Research Overview of STAR: TEA-21 Project

Prepared for Research Roundtable:
Managing Transportation As A Complex System

The Humphrey Institute's State and Local Policy Program has been working with the University of Minnesota's ITS Institute to conduct a set of federally sponsored studies along the general theme of how transportation systems can be planned sensitive to complex social, political, economic, and technological environment. The purpose of this document is to provide an overview of research that is currently underway, with special reference to the roundtable theme of managing transportation as a complex enterprise.

Before providing a summary, it is useful to provide a working definition of complexity. Drawing on the work of Sussman, transportation can be considered complex because it ascribes to the following characteristics:

> "A system is complex when it is composed of a group of related units (subsystems), for which the degree and nature of the relationships is imperfectly known. Its overall emergent behavior is difficult to predict, even when subsystem behavior is readily predictable. The time-scales of various subsystems may be very different (as we can see in transportation -- land-use changes, for example, vs. operating decisions). Behavior in the long-term and short-term may be markedly different and small changes in inputs or parameters may produce large changes in behavior." [1]

Over the two year course of conducting the STAR research, it has become clear that the research team was tapping into various elements of a complex process. These elements included:

- **Physical Network Developments** – despite a bevy of transportation policies procedures and financing incentives, it appears that transportation facility networks have self-organizing properties, which means there are certain tendencies for how highway networks evolve and these tendencies may conform to or challengepublic interests in alternative transportation patterns.
- **Wireless Network Developments** -new systems, like wireless systems, can have as much on an impact on transportation behavior as planned systems, such as ramp metering, though the former can occur in unspecified ways (eg. Mayday, in vehicle business-use). The implications are that new combinations of technologies and services can have unpredicted impacts of how transportation services are used.
- **Economic and Spatial Trends -** historical "accidents" of location (such as snowmobile industry location in rural Minnesota or printing business in the Metro area) can have large impacts on the economic value of IT in the region, including where business locate. This can add a level of spatial complexity to the mix, as dynamic economic conditions can affect where and how development occurs.
- **Behavioral Trends** – the conventional journey to the work mode of travel is becoming less dominant in predicting overall transportation demands as "non-work" trips (arguably less predictable) account for an increasing proportion of behavior.

[1] Joseph Sussman, "The New Transportation Faculty: The Evolution of Engineering Systems", Transportation Quarterly, Summer 1999").

The following attachments provide vignettes about specific research projects that we are conducting how they are embodying this theme of network complexity. The first two areas—physical network developments and wireless network developments—will be described in short presentations at the outset of the roundtable. The other two areas (economic/spatial, travel behavior) will be addressed during the research discussion sections.

INFRASTRUCTURE NETWORK DEVELOPMENT

I. Transportation Network Dynamics (David Levinson)

This project aims to understand transportation network dynamics - how networks grow and decline. Both the ways in which current network expansion (or contraction) decisions alter the choices of future decision-makers, and the means by which expectations of the future alter current decisions will be analyzed. This improved understanding of long-term network dynamics will lead to better planning and design of transportation networks to exploit network externalities. Potential users of the research include state departments of transportation and regional councils of government, which must decide how to best invest scarce resources, for instance, whether to invest more resources in existing transportation corridors or develop new ones.

Today's decisions depend on expectations of tomorrow. Demand is shaped by investments in new infrastructure and changes in public policy. While small segments of the network may be changed at any given time, those investments are limited by decisions that have come before; and perhaps more importantly, today's decisions constrain tomorrow's choices. This proposal will explicitly consider the growth of networks as endogenous, in contrast with current transportation planning practice that strives to exogenously direct that growth. A long-term database (at least 25 years, longer depending on data availability) will be constructed. This long-term view is needed because the results of investments take many years not just to implement (planning through design to construction is itself a long-term process), but also to bear fruit in terms of changes in travel demand and land use patterns. However prediction of the future is as much art as science, for if accurate predictions were possible, planning would be quicker, more efficient, and less controversial than today. This proposal does not aim to evaluate the accuracy of past forecasts, or the wisdom of subsequent investments, as several studies (e.g. Pickrell 1992, Richmond 1998) have already done so, rather it seeks to model how those investment decisions were made, for good or ill. *While this proposal focuses on urban highway networks, it is anticipated that future extension to urban transit networks, and intercity passenger and freight networks will be feasible.*

Previous research in transportation planning models has focused on understanding travel behavior, taking the network as given. The issue of long-term network dynamics has been largely unstudied outside of the macroscopic/historical sense. Grübler (1990), among others, has looked at long term technology diffusion issues, considering, for instance, the total length of roadway, or vehicle kilometers traveled, or autos owned over the span of decades. Several studies have examined specific networks (e.g. the London Underground (Barker and Robbins 1975)), but no general theoretical framework has been given for network growth at the microscopic level.

