Title
Telecommuting and Travel: State of the Practice, State of the Art

Author
Mokhtarian, Patricia L.

Publication Date
1991-08-01

Telecommuting and Travel: State of the Practice, State of the Art

Patricia L. Mokhtarian

August 1991
Reprint, No. 79

The University of California
Transportation Center

University of California
Berkeley, CA 94720

The University of California
Transportation Center

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U.S. Department of Transportation, the California State Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, and Irvine; the Institute of Urban and Regional Development at Berkeley; the Graduate School of Architecture and Urban Planning at Los Angeles; and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in Center activities. Researchers at other universities within the region also have opportunities to collaborate on selected studies. Currently faculty at California State University, Long Beach, and at Arizona State University, Tempe, are active participants.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. For a list of publications in print, write to the address below.

University of California
Transportation Center

108 Naval Architecture Building
Berkeley, California 94720
Tel: 415/643-7378
FAX: 415/643-5456

Authors of papers reporting on UCTC-sponsored research are solely responsible for their content. This research was supported by the U.S. Department of Transportation and the California State Department of Transportation, neither of which assumes liability for its content or use.

Telecommuting and Travel: State of the Practice, State of the Art

Patricia L. Mokhtarian

Institute of Transportation Studies
University of California at Davis

Reprint, No. 79

Transportation
Vol. 18, No. 4, 1991

The University of California Transportation Center
University of California at Berkeley

TELECOMMUTING AND TRAVEL: STATE OF THE PRACTICE, STATE OF THE ART

by Patricia L. Mokhtarian

Keywords

telecommuting, telecommuting centers, telework, transportation demand management, travel behavior, travel demand forecasting

Abstract

This paper provides an overview of the status of telecommuting in the United States, especially as it relates to changes in travel behavior. Regarding the state of the practice, the paper discusses some refinements to the definition of telecommuting that have developed through increased operational experience. It reports several policy statements involving telecommuting, and explores the appeal of telecommuting as a public policy instrument. It highlights some trends in the implementation of home-based and work center-based telecommuting, and suggests that visible public-sector involvement has been crucial to the increased activity in this area.

In sketching the state of the art, the paper outlines some frequently-stated hypotheses on telecommuting and travel behavior, and summarizes current empirical findings relating to those hypotheses. Finally, it suggests a variety of topics suitable for further research. These include studying factors influencing the ultimate adoption levels of telecommuting; impacts on energy/air quality, mode choice, and location/urban form; interactions with other transportation demand management strategies; relationships to the traditional urban travel demand forecasting process; cost/benefit tradeoffs; and telecommuting centers.

Introduction

Several years have elapsed since publication of the most recent conceptual (e.g, Salomon, 1986) and empirical (Nilles, 1988) overviews of the impact of telecommuting on travel. A lot has happened since then, as this special issue and other evidence indicate. It is timely, then, again to step back and take a broad look at the activity in this area. This paper focuses primarily on the status of telecommuting in the United States. Other papers in this issue describe examples of telecommuting in the Netherlands (Hamer, *et al.*, 1991) and Japan (Spinks, 1991), and there is considerable activity in the United Kingdom (Kinsman, 1987), Finland (Kauppi, 1991), Germany and elsewhere in Europe (Huws, *et al.*, 1990), and Australia (Wood, *et al.*, 1990).

This paper describes the role of telecommuting in transportation and other public policy, and suggests reasons for the increasing acceptance of telecommuting. It reviews the major research hypotheses regarding the transportation-related impacts of telecommuting, and summarizes the current findings. Finally, it discusses some fruitful directions for future research. Thus, the body of the paper is divided into six sections, relating to: (i) definitional issues, (ii) policy role, (iii) implementation, (iv) hypothesized transportation impacts, (v) current empirical findings, and (vi) future research directions. The first three areas might loosely be considered the "state of the practice", while the latter three relate to the "state of the art". While these six categories are intended to provide a convenient structure for organizing the discussion, it is in practice sometimes difficult to maintain those distinctions. The first three areas are especially interrelated. As will be seen, definitional issues have policy implications, besides relating to how progress in implementation is perceived. And the role of telecommuting in public policy has greatly influenced, and been influenced by, its implementation.

Status of Definitional Issues

With increased operational experience, there has been some evolution of the perception of what constitutes telecommuting. Early treatments of the subject tended to assume telecommuters had three attributes in common. First, telecommuters were presumed to be (1) *information workers*, and almost entirely *computer-based* (such as clerical-level data or word processors or professional-level programmers). Further, telecommuting was most often expected to be (2) all-or-nothing, that is, *full-time*, and (3) *work from home*. The assumption of these latter two characteristics implicitly or explicitly underlay many of the reasons advanced for pessimism about the long-range penetration of telecommuting, and/or concern about its negative impacts (reasons including the psychological and professional need for face-to-face interaction, the desirability of a buffer between work and home, the importance of visibility to professional advancement, and the need of unions for access to the workforce; Hall, 1989; Salomon and Salomon, 1984).

It is now evident that none of those three attributes is a necessary condition for telecommuting to occur. Specifically: (1) Computers certainly facilitate telecommuting more often for more people, but much information-related work is still done "the old-fashioned way" --

with pen, paper, and telephone. It is often this type of work that is performed while telecommuting. A nationwide survey by the market research firm Link Resources Corporation (Miller, 1991) found that only 36% of telecommuter households owned personal computers (PCs), and another 10% brought PCs home from the office with some degree of frequency. While PC ownership is higher among telecommuter households than among households with no homeworkers (only 15% of those own computers), it appears that more than half of the telecommuter households presently do not use computers while working from home. This aggregate statistic is consistent with observed patterns in a variety of specific recent telecommuting programs. It should be stressed, however, that computer use among telecommuters is almost certainly increasing steadily over time, so that the particular numbers reported will not apply for very long.

If not all information workers are wedded to computers eight hours a day, not all computer users are "information workers" in the conventional sense of the term. An enormous variety of jobs deal with information (with or without computers) to the extent that part-time telecommuting is feasible. For example, in the County of Los Angeles program, field workers such as welfare fraud investigators, health services inspectors, probation officers, and social service workers now conduct their "telephone and paperwork hour" from home at the beginning and/or end of the workday, rather than driving to a traditional office (typically in downtown Los Angeles) to complete these location-independent tasks (Gould, 1990). Realizing that these are not commonly considered "information" occupations, it appears that the "market" for telecommuting is perhaps broader, not narrower, than formerly believed.

(2) Recognition of part-time telecommuting as a viable option similarly broadens the base of potential adopters (although it also means that the average frequency of telecommuting for those doing it will be less than 100%. Thus, a forecast that x percent of the workforce telecommutes will mean that something less -- perhaps considerably less -- than x percent of all work trips are replaced). In several programs for which results are publicly available, the average amount of telecommuting per person is 1-2 days per week. Analysis of individual and aggregate frequencies of telecommuting, and how those frequencies change over time, is a research topic discussed further in the "Future Research Directions" section of this paper.

