

Major Issues and Findings in Telecommuting Studies

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. Introduction

Traffic congestion and air pollution are among the most serious problems facing large cities throughout the world. Telecommuting has become one of the most promising travel demand management strategies to cope with this situation. Telecommuting is often proposed as a way to decrease traffic congestion, energy consumption, and air pollution by reducing commuting travel (Bernardino et al. 1993; Lund and Mokhtarian 1994). The development of information technologies has improved the interactions among individuals and groups, relaxing physical and temporal constraints on activity performance. Consequently, the accessibility of employees through communication networks has become more important than their physical presence in the office. This encourages the adoption of telecommuting (Bernardino et al. 1993).

Since the 1970s, many researchers have studied the issues related to telecommuting. These issues include (1) sociological issues of telecommuting such as attitudes of employees and

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employers and characteristics of telecommuters, (2) impacts of telecommuting on travel behavior, transportation system, air pollution, residential location, and urban form, and (3) management-related issues of business firms. Most of the studies are descriptive and largely qualitative. From the beginning of the 1990s, researchers became involved in quantitative studies, analyzing the impacts of telecommuting on travel, air pollution, and the like. However, many of these quantitative studies have relied on noncomprehensive survey results. Most of these surveys are based on questionnaires of existing telecommuters, the stated preference approach, and travel diary data. Better data do not exist. Due to the short history of telecommuting practice, cumulative time-series data also do not exist. Furthermore, travel-related data for telecommuters rarely exist.

The purpose of the paper is to overview and briefly summarize the results and findings of existing studies on critical issues of telecommuting. Section II describes the definition and existing forms of telecommuting. Section III explains the advantages and disadvantages of telecommuting for the general public, for participating employees, and for companies. A comparison of home-based telecommuting and center-based telecommuting is also made in this section. Section IV discusses the characteristics and profiles of telecommuters. Section V describes the behavioral aspects of employees and employers toward telecommuting and the decision procedure in the adoption of telecommuting. Section VI discusses the impacts of telecommuting on transportation system, urban spatial structure, and air pollution. Section VII describes the impacts of telecommuting on urban spatial structure and travel, based on urban economic theory and focusing on the findings of Kim (1997). The paper concludes in Section VIII with future research directions.

II. Definition and Forms of Telecommuting

In the telecommuting literature, there are several definitions of telecommuting, depending on the settings of each telecommuting program. The term *telecommuting* is often used to mean working from home or remote work among others. However, telecommuting can be considered as one type of remote work. Mokhtarian (1991b) considers two criteria to define telecommuting: remote management and commute reduction. Based on these criteria, she defines telecommuting as working at home or at an alternate location and communicating with the usual place of work, using electronic or other means instead of physically traveling to a more distant work site.

Currently, two major forms of telecommuting exist: home-based telecommuting (HBT) and center-based telecommuting (CBT). HBT is full- or part-time working at home and requires telecommuters to report via telecommunication technology to their central offices. CBT is full- or part-time working in a facility that is referred to as a telecommuting center and the center is located closer to the employee's home. CBT requires a shorter trip than to a more distant central work location. There are two types of telecommuting centers: satellite work centers and local/neighborhood work centers. The former includes facilities used for telecommuting by the employees of a single organization while the latter includes facilities shared by two or more employers. A telecommuting center is different from a branch office in that it can be office space obtained exclusively for the purpose of telecommuting, or a portion of space devoted to telecommuting within a conventional branch or local office (Bernardino et al. 1993; Mokhtarian 1991b; Nilles 1988).

. Advantages and Disadvantages of Telecommuting

What are the advantages and disadvantages of telecommuting? Mah-massani et al. (1993), Sullivan et al. (1993), and Bernardino et al. (1993) identified these advantages and disadvantages. The advantages for the general public include (1) reduction of work trips and engine emissions in peak hours, (2) an opportunity for parents with young children or workers with disabilities to participate more fully in the labor force, and (3) enhancement of the image of those companies with telecommuting programs. The benefits for participating employees include reduced travel time and cost, reduced commuting stress, fewer distractions during work hours, greater flexibility to meet family commitments, a more comfortable work environment, and greater opportunity to participate in community activities. For the companies, the major advantages embody significant savings obtained by reduced requirements of office and parking space, less turnover, higher employee productivity, better morale of employees who are telecommuters, and improved ability to recruit qualified employees.

