills and knowledge, capital resources, and infrastructure that can increase a collection of firms’ chance of success. Disadvantages also can drive innovation. In the case of northwestern Minnesota, its remote location has prompted a focus on finding efficient ways to move goods. All of the firms studied had high-speed Internet access. All of them used some form of product, inventory, or supply tracking system. In addition, many expressed interest in distance learning and were enthusiastic about weather monitoring and travel information systems that could make transporting goods more reliable.

**DEMAND CONDITIONS.** If a strong local demand exists for products, companies in a cluster are more likely to innovate. Snowmobiling is a way of life in northwestern Minnesota, where snow can be on the ground seven months of the year. This strong local interest in recreational products may explain the
dominant market position of snowmobile producers in the region. However, increased domestic and regional competition has affected companies in the area, resulting in a greater emphasis on transportation and communication efficiencies. While most companies had websites, online sales make up a small portion of sales for most firms. Large firms get only about 10 percent of their sales online. Interestingly, one of the smallest firms interviewed had the largest percentage of sales through the Internet: more than 60 percent of revenues.

**RELATED AND SUPPORTING INDUSTRIES.** Porter found that a network of buyers and suppliers near each other could create a faster and more active exchange of information, collective learning, and supply-chain innovation. In northwestern Minnesota, large firms buy about 30 percent of their supplies from regional companies. Firms increasingly require their suppliers, transporters, and distributors to be able to connect to the company's computer system to monitor production. Design files are transferred via e-mail rather than traditional mail. Fully integrated supply management systems promise great efficiencies in manufacturing and transporting goods, though some smaller firms have been slower to adopt these methods.

**INDUSTRY STRATEGY, STRUCTURE, AND RIVALRY.**
The most productive atmosphere for innovation includes both intense competition and cooperation and collective action on shared needs. With two leading manufacturers of recreational vehicles in the area, competition certainly exists. Yet, several firms have formed a cooperative association to help them control costs for transportation and technology and business training. These issues affect all companies in the region, so cooperation makes business sense.

In addition to the four key elements, government and chance can play a role in the development of industry clusters. Porter says. For instance, explains Munnich, government plays a large role in providing travel information, distance learning opportunities, infrastructure for telecommuting, and other factors that can improve the climate for an industry cluster. “Part of what we point out to people,” Munnich says, “is that the drivers of these industry clusters are the businesses themselves. Industry clusters help you understand the dynamics of the industry.

“Sometimes people think that government is creating jobs. That’s not really true. We can help businesses be more competitive. Governments provide a whole range of services that have an impact on business, and transportation is one of them,” says Munnich.

It is not necessarily true that all four factors must be present for an industry cluster to be innovative and successful. State and Local Policy Program researchers have found that technology can replace some components of the diamond of advantage. For example, e-mail, fax, and other telecommunications tools can help companies maintain relationships with distant suppliers and customers.

**Inside a rural cluster**

Rural clusters differ significantly from clusters based in urban areas. Not surprisingly, they tend to be spread across larger distances, making transportation and communication more important issues for companies within the cluster. In addition, businesses based in rural areas tend to have less access to specialized services, such as financial services, engineering, management consulting, information technology advisors, and even high-end transportation services. Finally, among the recreational vehicle cluster, the extent of technology use varied widely.

“The challenge is that larger firms have been the drivers of technology and are very competitive,” says Munnich. “The question is whether the supplier chain will adopt technologies quickly enough. Eventually, they have to adopt the technology if they are going to do business with the larger company.”

These technologies have great potential for cost savings, particularly for transportation. ITS technologies merge public and privately owned systems, says Munnich. Logistics systems, such as those used by firms in the recreational vehicle industry cluster, allow companies to view transportation as a flexible rather than fixed cost. “Previously, shipping costs were viewed as a static part of doing business,” says Munnich. “Products needed to be shipped or there was no business.”