Research Problem Overview

When a transportation facility is built or expanded, travel increases on that facility both due to re-routing and re-scheduling and due to what is often called *induced* or *latent demand* (Noland 1998). As travel costs for commuters are lowered, the number of trips and their length increases. In market sectors of the economy, as population grows and preferences shift leading to higher demand, suppliers produce more product. While surface transportation decisions are often made in the political arena rather than the market, politicians also respond to their customers – the voter. It is not presently known to what extent changes in travel demand, population, income, and demography drive changes in supply. This *induced supply* question in transportation is an important step in understanding the long-term dynamics of transportation networks. Although over the short run transportation supply is inelastic; in the long run it varies.

Observation suggests the hypothesis that decisions to expand transportation networks are largely myopic, usually ignoring non-immediate effects. Furthermore, a project's study area is typically limited to a small geographic region. The myopic decision process, when applied sequentially, tends to improve the relative speeds and capacities of links that are already the most widely used, and thereby expand their use. This process is constrained by the cost of those improvements and limited budgets. The full ramification of network expansion on future infrastructure decisions is seldom considered. Improving one link will cause complementary (upstream and downstream) links to have greater demand, and competitors (parallel links) to have lesser demand (and be less likely to be improved). These network effects both complicate the problem and may suggest a structure for analysis.

In particular, the phenomenon of network hierarchy, or degree of network hierarchy, is an important issue. For instance, roads are classified in a way that designates most roads as relatively low speed, low volume links. Only a few links on the hierarchy of roads carry the bulk of traffic. Although planners and engineers design for the hierarchy of roads, those designs are constrained by previous decisions. In many respects, the hierarchy of roads is the network analogue of geography's central place theory, which seeks to explain how hierarchies of places develop (Christaller 1966). Models developed by Batty and Longley (1985), Krugman (1996), Landis (1994), and Wadell (2001), consider land use dynamics, allowing central places to emerge. However, those models take the network as given. *Clearly, there is a need for research that makes the network the object of study.* This needed research would develop a theory explaining the emergence of the hierarchy of roads.

Although networks are complex systems, it is possible to abstractly model their growth. Sussman (1999) describes a complex system as one comprising a group of subsystems that relate in some imperfectly known way. Such systems express a difficult to predict emergent behavior, and may operate on very dissimilar time scales. They are sensitive to initial conditions, so that small changes up front may produce large changes in outputs. It may be posited that principles of self-organization within the network give rise to the hierarchy of roads and the spacing between major roads. Self-organization properties have been observed in a number of fields in the sciences and social sciences (Anderson et al. 1988, Arthur 1990, Axelrod 1984, Dawkins 1989, Forrester 1973, Holland 1996, Kauffman 1993, Langton 1989, Prigogine and Stengers 1984, von Bertalanffy 1973, Wiener 1961). From the self-organization perspective, the hierarchy emerges as a function of the properties of general growth, induced demand, induced supply, and an underlying network structure (grid, radial etc.), rather than being the result of a detailed comprehensive master plan applied to a *tabula rasa*.

The "slope" of this hierarchy may be a natural function of current decision practices, but alternative investment strategies may lead to a "steeper" or "flatter" network. Over the longer term, the network growth process shapes location decisions, both locally relative to the siting of roads and regionally in a metropolitan area. To what extent this network structure can be anticipated, or is random, is an important research question. This problem is complicated by the discrete nature of transportation investment and by finite budgets.

Project Objectives

This research endeavors to understand the dynamic growth process of transportation networks at a theoretical and empirical level, recognizing the interdependence of supply and demand, and to develop a model to replicate that process. Key questions to be examined include:

- Why do networks expand and contract?
- How do expectations of the future (forecasts) affect current decisions?
- Do networks self-organize into hierarchies?
- What investment rules predict the sequence and location of network improvements?
- When are already existing facilities expanded (more lanes on the same link) as opposed to new facilities being provided (a new link)?
- How can transportation planning be improved to take advantage of a new understanding of network dynamics?

This proposal investigates new methods of modeling transport systems. The first part of the proposal will develop an underlying theory regarding the growth of transportation networks and examine stated policies, plans, and decision processes. The second part of the analysis aims to develop and apply methods to empirically estimate the underlying decision rules used for new network investment. The third part simulates the network growth process with application of those rules. The stated policies, plans and decision processes will be compared with the implicit rules of the second and third parts. The statistical estimates from the empirical model will allow us to assess its accuracy. Similarly, a comparison of the predictions from the simulation model with real network changes will be presented.