The major disadvantages for employees include less opportunity for social interaction with coworkers, fewer opportunities for on-the-job learning from senior workers, possibly lower salary under some scenarios, and fewer opportunities for promotion. Those for companies are potentially high initial investment to implement and operate a telecommuting program, difficulty of performance measurement, resistance from management, resistance from unions, and less data security.

Researchers including Bernardino et al. (1993) and Mokhtarian (1991b) also identified several advantages and disadvantages between HBT and CBT. The main advantages of HBT are that it requires no trips and provides more time for family interaction. However, HBT has several disadvantages, such as a possibility of family conflict, social isolation, management difficulty, high initial cost to provide expensive equipment, less data security, and a possibility of overwork of telecommuters. Compared to HBT, CBT brings greater possibilities for socialization as well as better infrastructure, easier management, more data security, and a more well-defined liability context. Nilles (1991) emphasizes that urban sprawl could develop if part-time HBT remains the dominant form. This is more likely unless the network of telecenters develops. He believes that CBT is a very desirable policy in that it will reduce or eliminate increased commuting distances even where workers change their residential locations.

. Who are Telecommuters?

One of the interesting questions about telecommuting is who can telecommute and who can not. What are the characteristics of telecommuters? Of course, not all workers can telecommute. Individuals who are career oriented may prefer to work in the central office, while those who are family oriented may prefer to telecommute. When evaluating the potential telecommuting adoption, it is necessary to consider job and commuting characteristics, as well as individuals' personalities, attitudes, lifestyles, cultural values, and other socioeconomic constraints. Bernardino et al. (1993) characterized telecommuters' profiles based on the sociological studies by Olson (1983, 1989), Olson and Primps (1984), Pratt (1984), Bailyn (1989), and Christensen (1988). Bernardino et al. (1993) list telecommuters as (1) male managers or professionals who perceive more value in part-time integration of work and family than career advancement, (2) full-time female clerical workers who have child-care responsibilities, (3) managerial and professional mothers with young children, (4) female workers who are more interested in home and family than in career goals, and (5) male workers who perceive some value in work but give priority to their preferred lifestyles and a balanced life over career and achievement.

Bailyn (1989) found that telecommuters tend to place a higher value on interesting work, family life, and leisure time than on pursuing a career while office workers are more career oriented and

pursue value status, prestige, and success more than family life, flexibility, and merely maintaining skills. In the decision to adopt telecommuting, workers would have different bargaining positions. Bernardino et al. (1993) hypothesized that telecommuters will either be in the position of bargaining for their working arrangement or, having no alternative, being exploited eventually.

. Decision Procedures of Telecommuting Adoption

Several studies have tried to model the choice of telecommuting. These studies can be classified as the stated preference approach and conceptual modeling. Models based on the stated preference approach include Bernardino et al. (1993), Mahmassani et al. (1993), Sullivan et al. (1993), and Yen et al. (1994). Among these, Mahmassani et al. (1993) and Sullivan et al. (1993) focused on employees' attitudes toward and participation in telecommuting. Yen et al. (1994) focused on the issues involved in employers' attitudes toward and adoption of telecommuting. Bernardino et al. (1993) considered both employees' and employers' perceptions and attitudes toward telecommuting. Mokhtarian and Salomon (1994) developed a conceptual model in the choice of telecommuting.

The stated preference approach in these studies is based on surveys of employees in different telecommuting scenarios. Employees are asked questions about their jobs and commuting characteristics, attitudes, and preferences toward many aspects of telecommuting. These studies can be summarized as follows: The adoption of telecommuting involves two types of decision-makers, the employee and the employer. Employees participate in telecommuting programs on a voluntary basis after receiving approval from supervisors. Therefore, the employers decision is crucial in the initiation of a telecommuting program. The main barriers to the employer's adoption of telecommuting remain with respect to management issues such as employees' productivity, executives' abilities to supervise telecommuters, and data security. Compared to employees, executives are more reluctant to adopt telecommuting. However, executives' awareness of telecommuting substantially reduces these barriers.

When employers decide to adopt telecommuting, employees' decision-making involves two sequential choices: the decision whether to telecommute and the decision of how much telecommuting to do. Some telecommuting programs may have a rigid schedule, specifying the number of days or specific days of the week. Other programs can be flexible, allowing the employee to decide the schedule. These studies also identified interesting responses of employees. First, the potential telecommuters would be willing to negotiate some salary reduction if their employers supply the necessary equipment and pay related costs and overtime. Second, the willingness to telecommute increases as the number of children in the household increases. Third, workers with computer knowledge and skills are more interested in home telecommuting. Fourth, more employees would rather telecommute only a few days per week instead of every day. Fifth, female employees tend to express a stronger preference for telecommuting than do male employees. Finally, the employees are willing to do more telecommuting as their commuting distances or time increases.