That’s still true, however shipping can be more efficient through use of ITS technologies that allow companies to track shipments and supplies. These tracking systems permit companies to manufacture product on a “just-in-time” basis, meaning supplies arrive just as they are needed on the manufacturing floor, saving the company the expense of keeping inventory or shutting down manufacturing if a shipment does not arrive on time.
As competition has increased globally, it has become essential for larger companies and their suppliers to use technology more. One challenge for a rural industry cluster is providing the training and support smaller firms need to adopt high-tech strategies. Companies may purchase software tools but finding the right training and support is sometimes difficult, Munnich says. "Simply providing companies with ITS or other technologies will not be sufficient," says Munnich. "There must be support for ITS technologies, coordination between businesses, and expandability for growing businesses that may not need the most expensive technologies immediately." With this support, ITS can help companies within the cluster maintain the traditional, symbiotic relationships that led to the formation of the cluster in the first place. Ostrem praises Munnich for the "practical" applications of the STAR research on industry clusters. "Transportation is important to all of the industries with which we work," says Ostrem. "We're hoping that this research will help uncover more and better ways for firms to operate to keep these companies growing."

Lee Munnich
Senior Fellow, Hubert H. Humphrey Institute of Public Affairs
Director, State and Local Policy Program
University of Minnesota
Phone: (612) 625-7357
E-mail: lmunnich@hhh.umn.edu

Photo courtesy of the American Automobile Association
The Well-Worn Path

Are transportation systems as well planned as we think?

Transportation systems appear to be as carefully thought out as anything in life can be. Certainly, politics may play a part in which road gets built first and unexpected factors—like a budget crisis—might delay a project. But, generally speaking, transportation is considered the realm of the planners and engineers. It’s driven by demographics, land-use projections, and forecasts that predict travel demand. The location of roads is laid out years—sometimes decades—in advance, and planners expect travelers will go where roads exist. However, the shape of road systems may not be solely a function of planning, but, rather, planning reflects natural characteristics of the networks that form road systems.

David M. Levinson, an assistant professor at the University of Minnesota’s Department of Civil Engineering and a member of the Sustainable Technology Applied Research (STAR) team, has developed a model of network dynamics that suggests that transportation systems may be self-organizing networks with intrinsic hierarchies. “Though hierarchies seem to be designed by planners and engineers, the results show that they are intrinsic properties of networks,” says Levinson, whose research focuses on the orientation of major roads in a network.

Previous research in transportation planning has focused on travel behavior, accepting the transportation network as a given. Levinson argues that networks may take shape based on a range of factors that are not explicitly controlled by planners. While influenced by past decisions, the dynamic of a road network also may affect its shape and hierarchies. The principle of self-organization argues that hierarchies emerge not as a result of a master plan but as the function of properties of general growth, induced demand, induced supply, and the underlying structure of the network, says Levinson.

This does not mean that planning is “all for naught,” says Levinson. “If we know where a major road might naturally be, then we know that if you go with the flow, that’s fine. But if you decide not to go there for some reason, then you’ve got your work cut out for you. But if you implement reasonable visions, it is not unreasonable to expect that travelers will follow.” Understanding network dynamics may help planners design better transportation systems and understand why road systems take the shapes they do.

An abstract model of the network

To set up an abstract model of a network, Levinson relied on earlier studies of complex systems. Complexity theory describes a complex system as one that is made up of a group of subsystems that relate to each other in an imperfectly known way. These systems tend to be difficult to predict. One reason for that difficulty is that initial conditions—even seemingly small ones—can have a large impact over time. However, work by such scholars as Joe Sussman indicates that complex systems also operate under a self-organizing principle. That is, even systems that seem chaotic develop hierarchies and
patterns over time. This principle of self-organization has been observed in complex systems in science and social science.

A transportation network can be modeled as a complex system made up of nodes (road intersections), links (road sections), and travelers, according to Levinson. In designing this research project, Levinson sought to discover under what conditions, if any, a hierarchy of roads might emerge. "What we were trying to do is develop a model that would predict the most likely network expansions in a system," says Levinson. "In practical terms, we're trying to figure out how much of a road network is determined by politics and how much is due to technical or structural factors inherent in the network."