(3) Many proponents believe that eventually, more telecommuting will take place from nearby work centers than from home. While start-up costs of telecommuting centers are higher, they enjoy certain potential advantages over working from home. For the employer, these advantages include: presenting a more professional image; an increased confidence in the worker's productivity; a better-controlled liability risk; and higher levels of security. For the employee, potential advantages include (Healy, 1968; Sahlberg, 1987): opportunities for interaction; separation of work from home; and shared access to equipment and services not available in the home. Thus, many personalities and jobs for which home-based work is not desirable may function quite well in a telecommuting center.

The seemingly innocuous question of how to define a telecommuting center turns out to be an important adjunct to consideration of its role as a transportation control measure for improving air quality. The issue is two-fold: (1) Since a telecommuting center is likely still to involve a vehicle commute trip (albeit a shorter one), should it count under a trip-reduction regulation? and (2) If it should count, how should it be defined so that a company subject to the regulation cannot claim that a branch office or decentralized function (such as accounting or data processing) is a telecommuting center? Mokhtarian (1991a) describes the development of one set of guidelines for distinguishing a telecommuting center from these other types of work locations.

Status of Telecommuting as Public Policy

The past few years have seen a strong surge of interest in telecommuting on the part of public policy makers as well as the private sector. Beginning in California, but spreading to other areas of the United States, telecommuting has become a visible, if still marginal, element of transportation/air quality planning. Telecommuting has found its way into a number of public policy statements, especially as a transportation strategy, but also addressing other policy concerns. For example:

- The 1989 Air Quality Management Plan for the South Coast (California) Air Basin sets the ambitious -- perhaps unrealistic -- goal of reducing work trips by 30% in the year 2010 due to the combined impacts of telecommuting and alternative work schedules (SCAQMD and SCAG, 1989).

- Regulation XV of the South Coast Air Quality Management District (SCAQMD) includes telecommuting on a menu of strategies large employers must use to decrease peak-period vehicle trips. Reg. XV is being widely studied, and to a certain extent, copied, by other areas of the country that are out of compliance with Federal Clean Air Act standards (SCAQMD, 1990).

- Upon the successful conclusion of the two-year pilot project for State of California employees, legislation was passed (State of California, 1990a) authorizing the establishment of telecommuting programs for any state agency. Following the October 17, 1989 Loma Prieta earthquake (which caused sections of the Oakland - San Francisco Bay Bridge and Interstate 880 to collapse, and damaged several other area commuting arteries), California Governor George Deukmejian issued an Executive Order which directed state agencies to include telecommuting in their emergency response to the quake (Executive Department, State of California, 1989; Pratt, 1991b).

- President Bush has endorsed telecommuting; in introducing the Statement of National Transportation Policy on March 8, 1990, he said, "Sometimes the best transportation policy means not moving people, but moving their work ... a trend known as telecommuting. Millions have already found their productivity actually increases when they work nearer the people they're really working for -- their families

at home ... Think of it as commuting to work at the speed of light." The National Transportation Policy Statement itself also has a short section on telecommuting (USDOT, 1990).

- The State of Washington has passed legislation requiring trip reduction plans to be prepared at the local level (State of Washington, 1991). The statute sets targets of reducing commute trip vehicle miles 15% by January 1, 1995; 25% by January 1, 1997; and 35% by January 1, 1999 (from a 1992 baseline). A "20% bonus" for work-at-home and alternate work schedules is built into the legislation: each commute trip reduced by these means "shall count ... as one and two-tenths vehicle trips eliminated for the purpose of meeting trip reduction goals."

- Chapter 90-291 of the Laws of Florida (State of Florida, 1990) authorizes the implementation of telecommuting programs for state agencies, citing "many documented benefits ... including less traffic congestion and the associated reduction in air pollution and energy consumption, improved employee morale and productivity, improved ability to hire additional individuals into the work force, improved ability to recruit and retain valuable employees, and reduced costs for office and parking space".

- The Commonwealth of Virginia House Joint Resolution (HJR) 77 (1990) requested the Virginia Employment Commission to prepare a report to the legislature on the feasibility of telecommuting. The resulting document (Commonwealth of Virginia, 1991) recommended establishing telecommuting programs in state agencies, followed by promotion and assistance to the private sector in implementation. The report cited the potential role of telecommuting in supporting Federal-level policies such as the Clean Air Act of 1990 and the Americans with Disabilities Act of 1989, and state-level efforts toward rural economic development. The Virginia General Assembly responded to the report by passing HJR 339 (1991), "encourag[ing] efforts to foster and promote telecommuting in the workplace."

In addition to these policy statements already in place, a number of other legislative initiatives are underway at Federal and state levels at the time of this writing. Telecommuting is also a recommended strategy in a variety of local and regional transportation plans, corridor studies, and trip reduction/mitigation ordinances, especially in California.

Why is telecommuting so attractive to transportation policy-makers? To put that question in perspective, it is important to emphasize that no policy body is proposing that telecommuting should replace more conventional transportation strategies. It is widely acknowledged that a variety of approaches will be needed to solve congestion, air quality, and energy problems. The contrast with a few years ago, then, is not that telecommuting has replaced that menu of strategies, but that it appears on the menu at all.

It would be overly simplistic and perhaps counterproductive to directly compare telecommuting to other commonly-discussed transportation mitigation strategies, along only one or

a small number of dimensions. However, certain aspects of telecommuting seem at least superficially appealing. First, *telecommuting can be implemented now*. It does not require lengthy planning, design, and construction lead times. There is no public resistance to its implementation, for example on environmental or negative externality ("not in my back-yard") grounds. Its feasibility does not depend on technological breakthroughs.

Second, *telecommuting is relatively inexpensive to implement* -- especially in terms of public funding. Government seed money is sometimes provided, but in the majority of settings, the costs of telecommuting are borne directly by the employers and employees who are benefiting from it. Third, *telecommuting expands personal choices rather than restricts them.* It provides another commute-trip option, without removing any existing options. It offers more flexibility in scheduling activities and the associated travel. People do not have to be induced to telecommute; large numbers (though naturally not everyone) want to do so.

Finally, *telecommuting addresses a variety of public- and private-sector concerns.* On the private-sector side, businesses typically do not establish telecommuting programs just because reducing congestion is good for society, except in response to policies (such as Regulation XV) requiring them to reduce peak-period travel. Rather, companies implement telecommuting when they find it is an answer to human resources problems (recruitment, retention, staffing flexibility and customer service, helping employees cope with domestic demands, productivity); facilities issues (office space, parking); and, sometimes, emergency preparedness/disaster response (Pratt, 1991a). It is partly because telecommuting can be a desirable business strategy that it is viewed as a desirable transportation strategy.