CONCLUSIONS

Current investment is related to anticipated future demand, and future investment depends on current demand and the extant network pattern. Demand and network growth are endogenous. This research will illuminate these processes to improve planning and evaluation methods. Incorporating explicit measures of network externalities in decision making will lead to better plans, network routing decisions, and implementation strategies. Understanding and illustrating how decisions in one point of time affect future choices should help guide planners and decision-makers desiring to shape the future. The long-term consequences of incremental changes will be assessed. This will help decision-makers assess the effects of expanding existing facilities or routes, or building in new rights-of-way or offering new services. This improved understanding of long term network dynamics would lead to better planning and design of road networks to exploit network externalities and maximize future choice for decision makers. The knowledge of how current decisions foreclose or create future opportunities should improve decision-making. Clearly, some details about the mechanics of the modeling have been left out due to space constraints, and other issues and opportunities will arise as the proposal is funded and the work is undertaken. *As the research is completed, a strategic effort to encourage planning agencies to adopt and employ these models will be undertaken*. Use of the technical advisory panel, including representatives from local planning and engineering agencies will be central to this undertaking.

The model can be used by planners and transportation managers to forecast future networks, just as current models are used to forecast population and travel demand. In particular, it will provide a tool to illustrate the implications of current decisions on the future shape of the network, a consideration that is lacking in most planning and engineering studies.

II. Wireless Network Dynamics

Introduction

Wireless networks are quickly becoming the networks of choice because they provide the flexibility required for an increasingly mobile population (Varshney & Vetter, 2000). While market research has consistently suggested mobile users value the use of cell phones for safety services (NHTSA, 1997), the data over the last decade shows that this “perceived” benefit is rapidly translating into exponential demand for services—a demand that may only grow given increased sensitivity to security and protection.

As such, this rapidly growing use of cell phones is placing a heavy burden on emergency response agencies. The advent of private sector telecommunications and cellular service has played a pivotal role in bringing the safety information network online. Wireless phones have rapidly become one of our greatest tools in improving emergency response time and saving lives. A wireless 911 phone call can shave valuable minutes from the time other-wise required for a caller to find a conventional phone to access emergency medical services. In the past ten years, wireless phone use has grown exponentially.

There are more than 120 million wireless users making about 155,000 emergency calls a day across the United States . For the same period, Emergency Medical Services notification times for fatal crashes have dropped an average of 30 percent , as a caller does not have to depend on a conventional phone line for communications access. The steady increase in wireless subscribership and increased burden placed on EMS agencies has created a need to integrate new technologies with the existing emergency response infrastructure. In addition, there is a need to integrate organizations within the infrastructure through private-private and public-private partnerships and thus create cross-organizational synergies for institutionalizing ERS/EMS. Deploying end-to-end E-911 systems will require new and nontraditional partnerships, particularly among wireless carriers, emergency dispatch center administrators (e.g. PSAPs), law enforcement, fire and EMS officials, automotive companies, consumer leaders, technology vendors, and state and local political leaders (Potts, 2000).

The need for local partnerships to implement ERS/EMS aspects of Intelligent Transportation Systems is evident from statistical data from rural areas of the country. According to the U.S. Department of Transportation, more than 56% of fatal automobile crashes in 2001 occurred on rural roads (NCSA, n.d.). The Minnesota Department of Transportation (MnDOT) reports that only 30 percent of miles driven within the state are on rural roads, yet 70 percent of fatal crashes occur on them (MnDOT, 2000). In addition, 50 percent of rural traffic deaths occur before arrival at a hospital. Appropriate medical care during the “golden hour” immediately after injuries is critical to reducing the odds of lethal or disability consequences. Crash victims are often disoriented or unconscious and cannot call for help or assist in their rescue and therefore rely heavily upon coordinated actions from medical, fire, state patrol, telecommunications and other entities.

In this study, researchers focus on implementation of Emergency Response and Management Systems (ERS/EMS) in rural areas of Minnesota for three specific reasons. First, Minnesota has been aggressively pursuing Intelligent Transportation Systems (ITS) initiatives for several years and thus offered a test bed for various research projects, some of which have been conducted very recently. Second, rural areas do not have the technological infrastructure that exists in larger metropolitan areas. This offers the researchers an opportunity to explore specific barriers that may not exist in metropolitan areas. Third, rural areas of the state have often established immature partnerships in relation to ERS/EMS deployment, whereas many metropolitan areas have well-established partnerships. Researchers have an opportunity to explore local implementation of effective ERS/EMS from interorganizational perspectives.