Levinson's model began with a simple 10-by-10 grid to represent a set of land uses and roads and a set of assumptions reduced to mathematical formulas. These mathematical models grow from such fields as regional science and economics. Very few such formulas exist for transportation, Levinson notes, perhaps reflecting the assumption that road systems are externally designed.

In Levinson's model, network structure, land use and demographic information (which determine travelers' behavior), and events are designated. Network nodes, road links, and travelers are agents within the system. A travel-demand model calculates the number of trips attracted to and generated by each point on the system. This model assumes that drivers will take the shortest and fastest route to their destination and that as this happens some links will attract more traffic than others. The model assigns revenue to each link of the system based on its traffic. A cost model in the system reflects the expenses necessary to maintain the link. Depending on revenue and cost, an "investment model" determines properties of each link for the next time segment of the model's operation. So, roads that have more revenue than cost are expanded and, therefore, can bear more traffic and that traffic moves at a faster speed. While this may not be a perfect representation of how transportation is funded, Levinson says the formula significantly mirrors the "bottleneck removal policy" that most governments follow in funding transportation. Simply put, roads with heavier traffic get more attention and greater spending, which attracts more traffic.

With this model, Levinson designated a 10-by-10 grid network with a set of identical links with uniform speed and travelers spread evenly across the region at the start of the experiment. He ran the system through a cycle of travel followed by investment eight times. At that point, a clear and stable hierarchy of roads emerged. While there was a major north-south and east-west artery, there also were roads forming a square a few links out from the middle of the system. The system produces higher traffic links at a regular spacing. This reflects, in a simplified form, the structure of a grid of lightly traveled roads with somewhat heavier-traveled roads every few "blocks" and a few very heavily traveled roads providing a beltway around the center of the system.

To test the model further, Levinson took a 50-by-50 grid and uniformly distributed the travelers and set identical speeds for each link on the grid. Within a few iterations, a stable and clear hierarchy of roads again emerged. That hierarchy so closely resembles the ring of freeways that circles most U.S. cities and the system of higher-traffic roads every few blocks that it could be mistaken for a simplified map of an urban transportation system. Further experiments with randomized initial conditions produced highly ordered (though not symmetric) networks. Says Levinson, "No matter how random the initial speed distribution is, when grown subject to localized investment rules the network is producing order by self-organization."
Testing the hypotheses about self-organization in networks with real data, Levinson used 25 years of road construction information from the Twin Cities of Minneapolis and St. Paul. This empirical model could successfully predict about 60 percent of the area’s road-expansion decisions. “This has been very gratifying,” says Levinson.

**Building on the model**

While Levinson’s model appears to mirror how network dynamics function in road systems, he thinks its predictive abilities could be improved with further modifications. For instance, the grid system the model requires necessarily sets up a boundary around the grid. That is, there cannot be traffic past the edge of the grid. This drives trips and traffic toward the center, which may influence the shape of the grid. It is possible, says Levinson, that “the edges of the network are the force creating the hierarchy—the greater utility of central links for traffic increases their flow and their speed.” Among his ideas for further research is to start with a one link network and allow it to grow or to begin with a completely connected network and remove the weakest links one-by-one.

The research presents other opportunities as well, such as exploring different rules for investment to see how they might affect network dynamics or using more sophisticated travel-demand models. Further research in the project will include looking at about 50 years of transportation flows and road decisions in the Twin Cities. Levinson hopes that this information and the model may be useful in predicting future road decisions.

While the formulas and modeling system are complex, the real surprise in this research is its simplicity, says Levinson. “If one looks at the complexity and bureaucracy involved in transportation infrastructure investment, one might conclude that it is impossible to model the transportation network dynamics endogenously. But this research has shown that simple localized investment rules can be used to reflect the overall system properties. It is the simplicity of the investment rules in mimicking the system properties that is the most striking aspect of this research.”