On the public-policy side, telecommuting can also support several agendas. Besides the related trio of transportation, air quality, and energy, telecommuting can contribute to issues dealing with the American family, employment for people with disabilities (and others with limited mobility, such as the institutionalized, the retired, the low-income), rural economic development, global competitiveness, health care, and community involvement.

Status of Telecommuting Implementation

Several researchers (e.g., Kraut, 1988; Huws, *et al.*, 1990) have pointed out the difficulties of reliably measuring the levels of home-based work that take place, both because of definitional inconsistencies and methodological difficulties. Home-based telecommuting is not immune from these problems. Thus, assessments of the amount and growth of telecommuting are somewhat problematic. Perhaps the most extensive and carefully crafted assessment is the Annual Work-At-Home Survey conducted by the Link Resources Corporation.

Based on national random samples of 2500 households each year, Link Resources estimates that the number of home-based telecommuters (conservatively defined as a company employee working at home during normal business hours) in the United States has increased two-and-a-half times in the past four years, from 2.2 million in 1988 to 5.5 million currently (Miller, 1991). The latter figure represents 4.4% of a total U. S. workforce of 122.9 million. Only 16% of that 5.5 million telecommute 35 or more hours per week; about half work from

home between one and four days a week (with two days the most common); about a quarter work from home less than one day a week; and for the remainder, the time is too variable to estimate (Miller, personal communication, July 15, 1991).

There are other, more qualitative, evidences of activity in telecommuting. Most of the policy bodies mentioned in the previous section, and many other government agencies besides, are involved in implementation of telecommuting programs, for their own employees as well as, perhaps, for private sector firms within their jurisdiction. An *ad hoc* group called the Telecommuting Advisory Council contains more than 350 members and several geographic chapters nationwide, and is in the process of incorporating as a non-profit entity. The California Department of Transportation has recently funded the development of a generic handbook for implementing telecommuting programs, which is available to any employer in the state (CTS and Caltrans, 1991).

Another sign of progress in the implementation of telecommuting is the emergence of several telecommuting centers. A description of the experimental telecommuting center established in Nykvarn, Sweden in the early 1980s notes:

> "The problems and threats that many pointed to in the discussions on the project have proved to be less important than expected. On the other hand the institutional and psychological obstacles are considerably greater than we expected. In particular the lack of organizational and institutional experience of remote work constitutes a considerable barrier to be overcome..." (Sahlberg, 1987).

These institutional barriers have continued to slow the adoption of non-home-based forms of telecommuting. However, the current crop of telecommuting center demonstration projects will provide additional information on how to overcome such barriers, or whether they are likely to be overcome.

The State of Hawaii opened the first-known public-/private-sector facility in the U.S., the Hawaii Telework Center, in 1989 (Hirata and Uchida, 1991). Funded with $125,000 from the State of Hawaii and more than $300,000 of in-kind equipment contributions from the private sector, the Center contains 17 workstations, split between State employees from a variety of agencies, and employees of several private-sector firms. The Center is located in a suburban technology park about 20 miles from Honolulu. It was established to demonstrate the feasibility of remote working to address the severe traffic congestion, office space constraints (with among the highest rents and lowest vacancy rates in the nation), and parking constraints associated with the concentration of employment in Honolulu. Another motivation was to explore the potential of telecommuting for economic development in remote island areas, to reduce the need to move to the Honolulu metropolitan area to find a job. After two years of operation, the Center is considered a success by the State, and efforts are underway to create additional centers.

Two telecommuting centers have opened in connection with the Washington State Energy Office telecommuting program in the Seattle area (*Puget Sound Telecommuting News*,

April 1991). The Washington State Telework Center opened in March 1991, with 13 workstations. Located in Seattle, it links telecommuters to their offices in the state capital of Olympia, more than 50 miles south. The Ballard Neighborhood Telework Center, in northwest Seattle, contains 7 workstations.

In California, legislation (State of California, 1990b) was passed authorizing state funding for up to two telecommuting centers, one in Riverside County and one in San Bernardino County. The bill appropriates $100,000 for each center from California's share of the Petroleum Violation Escrow Account (a Federal fund created from fines levied against oil companies found to have unfairly overcharged consumers during 1973-81), provided that equal amounts are contributed from the respective county transportation commissions and from private industry (for a total of $300,000 for each center). Site selection studies for these centers are currently underway.

The legislation requires an evaluation of these centers to be conducted, and is unusually specific as to the nature of that evaluation. In particular, "[t]he program evaluation shall include ... an estimate of the number of commute trips reduced as a result of this pilot project, and a projection of the number of commute trips that could be avoided if this program were extended for five years. The financial statement shall detail the costs of implementing this pilot project and compare the costs of the pilot project to the costs of traffic controls that would otherwise be necessary to accommodate the level of traffic which the program evaluation estimates could be diverted within five years if the pilot project were continued. The pilot project shall be considered a success if the number of normal commute trips diverted to telecommuting is cost-effective when compared to the alternative of constructing traffic controls necessary to reduce the same number of commute trips ..."

The analysis of commute trip impacts is a useful, though rather narrowly-defined, approach to assessing the cost-effectiveness of telecommuting centers. It is at least equally important, however, to analyze the economic viability of such centers in the broad sense. In the demonstration phase, these centers are typically fully funded by the government and its private partners, with no rent being charged directly to the telecommuters or their employers (the Ballard facility mentioned above is one exception). It has yet to be established under what, if any, conditions a telecommuting center will be economically attractive to an employer in a free-market environment.

The State of Kentucky is in an advanced stage of exploring these issues, with a feasibility study of the rural telecommuting center concept. The study, to be finished later this year, includes an examination of market demand factors, identification of potential prototype locations, and a review of policy issues (Kentucky Science and Technology Council, *et al.*, 1991).

For now, at least, it is clear that telecommuting is on the rise in the United States. Why this increase in activity? A number of factors can be suggested, but visible public sector involvement seems to have been crucial. On the policy side, Regulation XV in Southern California, for example, has certainly motivated a number of private sector companies to explore telecommuting more seriously and/or sooner than they would have otherwise.

At the same time, on the implementation side, several high-profile public-sector telecommuting programs, in the Southern California Association of Governments (SCAG, 1988), the State of California (JALA Associates, 1990), and the County of Los Angeles (Shirazi, 1990) served as effective catalysts. Public-sector involvement has (1) made telecommuting plans and procedures public and readily accessible; (2) supported empirical evaluations of the effectiveness of telecommuting, and (3) publicized the findings of those evaluations. Those three outcomes seldom occurred in the early private-sector programs, whose very existence was sometimes regarded as proprietary information, and whose consultants understandably had no incentive to share implementation strategies. In contrast, the high-visibility programs mentioned above, together with their successors, have made a vast amount of implementation and evaluation experience available. This information has lowered the "barrier to entry", and spurred the development of additional programs. The sharing of information through the Telecommuting Advisory Council and other mechanisms provides some credibility and some confidence-building for an organization newly considering telecommuting.