Study: Summary of Framework and Findings

Interorganizational Systems (IOS)

There is no doubt that we now live in a "Networked Society", much of which is wireless. The question whether we have learned to manage these networks in effective ways continues to dwell in the minds of researchers. Amin (2001) states that every economic and social function depends upon the secure and reliable operation of energy, telecommunications, transportation, financial, and other infrastructures. As these infrastructures have grown more complex to handle a variety of demands, they have become more interdependent (Amin, 2001). Effective operation of these networks requires the capability to manage many factors that lie beyond the control of one entity. The interconnections that cross organizational boundaries are often referred to as Interorganizational Systems (IOS).

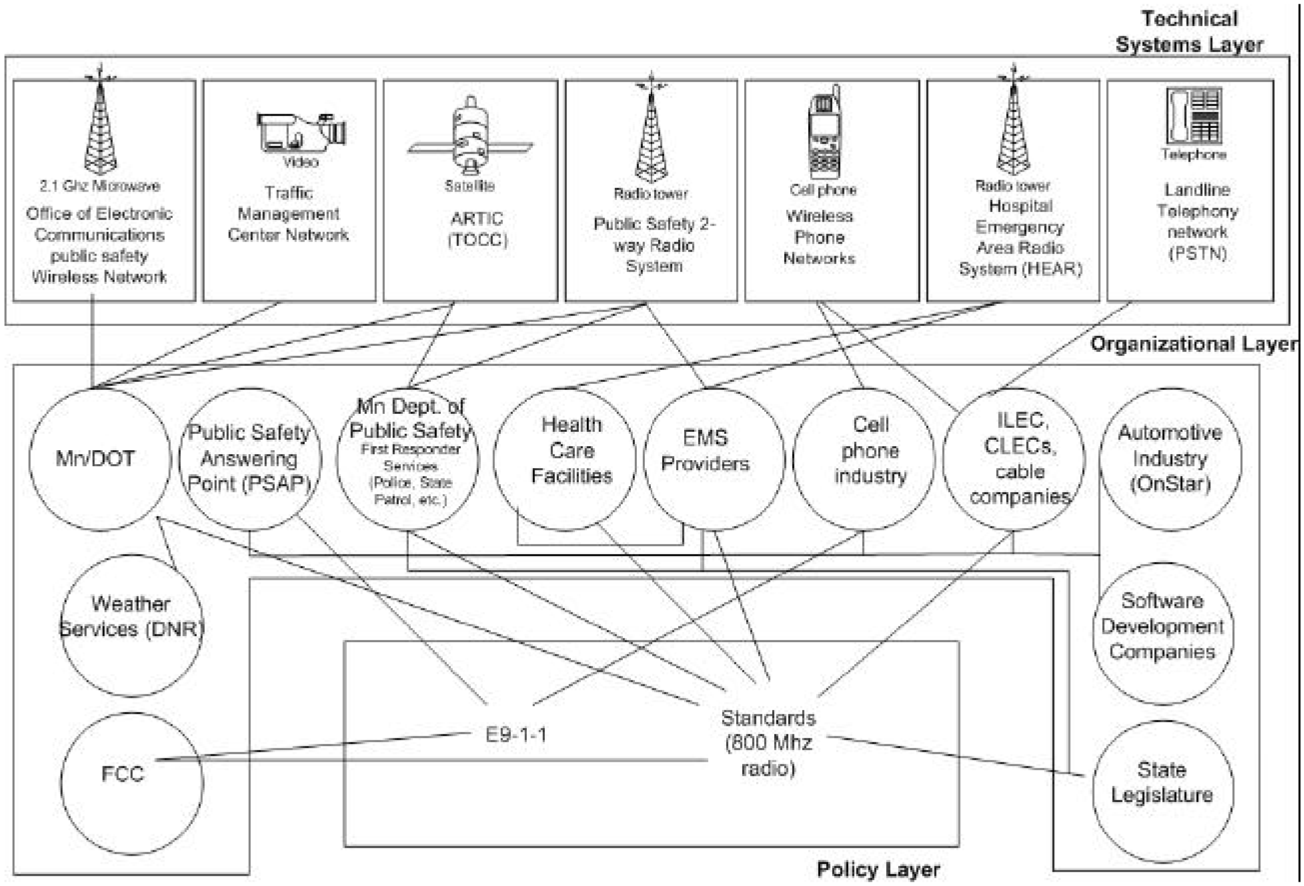
The case of ERS/EMS provides an interesting illustration of IOS in that public and private agencies need to interact both technically and organizationally in a time critical fashion to deliver health care services to travelers and other users of mobile communications. Moreover, as it is often the case in complex systems, the rapid growth of wireless emergency systems has "emergent properties" in that there has not been a uniform system for implementing such usage. Rather, it has grown out of the rapid penetration of commercial wireless services throughout the population. In this manner, the case of ERS/EMS also provides an interesting illustration of how ITS and policymakers need to respond to new forms of services that grow out of private industry platforms, but have direct implications for the goals of ITS—that is "providing the intelligent link between travelers, vehicles and infrastructure" (ITSA, 2001).