**Assistant Professor David Levinson**
Department of Civil Engineering
University of Minnesota
Phone: (612) 625-6354
E-mail: levin031@umn.edu
MAKING CONNECTIONS

STAR outreach efforts stand at the intersection of theory and practice

How will transportation planning take place in the future? Scarc resources, new technologies, greater understanding of complex systems and how they influence travel patterns, and a generally mature highway system are among the forces that researchers expect will shape transportation—and the people who plan it. How all of those factors will merge and mingle remains uncertain, though both researchers and transportation professionals agree that new skills and approaches will be necessary for transportation planners in the future.

Training current and future practitioners

A key component of the Sustainable Technologies Applied Research (STAR) project is to provide education and outreach to transportation professionals to ensure that the intersection of theory and practice is well marked and well understood.

Assuring that graduate students are well prepared to enter the transportation field is one aspect of meeting the needs of the profession. To benchmark the value of research assistantships and other training available at the University of Minnesota, alumni were surveyed about their experiences. Many former research assistants cited the benefit of the opportunity to conduct research in partnership with professors and professionals and address “real world” policy issues.

“I learned of many exciting programs and research under way in the transportation field,” reported David Van Hattum, executive director of 494 Commuter Services and a research assistant at the Humphrey Institute between 1991 and 1994. “In particular, I found a great bridge between my environmental policy interests and regional strategies to address traffic congestion.”

Meeting the information and education needs of those already in the profession is also a goal of the outreach and education component of the STAR project. To achieve this goal, researchers working under the STAR umbrella have been frequent speakers at conferences and forums sponsored by such organizations as the Intelligent Transportation Society of America, University of Minnesota Center for Transportation Studies, and other professional and association groups. Their articles often appear in professional journals and they have undertaken outreach projects both to disperse information about research and to assess the research needs of the transportation profession.

Exchange of ideas identifies new areas of inquiry

A roundtable discussion held at the University of Minnesota in November 2002 presents another good example of how STAR project staff reaches those currently in the field. The one-day program brought together a select group of researchers and transportation practitioners for a discussion of how new concepts, such as complexity theory, and new management challenges, including those precipitated by technology, would affect the profession. The overall goal of the roundtable was to recommend research and training activities that would be helpful to transportation planners.

The roundtable involved 14 people representing a wide range of perspectives, from those doing very theoretical research to the general manager of a metropolitan bus system. The small size of the group and the diverse perspectives of its members led to a free flow of opinions and ideas about transportation issues, says Lee Munnich, lead researcher on the STAR project and director of the State and Local Public Policy Program at the Humphrey Institute of Public Affairs. The forum had four specific goals:

- To share new research related to transportation systems as complex systems;
- To obtain reaction and input from researchers about the research implications of transportation planning and management practices;
- To address management and practitioner perspectives on planning transportation systems in the face of uncertainty; and
- To obtain management and practitioner perspectives on the training and research needs of new transportation professionals.

The program included several research presentations, including that being done by STAR researchers

PLACES AND NETWORKS
SIX PRINCIPLES OF COMPLEX SYSTEMS—AND HOW THEY AFFECT TRANSPORTATION

Understanding how transportation systems work is made easier if you understand the basics of complexity theory, says Thomas Horan, a STAR researcher and executive director of the Claremont Information and Technology Institute at the Claremont Graduate University in Claremont, California. Horan has employed complexity theory in his work on cellular technology and its impact on emergency response systems in rural areas.

He points to six principles of complexity theory that, when applied to transportation systems, can help professionals better understand the issues they face each day. The principles are:

Dis-equilibrium is the norm. Transportation systems never “settle down.” Workers in emergency management, Horan notes, face “hours of boredom interrupted by minutes of terror.”

Agents drive process. The behavior of travelers is fundamental to performance of the transportation system. Behavior may change spontaneously.