Telecommuting and Travel: Major Research Hypotheses

One of the expressed purposes for much of the implementation activity described in the preceding section has been to evaluate the effectiveness of telecommuting as a transportation improvement strategy. One can envision a variety of ways in which the ability to telecommute can affect individual and household travel patterns. These potential impacts are by no means always positive from a transportation policymaker's point of view. Some of the major research hypotheses that have been previously articulated (see, e.g., Salomon, 1986) involve the following aspects of travel behavior:

- *frequency:* work trips should decrease. Non-commute trips may increase, due to a psychological need for mobility, the availability of a vehicle to another household member, or the direct stimulation of travel for work-related activities (e.g. to the post office, or neighborhood office supply store).

- *time-of-day/day-of-week:* given the flexibility to do so, trips may be shifted to off-peak periods to avoid congestion delays, and/or to different days of the week.

- *destination/length:* work trips may be made to a local center rather than a downtown office building; non-work trips may be made closer to home rather than closer to work.

- *mode:* on the negative side, carpools and vanpools might dissolve if telecommuters drop out, and transit operators may lose revenue. On the positive side, trips made closer to home may shift to non-motorized modes such as bicycle and walk. And if telecommuting helps flatten the peak for use of transit modes, greater operational economies may result (Jovanis, 1983).

- *trip chaining patterns:* eliminating the work trip may break up efficient linked activity patterns, creating several one-stop trips instead of one multi-stop trip.

- *person(s) making the trip:* household-level assignments may change, with the telecommuter perhaps taking on more trips because s/he is at home and "available", or making fewer trips because a commuting spouse now makes the stop on the way to or from work.

- *vehicle ownership:* in the medium term, the ability to telecommute may eliminate the need for a car -- or, more likely, a second car.

- *residential/job location:* in the long term, telecommuting may stimulate movement further from work to housing in more desirable and/or affordable outlying locations. The additional miles traveled on commuting days may or may not outweigh the miles saved on telecommuting days. Once the ability to telecommute has been established, the worker may change jobs, moving to a more distant employer. Or, telecommuting may make it feasible to move a corporate facility without either relocating or losing some employees.

Current Research Findings

Early (1970s to early 1980s) assessments of the potential of telecommuting for reducing travel and energy consumption were generally quite optimistic. Subsequent (mid to late '80s) thinking, however, took a more cautious stance. It was argued, first, that telecommuting was as likely to induce new travel as to reduce commute travel, with the net impact likely to be an increase in travel. Second, it was argued that for a variety of reasons, telecommuting may not be adopted widely enough to make a significant impact on travel.

Until recently, few sources of empirical data were available to test these arguments, and the other hypotheses listed above. Indeed, it is still too soon to assess the ultimate adoption of telecommuting, although its prospects look brighter than they did a few years ago. However, a number of telecommuting projects have been and are being evaluated with respect to changes in travel behavior. From these projects, several conclusions are beginning to emerge. First, *commute travel is reduced -- by those who telecommute.* This self-evident finding is included only for completeness. The more interesting question, the ultimate extent of telecommuting, is discussed in the following section.

Second, *non-commute trips do not increase.* This welcome result has been independently replicated several times (Kitamura, *et al.*, 1990; Hamer, *et al.*, 1991; Mokhtarian, 1990). In fact, non-commute trips actually decrease, and in some cases tripmaking has been observed to decrease for telecommuters' household members as well. This finding is probably partly due to respondent fatigue (Pendyala, *et al.*, 1991). However, other explanations are plausible, and in some cases are at least partly supported by the empirical evidence. These include: (for telecommuters) a tendency to anchor non-work activities to the commute trip, and the threshold costs associated with getting dressed to leave the house; (for household members)

a desire to be at home with the telecommuter; and (for everyone) a heightened awareness on the part of the household of the need for reducing travel and/or traveling more efficiently.

Pendyala, *et al.* (1991) conducted an in-depth analysis of three-day travel diaries completed before and after telecommuting by 219 telecommuters, control group members, and driving-age household members in the State of California pilot project. They report the following three conclusions, among others: First, *telecommuters make proportionately fewer linked trips.* However, this is not a consequence of less-efficient trip-making activity; it simply reflects that fewer trips are being made altogether (an average of two on telecommuting days, one of which is a return-home trip). Second, *telecommuters tend to shift activities to destinations closer to home.* Interestingly, after telecommuting has begun, this "contraction of activity space" is observed on commuting days (once the work destination is accounted for) as well as telecommuting days. This suggests a learning process in which new destinations, closer to home, are discovered and more or less permanently adopted. Telecommuter household members also show a contracted activity space, indicating that they are not making the longer-distance trips formerly engaged in by the telecommuter. Third, *proportionately fewer peak-period trips are made when telecommuting.* However, this tends to be due simply to the elimination of the two commute trips. Non-work trips do not exhibit significant shifts in time.

Finally, there is evidence that *telecommuting can motivate significant residential relocation for a small minority of workers* (JALA Associates, 1990; Mokhtarian, 1991b). In the two-year data collection period of the State of California pilot project, 3% of the telecommuters indicated moving, or considering moving, 45 or more miles further from work since beginning to telecommute. It is unknown how many of those considering moving will actually do so, and it is not reported what proportion of those actual and potential moves would have occurred regardless. But of all those who moved or were considering moving, 29% reported that the ability to telecommute played a significant or decisive role in the choice. Based on these findings only, it seems that any net increases in vehicle-miles traveled due to long-distance moves are more than compensated for by travel savings on the part of others. However, these are only short-term results; the long-term trends may well be more pronounced.

Future Research Directions

The previous sections have raised a variety of useful research topics related to the impact of telecommuting on travel. Eight of these topics are elaborated below. This list is not necessarily exhaustive, even with respect to the subset of telecommuting issues related to travel. There are a variety of other research issues related to organizational behavior, social psychology, health impacts, and so on that are not addressed here. Thus, this list represents obvious gaps in current knowledge on the relationship between telecommuting and transportation that seem productive to pursue now or in the near future. However, this research agenda will undoubtedly evolve further as this dynamic area continues to mature.

How Much Telecommuting Will Occur?

The issue of how much telecommuting will occur is of paramount importance to ascertaining its value as a transportation mitigation strategy. Evidence is mounting that telecommuting has a beneficial impact on congestion, at least in the short term, in the small-scale settings in which it has been evaluated. The logical antecedent question is whether enough people will do it, often enough, to matter in the aggregate. The predictions that have been made to date have been primarily based on hypothetical scenarios embodying a range of assumptions about future adoption. What is needed is a model of the adoption of telecommuting that has a causal or behavioral foundation.