Mokhtarian and Salomon (1994) developed a conceptual model in the choice of telecommuting, considering various factors related to the choice. First, they consider environment such as institutional, social/ cultural, technological, physical (or spatial), and economic environment. These factors act as facilitators or constraints in the adoption of telecommuting. Facilitators are factors that allow change (the choice of telecommuting) or make the change easier, while constraints are factors that prevent or hinder change. Drives--factors that actually motivate a person to consider beginning to telecommute--are the stimulants that initiate the process of the change. This process leads to an active search for alternatives and the generation of the choice set.

Second, the individual perception mechanism acts as a filter that may eliminate the option to telecommute. This filtering process is affected by the individuals' attitudes. The information filtered in generates a new alternative in the choice set. The individual may begin to deliberate whether to adopt change with the activation of drives. Third, the alternatives are evaluated with respect to the benefits and costs of adoption. Finally, the individual adopts the best or second-best alternative as the preferred behavioral pattern.

. Telecommuting, Transportation, Urban Structure, and Emission

Urban and transportation planners are interested in the possible impacts of telecommuting adoption on urban society. Bernardino et al. (1993) summarized the impacts of telecommuting on travel behavior based on the studies by Salomon (1986), Nilles (1989, 1991), Mokhtarian (1991a), Pendyala et al. (1991), and Hamer et al. (1991). These impacts can be classified into short-term effects and long-term effects. The short-term effects include a reduction in the number of peak-hour trips, a shift of trip time to off-peak hours, a decrease in total distance and time traveled, a change of non-work trip destinations to be closer to home, disruption of trip chains, interruption of carpools, and a reduction in the number of trips and reassignment of activities of household members of the telecommuters. The long-term effects include a reduction in the level of automobile ownership, changes in job locations, and changes in residential locations.

The impacts of telecommuting on urban spatial structure have also received many urban planners' attention. Lund and Mokhtarian (1994) were the first researchers to develop a residential location model and to examine the impacts of home-based telecommuting on residential location. They found that the net impacts of telecommuting is to induce an outward location of residences from traditional centrally located workplaces, diminishing the reduction in commute distance traveled per year. Nilles (1991) pinpointed this problem involved with home-based telecommuting, indicating its possible impacts on urban sprawl based on the result of the California Telecommuting Pilot Project. He emphasizes the importance of regional telework centers as an alternative to support the increasing trend of telecommuting adoption while restricting urban sprawl. He expects that regional telework center telecommuting will become increasingly common and that average commuting distance to regional centers will slowly diminish as the number of centers increases until neighborhood telework centers become common.

The third area of interest related to the impact of telecommuting is air pollution. Issues related to air pollution have emerged in the field of transportation. Travel-related air pollution is primarily associated with distance-related running emissions and cold start emissions. The former is the major contributor to Particulate Matter (PM) and Oxides of Nitrogen (Nox), and the latter is the major contributor to Total Organic Gas (TOG) and Carbon Monoxide (CO) (Henderson and Mokhtarian 1996).

. Impacts of Telecommuting on Urban Spatial Structure and Travel

As described in the previous section, Lund and Mokhtarian (1994) were the first researchers to develop a residential location model and to examine the impacts of home-based telecommuting on residential location. However, their analysis is limited in that they simply minimized the summed cost of housing and travel and adopted an exogenous land-price function.

Kim (1997) overcame the limitations, addressing the following four central questions: (1) How do workers allocate their time to telecommuting and office work with respect to their residential location?; (2) How do different telecommuting programs affect urban spatial structure? Does the city expand when telecommuting programs are available? How big is the resulting city size?; (3)

Does utility of households increase with telecommuting programs available?; (4) Are emissions really reduced with telecommuting? If so, are emissions reduced throughout the city?

Focusing on providing the answers for these questions, he constructed an urban economic equilibrium model which permits a comprehensive analysis of the spatial impacts of telecommuting behavior in an urban space. Within this framework, he has carried out a comparative equilibrium analysis of alternative telecommuting policies with respect to HBT and CBT.