Findings

Both the interviews and reports served to identify major difficulties and achievements in establishing well-functioning and efficient ERS/EMS in Minnesota (see Figure 5). As a point of departure, it is important to note that Minnesota has established a strong record of demonstration and implementation for ITS generally. For example, Minnesota Guidestar, the state's ITS program, has carried out a number of projects to provide traveler information, promote transit ridership, and improve traffic control and incident management. Consequently, the Minnesota ITS program has deployed several ITS features (e.g. ramp meter controls) at a rate greater than the national average and continues to take a leadership role in testing rural deployments.

With regard to ERS/EMS specifically, results of expert interviews and document surveys revealed several critical issues. Experts discussed problems of unreliable technology in serving the public during emergency responses. Document surveys revealed difficulties such as establishing interagency cooperation, which was the key to successful implementation of ITS technologies. In interviews, experts discussed policy issues such as a lack of timely technology upgrades due to insufficient funding. Experts also raised issues related to a lack of policy incentives to provide full cell phone coverage in rural areas. As the discussion topics were qualified as technology, organizational, and policy issues, researchers organized the structure for analysis accordingly.

Figure 5. **An Interorganizational Architecture for Emergency Management Systems in Minnesota**



Implications

This study has raised several policy, organizational and technological issues for ERS/EMS in rural Minnesota as well as rural areas more generally:

Technology

The rise of wireless systems has a prominent effect on ERS/EMS. The rapid growth of wireless technologies and applications in transportation related emergencies detected by citizens and communicated via wireless systems signifies the increasing role of customer-based distributed systems in creating knowledge about service demand and delivery of services (Horan, 2002). The challenge is to devise and deploy new sets of location-specific devices (and call centers) that can in essence keep-up with emergent consumer demand. Advanced technologies further intensify the challenges of using increasingly distributed, complex, and interorganizational systems. At the same time, new technologies solve issues related to cooperated data creation, use and exchange within ITS infrastructures. E-911 provides a strong example of how a strong set of technological standards, or lack thereof, plays an important role in the implementation of an advanced technology in an interorganizational system.

Issues of interagency cooperation

The ERS/EMS partnerships of rural Minnesota present dynamics in building interagency relations under current federal, state and local policies. Their experience revealed a set of new considerations in management of interorganizational systems. For example, Departments of Transportation do not usually consider communications infrastructure to be a core function of their agency, yet they may be in the best position to provide backbone infrastructure services, as the 800 MHz report has suggested. MnDOT is currently one of the major radio users in the state and has the most significant need for radio communications. But, the state will have to construct the infrastructure in order to meet their current and emerging needs. Major interorganizational barriers were generated from varying positions in terms of finance, competencies, trust, and interest in cooperative relations. Concepts such as the self-organizing nature of the enterprise, the role of disequilibria in generating change, and the role of independent agents in affecting change have value in understanding these interorganizational networks.

Policy

Ubiquitous emergency management service is costly and raises public policy issues as to who absorbs this burden. The terrorist attacks on September 11, 2001 have heightened general interest in domestic preparedness and provision of emergency services (Howitt, 2001). These services ultimately fall upon a range of public and private service systems similar to ERS/EMS projects in Minnesota. The ERS/EMS study demonstrates that policies on implementation, standards, and sufficient funding can create favorable climate for interagency cooperation and hasten the upgrading of systems to promote regional implementation of the ITS architecture. However, there is widespread concern that regulations such as the E-911 mandate will impose costs on regions that they are not quite prepared to absorb, especially given current governmental shortfalls.

Summary

In sum, while the proposition that we are living in a "Networked Society" is fairly straight-forward and confirmable, the reality of making these networks work in a manner that is efficient and effective is a much more complicated affair. There is no doubt that the technology exists to support a fully operable, state of the art, end-to-end E-911 Emergency Management System, from the mobile caller to the local PSAP. However, these systems need to be justified in light of competing demands for resources that are particularly acute in rural areas. And at this policy-level, while regulations such as E-911 provide a useful "stick" to drive next generation systems, ultimately these systems need to be financed and supported at the local level. All ERS/EMS systems—like politics, are in the end local; and regional and statewide systems need to be devised to ensure timely deployment and management. Wireless telecommunications and ITS can play an important role in facilitating this deployment, but policymakers and planners must take the necessary steps to integrate into these public and private sector planning and deployment processes.