Along those lines, there are several related questions (also see the discussion below, under "Interactions with Other Demand Management Strategies"). First, *(i) who will telecommute, and why?* And as another approach to essentially the same issue, *(ii) who does/will not telecommute, and why not?* To help answer these questions, it seems important to understand who actually has a choice to telecommute. At least at this stage, situational constraints such as company or supervisor attitudes preclude many from considering telecommuting who would otherwise like to do so. Identifying those situational constraints and forecasting their role in future adoption is critical. After those people who actually have a choice are isolated, the factors affecting the choice to telecommute or not can be analyzed. Is it distance from work? Child care needs? Interestingly, in two small-sample studies (SCAG, 1988; Mokhtarian, 1991b) and work-in-progress on data from the State of California pilot project, no significant relationship was found between commute length and frequency of telecommuting (it is often not possible to determine the effect of commute length on the simple choice to telecommute, as commute length may be one of the criteria used to select telecommuters for a pilot project). Similarly, there is no predominance of families or single parents with young children. These tentative findings suggest again that telecommuting may be fulfilling different agendas for different people.

Another question related to how much telecommuting will occur is that, for a given person choosing to do it, *(iii) how often will an individual telecommute?* Changes in the frequency of telecommuting over time have been informally noted, but not carefully studied. For one thing, it is common to find that, at least at first, people are not able to telecommute as often as they expect to *a priori*. The amount of telecommuting may increase slightly over time for some, but it is also common to find some attrition among telecommuters. The amounts and causes of this attrition are typically not well-documented, especially in the larger programs. Thus, there is a need for study of telecommuting patterns over time: rates of attrition out of telecommuting, rates of new entry into telecommuting, and cyclical variations in the intensity of telecommuting. The goal would be to find ways of explaining observed patterns as a function of job, sociodemographic, and attitudinal characteristics. Ultimately, the study of those patterns and their causes should lead to an improved ability to forecast the demand for telecommuting.

Underlying all of the above discussion is *(iv) the need for collection of statistically reliable and definitionally consistent data on the amount of telecommuting and home-based work that is al-*

ready taking place at any given point in time. National data collection efforts such as the U.S. Census, the Current Population Survey, the National Personal Transportation Survey, and those conducted by agencies such as the Small Business Administration and the Bureau of Labor Statistics, as well as regional surveys of travel behavior, should include carefully-designed questions aimed at determining the amounts of working from home (in its various forms) and telecommuting (in its various forms) that are occurring.

Energy/Air Quality Impacts

Another set of questions relates to the energy/air quality impacts of telecommuting. These impacts may or may not be as favorable as the transportation impacts. First consider *(i) direct impacts.* Other things being equal, the lower the **vehicle-miles traveled**, the lower the fuel consumption and emissions. However, there are a number of relevant factors that might not be equal (see, e.g., Horowitz, 1982; California Air Resources Board, 1990). The **number of trips (cold starts)** matters, because a high proportion of the emissions for the entire trip are created by turning on the engine. If telecommuting were to generate new trips, or a higher proportion of unlinked trips, higher emissions might result. The **number of stops or links** on a given round trip matters, because even a hot start generates more emissions than a running engine. Thus, a 10-kilometer trip with four stops emits more pollutants and consumes more fuel than the same 10-kilometer trip with only two stops.

Speed is important: in general, slower speeds, and many accelerations/decelerations, result in higher emissions. A 10-kilometer trip at 20 kilometers per hour (kph) emits more than a 10-kilometer trip at 50 kph, and a trip in stop-and-go traffic that averages 20 kph will emit more than the same length trip with a nearly constant speed of 20 kph throughout. Thus if, due to telecommuting, more travel takes place in the off-peak at higher average speeds, a benefit to air quality will result. Even **ambient temperature** affects emissions, so travel taking place at different times of day may face different temperature conditions. Finally, the possibility must be considered that **a different vehicle may be used to make the trip.** An individual might use a fuel-efficient compact for a lengthy commute, but switch to a larger "gas-guzzler" for short trips on telecommuting days. Thus, a complete study of transportation-related energy and air quality impacts of telecommuting should account for the use of all vehicles in the household.

It is also important to examine *(ii) the total energy/air quality impacts* of telecommuting (see CEC, 1983 for an assessment of potential energy savings). Even if transportation energy is conserved, there may be increased energy use in the home that is not completely compensated for by decreased consumption in the conventional office. Lights and heating/ventilation/air conditioning systems may remain on in the office as well as in the home, for example. Less energy-efficient incandescent lights may be used in the home, rather than the fluorescent lighting more commonly found in offices. The air quality implications of producing the energy consumed while telecommuting should be examined. And in some parts of the country, notably the Pacific Northwest, concern has been expressed regarding the air quality impacts of an increased use of wood-burning fireplaces for home heating during winter days. Some calculations on total energy impacts have been made from the State of

California data (JALA Associates, 1990), but these should be refined in future studies, and extended to include air quality.

Impacts on Mode Choice

The impact of telecommuting on mode choice has not been a major focus of the studies conducted to date. While preliminary, small-sample findings seem positive (Mokhtarian, 1991a), there is also anecdotal evidence of negative impacts on ridesharing. Thus, it is desirable to analyze this aspect of travel behavior more rigorously, especially in areas with significant rideshare and transit mode shares. In conducting such an analysis, especially for impacts on ridesharing, it is important to realize that lower vehicle occupancies, in and of themselves, do not have undesirable consequences for congestion. As long as telecommuting simply removes a passenger from an existing carpool or vanpool, vehicle-miles traveled will not increase -- and will actually decrease unless the members of the car- or vanpool have the same origin and same destination. It is only when telecommuting contributes to the disintegration of the entire ridesharing arrangement, so that multiple vehicle-trips are made instead of one, that negative consequences result. Many ridesharing situations (Teal, 1987) either involve family members, can accomodate a certain amount of *ad hoc* participation (e.g. a vanpool where it is possible to pay by the ride), or otherwise have some built-in flexibility (e.g. carpooling only a few days a week to allow for personal or work-related business to be conducted on the way to or from the workplace on non-carpool days). The impact of telecommuting in these situations could be minimal.

Interactions with Other Demand Management Strategies

In transportation contexts, telecommuting most often appears on a list of transportation demand management (TDM) strategies for reducing the demand for peak-period vehicle travel. The interactions among these various TDM strategies are not well understood. Telecommuting could change the effectiveness of other TDM measures (positively or negatively), and vice versa. For example, the potential direct impact of telecommuting on mode choice was discussed immediately above. Conversely, strategies intended to shift commuters into higher occupancy vehicles may affect the adoption of telecommuting and/or the transportation impacts of telecommuting.