An urban land use model was first formulated by Alonso (1964), developing bid-rent approach in a monocentric urban area to analyze residential location behavior of urban households. Beckmann (1974) was one of the first authors to have incorporated the time cost of commuting into the urban land-use model developed by Alonso (1964). He analyzed the impact of leisure time on residential location behavior of urban households. Fujita (1989) extended the Beckmanns model, comprehensively analyzing residential location behavior of urban households with leisure time in an urban context. He called the model time-extended model.

Kim (1997) modified Fujitas time-extended model to conduct the appropriate analysis for answering the questions raised in his study and called it *modified time-extended (MTE) model*. Applying utility-maximization approach of microeconomic theory, he maximizes a utility function of a representative household subject to budget and time constraints. In this way, he analyzed residential location behavior of urban households and resulting urban spatial structure, conducting an equilibrium analysis. In order to analyze the impacts of alternative telecommuting policies of HBT and CBT, he extended the MTE model to incorporate each of these telecommuting policies, respectively. First, he formulated an HBT model to incorporate a HBT policy. Similarly to the MTE model, he conducted an equilibrium analysis of HBT model to analyze the impact of HBT policy on residential location behaviors of telecommuters and nontelecommuters, the resulting urban spatial structure, travel condition, and air pollution levels generated by commuting of the workers. Likewise, he formulated a CBT model to incorporate a CBT policy and conducted a similar analysis.

Next, he conducted a sensitivity analysis of the three models when major parameter values in these models change. With the reasonable values of the parameters, he has carried out a comparative equilibrium analysis of alternative telecommuting policies with respect to HBT and CBT and compared the results with MTE model. MTE model is the case without any telecommuting policy which is similar to many of the existing cities throughout the world. This type of phenomena can only be analyzed within an urban spatial equilibrium framework which incorporates the location and land use behavior of workers under alternative policies.

The major findings in his study are, first, such that telecommuters reside around the CBD while nontelecommuters reside away from the CBD. Spatial division of workers occurs. Second, the city expands due to the relocation of workers toward the suburbs as they telecommute more. Third, utility of all residents in the city increases due to lower residential density and the choice of work options. Fourth, land rent decreases significantly around the CBD while it increases a little around the suburbs. Fifth, the volume of traffic in a year is significantly reduced around the CBD. Sixth, vehicle distance traveled (VDT) in a typical day can be rapidly reduced as more workers telecommute.

The results indicate that an HBT program is a better option than a CBT program with respect to the equilibrium utility of the city and point-wise travel volumes at least around the CBD. Practically speaking, however, the latter would be more provable with respect to management considerations and individual preferences for social interaction. However, an appropriate combination of both telecommuting scenarios can be considered, corresponding to the situations that each city faces.

Some of his findings are quite startling. In particular, while it is commonly believed that a major benefit of telecommuting is the reduction of air pollution from auto emissions, he has shown that the total level of pollution may actually increase under quite reasonable assumptions. The

paradox arises from the fact that telecommuting can lead workers to move further from the CBD, resulting in longer, though less frequent, commuting trips which actually increase total exhaust emissions. This is particularly dramatic for the policy option of CBT.

The implications of his findings are that telecommuting will contribute to: (1) the improvement of traffic and environmental conditions in large cities; (2) ensuring space for urban public facility and infrastructure provision; (3) enhancing land use efficiency due to reduction of population density; (4) improvement of environmental quality thanks to reduction of air pollution from auto emissions; (5) reduction of housing price; and (6) elevating quality-of-life of urban residents. His results strongly suggest either telecommuting scenario to be a desirable policy to cope with the severe traffic congestion and air pollution that many large cities throughout the world including Seoul suffer from today.

. Future Research Directions

In this paper, we have presented an overview of the literature on telecommuting. We now briefly discuss future research directions in the following way. First, Kim's model (1997) can be extended to incorporate firms' behavior in the context of general equilibrium analysis. Firms' adoption of telecommuting as a work option is crucial for telecommuting to be realized. In his model, second, the level of air pollution is determined by residential location behavior of urban households. Thus, it would be interesting to internalize air pollution into the model which, in turn, affect residential location behavior of the households. Third, the impacts of telecommuting alone on travel and environmental condition may not be so large. Empirical studies can be performed to analyze the combined impacts of several other travel demand management strategies incorporated together with telecommuting. They include car pool, van pool, congestion pricing, HOV lanes, and so forth. Recently, some U.S. cities adopted so-called travel reduction program and many others are planning it as a travel demand management strategy.

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