Small changes affect the complex process. A relatively minor incident can have a large effect. A fender-bender may backup traffic for miles at the wrong time of day, to say nothing of the “gawker slowdown” on the opposite side of the road. A minor change in funding policy reverberates throughout a system.

Complex systems resist reductionism. Much of science tries to drive seemingly complex entities down to their smallest, most basic essence. That does not work in a complex environment. To understand travel choice, for example, you must understand community context and travel options and quality, as well as individual travel preferences.

Patterns emerge from simple rules. What drives the transportation issues communities and organization face? In emergency management, for example, a commitment to a quick response shapes how services are delivered.

Systems exhibit self-organizing characteristics. The variety of players and their relationships may shape how a system works. In transportation, many partnerships are possible.

David Levinson and Thomas Horan. It also featured feedback from Professor Joseph Sussman of the Massachusetts Institute of Technology. Sussman’s work has explored the idea that transportation systems are what he calls “Complex Large-scale Integrated Open Systems” or CLIOS. This means that the defining features of the system are that it is “composed of a group of related units for which the degree and nature of the relationship is imperfectly known.” Predicting the behavior of this type of system is difficult, even when the behavior of the various subsystems is understood, according to Sussman. Further complicating the operation of transportation systems is that they exhibit features of “nested complexity,” says Sussman.

“Nested complexity suggests that there is a physical system, the behavior of which, while complex, follows more quantitative principles that can be approximated by engineering and economic models,” says Sussman. “However, the physical system is embedded within a much messier sphere representing the policy system. This sphere represents the organizational and institutional framework of policymakers, firms, stakeholders, non-governmental organizations, and others that together comprise the broad policy system.”

Understanding this policy sphere requires different investigative methods—some of which may be quantitative, others not. Sussman’s analysis and the discussion among roundtable participants that followed spoke to issues that were familiar to many transportation professionals, says Marthand Nookala, director of the division of operations, safety, and technology for the Minnesota Department of Transportation. “The challenge is to implement them,” says Nookala.

Practitioners, for example, saw a gap between the science about complex systems that is emerging and the literature in organizational science about managing a complex system. How is it possible to manage a system in which a small action may produce unforeseen and large reactions? How does one manage systems in which relationships between parts are difficult to know and may never be known?

The roundtable gave researchers and practitioners a chance to exchange ideas about what types of further research based on complexity issues might be useful to practitioners. For instance, those working in the field were interested in how the institutional structure of transportation management interacts with the technological and physical structures of the transportation system. Practitioners noted there is little information about individual decision makers, such as travelers and political agents, and the relationship between these actors and the larger transportation system in which they operate.

The roundtable participants also thought that models attempting to explain transportation planning needed to look more closely at two things. First, funding policies and uncertainty about revenue often becomes an overriding factor in transportation planning. Because funding is the result of a “public will” to improve transportation, practitioners wondered how to better understand the forces that lead to active citizenry for transportation. Who are the agents that will lead the political will for change? Secondly, more research could be done in the area of sub-regional policymaking. Decisions made at
the local level—such as city or county development patterns—often have enormous ramifications on the transportation system.

A stronger relationship between academics and practitioners would encourage a more cohesive strategic planning process, says Munnich. Minnesota already benefits from a close relationship between Humphrey Institute researchers and transportation professionals, says Nookala. However, practitioners identified four areas in which academic research might be especially useful in the future. They are:

- Advice to management about applying research to professional questions;
- Training of transportation professionals through occasional day-long workshops;
- Shared learning opportunities to increase interaction and feedback between professionals and academics;
- Training undergraduate engineers to reflect the actual demand for planners.

"This was a good way to bring researchers and practitioners together," says Nookala of the roundtable. "There were definitely some ideas worth implementing."

"THE HUMPHREY INSTITUTE'S RESEARCH ON 'PLACES AND NETWORKS' WILL HELP US SIFT THROUGH THE COMPLEX ISSUES OF TRANSPORTATION AND TECHNOLOGY AND MAKE THESE SYSTEMS WORK FOR ALL CITIZENS."

