The Effects of Telecommuting and Intelligent Transportation Systems on Urban Development

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FROM policy and planning perspectives, it is important to learn the effects of information technology in general, and telecommuting and intelligent transportation systems (ITS) in particular, on urban development patterns. While some see these technologies leading to decentralization, others suggest no or minimal impacts.

The objectives of this paper are to (1) describe the state of knowledge on the effects of telecommuting and ITS on location decisions of households and businesses, (2) report results of a research study that focused on household location decisions, and (3) define the policy and planning implications for metropolitan areas.

The Knowledge-Based Society

Global forces are reshaping regional economies. As a consequence, the economic base of metropolitan areas in industrially advanced countries continues to shift from mass-production manufacturing to technology and knowledge-based systems of production and services. Projections by the U.S. Bureau of Labor Statistics suggest that almost all growth in nonfarm wage and salary employment is likely to take place in the service sector between 1998 and 2008.
The proportion of the U.S. labor force in information or information-intensive service businesses has been on the rise. Examples include education, health services, engineering, management and related services, computer data processing, banking, finance, insurance, real estate, public relations, personnel, and publishing. This trend is expected to continue.

**Telecommuting**

Telecommuting, a term coined by Nilles et al. more than a quarter of a century ago, refers to the use of information technology to partially or completely replace daily trips to and from the workplace. Telecommuting could involve working at home or at a “telecenter.” While the subject of the substitution of telecommunications for physical transport has been of interest since the early 1940s, telecommuting was never pursued seriously because of the inadequacies of the technologies and the ease of commutation. Because of energy supply problems and increasing commutation difficulties, interest in telecommuting grew again in the 1970s. Again, however, technologies were not sufficiently advanced to accommodate telecommuting. Computer hardware and software as well as telecommunications systems were insufficient to offer the technical support necessary. By the 1990s, advances in information technology as well as concerns over traffic congestion, energy consumption, and air pollution brought discussions of telecommuting to the fore once again. Although the availability and use of computers are not prerequisites for telecommuting, most tasks carried out by telecommuters today are done by the use of computers and communications systems that exchange information between the telecommuter and the main office.

In recent years, telecommuting has been widely recognized as a transportation demand management (TDM) strategy because of its potential to relieve traffic congestion, conserve fuel, reduce greenhouse gases, and improve air quality in urban areas. It is expected to reduce the number of peak-hour trips by reducing commuting. Telecommuting offers many benefits for individual workers as well. These include greater productivity, less stress, more flexibility to balance work with family commitments, greater job satisfaction, and lower costs of travel, clothing, and childcare. The Regional Municipality of Ottawa-Carleton in Ontario, Canada has included telecommuting as a transportation demand-management measure in its transportation master plan. Officials expect this measure to reduce peak-hour work trips by 7 percent and to have other transportation benefits such as reductions in kilometers traveled, fuel expended, and gases emitted.
In 1995, a U.S. Nationwide Personal Transportation Survey found that 4 percent of all workers were telecommuters. A more recent study in Baltimore, Maryland, found that 3.6 percent of employees in the Baltimore area and 6.8 percent of Washington, D.C. area employees telecommuted.

**Intelligent Transportation Systems**

Intelligent Transportation Systems (ITS)—combinations of microelectronics, mobile communications, computer informatics, and other advanced technologies—are being used to improve mobility (by reducing travel time and increasing reliability), safety, security, and productivity in the transportation sector. ITS can also help reduce energy consumption and greenhouse gas emissions, as well as increase transportation accessibility. ITS can be applied to all modes of surface transportation such as private cars, vans, trucks, and transit buses. The most significant aspect of ITS, which makes it distinct from any other transportation improvement strategy, is the use of information technology to help the components of surface transportation work together as an integral system. More than 400 ITS initiatives (i.e., experiments, projects) were underway in 1997 throughout the United States and Puerto Rico.