For example, the provision of child care at the worksite is expected to lower a commonly cited barrier to ridesharing -- the need to deliver children to day care on the way to work. This strategy could at best discourage some from telecommuting, and at worst lead to increased travel. Gordon (1991) relates the case in which a worker whose child was in a day care center next to the worksite made two round commute trips on telecommuting days (one in the morning to deliver the child, one in the evening to pick it up), compared to one round trip on a normal commuting day! On the other hand, strategies such as congestion pricing and parking pricing will almost certainly stimulate shifts to telecommuting as well as to transit and ridesharing.

Interactions between telecommuting and compressed work week options are also of interest; an employer whose staff is already out of the office one day in five may be reluctant to increase that by permitting telecommuting. These observations are not intended to place various TDM strategies in adversarial roles toward each other. They are intended to suggest that an awareness of "global" as well as "local" impacts are essential to determining the effectiveness of any given strategy. In all of these analyses, it will be important not to focus exclusively on extreme cases (although those are decidedly worth study), but to assess the extent to which counter-productive effects are likely to be the norm, and/or whether they are more than outweighed by positive effects in other cases.

Impacts on Location and Urban Form

The impact of telecommuting on residential location in particular clearly deserves further, long-term evaluation. Historically, transportation improvements leading to reductions in commute times have facilitated decentralization to lower-density and/or less expensive housing on the urban fringe (see, e.g., Muller, 1986). With telecommuting acting as such a transportation improvement, it seems reasonable to expect similar effects, at least in some cases. A primary question is whether long-distance moves properly attributable to telecommuting have the net impact of creating more vehicle-miles traveled than are saved through not commuting to work every day.

A broader issue, though, is the impact of telecommunications technology in general on the location of all kinds of activities -- and in the aggregate, the impact of telecommunications on urban form. These changes in urban form will, in turn, have derivative impacts on travel behavior. This is a complex issue which has attracted attention for at least the past two decades (e.g., Elton, 1973).

Perhaps one reason for this complexity is that telecommunications technology is most likely to be a permissive rather than a deterministic factor in location decisions (Moss, 1984; also see Salomon, 1987). In the case of residential location decisions, the ability to telecommute simply makes possible moves which are undertaken for other, more primary reasons such as a desire to escape the central city, for a change in perceived status, or for larger, lower-density housing. Similarly, a company seldom moves to a certain location <u>because</u> a particular technology is available there. Rather, telecommunications generally acts to reduce the need to be at <u>any</u> specific location. A move is then made if the perceived benefits of moving outweigh the costs, and the location is determined by primary factors such as costs (including transportation, communications, and rent costs), labor force availability, and amenities.

The facilitative nature of telecommunications technology no more sophisticated than the telephone was noted nearly 20 years ago: "the existing telephone system supported by occasional personal visits can support far more office decentralization than has occurred to date. Apparently, the capability to conduct business from remote locations has been a practical option for some time but until recently firms had little incentive to leave downtown. In a sense then, the communications revolution that makes decentralization feasible occurred

many years ago with the invention of the telephone" (Harkness, 1973). This permissive nature of telecommunications makes it difficult to properly model its role in location changes.

A subset of this issue is the role of telecommunications in the economic development of exurban or rural areas. This concept has been alluded to previously, and is being put into practice in a number of regions throughout the U.S. It should be noted in passing, however, that some of the applications referred to as "telecommuting" are more accurately characterized as functional or branch office decentralizations (because of the presence of an on-site supervisor), supported by telecommunications links to a headquarters facility.

Role of Telecommuting and Home-based Work in the Traditional Urban Travel Demand Forecasting Process

It may be the case that, as a commute mode, working from home has already achieved a share roughly comparable to that of transit in many U. S. cities. Link Resources (1991) estimates that 9.6% of the U. S. adult workforce can be classified as "homeworkers whose primary income is derived from self-employment". Suppose that the proportion of work trips actually reduced is only half that amount (both because not all of those primary self-employed homeworkers would otherwise be commuting to a conventional work location, and because some may still commute some of the time). Combining that 4.8% with the 1.8% of the trips eliminated by the 4.4% of the workforce that telecommutes about 40% of the time on average (as discussed earlier), suggests that working from home currently accounts for at least 6-7% of all "commute trips".

Accordingly, it is perhaps time to start thinking about how to incorporate telecommuting and home-based work into the traditional urban travel demand forecasting process. A home-based business should not ordinarily be classified as telecommuting, but to the extent that the business owner would otherwise be making a conventional commute, its transportation impacts may be quite similar to those of home-based telecommuting (Salomon, 1990). Work center-based telecommuting will have different transportation impacts, and should not be pooled with home-based telecommuting in this context. In fact, at the aggregate level at which the demand forecasting models are applied, a telecommuting center can perhaps effectively be treated as a conventional work location.

The traditional urban travel demand forecasting process (e.g., Kanafani, 1983) has four successive stages: trip generation, trip distribution, mode choice, and trip assignment. Typically preceding all of those stages is a land-use model that forecasts the spatial distribution of population and employment. Conceptually, the impacts of telecommuting and home-based businesses could be incorporated into any of those stages, although probably not into all of them simultaneously. This discussion can provide only a very rudimentary introduction to what would doubtless be a long-term, intricate series of modeling efforts, drawing from several previously-mentioned research topics, among others.

In the *land-use* model, the role of telecommunications in residential and job location should be considered. It is here that a potential proliferation of telecommuting centers might be

reflected. In the *trip generation* model, home-based businesses and telecommuting can be viewed as reducing commute-trip demand. Alternatively, home-based work could be incorporated into the *trip distribution* model. In this case, commute trips would be generated as usual, but for some proportion of trips, the destination would be home rather than the conventional worksite. (The generation and distribution of non-work trips has also been shown to be affected by telecommuting, as discussed in the preceding section).

Or, home-based businesses and telecommuting could be incorporated into the *mode choice* model, by considering them to be alternate modes to work. Trips would be "generated" from home and "distributed" to work locations, but the proportion of trips forecast to choose the "work from home" mode would then be eliminated before trip assignment took place. The impact of telecommuting on mode choice for the commute and non-work trips that are still made should also be included here. Finally, it is at the *trip assignment* stage that time-of-day shifts of travel due to telecommuting can be addressed.

Regardless of the stage(s) at which home-based work is accounted for, the output of the trip assignment model can at least theoretically be used to assess the impacts of the assumed levels and distributions of telecommuting on vehicle-miles traveled, congestion, and other indicators. This output can in turn be input to a model such as the Direct Travel Impact Model (DTIM), to estimate the regionwide air quality impacts of telecommuting (Seitz and Siller, 1991; Seitz, 1989).