—Congressman James Oberstar (D-Minn.)
### Places and Networks: New Hierarchies in Access and Activity

**STAR-TEA 21 Overview Matrix (June 2003)**

<table>
<thead>
<tr>
<th>Task, Topic, Principal Investigator, Objectives</th>
<th>Concept Phase Years 1 &amp; 2</th>
<th>Implementation Phase Years 3 &amp; 4</th>
<th>Synthesis Phase Years 5 &amp; 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial Impacts</strong> (Bolan, Krizek, Chapelle)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Understand how different elements of ICT influence travel behavior, activity, and shopping preferences.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Understand relationships between the above characteristics and attitudes.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Understand how ICT-travel relationships differ by region of country, technological literacy, and levels of congestion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Literature review.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Initial investigation of firm and household location.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- General Mills case study.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Model location patterns of information workers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Develop diffusion model.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Map literature related to ICT and household travel.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Survey households for telecommuting/travel behavior.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Develop/test location demand, postmodern urban growth, and transport demand models.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Integrate telecom substitution findings into travel demand literature.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rural and Wireless</strong> (Horan)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Devise architecture for describing the emergence of rural emergency management services with regard to technical, organizational, and policy dimensions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Examine the role of ontologies for assessing rural system performance and evaluation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Explore the implications of rural EMS framework for understanding and evaluating rural ITS systems in Minnesota and throughout the United States.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Literature review.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Case study of wireless EMS systems in Minnesota.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Model and assess EMS performance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Develop ontology and test on second case study.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Link to wireless and rural ITS national systems development.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Develop evaluation metrics for use in deployment.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Industry Clusters</strong> (Munnich)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Examine industry clusters as a conceptual framework to analyze the impacts of ITS on regional economies.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Apply the industry cluster approach in studying the effects of ITS technologies on a regional economy.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Examine the broader implications of ITS as an industry cluster and implications for public policy.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Suggest how the industry cluster approach can be used by transportation professionals in addressing the ITS and transportation challenges of a regional economy.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Literature review.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Conceptual design applying industry cluster framework to ITS.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Explore Minnesota industry cluster changes and the impact of these changes on ITS use.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Explore the broader relationship between ITS use and rural economies.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Integrate cluster findings into ITS strategies.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Productivity Impact</strong> (Levinson)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Understand and model how networks grow.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Literature review.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Review of productivity impacts of networks with initial data specification.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Examination of how networks grow and decline.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Formulate the new-node/link model.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Integrate the model with link expansion model.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Calibrate the integrated model for the Twin Cities.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Integrate into broader transportation planning/land use modeling research.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Consolidate findings into major report on study.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education and Outreach</strong> (Munnich, Horan, Keller)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Communicate research findings to practitioners.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Receive feedback from practitioners with respect to continuing and future research needs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Faculty exchange and planning meetings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Host industry cluster roundtable discussion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Survey of State and Local Policy Program research assistants.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Transportation management and planning (complexity) roundtable discussion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- White paper on impacts for transportation managers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Roundtable discussions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Conference presentations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Convene former State and Local Policy Program research assistants (new transportation professionals) to discuss ITS challenges and needs.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PROJECT LEADER: Lee W. Munnich, Jr.

PROJECT FACULTY: Richard Bolan, Kevin Krizek, Thomas Horan, David Levinson, and Lee W. Munnich, Jr.

REPORT COORDINATOR: Peter Bernardy

WRITER: Mary Lahr Schier

EDITOR: Julie C. Lund

PHOTOGRAPHY (unless noted): Jonathan Chapman

DESIGN: Sysouk Khambounmy

COVER IMAGE: Courtesy of the American Automobile Association

State and Local Policy Program
Hubert H. Humphrey Institute of Public Affairs
University of Minnesota
301 – 19th Avenue South
Minneapolis, Minnesota 55455
(612) 625-8575
www.hhh.umn.edu/centers/slp