Intelligent Transportation Systems can be categorized into seven user services:

1. **Travel and Transportation Management** – includes functions such as en-route driver information, route guidance, traffic control, incident management, and traveller services information.
2. **Travel Demand Management** – includes demand management operations, pre-trip travel information, and ride matching and reservation functions.
3. **Public Transportation Operations** – this service bundle consists of public transportation management, en-route transit information, personalized public transit, and public travel security.
4. **Electronic Payment** – includes functions in the area of electronic payment services such as electronic toll collection (ETC) and electronic parking payment.
5. **Commercial Vehicle Operations** – includes services such as commercial vehicle electronic clearance, automated roadside safety inspections, on-board safety monitoring, hazardous material incident response, and freight mobility.
7. Advanced Vehicle Control and Safety Systems – includes the following functions: longitudinal and lateral collision avoidance, intersection collision avoidance, safety readiness, pre-crash restraint deployment, and automated highway systems.

**Land Use**

One possible result of increasingly networked societies is an increase in online transactions, including teleshopping and telecommuting. These, in turn, could result in changes in the spatial structures of urban areas and in the way those areas are developed.

Theoretically, it would seem that innovations in information technology and improvements in transportation will lead to an increase in the flexibility people have when choosing where to live. Whether households will use that flexibility and whether, or if, that flexibility will result in changes to the spatial configurations of urban areas are questions still to be resolved. Similarly, the flexibility that technologies offer residents in their location choices is also available to businesses in their decisions about where to locate their offices and where (and how) to house their workers. Literature sources indicate that the nature of tasks performed in a significant number of occupations in the new economy is leading to a flexibility in the work location.

Some studies suggest that the revolution of information technology and the decentralized nature of information will cause more and more people and businesses to move to the outskirts of cities, forming societies like “edge cities” and “telecities.” These studies contend that dense cities no longer provide the cost-saving advantages they once did. It is also argued that location is not so crucially important because new technologies can allow businesses to substitute communication for transportation, and, in some instances, the transmission of information for the movement of goods and services.

In an early study on the impacts of telecommunications on metropolitan areas, Dakin made a number of important conclusions. In 1973, he accurately predicted that metropolitan areas would increasingly experience diffusion of population throughout their greater regions. Information technology would not only be used as an important enabling factor, but would play the key role in enhancing the level of transactions throughout the region, he argued.

There have been two possible scenarios as to how ITS will affect land-use decisions. ITS is different from transportation advance-
ments in that it promises to increase the system’s throughput substantially by making a much more efficient and smoothly operated system, with no (or minimal) physical expansion of the existing system.

The historical development of American cities has served as evidence that, in the long run, transportation improvements (mainly for motorists) have caused urban areas to expand in the direction of these improvements. In the case of ITS, it has been speculated that such transportation improvements may cause new land development further away from cities.

ITS is capable of reducing travel times between an origin and a destination (e.g., by increasing travel speeds or by optimizing traffic signals and thus minimizing delay for motorists) as well as increasing the travel-time reliability by means of providing real-time information to motorists. This capability may encourage individuals to move to less developed areas where housing is more abundant and cheaper, without having to spend more time traveling. This would result in the development of outlying satellite cities.

However, there is another possibility. The smoother traffic operations provided by ITS may also bring about latent (or induced) demand. That is, because there is a more efficient system, people who had previously foregone their trips (because of a congested and costly system, for example) may now make those trips, leading to consumption of more transportation services, thereby offsetting the benefits that are accrued from ITS. These issues have been discussed by, for example, Shladover, Mokhtarian, Ostria and Lawrence, and Grovdahl and Hill.

Office Location Decisions
Because of advances in information technology, logistics, and transportation, many companies have the capacity to distribute work and initiate telecommuting and other advanced technology-based programs. Therefore, they are free to (re)locate to any place with conditions appropriate to their needs. An early study on office siting in Japan recognized that modification of work patterns through the introduction of telecommuting was a contributing factor to relocating offices away from congested central Tokyo.

Factors that are likely to affect office location decisions in the information technology era are noted in Table 1. These combine traditional factors as well as new information provided in this section. The traditional view of important factors in firm location decisions includes land cost and availability, transportation, accessibility to consumers and suppliers, labor availability, wages, taxes, measures of agglomeration economies, and quality of life.
However, some research has shown that the ability to transfer information using communications channels is becoming increasingly an important factor in firms’ relocation decisions. This enhances the flexibility in the location of office activity. Kumar showed that advances in telecommunications technology would tend to cause a dispersal of information-based firms into different parts of a city and shift urban areas toward a multicentric form. The same study found a decline in average daily work trips for telecommuters, therefore suggesting a substitution effect of telecommunications.