III. Economic and Spatial Impacts

Information Technology and Implications for Multi-National Manufacturing Location Decisions - (Richard Bolan)

The following chart summarizes the long-term conceptual framework for the study. The chart focuses on the role of innovation in economic activity primarily, with the assumption that employment centers, telecommunications infrastructure and transportation infrastructure are the basic skeletal building blocks of urban form and that residential patterns are derivative of these basic building blocks.

As the chart suggests, change is initiated by an innovation in technology. The rate of change, however, is influenced by the rate of adoption of the innovation rate, or rate of diffusion. *In the case of telecommunications, this rate of adoption is very much driven by the influence of network externalities.* Assuming the cost of adopting the innovation remains constant, the presence of positive network externalities means that the benefits of adoption get larger the more people or organizations make the adoption decision. This is not always true in the adoption of new products or ideas, but in the case of telecommunications, as argued above, this phenomenon seems to be largely the case.

With the adoption of the new innovation, changes in the organizational milieu ensue. Advances in telecommunications introduce the requirement of new skills that, in turn, expand more specialized occupational opportunities, as in the example of the medical system or the radio and television industry. These advances also push for organizational restructuring. Configurations of authority and power are challenged as the new skills gain prominence within the organization. Relationships with suppliers and customers are altered. The pace of growth and change stimulated by the innovation impacts the entire organizational milieu.

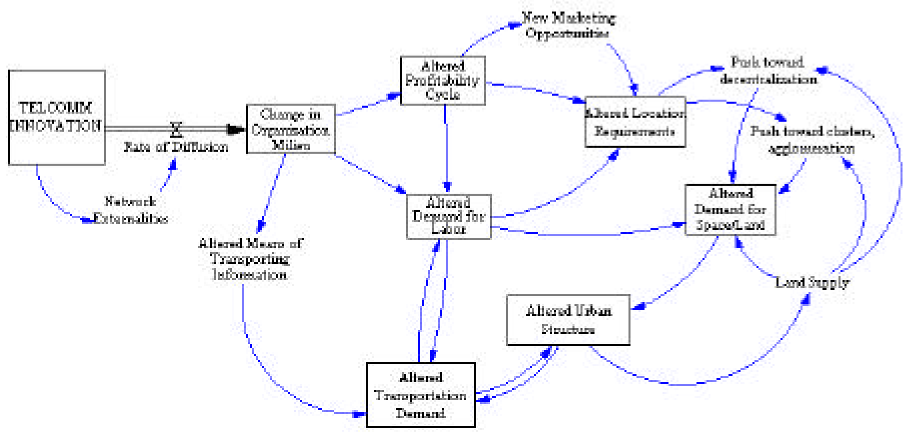


Figure 1. Conceptual Framework of Program

The combination of a new division of labor and organizational restructuring suggests that complexity may have significant and far-reaching impacts on the spatial location of activity. This, in turn, alters the profitability cycle and its various stages of the adopting organization as well as its demand for labor. Under this assumption, recent research on complexity theory and urban form will be the approach of investigation. Changes in complex systems alters the profitability cycle and the demand for new spatial needs of adopting organizations as well as their demand for labor. New opportunities for international markets may open up. From this, is the possibility of changed or enlarged location opportunities or requirements, with some factors pushing for greater clustering or concentration and others pushing for greater decentralization or dispersal. All of this influences the demand for production or service space and its land or real estate requirements. In turn, the satisfaction of this newly delineated location/space environment leads to an altered urban structure or form. This process has implications for transport demand from four sources:

1. the possible substitution of traffic on the telecommunications network for that originally on the transportation network (for example, e-mail vs. the postal delivery service);
2. an increase in transportation demand occasioned by the improvements in movement engendered by advances in application of telecommunications;
3. a change in the demand for labor force that may influence and augment commuting patterns; and
4. changes in urban structure and form arising from changing location decisions influencing or changing the spatial configuration of transportation demand.

Industry Clusters (Lee Munnich)