Cost/Benefit Analysis

There are two perspectives from which to compare the costs and benefits of telecommuting. In *(i) the managerial perspective*, the employer is naturally interested in whether the alleged benefits of telecommuting (improved recruitment and retention, increased productivity, reduced facilities expenses, and so on) exceed the costs. The usual difficulty is that not all benefits and costs can be easily quantified. Consider the benefit side. Retention of telecommuters can be compared against a control group, and (assuming telecommuters are, as supposed, less likely to leave a company) a dollar value can be placed on not having to recruit and train new workers as often. But what value can be placed on the benefit of being able to hire or retain an outstanding rather than merely competent worker, because of the ability of that worker to telecommute? Lower sick leave utilization of telecommuters, if true, can be measured and valued. But if the lower stress claimed for the telecommuting lifestyle translates into reduced health care costs, that relationship would be much more difficult to establish. And quantifying white-collar productivity (and therefore productivity changes due to telecommuting) is a notoriously elusive goal.

On the cost side, the "out-of-pocket" costs for equipment, telecommunications services, and potentially space in a telecommuting center are just the beginning. There are the costs of administering the telecommuting program, including selection, training, and monitoring. And there are the hidden costs: What is the cost of losing instant on-site access to an employee? of reducing the potential for serendipitous face-to-face encounters? And if

management's fears are realized, what is the cost of reduced productivity once an employee is out of sight?

Obviously, the answers to these questions will vary in each situation. The difficulty in finding all the answers should not prevent the challenge from being addressed. The managerial perspective on cost/benefit is important to transportation, if indirectly. The ability to present convincing evidence -- one way or the other -- of the impacts of telecommuting on the bottom line will almost certainly influence the degree and/or rate at which it is adopted.

The second perspective from which to compare the costs and benefits of telecommuting is *(ii) the transportation perspective.* The "Status of Telecommuting Implementation" section mentions the State of California legislation requiring a cost-effectiveness evaluation for telecommuting centers to be established in Southern California. Specifically, the study is to compare the costs of reducing travel through telecommuting against the costs of accommodating an equivalent amount of travel through "traffic controls". The language of the statute raises a variety of questions, such as: (1) what "traffic controls" are to be considered; (2) how to apportion fairly the costs of those controls between trips that would otherwise be "diverted to telecommuting", and other trips; and (3) whether the emphasis on "commute trips" as the transportation measure of interest is wise, in view of the fact that telecommuting centers (unlike home-based telecommuting) will still generate commute trips *per se.* Nevertheless, a study along those lines would be of immense interest to the transportation planning community. It would also be of interest to employers seeking to find the most cost-effective way to respond to trip reduction ordinances.

While it is useful to reduce the complexity of the problem by focusing on one perspective or the other, doing so yields a fundamentally incomplete picture. As noted throughout this paper, telecommuting is not just a transportation mitigation strategy, nor is it just a tool for improving business effectiveness; it can be viewed as both, and more. A comprehensive cost/benefit analysis, then, will include all relevant factors from both perspectives.

Telecommuting Centers

While worthy of stand-alone mention, telecommuting centers actually involve special cases of several of the issues described above. The two main issues are *(i) analyzing the transportation/air quality impacts*, and *(ii) assessing the financial feasibility* of such centers. Both questions are important to transportation planners. If the transportation/air quality impacts are negative or negligibly positive, this form of telecommuting should not be promoted as transportation policy. On the other hand, telecommuting centers may have considerable transportation benefits, but if they are not self-supporting they become less useful as a policy tool.

On the transportation/air quality side, some questions of interest are: Will non-motorized modes such as walk and bicycle be chosen more often for trips to a telecommuting center? Will ridesharing and transit be less likely to be chosen for these shorter trips? And to the

extent that vehicle trips are made, are telecommuting centers a viable tool for improving air quality? On the financial feasibility side, the questions relate to what it would take to make telecommuting centers economically attractive to employers. Partially combining both issues is the transportation cost-benefit analysis discussed earlier. That is, how much would it cost to achieve a comparable transportation benefit by conventional means?

Summary

This paper has presented a snapshot of telecommuting in the United States today, especially as related to transportation impacts. It has attempted to include some sense of history: what is different today from only a few years ago, and how we got here. The robust, multi-dimensional appeal of telecommuting as a public policy instrument has been explored, and progress in implementation has been demonstrated.

The paper has also attempted to include a sense of the future: unanswered questions regarding the ultimate extent of telecommuting, and its long-term impacts on transportation and land use. Preliminary answers to these questions are encouraging. But it is a truism that the only thing constant is change. Responses even to existing technology will continue to evolve in ways only imperfectly envisioned now. Further, new telecommunications technology will support applications barely imagined at this point. Understanding the transportation-related responses to those existing and future applications of technology will be a fertile area of research for many years to come.

Acknowledgements

Earlier drafts of this paper have benefited from comments by John Niles, Ilan Salomon, Elham Shirazi, and Ellen Williams.

References

California Air Resources Board (1990) *Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles (Executive Summary)*, Mobile Source Division, Sacramento, California, July.

California Energy Commission (CEC) (1983) *Telecommunications and Energy: The Energy Conservation Implications for California of Telecommunications Substitutes for Transportation*, prepared by JALA Associates. Sacramento, California: Document No. P400-83-042, December.

Commonwealth of Virginia (1991) *Report of the Virginia Employment Commission on The Potential Benefits of Telecommuting*, House Document No. 13, Richmond, Virginia.

Commuter Transportation Services (CTS) and California Department of Transportation (Caltrans) (1991) *The Telecommuting Handbook*. Los Angeles, CA.

Elton, M. C. J. (1973) Developments in telecommunications: Implications for planners. In *Transportation and Environment: Policies, Plans and Practice*, ed. by J. H. Earp, M. McDonald, and T. E. H. Williams, Southampton University Press, England.

Executive Department, State of California (1989) *Executive Order D-82-89*. Sacramento, California, October 30.

Gordon, A. (1991) Presentation on the Puget Sound Telecommuting Demonstration Project to The Telecommuting Phenomenon: Another Way to Work, a University of California (Irvine) policy conference, Irvine, California, July 15-16.

Gould, M. (1990) Presentation to the 51st National Conference of the *American Society of Public Administrators* on the County of Los Angeles Telecommuting Program. Los Angeles, CA. April 7-11.

Hall, D. T. (1989) Telecommuting and the management of work-home boundaries. Paper prepared for the Annual Review of Communications and Society, a joint project of the Aspen Institute and the Institute for Information Studies. Boston University, August.

Hamer, R., E. Kroes, and H. V. Ooststroom (1991) Teleworking in the Netherlands: an evaluation of changes in travel behavior. *Transportation*, Volume 18, Number 4.

Harkness, R. C. (1973) Communication innovations, urban form and travel demand: Some hypotheses and a bibliography. *Transportation*, Volume 2, pp. 153-193.