From a firm’s perspective, advances in information technology will be beneficial as these allow the firm to, for example, create satellite offices in outlying areas where real estate and labor costs are cheap. Also, companies can reduce their consumption of physical space at their existing locations.

In spite of the obvious effect of information technology on office (and residence) location decisions, land use and transportation models that are currently in use do not include a variable to account for the impact of telecommunications. Clearly, this is a serious deficiency to exclude a potentially critical factor into predictions of urban form. For example, reviews of urban models by Wagner and by Anas et al. showed that transportation is the only spatial interaction factor that is explicitly taken into consideration.

**Residential Location Decisions**

Key factors that are likely to affect the choice of residential location in the information technology era are noted in Table 1. The variables of interest in this paper are telecommuting and ITS.

<table>
<thead>
<tr>
<th>Residential Location</th>
<th>Office Location</th>
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<tbody>
<tr>
<td>• Household characteristics</td>
<td>• Nature of business</td>
</tr>
<tr>
<td>• Housing cost</td>
<td>• Distributed work</td>
</tr>
<tr>
<td>• Size of dwelling</td>
<td>• Agglomeration economies</td>
</tr>
<tr>
<td>• Availability of information technologies and services</td>
<td>• Land cost and availability/office cost</td>
</tr>
<tr>
<td>• Telecommuting</td>
<td>• Availability of human resources</td>
</tr>
<tr>
<td>• Intelligent transportation systems</td>
<td>• Availability of enabling information technologies</td>
</tr>
<tr>
<td>• Travel time to work and reliability</td>
<td>• Telecommuting</td>
</tr>
<tr>
<td>• Quality of education*</td>
<td>• Transportation: accessibility, travel time, reliability</td>
</tr>
<tr>
<td>• Travel time to school and reliability</td>
<td>• Intelligent transportation systems</td>
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<tr>
<td>• Quality of life—outdoor recreational opportunities</td>
<td>• Parking</td>
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<td></td>
<td>• Quality of life</td>
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*Due to uniformity of the quality of education throughout the Ottawa-Carleton Region (Canada), this variable was not included in the discrete choice model reported in this paper.*

Brewer  
Hackler  
Shen
Literature sources suggest the decentralizing effect on urban form of information technology-supported telecommuting programs. According to a report of the U.S. Department of Transportation’s Federal Transit Administration, telecommuting might encourage program participants to locate further from work than they would without telecommuting programs.

Available information based on the 1995 U.S. Nationwide Personal Transportation Survey shows that telecommuters travel longer distances than non-telecommuters do. The average trip length for telecommuters was found to be 25.6 kms vs. 20.5 kms for traditional commuters.

A telework symposium was held in Toronto in the mid 1990s to promote awareness of and education about telecommuting. There were mixed feelings about the spatial impacts of telework in that they ranged from no or minimal relocation impacts to high relocation impacts in terms of moving towards suburban and rural areas. In fact, in this symposium, the results of a national study funded by Canada Mortgage and Housing Corporation (CMHC) were presented that aimed at providing some insight into factors that affect telework and home-based employment. Some of their important findings as they relate to this research were as follows:

- Eighty percent of respondents were very satisfied with working at home
- The majority of teleworkers lived in single-family detached homes in suburban areas
- About 20 percent of teleworkers had moved or were planning to move outside the city.

However, no model was developed to analyze the acquired information.

**Empirical Analysis of Residential Location Choice**

As noted earlier, in recent years there has been much speculation and debate about the future of cities and the role of advanced information technology. Unfortunately, most of these debates tend to rely more on speculation, or unjustified assumptions about how information technology affects cities rather than on empirical analysis.

In a theoretical analysis, Lund and Mokhtarian developed a single partial equilibrium model based on Alonso’s model of residential location, which states that households will find a location so as to minimize their commuting and housing costs. The model showed that the introduction of telecommuting would cause a relocation further away from city centers. The extent of that relocation would depend
upon the level of telecommuting and the rate of change in land prices as one moves away from the city center. Hopkins et al. and Bernardino et al. also suspected that telecommuting might encourage people to move further to the urban fringe and/or rural areas because there would be less need for everyday travel.