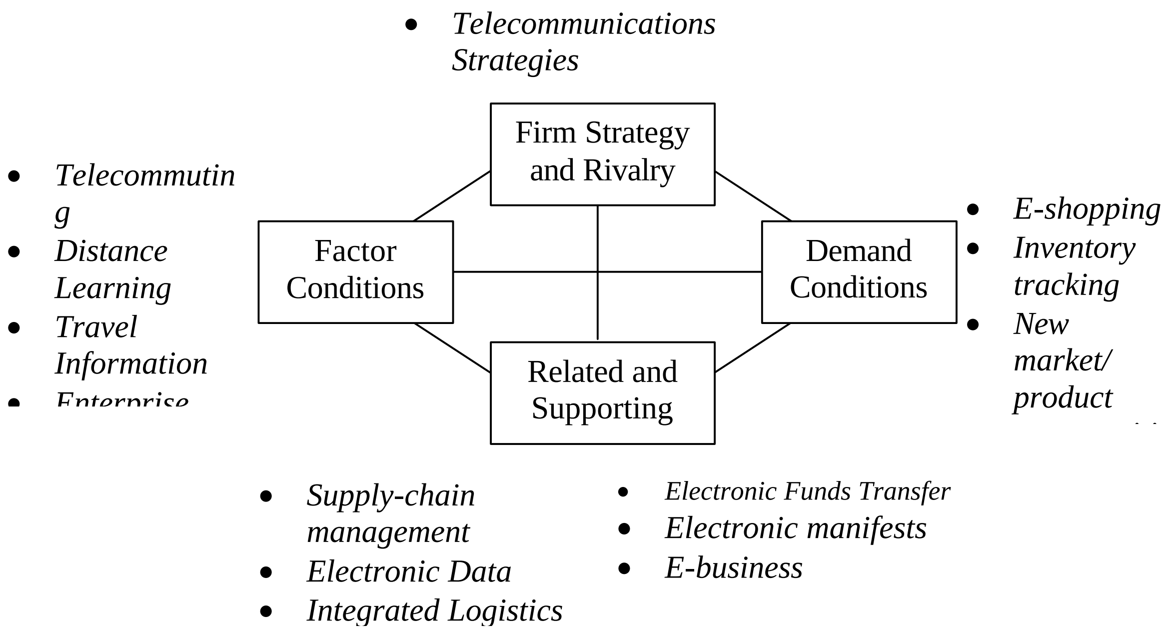
This study builds upon previous industry cluster studies by the State and Local Policy Program to examine the importance of transportation and information networks to industry clusters in rural areas and to assess the potential for ITS applications to enhance rural clusters.

The objective is to understand the relationship of ITS to successful industry clusters in rural areas. By understanding how more successful clusters are using or expanding their use of these technologies, it will help in defining better approaches for encouraging technologies within other rural industries as well as possible improvements in rural ITS systems. This study could lead to new partnerships by the ITS Institute with key industry clusters in rural areas.

The expected outcomes for this research are a better understanding of the relationship of ITS technologies to rural industry clusters, the effect of ITS and information technologies on decentralization vs. agglomeration of economic activities, and the impact of these technologies on the competitiveness of industries in remote locations and sparsely populated regions. The study draws upon Michael Porter's framework in analyzing industry competitiveness, with a particular focus on how ITS influences supplier relationships in competitive industries in a rural area.

This study will integrate supply chain, electronic data, electronic manifests, inventory tracking, and e-business/e-shopping using the Porter framework (see chart below). This study will initially gather information on the application of a range of ITS technologies on the competitiveness (i.e. productivity and innovation) in rural industry clusters, then focus on those technologies that key industry representatives identify as most significant. Based on our initial discussions with industry representatives, we anticipate focusing on those technologies that are most important to supplier relationships (e.g. supply-chain management, electronic manifests, e-business).

Potential Applications of ITS to Industry Clusters



Step 1. Select rural clusters for supply chain analysis

The purpose of the study is to determine which technologies are most important to successful industry clusters in rural areas. In this sense, all ITS applications may be considered. However, we anticipate focusing primarily on those technologies that influence supplier relationships. These include supply-chain management, electronic data interchange, integrated logistics management, electronic manifests and e-business. Most of these technologies are private though they may require significant interaction with systems influenced by public policy, such as telecommunications and intermodal logistics systems.

IV. A Framework for Analyzing the Effect of Information and Communication Technology (ICT) on Personal Travel and Community Design – (Kevin Krizek, Andy Johnson)

Increased use of ICT/telecommunications is rapidly changing the daily activities of individuals and businesses (Salomon and Koppelman, 1988; Mokhtarian, 1990; Nilles, 1991; Pendyala, Goulias et al., 1991; Gaspar and Glaeser, 1998; Shen, 1999; Golob, 2001; Mokhtarian, Nagurney et al., 2001; Hjorthol, 2002; Couclelis, forthcoming). The exploding use of email, the internet, and cell phones pervades even the simplest of transactions (Salomon, 1986; Salomon and Koppelman, 1988; Gillespie and Robins, 1989; Mokhtarian, 1991; Nilles, 1991; Handy and Mokhtarian, 1995; Handy and Mokhtarian, 1996; Gaspar and Glaeser, 1998; Gould, 1998; Goulias and Marker, 1999; Golob, 2001; Golob and Regan, 2001; Mokhtarian, Nagurney et al., 2001; Hjorthol, 2002; Couclelis, forthcoming). But does the increased use of information technology change household travel behavior and the way households spend their time? How do such services alter the ways individuals travel within metropolitan areas and spend their time?