Healy, T. J. (1968) Transportation or communications: some broad considerations. *IEEE Transactions on Communication Technology*, Vol. COM-16, No. 2 (April), pp. 195-198.

Hirata, E. Y. and E. K. Uchida (1991) Evaluation of the Hawaii Telework Center Demonstration Project. Presentation to the 70th Annual Meeting of the Transportation Research Board, Washington, DC, January 13-17.

Horowitz, J. L. (1982) *Air Quality Analysis for Urban Transportation Planning*. Cambridge, Massachusetts: MIT Press.

Huws, U., W. B. Korte, and S. Robinson (1990) *Telework: Towards the Elusive Office*. New York: John Wiley and Sons.

JALA Associates, Inc. (1990) *California Telecommuting Pilot Project Final Report*. Stock No. 7540-930-1400-0. State of California Department of General Services. North Highlands, CA 95660, June.

Jovanis, P. (1983) Telecommunications and alternative work schedules: Options for managing transit travel demand. *Urban Affairs Quarterly*, Vol. 19, No. 2 (December), pp. 167-189.

Kanafani, A. (1983) *Transportation Demand Analysis*. New York: McGraw-Hill Book Company.

Kauppi, H. (1991) Finland launches flexiwork program. *Telecommuting Review: The Gordon Report*. Volume 8, No. 3 (March 1), pp. 2-4.

Kentucky Science and Technology Council, Inc. (KSTC), GTE, South Central Bell, and the Kentucky Office of Business and Technology (1991) *Kentucky Rural Telecommuting Centers*. KSTC, Lexington, Kentucky, April.

Kinsman, F. (1987) *The Telecommuters*. New York: John Wiley and Sons.

Kitamura, R., J. Nilles, D. Fleming, and P. Conroy (1990) Telecommuting as a transportation planning measure: Initial results of State of California Pilot Project. *Transportation Research Record 1285*, pp. 98-104.

Kraut, R. E. (1988) Homework: what is it and who does it? Chapter 2 in *The New Era of Home-Based Work: Directions and Policies*, ed. by K. E. Christensen. Boulder, CO: Westview Press.

Link Resources Corporation (1991) 1991 Home office fact sheet. Link Resources Corporation, 79 Fifth Avenue, New York 10003.

Miller, T. E. (1991) 1991 Telecommuting data from Link Resources Corporation. Link Resources Corporation, 79 Fifth Avenue, New York 10003, June.

Mokhtarian, P. L. (1990) A typology of relationships between telecommunications and transportation. *Transportation Research* **24A**, No. 3, pp. 231-242.

Mokhtarian, P. L. (1991a) Defining telecommuting. Forthcoming *Transp. Research Record*.

Mokhtarian, P. L. (1991b) An empirical analysis of the travel impacts of telecommuting. Proceedings, 6th International Conference on Travel Behavior (Tome 1, pp. 147-160), Quebec, Canada, May 22-24.

Moss, M. L. (1984) New York isn't just New York anymore. *Intermedia*, Volume 12, No. 4/5, pp. 10-14.

Muller, P. O. (1986) Transportation and urban form: stages in the spatial evolution of the American metropolis. Chapter 2 in S. Hanson, ed., *The Geography of Urban Transportation*. New York: The Guilford Press.

Nilles, J. M. (1988) Traffic reduction by telecommuting: A status review and selected bibliography. *Transportation Research* **22A**, pp. 301-317.

Pendyala, R. M., K. G. Goulias, and R. Kitamura (1991) Impact of telecommuting on spatial and temporal patterns of household travel. *Transportation*, Volume 18, No. 4.

Pratt, J. H. (1991a) Employees' home offices -- a hidden asset. *Contingency Journal*, September/October.

Pratt, J. H. (1991b) The travel behavior impact of telecommuting following the San Francisco earthquake: A case study. *Transportation Research Record*, forthcoming.

Puget Sound Telecommuting Demonstration News (1991) Telework center "links" Seattle and Olympia, and Ballard's telework center. Washington State Energy Office, Olympia, WA 98504, April.

Sahlberg, B. (1987) Remote work in the ecotronic society. *Scandinavian Housing and Planning Research*, Vol. 4, pp. 193-198.

Salomon, I. and M. Salomon (1984) Telecommuting: the employee's perspective. *Technological Forecasting and Social Change*, Volume 25, Number 1, pp. 15-28.

Salomon, I. (1987) Geographical variations in telecommunications systems: The implications for location of activities. *Transportation*, Vol. 14, No. 4, pp. 311-327.

Salomon, I. (1986) Telecommunications and travel relationships: A review. *Transportation Research* **20A**, pp. 223-238.

Salomon, I. (1990) Telematics and personal travel behaviour with special emphasis on telecommuting and teleshopping. In *Telematics -- Transportation and Spatial Development*, ed. by H. M. Soekkha, *et al.* Utrecht, The Netherlands: VSP.

Seitz, L. E. (1989) California methods for estimating air pollutant emissions from motor vehicles. Proceedings of the 82nd Annual Meeting of the Air Pollution Control Association/Air and Waste Management Association (APCA/AWMA).

Seitz, L. E. and J. Siller (1991) *Coding Instructions: Direct Impact Travel Model* (Draft, March 28). California Department of Transportation, Division of Transportation Planning and Office of Computer Systems, Sacramento, California.

Shirazi, E. (1990) Implementation and preliminary evaluation results of several Southern California telecommuting pilots. Presentation to the 69th Annual Meeting of the Transportation Research Board, Washington, DC, January 8-11.

South Coast Air Quality Management District and Southern California Association of Governments (1989) *1989 Air Quality Management Plan*, El Monte, CA, March.

South Coast Air Quality Management District (1990) Regulation XV: Trip reduction/indirect source. El Monte, CA, adopted December 11, 1987; amended May 17, 1990.

Southern California Association of Governments (SCAG) (1988) *Evaluation Report: Telecommuting Pilot Project.* Los Angeles, CA, August.

Spinks, W. (1991) Satellite and resort offices in Japan. *Transportation*, Volume 18, Number 4.

State of California (1990a) Chapter 1389, Laws of California.

State of California (1990b) Chapter 1651, Laws of California.

State of Florida (1990) Chapter 90-291, Laws of Florida.

State of Washington (1991) Chapter 202, Laws of 1991.

Teal, R. F. (1987) Carpooling: who, how and why. *Transportation Research A*, Vol. 21A, No. 3, pp. 203-214.

U. S. Department of Transportation (1990) *Moving America: New Directions, New Opportunities*, February, p. 17.

Wood, J., P. Walsh, and W. Hui (1990) Teleworking "Down Under": An Overview. *Telecommuting Review: The Gordon Report.* Volume 7, No. 8 (August 1), pp. 2-4.