Amid a lack of empirical evidence, a research study was carried out at Carleton University in Ottawa, Canada, for the investigation of the impacts of telecommuting and related facets of ITS on land-use patterns. The focus of the study was on households’ residential location decisions. To study these effects, discrete choice methodology within the well-developed random utility theory framework was adopted. Discrete choice implies that the decision maker decides among discrete alternatives (e.g., choose A, B, or C; Yes/No). The theory of random utility maximization is based on the concept that an individual, when faced with a number of alternatives, chooses the one which maximizes his/her overall utility. Since all the factors that affect an individual’s choice are not known to the analyst, the individual’s utility (function) is treated as random (by the analyst), and thus the term random utility.

Figure 1 shows the location choice model development framework. As a part of the research framework, combined revealed-preference (RP) and stated-preference (SP) logit analysis was performed to estimate the parameters of the utility function. The revealed preference data represented actual choice behavior. On the other hand, the stated preference data represented stated intentions in well-structured choice settings. Logit analysis results in a probabilistic model that is developed for the analysis of discrete choice data and, therefore, forecasting choices. The combined revealed- and stated-preference analysis is a technique in which the data from SP observation are combined with those of RP observation to produce a more efficient and reliable estimate of coefficients of the utility function. The utility function contains variables that are considered by decision makers in a choice-setting.

The required data for model estimation were collected through an attitudinal survey of employees of selected private and public organizations within the Ottawa-Carleton Region (Canada). A two-part questionnaire was used. Part 1 was devoted to background questions regarding housing information, job and travel-to-work information, and household and demographic information. Part 2 covered the housing location game defined according to principles and methods of statistics. Housing location alternatives and their attributes formed the well-structured hypothetical choice setting.
Using the sequential maximum likelihood estimation (MLE) procedure, taste parameters of the combined RP and SP multinomial logit model were obtained. The MLE is an analysis technique where a model is first estimated with one set of data (often SP data), and then the predicted utility is re-scaled within a second model against another set of data (often RP data). Taste parameters, referred to as variables or attributes, are characteristics of an alternative and/or decision maker that are included in the utility function. Statistical inferences on the estimated parameters were made and measures of goodness-of-fit were also calculated. The measures of goodness-of-fit are statistical factors used to test how well the calibrated logit model fits into the data.

The results of this research suggest that telecommuting and ITS measures are highly significant factors in residential location decisions. In effect, these measures support decentralization of land use patterns. The basis of the inference is that the use of telecommuting
and the ITS-assisted travel would lead to choice of housing location in outlying satellite cities. The inferences drawn from this quantitative study reinforce the conclusions reached by a number of other studies (although of qualitative nature) that telecommuting and ITS are likely to lead to decentralization of land use patterns.

**Conclusions: Policy and Planning Implications**

A number of qualitative studies cited earlier suggest that the adoption of telecommuting and wide implementation of ITS are likely to lead to patterns of decentralized urban structure. Results of a quantitative research study involving discrete choice model development reported in this paper reinforce this conclusion. Although no empirical business location model was developed in this study, it is likely that the incorporation of information technology measures in such a model would confirm their dispersal impacts on office location choice, as they did for the residential model.

This study suggests an increased trend toward multinucleated urban structure, that is, a structure where a number of urban satellite nodes, containing mixed business and residential land uses, are located at some distance from the central core and along radial transportation corridors. In addition to enhanced quality of life, such multinucleated urban regions offer transportation energy efficiency and air quality advantages. A challenge for urban and regional planners and policy makers is to channel the decentralization trend in the direction of planned multinucleated urban regions. The ITS services should be blended with land use and infrastructure plans that promote economic and environmental benefits and discourage sprawl type of dispersed trip-making patterns. In the absence of well-defined policies and plans, urban sprawl and its associated adverse effects may result from the decentralization trend in the future. An associated challenge for cities will be to make the necessary adjustments in land-use plans and regulations so as to capitalize on the potential for telework and home-based employment for generating economic growth, saving energy, reducing emissions, and improving the quality of life.

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