What are the implications of such altered behavior for community design and issues of sprawl. It is difficult to tell.

To date, the overwhelming amount of past work has centered on the travel behavior impacts of one form of ICT: telecommunications (Pendyala, Goulias et al., 1991; Handy and Mokhtarian, 1995; Handy and Mokhtarian, 1996; Wells, Douma et al., 2001). Few studies have served to broaden this work to other dimensions of ICT; yet there is a call to do better of broadening such work in order to keep the transportation field relevant to planning and policy making (Golob, 2001). *For example, relatively little analysis has attempted to uncover relationships between travel behavior and internet shopping, e-commerce, mobile phone use (Claisse and Rowe, 1993) or other ICT elements. Individuals and households are certainly taking advantage of such facilities and broader use of ICT has been tentatively documented by changes in travel behavior* (Viswanathan and Goulias, 2001). But as with telecommunications, researchers do not have a full understanding if (or how) elements of ICT: substitute for travel, enhance travel, increase the operational efficiency of travel, or affect land use patterns (Salomon and Koppelman, 1988; Gould, 1998; Mokhtarian, Nagurney et al., 2001; Couclelis, forthcoming). Furthermore, it is unknown the degree to which such travel time savings might parlay into other travel. This proposal focuses on part one of a multi-year/phase study to understand the role of ICT in shaping household travel, time use, and implications for community design.

The initial task is to comprehensively survey existing literature to glean a thorough understanding of the state of the knowledge relating information technology to travel behavior. For purposes of this study, ICT are defined as those including, but are not limited to: email, use of the internet, person-to-person real time interactive, one way messaging, information retrieval, machine-to-machine communication. Household travel and time use is defined as behavior by residents and their household members related to travel mode, distance, time of day, purpose.

A considerable literature exists on the effects of telecommuting. This literature will be included in the synthesis, however, it tends to be constrained to the work commute, focusing on dimensions that include in influencing employee behavior or commuting patterns. Subsequently, a broader survey of the literature is required to understand more general dimensions of household travel (e.g., non-work travel and activity time) as they related to ICT. At present, a considerable void exists both from an empirical and conceptual standpoint as to how teleshopping affects household travel behavior (Salomon and Koppelman, 1988; Gould, 1998; Goulias and Marker, 1999; Kraan, Mahmassani et al., 2000).

The second task examines the degree to which existing data is able to illuminate the nature of this ICT research. Particular attention will be devoted to understanding the strength/weaknesses of existing travel survey data vis-à-vis this topic. Other sources will be explored as well (e.g., census data, available surveys such as the existing SLPP survey of Hennepin County employees). What behavior do they allow to understand and what behavior/tradeoffs are they unable to illuminate? It is anticipated that this section will culminate in a list of phenomena that are likely to remain outstanding, given typical survey instruments.

The third section will outline research questions that remain outstanding and have important implications for informing travel behavior, transportation policy, and/or land use policy. Particular attention will be devoted to understanding the role of ICT as it relates to at least four dimensions as outlined in the following table.

Household travel	**Household time use**	**Household behavior**	**Implications for Community Design**
▪ Trip elimination ▪ Trip substitution ▪ Trip time shifting ▪ Travel time savings ▪ Mode choice	▪ Time spent completing chores ▪ Time spend in leisure activity ▪ Location of time savings earned	▪ Improved product awareness ▪ Improved destination awareness ▪ Improved information, generally ▪ Impact on residential location decisions	▪ Increased demand for warehouses in outlying regions ▪ Increased demand for inner city activity

The nature of the research questions, and the phenomena that they will uncover, are guided by several factors that include, but not limited to:

- The degree to which ICT are likely to relate to sustainable transportation planning endeavors (e.g., decreased vehicle use),
- The degree to which ICT are likely to relate to land use planning and urban form (e.g., increased demand for fringe development, increased demand for café culture),
- The degree to which aspects of ICT cannot be answered by existing literature and surveys,

The ability to strategically complement existing SLPP work on telecommunications and time use diaries (e.g., Guidestar project). It is envisioned that this work would, among other things, serve to complement the Guidestar project and perhaps even serve to survey an existing population in the Twin Cities who will then serve as a control sample for this project.

This research will be used primarily as a precursor to later stages of this work aiming to empirically document many of the relationships and hypotheses that will be posed. However, the final product of this work—a framework for understanding the role of ICT on travel—is useful and needed for policy and decision makers. Currently, many decisions are made concerning the adoption of new policies or technologies with little understanding or appreciation for their likely effect.